

NEW ZEALAND EVIDENCE FOR HEALTH IMPACTS OF TRANSPORT

**A background paper prepared for the
Public Health Advisory Committee**

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December 2002



NATIONAL ADVISORY COMMITTEE
ON HEALTH AND DISABILITY
HIINGA KAITIHIRO I TE HAUORA O TE TANGATA

**Incorporating the Public Health Advisory Committee
Te Rōpū Tohutohu I Te Hauora Tūmatanui**

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Acknowledgements

This work was carried out during the first nine months of 2002 with support from the National Advisory Committee on Health and Disability (National Health Committee). Materials were collected from a variety of sources using web-based information as much as possible. We are grateful for comments and suggestions received from the two peer reviewers and from colleagues who read parts of the text in draft form.

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Summary

Transport is an essential sector in a modern economy, but the rapid movement of vehicles and the energy required to drive them creates health hazards that need to be managed for minimum health impacts. Descriptive statistical material on transport activities in New Zealand has been identified and relatively comprehensive statistics on traffic crash injuries exists. However, the review identifies clear gaps and biases in the data available.

Apart from the direct safety hazards involved with transport, indirect hazards such as air pollution, noise, and other environmental hazards like storm-water contamination, are created. In addition, private motor vehicle travel reduces opportunities for daily physical activity, and major roads can reduce community coherence and lead to social isolation.

All these factors have potential health consequences, but research in New Zealand to quantify the health risks is limited. However, this report identifies issues that would merit further research.

Introduction

The preparation of this report was commissioned by the Public Health Advisory Committee (PHAC) of the National Health Committee, as a part of its work on health impact assessment. The aim is to identify and summarise relevant evidence for the health impacts of land transport in New Zealand during recent years. The review will link to a summary of international evidence on the health impacts of transport, which is being undertaken by the Public Health Advisory Committee.

The intention is to cover both health promoting and health damaging aspects of land transport and to identify any health inequalities that may be associated with land transport. In particular, any differential impact between Māori and non-Māori is of interest for this report.

The report is a summary of existing evidence and does not include all New Zealand literature on transport and health. Substantial analysis of the health and environment issues surrounding transport is no doubt included in consultancy reports that are not publicly available. The field of traffic safety is well represented in the published literature, but research on other aspects of transport and health is still at an early stage.

A special effort was made to identify evidence in the “new” areas of health concern for transport, namely air pollution and lack of physical activity. Overall, the lack of published research in New Zealand on this topic makes a full assessment of the health impacts of transport difficult. In spite of the limitations, some clear trends and conclusions emerge, and suggestions for further research are made.

This report is based on review analysis and research by the same authors in preparation for journal publication.

1. Background and hazard exposure issues

1.1 Transport - its purposes and features

Transport is an essential sector in a modern economy and many positive features flow from it. It creates jobs. It makes it possible for people to access a more widespread job market through being able to live in one part of town and work in another. It brings attractive and/or necessary products, including food, from far away places. It increases our opportunities to take part in leisure and sports activities as well as to meet with family and friends. In these ways transport can promote public health in a broad sense and also improve access to health care. But transport is also associated with several types of health hazards.

Some may argue that transport-related health hazards are a “necessary evil” of a modern economy. In fact, like so many modern health hazards, the level of hazard exposure in a population can be reduced to very small levels by applying appropriate preventive policies and actions. New Zealand should be able to learn from the experiences of other economically advanced countries in reducing transport-related health hazard exposures and effects.

To identify such opportunities we need to understand our own exposures situation, the trends in transport-related health impacts, and the results of local applications of preventive measures. Health impact assessments of transport systems have until now focused on the car crash injury element, but isolated examples (e.g. Freeman and Scott-Samuel, 2000) have included most of the impacts identified in this report.

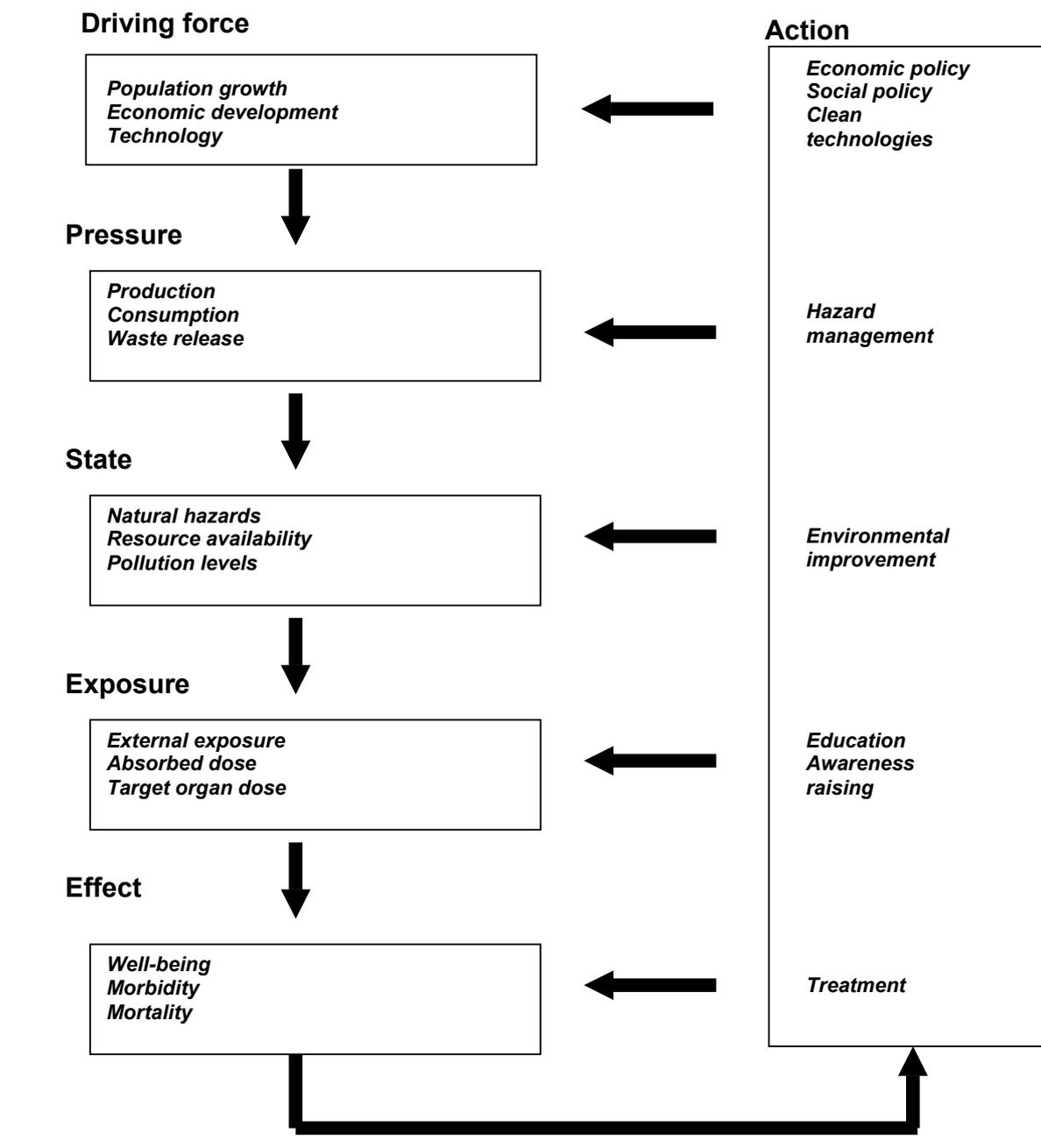
The methods to quantify car crash impacts are well developed, while air pollution and obesogenic (encouraging obesity) effects can be quantified with caution. Methods for quantification of other health impacts are still in their infancy.

This report aims to contribute to such understanding and to broaden the debate about transport and health from a focus on direct injuries to other health hazards. Its findings may be used to establish locally relevant risk functions for different modes of transport that could improve future health impact assessments and transport economic assessments in New Zealand.

The published research on transport and public health in New Zealand was very limited until the early 1990s when the Injury Prevention Research Unit at the University of Otago and the Injury Prevention Research Centre at the University of Auckland started producing a series of reports on different aspects of transport injuries. On the more comprehensive issue of transport and health, precious little has been published. An editorial for the New Zealand Medical Journal in 1993 (Roberts and Norton, 1993) mentioned most of the health issues in this report, but other published research has been very focused on one hazard exposure at a time.

Transport-related health impacts can be analysed from the viewpoint of the hierarchy of exposure factors that contribute to environmental health effects described with the DPSEEA framework (Figure 1). The driving forces are demographic (population growth, ageing); economic (increased demand for transport from a growing economy, shifts in demand from changing industry, changing work travel patterns); social (changing patterns of social, shopping, leisure and sports activities, changing attitudes to transport “norms”); and technological (telecommunications reducing transport need, more energy-efficient car engines, more convenient and pleasant public transport modes).

Figure 1. The DPSEEA framework to define environmental health indicators. (Kjellstrom and Corvalan , 1995; Corvalan et al., 1996)



Out of these driving forces, different pressures on the transport environment occur: more need for transport, more cars, more trucks, more air pollutant emissions, more noise, and so on. The increased pressures lead to a deterioration in the environment, leading to higher exposures to hazard in people that spend time in the affected environment. Eventually the exposures lead to health effects. Preventive action can be taken at each level of the hierarchy of this “cause-effect” framework.

This report will analyse primarily the transport and health issues related to motor vehicle transport of people, which in New Zealand, is the main area of health concern in relation to transport. Where possible, health risks of particular importance to Māori or to specific age and gender groups will be highlighted. It is important to note that both personal and freight transport create health hazards.

Table 1 summarises the trends for two major driving forces behind transport-related health hazards and impacts.

Table 1. Transport and health driving force and pressure variables (rounded numbers) and reported accidents (index for trend in brackets) (LTSA, 2002)

Transport mode	Population (Driving force)	Vehicles (Pressure)	Transport accidents with injuries or fatalities
1951	1,970,000 (100)	447,000 (100)	7,200 (100)
1960	2,400,000 (122)	806,000 (180)	13,200 (183)
1970	2,850,000 (145)	1,210,000 (271)	21,500 (299)
1980	3,180,000 (161)	1,790,000 (400)	16,500 (229)
1990	3,410,000 (173)	2,200,000 (492)	18,400 (253)
2000	3,830,000 (194)	2,600,000 (582)	11,200 (155)

The table shows that while the population has doubled in the last 50 years and the number of vehicles has increased nearly six times, the transport injury accident statistics first began to decline in 1970 and have continued to decline with the 2000 number half those of 1970. The trends in other health risks related to transport do not necessarily parallel these data, but overall the transport and health situation has experienced important changes during these 50 years.

In New Zealand, the trend over recent decades has been for a shift of passenger transport towards the private car for short and medium distances and towards air transport for longer distances (Statistics NZ, 2002 website). Freight transport has shifted from trains to trucks. These changes led to changes in exposure to health hazards and to subsequent changes in the occurrence of health effects.

Table 2 summarises the health aspects that will be considered in this report. The degree of health risk is indicated with the number of stars, combining tentative assessments of the prevalence of exposure to hazard and the relative risk of injury or disease associated with such exposures in New Zealand.

When interpreting health impact data, it should be remembered that the injury or disease “victim” may be riding in the vehicle causing the hazard (crash, air pollution, noise, etc), but may also be in or on another vehicle (e.g. bicycle hit by car), may be walking or standing at the roadside, or may happen to live in the vicinity of a heavy traffic road. The interpretation of transport-related health hazards therefore needs a number of different types of analysis to identify prevention possibilities.

The traffic crash injuries may occur with any mode of transport on its own, but many of these injuries are due to crashes involving vehicles or people using the same road space: for example, pedestrians hit by cars; cyclists hit by buses; motorcyclists hit by trucks. Health risks due to crashes for different modes of transport therefore appear quite different based on the numbers of injured people or the numbers of vehicles involved in a crash. Cars are the most common vehicles on the roads and their drivers and passengers contribute the greatest proportion of injured people, but the relatively small number of motorcyclists has a much higher risk of being injured per kilometre travelled.

Air pollution from transport is due to the pollution created by using energy to move the vehicles, usually by a liquid fossil fuel combustion engine (petrol or diesel). These engines emit air pollution wherever the vehicle is driven, while electric or fuel cell powered vehicles transfer the air pollution problem to the power plant or fuel production plant where the energy is converted to the “fuel” used. Only walking and bicycling emit no health damaging air pollution.

