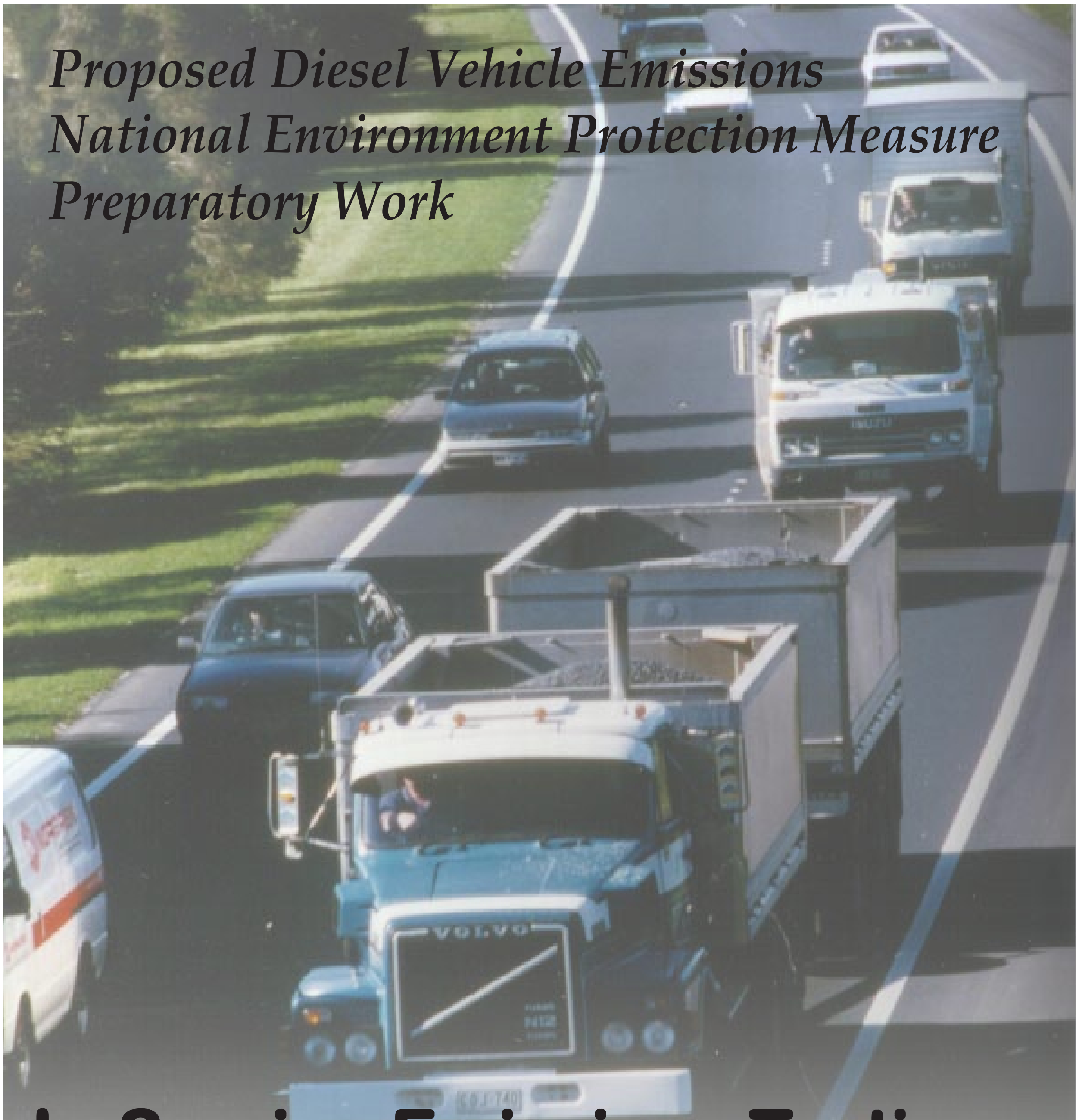
Proposed Diesel Vehicle Emissions
National Environment Protection Measure
Preparatory Work



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

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NEPC
NATIONAL ENVIRONMENT PROTECTION COUNCIL

Prepared for the

National Environment Protection Council

by

PARSONS

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

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

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

In-Service Emissions Performance - Phase 2: Vehicle Testing

In-Service Certification Correlation Studies

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

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

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

Electronic copies of these documents are available from:

National Environment Protection Council Service Corporation
Level 5, 81 Flinders Street
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These documents are also available online: http://www.nepc.gov.au

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- Cooks Diesel, and;
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    - Private owners from various sources
    - 4WD clubs: the Southern Cross 4WD Club, Toyota Landcrusier Club, and George's River Overland Club.
    - Fleet operators: Australia Post, 1st Fleet, McPhee, TNT, Boral, Toll SPD, Arnotts etc
    - Truck Service Centres: International Trucks, Mercedes Benz, Scania and Mack Trucks Australia
    - Truck Hire: Hertz, Budget, Ranger, Sargents and Kennards
    - Councils: Parramatta, Hawkesbury and Liverpool
    - Western Sydney Waste Disposal centre
    - West Bus, Forest Coach Lines and Sydney Buses
    - Truck Sale yards - Gilbert and Roach, All Trans, City Hino, Auburn Automobiles, Villawood Trucks, Bastians, Windsor Toyota and Stillwell Trucks

To all of you - *Thanks!*

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CONTENTS

1 PROJECT DESCRIPTION

1.1 Project Objectives

The objectives of the project were to, by means of a pilot vehicle emissions testing program to:

1. determine the emissions performance of the Australian diesel fleet as measured by the DT80 in-service emissions test.
2. identify the type and cost of repairs that result in improved emissions performance;
3. provide data to enable the assessment of the effectiveness, practicality and costs of using the DT80 test for measuring emissions from in-service diesel vehicles, and;
4. develop a package of procedures and equipment specifications for the DT80 test that could be used as the basis of an in-service emissions testing program.

1.2 Scope of Work

The project required:

- 615 vehicles to be randomly sourced from the diesel in-service fleet and tested in accordance with the DT80 short test protocol;
- 120 of the 615 vehicles to be diagnosed for faults likely to cause increased emissions, and;
- the repair and re-test of 40 vehicles diagnosed as having faults.

The specified test vehicle matrix is shown in Table 2-6.

In addition to containing a range of vehicle makes, models, ages and distances travelled, the sample had to contain a representative sample from both small and large fleets.

Emissions measured were:

- particulate matter (PM), and;
- oxides of nitrogen (NOx).

The mass of these emissions, the distance travelled during the test and the mass of the test vehicle was recorded to allow the calculation of results in grams/kilometer and normalised for vehicle mass as grams/kilometer.tonne.

Smoke emissions were also measured as % opacity (average and maximum).

2 METHODOLOGY

2.1 Emission testing

2.1.1 DT80 Test Protocol

The DT80 test protocol shown in Figure 2-1 was used for all tests. It is a transient mixed-mode test, having idle periods, three full-load accelerations, and a steady-state 80 km/h cruise. The test requires the use of a dynamometer having inertia simulation on acceleration.

The test has been shown to correlate with drive cycle tests and with compliance test results (refer to Project 2-2 and Project4).

Figure 2-1: DT80 Test Protocol

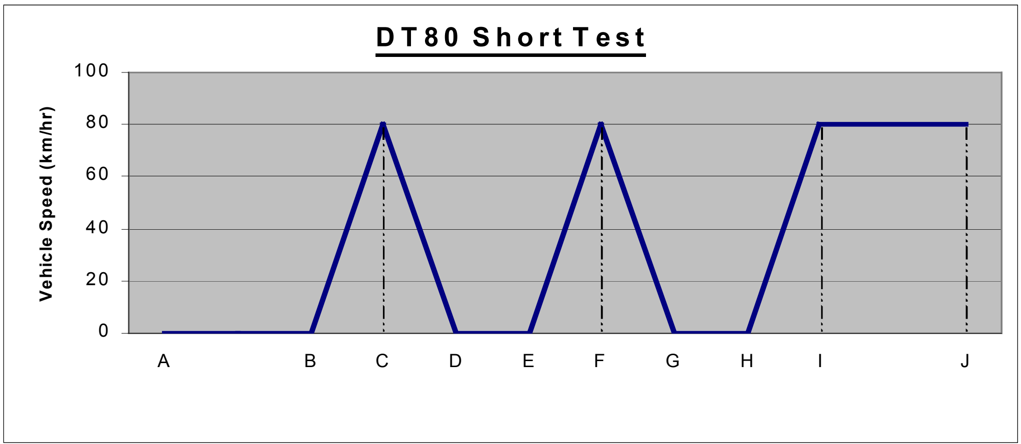


Table 2-1

Set dynamometer inertia load to (Tare+GVM)/2 Sample over complete cycle.		
A – B:	Idle. Select low gear.	60 s
B – C:	Wide open throttle acceleration to 80 km/h km/h.	
C – D:	Brake to stop.	
D – E:	Idle,	10 s
E - F:	Wide open throttle acceleration to 80 km/h	
F - G	Brake to stop.	
G - H	Idle.	10 s
H - I	Wide open throttle acceleration to 80 km/h.	
I – J	Maintain 80 km/h.	60 s
At J	Test complete.	

2.1.2 Test Equipment

The mobile system consisted of the following elements:

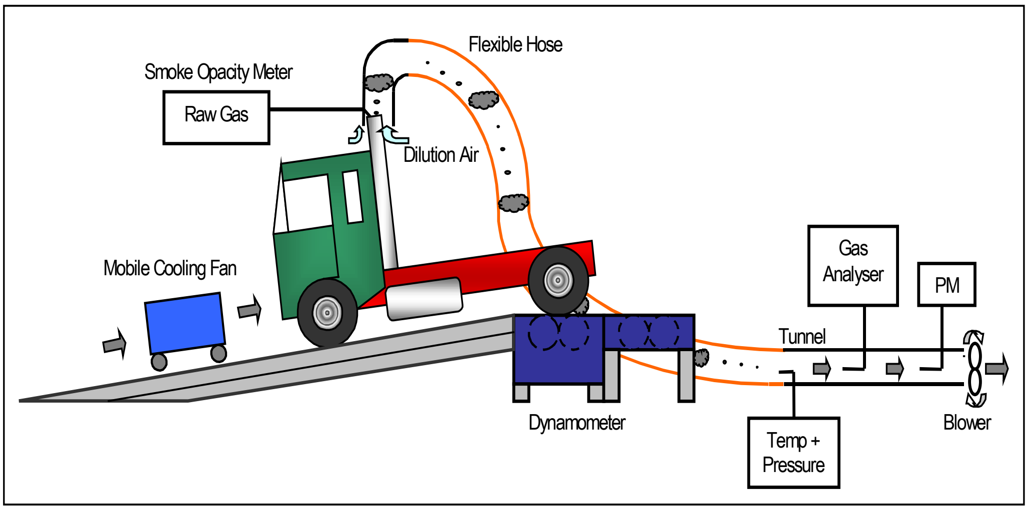
- Chassis dynamometer and vehicle access ramps
- Generator, lighting and safety barriers
- Exhaust sample handling system
- Emissions instrumentation
- Data acquisition/reporting system

In addition to the equipment mentioned above the following ancillary equipment was required to transport the system from site to site.

- Trailer (dual axle with tilt tray) to house and transport the dynamometer.
- Eight tonne Rigid Truck to transport a generator and access ramps and tow the dynamometer trailer.
- Small commuter van to house computers and emissions measuring instrumentation and tow a small trailer.
- Small trailer (8′ x 5′) to transport sample handling ducting and dilution air blowers.

Figure 2-2 shows a single axle truck with a vertical exhaust being tested on the chassis dynamometer. The rear set of rollers is used for bogie axle vehicles.

Figure 2-2: Mobile Testing System Layout



The details of the test equipment are contained in Appendix 2.

2.1.3 Test Procedure

Table 2.4 outlines the sequence and nominal duration of each activity involved in undertaking a test. Actual times achieved to complete the sequence during the project are presented in Section 8, Results.

Prior to commencement of testing vehicles were inspected for both safety and general condition in accordance with a detailed worksheet that also allowed for the recording of engine details and other information relevant to the vehicles operation

At the completion of testing, results were presented to the vehicle owner who was advised that there may be a follow up to recall the vehicle for diagnosis and possible repair and retest. The owner was also presented with a questionnaire to complete that provided feedback on the testing program from the vehicle owner's perspective. (refer to Appendix 1 for a copy of the inspection worksheet, results sheet and Questionnaire).

Table 2-2 : Test schedule and task duration estimate

Activity	Duration (Minutes)
Inspect vehicle and record details on worksheet and dynamometer	5
Secure vehicle on dynamometer – chock	5
Connect sample line to exhaust pipe	2
Perform test	3
Print result	2
Disconnect sample line from exhaust pipe	2
De-chock and drive vehicle off dynamometer	2
Discuss result with vehicle owner .	3
TOTAL	**24**
Plus calibration before first test (15mins) and dynamometer set up (45mins)	**60**
Plus shut down procedure after last test and loading equipment onto transport vehicles	**45**

NOTE: In a fully operational program, rather than a pilot study, a number of the above stages would be performed in parallel, thus significantly increasing throughput to about 5 vehicle per hour rather than 2 for this project.

2.2 Vehicle Sourcing

An important issue in sourcing vehicles is the establishment of a random sample that is representative of the in-service fleet. Failure to achieve a representative sample of the fleet could result in an over or under estimation of the scope of emission performance and the potential benefits to be gained from the repair of high emitting vehicles.

2.2.1 Types and ownership of sampled vehicles

According to the National Road Transport Commission analysis of, data compiled by the Australian Bureau of Statistics there are some 1.6 million light commercial Vehicles (petrol plus diesel) carrying freight in Australia. There are also 270,000 rigid trucks and 57,000 articulated trucks, which are largely diesel.

Very little recent data has been published on the number and composition of businesses operating trucks in Australia. Based on unpublished data from the ABS, the NRTC estimates that in 1995 there were 210,000 fleets operating freight carrying trucks over 4.5 tonnes GVM. Across all States, over 70 per cent of these fleets are single vehicle operators. Only a small number of large fleet operators exist.

Table 2-3 below presents the proportion of fleets by fleet size.

Table 2-3

- 72 per cent operate with only a single vehicle;
- 17 per cent operate with two vehicles;
- 10 per cent operate with between three and nine vehicles;
- 1 per cent operate with between 10 and 49 vehicles; and
- less than 1 per cent operate with more than 50 vehicles.

2.2.2 Number of vehicles operated by fleets and the effect on sampling

From the NRTC figures there are approximately 210,000 fleets comprised of vehicles over 4.5 tonnes (for the purposes of this project we assume the same numbers over 3.5 tonnes). About 98% of these can be classified as small (ie. 1-10 vehicles).

Based on the information presented above the distribution in Table 2-4 below can be estimated for vehicles over 4.5 Tonnes or for the purposes of this project over 3.5 tonnes.

Table 2-4: Analysis of Diesel Fleets over 4.5 tonnes

Size of Fleet	Percentage of fleet owners	Number of fleet operators	Total vehicles	Percentage of Vehicles > 4.5 Tonne
1 only	72	151,000	151,000	38%
2 only	17	35,700	71,000	18%
3-9 (Average 6 used)	10	21,000	126,000	31%
10-49 (Average 20 used)	1	2100	42,000	11%
>49 (Average 100 used)	<1	100	10,000	2%

Using the above estimates sampling of test vehicles was undertaken to the extent possible in accordance with Table 2-5 to ensure a representative sample.

Dealerships were considered as a source of non-fleet vehicles. A range of these dealers were selected to ensure a representative sample of vehicle makes, ages and conditions was obtained. Care was taken to avoid over sampling from an individual dealer that trades in vehicles aimed at a particular market segment.

Table 2-5: Vehicle sampling distributions

Vehicle Mass Category (GVM) & Fleet/Ownership Type	Total to be tested			Source
Vehicles <3.5 t	**165**			
All Types				From any source, provided that where a fleet is used as the source, ≤20 vehicles in total are sourced from that fleet and ≤8 per age category from that fleet
Vehicles ≥3.5t	**450**			
	Proportion	Target	Range	
1-2 vehicle operations	56%	250	230-270	From any source
Small Fleets (3-9 vehicles)	31%	140	120-160	From small fleets
Med-Large Fleets (≥10 vehicles)	13%	60	50-80	From med-large fleets (sourced from no less than 3 different fleets)

2.2.3 Number of Vehicles to be Sampled

The vehicles tested are listed in Appendix 1 with details of make, model, engine manufacturer, ADR category, ADR compliance date, GVM, Tare and odometer reading. During the course of the project it was decided to test 6 more vehicles and to repair an extra 13. This increased the sample to 621 tested, 120 diagnosed and 53 repaired and re-tested.

Table 2-6 compares the number of vehicles tested with the NEPC specified test sample (in brackets). The 6 extra vehicles tested were all light vehicles. The difficulty of obtaining old (pre-1989) vehicles meant that the sampling target was not reached for old light vehicles and particularly for old articulated trucks. To maximise the statistical validity of sampling additional vehicles were sampled in the 1990-1995 age groups.

Table 2-6 Vehicles tested

Vehicle Category[1]	No of Vehicles to be Tested by Year of Manufacture			Total
	1980-89	*1990-95*	*1996-00*	**621 (615)**
[2] Passenger Cars, Off Road Vehicles, & Light Trucks & Buses <3.5 t GVM	53(55)	62(55)	56(55)	171(165)
Rigid Trucks ≥ 3.5-12 t GVM	55(55)	55(55)	55(55)	165(165)
Rigid Trucks & Buses ≥ 12 t < 25 t GVM	55(55)	55(55)	55(55)	165(165)
[2] Articulated Trucks ≥ 42.5t **GCM**	28 (40)	52 (40)	40(40)	120(120)

Notes:

GVM = gross vehicle mass; GCM = gross combination mass (vehicle + trailer)

Diesel vehicles sold in Australia before 1996 only had to meet smoke emission standards. Vehicles (with the exception of vehicles less that 4.5 tonnes that were not required to meet a ADR 70 limits on particle emissions) sold after 1996 had to meet ADR 70/00 standards for smoke, particulates and NOx, It was therefore determined to combine the 1980-1989 and the 1990-1995 age groups for the purpose of analysis. This was done by aggregating the eight pre-ADR 70 vehicle categories into four categories.

2.3 Vehicles rejected from test.

Twenty nine vehicles were rejected from testing during the course of the project. This did not include those vehicles that could not start due to a flat battery or which were rejected because of their size or weight (eg. large mobile cranes, cement trucks).

Table 2-7 lists the vehicles that were accepted for test but could not complete the test sequence.

Table 2-7: Cause of Rejection and Frequency

Reason for Rejection	Number rejected	% of vehicles tested
Constant 4WD	1	0.2%
Mechanically unsound	4	0.6%
Exhaust leaking	5	0.8%
Traction control fitted or power divider disabled	9	1.5%
Exhaust diameter larger than standard size	9	1.5%
Tyre overheat	1	0.2%
TOTAL	**29**	**621**

Appendix 2 contains further details of the reasons for rejection.

