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On-road remote sensing of vehicle emissions in the Auckland Region

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Transit NZ

….and the motorists of Auckland.

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Executive Summary

Knowing the quantity of pollutants that the vehicle fleet is emitting to the air has become a vital question for many people and organizations. Historically in New Zealand, estimates have been made using emission factors derived from dynamometer testing using drive cycles. Recent studies, however, show that such methods tend to under-estimate "real-world" emissions. As a consequence, a remote sensing measurement programme was undertaken to gain better measurements of the vehicle fleet emissions in Auckland. Although remote sensing is widely used overseas, this was the first time such a system had been used in New Zealand to provide comprehensive real-world characterisation of vehicle fleet emissions.

Based on a well-established technique, the study measured tailpipe emissions from over 40,000 vehicles at 16 sites throughout the Auckland region during April 2003. Measurements were made of the emissions of the following key air contaminants in the exhausts of vehicles as they drove along the road:

- Carbon monoxide (CO)
- Nitric oxide (NO)
- Unburned hydrocarbons (HC)
- Opacity (smokiness) as an indicator of particulate emissions

A primary contaminant of concern – NO_2 – is not measured, and not reported here. The oxides of nitrogen (NO_x) produced in combustion, comprise a range of chemical species, mostly NO and NO_2 in varying proportions. The conversion process of NO to NO_2 is complex, and depends on atmospheric conditions and the variable presence of other contaminants. In addition, the proportions of NO_2 and NO being emitted from individual vehicles can vary substantially, from 5-10% of NO_2 in petrol vehicles, to up to 30% from diesel vehicles.

A statistically significant and representative sample of most vehicle types found in the Auckland motor vehicle fleet was obtained. The one type under-represented was the "heavy duty vehicle", as these often have exhausts located above the cab beyond the range of the roadside sensor. Analyses were conducted in order to characterise the nature and source of emissions as comprehensively as possible. These included breakdowns of emissions by vehicle age, fuel type, country of origin, mileage and area within Auckland. The key findings of the results are summarised as follows:

Gross Emitters: The most polluting 10% vehicles are responsible for:

- 53% of the total CO emissions.
- 39% of the total NO emissions.
- 51% of the total HC emissions.

Fleet Profile: Analysis of number plates of 34,500 vehicles shows that:

- The average age is 9 years (manufactured 1994).
- Vehicles in Manukau tend to be about 6 months older that the average age, those in Auckland and Rodney about 6 months newer, and the other areas close to the average age.
- The proportion of fuel types is 14% diesel and 86% petrol.
- The proportion of diesel vehicles coming into the fleet has grown (from less than 10% in the early 1980s to nearly 20% in the early 2000s).

Emissions by Age: The year of manufacture of each vehicle is known, showing:

- A steady drop in emissions of CO, NO and HC from 1980 to 2003.

Emissions by Fuel Type: For petrol versus diesel:

- Diesel vehicles emit less CO, NO and HC than petrol vehicles.
- Diesel vehicles emit significantly more particulates (greater opacity) than petrol vehicles.

Emissions by Country of Origin: Half (50%) of the Auckland fleet is non New Zealand new:

- Most imported vehicles are from Japan (97%).
- Imported vehicles generally have lower emissions than New Zealand new vehicles, for both petrol and diesel.

Emissions by Mileage: Based on odometer readings at warrant of fitness checks:

- Petrol vehicles with high kilometres have significantly higher emissions of all contaminants than low kilometre vehicles.
- Diesel vehicles with high kilometres have slightly higher emissions, with the exception of CO that is lower, than low kilometre vehicles.
- **WoF/Registration:** An analysis was conducted to test whether vehicles not having a current warrant of fitness or registration have different emissions:
- The 590 vehicles without WoF tend to have higher emissions of CO and HC.

- The 120 vehicles without a WoF for more than 6 months have significantly higher emissions of CO and HC.
- The 273 vehicles without registration also have higher emissions of CO and HC, and greater exhaust opacity.

Best versus the Worst: The emissions from the best and worst emitting vehicles are compared, by year of manufacture:

- The best 20% of older vehicles (1980-82) emit less pollution than the worst 20% of newer vehicles (2001-03).
- The best older vehicles can have emissions that are one fifth or less of the worst of new vehicle emissions.

International Comparison: Comparisons have been made with similar studies in the USA, showing that the average vehicle in Auckland emits:

- Double the amount of CO as in the US.
- Double the amount of NO as in the US.
- Three times the amount of hydrocarbons as in the US.

The remote sensing campaign has yielded significant "real world" information about emissions from the New Zealand fleet for the first time. The data have provided a baseline for emissions performance of the fleet so that the effectiveness of policies to reduce vehicle emissions can be monitored and have also directly contributed to ARC's objective to raise awareness about vehicle emissions and the need for vehicle maintenance.

In future the results will be used in a number of applications, including:

- To formulate more directed policy for targeting emissions reductions.
- To assess future trends in fleet emissions.
- As input to air shed modelling, run-off effects and health risk analysis.
- To validate emissions models.
- As input to assessments of effects of new roads projects.

Remote sensing offers benefits not possible with other methods and signals a way forward for methods to manage and reduce vehicle emissions in New Zealand.

1 Introduction

1.1 Air Quality and Health Effects

Poor air quality can seriously affect people's health and well-being. Major cities in New Zealand such as Auckland (see Table1.1), often record exceedences of the Ministry for the Environment guidelines for ambient air quality (MfE, 2002), which are intended to protect human health and the environment. Many of these exceedences are caused by motor vehicle emissions. Auckland Regional Council (ARC) started monitoring traffic-related air quality at Queen St in 1991, where regular exceedences of the guideline for carbon monoxide (CO) were recorded. The ARC now monitors air quality at peak traffic, residential and remote sites all around the region.

Table 1.1
Number of days of exceedence of the ambient air quality guidelines in Auckland (source: ARC).

	Number of Days in a Year When At Least One Exceedence Occurred				
	1998	1999	2000	2001	2002
PM_{10}	2	4	4	7	3
NO_2	23	27	23	38	30
CO	32	31	3	3	2
Total *	50	55	30	47	35

* The total number of days on which an exceedence of any of the air quality guidelines for fine particulate (PM_{10}), nitrogen dioxide (NO_2), or carbon monoxide (CO) occurred at one site or more (calculated from the sum of the separate days during which an exceedence was recorded, with no day being counted twice due to multiple exceedences).

Although most of the guideline exceedences occur at peak traffic monitoring sites, even very low levels of air pollution can damage health. A recent report to the Ministry of Transport (Fisher *et al*, 2002) estimates that particulate air pollution alone results in 436 premature deaths per annum in the Auckland Region, and that 253 of these are attributable to motor vehicle emissions.

Survey work undertaken by the ARC in 2001 suggested that air pollution was regarded as an environmental problem for the region by 47% of respondents (Forsyte Research, 2001). A national survey in 2000 by Lincoln University found that clean air ranks more highly for public spending than many other environmental issues and is exceeded only by people's desires for better health, education and crime prevention (Hughey *et al*, 2001).

1.2 Emissions Estimates And Reduction Strategies

Air pollution is a serious issue in the Auckland Region but in order for the Council to develop effective reduction strategies, the actual contribution arising from vehicles needs to be quantified.

However, New Zealand has very limited regulation of vehicle emissions. Although Central government is now implementing emissions requirements for new vehicles and developing in-use emissions requirements, one consequence of the historical lack of regulation is limited information surrounding the emissions performance of the fleet in New Zealand. This makes it almost impossible to develop targeted policies to reduce emissions, and to monitor the effectiveness of any policy that is implemented.

From the Auckland Air Emissions Inventory, vehicles in 2003 are estimated to produce up to 83% of the carbon monoxide (CO), 82% of the nitrogen oxides (NO_x) and 46% of the volatile organics (VOCs) through exhaust and evaporative emissions (ARC, 1997, and unpublished upgrades). These estimates are based on emission factors that have been developed from a limited number of chassis dynamometer drive cycle tests undertaken for selected New Zealand vehicles then extrapolated to the whole vehicle fleet (MoT, 1998a).

Studies (e.g. Walsh *et al*, 1996), however, show that dynamometer testing programmes tend to under-estimate "real-world" emissions. This is due to a number of possible factors – such as not adequately representing a true drive cycle, not estimating emissions properly, or not accounting for all vehicles – but the main reason is that the bulk of emissions generally come from a small proportion of vehicles known as the "gross emitters".

Overseas experience, especially in the United States, has shown that remote sensing is a very effective method for measuring the effect of gross emitters and assessing the state of the vehicle fleet (Cadle *et al*, 2003). A remote sensing system has been tested in several New Zealand cities in recent years, using infrared to measure carbon monoxide (CO) and hydrocarbon (HC) emissions (Gong, 2002). In these trials however, measurements were undertaken on a limited number of vehicles. Consequently, the study reported in this paper represents the first time that significant remote sampling has been implemented to provide a representative picture of the "real-world" emissions of the New Zealand fleet.

1.3 Objective of the Auckland Remote Sensing Study

As part of the 'Big Clean Up' campaign in 2003, the Auckland Regional Council (ARC) commissioned an "On-Road Remote Sensing of Vehicle Emissions" project to investigate the actual emissions from the fleet on the road network. The monitoring programme was carried out by the National Institute of Water and Atmospheric Research (NIWA) Ltd with assistance from the University of Denver, USA who developed the original technique in the early 1990s. The project was funded primarily by the ARC with a contribution from the Foundation Research Science and Technology via the Urban Air Quality Processes Programme (C01X0216).

The project involved a month-long field programme (April 2003) with measurements being taken at numerous locations throughout the Auckland region. Remote sensing equipment was provided by collaborators from the University of Denver group who developed the technique in the early 1990's. Their system has been fully commercialised and is used extensively in the USA and several other countries.

The project aim was to obtain emissions information for up to 40,000 vehicles, sampling across a wide sector of the fleet, to obtain a representative profile of vehicles in the Auckland region. The measured pollutants included CO, NO, HC, opacity (as a qualitative indicator of particulates).

Educating motorists on the need to properly maintain vehicles was a major focus of the campaign so the remote sensing system was coupled to an on-road display, giving drivers immediate feedback on the state of tuning of their vehicles. Based on the CO emissions of the vehicles, the display provided an immediate indication of the vehicle's emissions as follows:

- "Good"– your vehicle is performing well (CO $\leq$ 1.3%)
- "Fair" – your vehicle could do with a tune up (1.3% $<$ CO $\leq$ 4.5%)
- "Poor"– your vehicle is badly tuned and costing your money (CO $>$ 4.5%)

The cut off points of the three categories were based on the distribution of CO remote sensing measurements of vehicles operated in the United States (Bishop *et al*, 2000). CO was chosen as it is a good indicator of the state of tune. In this study, US cut off points for the three categories were adjusted to reflect New Zealand's older vehicle fleet and the relatively low number of vehicles that employ emission control technology.

This report presents the results and analysis of the emissions from the 52,000 vehicles sampled during the programme. A total of 42,000 valid emissions readings were recorded during the testing programme. The licence plates of these vehicles were recorded on videotape. The videotapes yielded approximately 38,000 vehicles with readable licence plates, which were transcribed from the video recordings. The details of these 38,000 vehicles have been extracted from the Land Transport Safety Authority's vehicle Motochek database (LTSA, 2003). The 38,000 Motochek enquiries returned data on 34,500 different vehicles. This indicates that the emissions of approximately 3,500 vehicles were measured more than once – for instance commercial vehicles that may have driven through the sensor system multiple times during the measurement period. The data extracted for each vehicle include the year of manufacture, fuel type, country of first registration (origin), odometer readings, and date on which the warrant of fitness (WoF) expires. The vehicle details were linked to the emissions data and to make comparisons and identify trends in vehicle emissions.

This report:

- Describes the remote sensing system used to make the measurements (Section 2)
- Provides a brief description of vehicle emission characteristics (Section 3)
- Identifies the monitoring sites used in the project (Section 4)
- Describes age and fuel profiles of the fleet which was sampled (Section 5)
- Compares the variation of emissions with year of vehicle manufacture (Section 6)
- Compares the emissions of petrol and diesel fuelled vehicles (Section 7)
- Compares the emissions from New Zealand new and imported used vehicles (Section 8)
- Identifies the influence of vehicle distance travelled on emissions (Section 9)
- Discusses the relationship between vehicle emissions and Warrant of Fitness/Registration (Section 10)
- Presents the distribution of vehicle emissions and identifies the proportion of the fleet which are "**gross emitters**" (Section 11)
- Compares the measurements taken at different sites and in different Cities and Territorial Local Authorities comprising the Auckland region (Section 12)
- Compares the results of this study with similar programmes undertaken in the United States of America (Section 13)
- Discusses some issues that warrant further clarification (Section 14)

2 Remote Sensing of Vehicle Emissions

2.1 How Does Remote Sensing Work?

The remote sensor used in this study was developed at the University of Denver, USA (see http://www.feat.biochem.du.edu/whatsafeat.html). The instrument consists of an infrared (IR) component for detecting carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbons (HC), and an ultraviolet (UV) spectrometer for measuring nitric oxide (NO). The source and detector units are positioned on opposite sides of the road. Beams of IR and UV light are passed across the roadway into the IR detection unit, and are then focused onto a beam splitter, which separates the beams into their IR and UV components. The IR light is then passed onto a spinning polygon mirror that spreads the light across the four infrared detectors: CO, CO_2, HC and a reference.

The UV light is reflected off the surface of the beam splitter and is focused into the end of a quartz fibre-optic cable, which transmits the light to an ultraviolet spectrometer. The UV unit is then capable of quantifying nitric oxide by measuring an absorbance band in the ultraviolet spectrum and comparing it to a calibration spectrum in the same region.

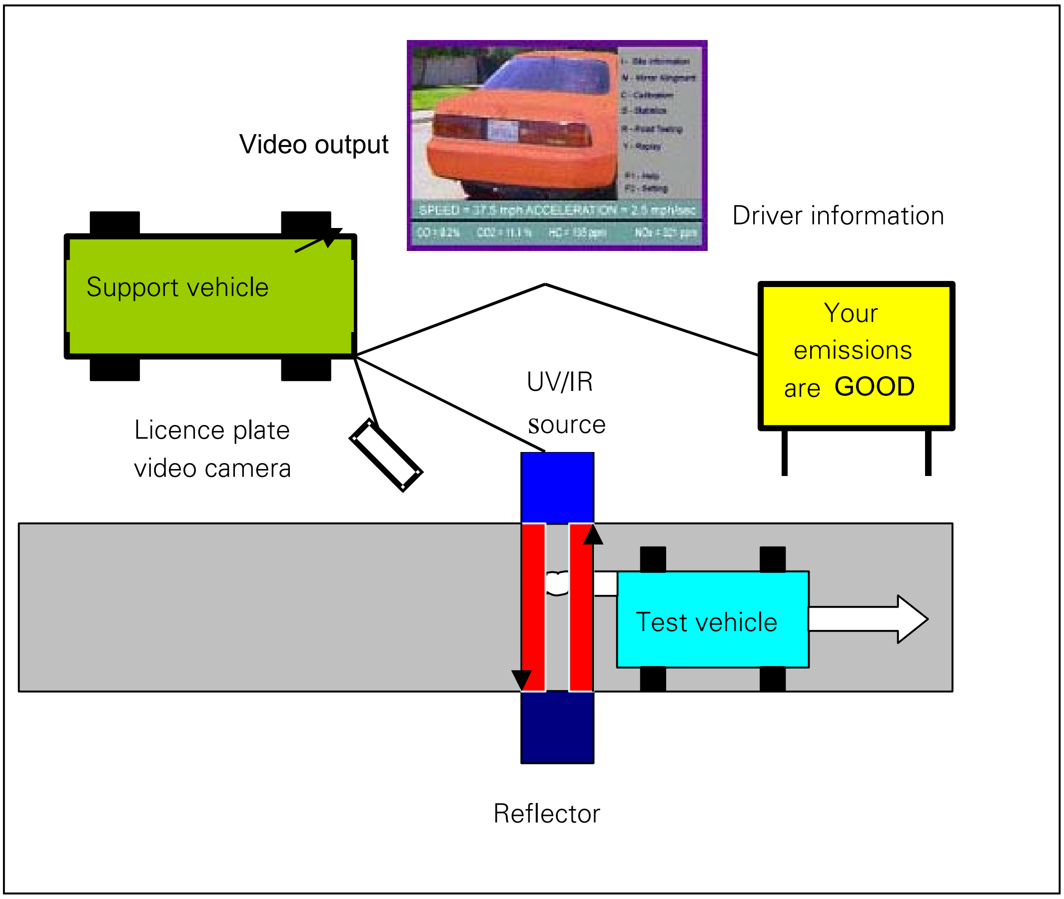
The exhaust plume path length and the density of the observed plume are highly variable from vehicle to vehicle, and are dependent upon, among other things, the height of the vehicle's exhaust pipe, wind, and turbulence behind the vehicle. For these reasons, the remote sensor can only directly measure ratios of CO, HC or NO to CO_2. The ratios of CO, HC, or NO to CO_2, are constant for a given exhaust plume, and on their own are useful parameters for describing a hydrocarbon combustion system. The remote sensor used in this study reports the %CO, %HC and %NO in the exhaust gas, corrected for water and excess oxygen not used in combustion.

Quality assurance calibrations are performed as dictated in the field by atmospheric conditions and traffic volumes. A puff of gas containing certified amounts of CO, CO_2, propane and NO is released into the instrument's path, and the measured ratios from the instrument are then compared to those certified by the cylinder manufacturer. These calibrations account for hour-to-hour variations in instrument sensitivity and variations in ambient CO_2 levels caused by atmospheric pressure and instrument path length. Since propane is used to calibrate the instrument, all hydrocarbon measurements reported by the remote sensor are given as propane equivalents.

The remote sensor was accompanied by a video system to record a freeze-frame image of the license plate of each vehicle measured. The emissions information for the vehicle, as well as a time and date stamp, is also recorded on the video image. The images are stored on videotape, so that license plate information could be incorporated into the emissions database during the analysis of the emission data.

Figure 2.1 shows a schematic diagram of a remote sensing system that measures CO, CO_2, HC, NO, and opacity set up along a single lane of road. The registration plate of the vehicle is recorded on video and make and model year of the vehicle are identified from the video picture.

Figure 2.1
Schematic diagram showing the remote sensing system in operation.



2.2 How Was It Deployed For This Study?

In this study, the remote sensor was operated on single lane roads, including motorway on ramps and off ramps, so that emissions from individual vehicles can be measured. The equipment was operated by NIWA and University of Denver staff, and was manned while at the testing sites. Figure 2.2 shows the remote sensing system in operation at a sampling site in the Auckland region. The emissions are rated as 'good', 'fair' or 'poor'. The rating is displayed on a sign about 50m ahead of the remote sensor.

Figure 2.2
The remote sensing system in operation at a sampling site in the Auckland region.

The project required a substantial level of operation of complex equipment on the edge of busy roadways. A great deal of effort had to be taken to (a) ensure the safety of the operators, (b) minimise effects on normal traffic flow, and (c) not cause any accidents.

Approvals and advice was sought and obtained from all relevant authorities, including the Police, the Land Transport Safety Authority, Transit NZ and each local authority. Specialised sub-consultants were employed to assist develop operational procedures and meet all health and safety requirements.

In a post-field programme review, it was found that the operational procedures worked well. No accidents were reported.

During the field programme, many members of the public were interested in the activities, and several motorists stopped to enquire about the work. A simple handout sheet was made available and all public enquiries dealt with satisfactorily.

Cautionary Note

1) Opacity:

Of all the measurements made by this remote sensing system, the opacity measure should be interpreted with caution. It is indicative only, and subject to greater interference and uncertainty. Data collected contains some negative values – which are obviously an artefact of the technique and probably below the lower limit of detectability. These have not been corrected for, nor adjusted at this stage.

2) Oxides of Nitrogen (NOx):

The oxides of nitrogen (NO_x) emissions from motor vehicles principally consist of nitric oxide (NO) and nitrogen dioxide (NO_2). NO is the dominant species contained in motor vehicle emissions and it is generally accepted to be a high proportion of the total NO_x that leaves the vehicle's tailpipe. For petrol vehicles the NO:NO_2 ratio is 0.9-0.95, for diesel it is 0.75-0.85 (DEFRA, 2003). Once in the atmosphere NO can be oxidised to NO_2 (the predominant pathway being a reaction with ozone). In respect to the adverse human health effects of NO_x, NO_2 is the species of primary concern. The remote sensing equipment used in this project is capable of only measuring NO. The purpose of this report is to present the results of the emission-testing programme and will only refer to NO. The amount of NO_2 discharged by vehicles, and the rate at which NO is converted to NO_2 are not addressed in this report.

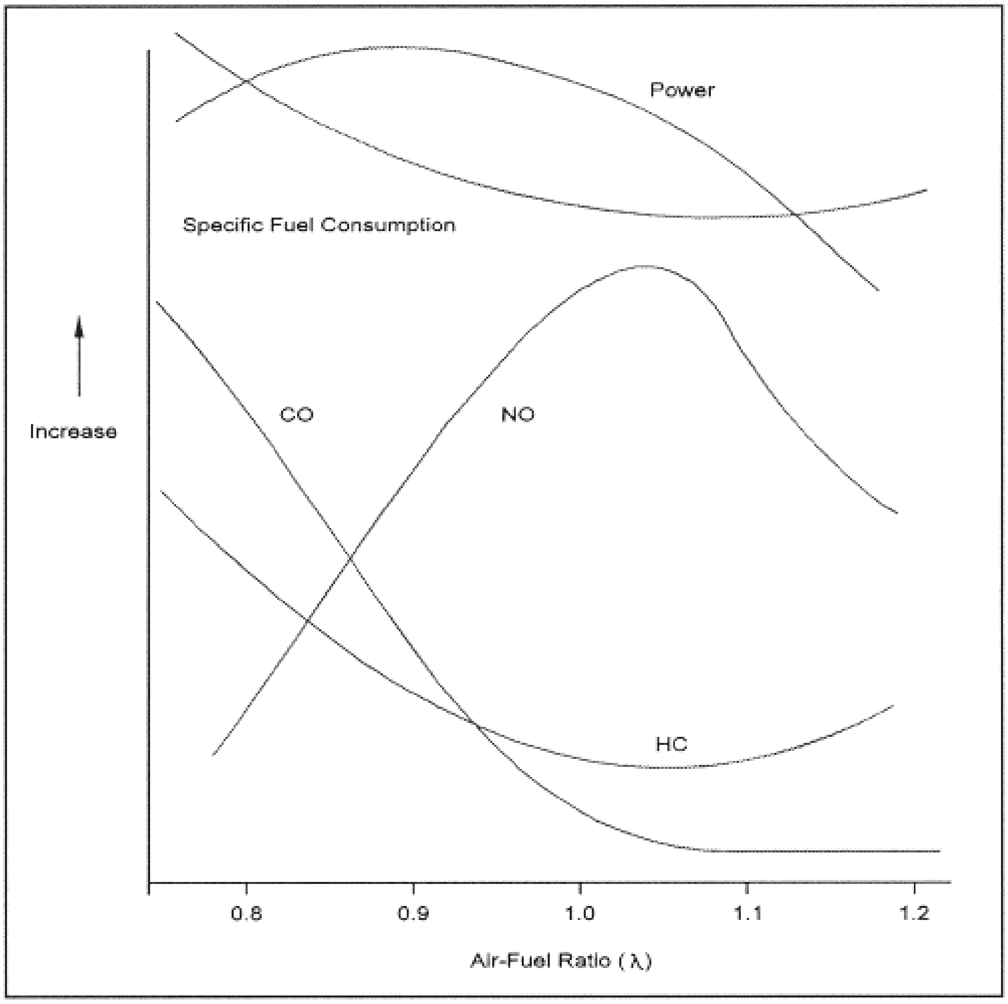
3 Characteristics of Motor Vehicle Exhaust Emissions

In an internal combustion engine, a chemical reaction occurs between the oxygen in air and the hydrocarbon fuel. In theory, the products of this chemical reaction are carbon dioxide (CO_2) and water (H_2O) and a release of energy (mainly heat). Oxides of nitrogen (NO, NO_2 and small amounts of others) are invariably produced in any combustion process involving air, which contains a high proportion of nitrogen. The production rate is dependent on the pressure and temperature, with higher temperatures being conducive to higher production rates.

Engines operate at what is termed the "stoichiometric" air/fuel ratio when there is the correct quantity of air to allow complete combustion of the fuel with no excess oxygen. In reality petrol engines may burn rich (a lower air/fuel ratio than stoichiometric). A richly tuned (or out of tune) engine will produce more products of incomplete combustion that include carbon monoxide (CO) and numerous hydrocarbons (HC) from unburned fuel. When petrol engines burn lean (a higher air/fuel ratio than stoichiometric), combustion is more complete, however there is a reduction in the power output of the engine. Diesel engines are always set to operate at leaner than stoichiometric air/fuel ratio whereas petrol engines may burn rich (particularly when warming up) or lean.

The relationship between fuel consumption, engine power output and emissions from petrol engines is illustrated in Figure 3.1. The maximum power output is achieved when the mixture is richer than stoichiometric, whereas best fuel economy and minimum CO emissions are achieved when the mixture is slightly lean. Higher levels of CO and HC emissions are associated with rich mixtures, whereas NO_x (mainly NO and a smaller proportion of NO_2) emissions peak when the mixture is slightly lean.

Figure 3.1
Air/fuel ratio performance relationships (MoT, 1998b)



The processes which result in the formation of CO, HC, and NO_x in exhaust emissions are summarized below (MoT, 1998b).

- **CO** –The oxidation of the carbon contained in the fuel does not proceed to the final product (CO_2) due to a lack of combustion air. Fuel-rich conditions will cause a steep rise in CO formation and emission without sufficient oxygen being available in the air:fuel mixture. A relatively low amount of CO in the exhaust gases indicates that a relatively high amount of complete combustion has taken place in the engine. This is also indicated by a relatively higher the amount of CO_2 in the exhaust gases.

- **HC** – unburned or partially oxidised fuel is the source of HC emissions. A lack of oxygen during combustion is a cause, but the main physical mechanisms are poor fuel:air mixing, particularly with fuel condensing on combustion chamber surfaces, and flame quenching before complete oxidation.

- **NO_x** – the formation of NO_x increases strongly (exponentially) with peak flame temperatures if endured long enough with the simultaneous availability of oxygen. In most vehicles (the 86% that are petrol powered), practically all of the on-road NO_x is emitted in the form of NO.

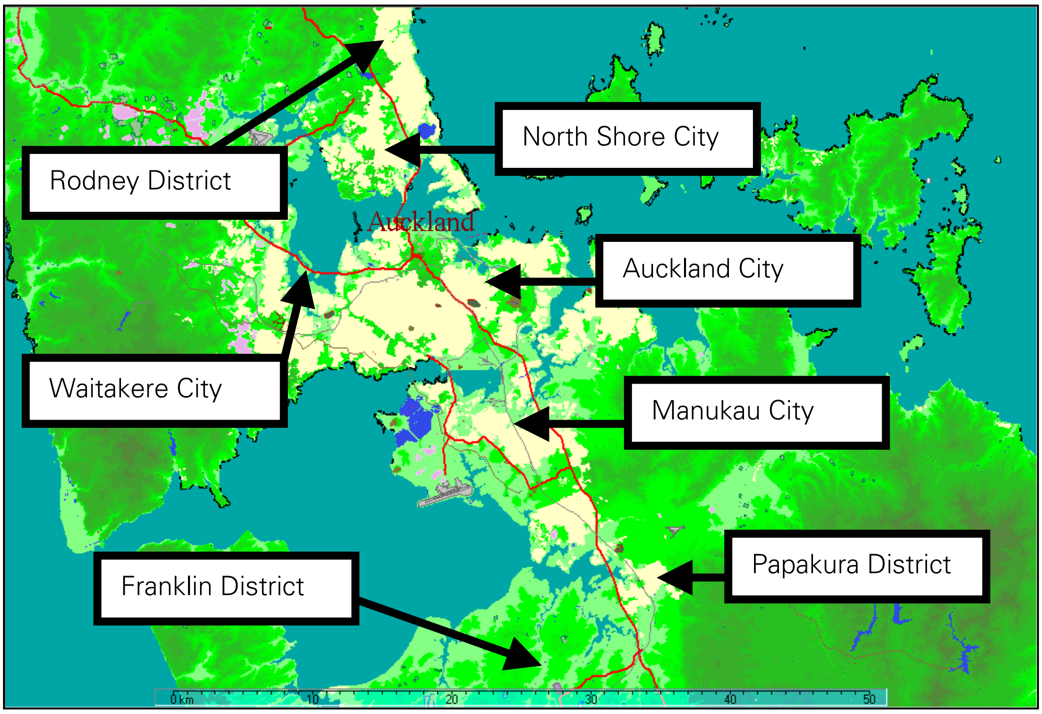
There are trade-offs between the emission of different pollutants and between fuel economy and emissions. In particular, NO_x control is at the expense of fuel consumption and higher CO emissions. Particulates can be reduced through higher temperature and faster combustion, whereas reductions in NO_x emissions require reduced combustion temperature.

Vehicle state-of-tune has an effect on fuel economy and emissions. Excessive CO and HC with reduced NO_x emissions may indicate an out-of-tune vehicle. Large reductions in CO and HC emissions may be observed after tuning vehicles to factory specifications. Properly operating modern vehicles with three-way catalysts are capable of partially (or completely) converting engine-out CO, HC and NO emissions to CO_2, H_2O and N_2.

4 Description of Monitoring Sites Sampled

The sampling campaign was carried out in April 2003 at fifteen sampling sites across seven territorial local authorities: Auckland City; Manukau City; Waitakere City; North Shore City; Franklin District; Rodney District; and Papakura District. The general locations of the monitoring sites are displayed in Figure 4.1. Detailed maps showing the exact location of each of the sites are contained in Appendix 1 (Maps of Monitoring Sites).

Figure 4.1
The general locations of the sampling sites used for in the remote sensing vehicle emissions campaign.



Around 52,000 vehicles were sampled with about 42,000 valid readings, (80.55% of the total sample). The location of sampling sites, sampling date and time, number of sampled vehicles and valid readings are listed in Table 4.1. As noted earlier, this report presents the results and analysis of the emissions from the 42,000 vehicles sampled during the programme, with more detailed analysis provided on the 38,000 vehicles for which data has been extracted from Motochek (LTSA, 2003) which returned data on 34,500 unique vehicles (approximately 3,500 vehicles were measured more than once). The data presented in this report were collected at the sites noted in Table 4.1.

