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Review of Health Costs of Road Vehicle Emissions

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ABSTRACT

The use of motor vehicle generates a range of external effects. There is a growing body of research aimed at quantification of the external effects, in physical units and dollars, as well as considering the policy implications. The NRTC has commissioned a review of the health impacts of motor vehicle emissions (and noise). The review has been completed by Leonie Segal, public policy economist and senior research fellow with the Centre for Health Program Evaluation. The results of the review are reported in this paper.

Despite the uncertainty in the data and knowledge about the relationships between important parameters, some conclusions about the effect of motor vehicle emissions on health, can confidently be drawn. Health effects are found to be minor, reflecting the relatively clean air quality of Australian cities. Health effects derive from respiratory illness attributed to high ozone days and small excess mortality from carcinogens of 10-18 case per year. The effect of particulates could not be determined. Due to the small number of estimated cases of excess morbidity and mortality, the total estimated value of health impacts is less than $50 per annum.

In conclusion, this review of the pertinent studies from the environmental health literature, costs of illness data and studies to estimate the health costs of road vehicle emissions, suggests that the health costs to Australia from road vehicle emissions are most likely to fall within the range of $20 and $100 million, with $50 million suggested as a reasonable point estimate. Over time, as further evidence concerning the relationship between pollutants and health is obtained a revisions of these estimates may be appropriate.

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Executive Summary

The use of motor vehicle generates a range of external effects. There is a growing body of research aimed at quantification of the external effects, in physical units and dollars, as well as considering the policy implications. The NRTC has commissioned a review of the health impacts of motor vehicle emissions (and noise). The review has been completed by Leonie Segal, public policy economist and senior research fellow with the Centre for Health Program Evaluation. The results of the review are reported in this paper.

The review has focused on the small number of recent studies designed to quantify the health impacts of motor vehicle emissions on the Australian community. An independent estimate of the health cost of vehicle emissions has been prepared as part of this review, based on Australian health data and incorporating published literature on environmental health (see Section III). An introduction to the environmental health literature, covering the important recent work on motor vehicle emissions, air quality and health, is provided in Appendix A. Noise costs have been a secondary focus of the review with little more than a cursory consideration, based on a limited number of documents. This work is report in Section IV.

Health costs of road vehicle emissions on the Australian community have been estimated in a small number of studies. The studies generally borrow heavily from United States research on the impact of air quality/vehicle emissions on health, using alternative methods to extrapolate that work to Australia. All studies have limitations, reflecting the state of knowledge concerning the relationship between air quality and health, lack of consensus concerning the appropriate methods for placing dollar values on health effects and difficulties with extrapolation of evidence and estimates developed for the USA.

Despite the uncertainty in the data and knowledge about the relationships between important parameters and agreed methodology, some conclusions about the effect of motor vehicle emissions on health can confidently be drawn. Health effects are found to be relatively minor, reflecting the relatively clean air quality of Australian cities. Health effects derive from respiratory illness attributable to high ozone days and small excess mortality from carcinogens of 10-18 case. Effect of particulates could not be determined due to small number of estimated excess morbidity and mortality. Total estimated value of health ….. is less than $50 per annum.

Air Quality

The potential health effect from motor vehicle emissions is directly related to air quality. Air quality of Australian cities tends to be relatively unpolluted compared with cities in the USA or Europe, the source of many epidemiological studies. Air quality monitoring data based on sites around Australia, demonstrate that concentrations of most air pollutants are now at 'acceptable levels', for which the evidence indicates no health risk. The pollutants NO_x, CO, SO_2 do not currently, and are not expected within the foreseeable future, to exceed acceptable levels. Atmospheric lead levels have been excessive, but with the reduction in use of leaded fuels, future atmospheric lead concentrations for Melbourne are estimated to remain below the existing (1.5 ug/m^3) and also the tighter proposed acceptable level of 1.0 ug/m^3.

Ozones and air toxins are at levels that potentially pose a health risk. For air toxins there is assumed to be no safe level. A proportional relationship between concentration and excess cancer risk is postulated, suggesting a small excess health risk from the very low concentrations of air toxins.

For ozone, the scientific evidence suggests that no health risk is posed at a maximum 1 hour concentration of less than 0.08 ppm. There is some uncertainty about whether a health risk is posed at concentrations between 0.08 ppm and 0.12 ppm, but with general agreement that rates above 0.12 ppm confer a definite health risk. It is generally assumed that health risk increases proportionally with exposure above 0.08 ppm. In recent years (1989-1993), in each of Melbourne and Sydney, there has been an average of 3 days on which ozone exceeded 0.12 ppm (the current 1 hour standard) and 17 and 15 days (respectively) when levels exceeded 0.08 ppm (the proposed 1 hour standard for Victoria). Motor vehicle emissions are the major contributor to the precursors for ozone.

The possible health risk associated with inhalable particulates is the subject of recent articles in the environmental health literature (see for instance Dockery et al 1993). Motor vehicles, especially diesel powered, are an important, but not necessarily major source of inhalable particulates. There is however no current evidence that fine particulates are above safe levels. Concentrations in inhalable particulates in Melbourne, are typically measured at 15-25 ug/m^3, and less than 10 ug/m^3 for fine particles (communication EPA). These are levels similar to or below the 'clean air' cities in the United States taken as the base case against which excess health risks associated with higher levels of pollutants have been measured. Further epidemiological and scientific study is required to conclusively establish safe levels for inhalable and fine particulates. To ensure relevance to Australia, such studies need to exclude sulphates as a potential confounder.

Valuation of Health Effects

Health effects have been estimated for ozone and air toxins in a small number of studies, the results of which are summarised in Tables E.1 and E.2 below. The key studies are:

- Chestnut et al 1994, The Health Effects and Health Costs in Melbourne: Due to Motor Vehicle Sourced Ozone and Air Toxins, Victorian Transport Externalities Study (VTES), vol 2; May, RCG/Hagler Bailly Inc, EPA.

- Inter-State Commission 1990, Road User Charges and Vehicle Registration: A National Scheme, March, vol 1, AGPS.

- Woodward et al 1993, Air Quality Goals for Ozone: Environmental, Economic and social Impact Assessment, Discussion Document and Options Report, Department of Community Medicine, University of Adelaide, Report to NH&MRC, August/November.

- Segal, L 1994, Review of Health Costs from Road Vehicle Emissions: Section III, Report to NRTC.

Recent New Zealand and Canadian studies which look at the costs of externalities of road vehicles, have been reviewed in Section 2 of this paper but are not referred to here as they do not contain any estimates of health costs of motor vehicle emissions for Australia.

Health Effect of Ozone Exceedences

There is scientific evidence of deleterious health impact on days on which ozone levels exceed 0.08 ppm (maximum 1 hour). The VTES report estimates the value of the health effect of ozone exceedences at between $360,000 and $5.28 million for Melbourne. (This suggests an upper estimate for ozone cost for Australia at $10 to $15 million. Only Melbourne and Sydney experience ozone concentrations beyond acceptable levels.)

The NH&MRC study estimates the health cost of ozone at between $180,000 and $3.48 million for Australia. This is the estimated cost of not meeting the proposed standard of 0.08 ppm. The cost of the health impact of ozone, estimated by L Segal as part of this Review of the NRTC is $14 million. The Inter-State Commission does not provide a separate health cost estimate for ozone.

The value of the health effects of ozone from these three studies is within the range of less that $1 million up to $15 million for Australia.

Table E.1: Estimated Value of Health Impact of Motor Vehicle Emissions Australia Key Studies

Estimated health cost of road vehicle emissions $ million			Source	Basis
	Low	High	a) VTES, 1994	Melbourne statistical division only. Based on USA environmental health literature. Includes cost of health services, morbidity, premature death.
Ozone (1992/3)	0.36	5.28		
Air toxins	26.0	45.2*		
Total (Melbourne)	26.4	50.5		
Total	787		b) Inter-State Commission	Estimate for Australia, based on US Federal Highway Cost Allocation Study, reflects emissions of 1977 US road fleet. No discussion of validity of extrapolation to Australia.
Ozone	0.18 to 3.48		c) NH&MRC	Estimate for Australia. Ozone only. Excess asthma morbidity postulated as the only health effect of ozone.
Ozone →	Respiratory 14		d) L Segal	Estimate for Australia 1989-90. Based on 0.1% cancers attribute to road vehicle emissions also 0.1% of all respiratory illness. Includes cost of treatment, notional values for loss of quality of life and premature death.
Air toxins	Cancers	32		
Total		46		

Source: a) Chestnut et al 1994, The Health Effects and Health Costs in Melbourne due to Motor Vehicle – Sourced Ozone and Air Toxins, Victorian Transport Externalities Study, vol 2, EPA, see Tables E-1 and E-2, p ES-3.

b) Inter-State Commission 1990, Road User Charges and Vehicle Registration: A National Scheme, vol 1, AGPS.

c) Woodward et al 1993, Air Quality Goals for Ozone: Environmental, Economic, and Social Impact Assessment –Discussion Document and Options Report, Department of Community Medicine, University of Adelaide.

d) Segal, L 1994, Review of Health Costs from Road Vehicle Exhaust Emissions, Section IV, Report to NRTC.

Note: * Estimate for 1990 in $1,992.

Health Effect of Low Level Air Toxins

It is postulated that there is no safe level of air toxins, and that there is an excess cancer risk proportional to ambient levels of air toxins. Estimates of the value of health effect of air toxins prepared by the VTES and L Segal are both based on the study by Hearn (EPA 1994). In the EPA study, relationships between air toxins and excess cancer risk developed by the USA EPA were applied to Melbourne air quality data, to estimate additional cancer deaths per year attributable to air toxins. Hearn has taken parameter values for the relationship between air toxins and cancer at the upper end of the plausible range, to provide an upper estimate for health impact. The estimated health impact of air toxins in Melbourne for 1990 was an additional 10.4 to 18 new cases of cancer/year. When related to all new cases of cancer in Victoria of 15,174 air toxins possibly account for 0.1% of all cancer cases.

Table E.2: Health Cost of Motor Vehicle Emissions per Unit of Transport Task, as a Function of Total Cost – Australia 1992

Vehicle task (a)		**Assumed Total Health Cost of Road Vehicle Emissions**			
		$10 million	**$50 million**	**$100 million**	**$200 million**
Vehicle travel (million veh-km					
All road vehicles	**165,034**	0.005¢/ veh-km	0.03¢/ veh-km	0.06¢/ veh-km	0.12¢/ veh-km
- passenger vehicle	126,167[1]				
- light commercial/trucks	26, 413[1]				
- heavy trucks/buses 12,454					
Fuel consumption (million litres)					
All fuel	**29,800**	0.05¢/litre	0.25¢/litre	0.5¢/litre	1.0¢/litre
- petrol	16,500				
- diesel	4,300				
Registered motor vehicles ('000)					
All vehicles	**9,685**	$1.0/ veh/an	$5.15/ veh/an	$19.32/ veh/an	$20.64/ veh/an
- passenger vehicle	7,995				
- light commercial/trucks	1,325				
- heavy trucks/buses 364					

Source: a) NRTC 1993, Investigation of Fuel-Only Charges for Heavy Vehicles, p 39, Table B.1.