Table 2. Types of health hazards related to transport and their relative importance at national level. (* approximate ranking of health risk)

Transport mode	Crashes	Air pollution	Noise	Physical exercise reduction +	Community disruption	Other environmental factors ++
Walking	(*)					
Bicycle	*					
Motorcycle	**	*	**	***	*	*
Car	***	***	***	**	***	***
Bus	**	**	**	*	*	*
Truck	***	**	**		***	***
Train	*	*	*	*	*	*
Ferries		*		*		*
Aeroplane	**	*	***		**	**

+ Buses, trains and ferries are not included, as these would be the alternatives to private vehicles

++ These are explained in Section 7

Similarly, noise, physical exercise reduction, community disruption and other environmental health hazards are primarily related to motor vehicle transport. The extent to which the different health hazards materialise for each mode of transport in a specific location is determined by local geographical, meteorological, social and physical planning

conditions. The main issue of concern in one country or community is not necessarily the same in another.

It should be pointed out that apart from potential health hazards, different modes of transport impact on society in other ways via physical damage and economic loss through crashes, energy consumption, ecological effects of air pollution, greenhouse gas emissions, and so on. When economic impacts of transport modes are assessed, these non-health factors also need to be taken into account, as well as the economic value of the transport activity itself.

Judging the relative importance of different factors is not an easy task. The way the impact is expressed is in itself important. For traffic crash impacts alone the “risk” can be expressed in five different ways:

- * Crude numbers of injury accidents, people injured or killed
- * Rates in the population (e.g. killed/1000 people)
- * Rates among the vehicles (e.g. killed per 1000 vehicles)
- * Rates per distance travelled (e.g. killed per vehicle-km)
- * Rates time travelled (e.g. killed/ hour of travel time)

Each of these expresses a different aspect of transport safety, and they are all valid measures for interpretation, but they are seldom reported routinely. Some comparisons can be made based on reports from the Land Transport Safety Authority (LTSA). More comment on the different measures will be given in the following sections.

1.2 Mobility of people and travel profiles

New Zealanders use a variety of transport modes for their everyday mobility. The predominant means of transport for most people is private car, either as a driver or a passenger (Table 3). People in all age groups use vehicles for over three quarters of their travel; the next most common means of transport is walking (10-20%), followed by bus (5-10%) and cycling (< 5%). Children spend approximately half an hour per day as car passengers while young adults spend seven hours per week in cars (Table 3).

Table 3: Typical weekly travel profile, by age and mode of travel, 1997-98
(LTSA, New Zealand Transport Survey 1999)

Age (years)	Walking	%	Passenger	%	Driver	%	Bus	%	Bicycle	%
0 - 14	1 hour	15	4 hours	70	0	0	30 min	10	15 min	< 5
15 - 24	1 hr 45 min	20	3 hrs 45 min	40	3 hrs 30 min	35	45 min	10	15 min	< 5
25 - 64	1 hour	10	1 hr 30 min	15	6 hrs	70	15 min	< 5	< 15 min	< 5
65+	1 hour	20	1 hr 15 min	25	2hrs 30 min	55	< 15 min	< 5	< 15 min	< 5

NB: Travel times are rounded to the nearest 15 minutes. Percentage travel times are rounded to the nearest 5%.

Cars versus public transport

Over the past decade, the total distance driven each year has increased by one third (the timeframe of one decade was chosen because national travel survey data only exist for this period). Part of this increase is due to growing numbers of New Zealanders of driving age, but people are also driving greater distances than they were ten years ago (LTSA 1999).

Census data shows an increase in the proportion of people driving to work, with a corresponding decrease in public transport utilisation. In 1996, 74% of people who travelled to work did so by driving, compared with 61% in 1986. In 1986, 8.1% and 1.7% of commuters travelled by bus and train respectively; by 1996 these proportions had fallen to 3.8% and 1.0% (MfE 2002).

Motorcycles

There has been a significant decrease in motorcycling over the last decade, with motorcycle ownership falling by 40 percent from 1989/90 to 1997/98. This decrease is thought to be due mainly to a decline in ownership of small motorcycles and scooters in preference for cheap cars as a means of transport within cities. The result has been a significant reduction of motor vehicle crashes involving motorcycles.

Cycling

Cycling as a means of transport has declined in the past 10 years, decreasing by almost 20 percent since the 1989/90 Travel Survey. The greatest decrease in cycling has occurred in school-aged children, for whom cycling was previously a common means of transport to and from school. The decline in cycling in this age group is thought to be due to concerns about child safety, and is in keeping with patterns observed in other countries (such as the UK). More children are now being driven to and from school (see Section 6). Cycling has also declined as a means of transport to work, from 5.7 percent of commuters in 1986 to 4.0 percent in 1996 (NZ Census data).

1.3 Motor vehicle ownership

New Zealand has one of the highest rates of motor vehicle ownership in the world, along with North America, Australia, Japan, and northwest Europe (Table 4) (Ministry for the Environment 1997). New Zealanders own an average of 66 vehicles per 100 population (LTSA 2002). This in itself is of course an important “driving force” behind the different public health impacts that are associated with vehicle driving.

Table 4: Vehicle ownership rates for OECD countries (figures from 1999)

(Land Transport Safety Authority, 2002)

Country	Vehicles per 100 people
USA	78
New Zealand	66
Australia	65
Canada	57
Sweden	52
United Kingdom	47

While almost half the population has access to two or more vehicles (Table 5), 8.1 percent of New Zealanders have no access to a car or other vehicle (New Zealand Census 1996). This highlights potential inequalities of access to transport, which in itself is important for health. Availability of transport enhances social relationships, and it may also be very important for access to health services and other amenities in society. Few people active in the New Zealand workforce are able to meet their weekly transport needs without access to a motor vehicle. The number of families with more than one vehicle is boosted when more than one person is employed or is studying away from the home. In families with young children, the tendency to use (need) a second car has grown as childcare, after-school activities, and children's sports activities expand. An analysis of vehicle access by gender (LTSA, 2001) showed very small differences. Multiple car accessibility is slightly more common among men than women, while no car access is more common among women (9.4%) than among men (6.8%).

Table 5: Access to motor vehicles (figures from 1996 census)

<i>Percentage of population with access</i>	<i>Number of Vehicles</i>				
	<i>None</i>	<i>One</i>	<i>Two</i>	<i>Three or more</i>	<i>Not stated</i>
Total population	8.1%	34.8%	34.7%	14.2%	8.1%
Maori	20.9%	42.0%	21.9%	8.0%	7.1%
Pacific	19.9%	44.4%	21.3%	7.6%	6.8%
Non-Maori, Non-Pacific	6.6%	33.9%	36.3%	15.0%	8.2%

1.4 Travel by motor vehicle

Vehicle travel is undertaken predominantly for work-related and recreational purposes (Table 6). Most motor vehicle trips are in cars and are short: two-thirds are for distances less than six kilometres, and half of these are less than two kilometres. Bus travel accounts for a small proportion of vehicle journeys, with almost half of all bus trips being made by teenagers. Taxi journeys account for less than one percent of vehicle travel. (LTSA, 1999)

Table 6 : Reasons for vehicular (car) travel - percentage of total distance travelled
(LTSA, New Zealand Transport Survey 1999)

<i>Reason for Travel</i>	<i>Percentage of Distance</i>
Social / recreational	32%
Work (getting to and from)	16%
Work (i.e. work business)	16%
Shopping	14%
To accompany someone (e.g. taking children to school)	13%
Personal business or services	8%
Education	1%

Regular commuting to work is a transport need for which alternatives to the private car may be most likely to be considered. According to the World Bank (World Development Report, 2000) Auckland stands out as one of the cities of the world with the lowest use of public transport for work commuting (6% of commuters).^{*} One can assume that the vast majority of commuters use private cars or cars provided by the employer (“company cars”). In Melbourne 16 percent of commuters use public transport and in Stockholm the number is 37 percent (World Bank, 2000).

Further information about commuting is included in the report “Quality of life in New Zealand’s six largest cities” (Manukau City Council, 2001). Public transport use (bus and train) as a mode of travel to work, is even lower in Christchurch than in Auckland (Table 7). Wellington has the highest use of buses and trains (17%) as well as the highest rate of walking, while Christchurch has the highest use of bicycles (7.8%). These modes all contribute to physical exercise integrated into “active transport” (see Section 5).

Table 7. Mode of transport to work on census day, 1996, % of population that used different modes (Manukau City Council, 2001)

City	Private car or motorcycle	Bus	Train	Bicycle	Walked or jogged	Worked at home	Other
Auckland	74.5	8.0	0.4	1.8	5.7	6.8	2.5
Manukau	82.8	4.6	0.8	1.3	3.2	5.6	1.6
North Shore	77.6	6.0	0.0	1.3	3.7	7.4	2.8
Waitakere	82.6	4.5	0.9	1.3	2.8	6.3	1.7
Wellington	60.8	13.7	3.1	2.2	12.9	4.9	2.5
Christchurch	75.2	3.9	0.0	7.8	4.8	5.8	2.5

Another type of commuting, increasingly carried out by private motor vehicle, is travel to and from school, usually involving a parent driving an individual child (Land Transport Safety Authority, 1999). A dramatic shift towards increased trips for this purpose was recorded in the New Zealand Travel Survey, as seen in Figures 2 and 3. Both in rural and

^{*} the 6% public transport commuting figure used by the World Bank (2000) is most likely an average for the Auckland region.

urban areas the number of school trips as a car passenger has doubled during the 1990s. In rural areas walking and cycling has been dramatically reduced, while in urban areas there have been only small changes in the number of such trips. The reasons for these changes are partly explained by longer distances to school in rural areas (due to school closures), reduction in provision of school buses, safety concerns by parents, combining children's with parent's travel needs, as well as changing "life-style behaviour" involving less use of the "old-fashioned" ways of transport. The ultimate impact is more car-related health risks and less "active transport" physical activity among children, increasing the risk of obesity.

Figure 2. Rural school transport. From the New Zealand Travel Survey

(Land Transport Safety Authority, 1999)

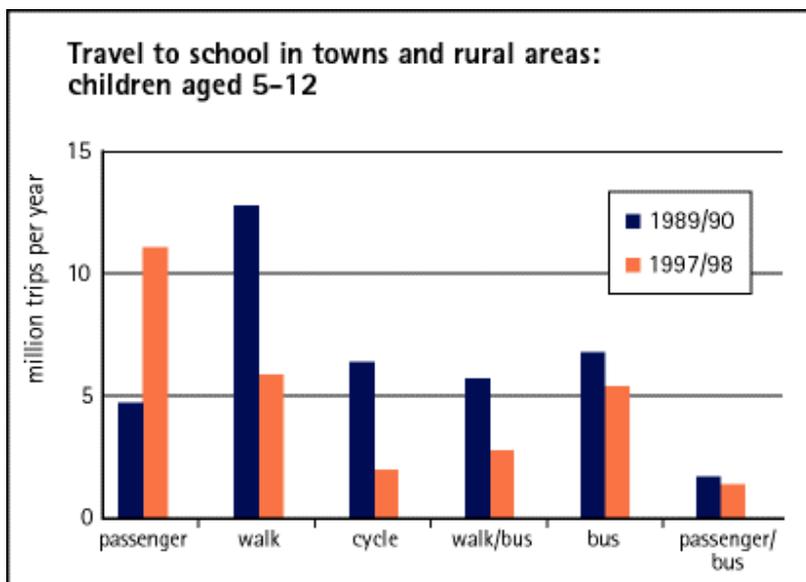
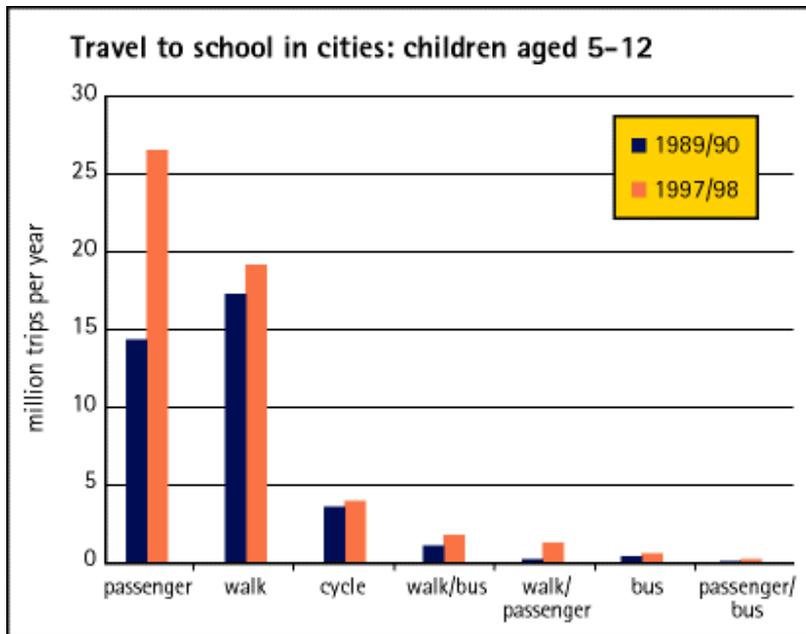