Table 4.1
Summary sites used in the sampling campaign

Site	Location	Date	Time	# of Vehicles	# of Valid Readings	% Valid readings
Manukau (MAN1)	Lambie Dr., Wiri (Northbound)	2-Apr-2003	05:50 to 12:50	3,888	2,787	71.68%
Manukau (MAN2)	Lambie Dr., Wiri (Southbound)	3-Apr-2003	06:30 to 13:00	3,709	2,717	73.25%
Waitakere (WAI1)	Te Atatu North (City bound)	4-Apr-2003	05:30 to 12:20	3,683	2,429	65.95%
Auckland (AUC2)	Lagoon Dr., Panmure (City bound)	7-Apr-2003	06:15 to 12:30	5,527	4,291	77.64%
North Shore (NOR2)	Oteha Valley Rd (Eastbound)	8-Apr-2003	05:50 to 18:20	7,468	6,911	92.54%
Waitakere (WAI2)	Lincoln Rd (Westbound)	9-Apr-2003	06:10 to 12:45	3,334	2,606	78.16%
Manukau (MAN1)	Lambie Dr., Wiri (Northbound)	10-Apr-2003	06:00 to 12:30	3,948	3,174	80.40%
Franklin (FRA1)	Glenbrook Rd (Westbound)	11-Apr-2003	06:20 to 12:30	1,470	912	62.04%
Auckland (AUC1)	St Heliers Bay Rd (Eastbound)	14-Apr-2003	13:00 to 19:00	3,878	2,321	59.85%
North Shore (NOR1)	Upper Harbour Highway (Westbound)	15-Apr-2003	13:00 to 18:20	2,495	2,234	89.54%
Manukau (MAN3)	Takanini onramp (Southbound)	16-Apr-2003	12:00 to 18:40	2,707	2,466	91.10%
Papakura (PAP1)	Elliot St, Papakura (Westbound)	17-Apr-2003	05:45 to 12:45	2,366	2,043	86.35%
Rodney (ROD2)	Grand Dr., Orewa (Southbound)	22-Apr-2003	12:20 to 18:30	3,820	3,385	88.61%
Rodney* (ROD1)	Grand Dr., Orewa (Northbound)	23-Apr-2003	06:00 to 12:30	2,595	2,406	92.72%
Manukau (MAN4)	Highland Park Drive, Highland Park (Eastbound)	24-Apr-2003	09:50 to 15:50	1,311	1,291	98.47%
BUS1*	Esmonde Rd (bus lane)	29-Apr-2003	06:15 to 12:30	56	46	82.14%
Total				52,255	42,019	80.65%

*Data from the BUS1 site has not been included in the analysis due to the relatively small number of "non-typical" vehicles (I.e. buses only) fleet measured at this site.

5 Age and Fuel Profiles of the Sampled Vehicle Fleet

Vehicle details have been extracted from the Land Safety Transport Authority's (LSTA) vehicle database (Motochek). Amongst the 38,000 returns from Motochek were 158 vehicles for which no information was available, 12 vehicles for which information had to be requested in writing, 291 with cancelled registration, and 56 vehicle dealer plates. These vehicles were removed from the database before analysis was started. In summary 38,000 enquiries returned usable details on approximately 34,500 individual vehicles once invalid and repeat plates (vehicles measured more than once) had been removed from the database. Figure 5.1a shows the year of manufacture for the 34,500 vehicles for which details have been obtained.

Figure 5.1a
Profile of year of manufacture

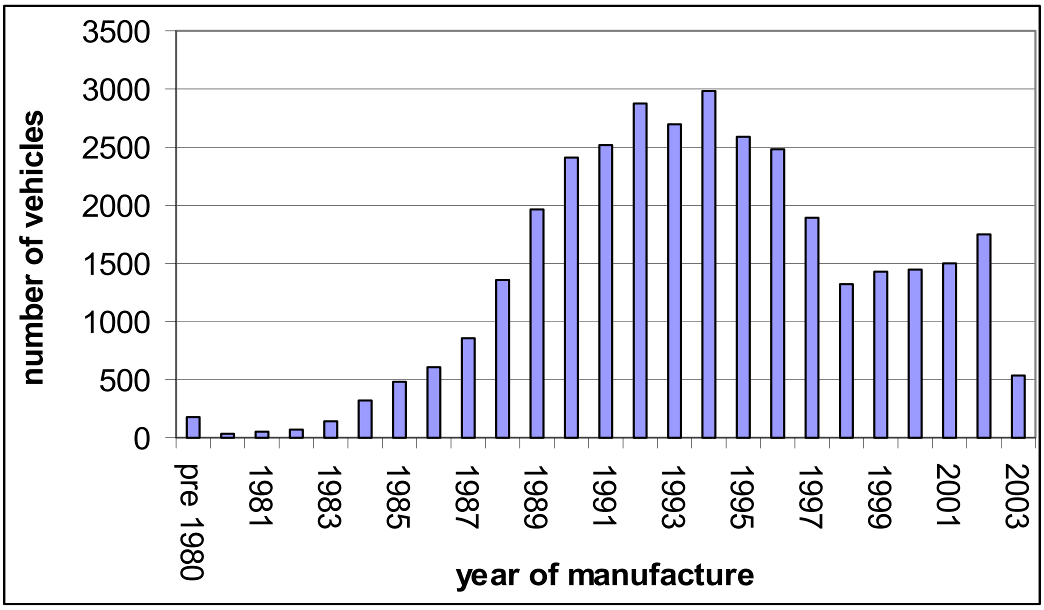
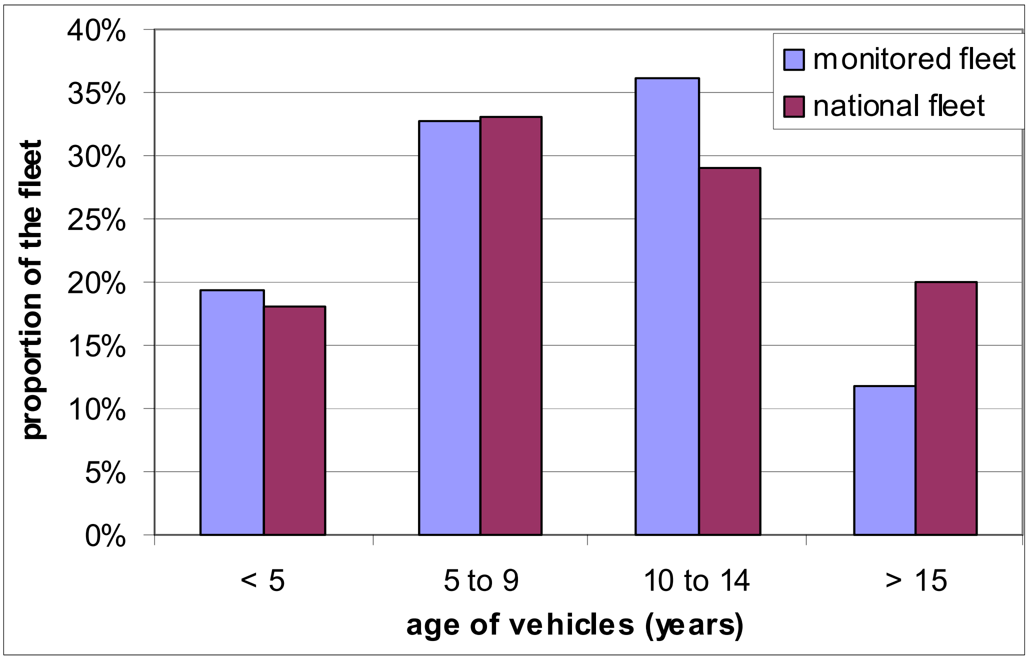


Figure 5.1a shows the age profile of the vehicles in the Auckland fleet. The distribution displays a bi-modal pattern with a peak around 1994 and another around 2002. This is most likely due to the two time points where vehicles can enter the fleet – the first as Japanese used imports (generally around 7 years of age) and the second as New Zealand new vehicles. This effect is discussed in more detail in Sections 8.1 and 8.2 of this report, which disaggregates the sample fleet into New Zealand new and imported used Japanese vehicles. The data displayed in Figure 5.1a show that few vehicles in the sample were manufactured before 1985, and the number of vehicles peaks with the years of manufacture 1992-1994. The average age of the vehicles in the sample fleet is 9 years old (manufactured in 1994), which compares to an average age of approximately 10 years for the Australian vehicle fleet in 2001 (AAA, 2003).

A comparison has been made between the age profile of the sampled fleet and the age profile of the total New Zealand vehicle fleet. The information of the New Zealand fleet was obtained from published statistics (Ministry of Economic Development, 2001), available in 5-year bands. These are shown in Figure 5.1b.

Figure 5.1b
Comparison of the age of vehicles in the monitored fleet and the New Zealand national fleet.



The comparison of the age of vehicles in the Auckland sampled fleet and the total New Zealand national fleet shows that:

- The sampled fleet has a very slightly higher proportion of new vehicles (less than 5 years old).
- Both fleets have the approximately same proportion of medium age vehicles (5 to 9 years old).

- The sampled fleet has a higher proportion of moderately older age vehicles (10 to 14 years).
- The sampled fleet has a significantly lower proportion of the oldest vehicles (15 years old or greater).

An analysis was also conducted on the proportions of petrol and diesel vehicles in the fleet, shown in Figure 5.2.

Figure 5.2
Proportion of the sample fleet using petrol and diesel fuels

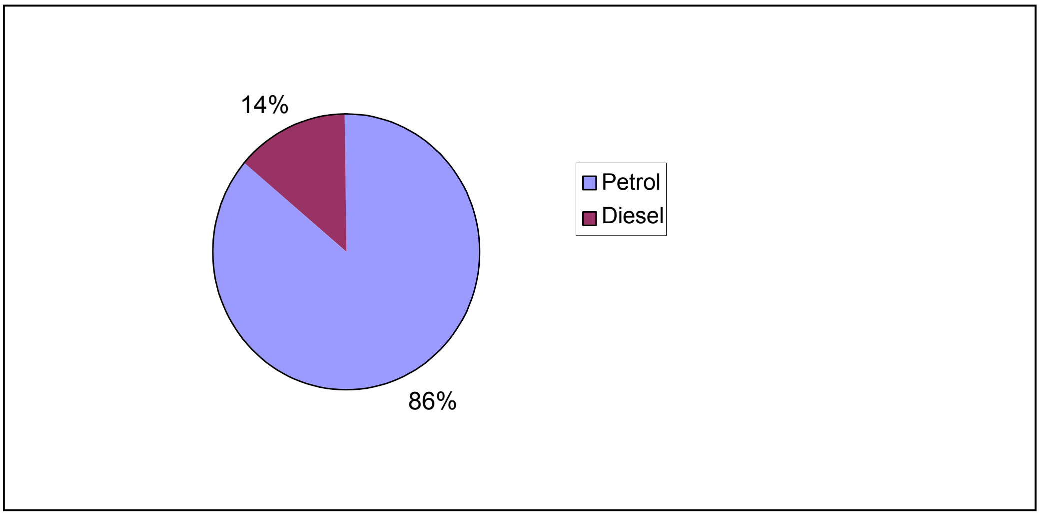


Figure 5.3 shows the variation of the use of petrol and diesel fuels with the year of manufacture of vehicles.

Figure 5.3
Variation of use of petrol and diesel fuelled vehicles with year of manufacture

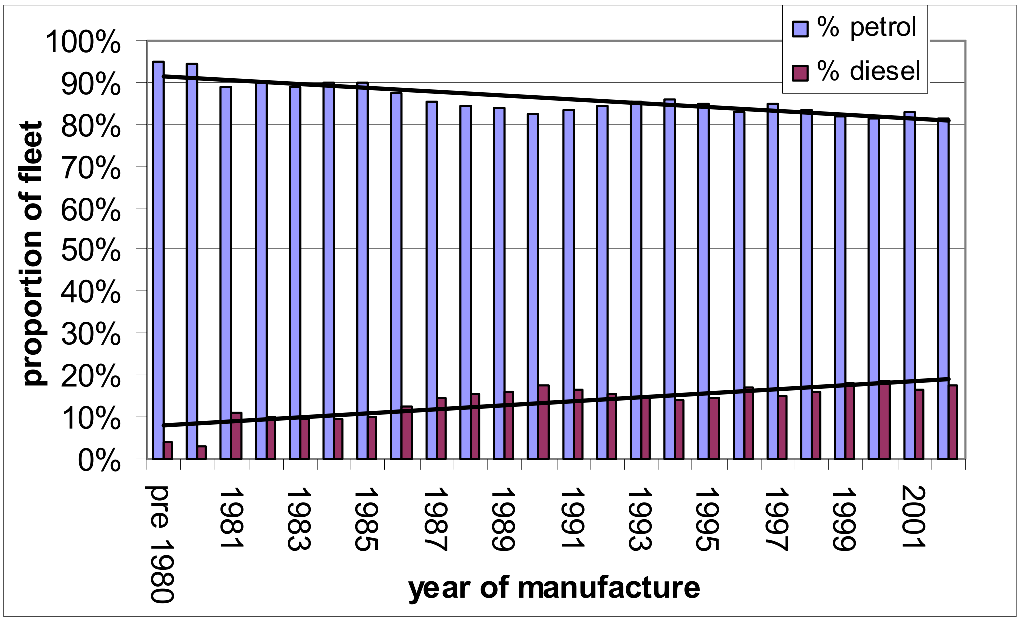
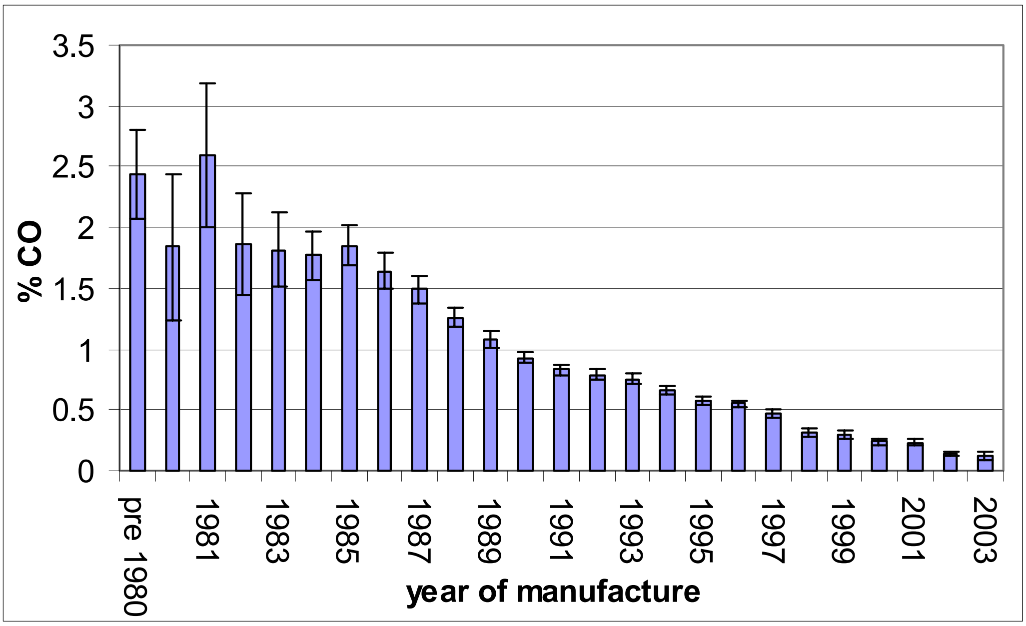


Figure 5.2 shows that across the sample fleet, 86% and 14% of the vehicles use petrol and diesel fuels respectively. Figure 5.3 shows that within the sample fleet there has been a general increase in the proportion of diesel-fuelled vehicles manufactured between 1980 and 2003. The data shows that approximately 10% of older vehicles are diesel-fuelled and this has increased to approximately 20% for recently manufactured vehicles.

6 Variation of Emissions with Vehicle Year of Manufacture

Figures 6.1, 6.2, 6.3, and 6.4 show how the sample fleet average emissions of CO, hydrocarbons, NO and opacity vary respectively with year of vehicle manufacture.

Figure 6.1
Variation of sample fleet average CO emissions with vehicle manufacture year



Explanatory Note: Error Bars

The error bars shown on the figures in this report indicate the confidence interval of the mean value. The plus and minus values of the confidence interval (**CI**) around the mean are calculated using the equation:

$$CI = 1.96 \times \left(stdev / \sqrt{n} \right)$$

Where: **stdev** is the standard deviation of the range of values, **n** is the number of values in the range

This is a standard sampling uncertainty, and should not be interpreted as an absolute uncertainty on the measurements, which may be affected by other undetermined factors – such as choice of roadway sites, time of day, season etc.

Figures 6.1 to 6.3 show relatively large confidence intervals for the vehicles manufactured before 1984. This is due to the smaller number of vehicles in these age categories and the relatively high degree of variation in the associated measurements. Generally, the sample fleet average emissions of CO, hydrocarbons and NO tend to be lower for newer vehicles, most likely due to improvements in vehicle engine management and the advent of emission control technology.

Figure 6.2
Variation of sample fleet average hydrocarbon emissions with vehicle manufacture year

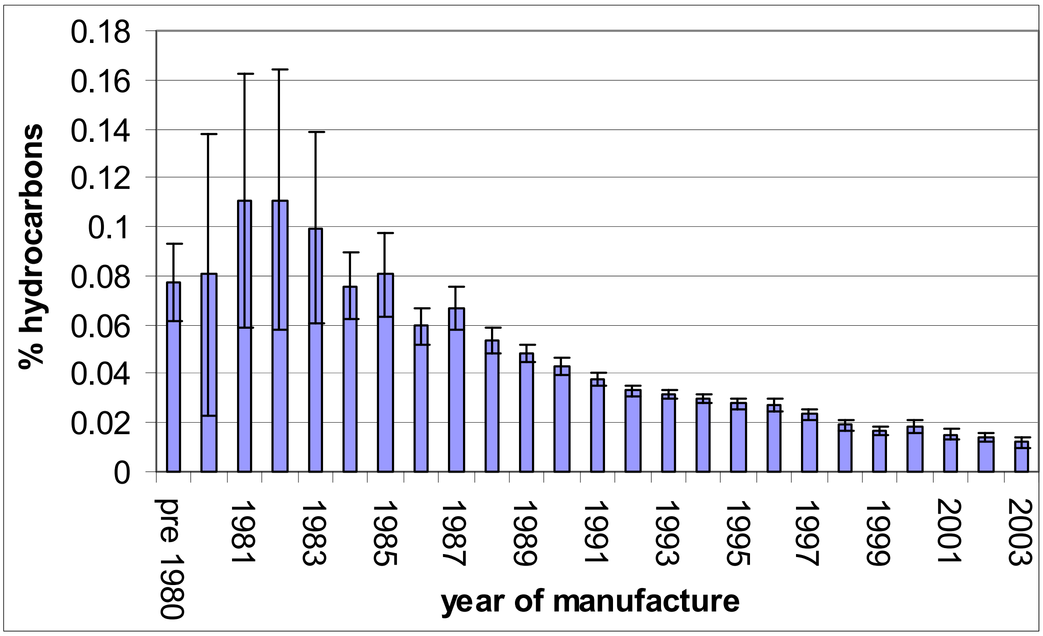


Figure 6.3
Variation of sample fleet average NO emissions with vehicle manufacture year

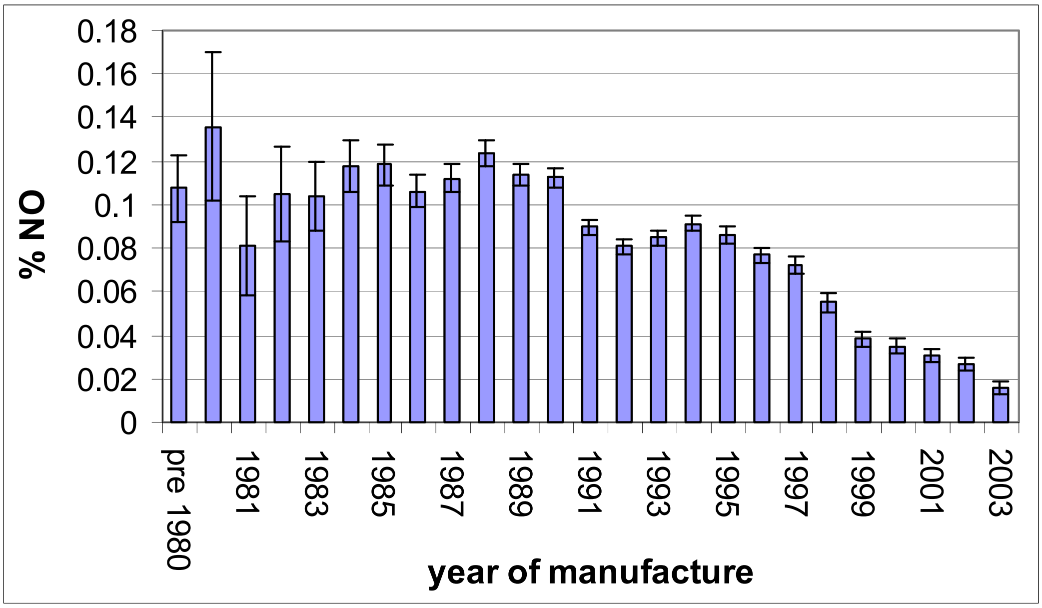


Figure 6.4 shows the variation of sample fleet average opacity measurements with vehicle manufacture date. Opacity is a measure of the "smokiness" of the vehicle plume. Opacity is NOT a direct measurement of the amount of particulate matter contained in the plume. However high opacity is frequently associated with high particulate concentrations, and therefore opacity can be used as a qualitative indicator of the amount of particulate matter contained within exhaust plumes. The method used by the remote sensing equipment to measure opacity results in fewer valid readings than for the gaseous pollutants. Approximately 37,500 data points are represented in the figures displaying the gaseous pollutant measurements, whereas Figure 6.4 is the result of approximately 31,500 valid opacity measurements from the years, 1983 to 2003.

Figure 6.4
Variation of sample fleet average opacity measurements with vehicle manufacture year

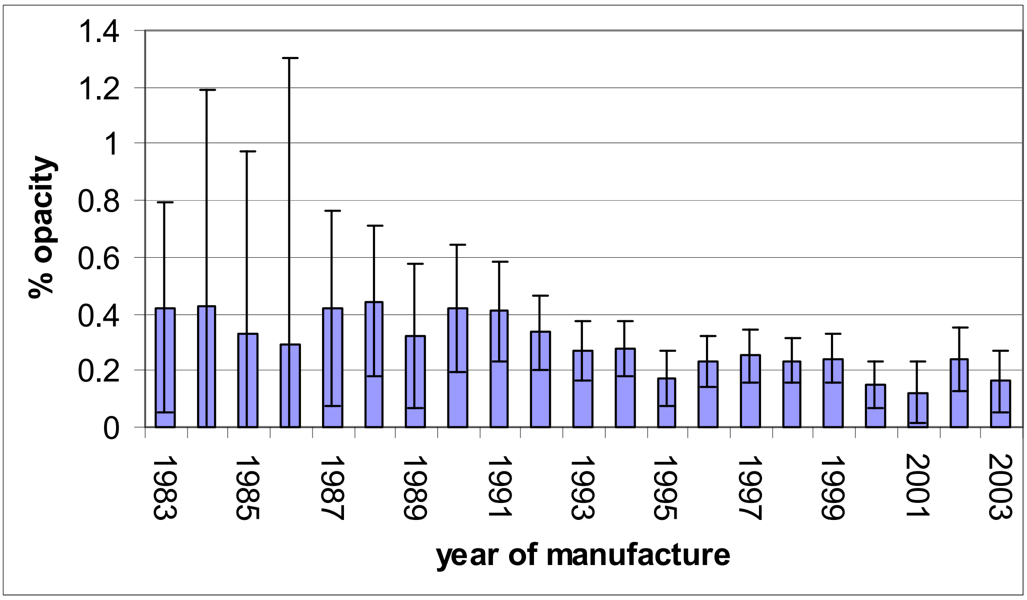


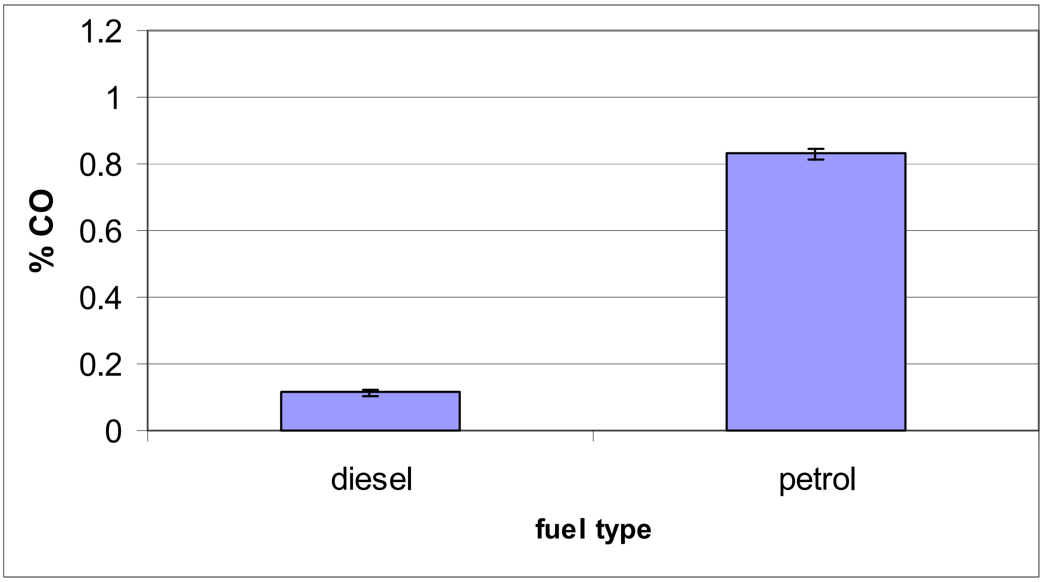
Figure 6.4 shows that opacity measurements are more variable than gaseous pollutants. Figure 6.4 suggests that the sample fleet average opacity measurements may be lower for newer vehicles. However, the confidence intervals for each of the average measurements are relatively large and the differences between the average opacity measurements of many of the years are not significant. Therefore, no firm conclusions can be drawn from these data.

Nevertheless, opacity is a good qualitative indicator, since it is the only emissions contaminant that is directly visible to the public, and this in itself could form a basis for identifying and addressing gross "visual pollution" emitters.

7 Comparison of Petrol and Diesel Fuelled Vehicles

To investigate how vehicle emissions vary with fuel type, the sample fleet data were disaggregated according to petrol and diesel fuels. The sample fleet contained approximately 29,100 and 5,300 petrol and diesel vehicles respectively. Only 20 of the 34,500 vehicles in the sample fleet listed their primary or alternative fuel as LPG or CNG. Therefore, this analysis only considers petrol and diesel fuels. Figures 7.1, 7.2, 7.3, and 7.4 show how the sample fleet average emissions of CO, hydrocarbons, NO and opacity vary respectively with fuel type.

Figure 7.1
Variation of sample fleet average CO emissions with fuel type



Figures 7.1, 7.2 and 7.3 respectively show that the sample fleet average emissions of CO, hydrocarbons and NO are higher for petrol-fuelled vehicles.

Figure 7.2
Variation of sample fleet average hydrocarbon emissions with fuel type

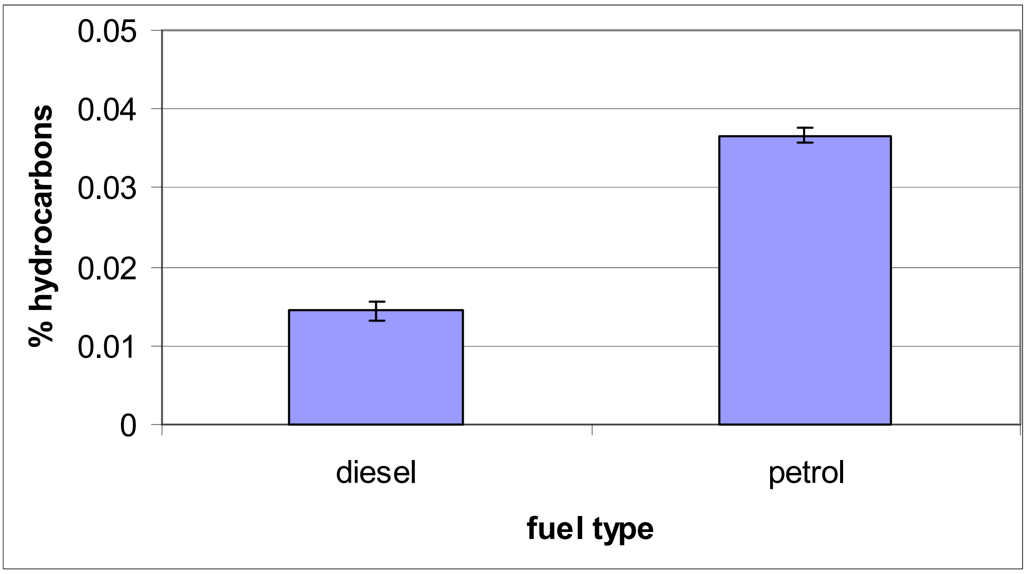


Figure 7.3
Variation of sample fleet average NO emissions with fuel type

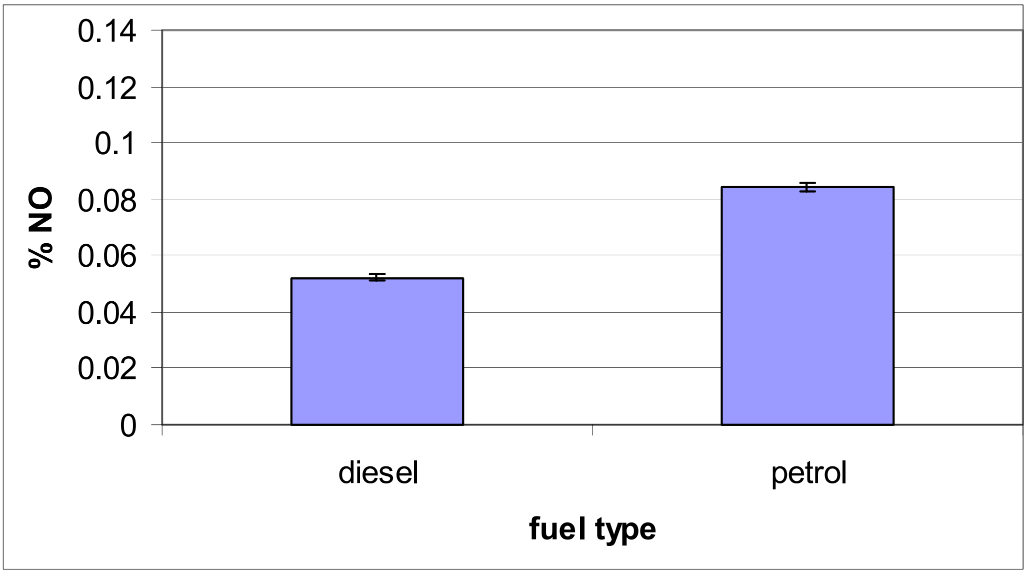
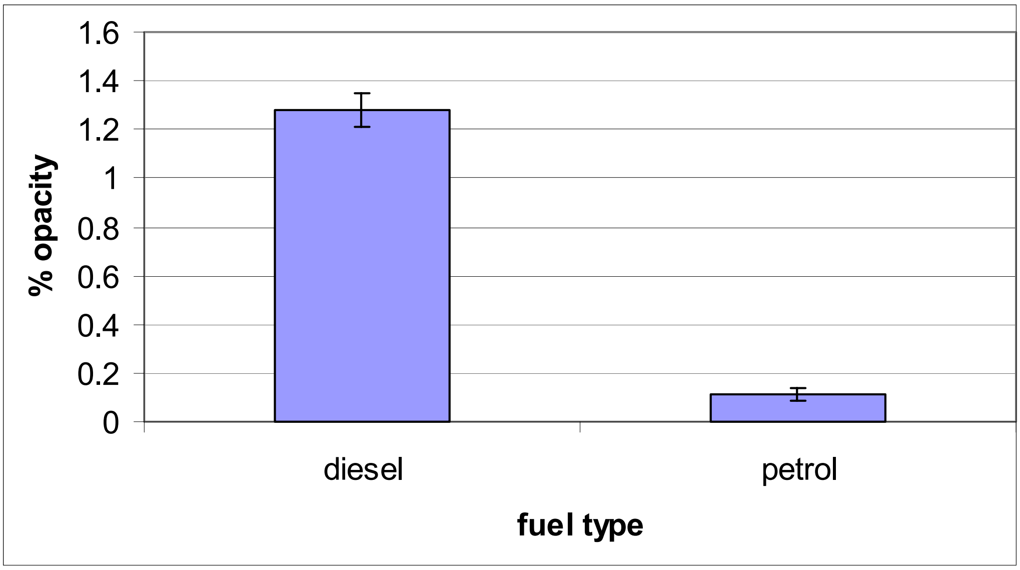


Figure 7.4
Variation of sample fleet average opacity measurements with fuel type



As noted in Section 6, the amount of pollutants a vehicle emits varies significantly with the year of manufacture. A comparison between emissions of CO, hydrocarbons, NO emissions and opacity measurements from petrol- and diesel-fuelled vehicles and how they vary with year of manufacture is made in Figures 7.5, 7.6, 7.7, and 7.8 respectively.