The VTES estimated the value of the additional cases of cancer at between $26 and $45.2 million for Melbourne, which would be equivalent to approximately $65 to $125 million for Australia. The estimate prepared by L Segal as part of this research for the NRTC, is $32 million for Australia. The higher VTES estimate is largely due to a difference in the unit value placed on premature death at $5 million/fatal case in the VTES study and $1 million/fatal case in the Segal estimate. The value of life typically used in economic analyses of road accident counter measures is less than $1 million (see VTES, volume 2, page 7, reference to ARRB 'Accident Costs for Project Planning and Evaluation', quoting $631,000 as the person cost of a road fatality). If anything, the unit value for premature death from cancer, for application to economic analyses, should be less than that applicable to road accidents, due to the younger average age of death from road accident fatalities.

Based on the available analysis, the value of the health effect of air toxins on Australia is almost certainly less than $100 million and could well be less than $30 million.

Health Effect on Fine Particles on the Cardiopulmonary System

None of the transport externality studies specifically address the possible health effects of respirable or fine particles on the cardiopulmonary system. The available scientific and epidemiological evidence does not allow an estimate of this effect for Australia to be calculated. The important studies in the USA, which have demonstrated the impact of fine particles on health status, have as the 'clean air' cities against which cities with more polluted air are compared, air quality similar to that of the larger Australian cities. Thus there is no evidence of health effect at levels of fine particles typical of Australian cities.

Total Value of Health Impact of Motor Vehicle Emissions

The Inter-State Commission (ISC) provides a total estimate of the cost of motor vehicle emissions of $787 million for Australia.

The VTES estimated the total health cost of road vehicle emissions for **Melbourne** to be in the range of $26 million and $50 million (VTES, RCG/Hagler Bailly, tables E.1 and E.2, p ES-3). Multiplying the estimated cost for Melbourne by 2.5 to get an indicative estimate for Australia yields a range of $65 million to $125 million.

The value of the total effect on health of road vehicle emissions, estimated for this Review is $46 million. This estimate incorporates many conservative assumptions which will tend to overstate the value of the health impact (for instance ozone is assumed to have an effect on all respiratory illness).

The ISC estimate at $787 million is far higher than derived from the other studies. The ISC estimate was developed as part of a wide ranging study into road use charges, with limited attention addressed to the cost of motor vehicle emissions (only 11 pages of a 648 page report, and most of this on the distribution of cost amongst the vehicle fleet, not derivation of the total cost estimate). The ISC estimate more than any other, relies on a simple transference of US estimates. There is little description of the method used and no attempt to demonstrate the validity of the approach. It would seem unwise to use the ISC estimate as indicative of the real costs of the health impact of motor vehicle emissions in Australia, now that more recent and more substantial studies have been completed.

It can also be noted that the ISC estimate, at $787 million, is exceptional in comparison with the estimated health cost of other risk factors. For instance, the health cost attributed to smoking related morbidity and mortality is estimated at $585 million in direct health care costs and $1,390 million including also a value for illness and premature death (National Centre for Health Program Evaluation and Australian Institute of Health and Welfare, 1994). Smoking is known to confer around ten times additional risk for lung cancer and substantial excess risk for all cardiopulmonary illness. It is almost inconceivable that the health impact of motor vehicle emissions, which through reduction in air quality confers only a small excess health risk, could be of the same order of magnitude as the health impact of smoking.

In conclusion, this review of the pertinent studies from the environmental health literature, costs of illness data and studies to estimate the health costs of road vehicle emissions, suggests that the health costs to Australia from road vehicle emissions are most likely to fall within the range of $20 and $100 million, with $50 million suggested as a reasonable point estimate. Over time, as further evidence concerning the relationship between pollutants and health is obtained a revisions of these estimates may be appropriate.

Unit costs by road vehicle task have been calculated for total health cost valued at between $10 and $200 million. This is reported in Table E.2 and shows for instance that at a total emissions cost of $50 million per annum, average cost per vehicle task would be:

- $5.15 per vehicle per year';
- 0.03¢per vehicle kilometre; or
- 0.25¢per litre of fuel.

Emissions costs have not been attributed to sections of the vehicle fleet, although an attribution on the basis of average fuel use would be quite simple. While an adjustment to reflect differential effect on air quality by vehicle class and location of transport activity may be desirable, it is probable that each fuel type and vehicle class make different relative contributions to ozone formation, air toxins and fine particulates. A better understanding of the relative importance of specific pollutants on health is really required for the attribution of emissions cost to vehicle class.

Section I: Introduction and Conclusions

1.1 Study Scope and Background

This report is the response to a request from the National Road Transport Commission to prepare a critical review of the major studies of the impact of motor vehicle emissions on the health of the Australian community and prepare an independent estimate of health costs.

In recent years, a number of studies have attempted to identify and measure the external effects of motor vehicles. While some reports acknowledge the need to be comprehensive and the desirability of including all external effects (negative and positive), in reality the focus is on negative externalities, particularly road accidents, congestion, road traffic noise and more recently the health effects of motor vehicle exhaust. The possibility of external benefits, tends to be neither acknowledged nor researched.

Studies of externalities may have differing objectives which can be expected to guide the study methodology. If the object is the setting of environmental standards and an appropriate externality reduction strategy, research should be focused at the margin; for example on the change in health cost achieved by alternative emissions reduction strategies. Community welfare is increased if negative externalities are reduced to the point where the marginal cost of the intervention to reduce emissions is equal to the marginal health benefit from reduced emissions. Estimates of the total value of externalities can provide a theoretical upper limit to the possible benefits from interventions to reduce externalities.

An alternative motivation for assessing the value of road transport externalities, is as part of a strategy of full cost recovery to meet allocative efficiency objectives, between competing transport modes. This objective requires that all externalities (both negative and positive) be incorporated in the analysis. Because of the high taxes on motor vehicle usage (through excise duties, state fuel tax and sales tax on motor vehicles) a proper accounting of external effects would not necessarily identify underpayment by the road transport sector.

1.2 Report Structure

A number of studies have been reviewed that are pertinent to the health impact of motor vehicle emissions. They are of two types:

- research into the value of the health impact of motor vehicle emissions; and
- medical/scientific papers/reports on the health impact of motor vehicle emissions.

The main conclusions derived from these studies on the health costs of motor vehicle emissions are presented in the Executive Summary. A discussion of methodological issues concludes this Introductory section. A review of the key studies to value the health impacts of motor vehicle emissions is presented in Section II. The report continues with an independent estimate of the cost of motor vehicle emissions (Section III) and noise (Section IV) based on Australian data. An introduction of the environmental health literature is provided in Appendix A.

1.3 Methodological Issues

Deriving a dollar value for the health impact of motor vehicle exhaust emissions is a complex exercise. The key studies have been reviewed in terms of their conceptual framework, their capacity to access satisfactory data, and the method used to value the health impacts.

Estimation of the cost on the community of the health impact from motor vehicle exhaust could proceed by way of one of two alternative approaches:

- determine the health impact attributable to reduced air quality contributed by road vehicles and place a dollar value on the estimated health impact; and
- the revealed preference approach, whereby households are assumed to be able to assess health impact and adjust residential location in response, so that differential land prices can be used to indicate value of different levels of air quality. (This technique is more commonly used to assess noise impact.)

All the studies reviewed broadly follow the first approach, that of separately measuring the health impact and its monetary value. A few methodological issues are briefly explored now.

1.3.1 Measurement of Health Impact

Experimental/laboratory studies in controlled situations and cross-sectional and time-series epidemiological studies form the basis of estimated health impact of reduced air quality contributed by motor vehicles. The laboratory studies define potential for health impact based on short term observations. Longer term impacts need to be derived from population based studies, but achieving adequate control of potential confounders which may independently influence health outcomes is a major problem. (these include demographic characteristics, lifestyle characteristics, normal fluctuation in disease incidence, change in management of disease, introduction of public health measures.) Allowing for confounders is a particular problem when the influence/effect scientists are trying to detect is small.

Evidence of health effect due to reduced air quality, in quantitative terms, is extremely limited, especially at air quality levels typical of Australian cities.

A recently released Australian study *Health and Community Services, Victoria and Environmental Protection Authority, Victoria (June 1994) Mortality and Air Pollution in the Western Metropolitan Region 1969-86* comparing the mortality of residents of different municipalities within the Western Metropolitan region of Melbourne and with the rest of Melbourne, with the aim of assessing the potential impact of air pollution was inconclusive. While substantial differences in mortality rates between areas was found, there was little evidence that these differences could be attributed to differences in air quality. (Generally the Western metropolitan region has better air quality, especially in relation to ozone, but higher mortality rates.)

The Victorian Environmental Protection Authority, (EPA Vic) and other environmental agencies are able to describe the major contributors to air quality. This is a matter about which there seems reasonable agreement. The EPA Vic is able to model air quality, as a function of pertinent parameters and can assess the impact for instance of changes in the vehicle fleet.

1.3.2 Dollar Value of Premature Death

Deriving an agreed value for the health impact of motor vehicle exhaust emissions requires a common view on:

- the precise health effects attributable to air pollutants;
- how the health impact will affect use of health services and associated net resource cost – one possible approach is to attribute a proportion of a disease category to motor vehicle emissions and allocate that same proportion of all costs of management to motor vehicle exhausts. An alternative approach is to identify directly the impact of air quality on individual symptoms and actual health service use associated with the nominated symptoms. Both approaches are used;
- valuation of illness and premature death – none of the techniques available for valuation of loss in quality of life and reduced survival is entirely satisfactory. This reflects both a failure to resolve difficult conceptual issues as well as inadequacies with the measurement techniques available.

Because of the importance of the value of life in the estimated health cost and the considerable range in proposed values, some limited discussion of the alternative approaches is presented here. The value of life does not have a unique solution and cannot be resolved in the context of this Review or any report prepared by a single agency. Value of life is an input to economic analysis of projects across many program areas including health and welfare, transport, the environment, sport/recreation, occupational health and safety, emergency services, etc. These programs also span all levels of government as well as the government private sector interface. Some consistency in the value of life across program areas would be desirable and suggests the need for an interdepartmental process.

None of the common approaches to valuation of life is entirely satisfactory. One common approach is to value life at the projected loss of future production (net or gross of consumption).

Refinements to this approach through application of a ‘notional wage’ to those not in the paid workforce, or use of the average wage for all do not address the fundamental issue of whether production foregone, however, measured, has anything to do with the cost to the community, the loss and anguish, of premature death.

It is similarly difficult to accept that wage differentials between more and less risky occupations provide a valid measure of the value of life. Wage rates and wage differentials reflect the complex play of labour market elements, demand and supply by region and industry, skill level, role and power of unions and labour regulations, the competitive environment in which industries operate. To allow for all possible confounders to establish wage differentials associated with risk alone, is arguably an impossible task. Further it is not clear how individual workers distinguish occupational risk. In any case individual response to perceived change in risk of death is not necessarily appropriate as the basis for a community value for premature death.