Figure 3. Urban school transport. From the New Zealand Travel Survey
(Land Transport Safety Authority, 1999)



1.5 Walking

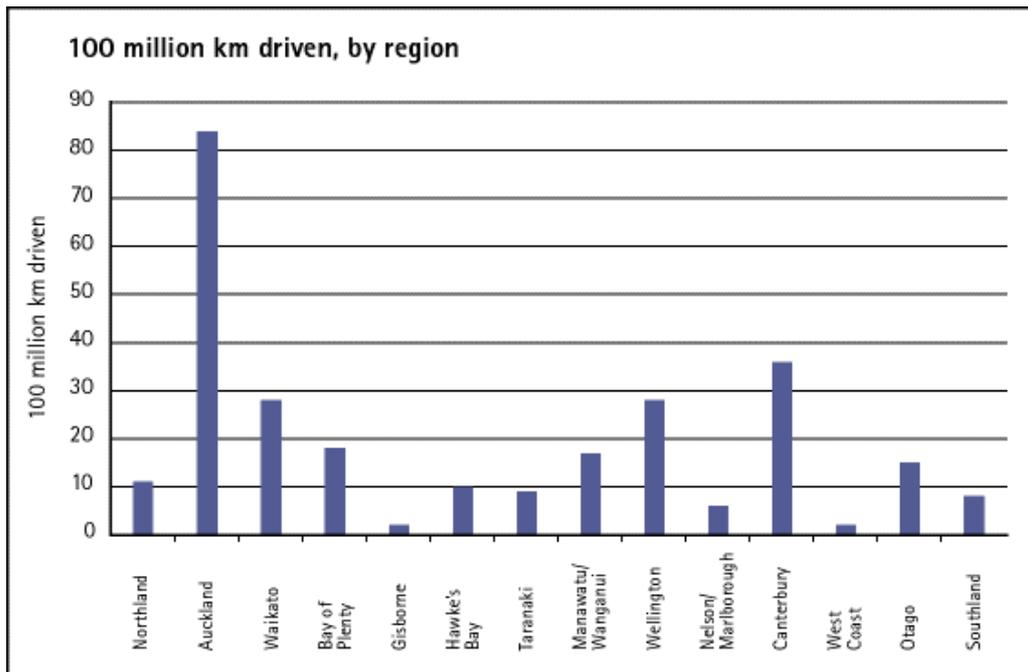
Walking is a particularly important means of transport for children and young people, and older adults, with these groups making around 25 percent of all journeys on foot. Walking represents a smaller proportion of travel for adults under 65 years. It is used more by women, Maori and Pacific peoples (LTSA 2000). The extent to which walking is used to travel to work (Table 7) depends on the geographic layout of a city and the availability of other transport. Wellington has more than twice as many regular walking commuters (12.9%) as any of the other five cities (Table 7).

An issue of importance for public health is the extent to which children walk for their daily mobility needs. The current debate about the increasing obesity in New Zealand has made special reference to the issue of children's physical activity and walking to and from school and play is an important natural way to get physical exercise. An important factor behind the increasing tendency for children to be driven to school is the perceived danger of walking along and crossing roads with traffic, as well as the "stranger danger" of people who could harm the child (Kearns, 2001). A detailed review of this issue (Collins and Kearns, 2001) presents strategies to reduce safety concerns at school level. An analysis of the "geography of the children's welfare" is suggested that gives a voice to the children themselves, and reduces the impact of the dominant car-oriented thinking.

1.6 Regional patterns of travel

Regions with larger populations represent a greater proportion of total national travel. In keeping with this pattern, travel in the Auckland region accounts for around one-third of the total national distance driven by motor vehicles (see Figure 4).

Figure 4 : Annual distance driven in each region
(LTSA, New Zealand Transport Survey 1999)



Mode of travel also varies between rural and urban regions (see Figure 5). Due to larger distances traveled, one can expect motor vehicle travel to play a more dominant role in rural areas, while walking would be more common in urban areas. Rural people spend less time walking and bicycling than their urban counterparts (Figure 5), but spend more time in buses, with car travel time use similar. In rural areas travel distances per trip are more than 25 percent longer than in urban areas (LTSA, 1999). The average speeds on rural roads would also be higher.

The longer time that city-dwellers spend walking and cycling compared with rural-dwellers is likely to reflect the closer proximity of work places, schools and other amenities.

Figure 5 : Time spent in different modes of travel in urban and rural areas
(LTSA, New Zealand Transport Survey 1999)

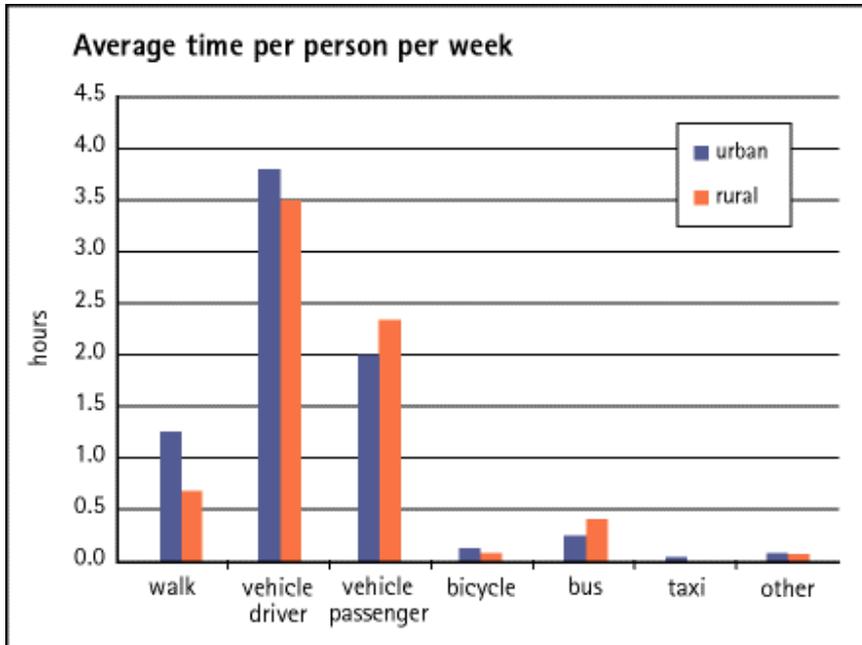


Table 7 highlights differences in commuting travel between six cities in three regions. The relatively high proportion of public transport use in Wellington has already been commented on. Another feature is the high proportion of cyclists in Christchurch (the flat topography facilitates this) and the high proportion of walking commuters in Wellington.

2. Safety

The most obvious health impact of land transport is road traffic injuries. This is well established in health statistics from all countries with significant motorisation. During the 1960s and 1970s in New Zealand the mortality and morbidity rates (in relation to population) were increasing. Since then the rates have decreased, in spite of continued increased motorisation (see Table 1), due to safety measures of various types. However, road accidents are still a major cause of death and disability in New Zealand. In this report, this issue will not be reviewed in complete detail, as so much has already been written about road crashes and health in New Zealand.

2.1 Road traffic injuries in New Zealand

New Zealand has a high road traffic mortality rate compared with other countries in the OECD. In 1998 the death rate from road crashes was 13.3 per 100,000 population – lower than the USA, but higher than Australia, Canada, Sweden or the United Kingdom (LTSA 2002a). New Zealand's high road accident fatality rate is partly due to the high number of

vehicles per capita (see Table 8), but the rate per vehicle is also one of the highest in developed countries.

Table 8: International comparison of road death rates, 1998

(Land Transport Safety Authority website)

Country	Vehicles per capita	Road deaths	Deaths per 100,000 population	Deaths per 10,000 vehicles
USA	0.77	41471	15.3	2.0
Australia	0.64	1763	9.4	1.5
Japan	0.61	10805	8.5	1.4
New Zealand	0.61	502	13.3	2.2
Germany	0.60	7792	9.5	1.6
Canada	0.59	2934	9.7	1.6
Norway	0.56	352	8.0	1.4
Sweden	0.51	531	6.0	1.2
United Kingdom	0.48	3581	6.1	1.3
Ireland	0.41	458	12.4	3.0
South Korea	0.28	10416	22.7	8.0

The Land Transport Safety Authority provides official statistics on road accident fatalities and motor accidents in New Zealand. These are updated regularly, and are available from the LTSA website at: <http://www.ltsa.govt.nz/research/toll.html>. During 2001, 453 people died on New Zealand roads. Although road fatalities provide a useful indication of the health burden of transport accidents, they do not tell the whole story. For every person killed in a road accident, an estimated seven people suffer serious but non-fatal injury resulting in hospitalisation, according to LTSA statistics (LTSA, 2002). A source of data on transport injuries that has been used only in a limited manner is the injury claims database of the Accident Compensation Corporation.

While road fatalities are likely to be accurately represented in the official statistics, other road injuries are significantly underreported. Studies comparing Ministry of Transport (and LTSA) figures with hospital admission and community survey data show that only a portion of serious crash injuries are reported (Morrison, Kjellstrom, 1987; Begg et al., 1990; Alsop and Langley, 2001). The most recent study (Alsop and Langley, 2001) found that only two-thirds of all hospitalised vehicle occupant traffic crash victims in 1995 were recorded in the official LTSA statistics, based on a probabilistic matching of individual records. Relatively small differences were found between regions, month and day of crash and type of occupant. However, passengers on motorcycles had the lowest reporting ratio (54%).

The earliest study (Morrison and Kjellstrom, 1987) was based on a simple comparison of annual numbers of hospitalised traffic crash victims and official statistics. The study found a steady decrease of reporting ratios for most road crash victims between 1973 and 1982. For instance, for car drivers and passengers it went from almost 100 percent down to 66 percent. This group had the highest reporting ratios and the lowest ratio was found for

cyclists (15-21%). Pedestrians and motorcyclists had similar reporting ratio trends; from 70 percent in 1973 to 47 percent in 1982. Very low reporting ratios were found for certain preschool children's injuries; for example, none of 21 hospitalised children who had fallen out of moving cars was reported, and only one of 36 children who had been injured by a car moving on a domestic driveway was reported (Morrison and Kjellstrom, 1987).

Similar gaps in official accident statistics are observed in other countries, including the UK, USA and Sweden. In general, less than 50 percent of traffic crash injuries are reported to police/transport authorities. If the under-reporting was constant over time and similar for all road users (the two-thirds found by Alsop and Langley 2001), one could make an adjustment of the official statistics, but this may still seriously under-estimate injuries among cyclists and child pedestrians.

The New Zealand Transport Survey provides extensive information on the risk of injury according to mode of transport, age, gender and ethnicity, and time of day. These data are based on road traffic injury statistics (including fatal and non-fatal injuries) from the Land Transport Safety Authority database, which is in turn derived from Traffic Crash Reports completed by police officers (LTSA 1999, pg 7). All these official figures will be affected by the reporting bias mentioned above, as many traffic crashes and injuries are never reported to the Police or the LTSA.

Epidemiological research on the relationship between injury rates and specific risk factors was very scarce until the 1990s, when the Injury Prevention Research Unit (Dunedin) and Injury Prevention Research Centre (Auckland) were established. A number of reports in the early 1980s by Kjellstrom and co-workers (see reference list) followed a descriptive analysis by Kjellstrom and Barney (1979). These reports were prepared to inform a national campaign for increased use of child restraints in cars. An evaluation of this campaign was published by Kjellstrom et al. (1987). A number of research projects on risk factors have been carried out by Langley, Begg, Norton, Roberts, Connor, Ameratunga et al. (see reference list), but these will not be reviewed in detail here.

2.2 Risk by age and gender

The highest risks for motor vehicle crash mortality and morbidity occur in the age group 15 to 24 years (Ministry of Health, 1999). The age-specific rate in 1988-1990 was approximately 80/100,000 people for males (Maori and non-Maori very similar) while it was approximately 30/100,000 for females. Children under age 14 have the lowest rates, while within this group boys have higher rates than girls. The higher rates among those over 15 years of age are at least partly due to a much greater exposure (in hours per week) as drivers and passengers than for children. Compared with other countries in the OECD, New Zealand has some of the highest traffic crash mortality rates (Ministry of Health, 1999; Table 8).

The rates go down after age 24, and then increase again after age 65 (Ministry of Health, 1999), again with higher rates among men than women and among Māori than non-Māori. The highest mortality rate (90/100,000) is found among Māori men over age 75.