Over half (18 out of 29) of the rejected vehicles were the very large (>25t) NCH vehicles. These were rejected mainly due to the inability of the vehicle to transfer power to the one set of drive wheels or because the exhaust pipe was a larger diameter than the standard 125 mm. For a test and repair program the following is recommended:

- The dynamometer used (in a fixed site only) has two sets of drive rollers rather than one.
- The exhaust sampling system accommodates 150 mm. diameter exhaust stacks.

The mobile dynamometer allowed testing to be carried out at fleet operators' yards, thereby limiting inconvenience and downtime. However as the project required a high proportion of individual owner and small fleet vehicles to be tested, a large number of vehicles still had to be collected and driven to a fixed test site.

To encourage participation from owner operators, owners were paid between $50 and $100 depending on the size of the vehicle in recognition of the disruption to their commercial activities.

2.3.1 Strategies for sourcing vehicles

The following strategies were also used to obtain a diverse and representative range of vehicles.

- The Australian Trucking Association (ATA) and their members provided vehicles for testing.
- A number of operators made their fleet sites available for the mobile testing system. This had the benefit of minimising the disruption to their operations; it allowed a higher throughput to be achieved and also acted as a hub from which to source other vehicles.
- To acquire four wheel-drive (4WD) vehicles, letters were sent to 25 4WD clubs and three responded. Parson's staff were then gave presentations at these clubs. Members interested were invited to attend a Bar-B-Q at the Parsons emissions testing facility in Auburn on consecutive weekends to have their vehicles tested. The result of this effort was a high level of attendance from the three clubs.
- Truck hire, auction yards and truck sale yards were visited, while people selling vehicles privately via the print media were contacted by phone. A variety of used truck sale yards and hire companies then participated in the program and. provided a source of individually owned vehicles of all makes, models and ages and of varying maintenance histories.
- The Flemington Fruit and Vegetable market, Western Sydney waste disposal site and quarry operators also gave approval to set up the mobile testing equipment on site and to invite people to have their vehicles tested as they arrived or departed.
- Council fleet depots and bus depots operated by government, private industry and the Olympic Games Authority were also used for testing.

The following short list of participating companies is an indication of the variety of vehicle sources and vehicle backgrounds included in the study.

- Private owners from various sources
- 4WD clubs: the Southern Cross 4WD Club, Toyota Landcrusier Club, and George's River Overland Club.
- Fleet operators: Australia Post, 1st Fleet, McPhee, TNT, Boral, Toll SPD, Arnotts etc
- Truck Service Centres: International Trucks, Mercedes Benz, Scania and Mack Trucks Australia
- Truck Hire: Hertz, Budget, Ranger, Sargents and Kennards
- Councils: Parramatta, Hawkesbury and Liverpool
- Western Sydney Waste Disposal centre
- West Bus, Forest Coach Lines and Sydney Buses
- Truck Sale yards - Gilbert and Roach, All Trans, City Hino, Auburn Automobiles, Villawood Trucks, Bastians, Windsor Toyota and Stillwell Trucks

Specific vehicle details of all 621 vehicles tested are listed in Appendix 2.

2.4 Fault diagnosis and repair

2.4.1 Selection of vehicles for repair

A sub set of 120 vehicles were recalled following the initial test and inspected for emission related faults. Of these 53 were selected for repair. Table 2-8 shows the number of vehicles undergoing diagnosis for each category and the number repaired (in brackets).

Table 2-8: Vehicle Diagnosis / Repair Matrix

Vehicle Category	No of Vehicles Diagnosed and Repaired ( ) by age category			Total
	1980-89	***1990-95***	***1996-00***	**120 (53)**
Passenger Cars, Off Road Vehicles, & Light Trucks & Buses <3.5 t GVM	7 (4)	14 (9)	12 (2)	33 (15)
Rigid Trucks ≥ 3.5-12 t GVM	10 (6)	12 (6)	12 (6)	34 (18)
Rigid Trucks & Buses ≥ 12 t < 25 t GVM	12 (6)	9 (4)	12 (5)	33 (15)
Articulated Trucks ≥ 42.5t **GCM**	6 (4)	7 (0)	7 (1)	20 (5)

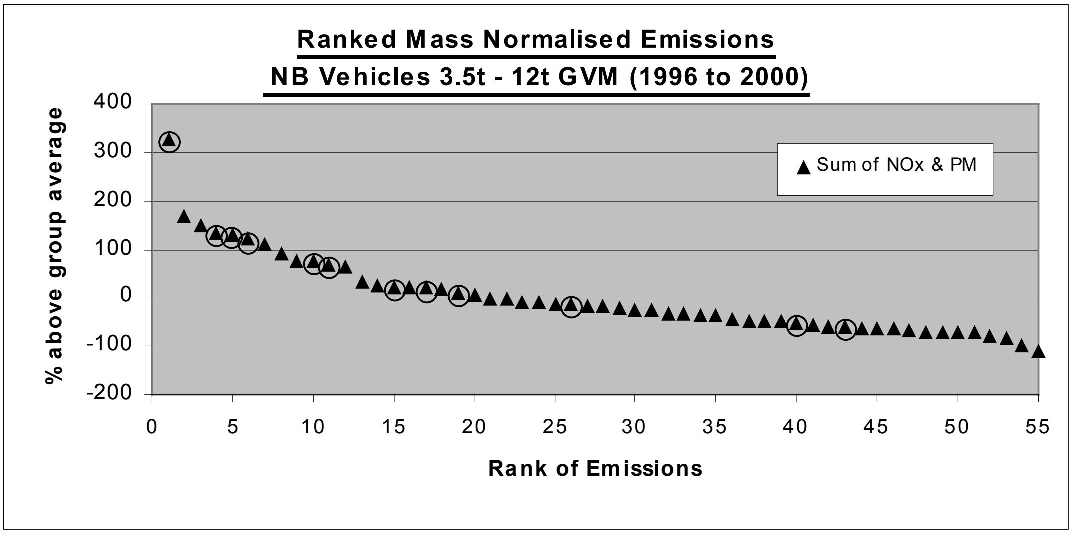
( ) vehicles selected for repair

2.4.2 Ranking and selection of vehicles for fault identification and repair

The methodology used to select vehicles for diagnosis is outlined below using the 3.5 to 12 tonne category as an example.

In selecting vehicles for diagnosis the sum of the percentages above the group average for NOx and PM emissions were ranked in descending order and plotted for each vehicle group. From these plots, the variation in summed emissions can be seen and vehicles of interest easily identified for diagnosis and eventually repair. As an example the 12 vehicles to undergo Fault Diagnosis from the 3.5-12t Rigid Truck, NB vehicle category (1980-1995) have been circled in Figure 2-3 and listed in individually in table 3.1.

Figure 2-3: NB Vehicles (1996– 2000) Ranked, Mass Normalised Emissions



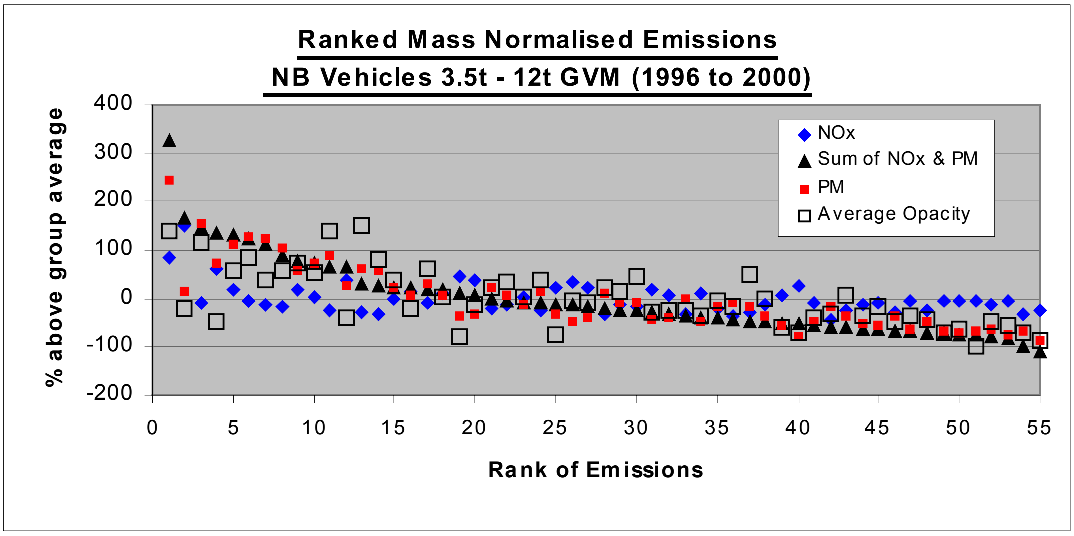
Once the data was ranked, specific vehicles were selected from:

- high ranking vehicles to enable the benefit of repair to be established.
- mid-ranking vehicles to establish the point at which significant emission related faults can no longer be identified and the point below which repair action does not make a significant difference in emissions performance.
- low emitting vehicles to establish if vehicles below average emissions can also benefit from repair.
- Having selected vehicles to undergo a diagnostic inspection, contact was then made with the owners of the vehicles to request they be made available. Not all vehicles initially

selected were available and so a vehicle closest to the initial rank was selected until a vehicle became available.

Vehicles were ranked in descending order of NOx plus article emissions and graphed as in Figure Figure 2-4. For the purpose of analysis each vehicle's corresponding emissions of particles, NOx and average smoke opacity were also plotted. The data was plotted as a percent above or below the mean for each pollutant.

Figure 2-4: Emissions ranking for vehicle category NB

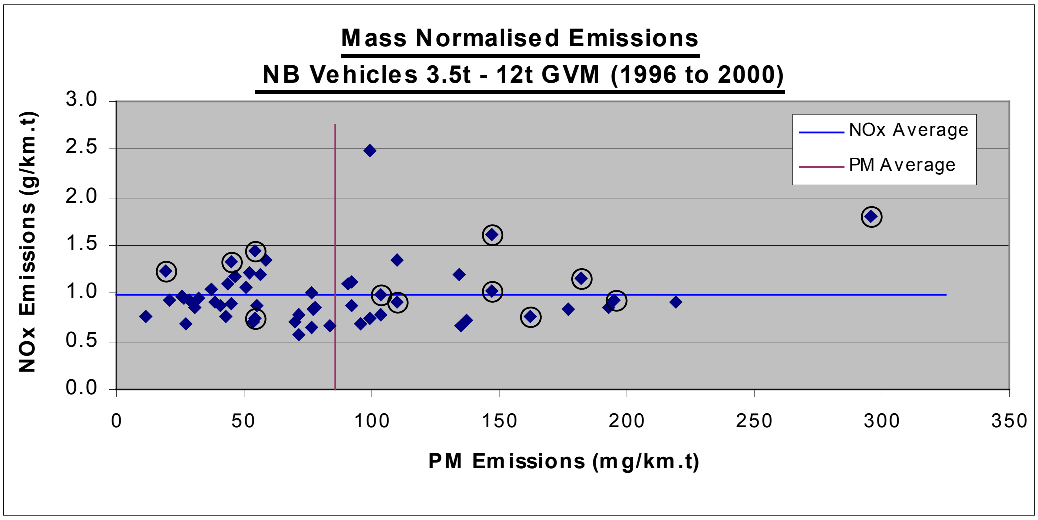


It should be noted that with the exception of a few high emitting vehicles NOx values varied little from the mean for all age and size groups. From the above plot it is clear that PM (red squares) has the greatest effect on determining vehicle ranking as NOx (blue stars) tends to stay just above or below the average line.

Smoke opacity is highly scattered and to some extent a lesser indicator of a vehicles emission performance and so has not been used to rank vehicles.

Figure 2-5 illustrates the PM and NOx distribution in grams/km.tonne rather than a percentage above the average. Again the NB category is used as an example of the plots used. The horizontal line is the NOx average value and the vertical line the average PM value for the NB category.

Figure 2-5: NB Vehicles (1996– 2000) NOx v PM emissions



Note: Circles represent vehicles selected for fault diagnosis.

Therefore the high emitting vehicles for the category are those in the upper and right hand quadrants.

2.4.3 Fault analysis and repair

A licensed diesel repair shop - Cooks Diesel Pty Ltd, was engaged to carry out all diagnostic and repair work. By using the one organisation throughout the project a more consistent and controlled standard of inspection was achieved. This improved the understanding of the relationships between emissions and engine operation/faults.

The cost of the each diagnostic was limited to an average of $200 per vehicle. This was found to be an appropriate funding level to enable the repairer to properly identify potential faults.

Three worksheets were developed to assist in recording information and streamlining the diagnostic process. Samples of these worksheets are at Appendix 1. Different worksheets were used if the vehicle emissions were either:

- Clear smoke – high NOx due to lean burn
- Black smoke – high PM due to overfuelling
- Blue smoke - high PM due to engine wear

The worksheets also facilitated the estimation of the cost of parts and labour to rectify the faults identified.

After completion by the mechanic the worksheets were assessed to determine if the vehicle would be repaired. The following issues were considered in selecting vehicles for repair:

- The presence of repairable faults
- The nature of the fault/s.
- The estimated cost of the repair;
- vehicle make and model, use, odometer, engine type and whether it was sourced from a private, government or fleet operator.

Once selected the vehicle owner was informed of the recommended repair and approval gained prior to proceeding with the repairs. Depending on the availability of parts a vehicle could be out of service for a day or up to a week. However, generally vehicles were returned the next day.

On completion of the repair the vehicle was re-tested.

The following information was recorded during the repair phase to enable a cost/benefit assessment of the repair:

- General condition of the vehicle prior to repair
- Nature of repair
- Cost to repair –labour and parts
- Time to repair
- Change in emissions performance
- General condition of the vehicle following the repair

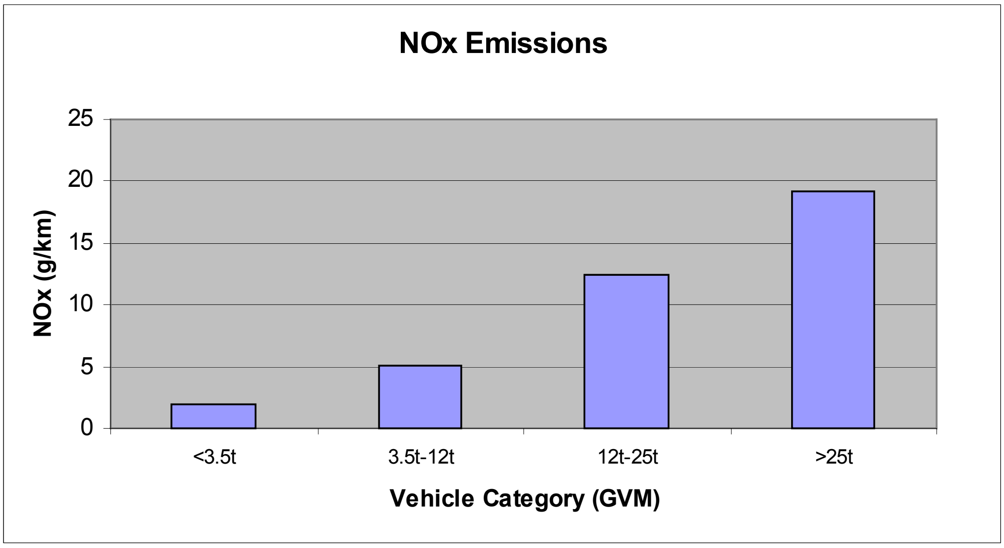
3 RESULTS: FLEET EMISSIONS

3.1 NOx Emissions

3.1.1 Impact of vehicle mass

These result shows that the increase in NOx g/km emissions across the increasing vehicle size categories is approximately linear with vehicle mass. This result is not unexpected as NO_x emissions are a function of engine load and the consequent fuel consumption. NOx emission concentrations from different diesel engines of the size range of vehicles in this study would generally be expected to have NOx emission concentrations as a function of engine load of a similar order. The mass emission rates would therefore scale approximately in proportion to engine exhaust mass flow rates, and thus power output. Therefore the larger vehicle classes which have significantly higher energy outputs for the test cycle, would exhibit higher NOx mass emissions.

Figure 3-1: NOx Emissions by Vehicle Category - g/km



As NO_x emissions in g/km correlate with vehicle mass, it follows that, if in-service emission levels were to be measured and regulated in g/km, then different limits would be required for each vehicle size/age category.

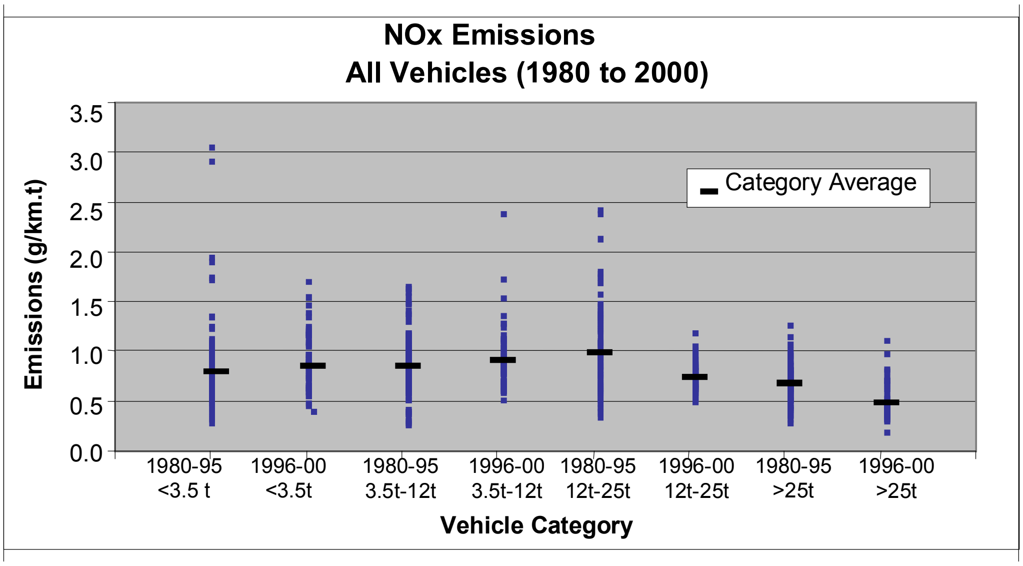
3.1.2 NOx emissions normalised for vehicle mass

When considering results normalised for test mass (g/km.tonne), as shown in Figure 3-2 NOx emissions vary little across the vehicle categories with the exception of buses. NOx emissions averaged between 0.5 to 1.5 g/km.tonne across the vehicle categories.

NOx emissions are greatest for the 12-25 tonne vehicles (1980 – 1995) and 3.5-12 tonne vehicles (1996 – 2000). Late model 12t-25t vehicles and all those over 25t had lowest average readings. The lower emissions for these classes is probably due to the fact that most of these vehicles are sourced from the United States and Europe and are built to more stringent emission standards than required in Australia.

Variation in emission performance was largest in the pre-ADR70 vehicles. The highest emitters were in vehicles less than 12 tonnes.