An alternative approach most common to the health sector, where extending life or enhancing quality of life is the primary goal, is to focus on the cost of alternative interventions to save a life or generate additional (quality adjusted) life years. The logic would be to fund the most cost-effective health programs until the health budgets were exhausted, with the least cost-effective health program able to be funded providing an ex-post measure of the value the community places on programs to save life, and by inference on the value of life itself. In the context of public sector decision making, establishing the value of life revealed by a range of public sector interventions designed to protect life/reduce death rates would form a valuable input into selection of a value of life to use in policy context. While the value of life that would be revealed from past decision making can be expected to yield an exceptionally wide range, it provides a means of estimating the opportunity cost of resources that might be allocated to enhancing air quality.

In the health sector, programs with a cost per quality adjusted life year of greater than $50,000 would certainly be considered marginal at best. This suggests that through the political process the community is seen to value ‘life saving’ interventions at under $1 million (depending on years of life ‘saved’).

Health Intervention	**Estimated cost/life year: $1988-89**
Hospital dialysis	48,000
Cervical cancer screening	31,000
Breast cancer screening	7-11,000
Non-drug blood pressure reduction clinic	5,000
Kidney transplant	4,600
Neonatal intensive care, babies 1-1.5 kg	1,200-3,000

From Australian Institute of Health and Welfare 1991, Cervical Screening in Australia: Options for Change, Prevention Program Evaluation Series no 2, AGPS.

1.3.3 Dollar Value of Change in Quality of Life

Valuation of loss/gain in quality of life can be addressed by willingness to pay techniques, asking patients or members of the community what they would pay to avoid certain conditions, or compensation required to forego full health for a nominated inferior health status. Multi-attribute utility scales are becoming more widely used for measuring quality of life. The responses to a questionnaire are collated to derive a score between 0 and 1 where 0 represents death or the worst possible health state and 1 full health. The score is used to calculate a quality adjusted life year, which is valued as for life itself.

Estimation of the cost of interventions to meet nominated air quality standards has been proposed erroneously as a measure of health effect of polluted air. What it can provide is a measure of the cost of improving air quality which may be useful to compare with an independent estimate of health effect to assess the appropriateness of nominated environmental standards, and whether a strategy to improve air quality will increase or reduce net community welfare.

Section II: Review of Key Reports: Published Reports Containing Estimates of the Costs of Motor Vehicle Noise/Emissions

The small number of studies that have attempted to value the effect of road vehicle emissions on health are reviewed in this section. There are in fact few independent estimates. All studies have limitations, which is not surprising given the state of scientific knowledge and lack of consensus concerning the best approach to the valuation of life and quality of life.

Particular attention is paid to the VTES report as a current Australian study.

Table 2.1 Documents Reviewed

Ref Key	Author and Title
2.1	Chestnut LG, Hurd, BH, Lang CM 1994, (RCG/Hagler, Bailly, Inc) 'The Health Effects and Health Costs in Melbourne due to Motor Vehicle-Sourced Ozone and Air Toxins', in *Environmental Protection Authority Victoria (1994)*, Victorian Transport Externalities Study, vol 2.
2.2	Inter-State Commission 1990, Road User Charges and Vehicle Registrations: A National Scheme: Volume 1, AGPS, section 4.7, 'Other costs associated with road use'.
2.3	Federal Highway Administration 1992, 'Final Report on the Federal Highway Cost Allocation Study, United States Department of Transport, Washington DC, Appendix E: 'Efficient Highway User Charges', section on 'Negative Externalities', (Source of the ISC estimate).
2.4	VHB Research Consulting Inc 1992, 'Environmental Damage from Transportation', chapter 13 of Report of the Royal Commission on National Transportation, Ministry of supply and Services, Canada.
2.5	Austroads 1993, Review of Vertical Exhausts.
2.6	Works Consultancy Services Ltd., Wellington 1993, Land Transport Externalities: Transit New Zealand, Research Report no 19.
2.7	NH&MRC Program of Research on Environmental Health and Air Quality Guidelines (see Section III).

2.1 VTES Victorian Transport Externalities Study

Report by Chestnut, LG, Hurd, BH, Lang, CM 1994, 'The Health Effects and Health Costs in Melbourne due to Motor Vehicle-sourced Ozone and Air Toxins', volume 2, EPA.

2.1.1 Scope

This document reports on research into the health effects of motor vehicle exhausts on the population of Melbourne, and valuation of those health effects. The study is restricted to the health effects of ozone an carcinogenic air toxins attributable to road vehicle emissions. It was noted that other emissions, specifically CO, SO_2, NO_2 and lead, are expected to be at or below recommended acceptable levels and thus not generate any health impact and were thus excluded from further consideration. Health costs attributable to motor vehicle emissions were calculated separately for ozone and air toxins.

Fine or respirable particles were not addressed at all, with no explanation of their exclusion from the analysis. Some explanation would have been desirable, given evidence on the potential importance of inhalable particles on health status. Inhalable particles have been incorporated to the extent that their effect is captured in the health impact of air toxins, which considers impact on cancer incidence only.

2.1.2 Ozone

i) Health effect attributable to ozone

The environmental science literature was reviewed by the authors to ascertain the nature of the relationship between ozone and health. Studies cited include cross sectional and time series studies, controlled human exposure studies and laboratory studies. A linear dose response relationship, above a threshold of 0.08 ppm was assumed to apply, based on a small number of US studies. This was used to estimate the impact of o zone on premature mortality, and acute respiratory symptoms, asthma attacks, and minor restricted activity days. These relationships are summarised in Table 2.2.

Table 2.2 Assumed Impact on Health Effect of Ozone Levels above 0.08 ppm, Peak One Hour Daily Concentration

Type of Health Effect	**Assumed daily individual risk factors per ppm maximum daily 1 hour ozone level > 0.08 ppm**		
	Low	Central	High
Asthma attack	0.106	0.188	0.520
Minor restricted activity day	0.0193	0.0467	0.074
Acute respiratory symptoms	0.079	0.153	0.229
Mortality	0.0	0.0000033	0.0000066

Source: VTES: Chestnut et al (1994) pp 2.27.

The meaning of the entries in Table 2.2 are not explained. My interpretation is, that for each day ozone levels exceed 0.08 ppm (maximum 1 hourly reading), for each 1 ppm above 0.08, excess risk of an asthma attack on that day is estimated to be between 10.6% to 52% or of acute respiratory symptoms between 1.9% and 7.4% and for death between zero and 0.00066%.

The report acknowledges that Australian studies, have in general not been able to identify any relationship between ozone and respiratory morbidity or mortality. The relationship based on US studies is thus taken to provide **an upper limit** for the 'true value'. Zero is the lower estimate for mortality impact. These relationships between air quality and health effect, were related to EPA data on projected ozone levels, to derive estimates of total health impact over a year.

ii) Monetary Values of Health Effect

The respiratory symptoms summarised in Table 2.2 are valued using willingness to pay studies undertaken in the USA. (Members of the community are asked through a survey instrument to place a dollar value on the nominated symptoms. The average results is taken as the value.) The estimated values for particular health states have been translated into current dollars using standard price deflators and average exchange rate for early 1994 to express the results in Australian dollars. The unit values resulting from this process are shown in Table 2.3 and suggest for instance that an asthma attack has been values at between \$16 and \$72 per attack. The unit value for premature mortality has been based on wage risk trade-off studies in which wage rates in jobs with differential occupational risk are compared to infer a value of life. (This has been discussed in Chapter 1 and also in Section 2.1.3.)

iii) Results

The estimated value of health effect from ozone is summarised in Table 2.3 (Chestnut et al 1994, table 3-3, pp 3-19, value per case, Table 4-1, pp 4-4 annual cases and monetary value of total health effect). The analysis assumes 85% of ozone is attributable to motor vehicles. The method for calculating total impact is based on the product of the estimated health impact and the unit values but with a probability assignment to parameter values. The total health effect of ozone is estimated to fall within the range of $113,000 to $6.8 million. The low and high estimates are said to identify the range within which one can be 50% confident the real value will lie. The middle value is said to be the simple product of the middle value of health impact and value.

2.1.3 Air Toxins

i) Health Effect Attributable to Air Toxins

The VTES report relies on an EPA study (Hearn 1994), for the estimated effect of specific air toxins from motor vehicle emissions on the number of new cases of cancer in Melbourne (1990 and 2005). Attributable risks in the EPA study are based on estimates developed by the United states EPA, taken at the 95% upper confidence level. They are thus seen to provide an upper limit for possible effect. Air quality in Melbourne was determined using the EPA model, incorporating vehicle kilometres of travel, meteorological data etc. The air quality model has been validated against actual air quality readings.]

The number of additional cases of cancer in Melbourne calculated by Hearn (1994) and used in the VTES, is presented in Table 2.4. Hearn suggests somewhere between 10 and 18 additional cases of cancer cases per year (1990) may be attributed to air toxins due to motor vehicle emissions. The most important contributor to excess cases being diesel and petrol particulates.

Table 2.3 Estimated Value of Health Effect Attributable to Ozone: Melbourne 1992/93

		Est annual cases due to ozone exceedences* (a)	Assumed value per case A$ (b)	Est value of health effect (a) ozone 1992/93 A$
Mortality	Low Central High	0.00 0.40 0.81	2,500,000 5,000,000 10,000,000	0 2,190,000 6,043,000
Asthma attack	Low Central High	1,057 1,876 5,188	16 44 72	24,000 89,000 300,000
Acute respiratory disease symptom day	Low Central High	6,616 12,976 19,422	4.5 9 18	49,000 114,000 275,000
Minor restricted activity day	Low Central High	1,581 3,825 6,061	20 31 53	40,000 111,000 244,000
TOTAL	Low Central High			**113,000** **2,504,000** **6,862,000**

Source: Chestnut et al 1994, (a) pp 4-4, (b) pp 3-19.

(ii) Monetary Valuation of Health Effect

Mortality/Valuation of Life – The authors briefly discuss two alternative methods for valuing life, the willingness to pay approach (WTP) and cost of illness (reflecting resource utilisation for health care plus foregone production). The authors postulate that the WTP method is the more valid approach. They further claim that value of life determined from occupational risk studies in which wage differentials for higher risk occupations is a valid application of the WTP method. The value of life/premature death derived from such studies (largely US studies) is quoted at around $5 million which is the central value of life used in the analysis. This figure is evidently consistent with an Australian estimate by Knieser and Leeth (1991). (The upper and lower values seem to be taken as 50% and 200% of the middle value.)

Table 2.4 Estimated Additional Cancer Cases per Year Attributed to Air Toxins Due to Motor Vehicle Emissions: Melbourne (Cases per year)

Hazardous Emission	Year	
	1990	**2005**
Diesel particles	1.6 – 8.1	0.26 – 13.0
Petrol particles	6.8	2.2
Benzene	0.97	0.7 – 1.9
Butadiene	0.47 – 1.3	0.37 – 1.6
Formaldehyde	0.53	0.3 – 0.37
Benzo(a)pyrene	0.03	0.01
Asbestos	0.0001 – 0.3	
Total cases due to air toxins from motor vehicle emissions	**10.4 – 18.9***	**6.2 – 19.1**

Source: Chestnut et al 1994, (based on Hearn 1994).