Figure 7.5
Variation of diesel- and petrol-fuelled vehicles average CO emissions with year of manufacture

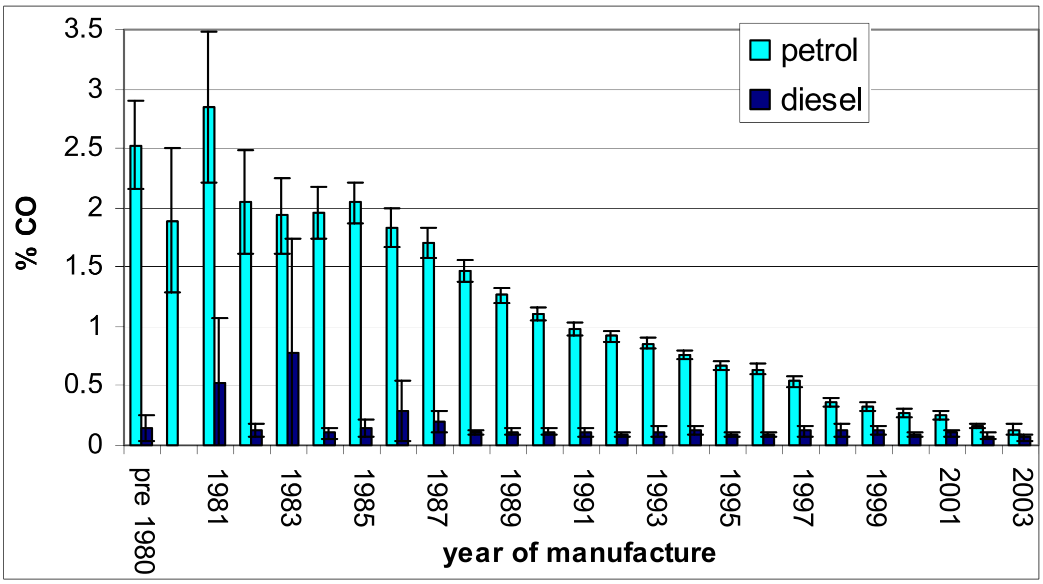


Figure 7.6
Variation of diesel- and petrol-fuelled vehicles average hydrocarbon emissions with year of manufacture

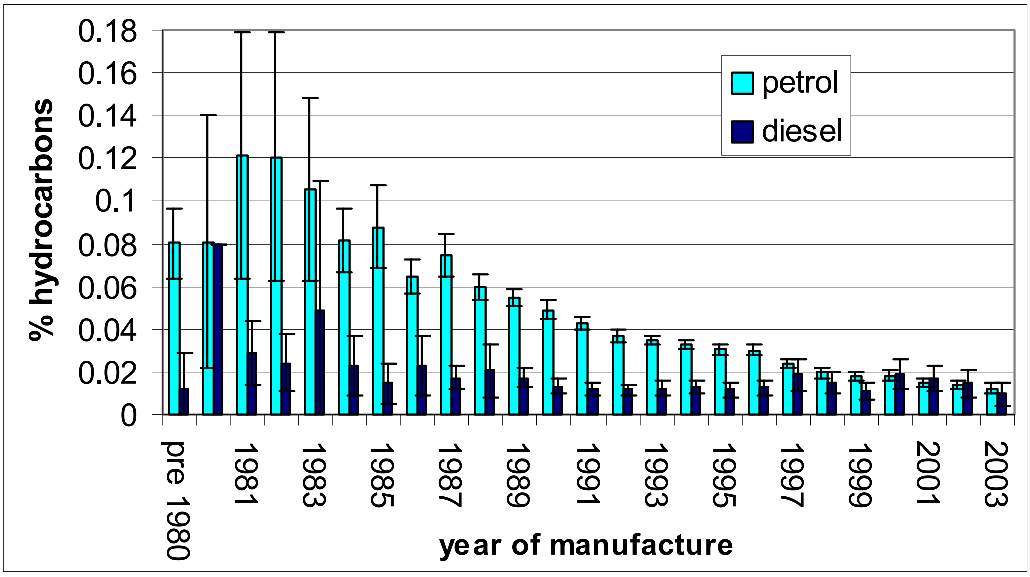


Figure 7.7
Comparison of NO emissions for diesel- and petrol-fuelled vehicles against the year of manufacture of vehicles

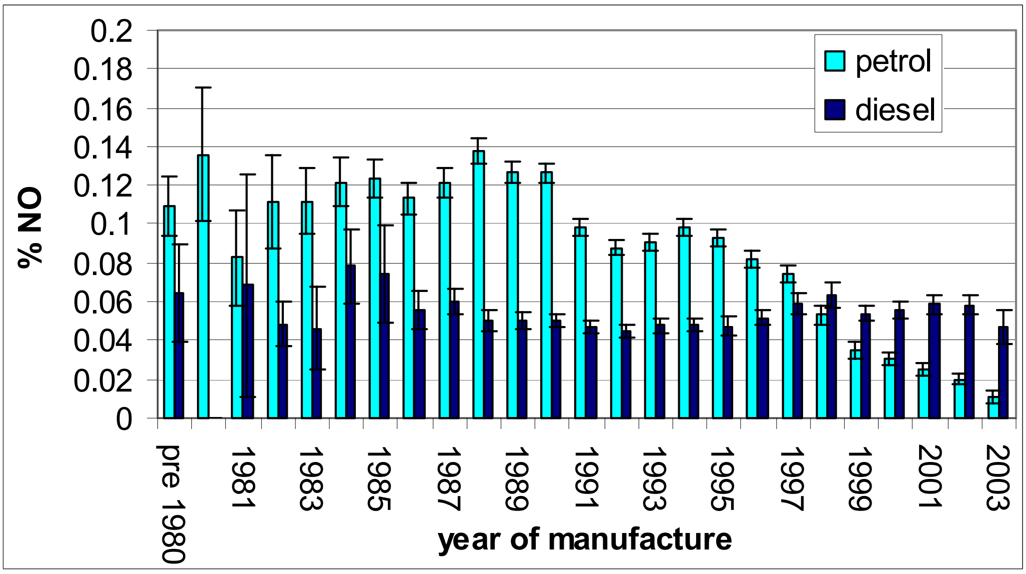
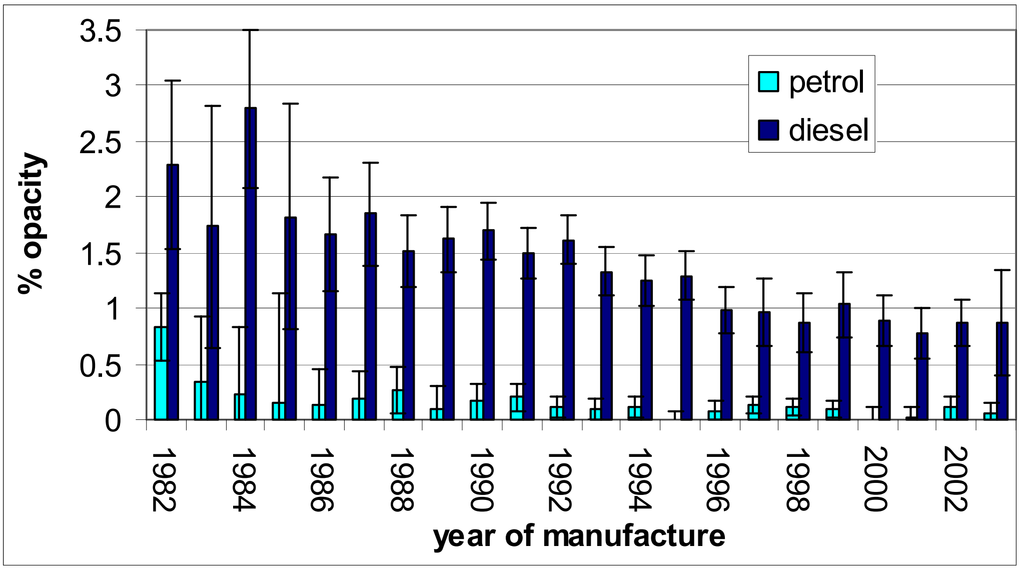


Figure 7.8
Comparison of opacity measurements for diesel- and petrol-fuelled vehicles against the year of manufacture of vehicles



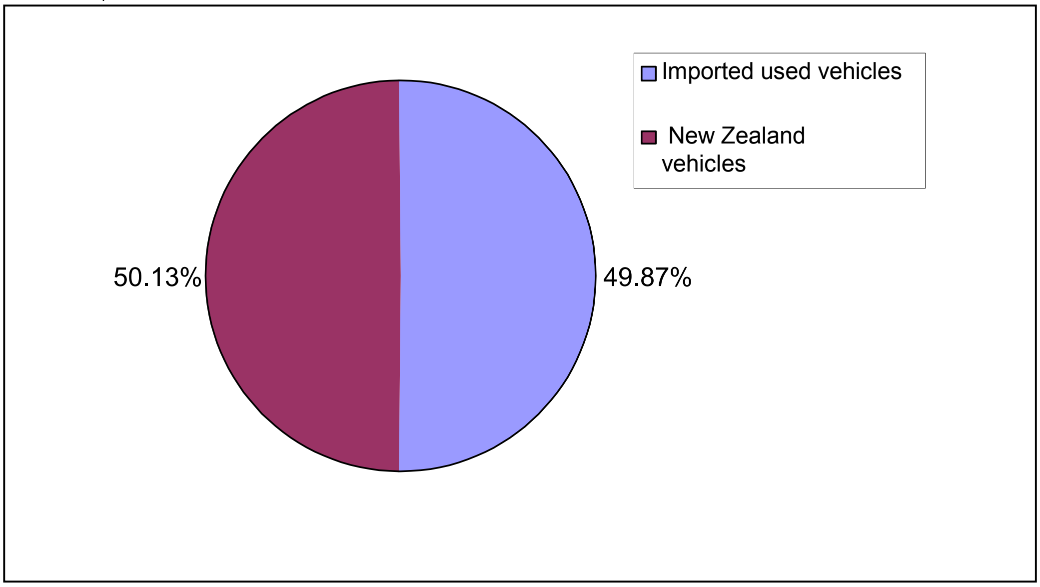
Figures 7.5, 7.6 and 7.7 show that emissions of CO, HC and NO from petrol-fuelled vehicles have improved at a faster rate than for diesel-fuelled vehicles. Figure 7.8 shows that opacity measurements from diesel-fuelled vehicles have improved at a faster rate than petrol fuelled vehicles.

A great deal of caution must be taken in interpreting these results. In particular, it is unrealistic to ascribe any meaningful effects based trend in the differential between NO measurements of petrol and diesel vehicles. This is because no assessment has been made of the direct NO_2 emissions, which could also have some increasing or decreasing trend. This feature of the vehicle fleet emissions has yet to be fully investigated.

8 Comparison of NZ New and Imported Used Vehicles

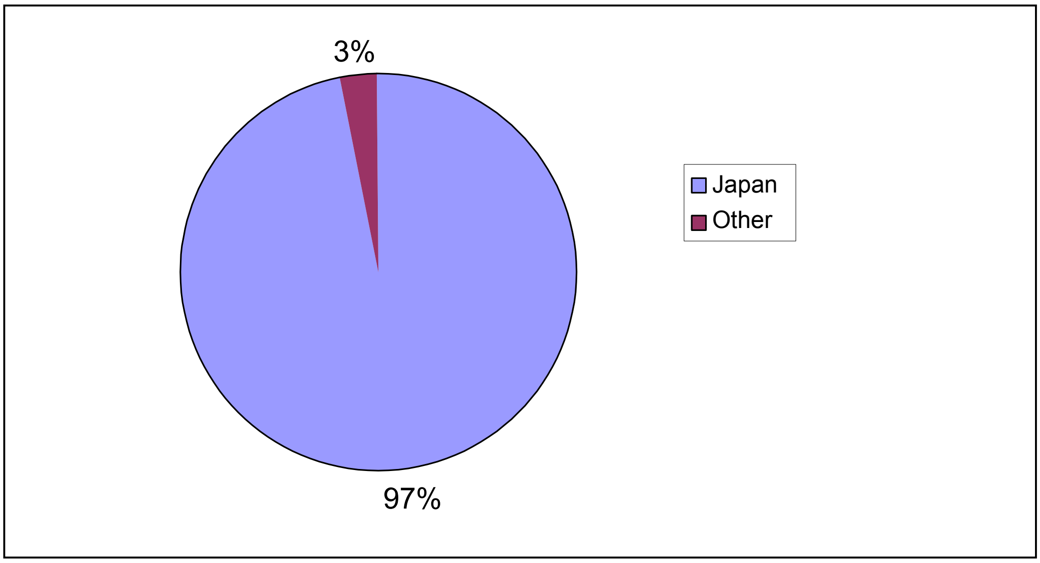
New Zealand's vehicle fleet contains a significant proportion of imported used vehicles. To investigate if the emissions of imported used vehicles differ from those of New Zealand new vehicles (vehicles first registered and only driven in New Zealand), the sample fleet was disaggregated according to county of origin. The Auckland sample fleet of 34,500 vehicles was found to be split essentially 50/50 between New Zealand new and imported used vehicles. Figure 8.1 shows the relative proportion of New Zealand new and imported used vehicles contained in the sample fleet.

Figure 8.1
Proportion of New Zealand new and imported used vehicles in the sample fleet



New Zealand imports vehicles from numerous countries. The sample fleet vehicles originated from at least 13 countries. The vast majority of used vehicles were imported from Japan, with small contributions from Australia, Britain, Singapore, South Africa and the USA. Figure 8.2 shows the relative numbers of imported vehicles from Japan and other countries.

Figure 8.2
Country of origin of the imported used vehicles contained in the sample fleet



8.1 Imported Used and New Zealand New Petrol Vehicles

A comparison of the emissions from New Zealand new and Japanese imported used, petrol-fuelled vehicles, manufactured between the years of 1986 and 1999 was undertaken. This subset of the sample fleet includes a total of 25,000 vehicles, of which 11,300 are New Zealand new vehicles and 13,900 are Japanese imported used vehicles. Figures 8.3 and 8.4 respectively show the profile by year of manufacture of New Zealand new and Japanese imported used petrol vehicles. Note that the data from Motocheck on vehicle origin are very sparse for vehicles manufactured before 1985.

Figure 8.3
Profile of New Zealand new petrol vehicles by year of manufacture

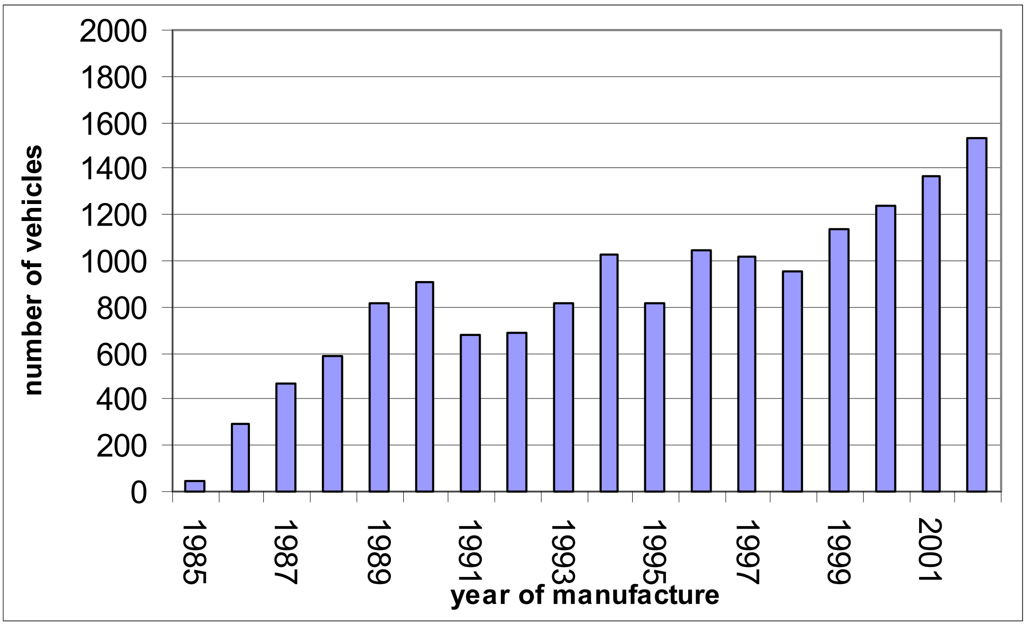
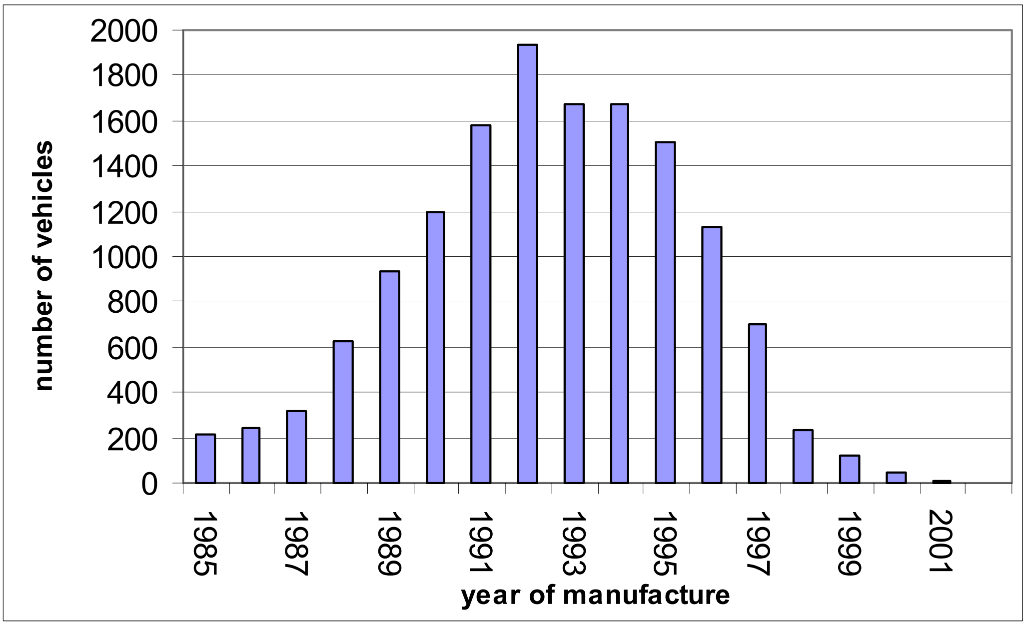


Figure 8.4
Profile of imported Japanese used petrol vehicles by year of manufacture



The profiles by year of manufacture of New Zealand new and Japanese imported used petrol vehicles within the sample fleet are very different. The profile of New Zealand new cars indicates that there are an increasing number of new vehicle registrations each year. The profile of the Japanese imported used vehicles suggests that these vehicles begin entering New Zealand fleet in significant numbers several years after their manufacture date.

Figures 8.5, 8.6, 8.7, and 8.8 show how the 1986-1999 petrol-fuelled fleet average emissions of CO, hydrocarbons, NO and opacity compare for New Zealand new and Japanese used imported vehicles.

Figure 8.5
Comparison of 1986-1999 petrol fleet average CO emissions with vehicle country of origin

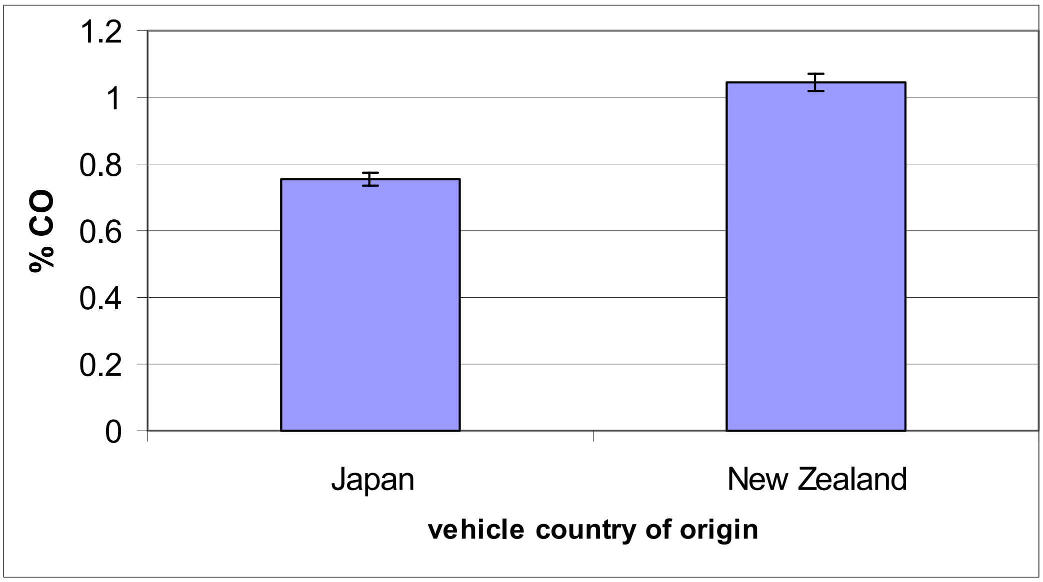


Figure 8.6
Comparison of 1986-1999 petrol fleet average hydrocarbon emissions with vehicle country of origin

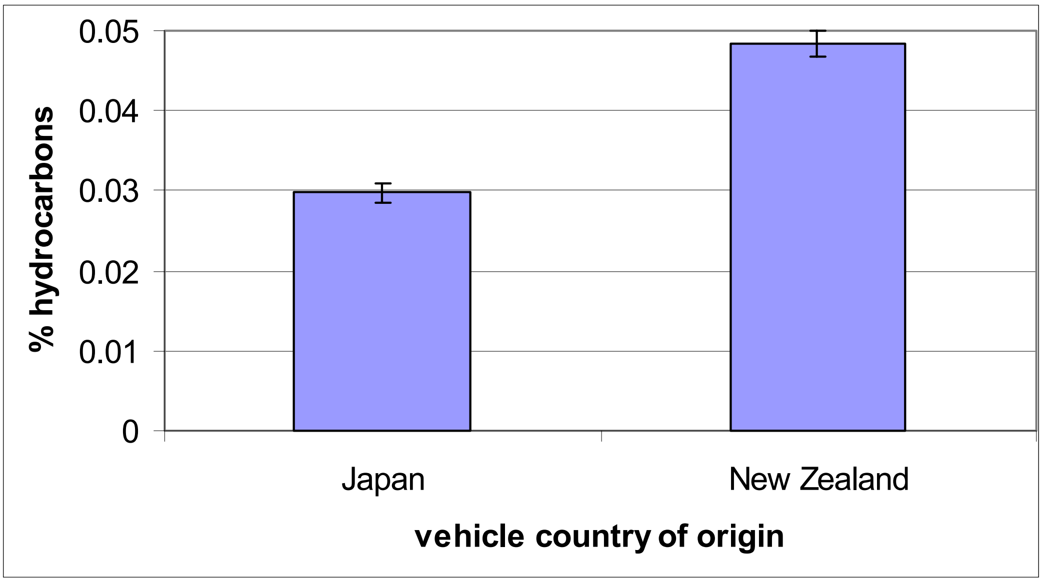


Figure 8.7
Comparison of 1986-1999 petrol fleet average NO emissions with vehicle country of origin

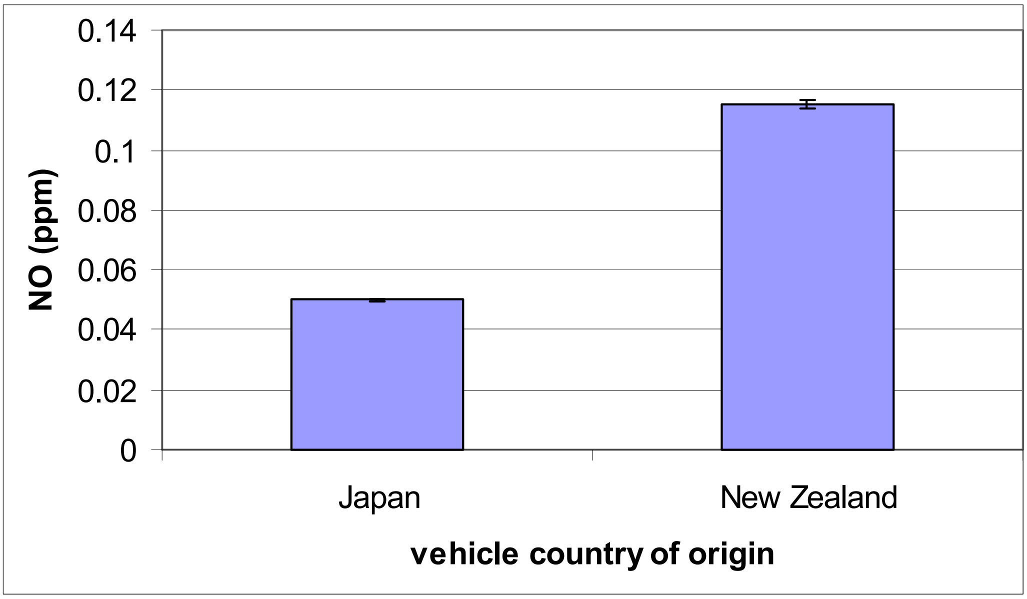
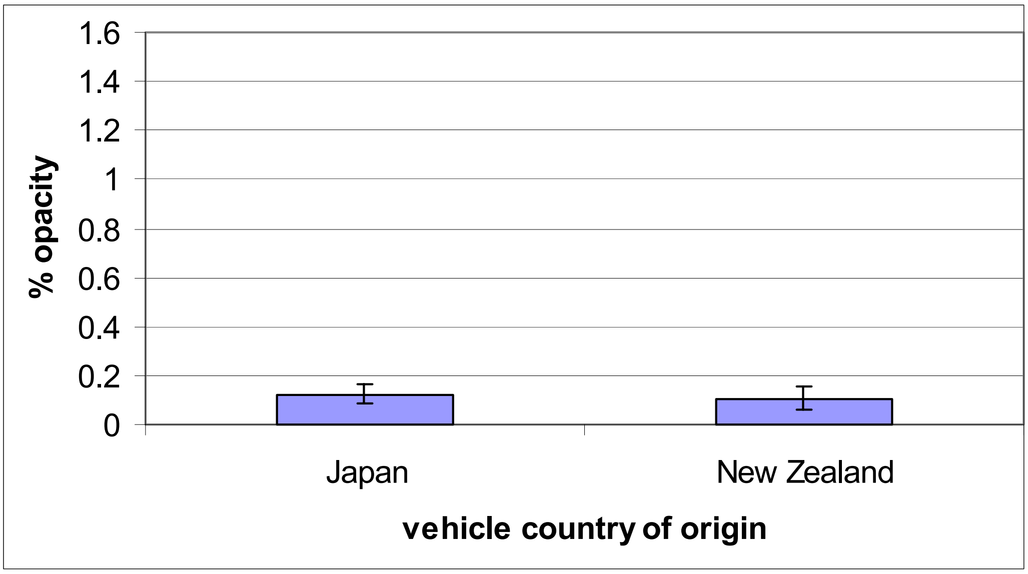


Figure 8.8
Comparison of 1986-1999 petrol fleet average opacity measurements with vehicle country of origin



Figures 8.5, 8.7 and 8.8 show that the 1986-1999 petrol fleet average emissions of CO, hydrocarbons and NO are higher for New Zealand new vehicles. Figure 8.8 shows that the opacity measurements from Japanese imported used vehicles are higher than those from New Zealand new vehicles.

As noted in Section 6, the amount of pollutants a vehicle emits varies significantly with the year of manufacture. A comparison between the 1986-1999 petrol fleet average emissions of CO, hydrocarbons, NO and opacity from petrol vehicles and how they vary with country of origin is made in Figures 8.10, 8.11 8.12, and 8.13.