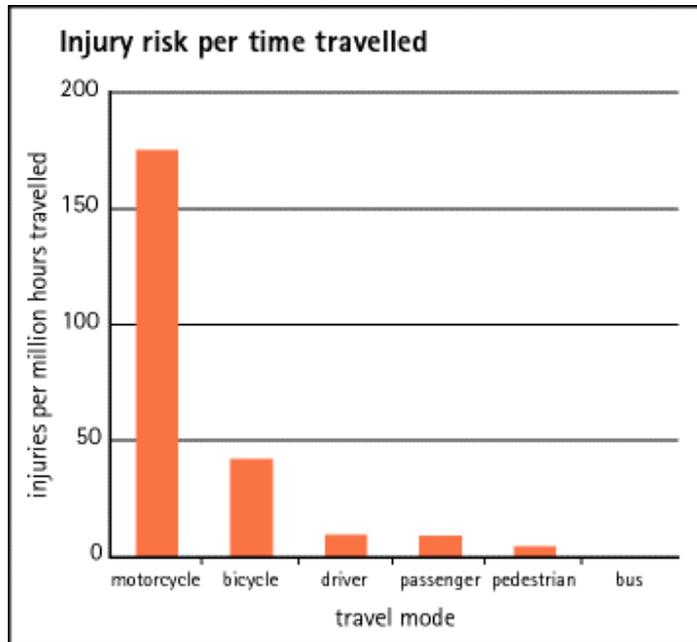
The age-sex-ethnic group variations for hospitalisations after motor vehicle crashes are similar to those mentioned above for mortality (Ministry of Health, 1999). The highest annual hospital admission rate is found for Māori men aged 15 to 24, at 1000/100,000, which means that 1 percent of all Maori men in the age group are admitted each year for crash injuries. Non-Māori men have a rate of 800/100,000 in this age group, and these rates drop by half in the next age group, 25 to 44 years. The time trends for the age group 15 to 24 show a slow reduction over time (Ministry of Health, 1999), but the Māori/non-Māori ratio is relatively stable.

Another way of expressing the health impact of traffic crashes on different age-sex-ethnic groups, is to calculate the disability-adjusted life years (DALYs) (Murray and Lopez, 1996). The DALYs express the “preventable” extent of lost “healthy life” for a particular population group or disease/injury category. The report *The Burden of Disease and Injury in New Zealand* (Ministry of Health, 2001a) shows that traffic crashes are number three in the ranking of DALYs lost for men (4.5% of all DALYs), with only ischaemic heart disease (15.6% of all DALYs) and chronic obstructive respiratory disease (5.6% of all DALYs) ranked higher. For women, the ranking for traffic crashes of 14 is 1.7 percent of total DALYs (Ministry of Health, 2001a). For Māori, the situation is similar (traffic crashes ranked 4 for men and 10 for women) (Ministry of Health, 2001b), while the contribution to total DALYs is higher (7.6% for men, and 3.1% for women).

2.3 Risk by mode of transport

Motorcyclists face the highest risk of injury per time spent travelling, with an injury rate of over 170 injuries per million hours travelled (around 18 times the injury rate of car occupants). Cyclists also have a high injury rate, at around 40 injuries per million hours travelled. The risk to pedestrians is lower than that of car drivers or passengers in terms of the number of accidents occurring for a given duration of travel.

Figure 6. Risk of injury (per time unit) by mode of travel
(LTSA, New Zealand Transport Survey 1999)



The incidence of injury gives us an idea of the relative risk involved in different modes of transport. The total number of injuries depends not only on the mode of travel, but also on the duration of travel undertaken by each mode. For example, most people spend much more time travelling by car than by bicycle (Figure 5), so overall their risk of injury in a car accident is much greater than their risk of being involved in a bicycle accident.

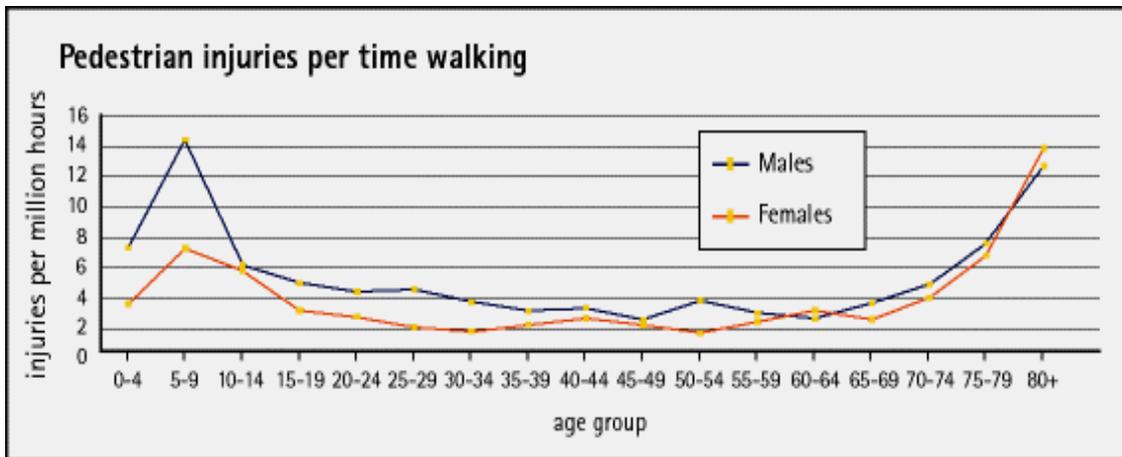
Taking into account the average travelling times for each mode of transport, between 15 and 48 drivers are killed (depending on age) for every 100 million km driven, while for motorcyclist the equivalent range of numbers is 325 to 973 (LTSA, 1999).

Risk to pedestrians

The risk of injury (per time unit) to pedestrians is highest at either end of the age spectrum. Primary school-aged children are vulnerable because they are less visible than adults, and have less experience and judgement in negotiating busy roads. Older adults are also at increased risk of injury, due to a combination of increased physical frailty and decreased agility and sensory perception. Male pedestrians are at higher risk than females in all age groups; this probably reflects behavioural differences between the sexes (LTSA 1999). Māori and Pacific peoples are twice as likely to be hospitalised as the result of a pedestrian injury compared with Pakeha: this is partly due to these groups spending more time walking in road environments (LTSA 2000).

Figure 7: Risk of injury to pedestrians by age

(LTSA, New Zealand Transport Survey 1999)



Pedestrian injuries are particularly significant in urban areas, where they account for over a quarter of all road fatalities. The majority of pedestrian injuries occur while a pedestrian is crossing the road, away from intersections and pedestrian crossings. Pedestrians tend to be injured more severely than vehicle occupants, due to their lack of physical protection (LTSA 2000).

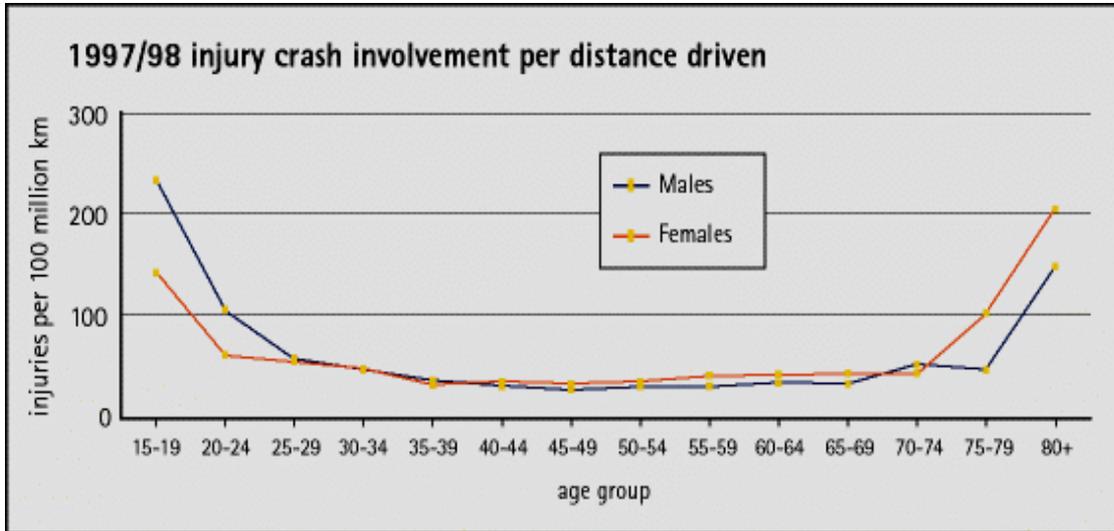
Two factors of major significance in pedestrian injury are speed and alcohol. Faster vehicle speed is associated with greater stopping distances and increased likelihood of death if a pedestrian is hit. Around 30 percent of all adult pedestrians killed on the road have a blood alcohol level over the legal driving limit (LTSA 2000).

Children in the Auckland region are at particularly high risk of road injury; despite comprising only 29 percent of the country's children, they account for 44 percent of all child pedestrian hospitalisations (LTSA 2000).

Risk for car drivers and passengers

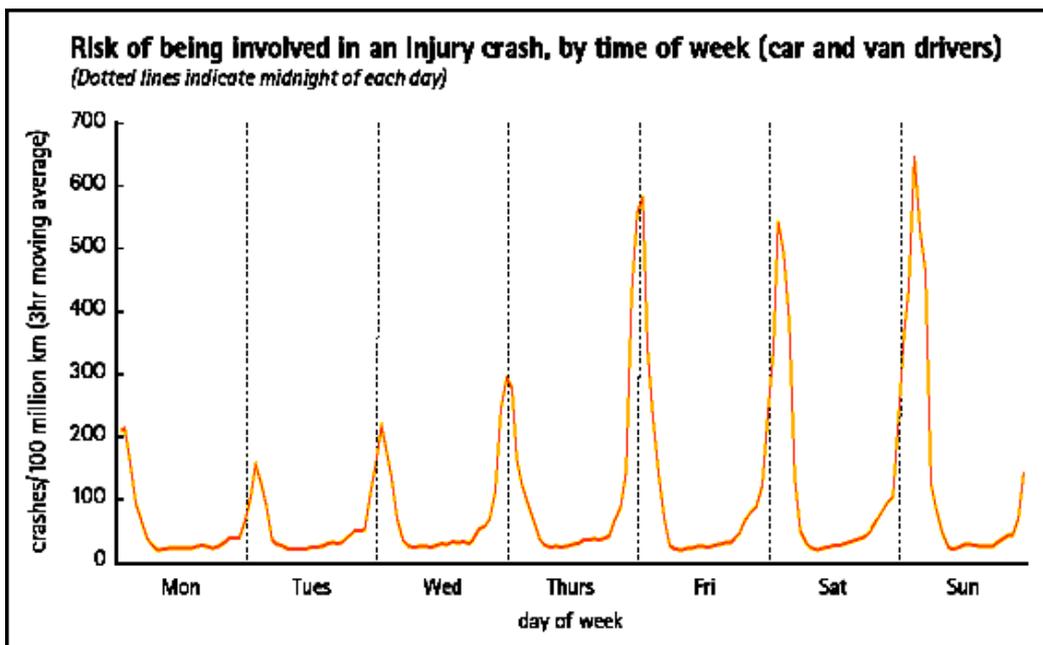
The risk of having a motor vehicle crash (per distance travelled) in which someone is killed or injured relates to both the age and sex of the driver (Figure 8). The risk is greater for drivers at either end of the age spectrum. Some of the increased risk in older drivers is due to increased fragility rather than an increased number of crashes – in other words, older drivers tend to be more physically fragile and thus are more likely to be seriously injured or killed in a crash compared with younger travellers.

Figure 8 : Risk of crash involving injury by age and sex of driver
 (LTSA, New Zealand Transport Survey 1999)



In younger drivers (< 25 years), males are significantly more likely to have a motor vehicle crash than females. From ages 25 to 74, the risk in both sexes is much the same. Over the age of 74, female drivers have a higher crash risk than males. Over all age groups, males are at higher risk than females, particularly in terms of fatal car crashes (LTSA, 2002).

Figure 9: Injury risk by day and time
 (LTSA, New Zealand Transport Survey 1999)



The risk (per time unit) of an injury-causing motor vehicle crash increases during the hours of darkness (when drivers may be particularly tired), and at peak drinking times. Thus the high-risk period each day is from 9 pm to 3 am, and this risk is greatest on Thursday, Friday and Saturday nights (Figure 9).