Note: * This represents approximately 0.1% of all new cases of cancer in Victoria (15,174 new cases in 1989.
G Giles et al 'Victorian Cancer Registry 1989 Statistical Report', Anti-Cancer Council of Victoria, October 1992. This was not mentioned in the VTES report.

<u>Method for valuation of additional cases of cancer</u> is quite complex and is described below:

- each additional case of cancer is classified as either fatal (survival of less than 5 years) for which a mortality cost is calculated, or curable (survival beyond 5 years) for which a morbidity cost is calculated. Average cost per case is the weighted average cost of the morbidity and mortality estimate;
- premature death is valued at $5 million (central estimate);
- for survival beyond 5 years, value of loss in quality of life/production loss based on:
    - ⇒ a US estimate of 'direct costs' calculated as life time health service costs of cancer management of US$5,172 - $19,524 (1975 dollars and 1969-71 health service data), plus 'indirect costs' of US136 - $112,884 in lost wages, using the midpoint and adjusting by CPI = US$49,000 for direct costs plus $295,000 for indirect costs in 1992 dollars;

⇒ indirect costs were adjusted downward to $87,000 to exclude cases resulting in deaths which were picked up in the separate mortality estimate;

⇒ the direct plus indirect cost estimate was then multiplied by 2 (US$272,000), based on evidence that WTP values are roughly twice ‘direct’ plus ‘indirect’ costs and that WTP is the best estimate of the ‘true’ value of premature death;

⇒ this estimate was then deflated to equate to Australian dollars and to reflect the typically lower cost of care in Australia. (Based on the relative cost of cancer management in Australia – Australian Institute of Health & Welfare – of $2.1 billion and the US estimate of US$82.2 billion, population adjusted, the suggested average cost of health care in Australia was 49% of that in the US). The result was a morbidity cost of $133,000 per newly diagnosed case.

- average value/new cancer case was calculated at $5 million x (1-cr) plus $133,000 x cr (where cr = 5 year cancer survival rate). The upper and lower limit for 5 year survival of 11% and 51% were used giving a weighted average value per new case of cancer of $2.5 million (51% 5 year survival) or $4.5 million (11% 5 year survival).

iii) Results Total Health Impact of Air Toxins

The estimated value of the health impact of air toxins is summarised in Table 2.5 and shows a range for possible health effect of $26 million to $89 million.

Table 2.5 Estimated Value of Health Effect of Air Toxins from Additional Cases of Cancer, 1990 and 2005

Estimated new cancer cases per year attributed to air toxin emissions from motor vehicles		**Estimated value of additional mortality and morbidity $ million**	
1990	10.4 – 18.0	$46.8 - $81.3	$26.0 - $45.2
2005	6.2 – 19.1	$28.0 - $84.0	$15.5 - $47.7

Source: Chestnut et al 1994, Table 4-3 p4-7.

2.1.4 Results Total Health Impact: Air Toxins plus Ozone

Total health effect from motor vehicle emissions on Melbourne was calculated simply as the sum of the calculated effect of air toxins and ozone. The range quoted in the Executive Summary of the VTES report excludes the high estimate (which assumes a value of life of $10 million). The modified range for health cost for Melbourne from motor vehicle emissions reported in Tables E.1 and E.2 is $360,000 to $5,276 million for ozone plus $26.0 - $45.2 million for cancer indicating total health cost for Melbourne within the range of $26 million and $50 million per year.

2.1.5 Comment

Methodology

Valuation of total health impact through estimation of the health effect of selected motor vehicle emissions and valuation of those health effects is valid. Furthermore use of dose response relationships developed on the basis of USA studies provides a not unreasonable basis for estimating health effects of air toxins and ozone in Australian cities. The nomination of 0.08 ppm as the baseline for health effect for ozone has wide agreement in the environmental health literature, and is the recommended acceptable level by the EPA, as a safe level unlikely to pose any health risk.

However there are a number of concerns with aspects of implementation, particularly relating to the valuation of illness and death, which is excessively cumbersome and incorporates assumptions which would not attract general support.

Scope of the Analysis

In view of important publications highlighting the impact of particulates of health, specific consideration of this source of pollution is desirable. While it is probable that evidence does not support the proposition that current levels are unsafe, the matter warrants explicit consideration. The exclusion of other pollutants is well justified by acknowledged low levels of concentrations in Australian cities (eg SO_2, NO_2). Exclusion of lead is perhaps more contentious. While levels of lead are falling to acceptable levels, it is possible effects on health have occurred in the past, which are still influencing health status.

Value of Life

The authors show little knowledge of the literature pertaining to valuation of life. Justification of the use of the 'willingness to pay' approaches does not acknowledge debate on the relevance of WTP for valuation of life, or problems with the techniques used for ascertaining 'willingness to pay'. The use of wage relativities for occupations having different levels of occupational hazard is not widely accepted as providing a valid estimate of the value of life. It is far from certain that confounders can be adequately controlled for, or that attitudes to risk and time preference can be allowed for or that the result in any case provides a measure of the 'value of life'.

Steedman and Bryan (*Cost of Road Accidents in Australia*, BTCE Occasional Paper No 91) present a thorough analysis of alternative methods for valuation of life. They estimate the cost of a fatal road accident in 1985 at $398,800 using the adjusted income method, or $451,307 using the opportunity cost method and $1.165 million using the WTP method. Parish (1991), also provides a critical review of the occupational hazard wage/risk trade-off approach. He recommends use of the Steedman and Bryan (1988) estimate of $631,171, based on loss of productive potential. The BTCE report on Costs of Road Accidents in Victoria in 1988, prepared for the VTES report, quotes the cost of premature death through road trauma at $631,171, using the production foregone approach (quoting work by ARRB, Andreassen, 1992, 1993) and $3.46 million based on US willingness to pay studies (Miller et al 1991). The cost of road accidents has been calculated using both estimates for the value of life saved. The estimated value of life derived from productivity foregone is closer to the numbers that would emerge from an analysis of government programs directed at mortality[1]

A value of premature death at $5 million used in the VTES Health Effects and Cost Study is high, in the context of alternative methodologies available for valuing life, revealed community preference as apparent in government spending on health programs, and values used by transport economists. Furthermore, if the reason for valuing life is to contribute to policy development, it is perhaps far more pertinent to establish value of life (life years) revealed by public sector resource allocation decisions, with respect of life saving interventions (especially in the health and welfare and safety field). This will more closely reflect opportunity dost of resources that could be allocated to enhancing air quality to achieve a health gain. In the health field, funded programs typically have been costed at between $1,000 and $100,000 per life year, with many potential programs, at the lower end of the range. The preparedness of the community to fund health programs, does not suggest a value of life anywhere near the $5 million assumed in the VTES analysis.

The assumed value of life is particularly pertinent in valuing the excess cancer risk. The proposition that an estimated 10 to 18 additional cases of cancer per year (relative to an expected incidence of 15,174 cases for Victoria) would 'cost' the community $26 to $81 million is difficult to accept. It may provide an upper limit on the possible value. The estimate for health costs associated with ozone at up to $5 million for Melbourne is less vulnerable to valuation of life, and provides a more plausible figure.

Valuation of Morbidity

No adequate conceptual framework is offered for consideration of the cost of illness. Cost of illness estimates are introduced with insufficient recognition of the limitation of the technique. The 'direct' cost of illness – the health resources allocated to disease management – properly provides a minimum or baseline estimate of cost of illness. The estimation and meaning of 'indirect' costs, in the form of lost production estimated from average wages, is contentious. Loss in wages represents a transfer payment. Whether there is a real resource cost, and if so of what order, can only be established through empirical analysis. Real resource costs consist of hiring and retraining costs and loss in productivity through use of less experienced workers. Some recent research suggests the real resource cost of absence from work is possibly 10% of total loss of future earnings, although other work suggests it can be higher than the lost wages.

The approach ignores the loss of contribution to the household unit due to death or illness. The approach to valuation of morbidity and premature mortality has ignored health economics literature on this issue.

[1] See for eg Carter 1993, The Breast Cancer Screening Program was estimated to cost $10-20,000 per life year saved, and identified as of moderate effectiveness for a health intervention.

Translation of US Data to Australia

The actual method of measuring the cost of each additional case of cancer, which involved taking 30 year old US data on cost of cancer, adjusting to 'Australian values' using recent AIHW data seems unnecessarily convoluted. It is not clear why the calculation was not directly based on the AIHW data, which is relatively recent (1989), based on Australian data and reflects the Australian health system and costs of care. (This is the approach taken in Section IV of this report.)

Classification of Cases of Cancer

The allocation of cases of cancer as either cured (still alive at 5 years), or fatal (death within 5 years) seems an inappropriate simplification. Cancer more plausibly has a combined morbidity/mortality impact and the increased cancer risk and cost could be calculated as a combination of morbidity and mortality impact.

Overview

The approach to estimation of the health effects is robust, although the failure to include particulates may represent a gap in the discussion. (The exclusion may reflect the scope of the original study brief.) While there is increasing evidence of the importance of respirable particles and fine particulates as a source of health risk, it is possible that levels of particulates in Melbourne are such as to pose an extremely small excess health risk. Inhalable particles typically occur in the range of 15-25 ug/m^3 in Melbourne, equivalent to air quality of the 'cleanest' city in the important US six cities study (Dockery 1993), where excess mortality was observed at particle levels of 30-45 ug/m^3.

The VTES report on health effects represents a major investigation of this complex topic. Despite some concerns about particular techniques, notably in the valuation of health effects, and incomplete attention to respirable particles, it is probable that the impact on health from road vehicles falls within the range estimated from this study. Compensating errors are likely to provide some balance. Certainly there is no reason to believe the actual cost is higher than suggested by this report, which can be taken as providing an upper bound on the costs of motor vehicle emissions.

2.2 Inter-State Commission

Inter-State Commission, 1990, Road User Charges and Vehicle Registrations: A National Scheme, March, vol 1, AGPS. (Section 4.5 pp 89-96 'Other costs associated with road use' and Appendix X pp 179-207, 'Road Use Other Than Road Track Costs', in vol 2.)

Source of the ISB estimate: Federal Highway 1982, Administration Final Report on the Federal Highway Cost Allocation Study, United States Department of Transport, Washington DC, May. Appendix E, 'Efficient Highway User Charges', Section on 'Negative Externalities'.

2.2.1 Scope

Section 4.5 of the Inter-State Commission (ISB) Report on 'Other Costs Associated with Road Use', covers crashes, congestion, noise, and air pollution. The report provides estimates of noise and air pollution as a total and by vehicle type as a proportion of vehicle operating cost and in cents/vehicle km. It is an extremely wide ranging report and perhaps because of this there was insufficient attention to environmental effects.

2.2.2 Approach

The ISB estimates of the cost of road traffic emissions are said to be based on the US Federal Highway Administration Cost Allocation Study (discussed below). The method used to extrapolate US estimates to Australia is explained briefly so that the steps taken cannot readily be ascertained. The broad approach seems to have involved:

- taking us estimates of emission damage costs per gram of pollutant;
- and us emission levels in grams per (vehicle) kilometre;
- translating this into pollution costs for Australia using the 1988 survey of motor vehicle usage.