Figure 8.10
Comparison of New Zealand new and Japanese imported 1986-1999 sample fleet average CO emissions for petrol vehicles against the year of manufacture

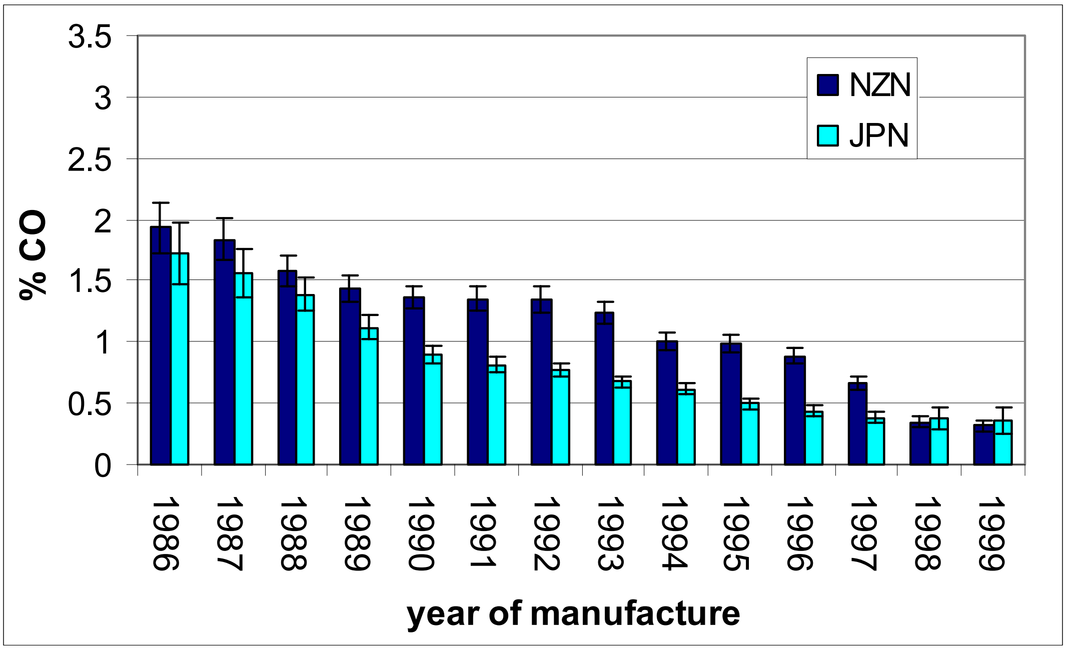


Figure 8.11
Comparison of New Zealand new and Japanese imported 1986-1999 sample fleet average hydrocarbon emissions for petrol vehicles against the year of manufacture

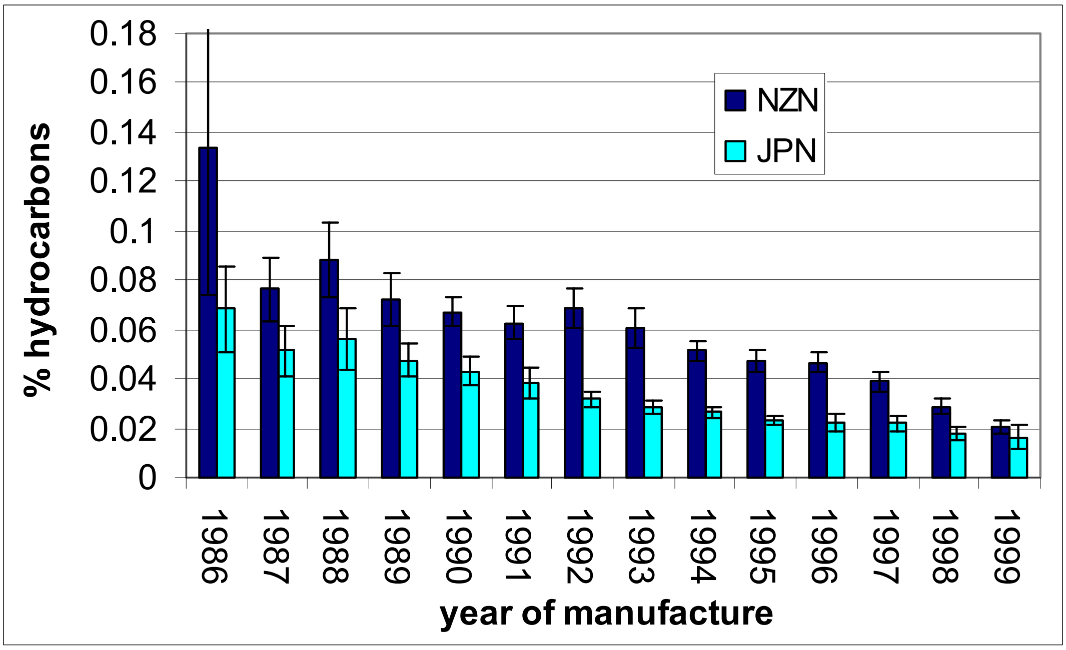


Figure 8.12
Comparison of New Zealand new and Japanese imported 1986-1999 sample fleet average NO emissions for petrol vehicles against the year of manufacture

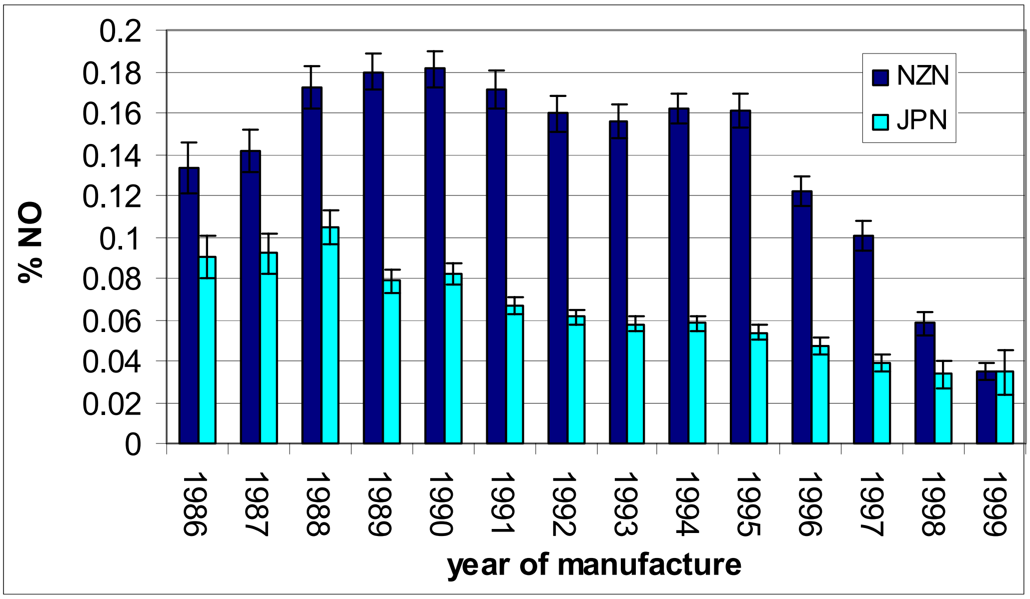
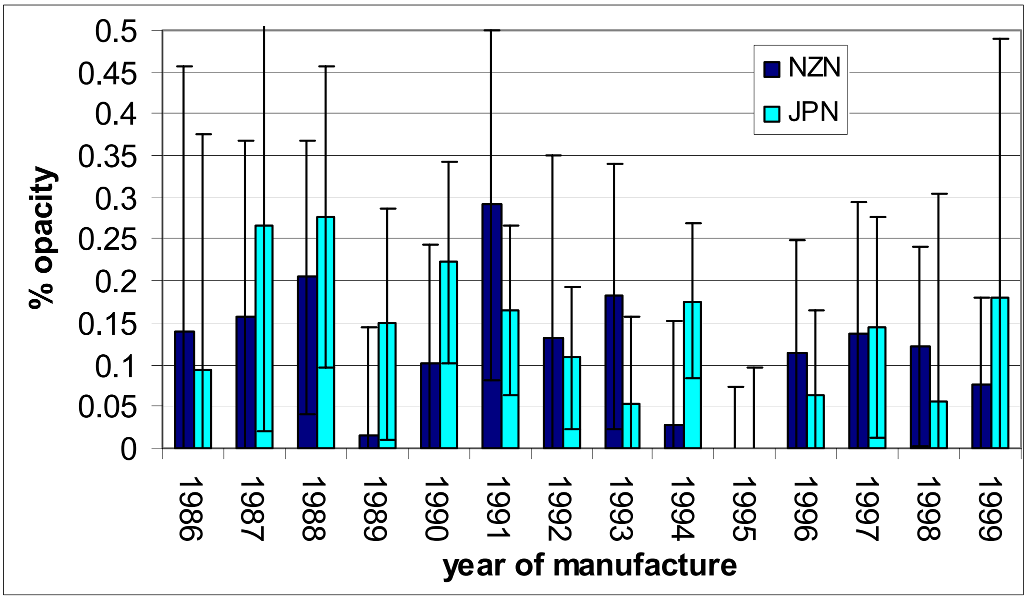


Figure 8.13
Comparison of New Zealand new and Japanese imported 1986-1999 sample fleet average opacity measurements for petrol vehicles against the year of manufacture



Figures 8.10, 8.11 and 8.12 show that the 1986-1999, petrol sample fleet average emissions, of CO, hydrocarbons and NO are generally higher for New Zealand new vehicles and that emissions of vehicles from both countries decrease for newer vehicles. It is interesting to note that the decrease is more dramatic for New Zealand new vehicles, resulting in emissions from later model New Zealand new vehicles being of a comparable level to those of the Japanese used vehicles.

Figure 8.13 shows no clear tend in opacity measurements with year of manufacture for either New Zealand new or Japanese used imported vehicles. The lack of a clear trend is most likely the result of a high year to year variability in the data caused by a smaller sample size of the opacity measurements and because measurements from petrol vehicles are generally low and close the detection limit of the instrument.

8.2 Imported Used and New Zealand New Diesel Vehicles

A comparison of the emissions from New Zealand new and Japanese imported used, diesel-fuelled vehicles, manufactured between the years of 1988 and 1998 was undertaken. This subset of the diesel sample fleet includes a total of 4,200 vehicles, of which 1,100 are New Zealand new vehicles and 3,100 are Japanese imported used vehicles. Figures 8.15 and 8.16 respectively show the profile by year of manufacture of New Zealand new and Japanese imported used diesel vehicles.

Figures 8.15 and 8.16 show that the profile of year of manufacture of New Zealand new and Japanese imported used diesel vehicles within the sample fleet similar to that shown for the petrol subset (see Figures 8.3 and 8.4). The profile of New Zealand new vehicles indicates that there are an increasing number of new diesel vehicles registrations each year. The profile of the Japanese imported used diesel vehicles suggest that these also begin entering New Zealand fleet in significant numbers approximately 7 years after their manufacture date.

Figures 8.17, 8.18, 8.19, and 8.20 show how the 1998-1998 diesel fuelled fleet average emissions of CO, hydrocarbons, NO and opacity respectively compare for New Zealand new and Japanese imported used vehicles.

Figure 8.15
Profile of New Zealand new diesel vehicles by year of manufacture

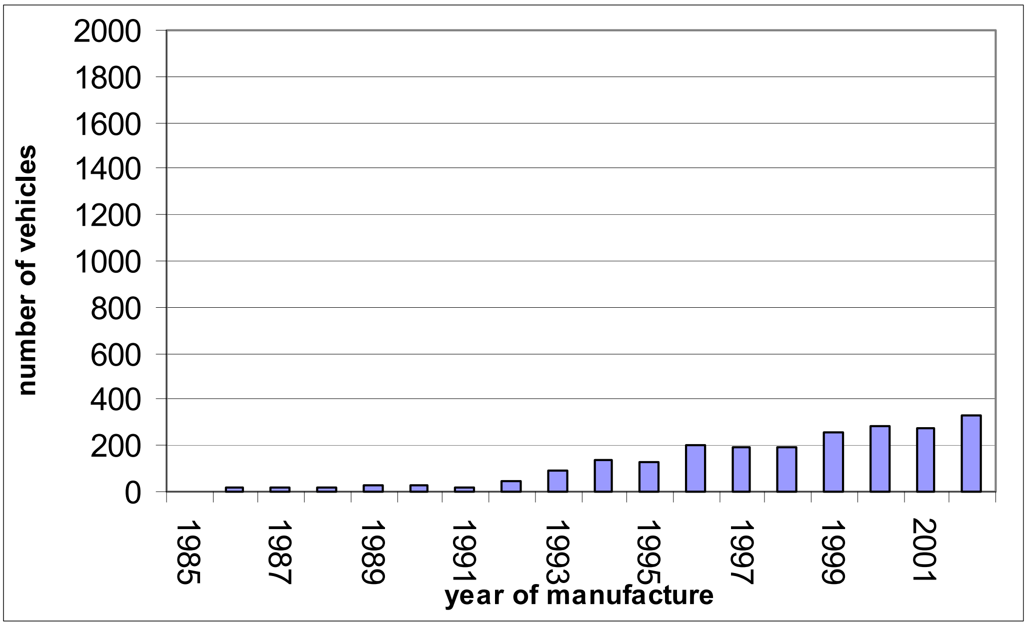


Figure 8.16
Profile of imported Japanese used diesel vehicles by year of manufacture

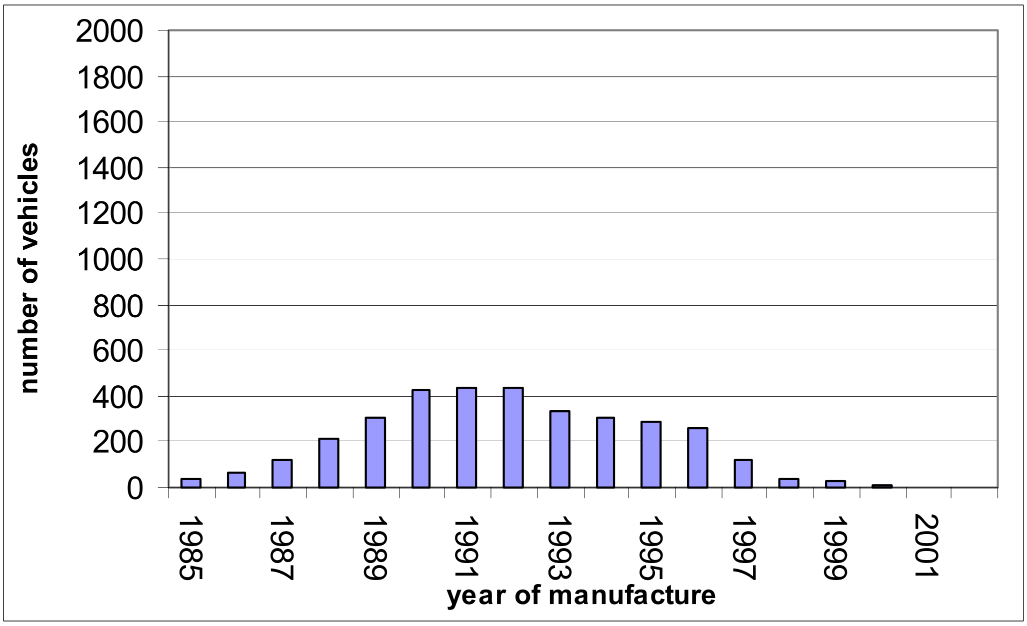


Figure 8.17
Comparison of 1988-1998 diesel fleet average CO emissions with vehicle country of origin

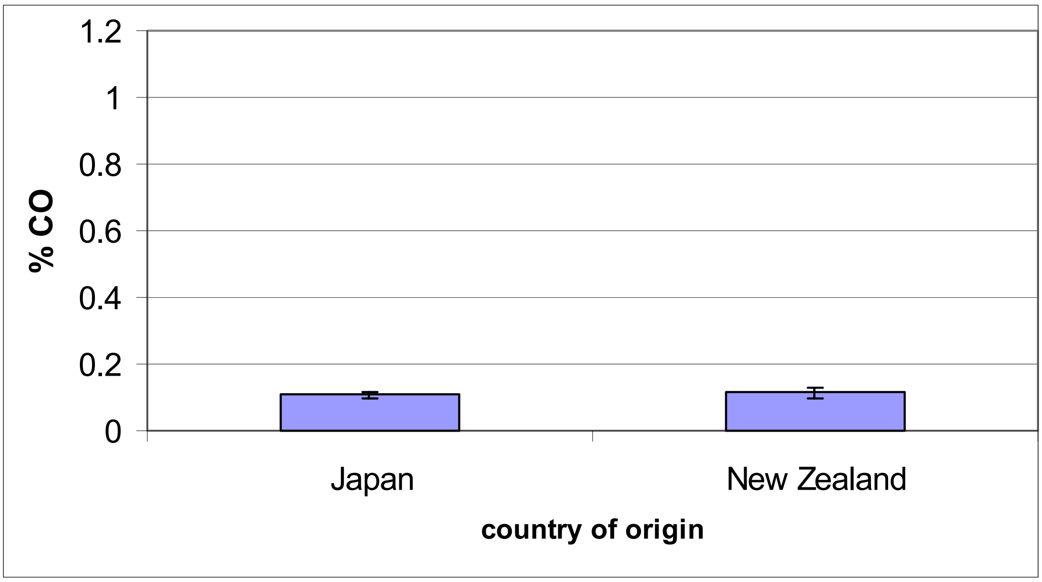


Figure 8.18
Comparison of 1988-1998 diesel fleet average hydrocarbon emissions with vehicle country of origin

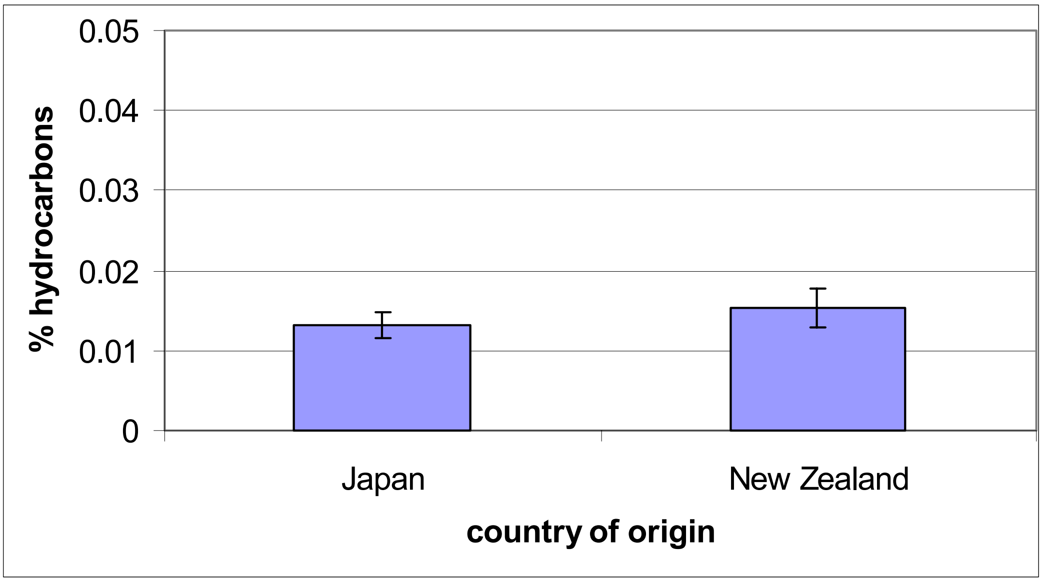


Figure 8.19
Comparison of 1988-1998 diesel fleet average NO emissions with vehicle country of origin

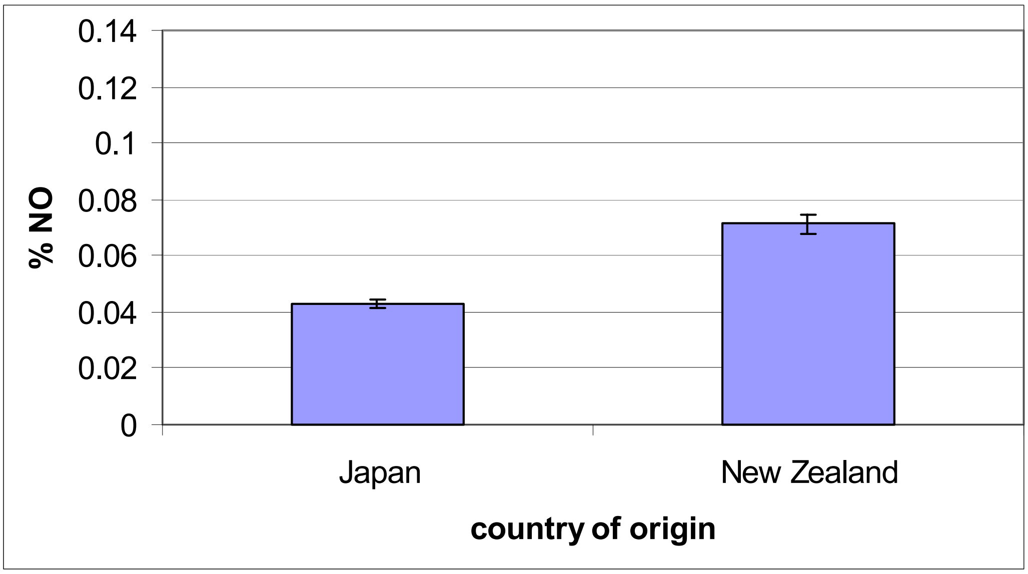
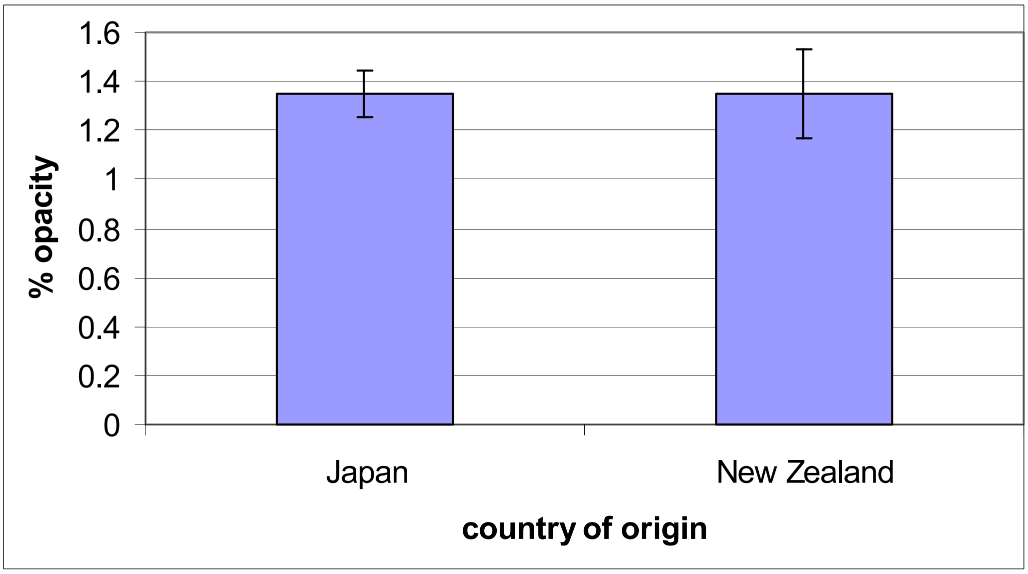


Figure 8.20
Comparison of 1988-1998 diesel fleet average opacity measurements with vehicle country of origin



Figures 8.17, 8.18, and 8.20 show that the 1988-1998 diesel fleet average emissions of CO, hydrocarbons and opacity for New Zealand new vehicles are approximately equal to those used vehicles imported from Japan. Figure 8.19 shows that the 1988-1998 diesel fleet average emissions of NO for New Zealand new vehicles is higher than those from vehicles imported from Japan.

The amount of pollutants a vehicle emits can vary significantly with the year of manufacture. A comparison of emissions of CO, hydrocarbons, NO and opacity from New Zealand new and Japanese used imported diesel vehicles manufactured between 1988 and 1998 is made in Figures 8.21, 8.22, 8.23, and 8.24.

Figure 8.21

Comparison of New Zealand new and Japanese imported 1988-1998 sample fleet average CO emissions for diesel vehicles against the year of manufacture

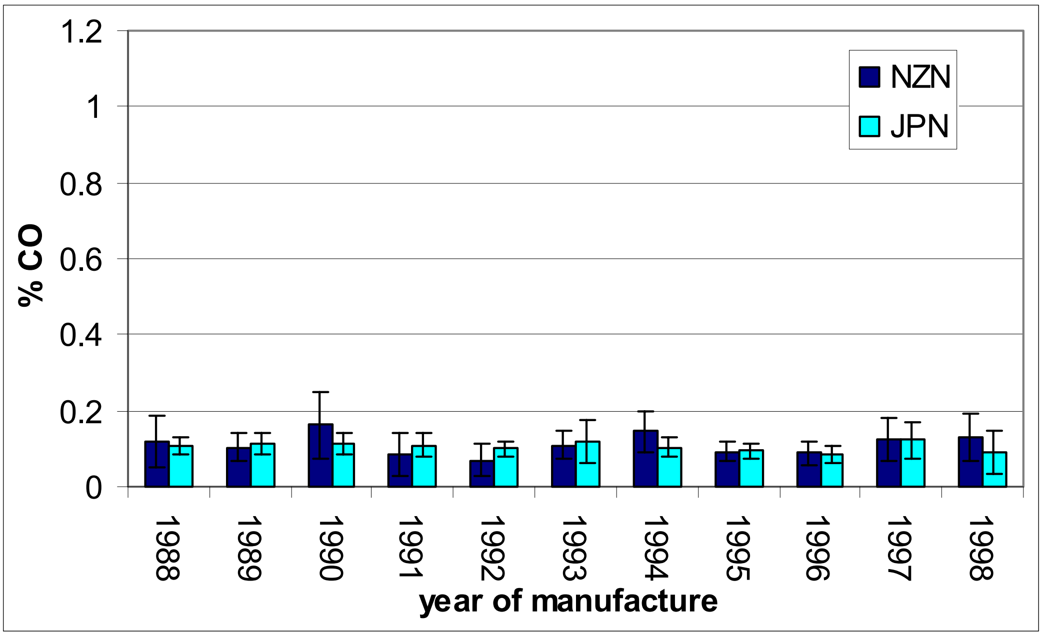


Figure 8.22

Comparison of New Zealand new and Japanese imported 1993-1997 sample fleet average hydrocarbon emissions for diesel vehicles against the year of manufacture

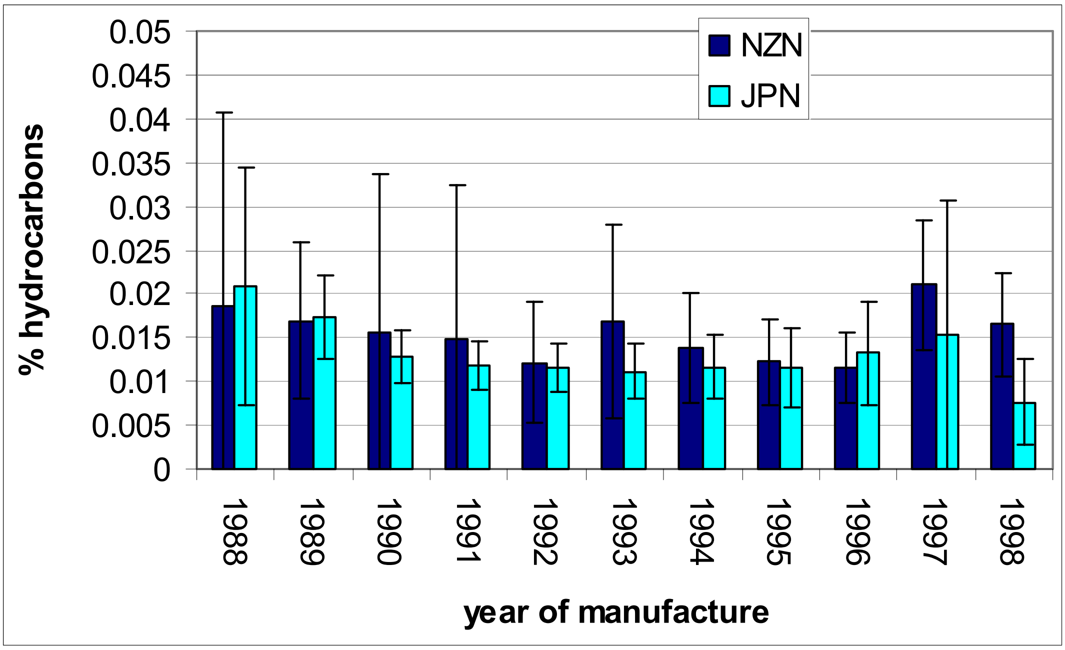


Figure 8.23

Comparison of New Zealand new and Japanese imported 1993-1997 sample fleet average NO emissions for diesel vehicles against the year of manufacture

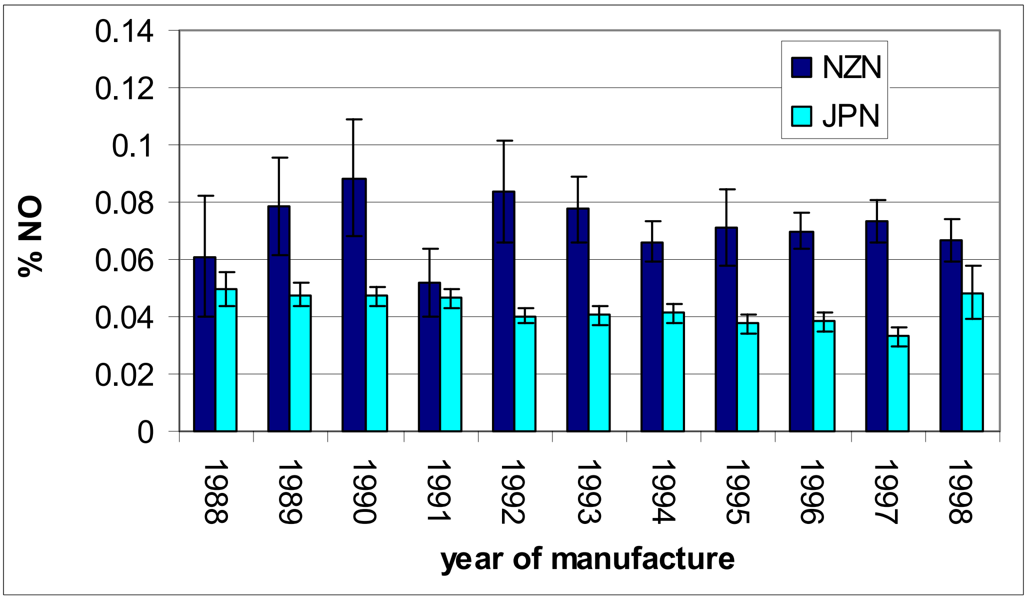
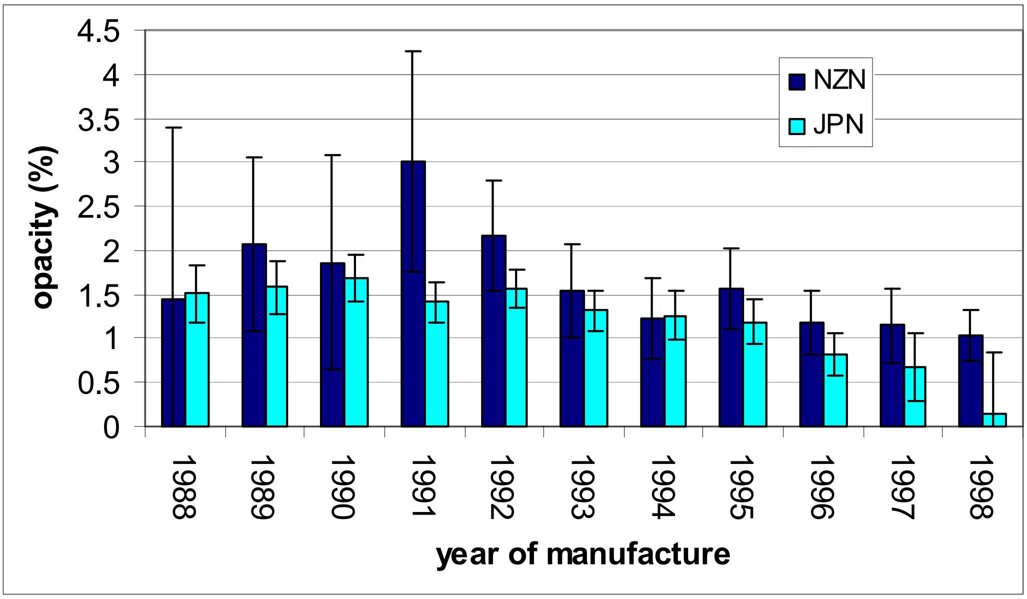


Figure 8.24
Comparison of New Zealand new and Japanese imported 1993-1997 sample fleet average opacity measurements for diesel vehicles against the year of manufacture



The results displayed in Figures 8.21 8.22, 8.23, and 8.24 are generated from a relatively small number of vehicles and over a relatively small number of years. Therefore, any trend observed in these data may not be as obvious or robust as those in previous sections.

Figure 8.21 shows no clear differences between or trends for CO emissions from Japanese used and New Zealand new diesel fuelled vehicles. Figure 8.22 shows no clear differences between or trends for hydrocarbon emissions from Japanese used and New Zealand new diesel fuelled vehicles.