Figure 3-2: NOx emission distribution (all vehicles)



There was a considerable range of performance within each vehicle category. This variation is likely to be a result of many factors such as engine design, certification limits and vehicle power to weight ratios, as well as engine condition. The variation relative to the respective mean values for each vehicle category is similar

The distribution of NOx emissions (see histograms Appendix 10) for vehicles in all categories show that approximately 75% of the vehicles in each category emit between 0.8 to 1.2 g/km.tonne of NOx. Although very few vehicles were identified as having NOx emissions significantly above average some vehicle did exceed the average by a factor of three.

Buses (ADR category ME) have been separated out from the 12-25t category due to the unusual high rate of NOx from these specific vehicles that significantly higher than the rest of the fleet.

For all vehicle categories, except buses, 80% of the fleet had NOx emissions of less than 1.2 g/km.tonne. For buses, only 40% of vehicles had emissions less than 1.2 gm/km.tonne. The distribution curve for buses does not conform to the typical bell shaped distribution typical of other categories and contains more high emitters than the other categories (Figure A10.3, Appendix 10). For example 18% of buses had emissions over 1.8 g/km.tonne compared to only 2% for the other categories.

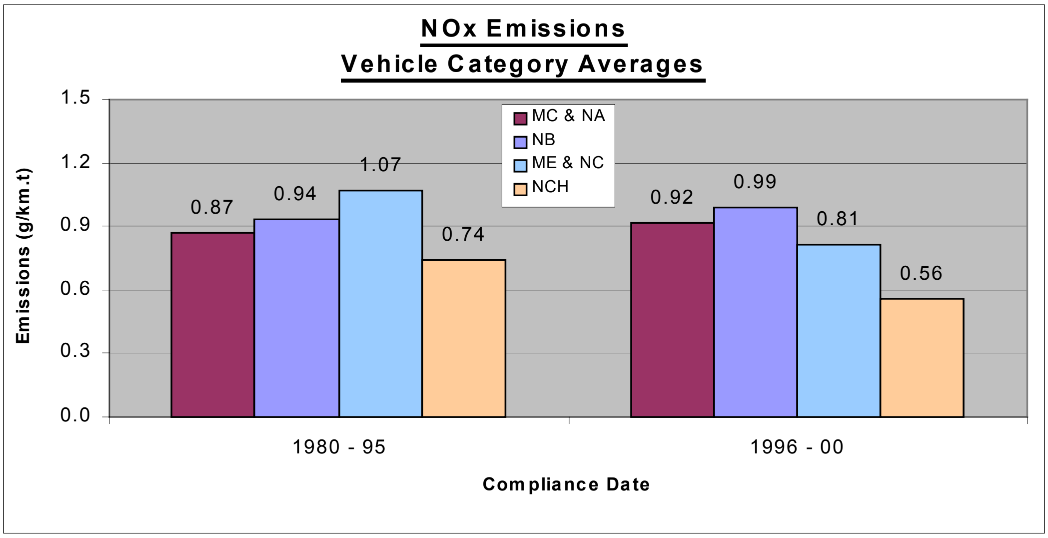
3.1.3 Effect of age, emission standards and accumulated distance travelled

The study found no correlation between date of manufacture, as established from the ADR compliance plate or accumulated distance travelled (odometer readings) and NOx emissions.

The lack of correlation could be the result of three likely factors. First, emissions of NOx do not appear to significantly change with age. This suggests that NOx emissions are a function of the design of engine components that are relatively insensitive to deterioration.

Secondly, the introduction of tighter emission standards in 1995 did not have a significant effect on NOx emissions, particularly for vehicles less than 25t. GVM. This suggests that the introduction of ADR70 did not impose additional requirements for control of NOx on vehicles entering the Australian market.

Figure 3-3: Average NOx Emissions



Finally, high emitting vehicles appear in both pre and post-ADR 70 age groups, giving rise to a high degree of scatter in the data.

Figure 3-4 to Figure 3-7 provide typical illustrations of NOx emissions for age and odometer reading.

Figure 3-4: NOx Emissions - NB Vehicles 12-25t (1980 – 2000)

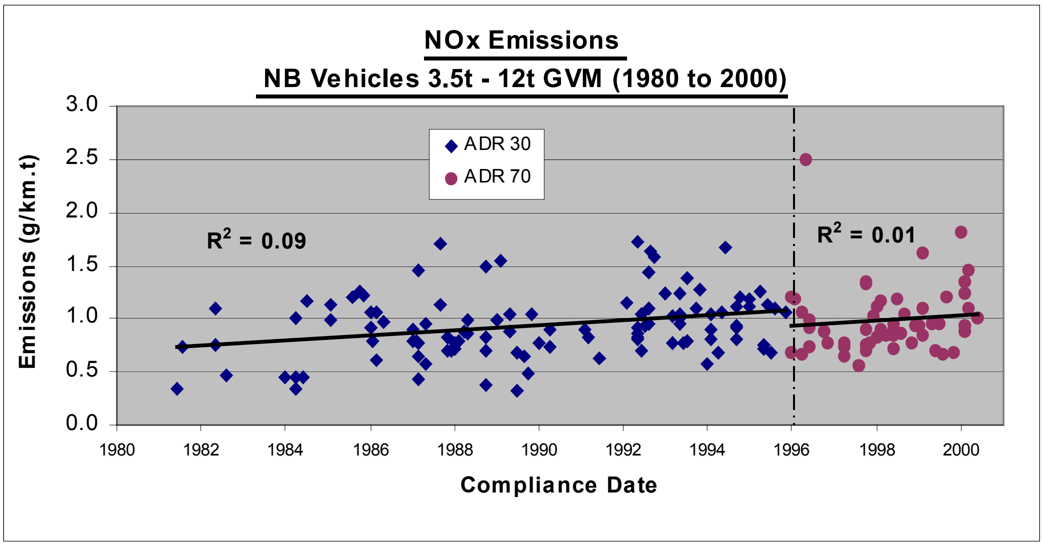


Figure 3-5: NOx Emissions - NCH Vehicles >25t (1980 – 2000)

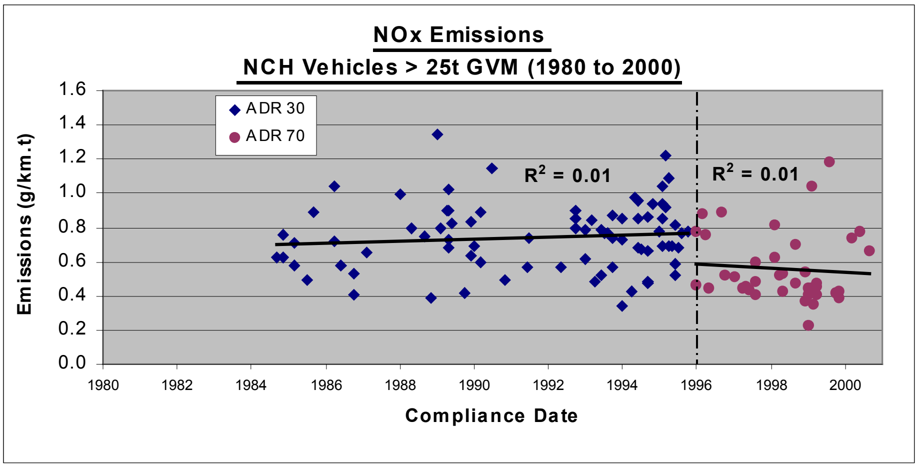


Figure 3-6: NOx Emissions by Distance Travelled NB Vehicles (1980– 1995)

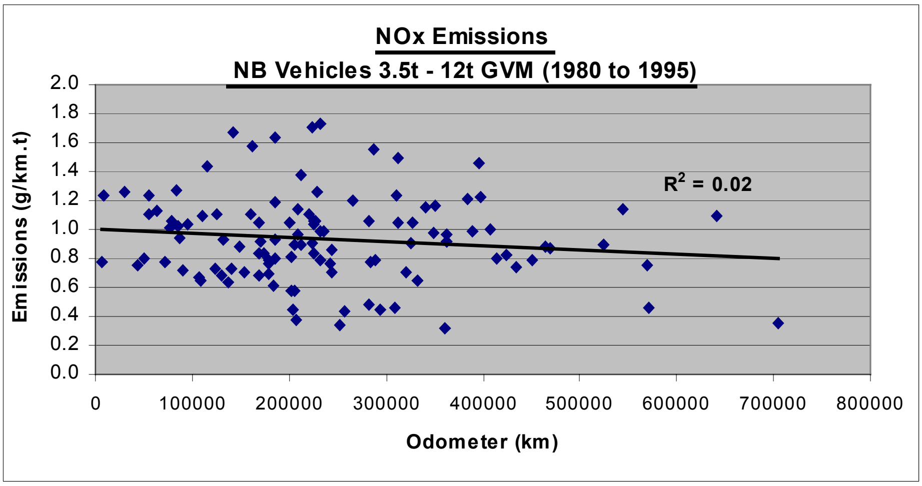
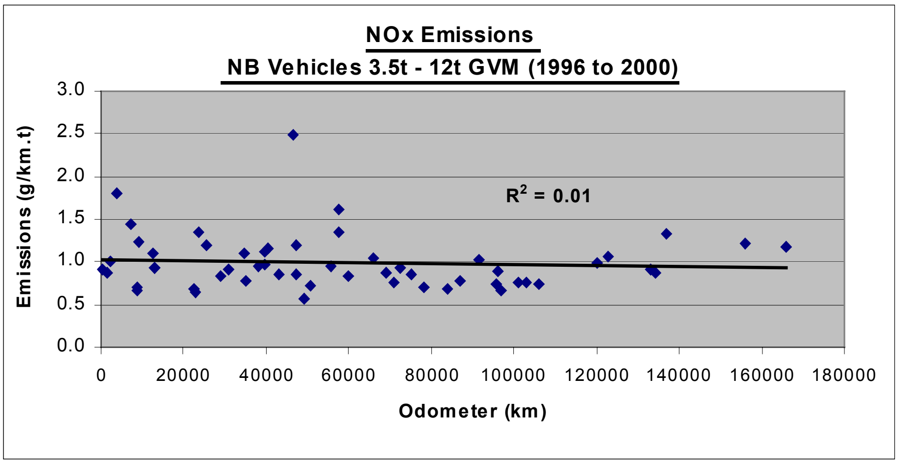


Figure 3-7: NOx Emissions by Distance Traveled NB Vehicles (1996-00)



3.1.4 Summary: NOx Emissions

- On a g/km basis the larger vehicles are the highest emitters. However, when the payload being carried is factored in, by normalising the results on a g/km.tonne basis, then there is very little difference between vehicle emissions per tonne. On a normalised basis the large (NCH category, over 25 tonne) vehicles have the lowest NO_x emissions..

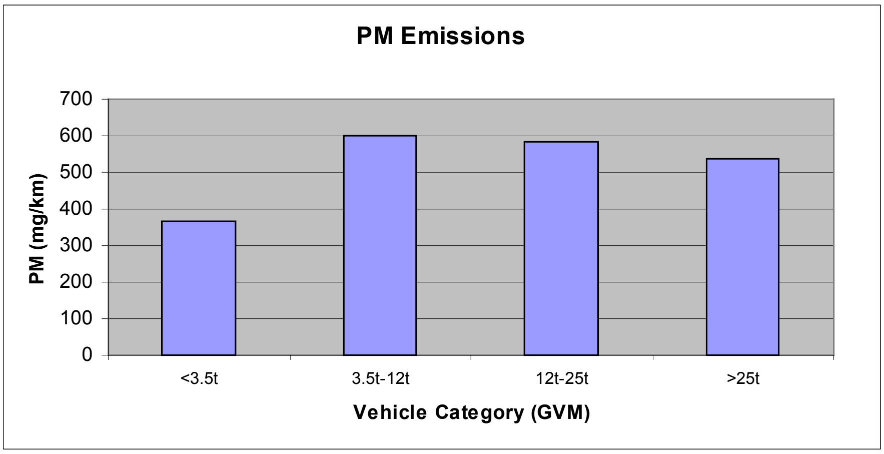
- Buses are very high emitters of NOx, even on a g/km.tonne basis, when compared to the rest of the fleet.
- A relatively small number (xx%) of gross emitters with emissions of up to 3 times the fleet average.
- The introduction of emission controls in 1996 specified in ADR70 appears to have had little effect on NOx emissions. .
- There study found no correlation between the level of NOx emissions and vehicle age or odometer reading.

3.2 Particulate Matter (PM)

3.2.1 Impact of vehicle mass

The mass emission of particulates from the light vehicle category is lower than from the other categories. Figure 3-8 shows that particulate emissions do not increase in proportion to the mass of the vehicle as NOx emissions do.

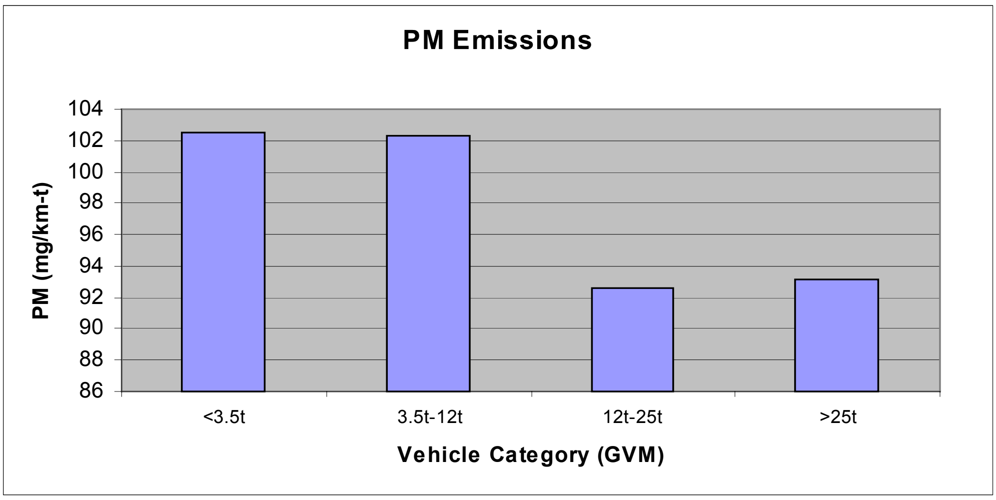
Figure 3-8: PM emissions all vehicles – g/km



3.2.2 Particle emissions normalised for vehicle mass

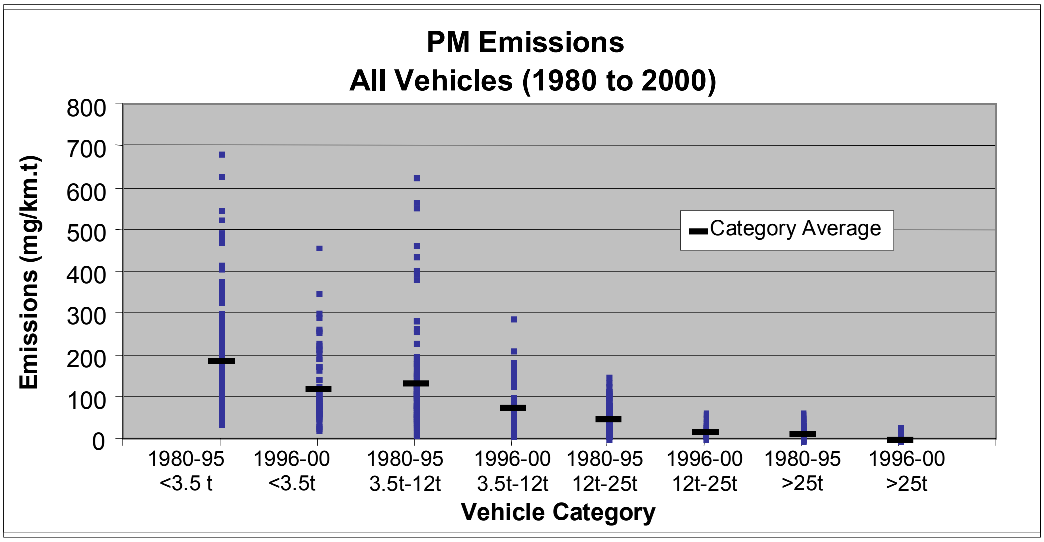
The normalised particle emissions (mg/km.tonne) decrease significantly with increasing vehicle size. That is, the transport of freight with larger vehicles results in much lower PM emissions per tonne of freight than with smaller vehicles.

Figure 3-9: PM emissions all vehicles – g/km.tonne



Using the normalised data the variation in the data is presented for each vehicle age and size category in Figure 3-10. The striking feature is the spread of data and the number of "gross emitting" vehicles in the light and medium duty sized vehicles. Some vehicles have particle emissions six times the average for their group. Pre-ADR70 vehicles (1980-1995) have a higher number of gross emitters and a larger spread of data indicating a larger potential benefit if emissions can be reduced in that age category.

Figure 3-10: PM emission distribution (all vehicles)



The distribution for the light-duty vehicles in Figure 3-10 shows that the PM emission levels vary considerably across the <3.5t (MC/NA) category and highlights the potential for emissions reductions. Compared to the 20% of light vehicles with emissions of over 225 g/km.tonne, only 10% of NB category vehicles and no NC or NCH category vehicles exceed these levels.

Consideration of the distribution of emissions within each vehicle category further illustrates the very large reduction in mass normalised emissions as the vehicle size increases. Table 3-1 compares the emission level of the emission level exceeded by the upper 20% of vehicles for each vehicle category. The level exceeded by the upper 20% of heavy NCH category vehicles is only around 12% of the level for light vehicles.