The ISB report refers to the increasing recognition of the potential health risk from fine particles, and notes that diesel engines pose the greatest hazard in this regard; 'a diesel engine emits less carbon monoxide than a petrol engine of the same power, it emits more nitrogen oxides and more than ten times as many particulates' (p 199). It is not clear how the effect of fine particles (or any other pollutant) was incorporated into the cost estimate.

2.2.3 Results

Total pollution cost for Australia from motor vehicle emissions is estimated at $787 million (see Tables 2.6 and 2.7 below). It is suggested in the ISC report that the figure is an underestimate, in that it makes no allowance for a greenhouse effect. Transferability of the US data was justified on the basis that vehicle design rules are similar in both countries.

2.2.4 Comment

Description of the method used to derive the pollution cost estimates is minimal, both in relation to derivation of the US estimates and the method of extrapolating this to Australia.

Table 2.6 ISC Estimates of Atmospheric Pollution Costs by Vehicle Type (cents per vehicle kilometre)

Vehicle type	Atmospheric Pollution cents/vehicle kilometre
Cars/station wagons	0.50
Light commercial	0.50
Rigid trucks	
- 2 axles to 12 tonnes	0.85
- 2 axles > 12 tonnes	9.50
- 3 axles	1.20
Articulated trucks	0.80
Buses < 5 tonnes	0.85
Buses > 5 tonnes	1.60

Source: Inter-State Commission, Table 15, p 204, vol 2.

Table 2.7 Estimates of Atmospheric Pollution Costs Attributable to Road Vehicles: Australia 1989-1990

	Automobiles (Petrol/Diesel)	Heavy Duty Petrol	Heavy Duty Diesel	Total Fleet
Interstate/rural				
-cents/vehicle km	0.006¢	0.024	0.014	
-annual million vehicle – km	48,790	908	5,371	
Annual cost $ million	3.1	0.2	0.7	4
Urban				
-cents/vehicle km	0.677¢	2.269	1.625	
-Annual million vehicle – km	99,021	1,238	5,168	
Annual cost $ million	670	28	84	782
TOTAL				
-annual million vehicle – km	147,812	2,146	10,539	
Annual cost $ million	674	28	85	787

Source: Inter-State Commission, Table 15, p 204, vol 2.

In relation to translation of the data to Australia there are a number of key concerns:

- the base line data for the US study reflects emissions of the 1977 vehicle fleet. NO discussion has been provided of the transferability of this to the current Australian road vehicle fleet, or how adjustments have been made;
- Australian fuels have a lower sulphur content than fuels used in the US. The implication of this for emissions and health effects has not been addressed;
- in the translation of vehicle emissions to air pollution and health impacts a range of local/regional factors are critical (including weather, demographic mix, exposure of population, etc). NO discussion has been provided on this matter. It is not possible to be confident that a simple extrapolation of US estimates of health effect without adjustment is appropriate.

The ISC report represents an early attempt to estimate the health (and noise) cost of road vehicle emissions in Australia. It has relied on a method which is far from ideal, but may have been all that was possible in the context of a very wide ranging study. The Commission acknowledges this in saying 'these estimates should be treated with considerable caution' p 202. Based on this review of the Inter-State Commission Report and the US federal Highways Cost Allocation Study from which the estimates were derived and in the light of more recent estimates of health costs, the ISC estimate no longer represents the best estimate and should no longer be used.

Federal Highway Cost Allocation Study

Appendix E to the US Federal Highway Cost Allocation Study 'Efficient Highway user Charges' p E-41 to E-50 on air and water pollution and noise, forms the basis of comments about this study. The empirical analysis of air pollution evidently draws on a research by Haugaard (1981) (full reference not provided). Appendix E contains only a brief overview of the method used to estimate emissions effects and cost, and a summary of the results.

The method for estimating costs of air pollution attributable to road traffic seems to have involved:

- determination of average emission rates in grams per vehicle mile for CO, HCs, NO_x, So_x and particulates for vehicle categories (automobiles, pickups, motorcycles, heavy petrol vehicles, heavy diesel vehicles) sourced to US EPA 1977;
- total pollution levels for a region were calculated on the basis of emissions, meteorological and topographic variables and the presence of other pollutant sources;
- damage to human health (mortality and morbidity) from pollutants was estimated from epidemiological data (specific studies were not cited), and costed to include medical bills and loss of earnings due to illness or premature death. Unit values were not cited;

- in order to assign pollution costs to road vehicles as against other sources, pollution costs were estimated in dollars per gram, these unit rates were then applied to vehicle emission estimates to yield a cents per mile by vehicle type.

Results are reported in a number of tables, and show for instance that an average car travelling 10,000 miles per year in a typical urban area creates pollution damage at the rate of US0.62¢per mile or approximately US$62 per year. A diesel truck in an urban area was estimated to cause damage worth 1.6¢ per vehicle mile. It was acknowledged that 'these numbers are rough averages and the actual contributions to damage costs, or the same vehicle under different conditions appears to be subject to wide variation'.

Comment

The main problem in the broad method used to estimate pollution damage costs relates to lack of explanation about how the method has been implemented. For instance there is no description of the source of information for health impacts, the role of particular pollutants, the scope or nature of health impacts or how they have been valued. The description provided is not sufficient to enable a judgement to be formed as to the validity of the methodology, the acceptability of its application, likely robustness of estimates or potential transferability to Australia.

2.3 Canadian Royal Commission on National Transport

VHB Research Consulting Inc, 'Environmental Damage from Transportation', March 1992, Chapter 13, Final Report of the Royal Commission on National Transportation, Ministry of Supply and Services, Canada.

2.3.1 Scope

The report contains a comprehensive discussion of alternative approaches to the valuation of non-traded goods, describing the various methods and their strengths and weaknesses. The authors demonstrate some confusion with the definition of costs and seem not to understand the difference between transfer payments and real resource costs. Section 4.2 of the VHB report covers damage due to changes in physical and chemical discharges. The relative importance of transport and passenger transport as a source of pollutants is identified. It is noted that the entire transportation sector accounts for between 25 and 30% of all CO_2, about 50% of NO_x, 2% of SO_2 and 1% of particulate emissions in Canada. In relation to these pollutants, passenger cars account for about twice the emissions of HCs and CO as trucks, while heavy trucks are responsible for almost all the particulate emissions. Trucks and passenger vehicles are responsible for similar emissions of NO_x (VHB 1992, Table 3, p 1084).

The report contains an estimate of the value of environmental impacts of intercity transport in Canada.

2.3.2 Model

Calculation of the cost of transport emissions involved:

- measurement of average emissions by vehicle (trucks and passenger vehicles) in total and by passenger – km;
- estimation of the impact of emissions on atmospheric pollution using models developed for this purpose;
- valuation of effects in terms of dollars per kilogram of pollutant are taken from the literature, based on studies for the power generation sector;
- these relationships are used to estimate the health effect. The major source of environmental damage is identified as SO_2.

2.3.3 Results

Emissions per passenger-km are estimated for rail, passenger vehicles, intercity bus, air and sea. They conclude that, in relation to inter-city passenger transport, environmental damage per passenger-km is highest in relation to rail transport and lowest for marine transport followed by inter-city bus, (VHB 1992, p 1060).

The health costs per 1,000 passenger-km have been calculated in C$1989 as follows:

- rail passenger transport — $5 to 10 / 1000 passenger-km;
- private passenger motor vehicle — $2.20 – 2.50 / 1000 passenger-km;
- Inter-city bus — $1.10 - 1.90 / 1000 passenger –km.

2.3.4 Comment

Various concerns about the source of the estimates were expressed by the authors who recommend a research agenda to improve the quality of the estimates. The report contains a clear statement that caution be exercised in their use, noting that at best they provide an indication of the order of magnitude of cost.

This work has not been used to develop an estimate of emissions cost for Australia, and there would seem no advantage in doing so if more direct means of estimation are available.

2.4 Review of Vertical Exhausts, Austroads, Sydney 1993

This report is concerned with the impact of changes to road freight vehicle exhaust location (height) on noise and air quality and health. In describing the potential health impact of vehicle emissions, the focus was on whether a change in exhaust location would make air quality better or worse and whether the effect substantial. No attempt was made to place a dollar figure on the health impact of motor vehicle emissions or how much it would change under alternative exhaust locations.

The study provides a thorough discussion of the issue of location of vehicle exhausts for road freight vehicles, but is only of marginal relevance to estimation of the total health impact of the road vehicle fleet.

The study did establish that a lowering of exhaust outlet for heavy vehicles would significantly reduce air quality and quality of life, especially through increases in diesel odour and diesel exhaust visibility. Only a marginal reduction in noise impact was expected. The potential role of diesel exhaust in terms of morbidity and mortality was said to be dominated by the potential carcinogenic effect. Based on the relationship between diesel particulate exposure and lung cancer (as reported by Harris 1982 in 'Diesel Emissions and Lung Cancer', *Risk Analysis*, vol 3, no 2, pp 83-100) possible additional lung cancer incidence was estimated at 0.2% per annum.

2.5 New Zealand Land Transport Externality Study

Works Consultancy Services Ltd., Wellington 1993, Land Transport Externalities: Transit New Zealand, Research Report no 19.

2.5.1 Content/Scope

This report is broad in scope, covering scale and significance of land transport effects:

- pollution, air, noise, dust, vibration
- effects on water systems, plant and animal habitats;
- recreational, cultural and spiritual, community disruption, lighting;
- accident hazard.

The report also discusses techniques for quantifying and valuing external effects and policy instruments for incorporating external effects. The report contains no original data collection or analysis. Its main purpose was that of developing a research plan for exploring externalities of the New Zealand land transport system.

2.5.2 Model

The report provides a review of the published literature, it documents published estimates of externalities made elsewhere. It was noted that estimates of air pollution costs attributable to health generally fall in the range of 0.3% to 0.4% of GDP. The estimated health effects of air pollution from road transport contained in the Inter-State Commission Report is quoted and the implied cost of extrapolating this estimate to New Zealand.

2.5.3 Results/Comments

The authors conclude that original research is required in New Zealand on this subject. It is stated that there is enough evidence to conclude that the scale of the problem is substantial and highly significant in terms of long term sustainability. This conclusion seems to have been drawn without the benefit of any data on air pollution levels in New Zealand. There is no consideration of the likely validity of the ISC estimate and it is not even acknowledged that the ISC estimate is an extrapolation of a US study.

Section III: Independent Estimate of Health Cost of Motor Vehicle Emissions: Australia

3.1 Introduction

The health cost estimates reviewed in Section II are largely based on US studies, adjusted by a number of steps, to translate to current Australian dollars, with incomplete explanation of the methods used. An attempt is made in this section to develop an estimate more directly from Australian data, with the basis of the analysis clearly described. The likely robustness of the estimate should be easier to judge than with a methodology based on complex manipulations of US data.