Figure 8.23 indicates that NO emissions are generally higher for New Zealand new vehicles and emissions of vehicles from both countries are relatively stable for the duration of the period analysed. Figure 8.24 suggests that opacity measurements are generally higher for New Zealand new vehicles but not significantly so. There is a trend for opacity of emissions of diesel vehicles to decrease for newer vehicles.

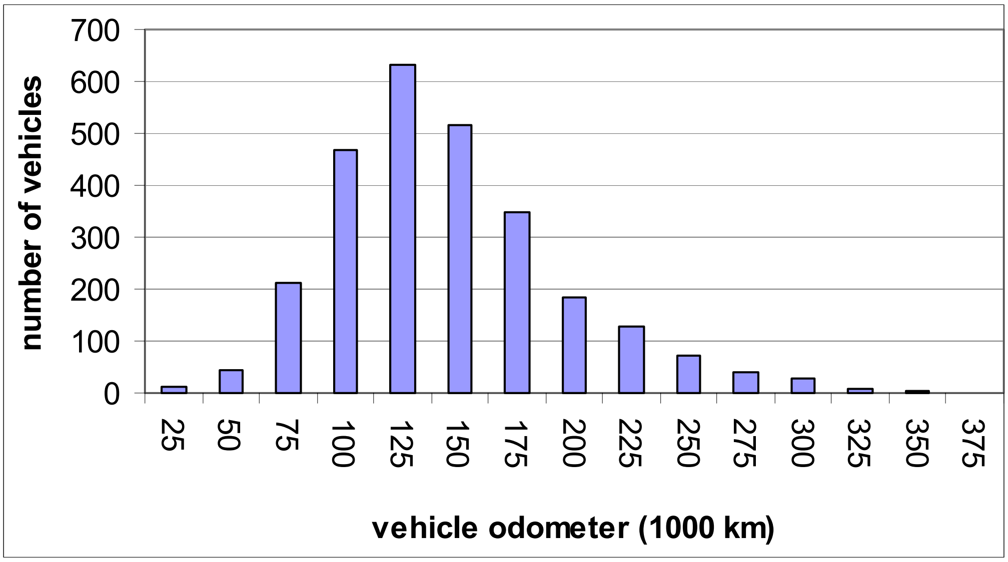
9 Influence of Vehicle Distance Travelled on Emissions

A comparison was made between vehicles that had relatively low and relatively high mileages. The effect that the distance travelled by a vehicle has on emissions for petrol and diesel vehicles is considered in Sections 9.1 and 9.2 respectively. Only vehicles with reliable odometers were used in the analysis.

9.1 Petrol Fuelled Vehicles

To minimise the effect that variation of vehicle age has on emissions, an analysis was performed on vehicles manufactured in each of the years, 1992, 1993 and 1994. The result of the comparison between high and low kilometre vehicles manufactured in 1994 is presented in this section. There were 2,700 petrol vehicles manufactured in 1994 that had reliable odometers. Figure 9.1 shows the distribution of distances travelled by petrol-fuelled vehicles manufactured in 1994. The average odometer reading of the 2,700 vehicles within this subset of the sample fleet was 124,000 km.

Figure 9.1
Odometer readings of petrol fuelled vehicles manufactured in 1994



The 1994 petrol fuelled vehicle fleet was disaggregated into quartiles according to the distances they had travelled. The emissions from vehicles with odometer readings in the upper quartile (160,000 km) were compared to vehicles in the lower quartile (97,000 km). The difference in emissions of CO, hydrocarbons, NO and opacity from high and low kilometre vehicles are shown in Figures 9.2, 9.3, 9.4, and 9.5.

Figure 9.2
Comparison of t6he 1994 sample fleet average CO emissions for petrol vehicles with high and low odometer readings

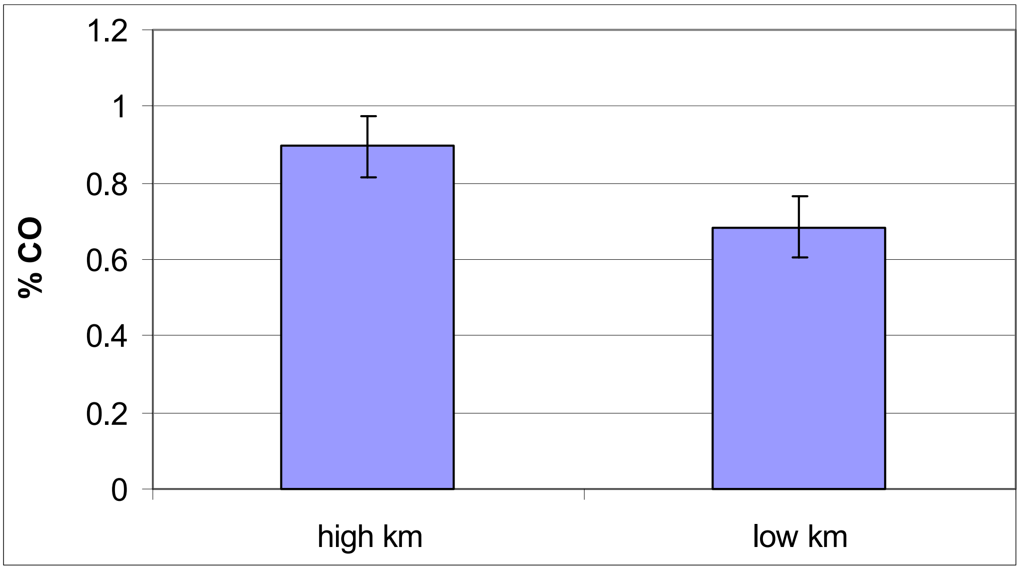
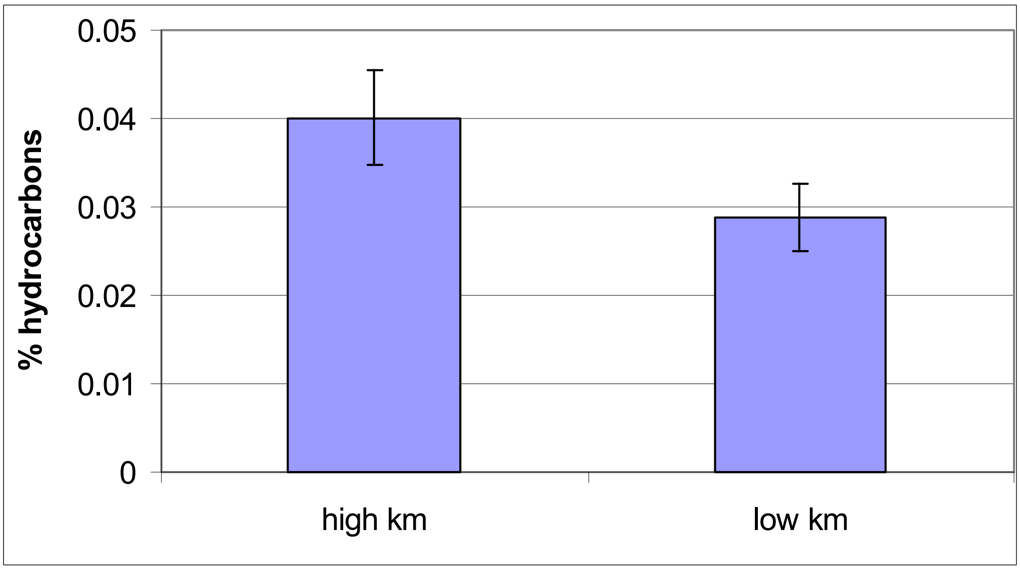


Figure 9.3
Comparison of the 1994 sample fleet average hydrocarbon emissions for petrol vehicles with high and low odometer readings



Figures 9.2, 9.3 and 9.4 show that the 1994 petrol fleet average emissions of CO, hydrocarbons and NO are lower for vehicles that have travelled less distance. Figure 9.5 shows that the opacity may be lower for low kilometre vehicles. A comparison of emissions from high and low kilometre vehicles manufactured in the years 1992 and 1993 yielded the same conclusions: High kilometre vehicles discharge significantly more CO, hydrocarbons and NO; and opacity appears to be higher for high kilometre vehicles, but the sampling uncertainty is large.

Figure 9.4
Comparison of the 1994 sample fleet average NO emissions
for petrol vehicles with high and low odometer readings

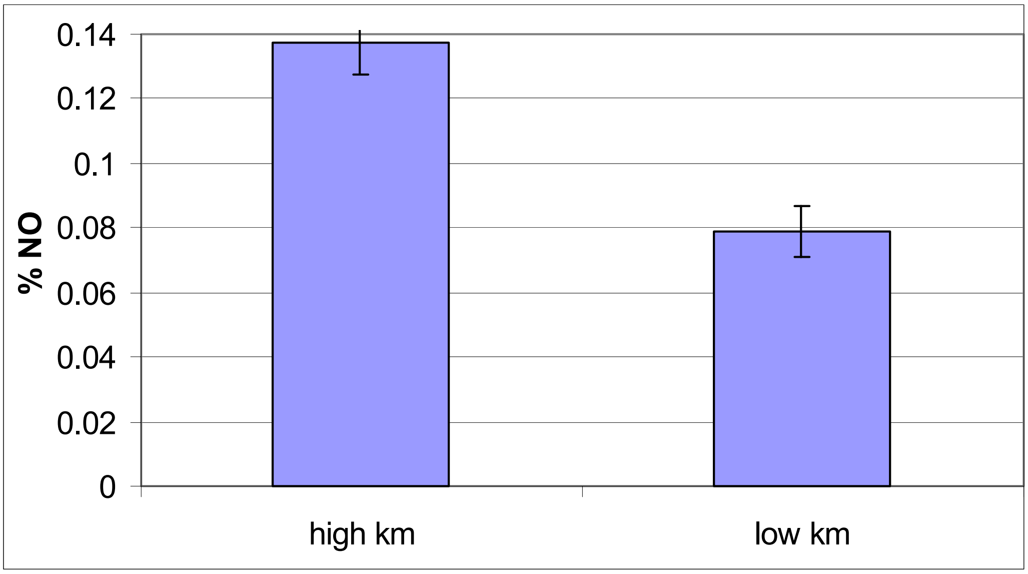
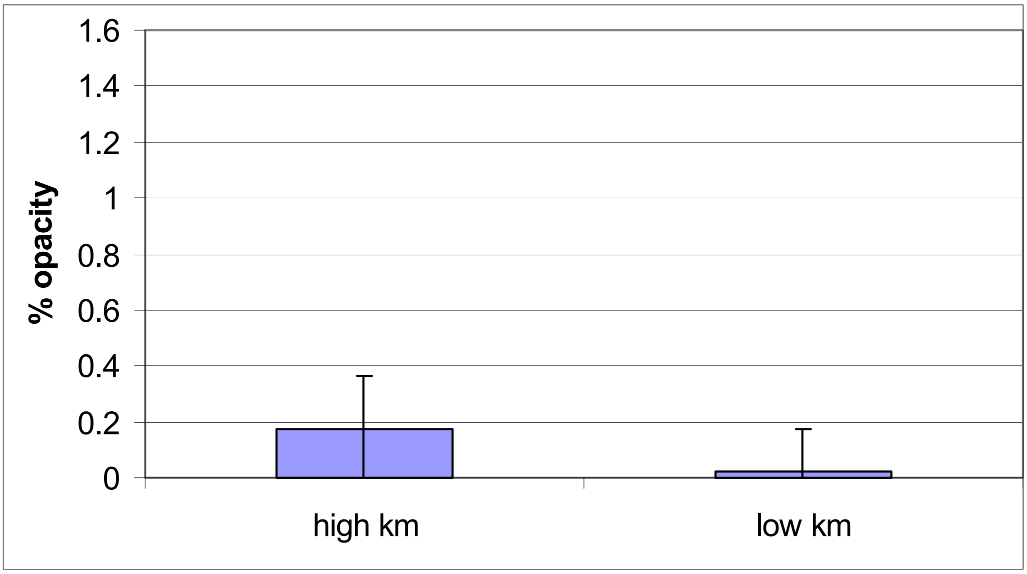


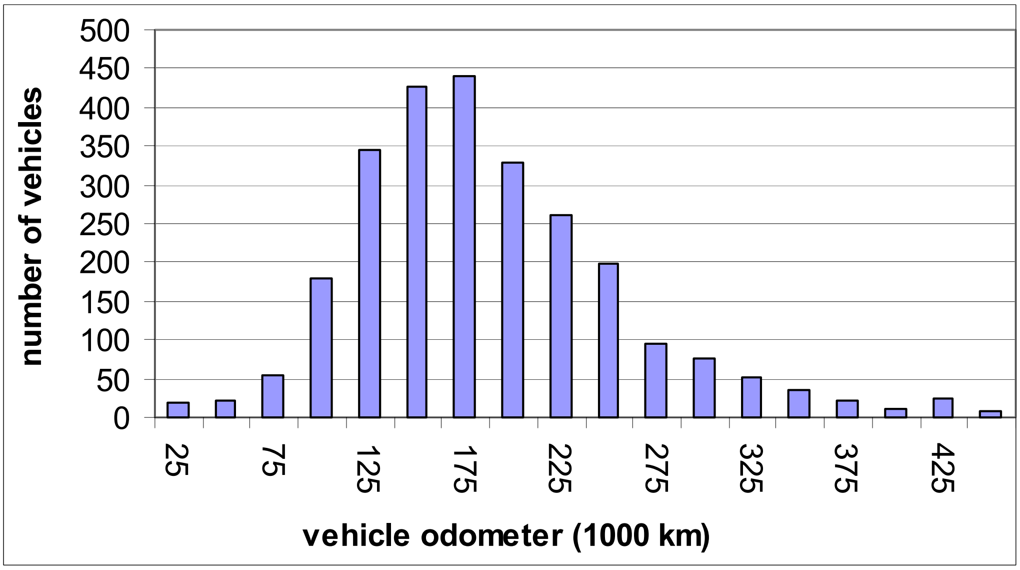
Figure 9.5
Comparison of the 1994 sample fleet average opacity emissions for petrol vehicles with high and low odometer readings



9.2 Diesel Fuelled Vehicles

Figure 9.7 shows the distribution of distances travelled by diesel fuelled vehicles manufactured from 1990 to 1995. The average odometer reading of the 2,600 vehicles within this subset of the sample fleet was 165,000 km.

Figure 9.7
Odometer readings of diesel fuelled vehicles manufactured from 1990 to 1995



The 1990 to 1995 diesel fuelled vehicle fleet was disaggregated into quartiles according to the distances they had travelled. The emissions from vehicles with odometer readings in the upper quartile (217,000 km) were compared to vehicles in the lower quartile (128,000 km). The emissions of CO, hydrocarbons, NO and opacity from high and low kilometre vehicles are compared in Figures 9.8, 9.9, 9.10, and 9.11.

Figure 9.8
Comparison of the 1990-1995 sample fleet average CO emissions for diesel vehicles with high and low odometer readings

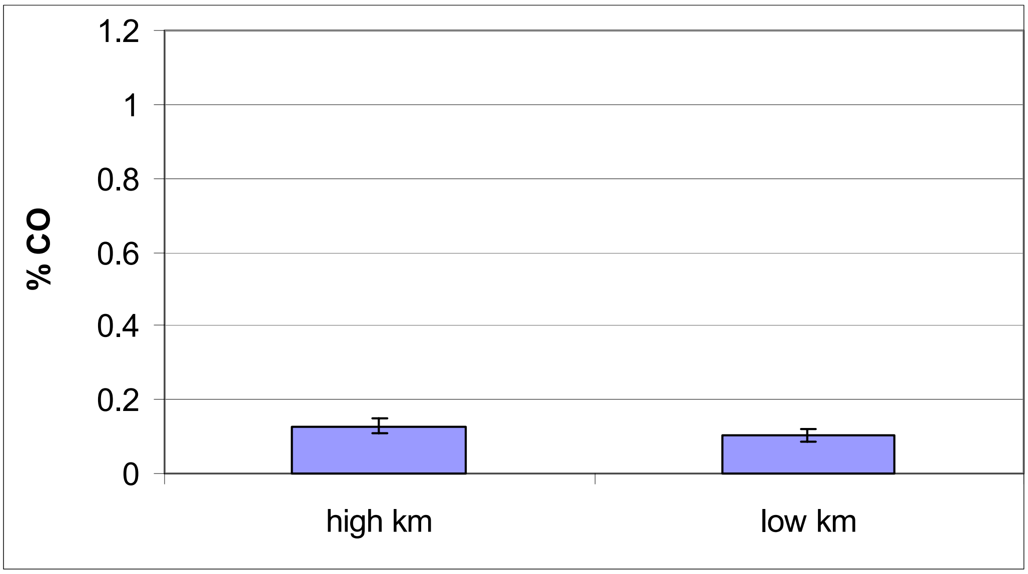


Figure 9.9
Comparison of the 1990-1995 sample fleet average hydrocarbon emissions for diesel vehicles with high and low odometer readings

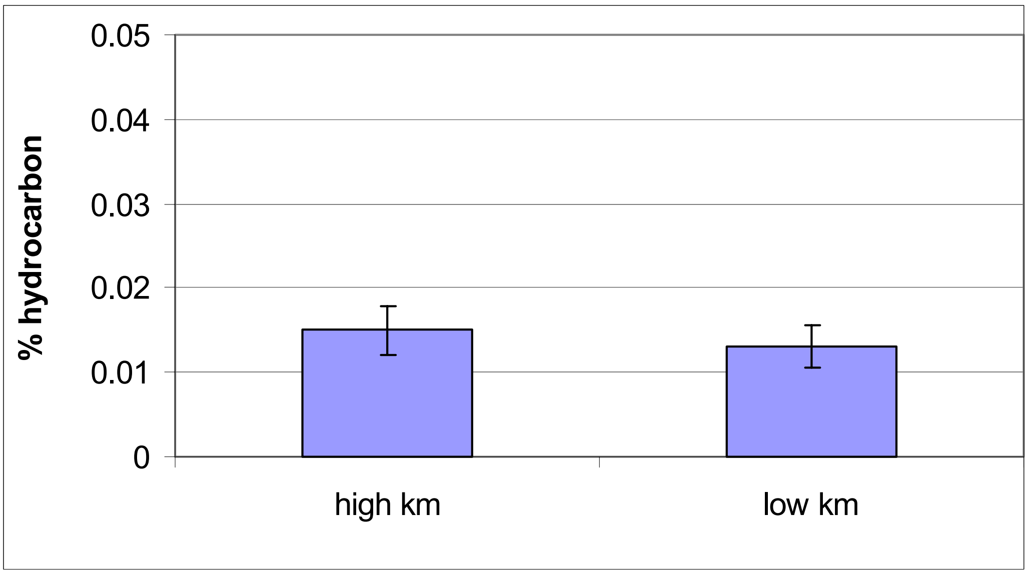


Figure 9.10
Comparison of the 1990-1995 sample fleet average NO emissions for diesel vehicles with high and low odometer readings

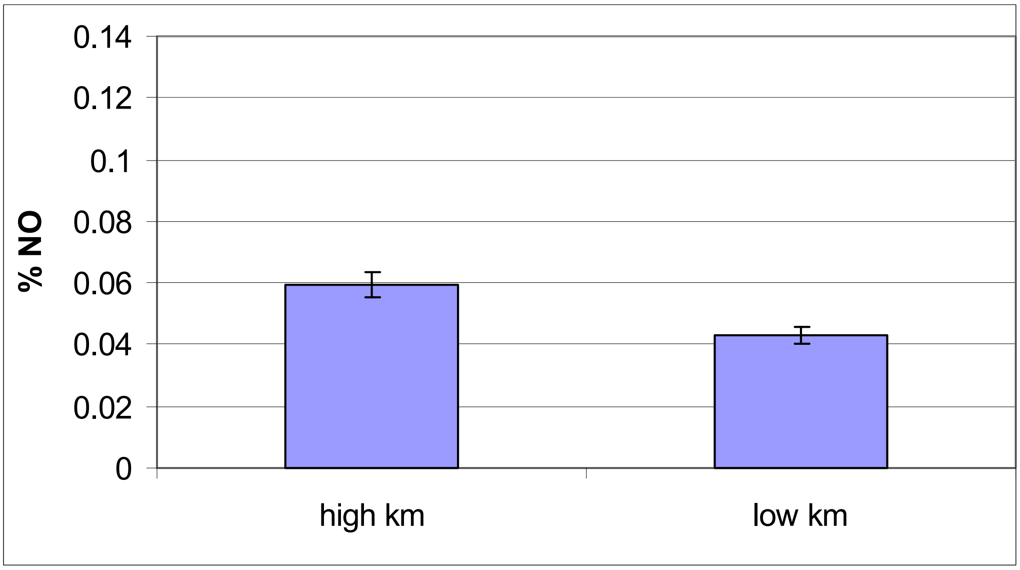
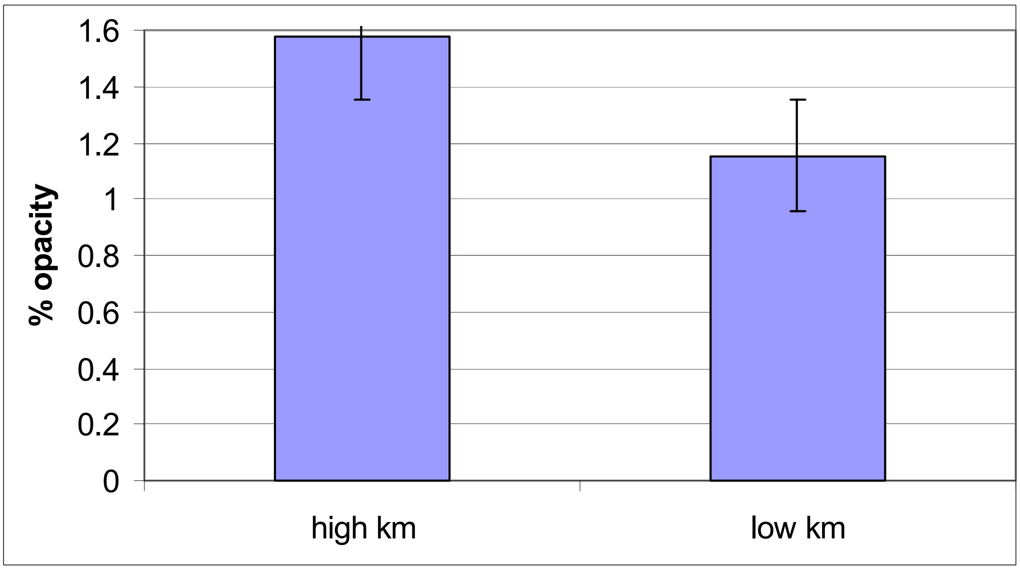


Figure 9.11
Comparison of the 1990-1995 sample fleet average opacity emissions for diesel vehicles with high and low odometer readings



Figures 9.8 and 9.10 show that the 1990-1995 diesel fleet average emissions of CO, and hydrocarbons were not significantly different for vehicles with high and low odometer readings.

Figures 9.10 and 9.11 show that the 1990-1995 diesel fleet average emissions of NO and opacity are higher for vehicles that have travelled greater distances.

10 Relationship Between WoF/Registration and Emissions

Comparisons were made between vehicles with and without a current:

- Warrant of fitness (WoF) at the time of the test
- Registration at the time of the test.

10.1 Warrant of Fitness

Valid WoF data was obtained from Motochek for 36,000 of 38,000 plates submitted. 590 (1.6 %) of these vehicles did not have a current WoF on the day when their emissions were measured by the remote sensor. To minimise the variation of emissions caused by vehicle age and fuel type, this comparison was carried out for petrol vehicles manufactured before 1996. This subset of the sample fleet provided a total of 20,200 measurements. 484 (2.4 %) of the petrol vehicles manufactured before 1996 did not have a current WoF on the day their emissions were monitored. Figure 10.1 shows the number of months that had elapsed since the WoF expired.

Figure 10.1
Number of months elapsed since WOF expired for petrol vehicles manufactured before 1996

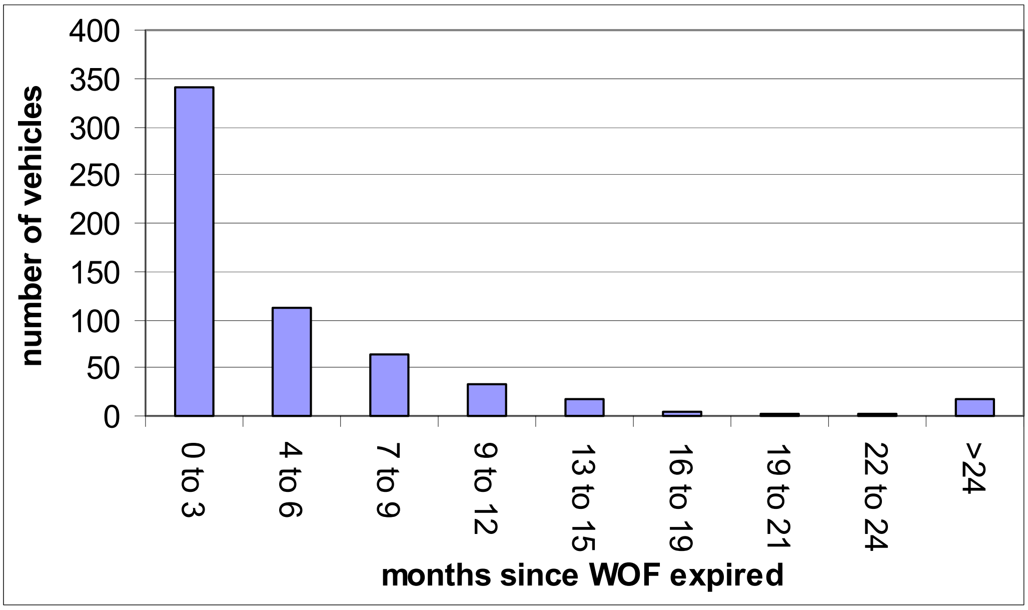


Figure 10.1 shows that a large proportion of the vehicles without WoFs had expiry dates within the 6 months that preceded their emissions being measured in the remote sensing programme. As an indicator of the proportion of vehicles which would be regulated by emission tests if they were included as part of the WoF programme, petrol vehicles manufactured before 1996 without WoFs were disaggregated into two groups: vehicles with WoFs which are out of date by 6 months or less (364 vehicles) and vehicles with WoFs which are out of date by greater than 6 months (120 vehicles). The rational for employing these criteria was that vehicles with WoFs, which are out of date by a period of greater than 6 months, are hypothesised to be "chronic WoF avoiders". Emissions from vehicles operated by this group of motorists would be unlikely to be controlled by any emission testing programme testing included as part of the WoF programme. It has been assumed that the bulk of vehicles without WoFs for less than 6 months are likely to be due to motorists simply forgetting to renew their WoF on time. Figure 10.2 shows the desegregation of vehicles without WoFs into those out of date by 6 months or less and those greater than 6 months.

Figure 10.2
Proportion of petrol vehicles manufactured before 1996 without WoFs that are 6 months or less past their expiry date

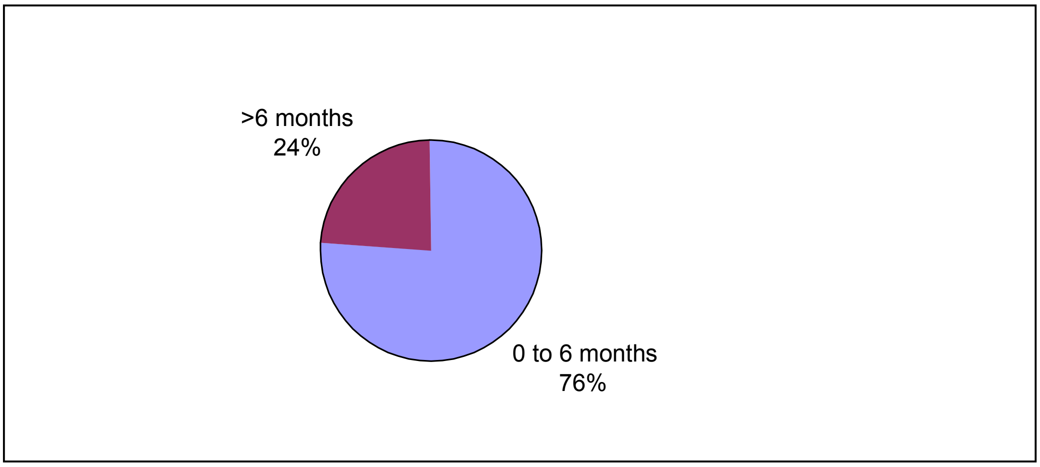


Figure 10.2 shows that 76% of the WoFs expired within the 6 months that preceded the remote sensing emissions testing programme.

Comparisons between emissions of CO, hydrocarbons, NO and opacity measurements from petrol vehicles manufactured before 1996 with and without a current WoF are made in Figures 10.3, 10.4, 10.5, and 10.6 respectively. In each of these figures the vehicles without WoFs have been disaggregated into recent expiries (6 months or less) and earlier expiries (greater than 6 months).