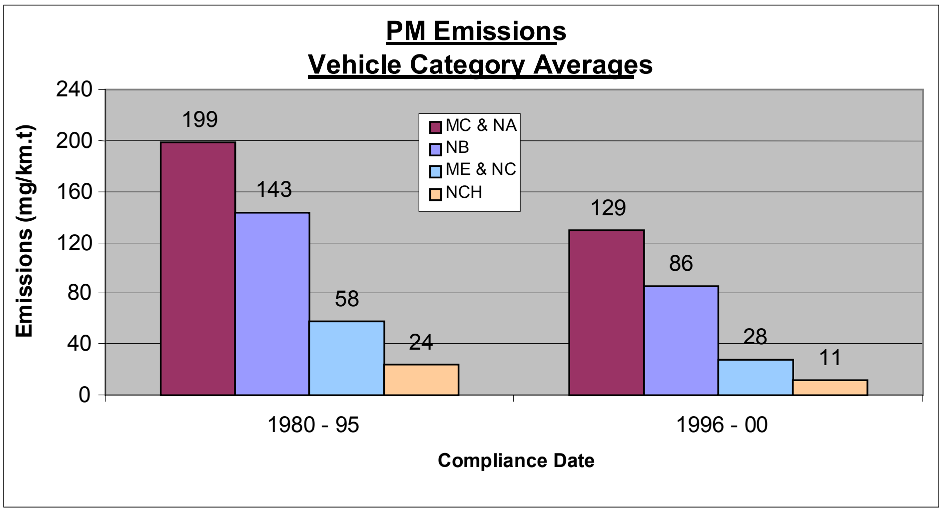
Table 3-1: Emission rates for the top 20% of vehicles

Vehicle Category	20% of vehicles emit higher than mg/km.t
<3.5 t	225
3.5 – 12t	175
12 - 25t	75
>25t	30

3.2.3 Effect of age, emission standards and accumulated distance travelled

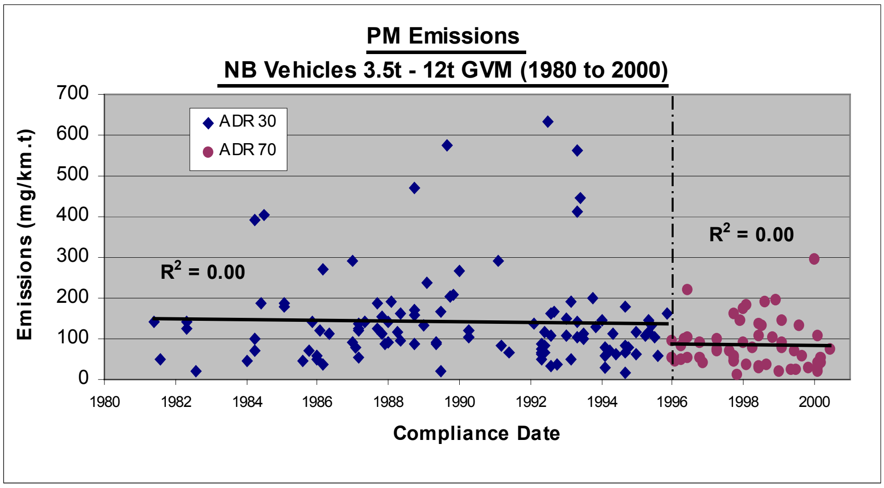
Emissions increase as the size of the vehicle decreases both the Pre and Post ADR70 groups. Also, PM emissions were lower for all Post ADR70 vehicle categories i.e. the newer vehicles as shown in Figure 3-11.

Figure 3-11: Average PM Emissions – Pre and Post ADR70



Although newer vehicles are generally cleaner than older vehicles there is no significant correlation between PM emissions and year of manufacture (ADR compliance date) for any vehicle categories. Figure 3-12 for the NB category illustrates this point and is typical of the other categories presented in Appendix 3.

Figure 3-12: PM Emission by year of manufacture - Pre and Post ADR70 NB Vehicles (1980 – 2000)



There is also no correlation of odometer readings with particle emissions for any vehicle category. Figure 3-13 and Figure 3-14 show the scatter of results for Pre and Post-ADR 70 groups respectively.

Figure 3-13: PM Emissions - NB Vehicles (1980– 1995)

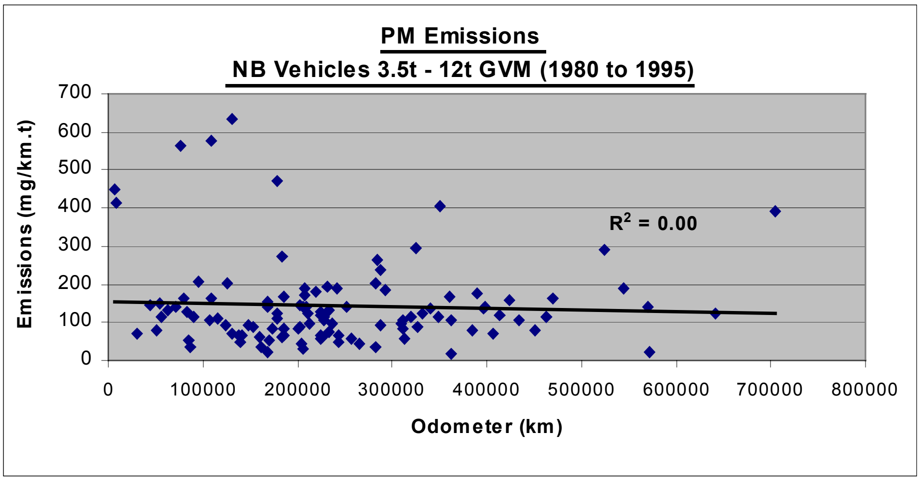
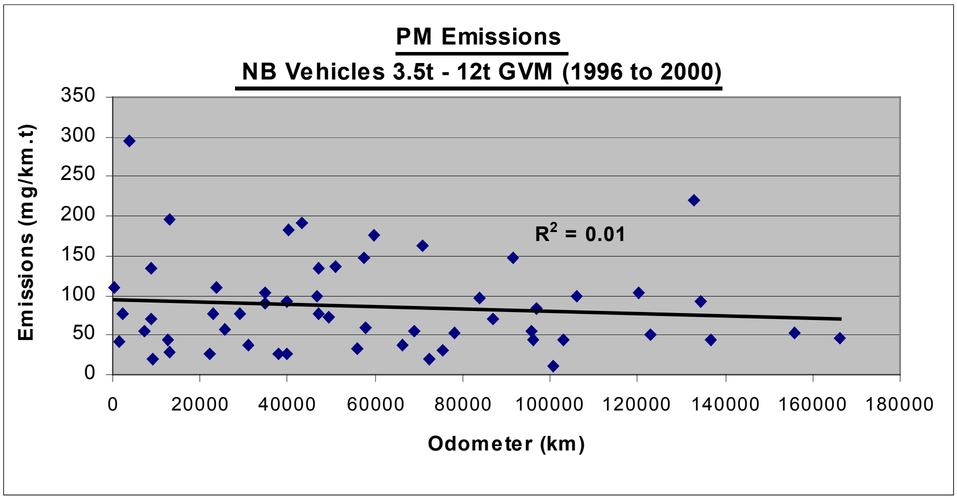


Figure 3-14: PM Emissions - NB Vehicles (1996– 2000)



The lack of correlation between the level of particle emissions and vehicle age or odometer reading is primarily the result of a randomness in the deterioration of particle emission performance. This suggests the timeliness and quality of maintenance a vehicle receives has a significant influence on particle emission performance.

Summary: Particulate Emissions

- Newer vehicles constructed to AD70 generally have lower emissions than pre-AD70 vehicles.
- Total emissions from trucks and buses under 3.5t are generally high and of similar values compared to the light commercial vehicles <3.5t. Total particle emissions are also a function of a vehicle's payload.
- On a mass normalised basis smaller vehicles are higher emitters than larger vehicles.
- The greatest variance in particle emissions occurs in the light and medium sized vehicle, under 25 tonne GVM, category. The high percentage of high emitters from light duty vehicles is consistent with that reported in the DNEPM Project 2-2 report.
- Some gross emitting vehicles have emissions levels up to 6 times the fleet average.
- No significant correlation between the level of particle emissions and vehicle age or odometer reading. The lack of correlation is primarily the result of deterioration of partilce emission performance. This suggests the timeliness and quality of maintenance a vehicle receives has a significant influence on particle emission performance.
- The profile of PM emissions across categories and within categories has a much greater variability between vehicles than found for emissions of NOx.

3.3 Smoke Emissions

3.3.1 Impact of vehicle mass

Across all size categories newer vehicles are somewhat lower emitters of smoke than older vehicles (Figure 3-15 and Figure 3-16). Vehicles built after 1995 and greater than 12 tonnes tend to be the cleanest vehicles. This reflects the fact that these vehicles are often built to the more stringent emission standards of their country of origin.

Figure 3-15: Smoke Maximum Opacity – all vehicles

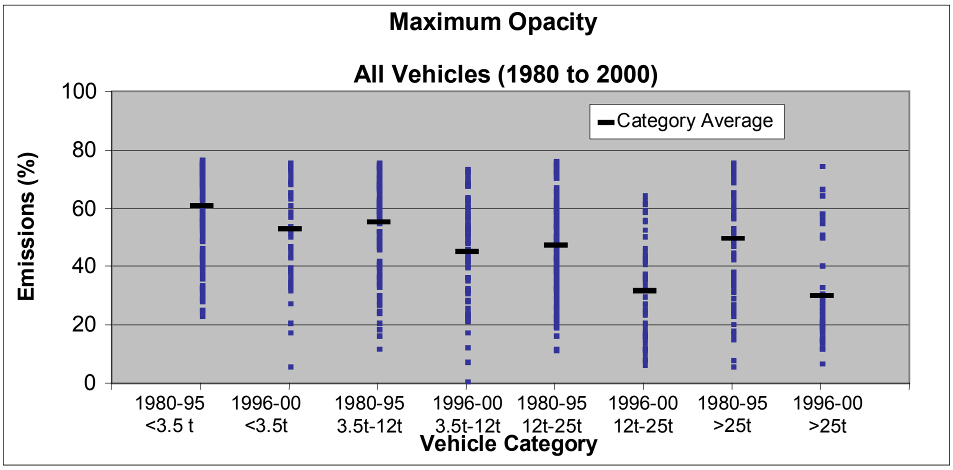
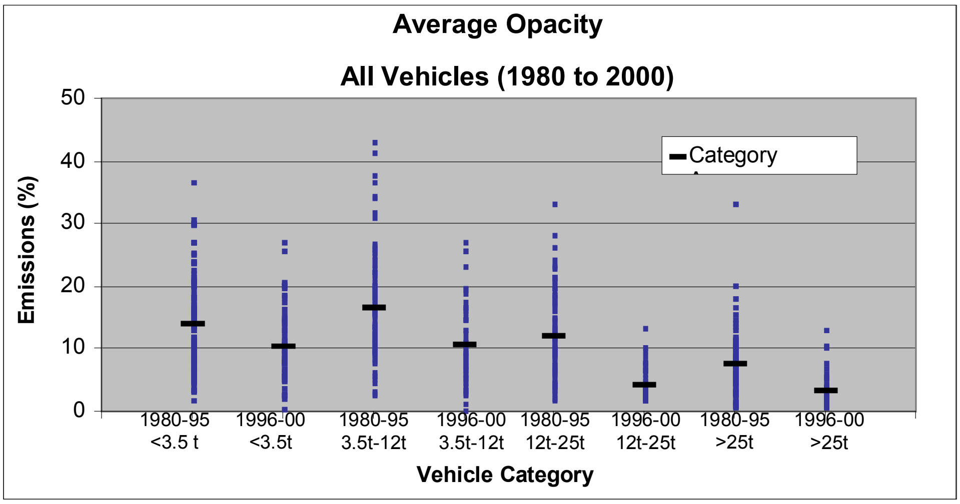


Figure 3-16: Smoke Average Opacity – all vehicles

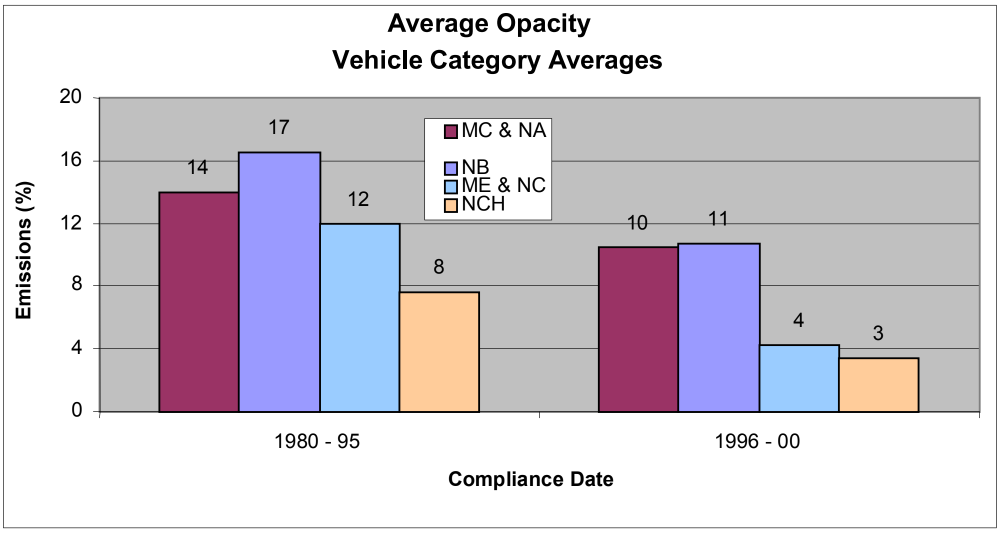


On average vehicles under 25 tonnes are the most significant emitters of smoke, especially in newer vehicles.

3.3.2 Effect of age, emission standards and accumulated distance travelled

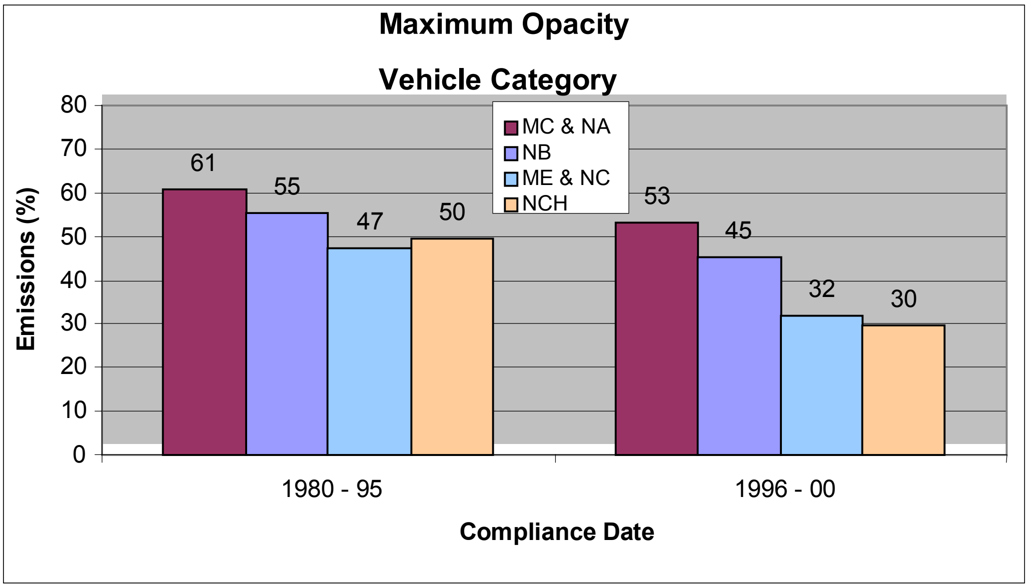
The newer post ADR70 vehicles as anticipated were lower emitters of smoke than the older engine technology vehicles that only had to comply with a steady state smoke test under ADR30.

Figure 3-17: Average Opacity – all vehicles



The picture changes slightly when the maximum rather than average smoke emissions are evaluated. The larger vehicles come into play with relatively higher maximum values. These high maximum emissions are what are seen as short black bursts of soot by the general public. Figure 3-18 illustrates this point but again the light and medium duty vehicles are still higher. As with average opacity the newer ADR70 vehicles are lower than the older ADR30 compliant vehicles.

Figure 3-18: Maximum Opacity –all vehicles



All vehicle categories show little correlation between smoke (both average and maximum) emissions and year of manufacture. The lack of correlation appears tto be the result of the high variability in smoke emissions.

Figure 3-19: Average Opacity - NB Vehicles (1980 – 2000)

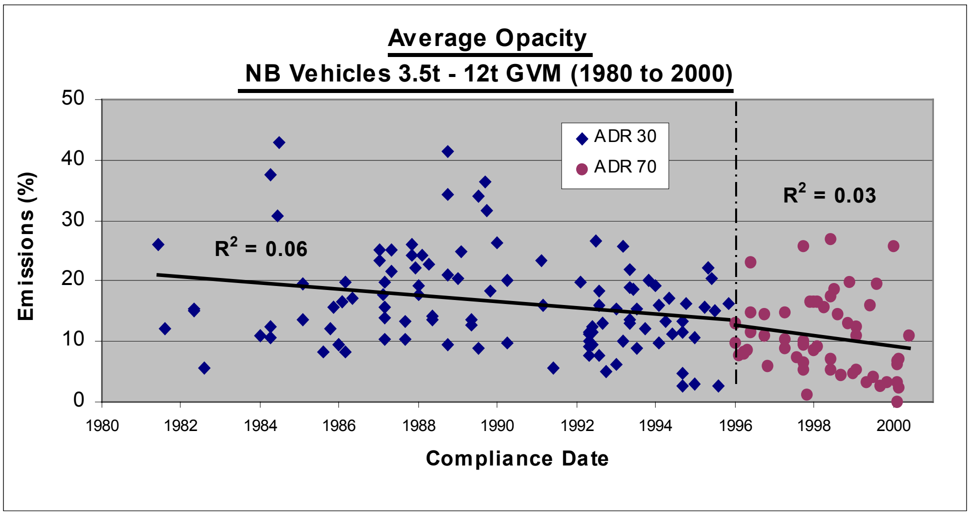
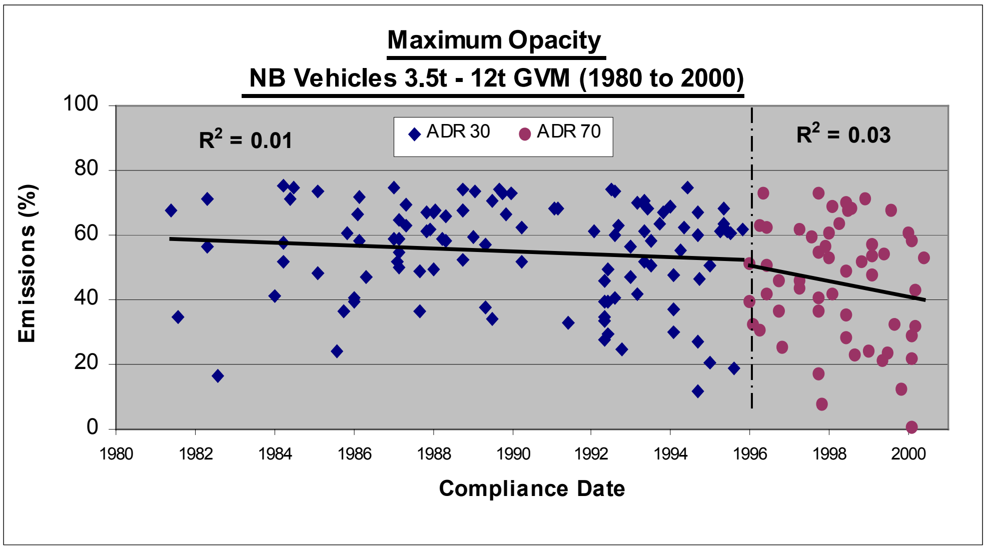


Figure 3-20: Maximum Opacity - NB Vehicles (1980 – 2000)



The *plots* show a trend of slightly lower emissions for the newer ADR70 compliant vehicles but still a large scatter exists. Refer to Appendix 4 for other category plots.