The task of this analysis is to:

- demonstrate the possibility of applying a methodology which is more directly based on Australian data and conditions; and
- derive an indicative estimate of the health cost of motor vehicle emissions based as far as possible on Australian data.

3.2 Methodology

An order of magnitude estimate for the health cost attributable to road vehicle emissions has been derived as follows:

- identification of major illnesses potentially affected (in regard to incidence or severity) by pollutants associated with road vehicle emissions;
- assessment of extent of illness potentially attributable to road vehicle emissions (reflecting the role of air pollutants in incidence and severity of disease and of road transport emissions as a contributor to air pollution), based on the international environmental health literature;
- estimation and valuation in dollar terms of the total burden of illness on the community (use of health services, premature deaths and morbidity) of diseases potentially exacerbated by motor vehicle emissions;
- application of aetiological fractions to total disease burden to provide estimates of health cost of road vehicle exhaust emissions for relevant disease classes;
- collation of data to yield total cost estimate. Use of sensitivity analysis to establish bounds for the 'true' cost of road vehicle emissions.

3.3 Analysis

The scientific literature suggests that the health conditions that may be exacerbated by vehicle pollution are primarily respiratory disease such as asthma and bronchitis and cancers.

More recent evidence demonstrates a potential impact on cardio pulmonary disease through inhalable particles, although it is not clear that levels of inhalable particles common in Australia pose any excess health risk. In attributing total disease burden to road vehicle emissions, it is assumed that health effect is limited to additional cancer risk through air toxins and additional respiratory illness on high ozone days.

Estimates of cost of illness by disease group are based on current research at the National Centre for Health Program Evaluation (NCHPE) and the Australian Institute of Health and Welfare (AIHW), both in progress and published.

Disease burden includes:

- resource cost of disease management – health service cost;
- annual deaths, more specifically premature death;
- morbidity or illness.

Estimates of disease burden for Australian in 1989 are presented for respiratory diseases and cancers in Table 3.1. The cost of managing respiratory disease is estimated at $1,435 million of which some 20% is attributable to asthma. Lung cancer represents less than 10% of the cost of managing all cancers.

It is clearly desirable to establish the actual disease which may be affected by air quality. However, the scientific literature while providing extensive qualitative discussion in this matter is not prescriptive. Thus in order to progress the analysis the approach has been to seek to establish a plausible upper bound estimate for health cost by taking the widest possible definition of diseases that may be influenced by motor vehicle emissions. Thus diseases potentially influenced have been taken to consist of the entire class of respiratory disease (not just asthma) and <u>all</u> cancers.

The assumptions embodied in the analysis are summarised here:

i) *Cost of health service utilisation* – valued directly from costs of disease management as estimated by NCHPE/AIHW study for relevant disease groups.

ii) *Cost of premature death* – based on a value of $1 million per life. This is selected as a middle estimate; higher than generally suggested by lost productive potential (at ~ $600,000) typically used in road accident studies, but lower than suggested by occupational hazard studies. In fact, a lower value of life figure than that commonly used in road accident studies would be justified as average years lost per fatality is less for deaths due to respiratory illness or cancer than for road accidents. The figure of $1 million is broadly consistent with community values as expressed in health sector funding, although certainly at the high end of the range, with programs costed at $30-$50,000 per life-year at the margin for funding support. (see also discussion in Section 2.1.5.)

iii) *Cost of illness* – unit costs for illness represent little more than illustrative values to enable indicative estimate of total cost to be developed. How a change in unit values would affect the total estimate can readily be explored. The values chosen are generous and if anything should overstate the value of the health impact.

Unit values assumed:

- $1,000 per hospital admission (with the typical admission being ~ 3 days);
- $25 per episode resulting in health professional consult; and
- $200,000 per nursing home admission (typically indicating a long term deteriorating condition).

These unit values are designed to reflect loss in quality of life associated with these events, and notionally include loss in ability to participate in normal activities (paid and unpaid work, leisure etc as well as pain/suffering/discomfort etc).

iv) *Attribution of disease burden to motor vehicle emissions*

Cancers – Hearn (1994) has calculated that air toxins were responsible for between 10.4 and 18 extra cases of cancer in Melbourne in 1990. When compared with 15,174 new cases of cancer reported in Victoria in 1989 this suggests that 0.1% of cancer morbidity and mortality may be attributable to road vehicle emissions. It is thus assumed that 0.1% of all cancer costs are attributable to road vehicle emissions.

Respiratory disease – There is scientific evidence to suggest that high ozone days over 0.08 ppm (1 hour) may contribute to severity of respiratory disease in exposed populations on those days. The evidence is however far from definitive in terms of the extent of effect, although at ozone levels common in Australia, the evidence would suggest only a small health effect. Without firm evidence on the size of health effect a scenario development approach has been used, incorporating plausible assumptions – but selecting assumptions likely to overstate the health effect – to yield an indicative upper estimate for health effect.

Estimated health effect from ozone incorporates the following assumptions:

- ozone is assumed to impact on all respiratory disease equally;
- excess risk occurs only on high ozone days (> 0.089 ppm);
- there are 15 days/annum on average on which ozone exceed 0.08 ppm (in parts of Melbourne and Sydney);
- 15% of the Australian population would be exposed to high ozone levels on high ozone days (~ one third of the populations of Melbourne and Sydney); and
- on high ozone days the level of respiratory illness would be 15% worse (in terms of number of cases or severity).

Based on this set of assumptions, ozone would confer an additional 0.1% morbidity/mortality in relation to respiratory illness (17/365 days x 15% exposure x 15% excess illness). The cost implication of this is shown in Table 3.2.

Table 3.1 **Burden of Illness: Respiratory and Respiratory Cancers: Australia 1989**

	Health Service Cost $ million *	**Mortality**		**Hospital Admissions**
		Deaths	Years lost to 75	
Diseases of the Respiratory System	**1,435**	**10,703**	**N/A**	**264,850**
Eg: Pneumonia	107	2,065	N/A	28,426
Influenza	26	261	N/A	2,889
Asthma	275	962	N/A	63,188
Cancers	**895**	**30,699**	**237,218**	**238,573**
Eg: Lung Cancer	67	6,308	43,504	14,883

Source: National Centre for Health Program Evaluation (NCHPE) and Australian Institute of Health and Welfare (AIHW); based on the Macro Economic Model, data supplied by Mr Rob Carter, Deputy Director, NCHPE.

* Health service cost cover some 85% of the health budget and include hospital admissions, GP visits, other medical services, allied health referrals from GP's, nursing home care, and pharmaceuticals. Excluded are outpatient services, community based services, health promotion/disease prevention activities.

N/A Not yet available.

3.4 Results

Calculations of health cost attributable to motor vehicle emissions are presented in Table 3.2 and show health impact, unit value and basis of attribution. The estimated health cost attributable to road vehicle emissions for Australia is estimated at $46.6 million, consisting of $32 million in excess cancer risk plus $14.5 million through extra respiratory illness.

Refinement of this approach could be achieved through a more thorough analysis of environmental health literature to revise the attributable fractions for disease sub-groups. Additional work to develop unit costs for morbidity and mortality would also be desirable.

It is not expected that additional work would result in any substantial adjustment to the total health cost estimate, and certainly it is most unlikely the real value is in excess of that estimated given the number of conservative assumptions (ie high values for possible health effect and unit values) built into the analysis.

Table 3.2 Indicative Health Impact and Cost of Motor Vehicle Emissions Annual 1990

Attribute	Total Health Impact	Unit Value	Total Value of Health Impact = Health Impact x Unit Value x %* Attribution to Road Vehicle Emission	
Health service utilisation		As recorded		
- cancers	$895 million		$895 @ 0.1%	= $0.90 m
- respiratory	$1,435 million		$1,435 @ 0.1%	= $1.44m
Mortality				
Life years lost to 75#				
- cancers	237,218	%50,000	@ 0.1% = 237.2 x $50,000	= $11.9m
- respiratory	N/A			
OR Deaths				
- cancers	30,699	$1 million	@ 0.1% = 30.7 x $1m	= $30.7m
- respiratory	10,703		@ 0.1% = 10.7 x $1m	= $10.7m
Morbid events				
- hospital admission				
· cancers	238,573	@ $1,000	@ 0.1% x 239 x $1,000	= $0.24m
· respiratory	264,850		@ 0.1% x 265 x $1,000	= $0.27m
- medical/allied health				
· cancers	3.1 million	@ $25 each	@ 0.1% = 3,100 x $25	= $0.08m
· respiratory	16.1 million		@ 0.1% = 16,100 x $25	= $0.40m
- nursing home (admissions)				
· cancers	1,942	@ $100,000	@ 0.1% = 2 x $100,000	= $0.19m
· respiratory	2,000		@ 0.1% = 2 x $100,000	= $0.20m
TOTAL:				
· cancers			$32.1 million	
· respiratory			$14.45 million	
All health impact			**$46.55 million**	

Note:

* Proportion of health cost attributed to road vehicles
Cancers: Air toxins based on D Hearn, EPA 1994, 0.1% of cancers attributable to air toxins from road vehicle emissions (see text).
Respiratory: (see text) assumes:

- on average 15 exceedences > 0.08 occur in Sydney: Av 1988-1992 > 0.12 ppm = 3 and > 0.08 ppm = 17; Melbourne : Av 1989-1993 > 0.12 ppm = 3, Av 1989-1991 > 0.08 ppm = 15;
- excess morbidity/mortality only on high ozone days;
- morbidity/mortality is increased by 15% on high ozone days in exposed populations assumed to represent 15% of Australians.

Based on these assumptions 0.1% (15% of 15% of 5%) of respiratory illness would be attributable to ozone exceedences (which it is assumed is fully attributable to road vehicle emissions).

Reduction in life years lost to age 75 is an alternative approach to valuation of effect on mortality. If valued at $50,000 per life year saved this would amount to a cost of $11.9 million which is substantially less than the estimate of $30.7 million based on an assumed value of $1 million per life.

Section IV: Noise Cost

4.1 Introduction

A small number of the documents reviewed have developed estimates of the cost of road traffic noise. As this is very much a secondary focus of this study, only cursory consideration is given to this work. An independent estimate of the cost of road traffic noise for Australia has been calculated by extrapolating the estimate developed for Victoria for the Transport Externalities Study to Australia.

4.2 Estimates of the Cost of Road Traffic Noise – Inter-State Commission

The Inter-State Commission (1990) contains an estimate of the annual cost of road traffic noise, expressed in terms of road vehicle task, as well as a total annual cost. This estimate is an extrapolation of results of the US Cost Allocation Study. The estimated total noise cost is $534 million. A transport economist with the BTCE has suggested the ISC work misrepresents the US study, with the result that the estimate is too high (personal communication).

Table 4.1 Estimated Cost of Motor Vehicles: Road Noise, Cents per Vehicle Km

Vehicle Type	Noise Cost Cents per Vehicle Km
Cars/Station wagons	0.1
Light commercial	0.1
Rigid Trucks	
- 2 axles to 12 tonnes	1.5
- > 12 tonnes	3.5
3 axles or more	5.1
Articulated Trucks	3.8
Buses - < 5 tonnes	1.8
- > 5 tonnes	1.8

Source: Inter-State Commission op cit. Tab 4.12, p97 and p96.