2.4 Risk by ethnicity and socio-economic grouping

Drivers of Māori or Pacific ethnicity face a higher risk of injury per distance driven than Pakeha/European drivers. The risk of being hospitalised as a result of a road crash is three times higher for Māori and almost three times higher for Pacific drivers (LTSA 1999; Irving et al, 1994).

A special analysis of the relation between socio-economic status and traffic crash mortality was carried out by Zhang and Kjellstrom (to be published) for this report. Deaths due to traffic crashes (International Classification of Diseases codes: E810-E819 in ICD-9) were extracted from the national death registration data for persons dying between 1992 and 1997. Accumulated person-years over the study period were calculated using 1991 and 1996 census data for New Zealand. The study includes males aged 20 to 59 years only.

Three broader categories of social class groups (high, medium and low) were divided according to values of the New Zealand Socio-Economic Index of Occupational Status (Davis et al., 1997). The age-standardised mortality rate and age-standardised rate of Potential Years of life Lost (PYLL) before age 65 were calculated for each category. All rates (Table 9) were age-standardised to Segi's population.

Table 9. Age-standardised mortality and PYLL rates per 1000 by NZSEI social class groupings (Zhang, Kjellstrom, to be published)

	Social class group: High	Medium	Low
Traffic crash mortality rate/1000	16.3	28.5	37.5
Traffic crash PYLL rate/1000	4.9	9.3	12.0
Total mortality rate/1000	206	289	340
Total mortality rate excluding traffic crashes	190	260	303
Total PYLL rate/1000	37.5	53.9	65.8
PYLL rate excluding traffic crashes	32.6	44.6	53.9

The table shows that in this age group among males the traffic crash mortality rate is more than twice as high among the low social class group as among the high one. The medium social class group has traffic crash mortality in between. PYLL rates show an even stronger socio-economic gradient (Table 9). The result of these findings, when comparing total mortality or PYLL rates, is that the remainder of mortality (minus the traffic crash contribution) shows a less prominent social class gradient. Traffic crash mortality is therefore an important explanatory variable for the social class gradient (Zhang and Kjellstrom, to be published).

3. Air pollution (vehicle emissions)

3.1 Potential health effects and dose-response relationships

Vehicles with internal combustion engines emit air pollutants, including particulate matter (dust), carbon monoxide, nitrogen oxides, and a variety of hydrocarbons. Previously, lead compounds were added to petrol, and lead emissions were a major environmental health problem, but the sale of leaded petrol was banned in New Zealand in 1996. Studies in the 1970s and 1980s showed that a relatively high average lead concentration in children's blood was likely to be partly associated with emissions from vehicles (Kennedy et al., 1988) (further details below).

Nitrogen oxides and hydrocarbons can oxidise oxygen in air to ozone if exposed to high levels of sunlight. This "secondary air pollutant" is becoming an increasing health problem in New Zealand, due to the increasing amounts of air pollutants from vehicles, and possibly to increasing UV-radiation at ground level caused by stratospheric ozone layer depletion.

The generic knowledge about the health concerns for each pollutant has been published in a number of documents in New Zealand recently and will not be repeated here (see for example MoT, 2002). A number of reviews from overseas national and international agencies also provide key information. Table 10 summarises the current evidence. In addition to these pollutants, hydrocarbons other than benzene are included in motor vehicle emissions and they contribute to secondary ozone formation and to the lung cancer risk of vehicle air pollution.

Table 10. Impact of motor vehicle emissions on health

Contaminant	Formation	Absorption and effects in lung	Health effects
Carbon monoxide (CO)	Gas formed from incomplete combustion of fuels such as petrol and diesel	<ul style="list-style-type: none"> - Absorbed into the bloodstream - Reduces the oxygen-carrying capacity of blood (which can adversely affect the brain and heart) 	<ul style="list-style-type: none"> Increased hospital admissions & mortality from cardiovascular disease Headaches Dizziness, Disorientation Visual disturbances Stress, anxiety Acute death after very high exposure
Nitrogen dioxide (NO ₂)	Gas produced during fuel combustion	<ul style="list-style-type: none"> - Directly affects the lung. - Impairs the lung's immune defence mechanisms 	<ul style="list-style-type: none"> - Increased frequency of coughing, wheezing & breathlessness - Increased susceptibility to infections & asthma attacks - Increased severity of asthma attacks - Increased reactivity to natural allergens - Stress, anxiety, irritability
Fine particles (eg. PM ₁₀ which is particulate matter smaller than 10 µm)	Solid particulate matter produced from emissions	<ul style="list-style-type: none"> - Penetrates into the lungs - contains chemical and biological (e.g. pollen) contaminants in solid form - lung cancer risk may be due to components of the particles or gaseous hydrocarbons in the emissions 	<ul style="list-style-type: none"> - Exacerbates respiratory conditions such as bronchitis and asthma - Increased mortality - Increased hospital admissions for respiratory and cardiovascular disease - Increased frequency of respiratory symptoms - Reduced resistance to infection - Increased school absences, lost work days and restricted activity days – exacerbating stress and anxiety - Increased risk of myocardial infarction and cardio-respiratory death - increased risk of lung cancer
Benzene	Produced by fuel consumption	Known carcinogen	<ul style="list-style-type: none"> - Bone marrow suppression - Leukaemia
Lead	Leaded petrol was used in New Zealand until 1986	Absorbed via lungs into blood stream	Negative impact on children's neurocognitive functioning

Sources: USEPA (1998); WHO (2001)

3.2 Motor vehicle emissions in New Zealand

Motor vehicles in New Zealand emit the air pollutants listed above to the same extent as in other countries, except that there is no legal requirement here to fit catalytic converters on cars, which makes our emissions of CO, NO₂ and hydrocarbons higher than in countries with more widespread use of these devices. However, the final air concentrations of pollutants and the exposure levels are dependent on the density of vehicles in urban areas, the topography and the meteorology of these areas. In comparison with cities in other industrialised countries New Zealand does not have very high urban air pollution levels (Ministry for the Environment, 2002).

An important issue is to what extent air pollutants are emitted from sources other than vehicles, from industry or residential heating systems (mainly open fires and wood burners), and the resulting total emissions. Epidemiological studies generally cannot separate the sources of pollutants. Studies in New Zealand referred to below therefore need to be interpreted with caution. Wood smoke is a major problem during the winter and industrial emissions have importance in local “hot spots” (MfE, 1997).

Issues of air pollutant emissions and the technical and other means of reducing emissions have been reviewed recently in a number of documents from the Ministry for the Environment, Ministry of Transport, Transit New Zealand and Regional Councils. In addition, a number of scientific reports have analysed air pollutant emissions and the relevant chemistry and meteorological aspects (e.g. studies related to hydrocarbons by Graham and Narsey, 1994; Narsey and Stevenson, 1997; Stevenson and Narsey, 1998; Kuschel et al, 1998). A review of this material would go beyond the remit for the current report. The focus here will be on studies of human exposures and effects.

Air pollution has been monitored in several New Zealand urban areas (see Ministry for the Environment website www.mfe.govt.nz). Christchurch and Auckland have the longest records of monitoring with measurements of particulate matter, CO, NO₂, SO₂ and lead. Particle monitoring was originally for Total Suspended Particulates, but since 1988 fine particle (PM₁₀) monitoring has been carried out continuously at one site in Christchurch, and in recent years PM₁₀ has also been monitored in Auckland and a few other areas, temporarily.

3.3 Human exposures and health effects

Reports to date

A risk assessment, based on international dose-response relationships and the current air pollution levels in Christchurch (Foster, 1996) concluded that each year the days of high air pollution possibly cause 29 extra deaths and 40 extra hospital admissions. An updated analysis (Wilton, 1999) showed that the estimated number of deaths may be twice as high. Wood smoke from open fires was considered the main cause of air pollution, but some also came from vehicles. According to emission inventories, approximately 90 percent of particle pollution in the winter (May-August) is due to wood smoke, and vehicles emit most of the remaining 10 percent. During the rest of the year almost all particle pollution is due to vehicle emissions. In addition to the extra deaths, it was estimated that air pollution caused 82,000 days of ‘restricted activity’, such as absence from school or work due to respiratory symptoms (Canterbury Regional Council, 1997). A recent study (Hales et al., 2000) indicates that an increased total and respiratory mortality associated with PM₁₀ levels can indeed be measured in Christchurch. This study also found an association between high daily temperature and daily mortality, contributing evidence for the effects of climate change on health (Hales et al 2000).

Another risk assessment of the health effects of air pollution has been produced for the land transport pricing study of the Ministry of Transport (MoT, 1996). The aim was to estimate

the cost of health damage due to air pollution and other environmental impacts from motor vehicles on roads. Based on a review of a number of epidemiological studies it was concluded that lifetime exposure to 10 ug/m³ particulate air pollution would increase total mortality by 1.6 percent and that lifetime exposure to 1 ug/m³ benzene would increase the cancer mortality rate by four per million. The estimates were eventually expressed as the estimated cost in dollars per kilometre of road. The cost of particulate air pollution health damage was about 20 times greater than the cost of benzene health damage. These calculations are likely to be very approximate, but they indicate the importance of particulate air pollution from vehicles.

A small number of studies have investigated exposures to lead in New Zealand. One of these (Kennedy et al., 1988) studied the potential for exposure from air pollution close to Auckland motorways and documented in detail the increased dust and soil lead levels caused by lead emissions from motor vehicles. However, the contribution of air lead to children's blood lead could not be quantitatively estimated. Groups of children living in new houses along motorways appeared to have on average slightly higher blood lead levels than children in areas remote from major roads (not statistically significant). However, when the same children living along motorways were re-tested after one year, generally their blood levels decreased as an effect of age. Another study of almost 3,000 blood leads analysed at Christchurch hospital between 1978 and 1985 showed a steady decrease of the levels in spite of the fact that the use of lead in petrol had not changed (Hinton et al. 1986). Reduced exposure to other sources of lead, such as house paint and soldering in food cans, was considered the likely explanation of the trends. An update of this study (Walmsley et al., 1993) did not show any reduction of the average lead levels that could be related to reductions in petrol lead. Other studies in New Zealand have focused specifically on the issue of exposure to lead in house paint, which is an important remaining public health concern.

A panel study of 40 subjects in Christchurch with Chronic Obstructive Pulmonary Disease (Harre et al., 1997) analysed their reported prevalence of night-time chest symptoms in relation to PM₁₀ air pollution. Symptoms were increased during the day after a 24-hour period when the PM₁₀ levels increased by 35 ug/m³ or more. The small study size makes it difficult to draw definite conclusions. A study of the correlation between ambient air pollution and hospital admissions for cardio-respiratory diseases in Christchurch (McGowan et al 2002) showed an increase the day after a high pollution day, similar to the findings for mortality by Hales et al (2000).

Petroleum and engine oil are sources of several toxic substances including heavy metals and polyaromatic hydrocarbons. Vehicle exhausts form deposits in roadside areas, which dissolve in rainfall to cause contamination of water and soil (ARC 2002). During the early 1990s (when New Zealand was still using leaded petrol), petroleum contamination was estimated to account for 40 to 60 percent of human lead uptake (Menkes, Horrocks 1994).

Further details about ongoing research in New Zealand on the health effects of motor vehicle air pollution are given in Annex 2.

Recent risk assessment of motor vehicle air pollution

The recent research on air pollution health effects overseas has created an interest in using risk assessment methodologies to estimate the potential health impacts in the whole of New Zealand. With support from the Ministry of Transport a study of mortality associated with total air pollution as well as motor vehicle-related air pollution was carried out (Fisher et al., 2002). The methodology copied that used for a similar study in Switzerland, Austria and France (Kunzli et al., 2000), but the exposure estimates were based on local air monitoring and meteorological data. The fact that the Christchurch study can demonstrate mortality effects, and that the dose-response relationships in New Zealand are similar to those used in the European study (4% mortality increase per 10 ug/m³ increase of annual PM₁₀), gives some confidence in the validity of the mortality estimates.

The results for the major cities are given in Table 11. The mortality related to vehicle emissions is substantial in Auckland. The relative importance of vehicle-related air pollution and other pollution varies between cities, and Christchurch is estimated to have a much larger proportion of total air pollution mortality due to non-vehicle emissions (mainly wood smoke).

Table 11. Estimated annual additional mortality due to air pollution exposures (Fisher et al., 2002)

Area	Annual mortality effect of total PM₁₀	Annual mortality effect of vehicle PM₁₀
Auckland	436	253
Wellington	79	56
Christchurch	182	41
Dunedin	48	6
Other urban areas, N. Island	133	21
Other urban areas, S. Island	80	19
Total	970	399

As total mortality in New Zealand is about 40,000 per year, this constitutes more than two percent. Considering that a very large fraction of mortality is not preventable, this can be considered a major public health impact.