Figure 10.3
Comparison of CO emissions from petrol vehicles manufactured before 1996 with and without a current Warrant of Fitness

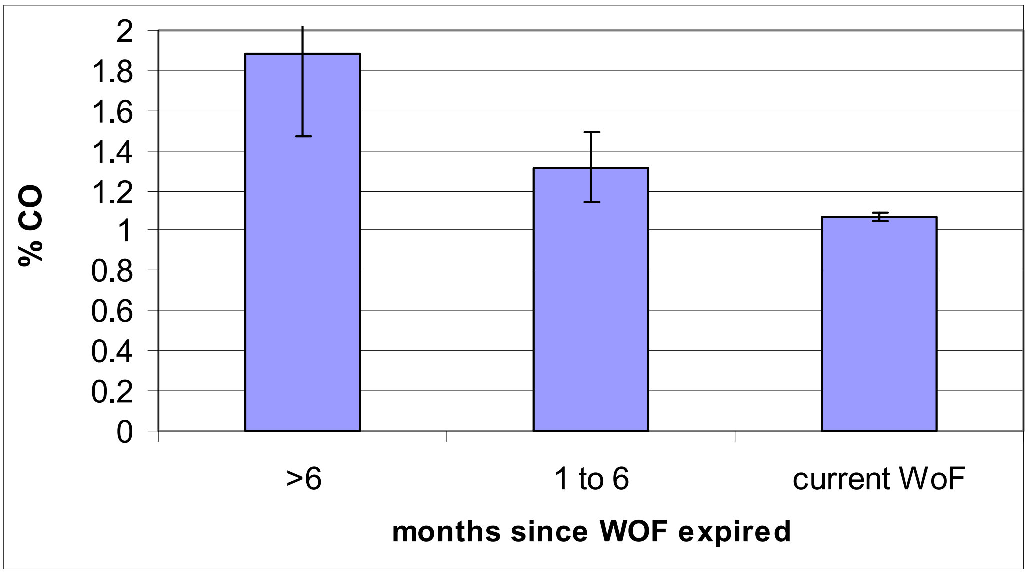


Figure 10.4
Comparison of hydrocarbon emissions from petrol vehicles manufactured before 1996 with and without a current Warrant of Fitness

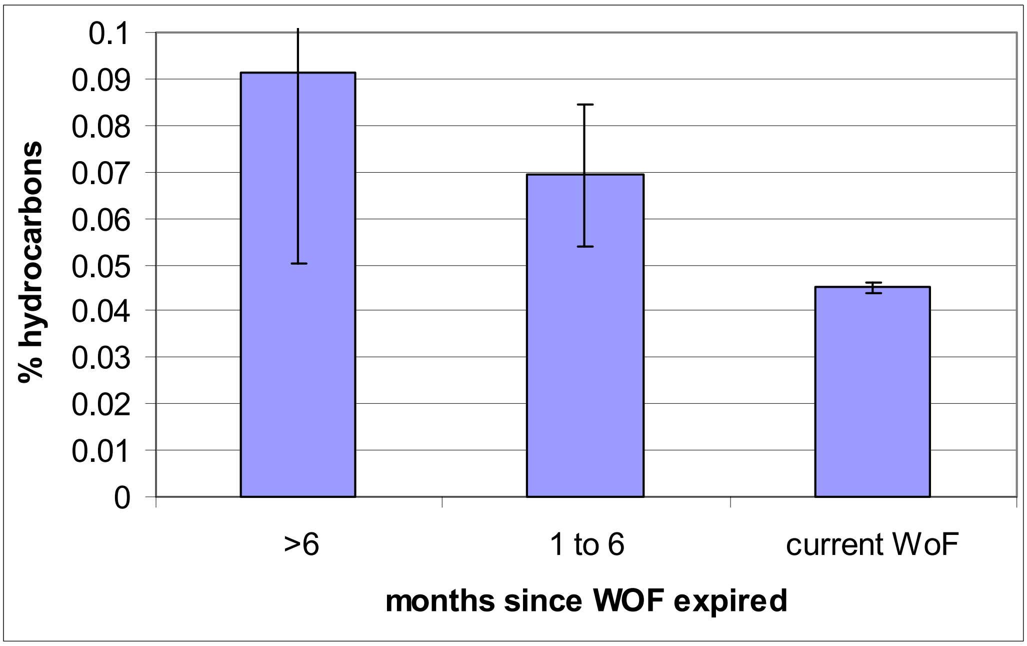


Figure 10.5
Comparison of NO emissions from petrol vehicles manufactured before 1996 with and without a current Warrant of Fitness

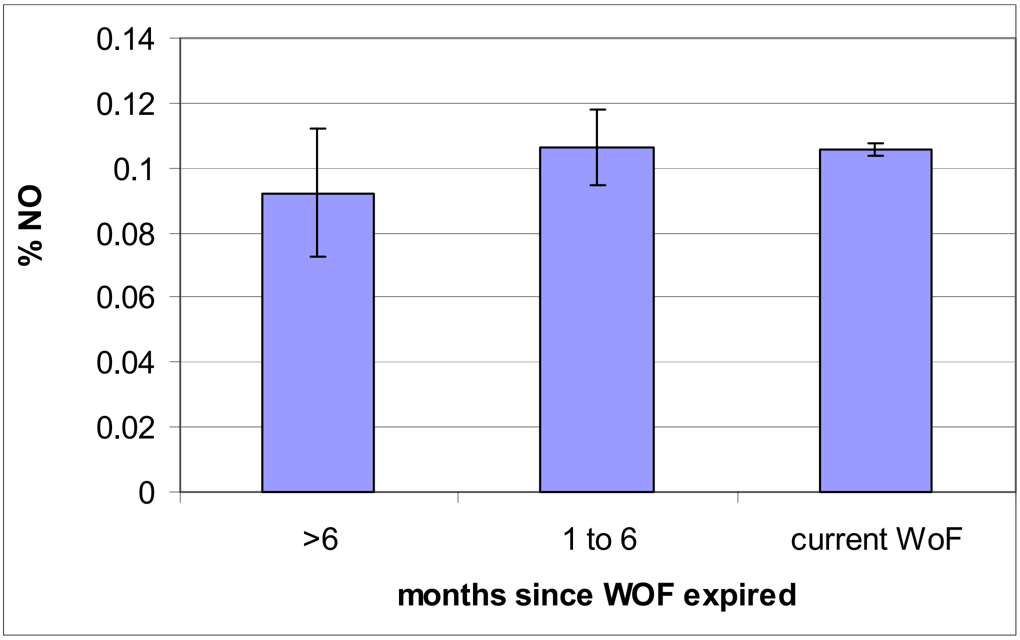
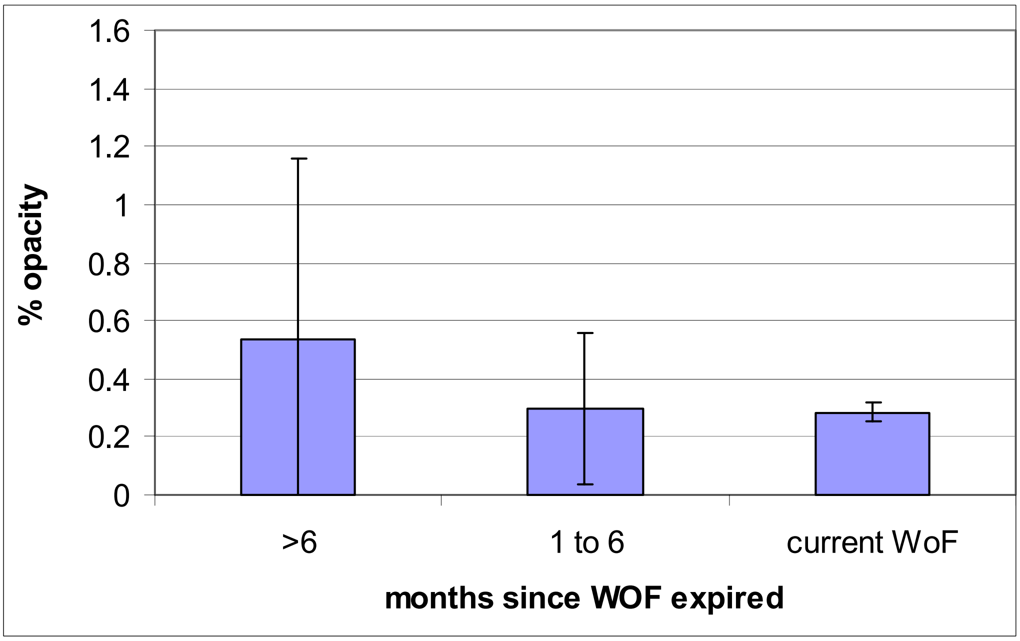


Figure 10.6
Comparison of opacity emissions from petrol vehicles manufactured before 1996 with and without a current Warrant of Fitness



Figures 10.3 and 10.4 respectively show that emissions of CO and hydrocarbons from petrol vehicles manufactured before 1996 are nominally higher from vehicles without a current WoF. Figures 10.3, 10.4 also show that emissions of CO and hydrocarbons from vehicles with WoFs that expired more than 6 months before the remote sensing tend to be higher (but not significantly so) than those with more recently expired WoFs. Figures 10.5 and 10.6 show that the difference in emissions of NO and the difference in opacity between the vehicles with and without a current WOF are not significant.

10.2 Vehicle Registration

Valid data on the status of vehicle registration was obtained from Motochek for 34,000 of 38,000 plates submitted. 273 (0.8 %) of these vehicles had either lapsed or cancelled registration on the day when their emissions were measured by the remote sensor. To minimise the variation of emissions caused by vehicle age and fuel type, the comparison was carried out for petrol vehicles manufactured before 1996. This subset of the sample fleet provided a total of 20,500 measurements. 244 (1.2 %) of the petrol vehicles manufactured before 1996 had either lapsed or cancelled registration on the day their emissions were monitored. 202 of the 244 vehicles without current registration also had no WoF.

Comparisons between emissions of CO, hydrocarbons, NO and opacity measurements from petrol vehicles manufactured before 1996 with either lapsed or cancelled registration against those with current registration are made in Figures 10.7, 10.8, 10.9, and 10.10 respectively.

Figure 10.7
Comparison of CO emissions from petrol vehicles manufactured before 1996 with and without a current registration

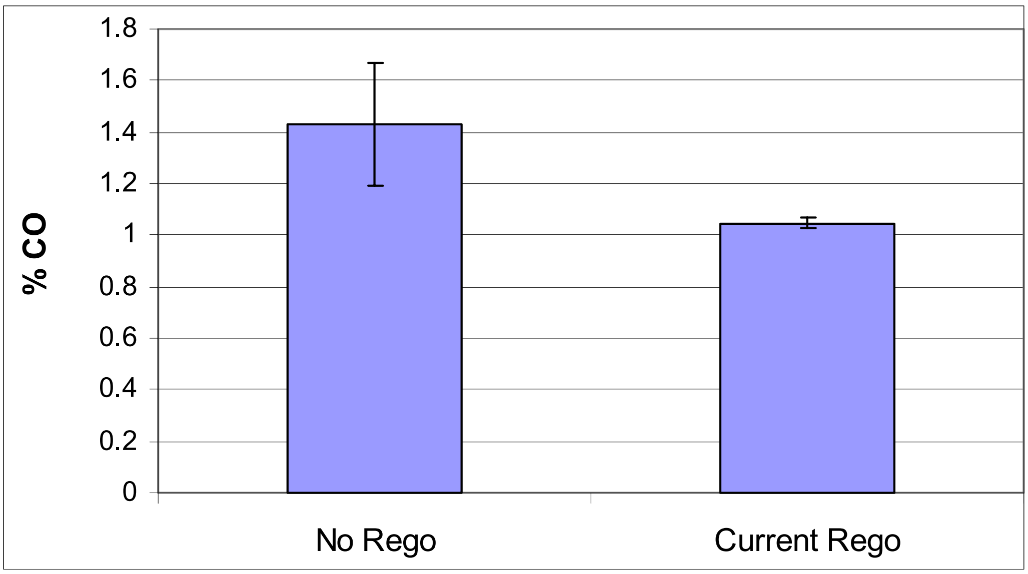


Figure 10.8
Comparison of hydrocarbon emissions from petrol vehicles manufactured before 1996 with and without a current registration

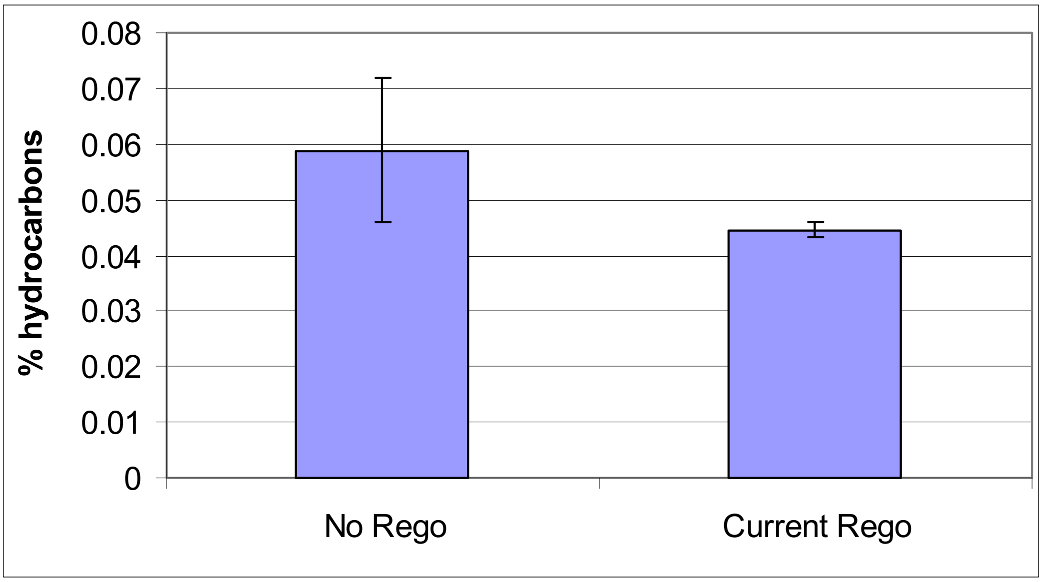


Figure 10.9
Comparison of NO emissions from petrol vehicles manufactured before 1996 with and without a current registration

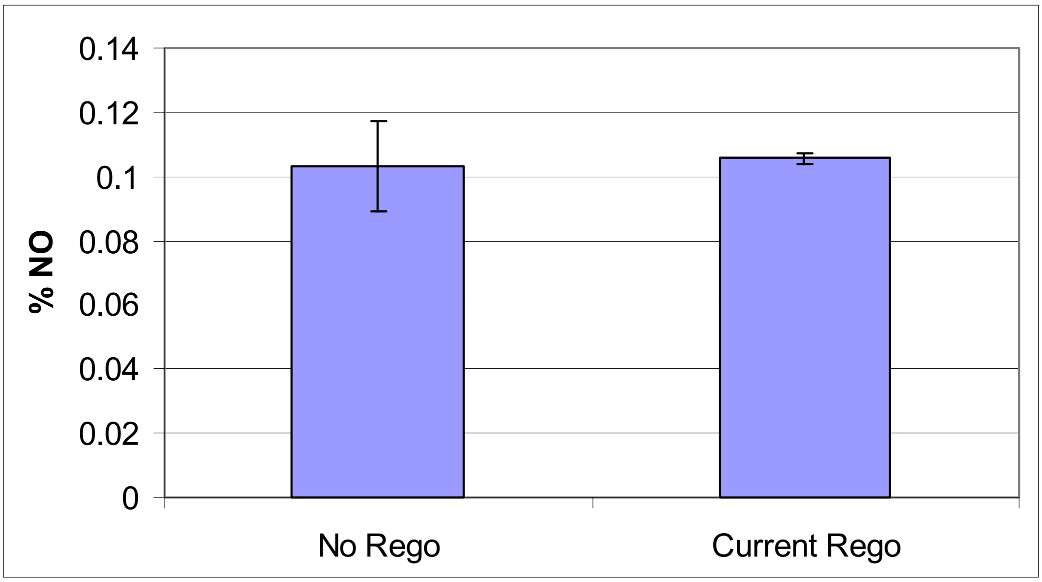
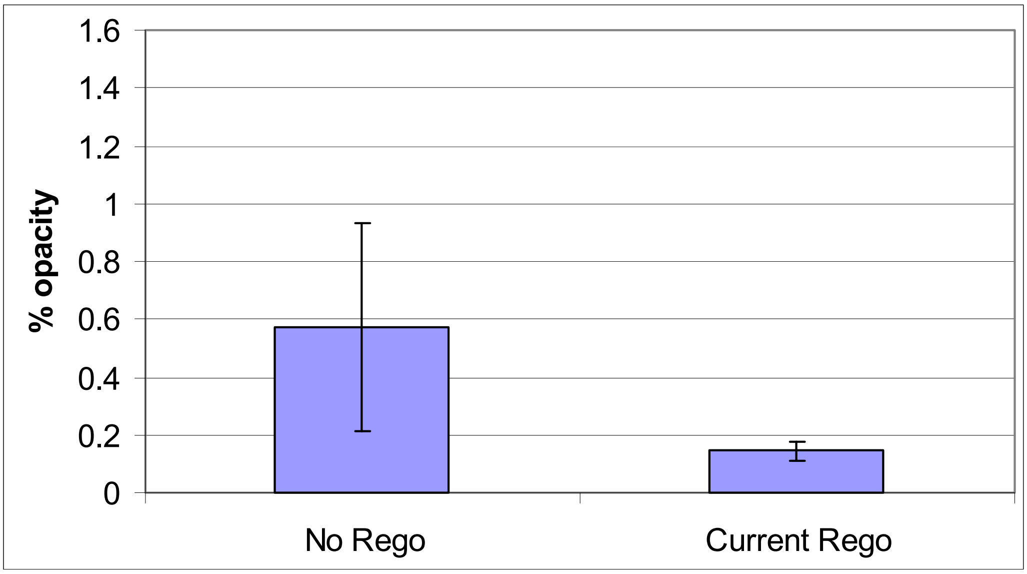


Figure 10.10
Comparison of opacity emissions from petrol vehicles manufactured before 1996 with and without a current registration



Figures 10.7, 10.8 and 10.10 show that emissions of CO, hydrocarbons and opacity emissions from petrol vehicles manufactured before 1996 are significantly higher from vehicles without a current registration. Figure 10.9 shows that the difference in emissions of NO between the vehicles with and without current registration is not significant.

10.3 Combined Effect of Vehicle Age and Maintenance on Emissions

To illustrate the effect of vehicle maintenance on emissions, the sample fleet was broken down by year of manufacture and into five equal groups (quintiles, 20%) according to their emissions. The first quintile represents the top 20% emitters of the vehicles for the model year, the fifth the lowest. Figures 10.11, 10.12 and 10.13 show average CO, NO and HC emissions disaggregated into quintiles by year of manufacture. Note that emissions are ranked lowest (fifth quintile on front row) to highest (first quintile on back row).

Figure 10.11
CO emissions disaggregated into quintiles by year of manufacture

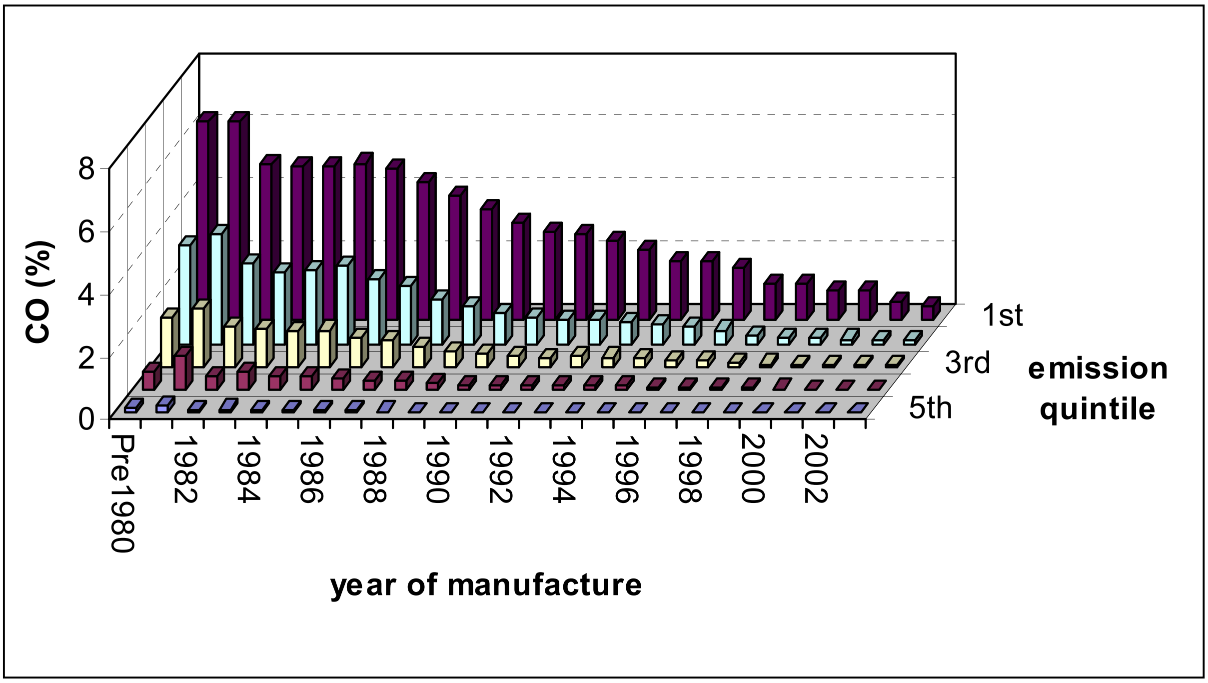


Figure 10.12
NO emissions disaggregated into quintiles by year of manufacture

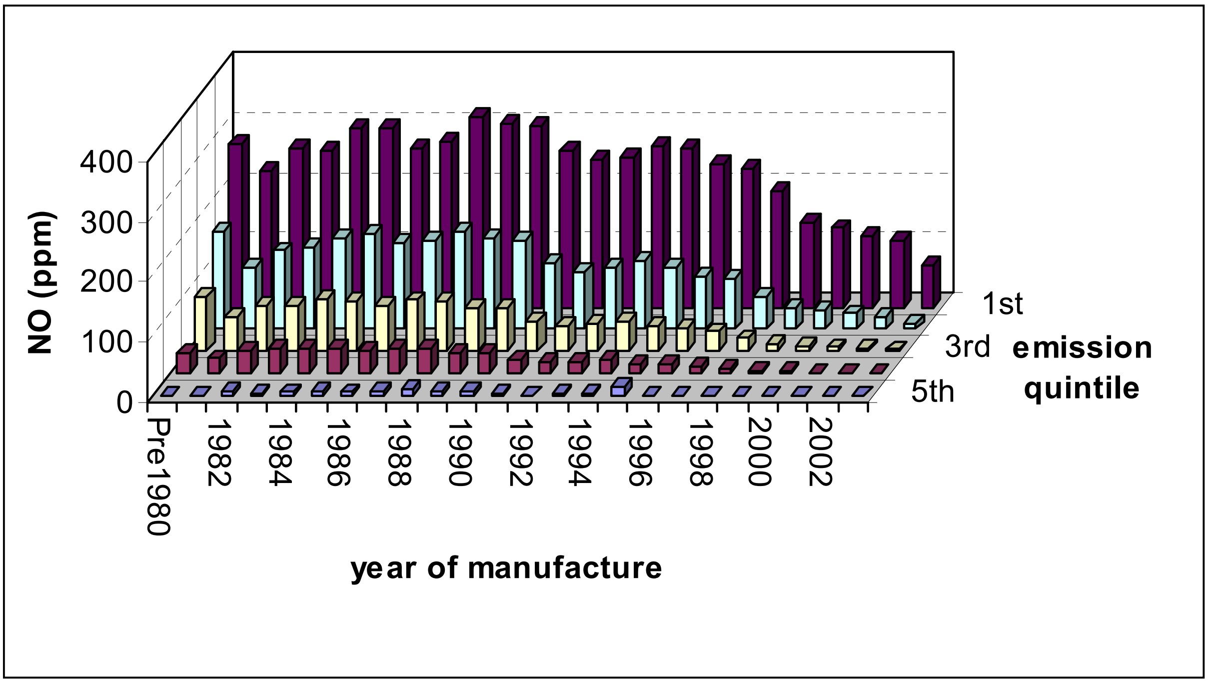
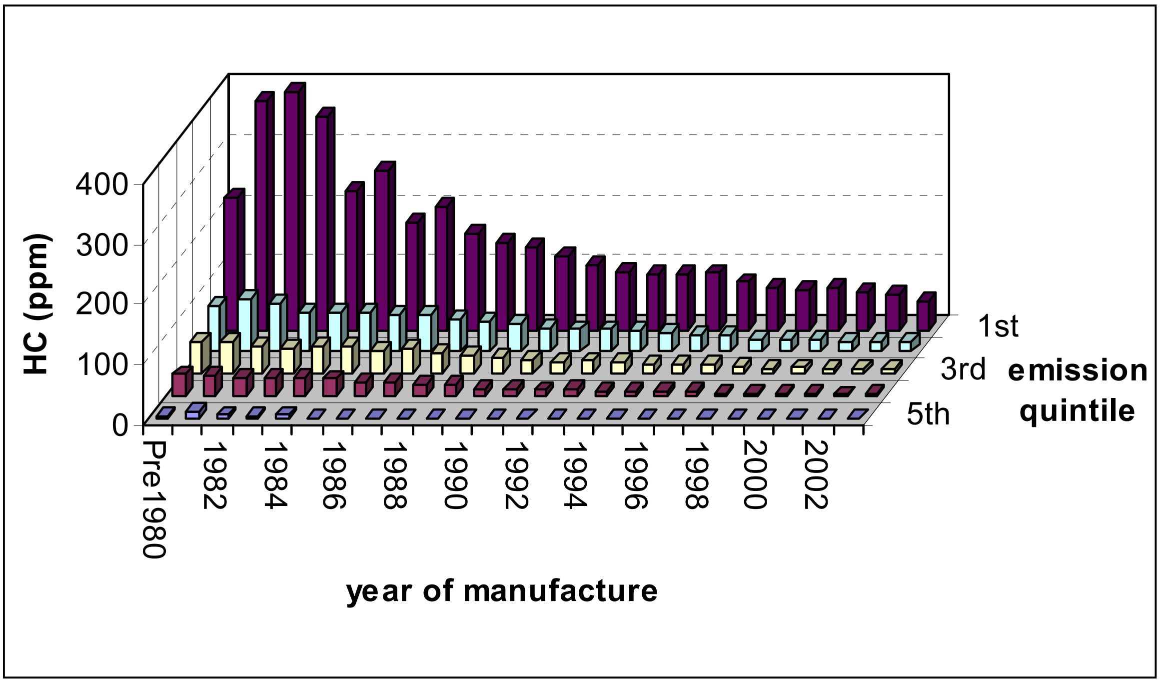


Figure 10.13
HC emissions disaggregated into quintiles by year of manufacture



Figures 10.11, 10.12 and 10.13 show a drop in emissions from older to newer vehicles in all quintiles. This is consistent with the observations made earlier in this report. Figures 10.11, 10.12 and 10.13 also show that differences in emissions within a model year are greater than differences between the averages of the various years of manufacture. The intra-year variation of CO emissions results in the 20% dirtiest (1st quintile) newest vehicles (model year 2001-2003) emitting greater quantities of CO (average 0.48-0.96%) than the 20% cleanest (5th quintile) oldest vehicles (model year pre1980-1982) (average 0.11-0.22%). The same result is observed in the NO and HC data. The trends illustrated in Figures 10.11, 10.12 and 10.13 are consistent with overseas studies (Zhang *et al*, 1995). The difference between low emitting older vehicles and high emitting new vehicles supports the commonly accepted notion that good vehicle maintenance significantly reduces emissions.

11 Distribution of Vehicle Emissions and the 'Gross Emitters'

Overseas studies have shown that the total amount of emissions from the on road vehicle fleet is often dominated by a relatively small number of vehicles with very high emissions. These vehicles are termed "gross emitters".

11.1 Quantifying the Contribution of Gross Emitters

This section presents the results and analysis of the emissions from the 42,000 vehicles sampled during the campaign to identify what proportion of the sampled fleet are gross emitters. Figure 11.1 shows the fleet emissions of CO, HC and NO emissions broken down into concentration categories. For each category the relative number of vehicles measured and the total amount of pollutant discharged is given.

Figure 11.1 illustrates the skewed nature of automobile emissions in the sampled fleet, which shows that the bulk of the vehicles are low emitting. For example, 85.6% of the fleet results in only 36.4% of the total CO emissions, 88.8% of the fleet produces 46.9% of the total HC emissions and 65.4% of the fleet emits 18.1% of the total NO emissions. Emissions for all three contaminants are dominated by a small number of high emitting vehicles.

Figure 11.2 shows the contributions of the vehicle fleet to the cumulative total emissions. The measured vehicles are sorted by descending emissions. The cumulative total emissions (the vertical axis) is normalised to the total emissions from all the measured vehicles. The skewed distribution is generated by the high percent of total emissions from the dirtiest 10% of the fleet.

Figure 11.3 shows the relative contribution of gross emitters to the total emissions, broken down by "decile" according to their emissions. The 1st decile represents the worst 10% emitters of the vehicle fleet, and so on. Again, the majority of vehicles fall into the lower emitting categories (see Figure 11.1), but that the majority of emissions come from the few vehicles in the high emissions categories (see Figure 11.3).

Figure 11.1.
Emissions distribution of the sampled fleet for CO, HC and NO

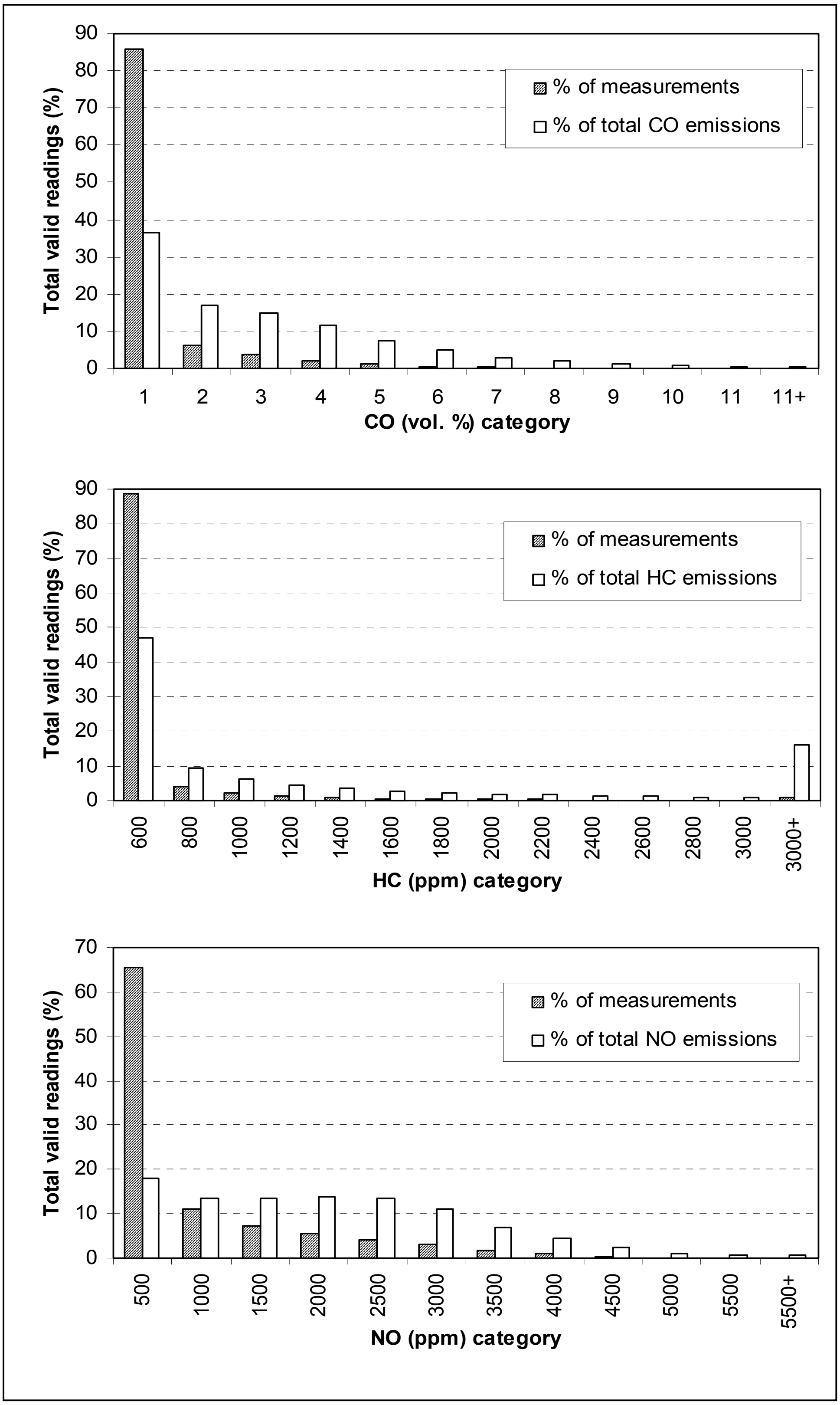


Figure 11.2
Relative fleet cumulative contribution to total CO, HC and NO emissions.