Figure 3-21: Average Opacity - NB Vehicles (1980– 1995)

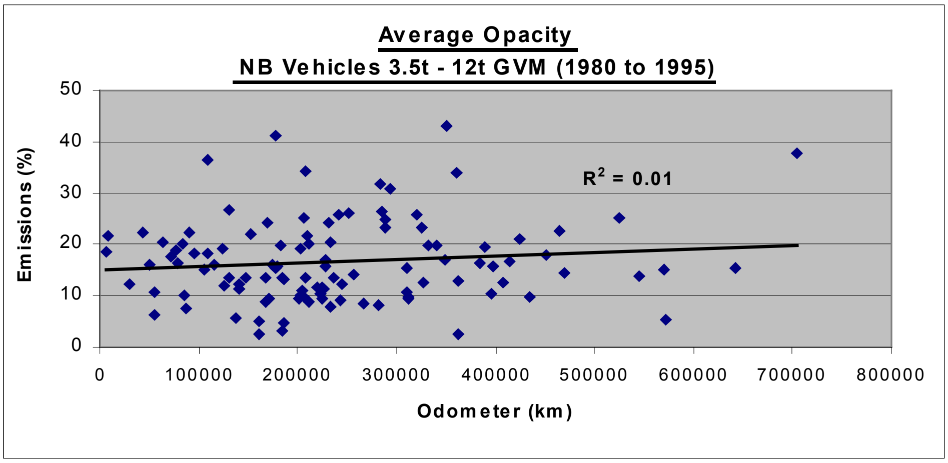
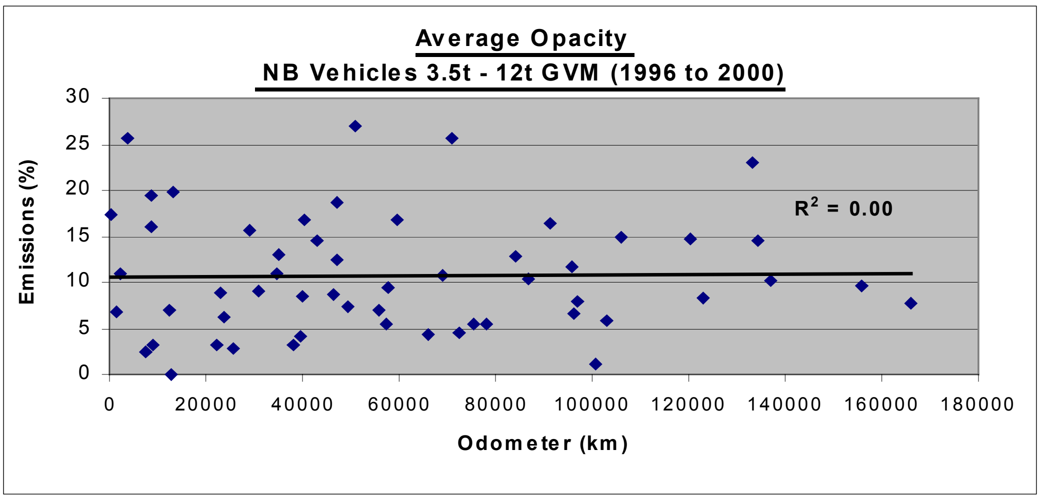


Figure 3-22: Average Opacity - NB Vehicles (1996– 2000)



3.3.3 Summary: Smoke Emissions

- Post-ADR 70 vehicles are lower emitters of smoke than pre-ADR 70 vehicles.
- There are large variations in the maximum and average opacity readings (from 10 to 75%) across all vehicle categories. Each category has vehicles that exceed 75% maximum opacity.
- The average opacity results are lower for larger vehicles.
- There is no correlation of smoke emissions, either maximum or average emissions, with vehicle age or odometer reading.

4 RESULTS VEHICLE EMISSIONS RELATED TO CONDITION OR FLEET SIZE

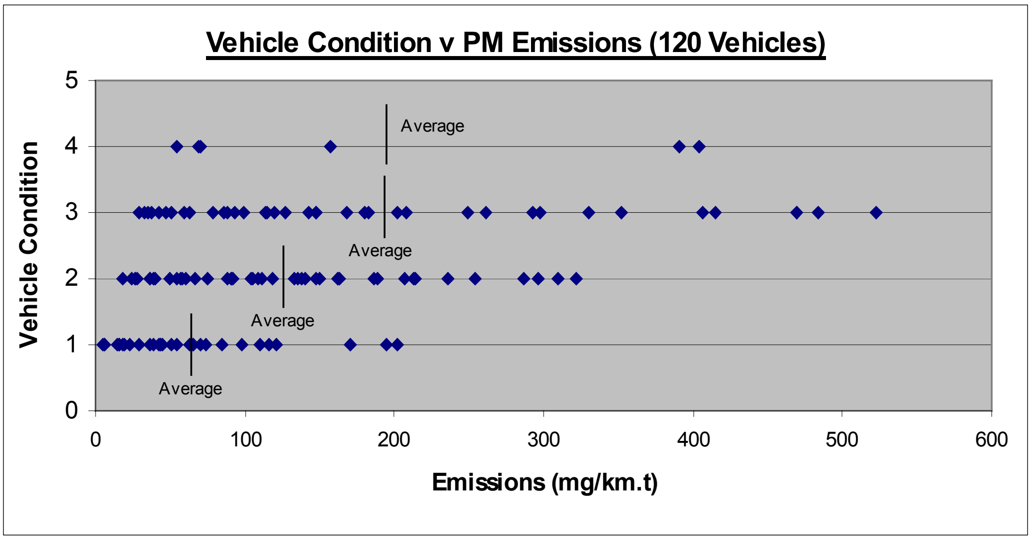
Using PM as the determinate the following section attempts to identify trends in those vehicles considered "gross emitters" by assessing their general condition and the fleet size from which they originated.

In addition, those vehicles submitted for fault diagnosis (120) were allocated a general condition rating. The rating was determined by the diesel mechanic and ranged from 1 to 5 with 1 being the best condition. Factors such as general cleanliness of the vehicle, oil/fuel/water leaks, condition of cab and engine, and signs that the vehicle was being regularly maintained were taken into account when assessing the rating.

The following figures present the ratings against various vehicle and fleet indicators to attempt to identify trends in emissions with vehicle operation and type.

It also shows that the diesel mechanic found it difficult to identify vehicles that were gross emitters based on just an inspection ie very few vehicles were rated above 3 even though many registered on the test as high emitters. Figure 4-1 supports this although on first inspection a trend is evidenced by the shift in the vertical average lines as the vehicle condition deteriorates which suggests - the higher the rating (on average) the higher the PM test result. The scattering of the data and the poor relationship with vehicles rated above 3 dismiss this relationship as the figure also shows that a large number of high emitting vehicles measured from testing (right hand side of the chart) where only given a 3 rating whereas a number of vehicles rated 4 actually tested relatively clean.

Figure 4-1: Vehicle Condition vs PM Test Result for PM –all vehicles



The diesel mechanics carrying out the work advised that physical tests and measurements were needed to confidently identify an emission related fault apart from obvious fuel pump tampering (cutting of setting screw lockwire) that can be detected quite easily by visual inspection. It is difficult to rate a vehicle's state of repair or emission status with any level of confidence based on an external visual inspection and that further more intrusive diagnostic work is required to assess a vehicle properly.

Figure 4-2 identifies the effect of the size of a fleet on emission performance. The red line is the group average which suggest the best vehicles are operated by small fleet operators. However the very small number of vehicles inspected in this group limits conclusions that can be drawn. Thus if a comparison is just made between the individual vehicle operators (private/owner drivers) and the medium to large fleet operators there is not a significant difference in the general condition although large fleets are slightly lower. This could be explained by private operators not financially able to afford the downtime to maintain their vehicles and large operators not allocating the required resources per vehicle to properly maintain the fleet.

Figure 4-2: Vehicle Condition by Fleet Size – all vehicles

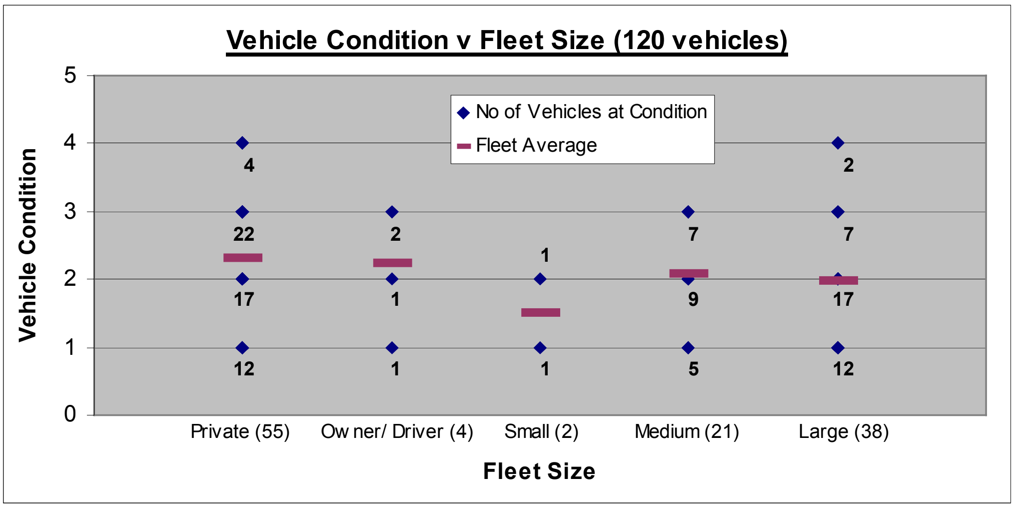
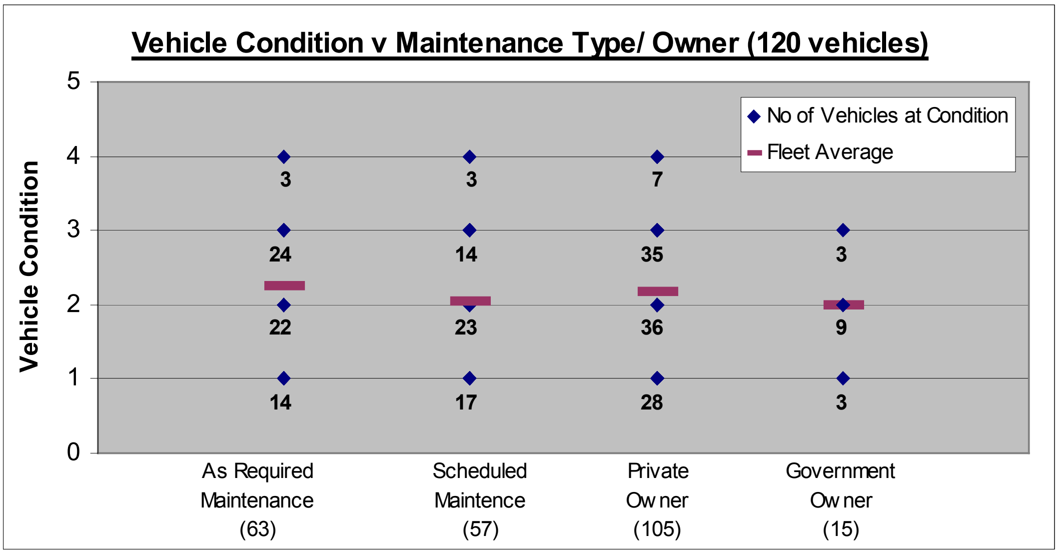


Figure 4-3: Vehicle Condition by ownership – all vehicles



While Figure 4-3 shows the government fleet to be in better condition than the private fleet operators it must be stated that the government fleet included vehicles that were only a few years old.

The terms "As required" or "scheduled" maintenance is an artificial label assigned to vehicles by the sourcing staff knowing the people or company from which the vehicle was obtained. It is not an absolute measure but is an observation made during the sourcing effort. Again it shows expected trends that scheduled maintenance will generally improve the vehicles condition.

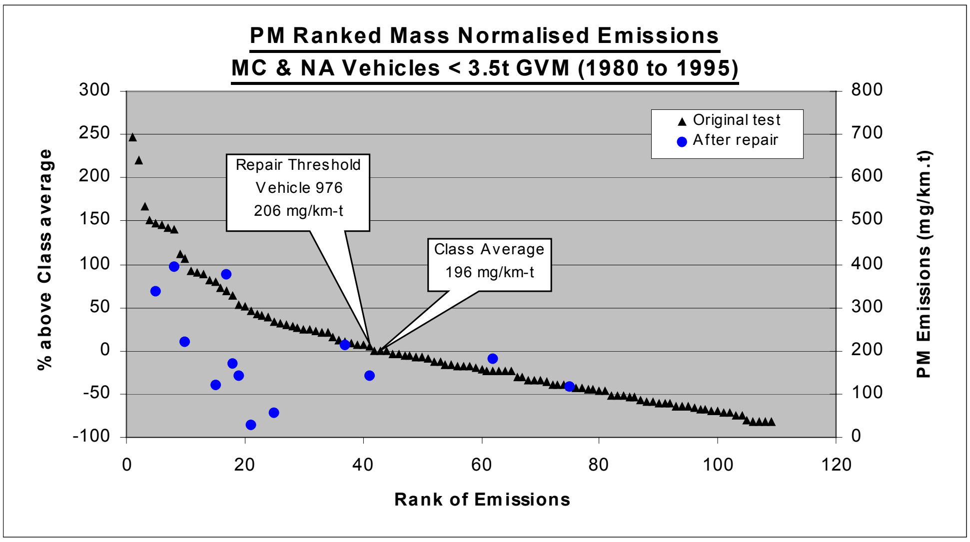
5 RESULTS: FAULT DIAGNOSIS AND REPAIR

5.1 Determination of Repair Threshold Points

To investigate the effect on the fleet from repair action each vehicle category was evaluated to determine the point - named the Repair Threshold Point (RTP) at which repair action ceases to provide a significant emission benefit.

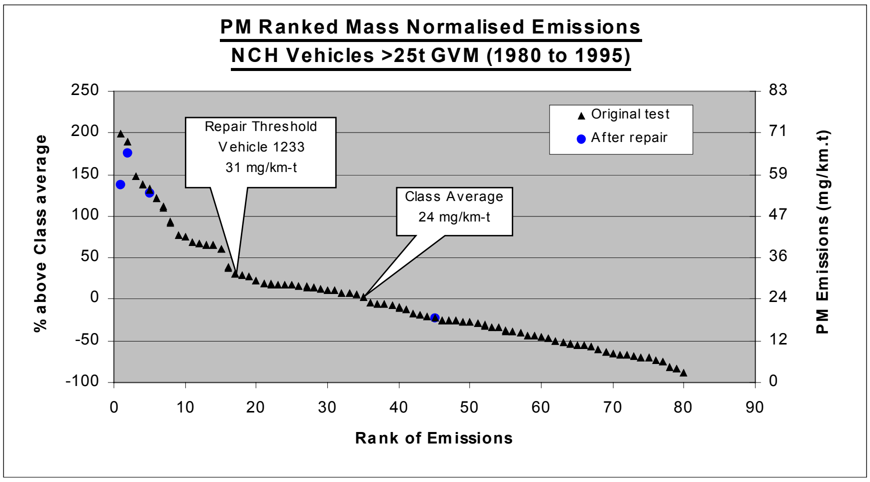
For each vehicle within each category, and for each emission, the percent difference between the vehicle's emissions and the category average was ranked. These rankings were then plotted and the specific emission for the repaired vehicles added to the plot. The RTP was then determined by examining the emission reductions for those vehicles that had been repaired (Refer to Figure 5-1 for an example) and selecting the lowest ranked vehicle that benefited from repair action. In the example the repair threshold is at vehicle test number 1269 at a PM emissions score of 113.2 mg/km.t.

Figure 5-1: NB Vehicles (1996– 2000) Ranked, Mass Normalised Emissions



However, in some cases there were insufficient repaired vehicles to justify selection of a repair threshold. In these cases, a repair threshold was selected at the inflection point i.e. where the curve suddenly increases in steepness indicating a jump in emission levels. The RTP was judged to be slightly higher than this point taking into account the fleet average line as per the NCH category vehicles (>25t) shown in Figure 5-2.

Figure 5-2: NB Vehicles (1980 – 1995) Ranked, Mass Normalised Emissions



The MC vehicle category RTP was selected differently again. For this category the pre and post ADR 70 categories were combined to provide a common RTP for both groups. This was done as none of these vehicles were required to meet the tighter emission standards brought in under ADR70. Thus there is little reason to expect vehicles manufactured prior to 1995 to perform any differently than those post 1995 that escaped the tighter emissions requirements. The RTP for both Pre and Post ADR70 groups is therefore 206mg/km.t. All other vehicle categories and pollutant graphs are contained in Appendix 9.

Having established the Repair Threshold Point (RTP) for each vehicle category, the changes in emissions were determined for those vehicles above the RTP for each pollutant. The average emissions for vehicles above the repair threshold were determined and compared to the emission levels at the repair threshold.

Therefore, by assuming that vehicles selected for repair (i.e. above the RTP) will be repaired to just below the repair threshold, the approach used by this study represents the minimum emissions that could be achieved, placing no emission benefits for those vehicles serviced below the RTP.

Table 5-1 presents the repair threshold points (RTP) selected for each vehicle category and the percentage of vehicles above the point. That is, if the RTP were used as the IM cut point then all those vehicles above the point would fail and require some level of repair.

Table 5-1: Repair Threshold Points

Vehicle category		PM (mg/km.t)*	NOx (g/km.t)	Smoke Ave %
MC <3.5t	**1980-1995**	206	1.07	16
	1996-2000	206	1.07	16
NB 3.5-12t	**1980-1995**	113	1.06	17
	1996-2000	104	1.24	17
NC 12-25t	**1980-1995**	72	1.59	12
	1996-2000	38	1.03	11
NCH >25t	**1980-1995**	31	0.94	11
	1996-2000	15	0.84	11

*Rounded to whole numbers

5.2 Frequency of vehicles exceeding the repair threshold

Older light duty vehicles under 3.5 tonnes and 12 to 25 tonnes had the highest percentage of vehicles that exceeded the effective repair threshold for particle emissions. In terms of NOx emissions lighter vehicles showed more responsiveness to repair than larger vehicles. Older vehicles showed a larger response to repair for smoke emissions than newer vehicles.

Table 5-2

		Percentage of vehicles sampled exceeding the effect of repair threshold		
Vehicle category		**PM**	**NOx**	**Smoke**
MC <3.5t	**1980-1995**	36%	13%	30%
	1996-2000	20%	30%	16%
NB 3.5-12t	**1980-1995**	13%	29%	41%
	1996-2000	13%	15%	15%
NC 12-25t	**1980-1995**	28%	9%	44%
	1996-2000	24%	9%	2%
NCH >25t	**1980-1995**	21%	14%	18%
	1996-2000	20%	10%	3%

5.3 Benefits of repair

This discussion is focussed on PM as it is the pollutant:

- that has been shown to vary the most within a category of vehicles;
- that has been shown to be most affected by repair, and;
- that is most likely to be the focus in a test and repair program.

The benefit of repair to the RTP for PM is presented in Table 5-3 below lists the change in emissions for each vehicle category from vehicles tested above the PM RTP and repaired. The consequential change in NOx and Smoke is shown as well as the change in PM.

For example in NB (Rigid Trucks 1980-1995) vehicles have been assigned an RTP of 113mg/km.tonne. If the emissions of all vehicles in the category above this value were reduced, through repair action, to this value particle emissions would be reduce on average by 94g/kmt. NOx would increase by 0.06g/kmt and smoke opacity would decrease by 4% using those vehicles tested in this study.