Further detailed research is being planned by a consortium of different institutions, including analysis of the potential health improvements of different scenarios for reducing heating and vehicle-related air pollution.

4. Noise

4.1 Potential health effects of transport related noise

Noise is known to have an adverse impact on health, particularly for communities close to major traffic routes, airports or noisy industries. The effects of annoyance and sleep disturbance are difficult to quantify in terms of their impact on health (Berglund, Lindvall, 1995); nevertheless, these are a source of concern in considering the health effects of transport.

A review of seven community surveys (Hunt, 1989) identified the negative effects of traffic noise most commonly reported by local residents:

- interference with communication including conversation, use of telephone, television and radio
- sleep disturbance
- vibration from passing traffic.

Survey respondents indicated that traffic noise caused most disturbance in the early morning and late night, and that “stop/start” traffic conditions were more annoying than continuous traffic flow (Hunt 1989). This is in accordance with the finding of studies of airport noise (Berglund and Lindvall, 1995). The disturbance of such noise is more related to the hourly frequency of loud aircraft movements than the degree of loudness of the noise itself.

A recent study of airport noise effects comparing school children in Munich before and after a new airport was opened and the old airport closed (Hygge et al., 2002) showed that short-term and long-term memory, reading ability and speech perception all were affected by the noise exposure. Any reduction in these variables may also reduce the children’s cumulative learning at school and their future livelihood.

The disturbance effects have been an important issue for the plans to build a second runway at Auckland International Airport, but compared to airports overseas (e.g. Sydney) the number of aircraft movements at New Zealand airports is small. In addition, very few landings and starts take place during night-time, when the disturbance effect may be greatest.

4.2 Traffic-related noise in New Zealand

There is very little New Zealand data on noise levels from land transport or the effects on the health and well-being of communities. Each city council has a noise control service that deals with noise complaints from local residents; however the majority of complaints relate to domestic noise such as stereos and parties or local events such as rock concerts. In Manukau City, for example, vehicle-related noise accounts for only one percent of all noise complaints (City Councils 2002).

In the absence of any formal monitoring system for traffic-related noise, information is limited to occasional community surveys and some studies carried out by or on behalf of local government departments (often by consultancy firms). Transit New Zealand carried out a study of residential exposure to traffic noise in Christchurch during the early 1990s. This recorded levels of noise exposure similar to those experienced by urban populations in Australia, France, Germany and Switzerland, but greater than those recorded in the Netherlands (Hunt 1992).

Analysis of community perception of noise disturbance and methods to reduce noise from roads has also been carried out by Transfund New Zealand (a Crown entity responsible for promoting safe and efficient roading systems in NZ) (2001). Guidelines for maximum daytime noise levels (55 dB) have been developed by Transit New Zealand (Transit NZ, 1994) and tests made of different road surfaces and other factors to identify means of reducing road noise.

Two current studies which may yield useful information are being carried out on behalf of the Ministry of Transport and Transfund. Opus International is undertaking a study on community perceptions of traffic-related noise on behalf of Transfund. Noise levels were monitored near several roadways throughout the country, and local residents were surveyed about their experience of traffic noise. The relevant roadways were then resealed, and noise monitoring and resident surveys were repeated to detect any changes in either objective noise levels or community perception. The study report is expected to be completed late 2002 (Wood 2002).

Another New Zealand study on traffic noise levels and their community impact is being carried out by Sinclair Knight Merz Ltd on behalf of the Ministry of Transport. This study is using a noise impact analysis model to correlate traffic noise levels with community impact (in terms of annoyance and sleep disturbance). The study is also expected to be completed in late 2002 (Clark 2002).

5. Physical activity

5.1 Potential health effects of lack of physical activity

Regular, moderate physical activity is known to produce significant health benefits, including:

- Reduced mortality from coronary heart disease
- Reduced mortality from cerebrovascular disease
- Reduced risk of developing Type II diabetes
- Reduced risk of colon cancer
- Fewer falls for older people
- Reduced feelings of anxiety and depression (Hillary Commission 1998).

Sport and Recreation New Zealand (formerly the Hillary Commission) recommends 30 minutes of moderate physical activity (e.g. brisk walking) each day in order to enjoy these health benefits.

In 1997 the Hillary Commission carried out a national Sport and Physical Activity Survey to ascertain patterns of physical activity amongst New Zealanders. Salient results from this survey include:

- 34 percent of New Zealand adults are insufficiently active to benefit their health
- New Zealand has high levels of physical activity compared with other industrialised countries: levels of inactivity are over 40 percent in Australia, and over 60 percent in Canada, the UK and the USA
- Inactivity is most common in the 25 to 49 year old age range
- Māori and non-Māori are equally active (75% of Māori were reported as “active”, while for European New Zealanders the number was 69%, and for other ethnic groups 58%)
- Adults throughout the country have similar levels of activity, while young people in Auckland are less active than those in the rest of the country.
(Hillary Commission 1999).

Participation in physical activities is high amongst school children, who benefit from school-related sports and recreational activities (West et al 2002). Levels of participation tend to decrease after young people leave school and enter the workforce.

Using data from the 1996/97 New Zealand Health Survey, Tobias and Roberts estimate that physical inactivity accounts for the death of 2,600 New Zealanders each year or nine percent of all deaths (Tobias & Roberts 2001). This figure is likely to increase in future, as current demographic trends suggest the prevalence of physical inactivity will rise four percent by 2021. Despite similar activity levels, physical inactivity accounts for a greater proportion of deaths in Māori (9.4% in males, 10.3% in females) than in non-Māori (8.8% in males, 9.8% in females) (Tobias & Roberts 2001). Tobias and Roberts estimate that a 10 percent increase in the number of adults who are physically active would prevent approximately 600 premature deaths each year.

Physical activity also helps to control body weight, and therefore has the potential to reduce the adverse health effects of obesity. Obesity is a growing problem in New Zealand: in the eight years from 1989 to 1997, the prevalence of obesity doubled to 17 percent of the adult population (Ministry of Health 2002).

Amongst European New Zealanders, average body mass index increases with decreasing socio-economic status (this pattern is not observed in Māori or Pacific peoples) (Dryson et al 1992). Obesity accounts for a significant share of the mortality burden from diseases such as diabetes (44-46%), coronary heart disease (22-25%) and hypertension (57-66%) (Galgali et al 1998).

5.2 Transport and physical activity in New Zealand

There is no New Zealand data directly examining the relationship between transport and levels of physical activity. It is clear, however, that people are relying more on private vehicles as a means of transport, and less on walking or cycling (LTSA 1999 and 2000). The Hillary Commission identifies several environmental barriers to physical activity, including:

- Missing or ill-designed footpaths with poor lighting
- Perceived lack of safety of pedestrians, particularly children and women, both from motor vehicle hazards, and hazards from violent or inappropriate behavior of other people
- Transport networks that discourage people from walking or cycling.
(Hillary Commission 1998).

Such barriers need to be reduced if walking and cycling are to be encouraged as a healthy means of travel.

Promotion of walking, cycling and public transport will encourage greater levels of physical activity in everyday life. This is consistent with the recent shift “from promoting participation in structured exercise programs and vigorous sports, to incorporation of a wide range of physical activities into everyday life, whether in the home, at work or while commuting or recreating” (Tobias & Roberts 2001). Physical activity is more likely to be adopted and sustained when it is “integrated into the routines of everyday life” (Hillary Commission, 1999).

6. Community disruption and social isolation

6.1 Potential health effects of social isolation

The relationship between social cohesion and health has received increasing interest in recent years. Reviews of the international evidence conclude that good levels of social support are associated with better health outcomes (National Health Committee 1998; Crampton 1997).

New Zealand data relating social networks and health status is sparse. The Department of Public Health in the Wellington School of Medicine and Health Science has undertaken research on the link between social involvement and mortality, using an index of ‘social capital’ derived from the 1996 census. Preliminary results indicate a small negative relationship between social involvement and regional mortality, suggesting that social participation has a health protective effect (Howden-Chapman 2001). Further information on the association between social networks and mortality may emerge from the New Zealand Census Mortality Study (Blakely 2002).

6.2 Transport, social isolation and health in New Zealand

The influence of transport on social cohesion is complex. Transport provides an important means of contact between family members, friends and members of voluntary organisations and communities. At the same time, roadways and traffic act as a physical and psychological barrier to social contact.

Whether the positive or negative social effects of transport dominate depends on both the volume and the geographical location of transport networks. In rural areas, transport is essential to maintaining social contact and to accessing facilities such as schools, shops and community meeting areas. In urban neighbourhoods, busy roadways and heavy traffic flows often act as barriers to community contact. This paradox is summarised in a parliamentary report by the Transport and Environmental Committee: “In essence, roads in rural and provincial communities tend to connect people into communities, while roads in urban areas can divide communities due to traffic volumes, loss of land and dispersion of activity” (Transport and Environment Committee 1998, pg 43).

There is little information regarding the positive impact of transport on social networks in New Zealand, but some general issues have been identified:

- Facilitates social contact
This is particularly relevant in rural areas, where people are more reliant on vehicles as a means of transport. Residents in rural areas cover greater distances by car (or bus) than those in urban areas (LTSA 1999).
- Enables people to reach places of work, education and recreation
Car travel is the most common means of transport to school or work (LTSA 1999).
- Facilitates access to various services in the community (shops, health services, sports facilities, etc.), which is particularly important in rural areas.

More has been written about the negative social impacts of road transport in New Zealand:

- Social severance
‘Social severance’ is the term used to describe the negative effect that roads and traffic have on social interaction within a community (Tate 1997). For instance, this may happen when a road or a motorway cuts through a community, separating it into sections, which are not easily accessible to one another. International literature indicates that social severance has its greatest impact on those with limited mobility, such as children, the elderly, and people with disabilities. Transport-related social severance has not yet been studied in New Zealand communities, although Transfund New Zealand is developing a model with the intention of undertaking such studies (Tate 1997, Read & Cramphorn 2001).
- Physical impact of roads and other transport facilities
High rates of private vehicle usage lead to increased traffic volumes, and create pressure for the expansion of roadways. These factors have an impact on local communities. Roading and parking areas are estimated to account for 25 to 30 percent of urban land in Wellington city, and more in Auckland city (TEC 1998).
- Dominance of private cars contributes to social inequalities

Social isolation may be increased by lack of car access, especially in areas with poor public transport (National Health Committee 1998). Figures from the 1996 census indicate that 8.1 percent of people in New Zealand do not have access to a car (Atkinson 2002). According to the New Zealand Transport Survey, car usage is lower in women, in Māori and Pacific peoples and in those with low income (LTSA 1999).

- Reliance on private vehicles contributes to weaker public transport systems
This is a particular issue in Auckland, where transport is dominated by car travel. The prominence of vehicle transport has contributed to the way in which the city has developed, with residential suburbs spread over a large geographical area. Motorways form the main link between the different parts of Auckland, and people are heavily reliant on cars to move about the city. The Auckland Regional Council recognises that the vehicle-oriented layout of the city has significant disadvantages for those without access to a car. Car access in Auckland is below the national average, with 11 percent of households having no access (Auckland Regional Council 2002).

7. Environmental and other factors

7.1 Potential other environmental health hazards related to transport

In 1998 the Parliamentary Transport and Environment Committee undertook an inquiry into the environmental effects of transport. Its interim report (Transport and Environment Committee 1998) identifies six environmental areas on which land transport has a significant impact:

- Global climate change
- Water and soil quality
- Local air quality
- Noise and vibration
- Community and amenity impacts
- Sustainable management of energy.

Local air quality, noise and community and amenity aspects have already been mentioned in previous sections. We will describe the New Zealand evidence about health effects of the other areas here. It should be mentioned that another important factor to health is petrol sniffing, which is indirectly associated with the transport system through the easy access to petrol, and is an occupational hazard for commercial drivers. This will not be discussed here, but it is certainly an important public health issue.