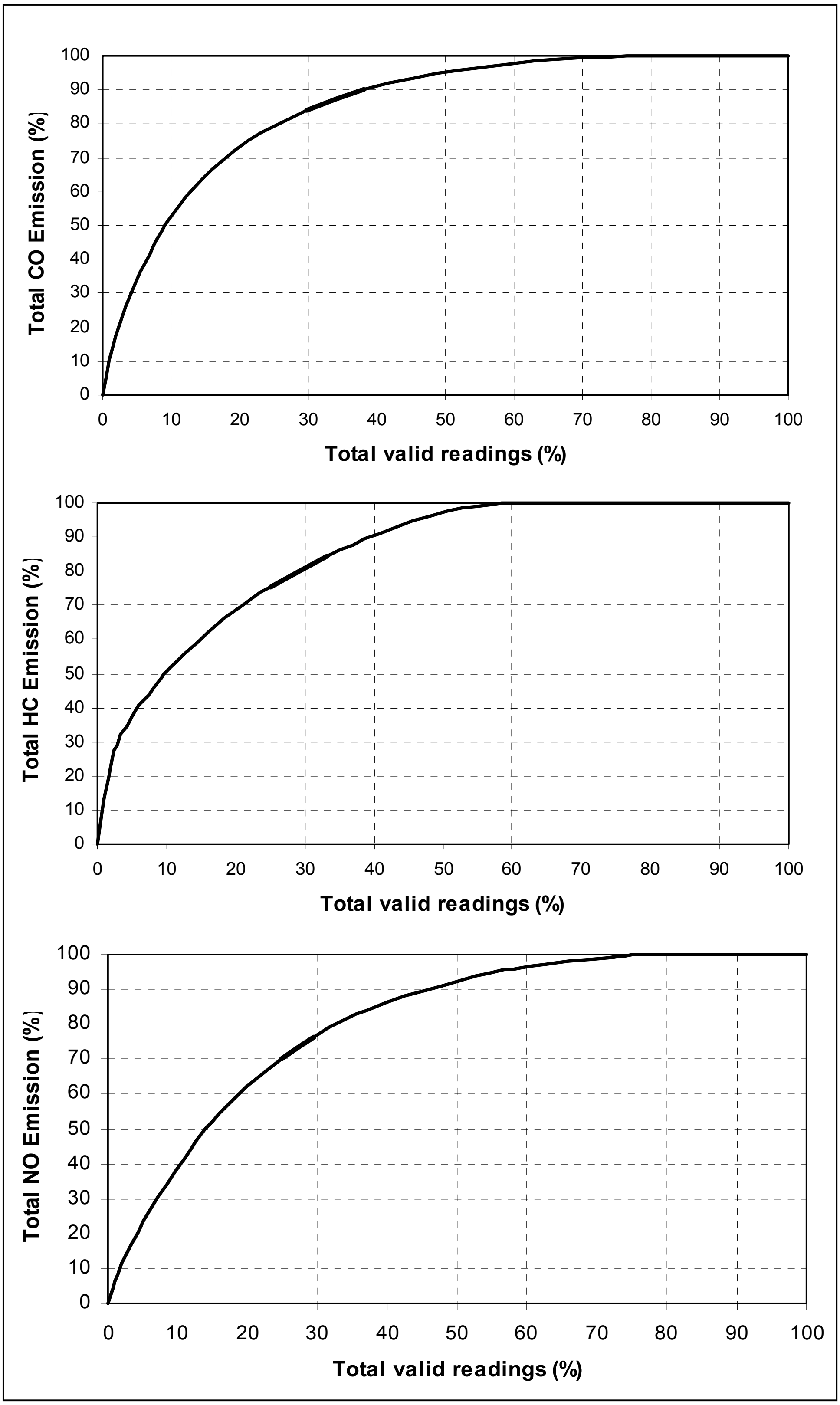
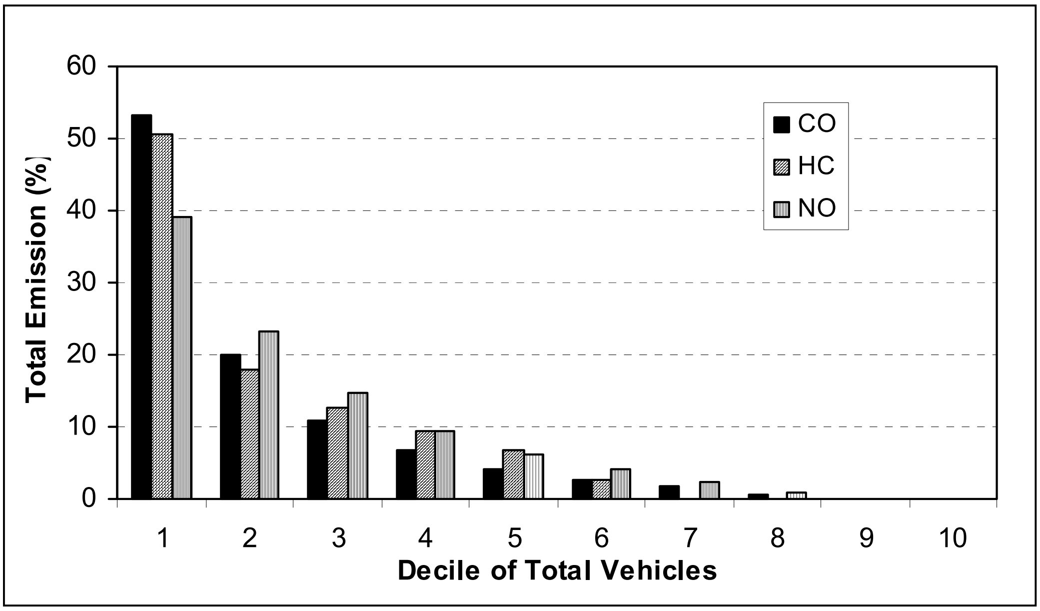


Figure 11.3
Relative contributions to total emissions



Figures 11.2 and 11.3 indicate that 'most CO polluting' 10% vehicles are responsible for:

- 53% of the total CO emissions,
- 51% of the total HC emissions,
- 39% of the total NO emissions.

On the other hand, the cleanest 50% of the fleet contribute to only 5%, 3%, and 8% of the total emissions for CO, HC, and NO, respectively.

High CO emissions are a particularly useful indicator of poor vehicle maintenance and poor fuel economy. Finding and fixing these gross polluters is possibly the most cost-effective tool available for reducing urban air pollution. Figure 11.4 presents the portion of vehicles in each emissions category of "Poor" (%CO > 4.5), "Fair" (1.3 < %CO ≤ 4.5), and "Good" (%CO ≤ 1.3) (Bishop *et al*, 2000), and the portion of the total CO emissions coming from each category.

Figure 11.4
CO indicator categories and their relative contributions to the total CO emissions

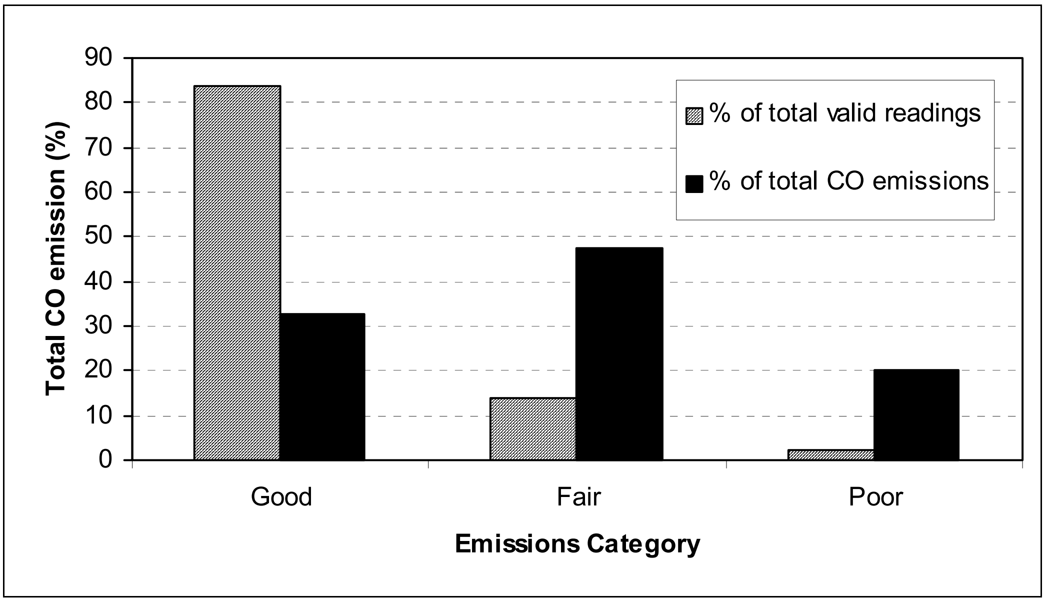


Figure 11.4 figure shows that badly maintained vehicles ("Poor") that account for only 2.3% of the fleet are responsible for 20.0% of the total CO emissions. Fairly maintained vehicles ("Fair") at 13.9% of the fleet are responsible for 47.5 % of the total CO emissions, and properly maintained vehicles ("Good") at 83.8% of the fleet are responsible for only 32.5% of the total CO emissions.

11.2 Profile of Gross Emitting Vehicles

From the subset of approximately 38,000 measurements for which both emissions and registration data are available, a profile was developed of the type of vehicles that are likely to be high emitters. The analysis presented in this section used the 20% highest emitting vehicles for each contaminant– CO, HC, and NO. In the case of opacity, the 100 highest measurements (out of 30,969 valid measurements) were selected because many of the readings were negative (possibly as a result of many petrol vehicles emitting at levels below the detection limits of the opacity equipment). As 100 is a small sample size, the vehicles chosen may not be truly representative of the actual high opacity emitters so the conclusions drawn for these should be regarded as indicative only.

Additional profiling was also carried out on the 1%, 5%, and 10% highest emitting vehicles to allow an assessment of the effectiveness of targeting different sections of the fleet for mitigation measures. The results of these analyses are contained in Appendix 2, Analysis of High Emitters.

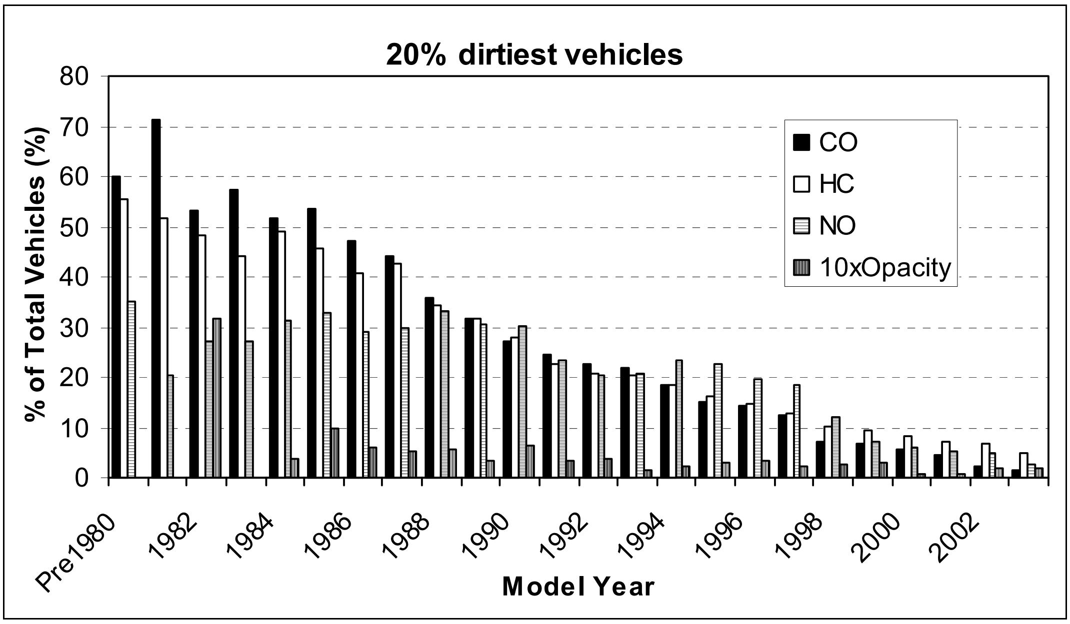
The profiling results from the highest 20% emitters is contained in Table 11.1. The factors considered in the profiling are discussed following Table 11.1.

Table 11.1
Comparison between the 20% dirtiest vehicles (100 dirtiest vehicles for opacity) and the whole fleet.

Pollutant	CO	HC	NO	Opacity	Whole fleet
Number of vehicles in subset	7507	7444	6507	100	34500
% of total emissions	73%	68%	63%		100%
Average model year	1991	1991	1992	1992	1994
Mileage ('000s km)	151	139	142	165	125
No current WOF	3%	3%	2%	5%	2%
Fuel: petrol	99%	94%	97%	73%	84%
Fuel: diesel	1%	6%	3%	26%	16%
Origin: NZ new	53%	56%	68%	47%	49%
Origin: Japanese import	39%	37%	27%	50%	47%
Owner: company	8%	11%	11%	24%	19%
Owner: private	90%	87%	88%	74%	79%
Vehicle type: car	90%	89%	88%	69%	86%
Vehicle type: truck	9%	10%	11%	30%	14%
Vehicle use: private passenger	92%	92%	90%	79%	91%
Vehicle use: transport goods	6%	6%	6%	15%	5%
TLA: Auckland	15%	17%	13%	4%	17%
TLA: Manukau	33%	37%	25%	58%	33%
TLA: North Shore	25%	17%	32%	15%	25%
TLA: Waitakere	10%	9%	11%	7%	12%
TLA: Papakura	5%	5%	6%	2%	5%
TLA: Rodney	10%	14%	11%	12%	12%
TLA: Franklin	2%	1%	3%	2%	2%

Model year. High emitters may come from any model year, including the current year. For example, five vehicles of model year 2003 are among the 20% dirtiest CO vehicles. However, older vehicles are more likely to be high emitters than newer ones. The average model year of high emitters is 1991-1992, compared to 1994 for the whole sample fleet. Figure 11.5 shows the fraction of high emitters in each model year, demonstrating increasing the proportion of high emitters with older vehicles.

Figure 11.5
The fraction of high emitters (20% dirtiest vehicles) in each model year, expressed as a percentage for CO, HC, and NO but as numbers in a thousand for opacity.



Cumulative mileage. The Motochek database (LTSA, 2003) indicates,about half the odometer readings are reliable for high emitters, compared to 68% for the whole fleet. The cumulative mileage is calculated by using only reliable odometer readings. The average cumulative mileage of high emitters is higher than the whole fleet average, particularly for high opacity vehicles.

Current WOF. 5% of high opacity vehicles are without current WOFs, which is greater than the 1.6% fraction for the whole fleet. The percentages of high CO, HC, and NO emitters without current WOFs are similar to that of the whole fleet.

Fuel. A higher proportion of petrol vehicles have elevated CO, HC, and NO emissions compared to the whole fleet. By comparison, a higher proportion of diesel vehicles have elevated opacity readings than is reflected in the whole fleet. As a result, nearly all (94-99%) the high CO, HC, and NO emitters are petrol vehicles, while a quarter (26%) of the high opacity emitters are diesel vehicles. No conclusion can be reached on the proportion of diesel versus petrol contributions to NO_2.

Country of origin. Compared to the whole fleet, more New Zealand new vehicles are highlighted as high CO, HC and NO emitters than imported used Japanese vehicles. For high opacity vehicles, the proportion is distributed approximately equally between New Zealand new and imported used Japanese vehicles.

Ownership. Compared to the whole fleet, the proportion of privately owned vehicles with elevated CO, HC, and NO emissions is slightly higher than company-operated vehicles. The proportion of company-owned vehicles in high opacity emitters is slightly higher. This may be a reflection of the higher proportion of diesel vehicles operated by companies.

Vehicle type and usage. More trucks and vehicles used for goods transport appear as high opacity emitters than in the whole fleet. This is likely to be a result of the relatively high proportion of diesel fuelled vehicles contained in this subset.

Territorial Local Authorities (TLAs). A third of the vehicles were sampled in Manukau city. However, over half (58%) of the high opacity emitters are from sampling sites in Manukau city.

In conclusion, high emitters may come from any category of vehicles. However, high emitters tend to be more closely associated with a number of factors. The analysis suggests that, among the factors discussed above, model year and fuel type may be the most important. Older vehicles are more likely to be high emitters than newer ones. Nearly all of the high CO, HC, and NO emitters are petrol vehicles, whilst a quarter of the high opacity emitters are diesel vehicles.

12 Comparison of Different Sites and Territorial Local Authorities

The programme was designed to collect a representative sample of vehicles from across the seven different Territorial Local Authorities (TLAs) in the Auckland region. This section presents and compares the average emissions at each of the sites. The data from the sites within each TLA were aggregated and a comparison was made between them. Figure 12.1 compares the average CO emissions from each of the sites. Table 12.1 shows average emissions of the vehicle fleets at each site and the overall fleet for all the sites. Figure 12.2 compares the average CO emissions from within each of the seven TLAs.

Figure 12.1
Comparison of average of CO emissions from the 15 sampling sites

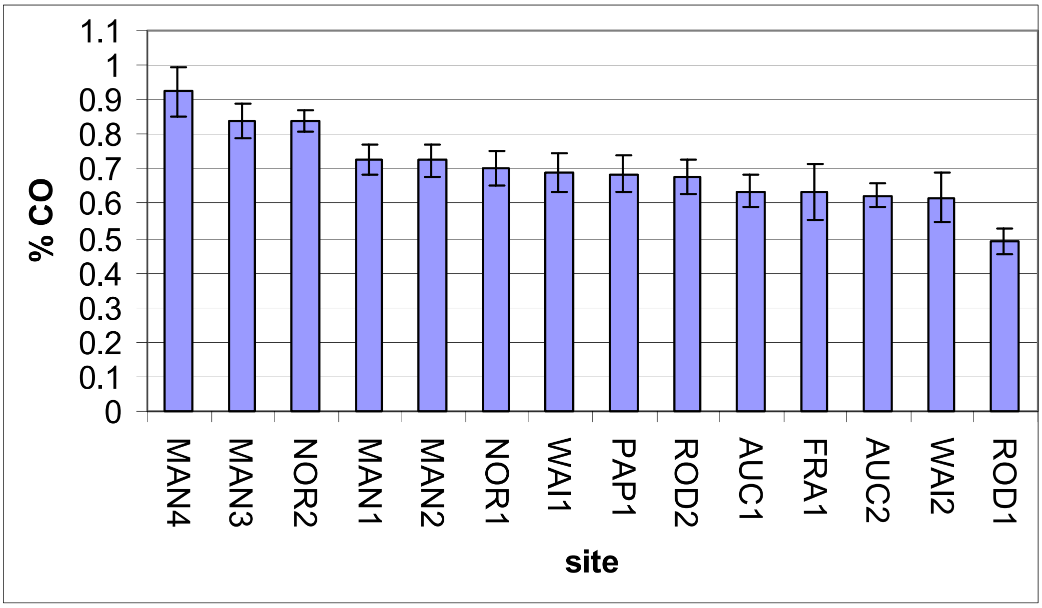


Table 12.1
Average emissions of the vehicle fleets sampled at each site.

Site	Date	Average CO	Average HC	Average NO	Average year of manufacture
Manukau (MAN1)	2-Apr-2003	0.79%	691ppm	No data	April 1993
Manukau (MAN2)	3-Apr-2003	0.73%	328ppm	No data	March 1993
Waitakere (WAI1)	4-Apr-2003	0.69%	244ppm	588ppm	June 1993
Auckland (AUC2)	7-Apr-2003	0.62%	308ppm	655ppm	June 1994
North Shore (NOR2)	8-Apr-2003	0.84%	298ppm	940ppm	Nov. 1993
Waitakere (WAI2)	9-Apr-2003	0.62%	243ppm	809ppm	Sept. 1993
Manukau (MAN1)	10-Apr-2003	0.73%	359ppm	774ppm	April 1993
Franklin (FRA1)	11-Apr-2003	0.63%	291ppm	907ppm	Sept. 1993
Auckland (AUC1)	14-Apr-2003	0.65%	340ppm	496ppm	Sept. 1994
North Shore (NOR1)	15-Apr-2003	0.70%	262ppm	962ppm	March 1994
Manukau (MAN3)	16-Apr-2003	0.84%	316ppm	1053ppm	May 1993
Papakura (PAP1)	17-Apr-2003	0.68%	316ppm	782ppm	Nov. 1993
Rodney (ROD2)	22-Apr-2003	0.68%	390ppm	558ppm	Jan. 1994
Rodney (ROD1)	23-Apr-2003	0.49%	264ppm	784ppm	July 1994
Manukau (MAN4)	24-Apr-2003	0.92%	286ppm	1270ppm	na
Average		0.71%	330ppm	794ppm	Nov. 1993

The data contained in Table 12.1 and Figure 12.1 show that there is a variability of average CO emissions at the different sampling sites. The sites can be broken down into three groups based on their relative CO emissions. The Rodney 1 site is the only site with relatively low emissions. The group of sites with emissions in the middle range include Waitakere 1 and 2, Auckland 1 and 2, Franklin 1, Rodney 2, Papakura 1, North Shore City 1 and Manukau 1 and 2. The group of sites with relatively high emissions includes North Shore City 2 and Manukau 3 and 4. It is not surprising to see Manukau 4 fall into the high CO emissions group. This site was set up to monitor vehicles leaving a shopping centre and therefore would be expected to contain a relatively high number of vehicles operating with cold start engines.

Figure 12.2
Comparison of average of CO emissions from the 7 TLAs

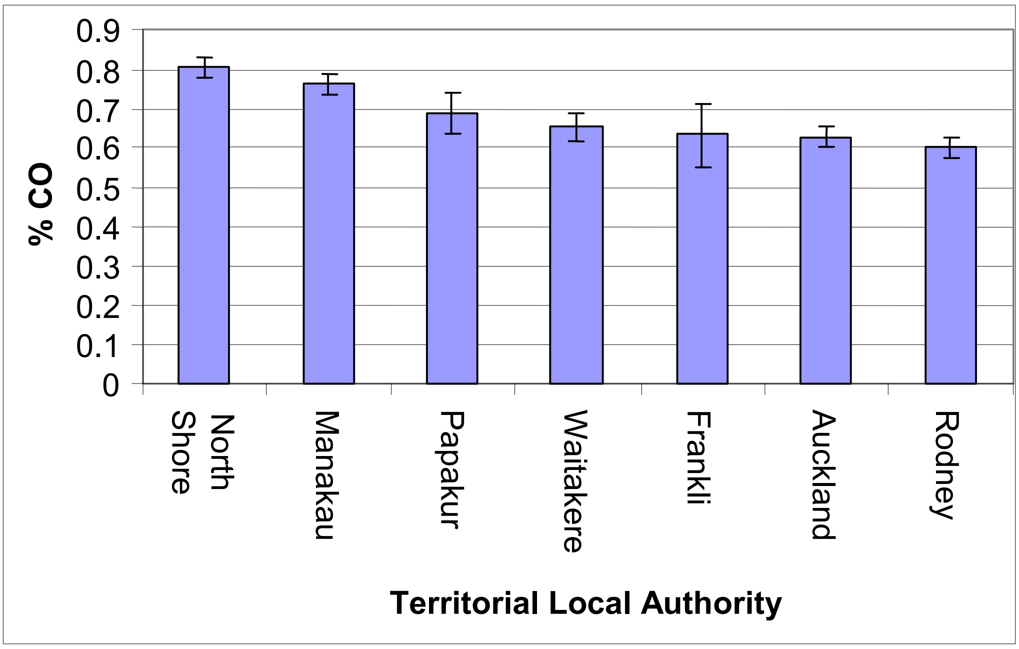


Figure 12.2 shows the variability of average CO emissions recorded in the different TLAs. In calculating the average CO emissions from Manukau City, MAN4 (the cold start site) has been excluded. The TLAs can be broken down into two groups based on their relative CO emissions. The group of TLAs with CO emissions in the lower range include Rodney, Auckland, Franklin, Waitakere, and Papakura. The group of TLAs with CO emissions in the higher range include North Shore City and Manukau.

Figures 12.3 and 12.4 show the average year of manufacture of the vehicles sampled at each site and within in each TLA respectively.

Figure 12.3
Average year of manufacture of the vehicles sampled at each site

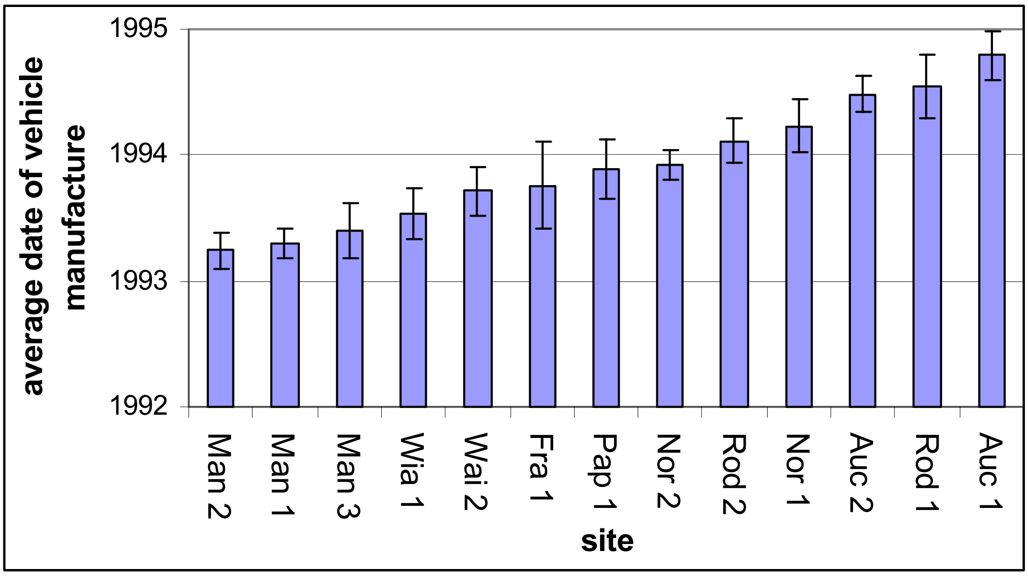
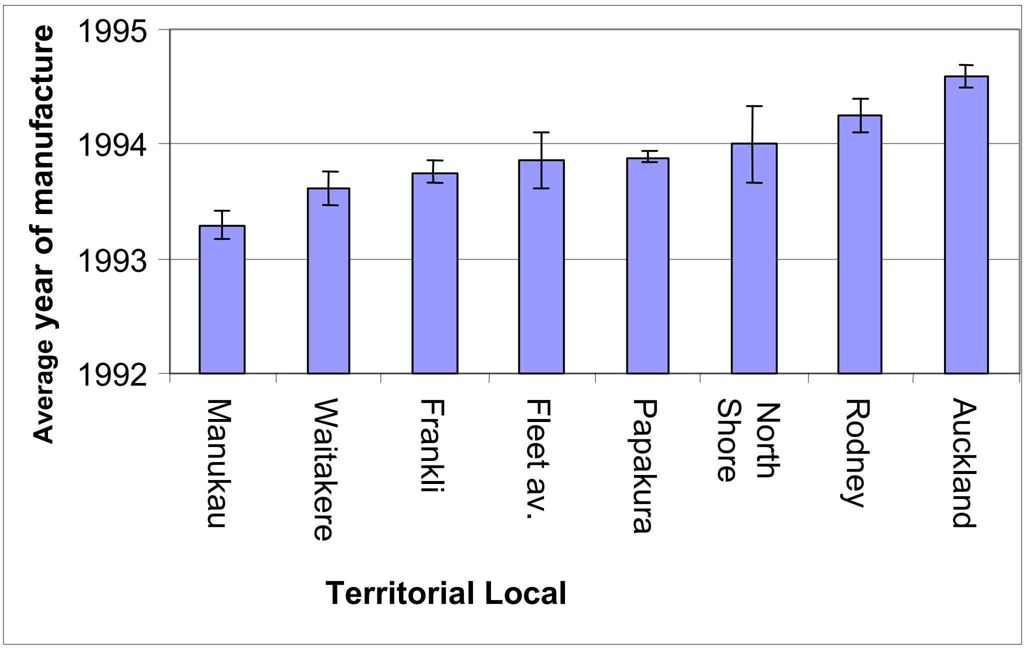


Figure 12.4
Average year of manufacture of the vehicles sampled in each TLA



The data displayed in Figures 12.3 and 12.4 suggests that vehicles sampled in:

- Manukau City were relatively older.
- Waitakere City, Papakura and Franklin Districts and North Shore City were approximately the same age as the fleet average.
- Auckland City and Rodney District were relatively newer.

There is a slightly larger that one year difference in average age between the oldest and newest fleets – in Manukau and Auckland City.

To some degree the effect of vehicle age is reflected in the difference between the CO emissions measured in each of the TLAs (Figure 12.2). The lowest CO emissions were measured in Auckland City and Rodney District, which have relatively newer vehicles. The highest CO emissions were measured in North Shore and Manukau Cities, which have average and relatively older vehicles respectively.

13 Comparison with Measurements from the USA

This section compares the emissions measured in the Auckland sampling campaign to similar measurements made in the USA. Measurements made in the vehicle fleets of Los Angles and Denver (2001), Phoenix and Chicago (2000) will be used for the comparison (data taken from http://www.feat.biochem.du.edu/whatsafeat.html).

Table 13.1 compares the Auckland vehicle fleet average with similar measurements made in a number of Cities in the United States. The numbers of vehicles tested at each site are also shown.

Table 13.1
Comparison of the Auckland fleet average emissions with US cities

Location	Vehicle Number*	Average CO	Average HC	Average NO
Los Angeles (LaBrea) 2001	24,751	0.44%	125 ppm	411 ppm
Los Angeles (Riverside) 2001	24,381	0.39%	100 ppm	400 ppm
Denver 2001	27,702	0.34%	112 ppm	483 ppm
Phoenix 2000	26,458	0.27%	99 ppm	448 ppm
Chicago 2000	26,054	0.26%	94 ppm	316 ppm
Average of the 5 US sampling programmes	129,346	0.34%	106 ppm	412 ppm
Auckland 2003	42,057	0.71%	330 ppm	797 ppm

*Valid readings for CO emissions.

The data displayed in Table 13.1 show that on average the Auckland vehicle fleet emits a higher proportion of CO and greater amounts of hydrocarbons and NO than the vehicles measured in any of four US cities used in the comparison. By comparison to their US counterparts, the vehicles used on the roads of Auckland emit approximately:

- Double the amount of CO
- Double the amount of NO
- Three times the amount of hydrocarbons

14 Discussion

This is the first time such a comprehensive on-road vehicle monitoring programme has been conducted in New Zealand. The campaign used equipment and experience from collaborators who have conducted similar studies elsewhere. However there are a number of issues that warrant further clarification.

Firstly, this study only considered the vehicle fleet in Auckland, and results may not be applicable to other locations in New Zealand.

Secondly, the sampling strategy attempted to obtain a representative sample of vehicles on Auckland roads, but this may have been biased by some factors. One is that only certain types of roads are amenable to being monitoring using remote sensing – single lane, no obstructions, reasonable traffic flows etc. Another is that large heavy duty vehicles are under-represented because their exhausts are often aligned vertically and above the cab height – beyond the reach of the sensor used. In addition, the measurements are a snapshot of the situation in April (autumn) – there may be different emissions characteristics at other times of year, or when other fuel batches are in the system.