5.3.1 Emissions Reduction for PM Related Repairs

Using repairs to the MC vehicle category as an example the minimum emission reductions are shown in Table 5-3

Table 5-3: Minimum Emission Reductions for MC Category Vehicles

Repair Threshold Class 3 Vehicles	NOx Change gm/km-t	PM Change mg/km-t	Average Opacity Change %
PM => 206 mg/km-t (based on repair to test vehicle 1309)	+0.08	-69	-4
NOx => 1.37 g/km-t (based on repair to test vehicle 1695)	-0.18	-50	-8
Average Opacity =>16% (based on repair to test vehicle 1752)	-0.07	-38	-4

Note : Negative values indicate a reduction in emissions, positive numbers indicate an increase in emissions.

The data in the table illustrates that a repair on a vehicle that had a PM emission score above 206 mg/km-t would result in an average reduction of 69 mg/km-t PM, but an increase in 0.08 g/km-t NOx and an increase of 4% in average opacity per vehicle repaired.

However, if the vehicle was repaired to focus on reducing a high NOx score above 1.37 g/km-t, not only would the NOx emissions be reduced, but the PM (by a lessor amount than the targeted PM repair) and average opacity would also be reduced. According to the data if NOx or smoke are selected as the target pollutants the repair benefits differ. The benefits resulting from repairing vehicles down to the NOx or Smoke RTP's are provided in Appendix 9.

An analysis of the vehicles ranked highest for their combine NOx + particle scores showed clearly that excessive particle emissions were responsible for the high ranking in all but a few cases. It is also reasonable to assume that a mechanic will fix what they find faulty rather than focus on an emission score. It is therefore logical to determine the impact of repairing high emitting vehicles by use of the particle repair threshold based on repair of identified faults.

Table 5-4: Effect of repair using repair threshold for particles

Vehicle Category	Repair Threshold	NOx Change g/km-t	PM Change g/km-t	Average Opacity Change %
MC 1980-1995	>206 mg/km-t	-0.11	-124	-8
MC 1996-2000	>206 mg/km-t	+0.08	-69	-4
NB 1980-1995	>113 mg/km-t based on repair of test vehicle 1269	+0.06	-94	-4
NB 1996-2000	>104 mg/km-	-0.05	-60	-3
NC 1980-1995	>72 mg/km-t	-0.38	-24	+4
NC 1996-2000	>38 mg/km-t	+0.18	-14	+2
NCH 1980-1995	>31 mg/km-t	+0.1	-8	-3
NCH 1996-2000	>15 mg/km-t	-0.02	-11	-4

5.3.2 Summary – Repair Thresholds

The following points are made:

Particulate

- The RTP's and emission reductions for PM repairs conform to the anticipated pattern; higher repair thresholds for older vehicles and also higher thresholds for smaller vehicles.
- Significant PM reductions can be achieved by repairing vehicles below 25tonne with little change in NOx emissions. Vehicles above (NCH category) show improvement but to a lesser extent.

NOx

- The repair thresholds and the emission reductions for NOx repairs, like PM, also tend to conform to the anticipated pattern of higher repair thresholds for older vehicles and higher thresholds for smaller vehicles.
- Vehicles above 25t show relatively no change in emissions from repair.
- Except for light commercials (MC) generally NOx emissions benefits can be obtained without significant increases in PM emissions.
- Negligible changes in average opacity occur due to NOx repairs above the threshold.

Smoke

- The repair thresholds and the emission reductions for average opacity repairs are higher for older vehicles and tend to be higher for smaller vehicles.
- Repairs for average opacity tend to make a small reduction in average opacity, a significant reduction in PM (particularly for the older smaller vehicle classes), but do not result in a significant change in NOx emissions.

5.4 Cost Effectiveness of Repair

Two cost/benefit analysis have been conducted. The first shows the effect of repairing just those vehicles with emissions above the RTP, as would be the case in test and repair program. The second shows the effect of repairing all vehicles which have been diagnosed with identifiable faults. Some of the latter vehicles will have emissions below the RTP and the fleet average.

5.4.1 Vehicles repaired above the RTP

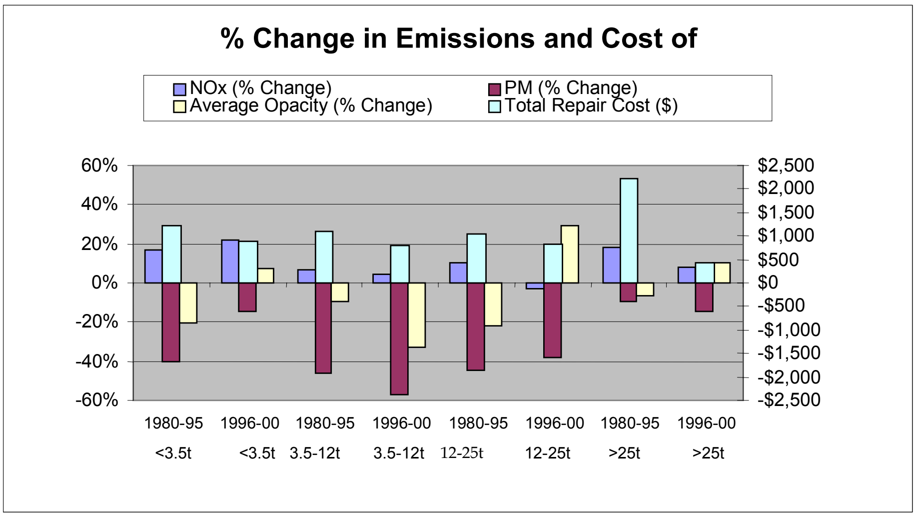
The average costs for vehicles repaired above the RTP for each vehicle category are listed in Table 5-5 and illustrated in Figure 5-3. A breakdown of the repair costs and the change in emissions in units of gram/km.tonne for each vehicle category are provided in Table 5-7.

Table 5-5: Average Cost of Repair by Vehicle Category

		NOx (% Change)	PM (% Change)	Average Opacity (% Change)	Total Repair Cost ($)
MC/NA	**1980-95**	16.7%	-40.4%	-20.5%	$1,214
	1996-00	21.9%	-14.5%	7.5%	$882
NB	**1980-95**	6.5%	-46.4%	-9.4%	$1,100
	1996-00	4.3%	-56.8%	-32.9%	$794
ME/NC	**1980-95**	10.3%	-44.3%	-22.3%	$1,044
	1996-00	-2.6%	-37.7%	29.3%	$826
NCH	**1980-95**	18.4%	-9.5%	-6.3%	$2,221
	1996-00	8.3%	-14.3%	10.5%	$426

Figure 5-3 below illustrates the percentage changes for each pollutant against the costs associated with the repair for each vehicle category.

Figure 5-3: Average Cost / Benefit for Vehicles Above RTP



Overall it can be seen that the light and medium duty vehicles <25tonne (MC/NA, NB, ME/NC) benefit most from repair and that costs are lower for this group than the larger vehicles >25tonne (NCH).

This is highlighted in Table 5-6 below when the groups are segregated and compared.

Table 5-6: Average Cost of Repair Based on Test Mass

	<25tonne	>25tonne
Ave Cost of repair	$978	$1,324
Ave PM change	-40%	-11.9
Ave NOx change	+9.5%	+13.4%
Ave Smoke change	-8.1%	+2.1%

Table 5-7 Breakdown of Repair Costs and Emissions Benefits

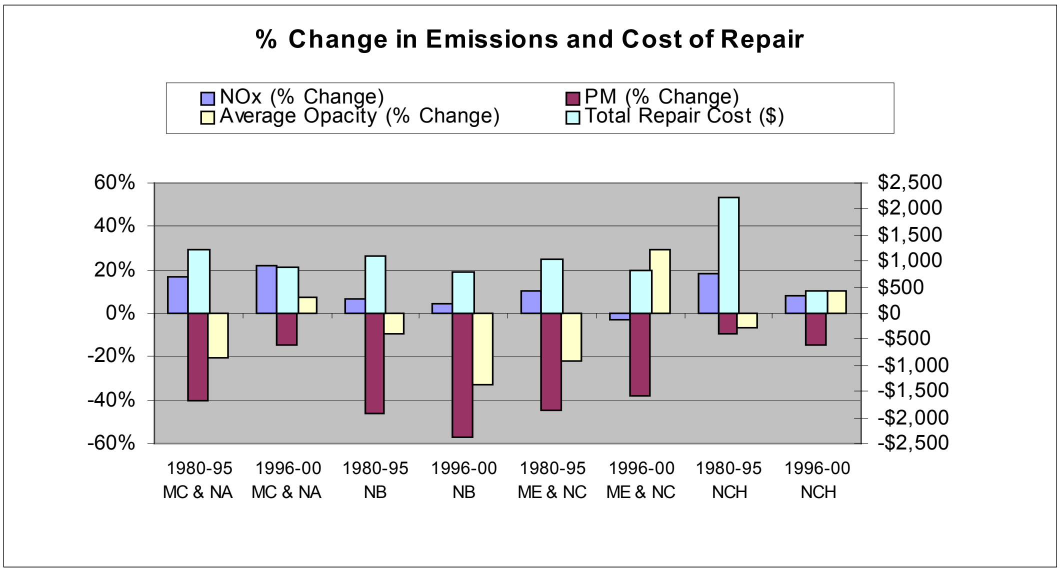
Vehicle Description			Benefits Per Repaired Vehicle						Ave Costs Per Repaired Vehicle				
Category	Model Years	No.	NOx		PM		Average Opacity		Diagnosis Cost ($)	Repair Cost ($)	Total Cost ($)	Cost ($) per mg/km.t of PM	Repair Time (Hours)
			g/km.t	% Change	mg/km.t	% Change	%	% Change					
MC & NA	1980-95	11	0.138	16.7%	-133.4	-40.4%	-4.4	-20.5%	$100	$1,114	$1,214	$9	9
	1996-00	2	0.190	21.9%	-40.5	-14.5%	1.5	7.5%	$100	$782	$882	$22	7
NB	1980-95	11	0.066	6.5%	-102.5	-46.4%	-1.9	-9.4%	$150	$950	$1,100	$11	8
	1996-00	6	0.055	4.3%	-101.4	-56.8%	-5.4	-32.9%	$150	$644	$794	$8	7
ME & NC	1980-95	7	0.082	10.3%	-47.2	-44.3%	-4.8	-22.3%	$200	$844	$1,044	$22	6
	1996-00	5	-0.021	-2.6%	-19.9	-37.7%	2.1	29.3%	$200	$626	$826	$41	6
NCH	1980-95	3	0.110	18.4%	-6.1	-9.5%	-1.4	-6.3%	$250	$1,971	$2,221	$364	13
	1996-00	1	0.043	8.3%	-2.2	-14.3%	0.4	10.5%	$250	$176	$426	$194	1
Subtotal	1980-95	32	0.098	12.0%	-92.0	-40.4%	-3.4	-15.7%	$153	$1,079	$1,232	$46	8
	1996-00	14	0.046	4.6%	-56.5	-40.9%	-1.3	-1.8%	$168	$624	$792	$35	6
	Total	**46**	**0.083**	**9.7%**	**-81.2**	**-40.6%**	**-2.7**	**-11.5%**	**$158**	**$940**	**$1,098**	**$42**	**8**

Note: The table only provides effect of repair data for vehicles exceeding the effect of repair threshold. The total number of vehicles (46) is less than the total vehicles repaired (52) during the study.

5.4.2 Cost effectiveness for all 52 vehicles repaired

Figure 5-4 below presents the average emission reductions and costs for all 52 vehicles (grouped by vehicle category) that underwent repair. The figure shows that fundamentally there is no discernable difference in the cost of repairs and general shape of the graph for all vehicles repaired compared to the graph for only those vehicles repaired above the PM RTP.

Figure 5-4: Average Cost / Benefit by Vehicle Category



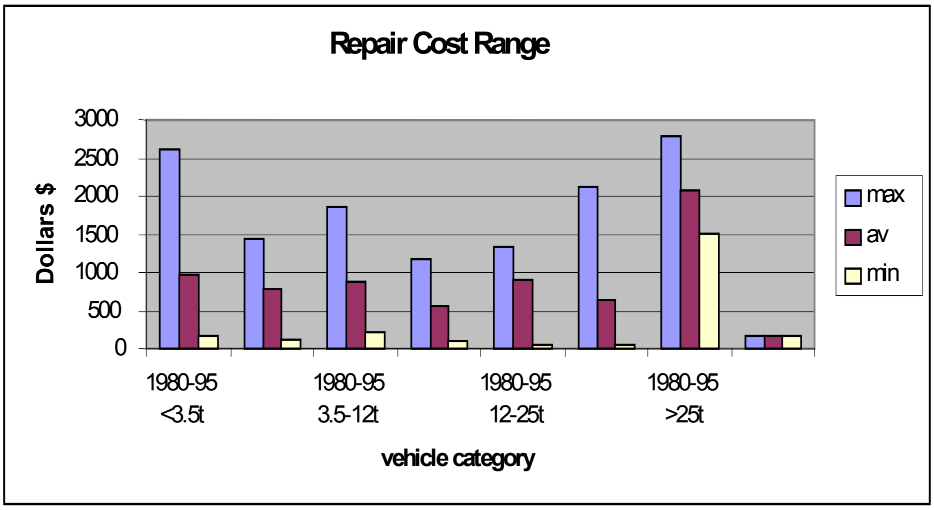
5.4.3 Repair Cost Variance - maximum, average and minimum costs

Table 5-8 and Figure 5-5 show the variation in costs within each category and in relation to the fleet. The maximum, average and minimum repair costs for each vehicle category are listed.

Table 5-8: Repair Cost Range by Vehicle Category

Cost $	<3.5t 1980-95	<3.5t 1995-00	3.5-12t 1980-95	3.5-12t 1995-00	12-25t 1980-95	12-25t 1995-00	>25t 1980-95	>25t 1995-00
max	2619	1431	1846	1171	1330	2129	2771	176
av	982	782	879	555	901	626	2073	176
min	169	132	223	98	60	60	1524	176

Figure 5-5: Vehicle repair costs by vehicle class.



The following observations are made as to the relative vehicle category costs:

- On average the cost of repairs for vehicles below 25t are approximately $1,000 but the average cost doubles to approximately $2,000 for vehicles above 25t.
- There is a large difference between the maximum and minimum costs for all categories, which corresponds to the varied type of repairs carried out.
- For vehicles below 25t the cost differential between Pre and Post ADR70 emission standards is approximately 20% ($200) - the older vehicles being the more expensive to repair.
- For vehicles above 25t it would first appear that costs decrease for newer vehicles however the data is misleading as very few vehicles were diagnosed to have a fault in the new vehicle as so repairs were minimal. Advice from the Diesel Mechanic is that if a fault does occur in the newer advanced technology vehicles (having electronic engine management) then the cost of repair can be far greater than the older Pre ADR70 vehicles.

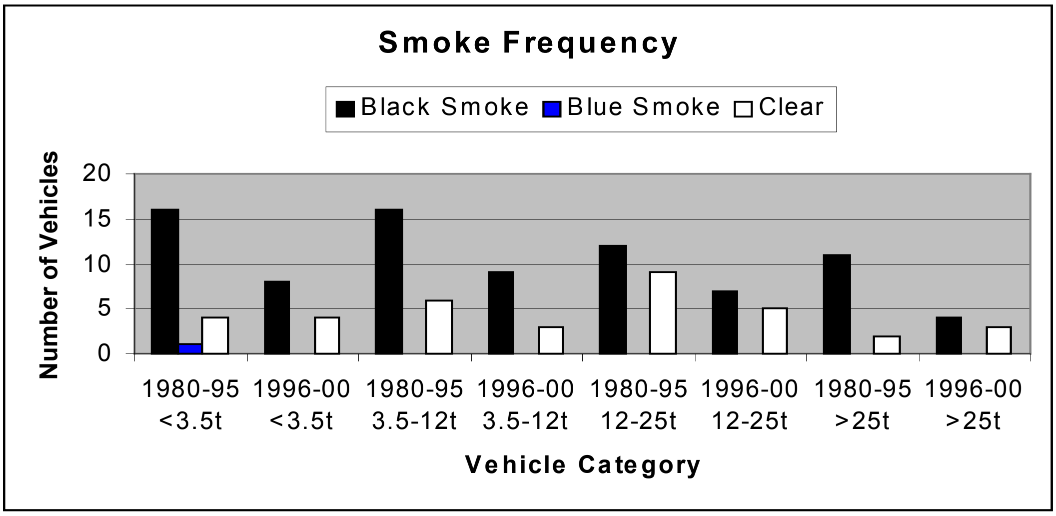
5.5 Faults related to emission performance

5.5.1 Fault identification by smoke observations

In diagnosing emission faults the diesel mechanic first quickly established the line of repair action by determining the colour of the exhaust emissions - black, blue or clear exhaust. Black smoke being a fuel related PM problem, blue smoke an engine wear PM problem and clear exhaust possibly a NOx problem.

The majority of vehicles were initially diagnosed having black smoke or clear exhaust and only the odd one in the 3.5t vehicle category with blue smoke. Thus the majority of the faults discussed are related to over or under fuelling or poor combustion rather than engine wear.
Figure 5-6 below are not test results but observations made by the diesel mechanic during the diagnostic on the inspection worksheets.

Figure 5-6: Colour of smoke emitted by vehicle class.



It is evident from Figure 5-6 that a greater number of the older technology pre 1995 vehicles were observed to emit black smoke than the newer Post 1995 categories across all size groups. It is also clear that each vehicle category consists of vehicles emitting black smoke.

5.5.2 Emission related faults and their frequency of occurrence

Figure 5-6 lists the range and number of faults diagnosed in the 120 vehicles inspected. It is evident that the majority of emission related faults occur in components for which manufacturers recommend regular maintenance.

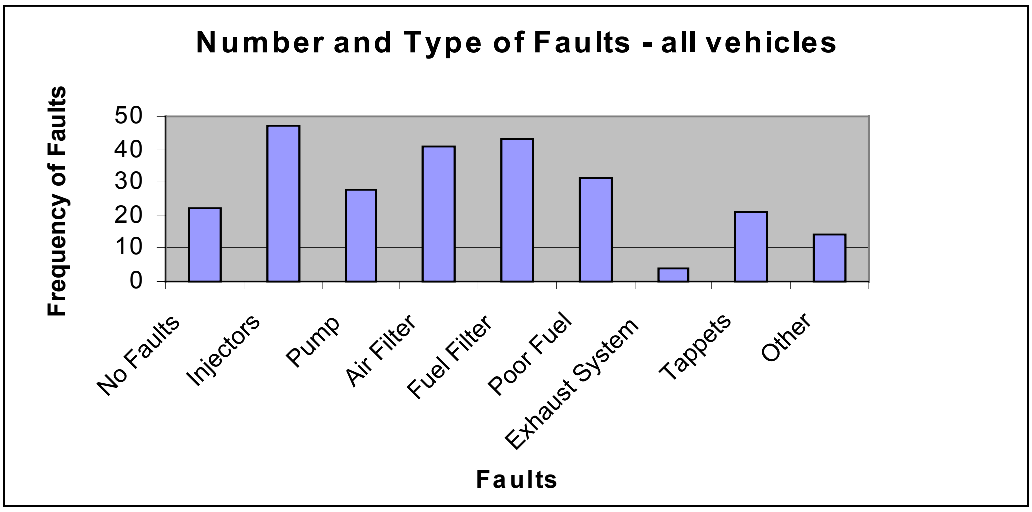
Multiple faults were detected in many vehicles and so more often than not a repair would require replacement or repair of multiple items such as fuel injectors, fuel pump and fuel filter etc. The chart does not include tampering as a fault. This is discussed in section xx.