4.3 New Zealand Study

The New Zealand externalities study contains a summary of overseas estimates of the proportion of the population affected by road traffic noise at various levels. At Leq > 65 db (A) this varies from a high 31% in Japan and 23% in Spain to lows of 5% in Norway, 7% in the USA and 8% in Germany. It was also noted that the value of road traffic noise impact tends to be valued at between 0.06% and 0.2% of GDP and when measured through hedonic pricing techniques within the range of 0.1 to 1.0% per unit change in Leq. The GDP estimate if transposed to New Zealand provided an estimated cost of noise of between $44 to $150 million.

4.4 VTES: Cost of Road Traffic Noise in Melbourne

Nairn and Partners, L Segal, H Watson 1994, 'A Preliminary Assessment of the Levels of Costs of Noise on Arterial Roads in Melbourne', in *Victorian Transport Externalities Study*, EPA, volume 2, May.

4.4.1 Cost of Motor Vehicle Noise Intrusion Melbourne Metropolitan Area

An estimate of the cost to the community of road traffic noise was prepared for the Victorian transport Externalities Study. The estimate pertains to the Melbourne metropolitan area and was calculated as follows:

i) *The kilometres of road network, in the Melbourne metropolitan area for which abutting properties can be expected to be noise affected was estimated.*

This was derived using the RJ Nairn TRANSTEP network analysis package. Definition of roads expected to generate noise levels in the 63-68 dB(A) range and 68+ dB(A) range L10 (18h) (noise level exceeded for 10% of the time during each hour, averaged over the 18 hour period from 6 am to 12 pm).

ii) *The extent of beneficial uses along noise affected routes was estimated.*

It was assumed for simplicity that beneficial uses for which road traffic intrusion is a concern, is confined to residential use. Two samples of Melbourne road network, noise affected in the 63-68 dB(A) range and in the 68+ dB(A) range were visually inspected to calculate average density of residential dwellings on noise affected arterials.]

iii) *Valuation of loss of amenity for noise affected residential property.*

The valuation of the loss in amenity from road traffic noise and related intrusions was calculated using the hedonic pricing method. Differential residential land prices provide evidence of revealed preference for attributes associated with residential properties which vary between alternative parcels of land. Dwelling units located on busy noisy main road locations are cheaper than equivalent dwelling units in similar locations which are not noise affected. The difference in value, provides an estimate of the undesirable aspects of living on a main road, largely road traffic noise, (but also safety, access to driveways, parking). Differential land prices attributed to road traffic noise were based on a review of Streeting (1990)[2] of hedonic pricing (prepared for the Resources Assessment Commission).

Streeting concluded that a one unit increase in level of noise exposure (measured by Leq) results in an average reduction in dwelling price (noise depreciation index) of between 0.8% and 1.26% of property value. Relative to a quiet residential street at ~ 55 dB(A),

[2] Streeting MC 1990, A Survey of the Hedonic Price Technique, Resource Assessment Commission, AGPS.

average value of property price difference of ~ 10% for exposure of 65-68 dB(A) and ~ 15% for properties exposed to noise above 68 dB(A). Nelson (1982) in a survey of traffic noise studies found that from a range of studies the weighted mean noise depreciation index was 0.5% of property value per decibel.

iv) The cost of noise intrusion was calculated by applying two alternative values for the noise depreciation index of 0.5% and 1% to average dwelling price based on dwelling sales as recorded by the Valuer-General's Office, Victoria.

v) The net present value estimate was translated into an annual value by applying a 5% social rate of discount.

Results

The results of the analysis are presented in Table 4.1, a reproduction of Table 2 'Loss of Amenity from "Excessive" Noise on Arterial Roads', VTES, volume 2, p8. Total net present value of loss of amenity from road traffic noise in Melbourne metropolitan area was estimated at $1,712 million, based on a noise depreciation index of 1% consisting of $1,219 for properties affected by noise in the 63-68 dB(A) range plus $493 million for properties affected by noise greater than 68 dB(A). Using a noise depreciation index of 0.5% the estimated net present value of noise costs was $860 million. This does not represent an annual cost but the capitalised value.

The net present value estimate is translated into an annual cost of road traffic noise of $43 to $86 million per year (Table 3, p8), assuming a 5% real rate of discount.

Table 4.2 Estimated Cost of Road Vehicle Noise Melbourne (present value estimate)

Noise Range	Affected Road, Km	Dwelling Units/Km	Average loss of amenity Per Dwelling Unit		Total Cost of Noise NPV*	
63-68 dB(A)	1,389	65	$6,800	$13,500	$614 million	$1,219 million
> 68 dB(A)	438	58	$9,700	$19,400	$246 million	$493 million
Total	1,827				$860 million	$1,712 million

Source: Nairn, Segal & Watson 1994, VTES, vol 2, Table 2, p8.

* The method of calculation based on property values results in a net present value estimate, not an estimate of annual cost.

Comment and Qualifications on Estimate

The VTES report itemises the major qualifications on the analysis which are summarised below. However despite these limitations the broad structure of the analysis is sound and it can be expected that the estimated cost is of the right order of magnitude. Any errors can be expected to be partially compensating.

i) Melbourne only

The cost of noise intrusion was calculated for the Melbourne metropolitan area and notionally adjusted to yield a plausible figure for Victoria. Road traffic noise while a more significant problem in major cities, which combine heavily trafficked routes with high residential density, will still generate costs on communities in major provincial centres and small settlements. Night time truck traffic can be a particular problem. More substantial research on this issue would need to explicitly consider non-metropolitan locations.

ii) Residential only

The assessed value is based on residential use only. It therefore ignores the deleterious affects of road traffic noise on other uses. Consideration of a wider range of affected groups would increase the value of the noise externality.

iii) Length of road-way

The estimated length of road-way which is noise affected is based on a model which may result in some error. This could only be checked by a detailed site recording program.

iv) The number of affected dwelling units

The number of dwelling units has been based on an estimated average number of dwelling units per kilometre which has been derived from sample counts. Substantial variability in residential density was observed. It is possible that the average derived poorly approximates dwelling densities across the arterial network.

v) Value of disamenity

The loss of quality of life from road traffic noise has been based on a land value differential calculated using a formula relating property value to road noise and average property prices. This can at best provide a reasonable approximation of the loss of quality of life experienced by householders. The value of residential properties based on weighted average sales prices for houses and flats as provided by Valuer-General's Office can be taken as a sound estimate of the actual value of dwelling units.

4.5 Indicative Cost of Noise Intrusion – Australia Based on the VTES

At the simplest level the Melbourne noise cost estimate could be factored using the relativity between the Melbourne and Australian populations. This would provide an upper limit as noise intrusion is greatest in the larger cities.

Taking the noise cost estimate for Melbourne of $43 to $86 million, this suggests a value for Australia of, at most, $200 to $400 million. Original work on this matter is really required to confirm a value for Australia. In allocating cost to vehicle class, clearly truck traffic should be allocated a greater share as being responsible for noise on a per vehicle basis. Specific work on this could not be done as part of this study. This represents an activity for future research.

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See also Section II and Appendix A

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Appendix A

Key Documents: Environmental Health Literature

A.1 List of Key References

A list of references is provided below which provides an introduction to the environmental health literature. It has not been possible to prepare a comprehensive review of the environmental health literature for this study, however, the referenced documents contain both selected reports of primary research but also some excellent review documents. Description of the scope and conclusions of a few of these reports is provided below. Having some knowledge of current research on the relationship between pollutants and health is invaluable. Undue reliance on secondary resources may be unwise.

1a Dr Jonathan Streeton 1990, Air Pollution Health Effects and Air Quality Objectives in Victoria for the EPA, Victoria.

1b EPA 1990, Explanatory Document for Streeton Report, October EPA, Victoria.

2a Abramson M & Voigt T 1991, Ambient air pollution and respiratory disease, Department of Social and Preventative Medicine, Monash Medical School.

2b Abramson M & Voigt T 1991, Ambient air pollution and respiratory disease, Department of Social and Preventative Medicine, Monash Medical School.

3 Health and Community Services, Victoria & EPA Victoria 1994, Mortality and air pollution in the Western Metropolitan Region 1969-86, Chair of Steering Committee, Dr Jonathan Streeton.

4 Marks GB 1994, ‘A critical appraisal of the evidence for adverse respiratory effects due to exposure to environmental ozone and particulate pollution: Relevance to air quality guidelines’, *Australian & New Zealand Journal of Medicine*, vol 24, pp 202-213.

5a Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BC, Speizer FE 1993, ‘An association between air pollution and mortality in six US cities’, *The New England Journal of Medicine*, vol 329, no 24, pp 1753-1759.

5b Dockery DW, Speizer FE, Stram DO, Ware JD, Spengler JD, Ware JH, Ferris BC 1989, ‘Effects of inhalable particles on the respiratory health of children’, *American Reviews of Respiratory Disease*, vol 139, pp 587-594.

6 United Nations Environmental Program, International Labour Organisation, World Health Organisation, (available through Dr Leo Heishkenan, Health and Environmental Policy Department, Human services and Health).

6a International Program on Chemical Safety, 1994, Environmental health criteria for nitrogen oxides, April, Internal Technical Report.

6b International Program on Chemical Safety, 1994, Environmental health criteria diesel fuel and exhaust emissions, March, Internal Technical Report draft).

6c Manuell R, Callan P, Bentley K, McPheil, Smith E (eds) 1992, ‘International workshop on human health and environmental effects of motor vehicle fuels and their exhaust emissions’, *Conference Proceedings,* published by the International Program on Chemical Safety, Department of Human Services and Health, Clean Air Society of Australia and New Zealand, April, Sydney, Australia.

7 NH&MRC program of research re environmental health and air quality guidelines.

7a Woodward AJ, Calder I, McMichael AJ, Pisaniello D, Scicchitano R, Steer K, Guest CS 1993, Options for revised air quality goals for ozone, Report to Commonwealth Department of Health, Housing and Community Services, prepared by the Department of Community Medicine, August, University of Adelaide, South Australia.

7b Woodward AJ, McMichael AJ, Guest CS 1993, Air quality goals for ozone: Environmental, economic and social impact assessment, Discussion document, Department of Community Medicine, November, University of Adelaide, South Australia.

8a US EPA 1992, Summary of selected new information of effects of ozone on health and vegetation: Supplement to 1986 air quality criteria for ozone and other photochemical oxidants. Office of Health and Environmental Assessment, US EPA, Office of Research and Development Research, Triangle Park, NC 27711.

8b US EPA 1993, Motor vehicle related air toxins study. US EPA office of Mobile Sources. Emission Planning and Strategies Division, 2565 Plymouth Road, Ann Arbor, Michigan 48105.

9a Holgate S (Chair), Advisory group on the medical aspects of air pollution episodes, First report ozone, London MHMSO, Department of Health.

9b Holgate S (Chair), 1992, Advisory group on the medical aspects of air pollution episodes, Second report sulphur dioxide, acid aerosols and particulates, London, HMSO, Department of Health.