Global climate change

Combustion of fossil fuels in motor vehicles produces carbon dioxide (CO₂), a major greenhouse gas contributing to global climate change (TEC 1998; MfE website www.climatechange.govt.nz). New Zealand is unusual among economically advanced countries because as much as two-thirds of our greenhouse gas emissions are in non-CO₂ form, mainly emitted as CH₄ from sheep and cows. Thus transport emissions only contribute to the remaining third, which also includes CO₂ from coal and oil-powered electricity generation, manufacturing, and residential heating. Transport contributed 8.2

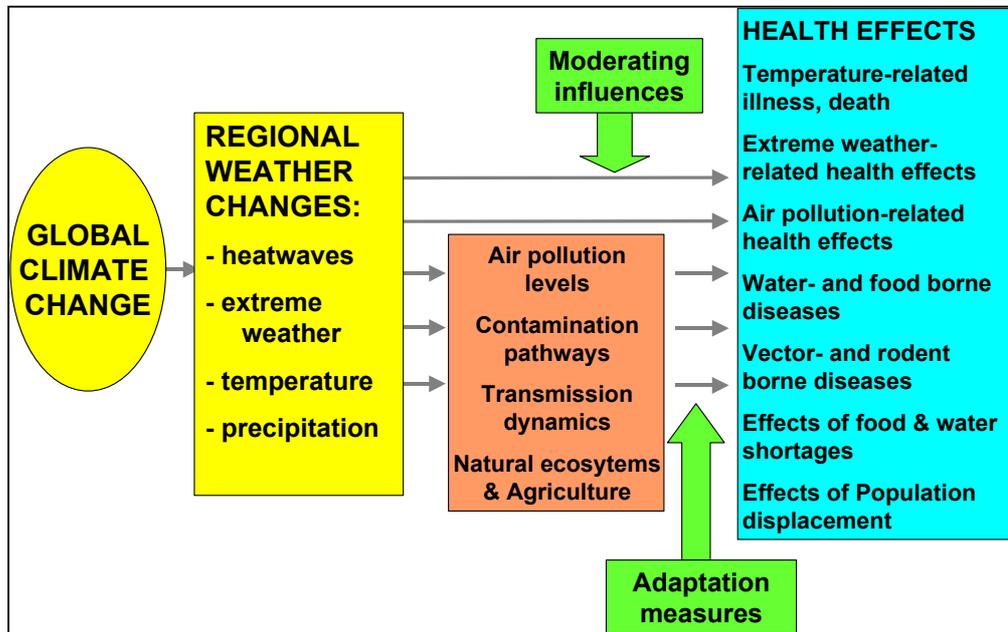
million tons of CO₂ emissions in 1990, which had increased to 12 million tons in 2000. This is 40 percent of New Zealand's carbon dioxide emissions and the most rapidly increasing part of the total CO₂ (MfE 1997). To meet the requirements of the Kyoto Protocol, New Zealand needs to reduce its emissions below the 1990 level. Reductions in the agricultural sector may have direct detrimental effects on production. Reductions in transport emissions would therefore be helpful, but the current trend is in the opposite direction.

Climate change involves an increase in temperature in many parts of the world, a change in rainfall patterns (which could become drier or wetter), and an increase of extreme weather events such as hurricanes and blizzards. In New Zealand the estimated temperature increase in the next 80 years is between 0.6 and 2.8°C based on global climate modeling (MfE, 2001, climate change impacts report). The rainfall is expected to increase by up to 25 percent in the Western North Island, the west Coast and Southland, while it is expected to decrease by up to 20 percent along the east coast of both Islands and in Auckland and Northland. These changes can have important impacts on agriculture, and they can impact health directly as well as indirectly via extended distributions of disease vectors such as the dengue-spreading mosquito (MfE, 2001).

The transport-related emissions of greenhouse gases from New Zealand are of course small in relation to the emissions in other countries. A direct link between local emissions and climate change in this country cannot, therefore, be made. However, New Zealand's stance on this issue will be important for a common global approach to reducing the impacts of climate change.

There are already signs that the average temperature has increased in New Zealand since the 1970s (MfE, 2001). Health impacts have yet to be recorded, but the list in Figure 10 includes several effects that may become a concern here. A review of the human health impacts of climate change in Australasia (McMichael et al., 2002) has highlighted the areas of concern in Australia with some comment on the potential issues in New Zealand and the Pacific Islands. Vector-borne diseases are the most prominent threats, but diarrhoeal diseases, deaths from thermal extremes, increased solar UV radiation exposure and direct effects of cyclones and bushfires may also become major concerns.

Figure 10. Potential health effects of climate change and the underlying mechanisms (McMichael, 2002)



Water and soil quality

Transport runoff is a major source of water contamination in harbour and estuarine areas, with pollution from heavy metals and polyaromatic hydrocarbons (MfE 1997). Other water and soil issues include:

- loss of topsoil and waterway contamination during road construction
- soil and water contamination from disposal of waste oil and tires
- increased stormwater run-off from sealed road surfaces (TEC 1998).

Little research has been carried out on these issues. Some local studies on the relationship between vehicle emissions and stormwater quality have been undertaken in some cities (e.g. Auckland) (Ministry for the Environment 1997).

Sustainable management of energy

Energy consumption in the transport sector is rising much faster than in other sectors. Petroleum is a non-renewable resource, most of which has to be imported. This raises concerns about New Zealand’s increasing reliance on petrol as an energy source (TEC 1998).

On the basis of its findings, the Transport and Environment Committee (TEC, 1998) made a number of recommendations to the Government. These included:

- make reducing the adverse environmental effects of road transport an explicit goal of any road reform proposals
- require that environmental damage from road transport be ameliorated to an appropriate level using roading revenue
- use some of the revenue from road pricing to finance the development of a range of efficient and attractive public transport options suited to each region. (TEC 1998).

Public transport plays an important role in developing sustainable means of travel. The Parliamentary Commissioner for the Environment has criticised New Zealand's weak public transport system, and emphasised the need to invest in public transport "to improve overall energy efficiency and ensure [an] affordable, accessible means of mobility for the transport disadvantaged" (PCE 1998).

8. Conclusions

Transport is an essential sector within the New Zealand economy. It comes with a price though; the various health impacts caused by our modern motor vehicle-based transport system. The car crash injuries, the lung effects of vehicle-related air pollution, the disturbance effects of noise, the reduced physical activity and associated obesity, and the community disruption from major roads, are all briefly reviewed in this report.

The report was aimed at bringing together New Zealand research evidence about the health impacts at national and local level. Traffic crash injury research has been relatively active, but in other areas only limited data exist. It is not possible to accurately compare the overall health impact of the different health hazards associated with motor vehicles, but a recent analysis of the mortality due to vehicle emissions in urban areas may provide some guidance. The analysis found that the number dying due to vehicle air pollution may be similar to the number killed in car crashes. Thus, the "hidden road toll" may be at least as large as the visible road toll due to crashes.

A more quantitative assessment of the health impact of the transport system in New Zealand and the possibilities to reduce the impacts through specific interventions would be of great help to decision-makers. Research is needed to establish the quantitative relationships between exposures and health effects, and to quantify the impact of different policies and actions. The air pollution exposures and effects need further study in order to prioritise measures to reduce car emissions, both technical and administrative. The "obesogenic environment" that encourages car use, instead of walking and cycling, needs to be better described, and its health impacts better quantified. The impacts of noise on mental health, school achievement, and general well-being also needs study.

It is important to note the varied effects of some interventions to reduce health impacts. For instance, electric cars reduce local air pollution, but will not necessarily reduce the car crash injury problem. Instead, they basically move the issue of energy-related air pollution and greenhouse gas emissions to a different site. Hybrid cars or better fuel quality reduce both air pollution and greenhouse gas emissions, but again will not reduce car crashes. On

the other hand, shifting private car use to public transport reduces car crashes as well as all the other hazards.

Research on the full health improvement that can be achieved by different interventions and the associated economic benefits and costs would be of great value in developing integrated policies to improve the transport system nationally and locally.

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Annex 1.

Bibliography of New Zealand resources and websites

General

New Zealand Transport Survey, 1999

This is a nationwide survey of the travel behaviour of New Zealanders, undertaken by the Land and Transport Safety Authority in 1997/98. A similar survey was undertaken in 1989/90, providing a basis for comparison and allowing us to identify trends in travel behaviour over time. Investigators surveyed around 14,000 people from 7,000 randomly sampled households (the response rate was 75%). Participants were interviewed in their homes, and asked to describe all their travel (including walking, cycling, travel by vehicle, train and aeroplane) during two particular days. These days were spread throughout the year, so that investigators were able to compile a database representative of a year's average travel by all New Zealanders.

The full survey report is available from:

http://www.ltsa.govt.nz/research/travel_survey.html##

New Zealand census data

Data is available from Statistics New Zealand on a wide variety of factors reported in the five-yearly New Zealand Census. These factors include travel patterns to work, vehicle ownership, etc.

Available from: <http://www.stats.govt.nz>

Environmental performance indicators

These are reported by the Ministry for the Environment, and incorporate data from Statistics New Zealand, the Land Transport Safety Authority and the Ministry of Transport in a readily accessible form. Examples are data on mode of journey to work and vehicle fleet composition.

Available from: <http://www.environment.govt.nz/transport>

Environmental health indicators

Work on this is being developed for the Ministry of Health by ESR.

Auckland Regional Council website on transport

Provides information about transport patterns within the Auckland region, including environmental and social issues. Links to the *Auckland Regional Transport Strategy*, which is the Council's overall plan for transport network improvements over the next 50 years.

Available from:

<http://www.arc.govt.nz/arc/index.cfm?820627A3-397C-44B7-AB23-0D8C4145CD96>

Transfund New Zealand

This is a crown entity responsible for monitoring and promoting the safety and efficiency of the New Zealand roading system. As part of this role Transfund commissions research, most of which is carried out by consultancy firms (such as Opus International Consultants Ltd and Sinclair Knight Merz Ltd). The majority of these studies are of a technical nature, although some small studies have examined the impact of road traffic noise on local communities.

Website: <http://www.transfund.govt.nz>

Transfund research reports are distributed on a commercial basis by Standards New Zealand. Website: <http://www.standards.co.nz>

Background, travel patterns

1. Land Transport Safety Authority. 2002a. *International comparison of death rates* (derived from OECD International Road Traffic and Accident Database). Accessed 12/06/2002. Available from: http://www.ltsa.govt.nz/research/annual_statistics_2000/docs/international_table_1.pdf
2. Land Transport Safety Authority. 1999. *The New Zealand Transport Survey*, Land Transport Safety Authority, Wellington, 1999. Available from: http://www.ltsa.govt.nz/research/travel_survey.html

Provides extensive information on transport patterns in NZ, including how these have changed over the past decade.

3. Land Transport Safety Authority. 2000. *New Zealand Pedestrian Profile*, Land Transport Safety Authority, Wellington, November 2000. Available from: <http://www.ltsa.govt.nz>

Some data on patterns of pedestrian travel (largely derived from *The New Zealand Transport Survey*).

4. Ministry for the Environment. 2002. *Environmental Performance Indicators: Travel Patterns to Work*, Ministry for the Environment, Wellington, May 2002. Available from: <http://www.environment.govt.nz/transport>

Describes usual mode of transport used by New Zealanders in traveling to work. Data from the NZ Census (Statistics NZ).

5. Ministry for the Environment. 1997. *The State of New Zealand's Environment*, Ministry for the Environment, Wellington, 1997. Available from: <http://www.mfe.govt.nz/transport>
6. Statistics New Zealand. 2002. *Road Transport*. Statistics New Zealand, Wellington, May 2002. Available from: <http://www.stats.govt.nz/domino/external/web/nzstories.nsf/Response/Road+Transport>

Provides some general data on road transport topics in New Zealand (eg, number of licensed vehicles); includes links with other government web sites.

7. Statistics New Zealand. 2001. *New Zealand Official Yearbook 2000*, Statistics New Zealand, Wellington, 2001.

Detailed statistical data on transport patterns in NZ, including vehicle and rail transport, vehicle registration, traffic offences, and public roading.

8. Auckland Regional Council, website on *Transport*. Accessed 30/05/2002. Available from: <http://www.arc.govt.nz>

Provides comprehensive information on transport in the Auckland region, including travel patterns and how these have changed over time, vehicle ownership, effect of vehicle emissions, and social implications of a car-oriented transport system.

Safety

9. Land Transport Safety Authority. 2002. *Stats. Road crash data from the LTSA*. Accessed 30/05/2002. Available from:

http://www.ltsa.govt.nz/publications/research_stats.html.

Provides monthly update on New Zealand road crash, injury and fatality statistics.

10. Land Transport Safety Authority. 1999. *The New Zealand Transport Survey*, Land Transport Safety Authority, Wellington, 1999. Available from: http://www.ltsa.govt.nz/research/travel_survey.html##

Provides comprehensive information on risk of injury according to age, gender, ethnicity, mode of transport, time of day and day of week.

11. Land Transport Safety Authority. 2000. *New Zealand Pedestrian Profile*, Land Transport Safety Authority, Wellington, November 2000. Available from: <http://www.ltsa.govt.nz> Data on risk of injury to pedestrians.

12. Transport Accident Investigation Commission.

This Commission investigates aviation and rail accidents and provides an annual report to parliament with details about each incident. This can be used to assemble a picture of how injuries and fatalities in these types of accidents have changed over the years.