Table 5-9: Number and Frequency of Faults

Vehicle Category	Age	NIL	Injector	Fuel Pump	Air Filter	Fuel Filter	Bad Fuel	Tappet	Exhaust	Other
MC	1980-95	1	14	7	8	10	6	2	1	2
	1996-00	6	2	2	2	3	3	0	0	0
NB	1980-95	2	12	6	10	13	6	9	2	8
	1996-00	1	4	2	4	4	4	2	0	1
NC	1980-95	2	6	4	6	4	2	2	0	0
	1996-00	7	4	4	3	3	5	4	0	1
NCH	1980-95	1	5	3	6	5	2	2	1	1
	1996-00	2	0	0	2	1	3	0	0	1
	TOTAL	**22**	**47**	**41**	**41**	**43**	**31**	**21**	**4**	**14**
		18%	**39%**	**23%**	**34%**	**34%**	**26%**	**17%**	**3%**	**12%**

Figure 5-7 illustrates the range and frequency of faults by vehicle size and age category.

Figure 5-7: Number and Type of Faults – All Vehicles



Fuel injectors were the components most often diagnosed as requiring repair action. However it is interesting to note that not just fuel or engine related faults were diagnosed as the cause for high emissions. The condition of the air inlet and exhaust system and the quality of the fuel were also important factors. The column labeled others includes such items as slipping or worn clutch, worn crankshaft keyway, etc. The actual repairs carried out on each of the 40 vehicles is contained in Appendix 7.

The smaller <3.5t and 3.5-12t pre ADR70 groups have a very high number of air filter, fuel filter and injector faults. This suggests that these vehicles are not serviced regularly and are deteriorating more rapidly.

5.5.3 Impact of fuel quality

This high number (26% of vehicles diagnosed) of vehicles with poor quality fuel is not surprising given the lack of fuel standards, the high cost of clean fuel, the low margins in the transport industry and until recently the lack of fuel excise auditing. Rumours and some evidence of fuel adulteration have been in the industry for some time but it is surprising the extent of cases identified in this small study.

Poor fuel is also a major contributor to some of the other faults identified such as blocked fuel filter (35% of cases) and worn injectors (39% of cases). Petrol, water, paint thinners, engine oil etc in the fuel causes erosion and deterioration of mechanical components in the fuel system and line restrictions that effect the engines air/fuel ratio and ultimately the vehicles emissions performance. Replacing contaminated or adulterated fuel with clean fuel was required on many occasions.

5.5.4 Faults relating to only those vehicles considered high PM emitters

The results show that there are significant numbers of in-service vehicles with emissions performance significantly worse than could be reasonably expected given the age and usage of the vehicle.

Table 5-10 below demonstrates that older vehicles show a greater frequency of faults, which adversely affect emissions performance, than newer vehicles. Nevertheless, a significant number of vehicles less than five years old also have faults that are related to deterioration in emission performance.

Table 5-10: Number of Vehicles with Significant Emissions Faults

Vehicle Mass	Vehicles < 5 years old Post ADR 70			Vehicle 6-20 years old Pre ADR 70		
	% with significant emission faults			% with significant emission faults		
	NO_x	Particles	Opacity	NO_x	Particles	Opacity
< 3.5 tonnes	4	13	4	5	32	10
3.5 -12 tonnes	2	13	5	5	12	14
12- 25 tonnes	0	11	0	3	20	3
> 25 tonnes	0	8	0	0	1	1

NOTE: Values based on the percentage of vehicles identified that have emission levels above the Repair Threshold Points.

These results suggest that a significant number of vehicles are operating well below their optimum emissions performance (even accounting for reasonable deterioration) and significant emission reductions could be achieved from moderate improvements in maintenance.

Figure 5-8 to Figure 5-11show the relative difference in the types of repairs found in those vehicles repaired above the PM RTP. Both Pre and Post ADR70 vehicles are shown for each size category.

In all cases fuel injectors rank the highest but it is interesting that each group has a similar range of faults.

Figure 5-8: Fault Diagnosis - MC & NA Vehicles <3.5t (Above PM Threshold)

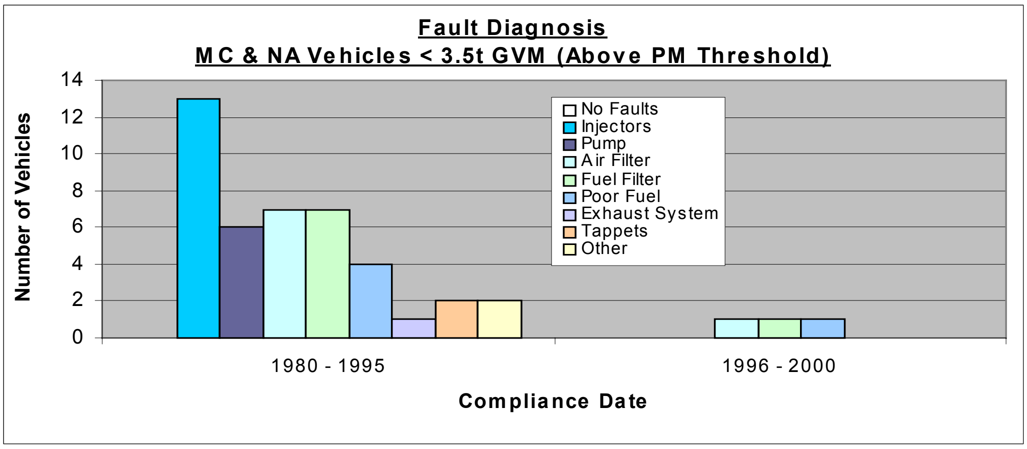


Figure 5-9: Fault Diagnosis - NB Vehicles 3.5t-12t (Above PM Threshold)

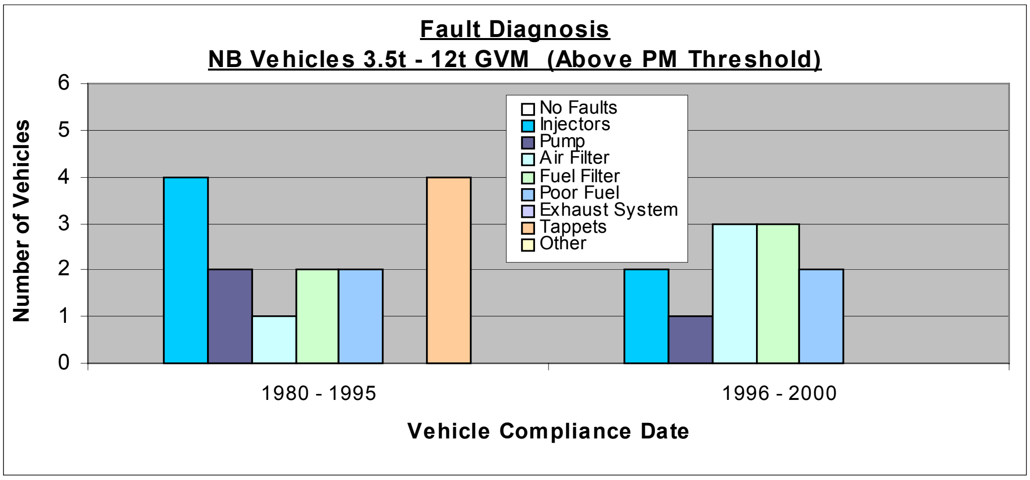


Figure 5-10: Fault Diagnosis - Me & NC Vehicles 12t-25t (Above PM Threshold)

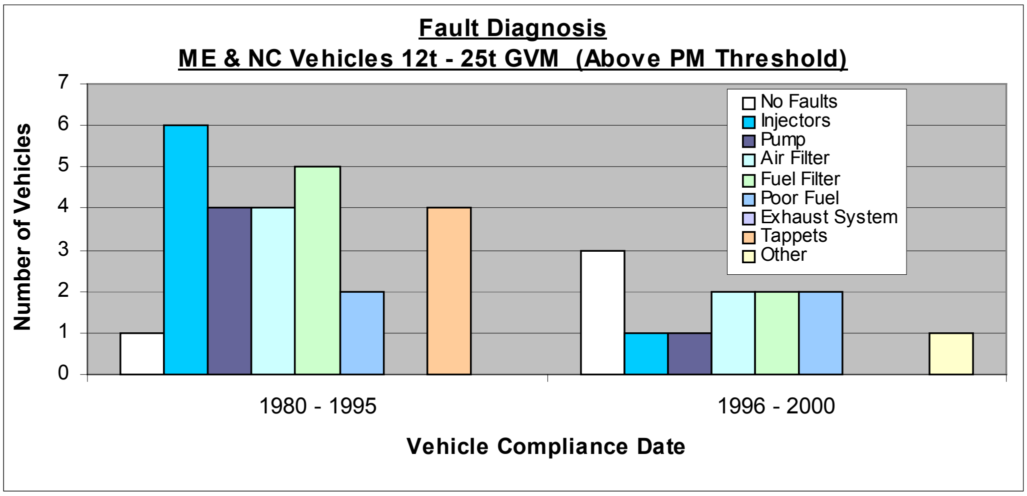
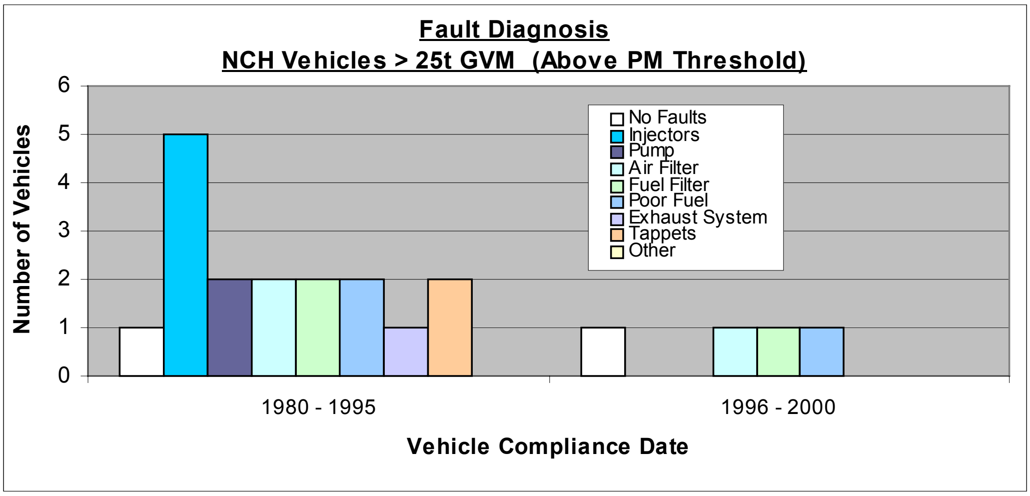


Figure 5-11: Fault Diagnosis - NCH Vehicles >25t (Above PM Threshold)



5.5.5 Tampering

In addition to diagnosing vehicle faults the licensed mechanic found that many vehicles had been tampered with either deliberately or through very negligent maintenance actions. Figure 5-12 and Table 5-11 illustrates the rate of tampering for all vehicles (120) undergoing the diagnostic inspection and table 4.2 presents the percentage of vehicles repaired above the PM RTP that were found to have been tampered with.

Figure 5-12: Vehicle Tampering - Vehicles that underwent diagnostic inspection

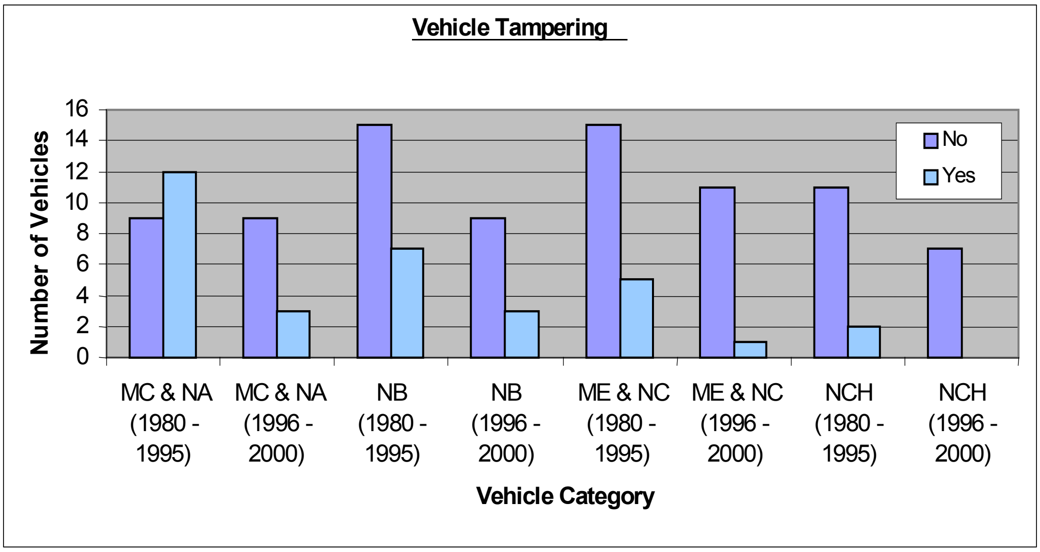


Table 5-11: Frequency of emission related engine component tampering

Frequency of tampering in high emitting vehicles (%)				
	<3.5t	**3.5-12t**	**12-25t**	**>25t**
1980-1995	69	67	50	40
1996-2000	0	50	14	0

Note: Values are the frequency of occurrence in vehicles identified as having emissions above the Repair Threshold for particles.

Key findings:

- The most frequently occurring faults related to deterioration of emission performance include fuel injectors, and fuel and air filters.
- Most emission related faults involve engine components for which manufacturers recommend regular maintenance.
- Lack of regular maintenance appears to be common in high emitting vehicles.
- A high number of vehicles were diagnosed as operating on poor quality fuel.
- Poor fuel is also a major contributor to some of the other faults identified such as blocked fuel filter (35% of cases) and worn injectors (39% of cases).
- Tampering occurs in very high percentages across all vehicle categories except for those >25tonne and less than 5 years old.
- Approximately 25% of all vehicles diagnosed had been tampered and in some cases (Pre ADR70 vehicles <25t) over 50% of the vehicles repaired above the PM RTP showed evidence of tampering.

5.6 The range and cost of repairing emission related faults

5.6.1 Variation in result

Repairs varied from vehicle to vehicle depending on the power to weight ratio of the engine, level of maintenance the vehicle had received over time, the design standard which the vehicle met, the condition of the fuel used during its operation and other factors.

The fact that one vehicle will benefit from a certain repair while another of the same make and model will not is common to both diesel and petrol vehicles. However the data suggests that emission reductions can be achieved from a large section of the diesel fleet to the extent that relatively inexpensive repairs can significantly reduce PM emissions.

The study also found that it is difficult to reduce NOx emissions unless there is a fundamental fault related to high levels of NOx. It is also noted that reductions in PM emissions tend to be accompanied by slight increases in NOx emissions, due to increased power outputs as a result of the repairs.

The study identified the following two points of interest regarding specific repair costs.

1. There are a large range of repairs that will provide emission benefits
2. The higher the repair cost does not necessarily mean greater reduction in emissions.

The following examples of specific vehicle repairs are provided to illustrate the cost range and emission benefits achieved from that cost.

The study showed that a $60 repair might provide just as big an emission benefit as a $1000 repair. In one case a one- hour resetting the pump to engine timing at a cost of $60 on one vehicle gave a similar emission improvement as replacing injector nozzles, springs and filter at a cost of $1330 on another.

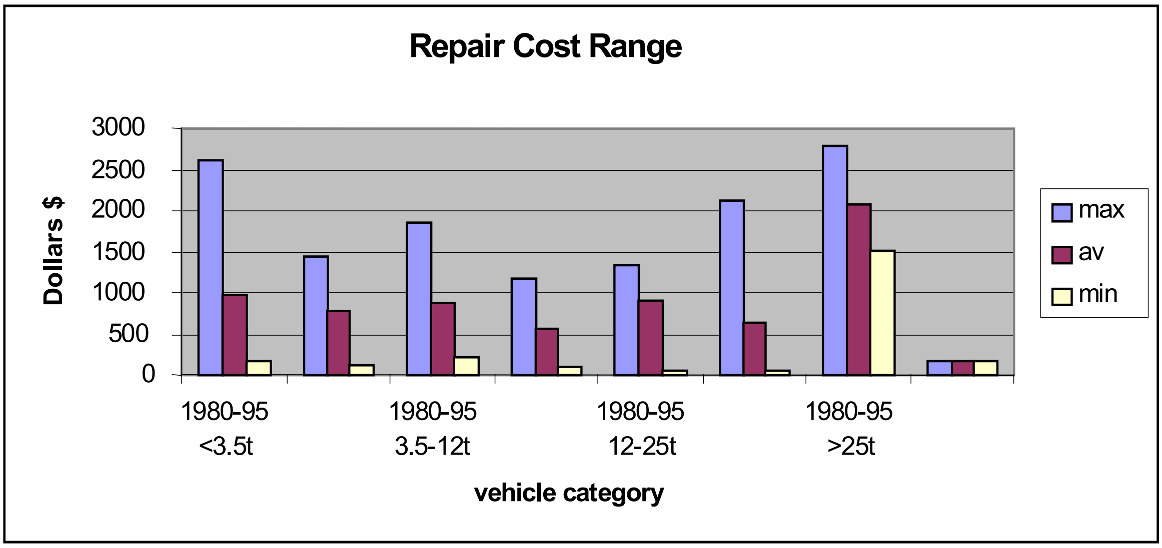
5.6.2 Repair Cost Variance - maximum, average and minimum costs

Table 5-12 and Figure 5-13 show the variation in costs within each category and in relation to the fleet. The maximum, average and minimum repair costs for each vehicle category are listed.

Table 5-12: Repair Cost Range by Vehicle Category

Cost $	<3.5t 1980-95	<3.5t 1995-00	3.5-12t 1980-95	3.5-12t 1995-00	12-25t 1980-95	12-25t 1995-00	>25t 1980-95	>25t 1995-00
max	2619	1431	1846	1171	1330	2129	2771	176
av	982	782	879	555	901	626	2073	176
min	169	132	223	98	60	60	1524	176

Figure 5-13: Vehicle repair costs by vehicle class.