9c Seaton A (Chair) 1994, Expert panel on air quality standards benzene, Department of Environment, London, HMSO.

10 International Symposium on the Health Effects of Gasoline 1993, Papers published in *Environmental Health Perspectives*, December, supplements vol 101 supp.

11 Mage D & Zali O (eds) 1992, Motor vehicle air pollution public health impact and control measures, Division of Environmental Health, World Health Organisation, Geneva, Switzerland.

12 Freeman D & Cattell CR 1988, 'The risk of lung cancer from polycyclic aromatic hydrocarbons in Sydney air'; *Medical Journal of Australia*, vol 149, pp 612-615.

13 US EPA 1979, Methods development for assessing air pollution control benefits, vol 11: Experiments in valuing non-market goods: A case study of alternative benefit measures of air pollution control in the south coast air basin of Southern California. EPA Washington DC, 20460.

14 Detels R, Tashkin DP, Sayre JW, Rokaw SN, Massey FJ, Coulson AH, Wegman DH 1991, 'The UCLA population studies of CORD:X. A cohort study of changes in respiratory function associated with chronic exposure to SO_x, NO_x and hydrocarbons', *American Journal of Public Health*, vol 81, no 3, pp 350-359.

15 Marecek J, Shapiro IM, Katz SH, Hediger ML 1983, 'Low level lead exposure in childhood influences neuropsychological performance', *Archives of Environmental Health*, vol 38, no 6, pp 355-395.

16 Lippman M & Lioy PJ 1985, 'Critical issues in air pollution epidemiology', *Environmental Health Perspectives*, vol 62, pp 243-258.

17 Englert N, Konig R, Seifert B 1989, 'Respiratory diseases in children in Berlin (West) in relation to air quality', in *Man and His Ecosystem: Proceedings of the 8th World Clean Air Congress* (eds) IJ Brasser & WC Mulder, the Hague, Netherlands, vol 1, Elsevier Science Publishers, BV Amsterdam, the Netherlands.

18a Bates DV & Sizto R 1987, 'Air pollution and hospital admissions in Southern Ontario: The acid summer haze effect', *Environmental Research*, vol 43, pp 317-331.

18b Bates DV, Baker-Anderson M, Sizto R 1989, 'Two studies of the relationship between environmental variables and respiratory morbidity using hospital data', in *Man and His Ecosystem: Proceedings of the 8th World Clean Air Congress*, (eds IJ Brasser & WC Mulder, the Hague, Netherlands, vol 1, Elsevier Science Publishers, BV Amsterdam, the Netherlands.

A2. Understanding of key issues derived from the environmental health literature

It is not possible within the scope of this document to provide a comprehensive review of the environmental health literature and its major findings. What has been attempted is far less ambitious and includes identification and referencing of some of the key documents in the field, a review of the content of selected documents and a summary of some of the conclusions that can be drawn from this literature

Laboratory, experimental and epidemiological studies suggest that respiratory health can be affected by concentrations of ozone above 0.12 ppm, particularly inflammation in the lung and airflow reduction. Relevance for asthma is less consistent. Weaker evidence pertains to the influence of ozone in the range 0.08-0.12 ppm. There is no evidence to suggest clinically significant respiratory health effects at 1 hour exposures below 0.08 ppm. The potential effect of ozone on health in Australia is small simply because of the relatively clean air quality.

High ozone days (>0.12 ppm) are expected to average less than 5 per year in Australia's two largest cities, and around 15 days with readings in excess of 0.08 ppm (1 hour).

Recent evidence about the effect of particulates suggests this may be of far greater importance for health and not just through respiratory but also through the cardiopulmonary system, which represents a far broader spectrum of disease. The implication for Australia is not clear, as with most studies, air quality in Australian cities represents the cleaner end of the range against which health effects are determined.

Further the role of SO_2 in combination with particulates is important, and levels of SO_2 are substantially lower in Australia than overseas. However, further work in both monitoring particulates and studies to determine health effects at the levels common in Australian cities is desirable. Road vehicles are not the major source of particulate pollution.

A.3 Introduction to Selected Articles/Reports

2 Abramson M & Voigt T 1991, Ambient air pollution and respiratory disease, Department of Social and Preventative Medicine, Monash Medical School.

A review of experimental evidence and epidemiological studies for acute toxicity of SO_2, NO_2 and ozone, particularly in susceptible individuals with obstructive airways disease.

4 Marks GB 1994, A critical appraisal of the evidence for adverse respiratory effects due to exposure to environmental ozone and particulate pollution: Relevance to air quality guidelines', *Australian & New Zealand Journal of Medicine*, vol 24, pp 202-213.

The 'review examines the evidence of adverse respiratory effects of ozone and particulate pollution that is relevant to the establishment of air quality guidelines in Australia'. A total of 99 papers/reports on health effects of ozone and particulates are cited. The review was conducted by a research scholar with the Institute of Respiratory Medicine, Royal Prince Alfred Hospital, Sydney. Direct communication supplemented material presented in the paper. This is a most informative review.

The review suggests ozone at levels common in Australia is most unlikely to influence either rates of asthma or severity of illness but may have some minor effect on other respiratory illness. Particulates are identified as requiring further study but of potential concern.

The discussion is descriptive rather than quantitative which limits its usefulness for valuing the health impact of road vehicle emissions.

5 Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BC, Speizer FE 1993, An association between air pollution and mortality in six US cities.

A well constructed epidemiological study which looks at predictors of mortality differential is the US six cities study. This is a prospective study with 14 to 16 years follow up of 8111 participants, aged 25-74 years on enrolment, across six US cities. At follow up a total of 1430 deaths, with crude death rate per 1000 person years of follow-up varying from 232 to 291 between the best and worst city. Age standardised death rates were adjusted for smoking (number of cigarettes and whether current or past smoker), body mass index, diabetes, hypertension, educational level and exposure to workplace pollution. Adjusted death rates were then related to indicators of air quality, including: total particles, inhalable particles, fine particles, sulphate particles, aerosol activity, sulphur dioxide, NO_2, ozone.

There was found to be a substantial and highly significant correlation between:

- all cause mortality, lung cancer mortality and cardiopulmonary mortality; and
- fine particles, respirable particles and sulphate particles

No relationship between ozone and mortality was found, although the range for ozone in the six cities may have been insufficient to identify any impact. In relation to particulates a clear dose response relationship was identified. The relative risk of death between the most polluted city to least polluted city is shown in Table A1. The authors conclude that there is a large and statistically significant correlation between mortality and air pollution as measured by respirable particles, fine particles or sulphate particulates. While acknowledging the observation could be caused by an associated factor the results are consistent with other studies that highlight the impact of particulates on health. Important possible confounders have been controlled for in the study, strengthening the confidence in the conclusion.

In relation to cause of death, relative risk between the most polluted and least polluted city was 1.26 for all cause mortality, 1.37 for lung cancer and 1.37 for cardiopulmonary disease. (Note with lung cancer for comparison the relative risk is 8.00 for current smokers and 2.54 for previous smokers and for cardiopulmonary disease 2.3 and 1.52 for current and previous smokers respectively). There was zero relative risk between the least and most polluted cities in relation to deaths from other causes.

Comment

Based on communication from the EPA Victoria, it is apparent that air quality in Melbourne is close to that of Portage Wisconsin, the least polluted city of the six against which the relative risks were calculated. Observations of inhalable particles in Melbourne typically average 20 ug/m3 and generally fall within the range 15-25 ug/m3. Fine particles would typically average around 10 up/m3. The six cities study thus provides no evidence concerning the relative health risk posed by pollution from particulates in Melbourne or other Australian cities, as there is no information on which to extrapolate relative mortality rate to lower, less polluted levels.

Table A1 **Relative Risk of Death – All Cause Mortality – Per Annum Least Polluted to Most Polluted City in Six Cities* Study**

Air Quality Indicator	Range of Values – Least Polluted to Most Polluted City	Relative Risk of Death pa; Most Polluted to Least Polluted City
Inhalable particles < 10 um	18.2 to 46.5 ug/m3	1.27 (1.08 to 1.48)**
Fine particles < 2.5 um	11.0 to 29.6	1.26 (1.08 to 1.47)
Sulphate particles	4.8 to 12.8	1.26 (1.08 to 1.47)

Source: Dockery et al 1993, p.1755 and p.1758.
Note: * Six cities: Portage, Wisconsin (least polluted city); Topeka, Kansas; Watertown, Massachusetts; St Louis; Harriman, Tennessee; Steubenville, Ohio (most polluted city).
** 95% confidence limit.

6 Woodward AJ, McMichael AJ, Guest CS 1993, Air quality goals for ozone: Environmental, economic and social impact assessment, Discussion document, November, Department of Community Medicine, University of Adelaide and 1993 Options Report, August.

This report is part of a research program commissioned by the Commonwealth Department of Human Services and Health to contribute to a review by the NH&MRC of its air quality goal for ozone. This report covers methodological issues, evidence on health effects, environmental impact assessment and economic impact assessment and social impact assessment. Health effects are discussed in more detail in the August 1993 Options Reports.

An estimate of the health benefits and their value from tightening ozone standards from 0.12 ppm down to 0.08 ppm (as proposed in Victoria) is developed in the report. The method and results are summarised below. The authors suggest a reduction in excess asthma episodes among susceptible members of the population will be the main health outcome of a more stringent goal for ozone. (I would not have thought the sole focus on ozone was well supported by the literature.)

Calculation then proceeded roughly as follows: (see Woodward et al Section 7.10, pp 37-39).

- Estimated annual cost of asthma is $320 million in medical related costs plus $260-$400 million in lost productivity ($580-$720 million).
- There is an estimated 1.7 million asthmatics; 10% of the population suggested by recent prevalence surveys.
- Achievement of 0.08 ppm maximum 1 hour level would save between 80,000 and 640,000 episodes of asthma per year assuming:
  - ⇒ 1 million people would be exposed to ozone >0.08 ~ 16 times per year, of whom 100,000 would be asthmatics;
  - ⇒ asthmatics have a 10% probability of an episode on each day, ie 36.5 episodes per asthmatic per year;

- ⇒ on high ozone days an extra 3% to 225% episodes;
- ⇒ potential episodes avoided 10,000 x 16 x .03 to 16,000 x 25 = 48,000 to 400,000.

- Average cost per asthma episode = \$580 - \$720 m/(1.7m x 36.5 episodes) = \$9.40 – 11.60.
- Potential value of avoiding asthma episodes = \$451,000 to \$4.64 million.

The range quoted for possible cost of ozone > 0.08 ppm was \$180,000 to \$3.48 million. The lower minimum estimate calculated on the assumption that asthma prevalence was really 20% not 10%, suggesting a far lower cost per episode. (There is some difficulty in reproducing the exact calculations contained in the report.)

Other Health Costs:

- Attributable to minor improvements in capacity for physical activity. Not able to be quantified, but expected to be small, due to lack of evidence of other than transient impacts.
- It was stated that the asthma cost failed to take account of quality life impacts. In fact the inclusion of 'lost production' in the estimate may well provide a reasonable surrogate for quality of life loss.
- Effects other than on asthma have been assumed to be negligible.