Thirdly, the study presents no data or conclusions relating to nitrogen dioxide (NO_2). The measurement technique does not address NO_2 and its formation and occurrence due to vehicle exhaust emissions is complex.

Despite these cautionary notes, a very large number of vehicles were sampled – around 5% of the fleet – and the results are considered valid within normal sampling constraints.

No attempt has been made here to compare these results with other types of measurements (e.g. dynamometer checks on the vehicles sampled), or emissions models (e.g. NZTER from the Ministry of Transport). These will be part of the next stage of the research programme associated with this measurement campaign.

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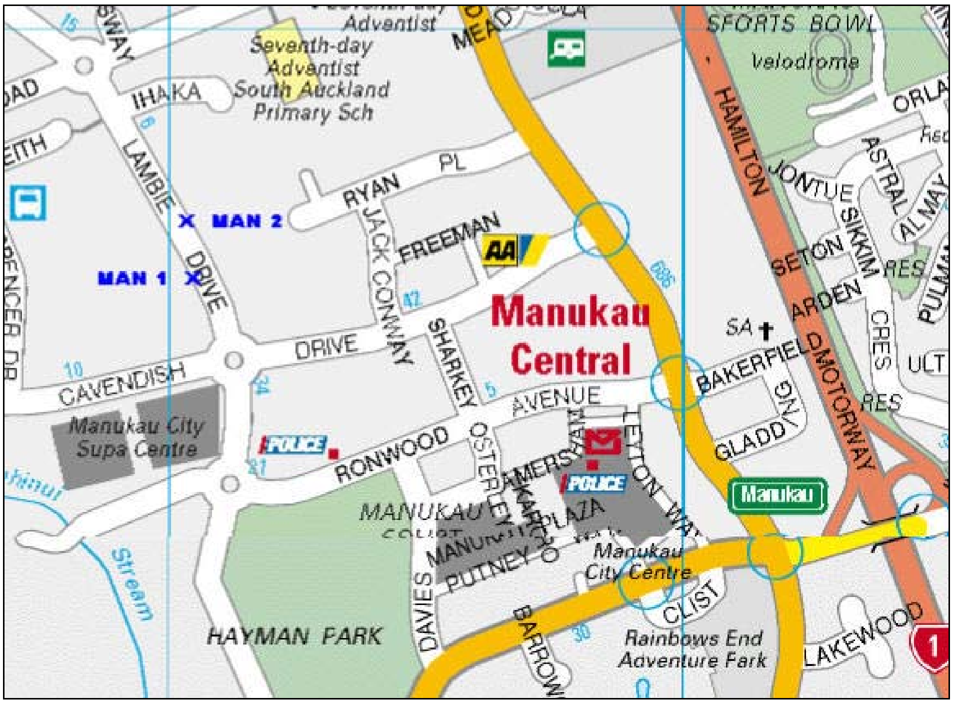
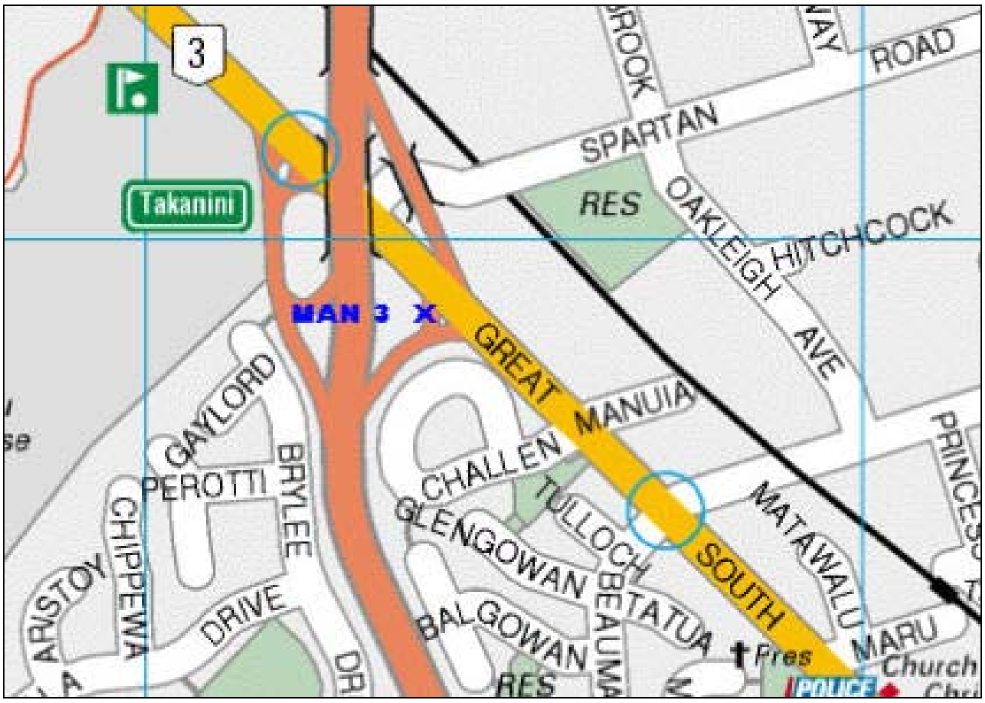
Appendix 1. Maps of Monitoring Sites

Manukau City

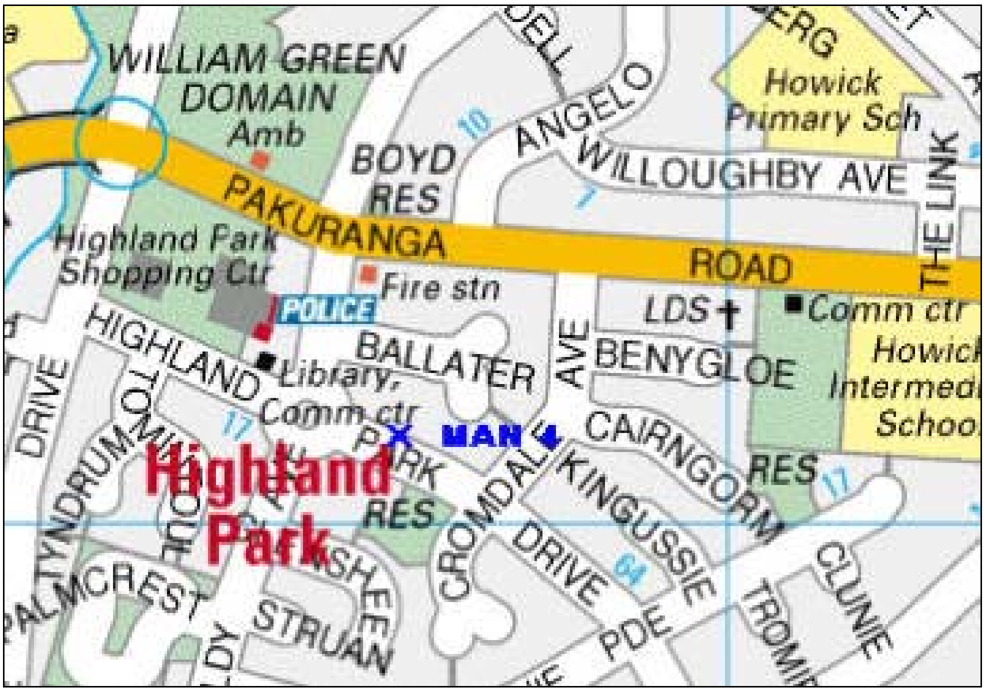


MAN1 site located at Lambie Dr., Wiri (Northbound). Sampling was carried out on 2 April 2003 (time: 05:50 – 12:50) with 3,888 total readings and 2,787 valid readings (71.68% of the total readings), and on 10 April 2003 (time: 06:00– 12:30) with 3,948 total readings and 3,174 valid readings (80.40% of the total readings).

MAN2 site located at Lambie Dr., Wiri (Southbound). Sampling was carried out on 3 April 2003 (time: 06:30 – 13:00) with 3,709 total readings and 2,717 valid readings (73.25% of the total readings).



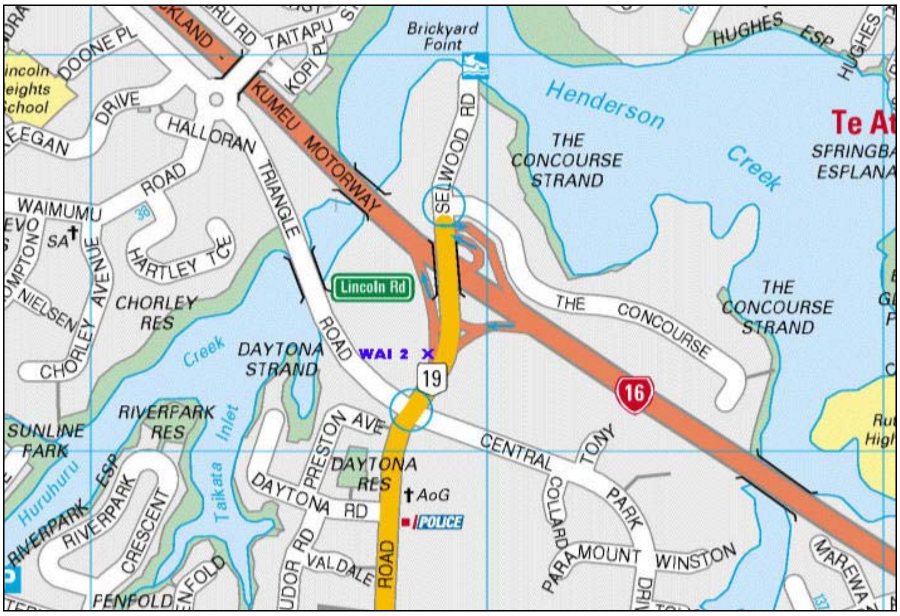
MAN3 site located at Takanini onramp (Southbound). Sampling was carried out on 16 April 2003 (time: 12:00 – 18:40) with 2,707 total readings and 2,466 valid readings (91.10% of the total readings).



MAN4 site located at Highland Park Drive, Highland Park (Eastbound). Sampling was carried out on 24 April 2003 (time: 09:50 – 15:50) with 1,311 total readings and 1,291 valid readings (98.47% of the total readings).

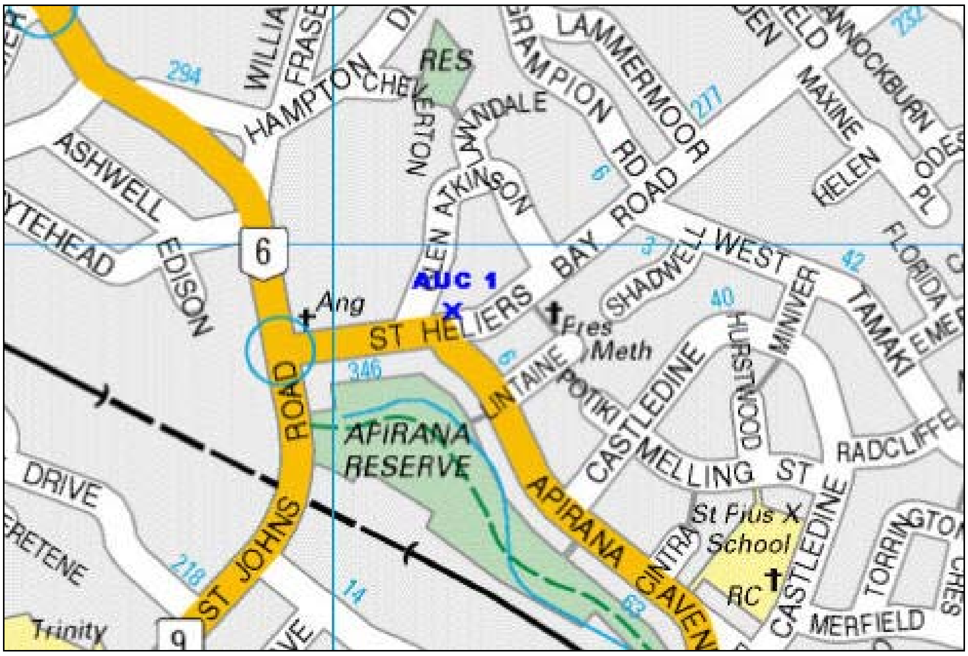
Waitakere City

WAI1 site located at Te Atatu North (Citybound). Sampling was carried out on 4 April 2003 (time: 05:30 – 12:20) with 3,683 total readings and 2,429 valid readings (65.95% of the total readings).



WAI2 site located at Lincoln Rd (Westbound). Sampling was carried out on 9 April 2003 (time: 06:10 – 12:45) with 3,334 total readings and 2,606 valid readings (78.16% of the total readings).

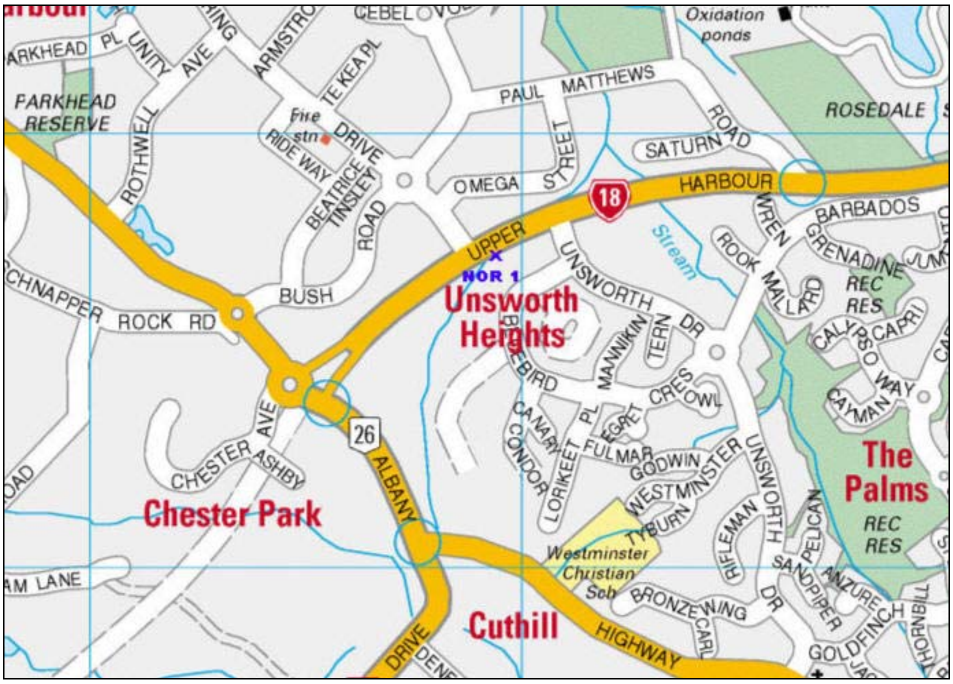
Auckland City



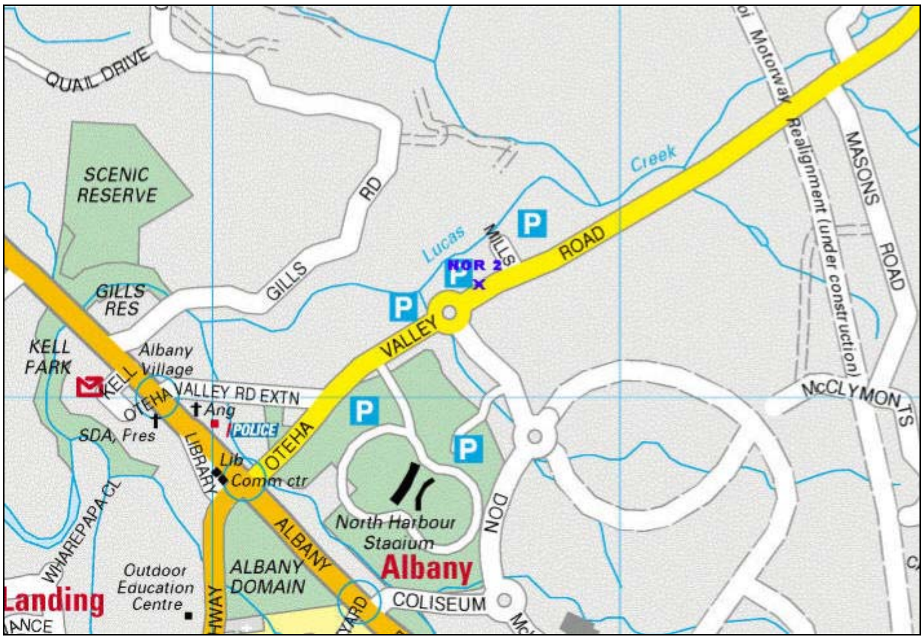
AUC1 site located at St Heliers Bay Rd (Eastbound). Sampling was carried out on 14 April 2003 (time: 13:00 – 19:00) with 3,878 total readings and 2,321 valid readings (59.85% of the total readings).

AUC2 site located at Lagoon Dr., Panmure. Sampling was carried out on 7 April 2003 (time: 06:15 – 12:30) with 5,527 total readings and 4,291 valid readings (77.64% of the total readings).

North Shore City



NOR1 site located at Upper Harbour Highway (Westbound). Sampling was carried out on 15 April 2003 (time: 13:00 – 18:20) with 2,495 total readings and 2,234 valid readings (89.54% of the total readings).



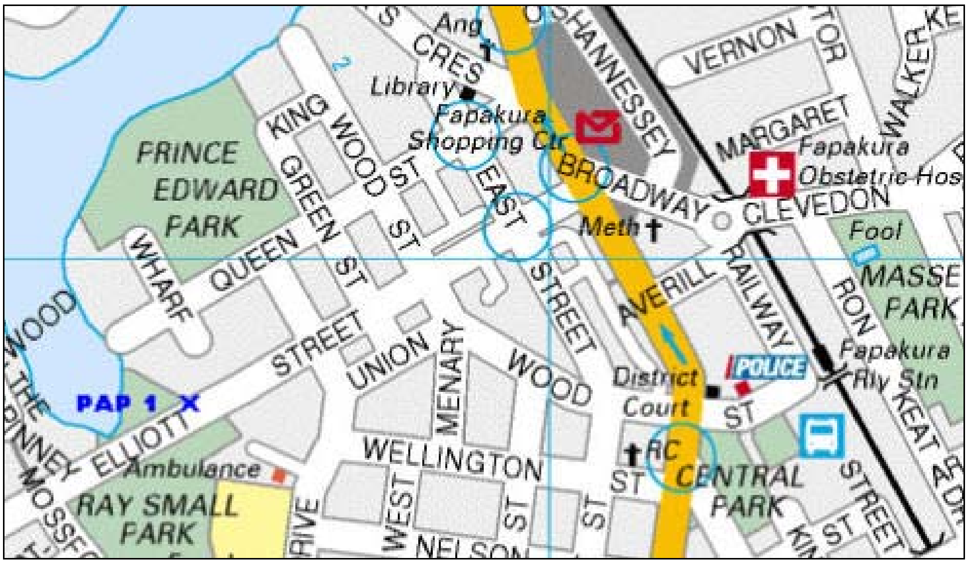
NOR2 site locates at Oteha Valley Rd (Eastbound). Sampling was carried out on 8 April 2003 (time: 05:50 – 18:20) with 7,468 total readings and 6,911 valid readings (92.54% of the total readings).

BUS1 site located at Esmonde Rd (bus lane). Sampling was carried out on 29 April 2003 (time: 06:15 – 12:30) with 56 total readings and 46 valid readings (82.14% of the total readings). This site is designed to monitor emissions from buses.

Franklin District

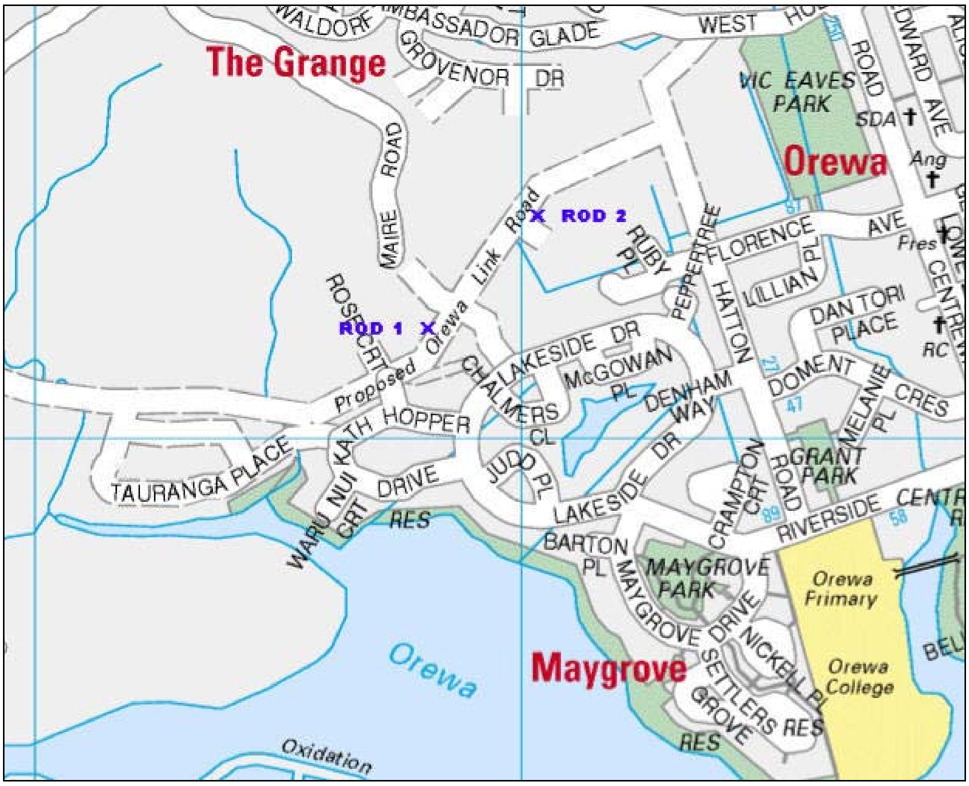
FRA1 site located at Glenbrook Rd (Westbound). Sampling was carried out on 11 April 2003 (time: 06:20 – 12:30) with 1,470 total readings and 912 valid readings (62.04% of the total readings).

Papakura District



PAP1 site located at Elliot St, Papakura (Westbound). Sampling was carried out on 17 April 2003 (time: 05:45 – 12:45) with 2,366 total readings and 2,043 valid readings (86.35% of the total readings).

Rodney District



ROD1 site located at Grand Dr., Orewa (Northbound). Sampling was carried out on 23 April 2003 (time: 06:00 – 12:30) with 2,595 total readings and 2,406 valid readings (92.72% of the total readings).

ROD2 site located at Grand Dr., Orewa (Southbound). Sampling was carried out on 22 April 2003 (time: 12:20 – 18:30) with 3,820 total readings and 3,385 valid readings (88.61% of the total readings).

Appendix 2. Analysis of High Emitters

Table A2.1
Comparison between the 1% dirtiest vehicles and the whole fleet.

Pollutant	CO	HC	NO	Whole fleet
Vehicle number	375	372	325	
% of total emissions	10%	17%	6%	100%
Average model year	1989	1990	1992	1994
Mileage (1000km)	154	135	152	125
No current WOF	6%	5%	1%	2%
Fuel: petrol	99%	95%	99%	84%
Fuel: diesel	1%	5%	1%	16%
Origin: NZ new	41%	59%	81%	49%
Origin: Japanese import	46%	30%	14%	47%
Owner: company	10%	13%	12%	19%
Owner: private	87%	86%	86%	79%
Vehicle type: car	85%	80%	87%	86%
Vehicle type: truck	14%	19%	12%	14%
Vehicle usage: private passenger	88%	83%	91%	91%
Vehicle usage: transport goods	11%	13%	7%	5%
TLA: Auckland	13%	17%	15%	17%
TLA: Manukau	33%	43%	30%	33%
TLA: North Shore	25%	16%	37%	25%
TLA: Waitakere	12%	5%	3%	12%
TLA: Papakura	7%	3%	6%	5%
TLA: Rodney	9%	15%	7%	12%
TLA: Franklin	2%	1%	2%	2%

Table A2.2
Comparison between the 5% dirtiest vehicles and the whole fleet.

Pollutant	CO	HC	NO	Whole fleet
Vehicle number	1876	1861	1627	
% of total emissions	34%	37%	23%	100%
Average model year	1990	1991	1992	1994
Mileage (1000km)	153	138	143	125
No current WOF	4%	4%	1%	2%
Fuel: petrol	99%	94%	99%	84%
Fuel: diesel	1%	6%	1%	16%
Origin: NZ new	45%	57%	75%	49%
Origin: Japanese import	44%	35%	19%	47%
Owner: company	8%	12%	10%	19%
Owner: private	89%	86%	89%	79%
Vehicle type: car	88%	87%	89%	86%
Vehicle type: truck	11%	12%	10%	14%
Vehicle usage: private passenger	91%	89%	92%	91%
Vehicle usage: transport goods	8%	6%	6%	5%
TLA: Auckland	13%	15%	11%	17%
TLA: Manukau	32%	47%	29%	33%
TLA: North Shore	30%	11%	38%	25%
TLA: Waitakere	9%	8%	5%	12%
TLA: Papakura	4%	4%	5%	5%
TLA: Rodney	9%	15%	9%	12%
TLA: Franklin	2%	1%	2%	2%

Table A2.3
Comparison between the 10% dirtiest vehicles and the whole fleet.

Pollutant	CO	HC	NO	Whole fleet
Vehicle number	3753	3722	3254	
% of total emissions	53%	51%	39%	100%
Average model year	1990	1991	1992	1994
Mileage (1000km)	153	139	142	125
No current WOF	3%	3%	1%	2%
Fuel: petrol	99%	93%	99%	84%
Fuel: diesel	1%	6%	1%	16%
Origin: NZ new	49%	56%	73%	49%
Origin: Japanese import	42%	36%	22%	47%
Owner: company	8%	11%	10%	19%
Owner: private	90%	87%	88%	79%
Vehicle type: car	90%	88%	89%	86%
Vehicle type: truck	10%	11%	10%	14%
Vehicle usage: private passenger	92%	91%	92%	91%
Vehicle usage: transport goods	7%	6%	6%	5%
TLA: Auckland	13%	16%	11%	17%
TLA: Manukau	32%	41%	26%	33%
TLA: North Shore	28%	13%	36%	25%
TLA: Waitakere	10%	9%	8%	12%
TLA: Papakura	4%	5%	6%	5%
TLA: Rodney	10%	15%	11%	12%
TLA: Franklin	2%	1%	2%	2%

Figure A2.1.
The fraction of high emitters (1% dirtiest vehicles) in each model year

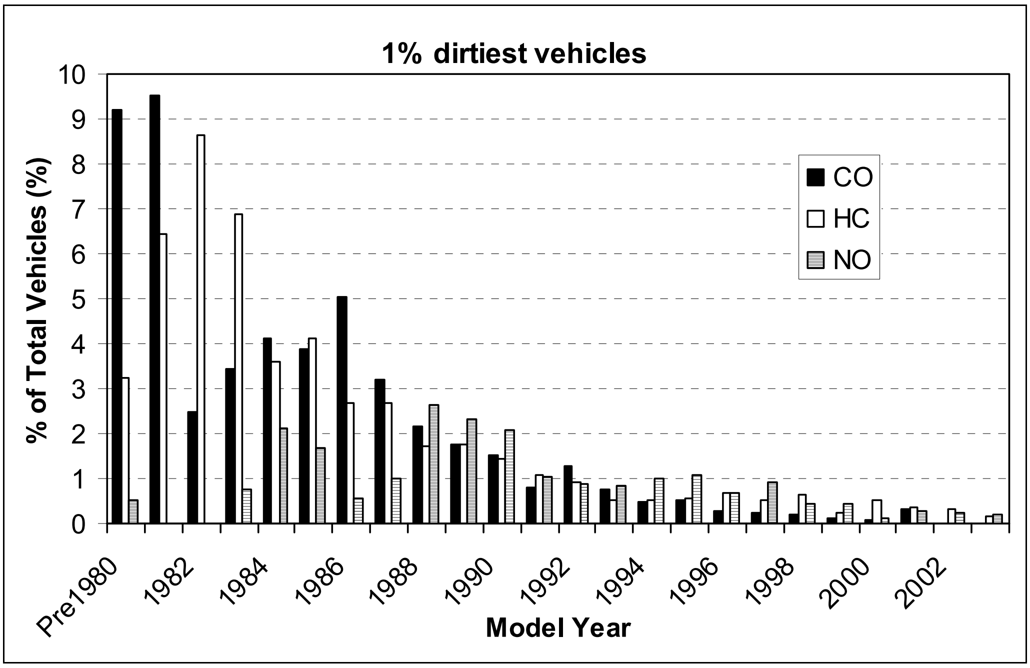


Figure A2.2.
The fraction of high emitters (5% dirtiest vehicles) in each model year

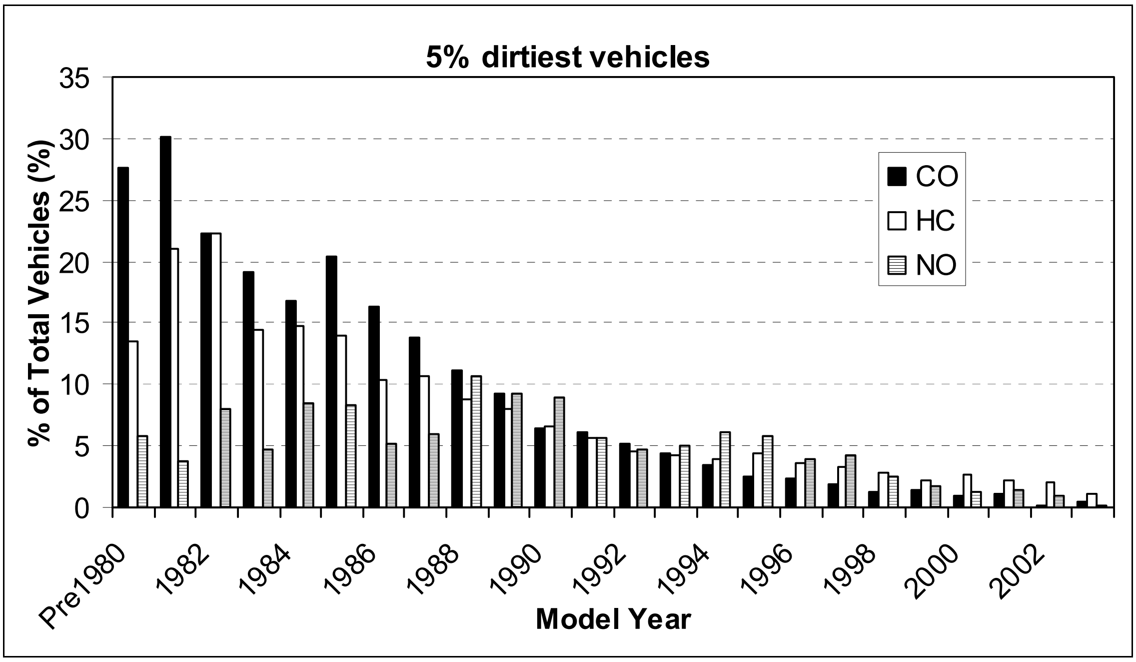


Figure A2.3.
The fraction of high emitters (10% dirtiest vehicles) in each model year