13. Injury Prevention Research Unit, University of Otago.

Research unit based in Department of Preventative and Social Medicine, Dunedin School of Medicine. The unit has undertaken a large amount of research relating to motor vehicle crashes, especially those involving young drivers and motorcycles (see publications by DJ Begg and JD Langley). Much of this research has made use of data from the Dunedin cohort study. The IPRU website provides summaries of current studies, factsheets on injury trends and a database of IPRU publications. Available from: <http://www.otago.ac.nz/ipru/Research/Transport.html>

14. Injury Prevention Research Centre, University of Auckland

Centre of research into injuries in New Zealand. During the early-mid 1990s the IPRC conducted a significant amount of research into child pedestrian injuries (see publications by R Norton and I Roberts). Since then their research has increasingly emphasized other types of injury. Website provides list of factsheets, reports and publications (but cannot access information online). Available at: <http://www2.auckland.ac.nz/ipc/>

Air pollution

1. Ministry of Transport. 2002. *Health Effects due to Motor Vehicle Air Pollution in New Zealand*. Ministry of Transport, Wellington, January 2002. Available from: http://www.mot.govt.nz/downloads/niwa_report.pdf

Report on health effects of air pollutants from motor vehicles, including carbon monoxide, nitrogen dioxide, hydrocarbons, sulphur dioxide, particulates and ozone. Outlines data from New Zealand studies, and gives estimate of deaths attributable to motor vehicle emissions.

2. Ministry of Transport. 2001. *Smoky Vehicles Survey*. Ministry of Transport, Wellington, October 2001. Available from: http://www.mot.govt.nz/downloads/smoky_vehicles_survey_1001.pdf

Presents results of 'Smoky vehicles survey' carried out in October 2001. Results are compared with those of similar survey (from May 2000) to assess impact of amendments to Regulation 28 of the Traffic Regulations (1976), which were made in March 2001.

3. Ministry for the Environment. 1997. *The State of New Zealand's Environment*. Ministry for the Environment, Wellington, 1997. Available from: <http://www.mfe.govt.nz/transport>

Chapter 6 provides an outline of the impact of vehicular transport on air quality, in terms of both localised traffic pollution and the contribution of transport to ambient pollution (eg, due to domestic fires in Christchurch).

Noise

1. Hunt M. 1989. *Synthesis of surveys on reaction to road traffic noise in New Zealand; a report to the Traffic Committee, Roads Research Unit, National Roads Board*. National Roads Board, Wellington, 1989.

Summarises seven 'social' surveys carried out in different parts of the country pre-1980 (so fairly old data). Survey populations were generally small and non-random. No quantitative data, but provides an indication of the issues people raise re traffic noise.

2. Hunt M. 1992. *Traffic noise in populated areas*. Transit New Zealand, Wellington, 1992.

Presents results of study in Christchurch, in which noise levels were measured during 18 hr period (6am to 12 midnight). 13.3% of population were exposed to noise levels over 60-65 dB(A) L10 (OECD average is around 14%).

3. City Councils of Auckland, Christchurch, Manukau, North Shore, Wellington and Waitakere. *Quality of life in big cities of New Zealand*. Available from: <http://www.bigcities.govt.nz/index.htm>. Accessed 12/06/2002.

Gives brief idea of the type of complaints received by noise control centres.

4. Wood W. Opus International Consultants Ltd, Central Laboratories, Wellington. Personal communication, 6 June 2002.

Bill Wood, Opus International, Central Laboratories.

10. Clark B. Sinclair Knight Merz Ltd, Wellington. Personal communication, 12 June 2002.

Physical activity

1. Hillary Commission. 1998. *Physical Activity Taskforce Report*. Hillary Commission, Wellington, June 1998. Available from: <http://www.hillarysport.org.nz/pub.shtml>

Has very useful summary data about health effects of physical activity.

2. Hillary Commission. 1999. *Push Play Facts Summary*, Hillary Commission, Wellington, 1999. Available from:

<http://www.hillarysport.org.nz/pushplay/pdfs/summary/pdf>

Brief (2 page) summary, slightly more up to date than Taskforce Report (eg, states that Māori and non-Māori have similar activity rates – whereas Taskforce report states lower rates for Māori).

Community disruption and social isolation

1. National Health Committee. 1998. *The social, cultural and economic determinants of health in New Zealand: action to improve health*. National Advisory Committee on Health and Disability, Wellington, June 1998.
2. Crampton P. 1997. Chapter 7: Social capital and health. In: Robinson D (ed) *Social Capital and Policy Development*. Institute of Policy Studies, Victoria University, Wellington, 1997.

Summarises some international data on health and social capital/support.

3. Howden-Chapman P. 2001. 'Social capital and social policy.' Presentation of unpublished data, made at Special symposium on explanations for socio-economic differences in health, Massey University Centre for Public Health Research, Wellington, 8 August 2001. Transcript available from:

<http://publichealth.massey.ac.nz/Occasional%20Social%20Capital.pdf>

4. Tate FN. 1997. *Social severance*. Transfund New Zealand Research Report No.80, Transfund New Zealand, Wellington, 1997.

Outlines a model for assessing social severance due to transport in New Zealand. This is a model only – no actual NZ data on social severance. Draws on similar models developed in Denmark, Sweden, UK.

5. Read MD & Crampton B. 2001. *Quantifying the impact of social severance caused by roads*. Transfund New Zealand Research Report No. 201, Transfund New Zealand, Wellington 2001.

Annex 2. Ongoing research on air pollution health effects

Epidemiological studies of the association between air pollution and mortality to follow up on the results by Hales et al. (2000) are in progress. Since then Kjellstrom et al (to be published) have collected all available air monitoring data for 1988-1997 from a central city site in Christchurch, as well as all data from two other sites. Measurements of PM₁₀, CO, NO₂, and SO₂ (which is always low), and temperature at ground level, temperature at 10m above ground, relative humidity, wind-speed and wind direction have been carried out continuously and recorded every 10 minutes since 1988. From these data hourly averages were calculated and used in the above studies. The measurements are carried out by the local government environment agency (Environment Canterbury). Data from parallel monitoring of the air pollutants with different methods were used to standardize the results toward a common measurement method (TEOM at 40°C, which is what is currently used). About 10% of the hours had missing data because of breakdown of equipment or power cuts. In order to make the data set complete a statistical modeling technique using time and meteorological data was used (Shrestha et al., 2002).

Based on this completed data set likely human exposures during different seasons, day of week, and hours of day can be calculated. The hourly PM₁₀ concentrations in winter and summer are different during weekdays and weekend days (see figures A2.1 and A2.2) (Kjellstrom et al., 2002). The daily pattern fits with the likely patterns of vehicle driving and heater use.

Figure A2.1. Hourly PM₁₀ concentrations, winter
(Kjellstrom et al., 2002)

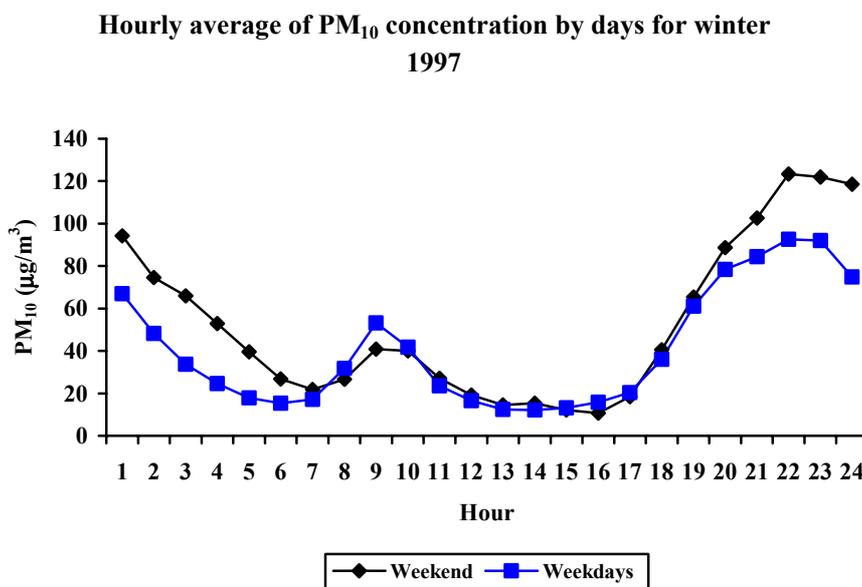
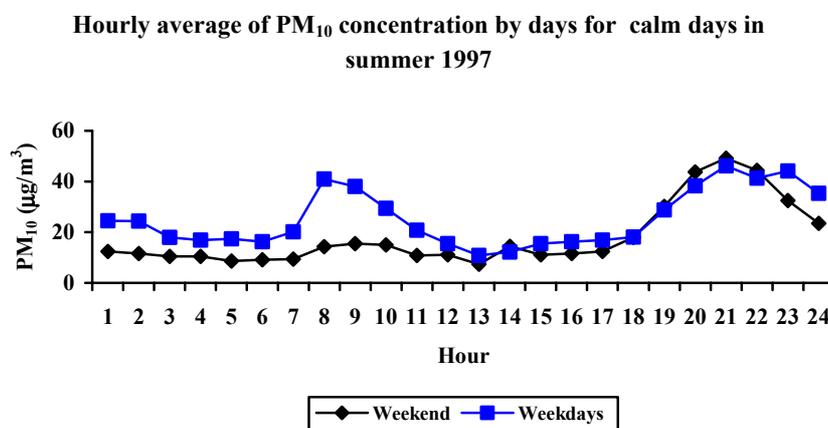


Figure A2.2. Hourly PM₁₀ concentrations, summer
(Kjellstrom et al., 2002)



The evening-night peak in the winter is much higher than the morning peak reflecting the longer heater burning in the evening. In the summer a main peak occurs at 8 am on weekdays reflecting the vehicle driving patterns, which also create a similar size peak in the evening. It is also clear from the figures how much higher the winter concentrations of PM₁₀ are (evening levels of more than 100, vs. 40 ug/m³ in the summer). In the winter (May-August) 24-hour PM₁₀ values exceed the local air quality guideline (50 ug/m³) on about 30 days each winter (25% of days).

Poisson regression time-series analysis according to the method used by Hales et al (2000) was used for preliminary analysis of the daily mortality impact in the winter and the summer, using one-day time-lag for the mortality. In this analysis the data for the other air pollutant variables were not included, because of a strong correlation between the variables, which distorts the results. The results for 1988 to 1997 are shown in Table A2.1. The units for the slope coefficients are deaths per PM₁₀ ug/m³ or deaths per degree C. The variable HOT is the maximum hourly temperature above 27°C and the variable COLD is the minimum hourly temperature.

Table A2.1. Results of Poisson multiple regression of daily mortality, PM₁₀ and temperature, Christchurch 1988-1997 (Kjellstrom et al, 2002).

Variable	Coefficient	Stand. error	Lower 95% C.I.	Upper 95% C.I.
Summer				
PM ₁₀	0.0034	0.0013	0.00086	0.00585
HOT	0.0256	0.0081	0.0098	0.0414
Winter				
PM ₁₀	0.00052	0.00048	- 0.0004	0.00146
COLD	- 0.0052	0.0037	- 0.0124	0.0019

The table indicates that with this 10-year data set the summer effects of PM₁₀ (vehicle sourced) and high hourly temperature (above 27°C) are both statistically significant. Daily mortality increases 3.4% per 10 ug/m³ PM₁₀, and 2.6% per degree Celcius of HOT temperature. Further analysis with a “best-fitting” curve comparing daily mortality and PM₁₀ (Kjellstrom et al., 2002) shows that the dose-response curve is much steeper in the range below than above 50 ug/m³.

In the winter the mortality increase by PM₁₀ or COLD temperature is not statistically significant, but a larger dataset may show significance. At face value, daily mortality increases 0.52% per 10 ug/m³ and 0.52% per degree C of colder hourly temperature. However, in the winter, PM₁₀ and cold temperature are closely correlated, and if they are analyzed separately in the Poisson regression, each of them is statistically significant (0.88% increase of daily mortality per 10 ug/m³ PM₁₀, and 0.73% increase of daily mortality per degree C cold temperature). This issue will be explored further in the continued analysis.

In conclusion, the difference between summer and winter findings may be explained by different chemical composition and size of particles in the summer (motor vehicle pollution, with PM₁₀ levels below 50 ug/m³) and the winter (primarily wood smoke, with PM₁₀ exceeding 50 ug/m³ approximately 25% of winter days). It may also be that secondary air pollutant (ozone) formation during summer days contributes to the steeper dose-response curve. Monitoring of ozone is at its infant stage, but may provide answers to this question in the future.