Note. Vehicle Test No 1700 <3.5t (1980-95) is not included in these figures as it is classed as a major repair (crankshaft removal and new clutch costing $5,700)

The following observations are made as to the relative vehicle category costs:

- On average the cost of repairs for vehicles below 25t are approximately $1,000 but the average cost doubles to approximately $2,000 for vehicles above 25t.
- There is a large difference between the maximum and minimum costs for all categories, which corresponds to the varied type of repairs carried out.
- For vehicles below 25t the cost differential between Pre and Post ADR70 emission standards is approximately 20% ($200) - the older vehicles being the more expensive to repair.
- For vehicles above 25t it would first appear that costs decrease for newer vehicles however the data is misleading as very few vehicles were diagnosed to have a fault in the new vehicle as so repairs were minimal. Advice from the Diesel Mechanic is that if a fault does occur in the newer advanced technology vehicles (having electronic engine management) then the cost of repair can be far greater than the older Pre ADR70 vehicles.

6 DT80 TEST: OPERATIONAL ISSUES

6.1 Vehicle Throughput

Testing of vehicles, as mentioned previously in the Methodology section was carried out in three phases having deployed and calibrated the mobile testing system. The time taken to deploy the system at a new test location and carry out checks of the system in readiness to commence testing was not recorded but generally took between 40 and 60 minuets.

The time taken to complete each of the following three steps for each vehicle tested was logged during the course of the project.

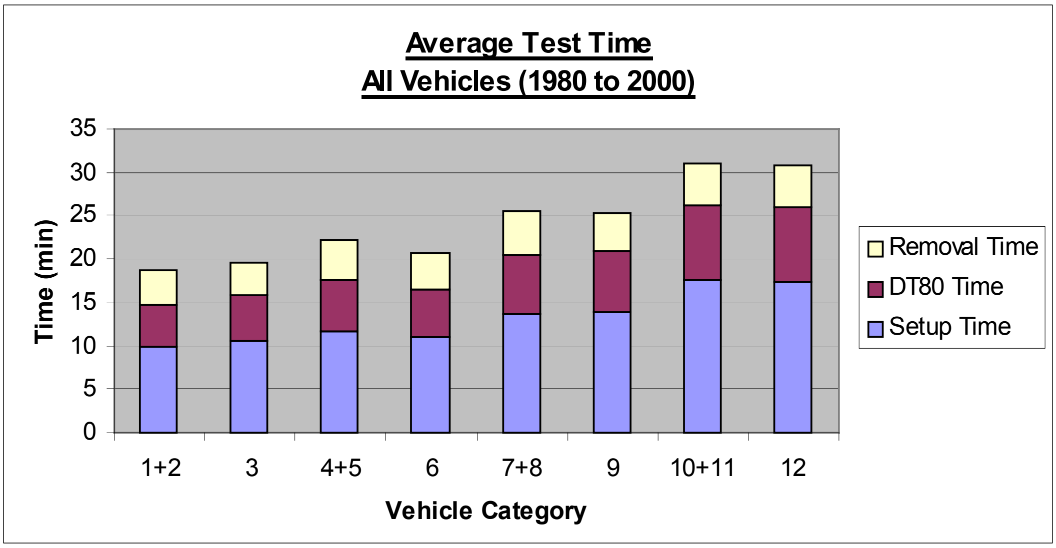
1. **Equipment set up** – time from when the vehicle commences up the ramp to be secured to the dynamometer and connected to sample handling equipment until the DT80 test commences.

2. **DT80 test** – from start of preconditioning to the end of the test cycle

3. **Vehicle removal**– the time taken to dismount the vehicle from the dynamometer and sample handling equipment.

Figure 6-1 illustrates the relative time taken for each step for each vehicle category.

Figure 6-1: Throughput to complete DT80 test



As anticipated the larger the vehicle the greater the set up time and the time taken to complete the DT80 test protocol. Removal times are fairly constant across the vehicle size range.

The most time consuming aspect of the procedure is the set up. However it is this particular aspect of the test protocol that has the greatest potential to be reduced through purpose built vehicle tie down, exhaust connection and dynamometer mounting systems. The DT80 test time could also be reduced if the idle and cruise sections of the test where reduced to 30seconds rather than 60 seconds.

Overall it is anticipated that an IM test facility incorporating a level of automation will be able to test 5 vehicles per hour using a two position lane format.

6.2 Overall Performance of the Test

The DT80 test proved to be both practical and effective in undertaking the Pilot IM study. However during the course of the study a number of enhancements and refinements have been identified that would improve the test system for real world use in an IM program. These are identified under the heading Enhancement Potential but first it is important to evaluate the test in its "raw" state as required by the study objectives. To do this we have used the same criteria (except correlation criteria) originally used in Project 2-2 to identify the best of the 6 short tests evaluated. Comments are made under the following headings in relation to how the test performed during the study.

1. Ability to identify high emitting vehicles
2. Sensitivity to changes in emissions
3. Suitability across fleet size age
4. Ease of use- level of technical expertise
5. Ease of use- level of technical expertise
6. Time to test (preparation and test0
7. Resource requirements

6.3 Ability to identify high emitting vehicles

The data shows that the test was able to identify high emitting vehicles particularly in the categories below 25tonne. The shape of the curves for these categories is consistent with that expected from in-service vehicles used regularly on a commercial basis by a range of small and large operators with varying degrees of maintenance activity. Those vehicles above 25tonne show less variation in emission performance reflecting closer attention to vehicle and engine condition by the owners and possibly a more robust engine design and one specified to deliver a good power to weight ratio.

Thus it is not unexpected that the test showed these trends and the numbers of high emitters across the various vehicle categories.

The data also reflects the general observations made by the testing staff and Diesel mechanic as to the general condition of the vehicle and exhaust colour during the test and the repair diagnosis. However there were a few cases where while the test identified the vehicle as a high emitter when re-tested the results showed no reduction in PM emissions. It is inevitable that, in some cases, vehicles may not respond to repairs, either through miss-diagnosis of faults or through some factors not readily determined in a workshop situation.

6.3.1 Sensitivity to changes in emissions

The air sampling system and emissions measurement was able to discriminate between gross emitters and low emitters as evidenced by the range of values reported.

6.3.2 Suitability across fleet size age

While the throughput rate was slowed for vehicles above 25 tonne due to the extra care needed to ensure safe working conditions and issues dealing with very large or high exhaust pipes the majority of vehicles were tested successfully.

Overall the actual test (DT80) performed well in providing a solid basis for assessing a vehicles emission status, identifying gross emitters and comparing one vehicle category against another.

6.4 Ease of use- level of technical expertise

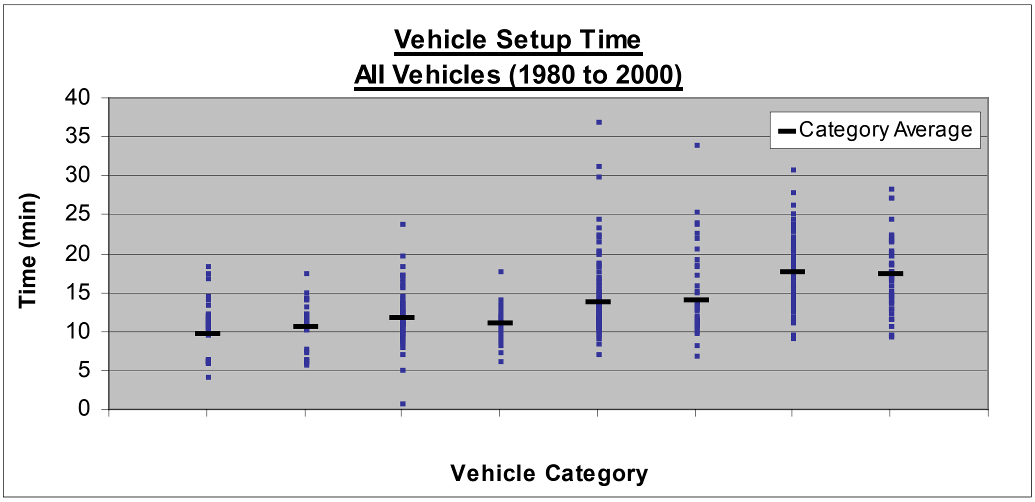
To test 621 vehicles within the space of 5 months is an achievement that is directly related to ease of use. The simplicity of the test and equipment used allowed relatively low skilled truck drivers to perform the test (drive the vehicle) with a semi-skilled operator setting test parameters and printing a result. As the process of collecting, and calculating a result is automated from a command signal when the driver commences the test there is limited data entry required by the operator and therefore the potential for error reduced. This not only increased throughput but delivered a more consistent and repeatable result.

Calibration and maintenance of the system is still required by a trained technician.

6.5 Time to test (preparation and test)

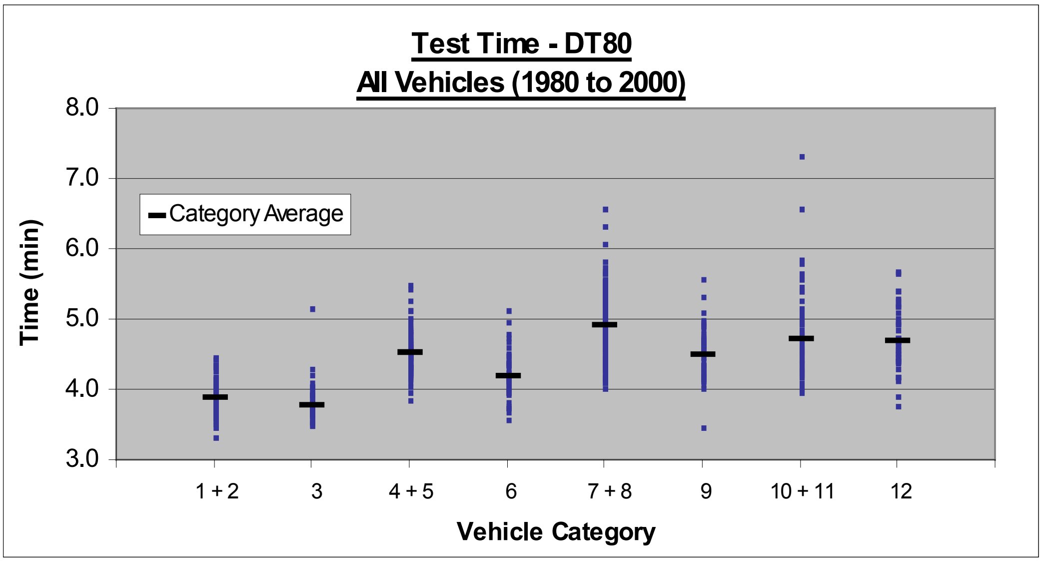
Deployment of the mobile equipment took ~45mins. Vehicle preparation including tie down onto the dynamometer and connection of the exhaust sample handling system varied depending on the particular vehicle however the average time spent was about 15mins as illustrated in Figure 6-2

Figure 6-2: Mobile measuring system - time to set up equipment



The actual test also varied in length depending on the vehicles condition, size and power to weight ratio of the engine. However typically testing ranged from 3 to 7 mins and averaged about 4.5mins as evidenced in Figure 6-3 below. Results were printed within 30seconds of completing the test.

Figure 6-3: Time to complete the DT80 test



6.6 Resource requirements

The use of low cost PM measuring equipment and simple/small scale sample handling equipment allowed the complete measuring system to be both affordable in the context of the project and a future IM programs as well as being portable to ensure fleet representation.

In terms of operating staff three people ere required to operate the system including transportation, set up and deployment of dynamometer, electric power, measuring system and calibration prior to commencement of testing. Typically one person sourced vehicles from the test site and positioned the vehicle on the dynamometer, the second person would secure the vehicle to the dynamometer and attached sample handling equipment and make sure the area was safe to test. Following this he would then inspect the next vehicle, note rego, weight and engine details and ensure the vehicle is safe to test. The third person entered the relevant details into the computer, set loads and ensure the measuring system was ready for test upon initiation from the vehicle driver – the first person.

In an IM situation where there is no need to source and return a vehicle two people would be adequate to perform the test.

7 IM PROGRAM COSTS & INFRASTRUCTURE REQUIREMENTS

7.1 Repair Facility Requirements.

Examples of the diagnostic worksheets used to diagnose vehicles are provided at Appendix 13. With regard to equipment and materials needed the following table provides a cost estimate of the basic type of equipment required to diagnose faults and equipment costs to repair faults related to emissions. The equipment listed is not for a typical mechanic service workshop but one that can perform injector and fuel pump overhaul, calibration and timing adjustments. The large equipment expense listed are primarily related to fuel pump calibration that covers both small and large vehicles.

Cost associated with general vehicle service/maintenance centres who's principle focus is diagnosing faults and replacing filters, injectors, fuel, oil etc would have no additional cost or only a fraction of the costs listed in Table 7-1. It is only when pump calibration and injector overhaul is required that speacialised equipment becomes essential. This equipment is generally held by dedicated pump calibration shops certified to carryout the work.

Table 7-1: Diagnostic and Repair Equipment List

Basic Equipment [1] (Diagnosis)	Cost $	Extra Equipment [2] (Repair)	Cost $
Diesel mechanics toolkit	$4,000	Injector pop-tester, brackets and pipes etc	$3,000
Injector removal sockets	$1,000	Diesel test bench with extensive capability	$75,000
Timing tools & dial gauges	$3,000	Brackets, test pipes and test injectors to suit above test bench	$75,000
Quality multimeter	$500	Specialist dismantling tools and reassembly for both pumps and injectors	$100,000
Diesel compression gauge & extensive adaptor range	$1,000		

Notes:

1. Later series engines with unit or common rail electronic injection require original engine dealership computerised equipment for diagnosis.
2. Later series engines are either unit injection or computerised controlled pumps and are sold as complete units and are seldom repaired at workshop level.

7.2 Emission Test Station Requirements

The following outline descriptions and specifications are for a dedicated emission testing facility. If a jurisdiction wishes to upgrade an existing inspection/test lane to include emissions testing, the specifications in this section will need to be adapted to integrate the emissions testing capability into the existing building and equipment layout.

This section covers all key aspects of emission test facility equipment, buildings, logistics and costs (capital and operations).

7.2.1 Emission Testing Equipment Specifications

Earlier NEPC projects have confirmed the need to use transient loaded (dynamometer) testing to obtain emission measurements that correlate well with actual on-road emission rates. The key elements of such a system include:

- dynamometer and related control equipment

- exhaust sample handling and sample preconditioning
- total exhaust flow measurement and/or control
- gaseous, smoke and particulate measuring equipment
- vehicle and test data capture and reporting

The specifications contained in Appendix 15 are for a system capable of testing vehicles ranging from passenger and light commercials through to heavy vehicles having a GVM or GCM up to 45 tonnes. To accommodate this range of vehicle mass at reasonable cost, the effective mechanical inertia (flywheel effect) included in the dynamometer system has been specified at 1400kg. Additional acceleration inertia forces, for vehicles having a test mass exceeding 1400kg, are generated by the dynamometer's power absorption unit.

The specifications anticipate that deceleration (overrun) inertia above 1400kg is not simulated because of the quantum increase in cost of providing multiple flywheels or motoring inertia simulation for heavy vehicles. If it is intended that the system will be used only for medium and heavy-duty vehicles, the mechanical flywheel mass may be increased to 2500kg to provide additional speed stability and to assist with smoother gear changing on heavy vehicles.

The system shall be capable of testing road vehicles on a range of user-defined steady state or transient drive cycles. The system shall measure and report on mass emission rates of:

- carbon monoxide (CO),
- carbon dioxide (CO_2),
- oxygen (O_2),
- total hydrocarbons (HC),
- methane (CH_4) <*OPTION*>
- oxides of nitrogen (measured as NO),
- fine particulates (PM10 and/or PM2.5), and
- smoke opacity.

The system comprises:

- Dynamometer and associated control systems
- Exhaust sample handling and preconditioning
- Gaseous emissions measurement
- Particulate emissions measurement
- System integration, data management and storage
- Electrical power supply, utilities

The emissions measuring system shall operate as an integrated, stand-alone vehicle testing system comprising:

- Chassis dynamometer and associated control systems
- Exhaust sample handling and preconditioning
- Gaseous emissions measurement
- Particulate emissions measurement
- Data management, storage and report generation
- Vehicle restraints, safety systems and engine cooling fan.

The potential uses of this equipment include:

- regular emission testing of the whole fleet;
- as an auditing tool in fleet maintenance programs;

- comparison of emissions from vehicles using petrol or diesel and similar vehicles powered by alternative fuels.

7.2.2 IM Facility and Equipment Budgetary Costs

The costs outlined below are based on our own experiences in planning and setting up the Parsons mobile and fixed emissions testing capabilities.
To be fully self-contained, the system whether fixed or mobile should comprise the following main elements.

- **Test facility to house the equipment** – for fixed facility this would require soundproofed test lane enclosures as well as a suitable building.
- **Emissions analysis equipment** capable of measuring Total Suspended Particulates (TSP), Oxides of Nitrogen (NOx), Smoke Opacity and if required Carbon Dioxide (CO_2). Depending on specific requirements, this equipment can be commercial grade, suitable for rapid identification of high polluters, such as in an Inspection & Maintenance (I/M) program. Alternatively, it could be highly accurate and responsive laboratory grade instrumentation, including size specific particulate analysis (PM10, PM2.5 and PM1.0). As well as measuring emission concentrations, the system must incorporate a means of mass flow measurement.
- **Dynamometer** with transient inertia simulation capability, graphical drivers aid, control and display software, communications between control computer and emissions analysis equipment, on/off ramps, vehicle restraints, axle pull-down system and safety barriers.
- **Electric power generator**, for dynamometer power absorber system, plus lighting and any other ancillary equipment requiring mains power
- **Vehicle(s)**, for towing/carrying the dynamometer, generator, emissions measuring equipment and supporting paraphernalia.
- **Indicative costs** for systems with I/M grade analysers are as follows:

Note 1: electricity, insurance and other recurring costs other than consumables directly related to lane operations are not included. Salaries are actual salaries and do not include overhead.
Note 2: the mobile costs relate to a single unit. Fixed facility costs assume a two-lane facility.
Note 3: Maximum throughput per lane (or for a mobile system) is estimated to be 5 vehicles per hour.

7.3 For a Mobile System

EQUIPMENT DESCRIPTION	LIGHT DUTY		HEAVY DUTY	
Dynamometer, computer, ramps, etc (heavy duty dyno includes dual axle capability).	$190,000		$350,000	
Emissions Measuring Equipment (I/M grade)	$90,000		$95,000	
Vehicles (1 x 4~6tonne + 1 x light commercial) for conveying system to operating location.	$85,000		$105,000	
Vehicle fit-out, including calibration gases, computers, data loggers, wireless comms systems, racking, air-con, etc	$100,000		$100,000	
Generator + ancillary equipment + trailers	$50,000		$80,000	
Software licenses and database/comms design	$120,000		$120,000	
Operations staff 3 x lane operators 1 Admin	 @45K @35K	$170,000 pa	 @45K @35K	$170,000 pa
Calibration equipment		$20,000		$20,000
Reference gases & consumabless		$10,000pa		$10,000pa
TOTAL (CAPITAL)	**$655,000**		**$870,000**	
TOTAL (RECURRING)	**$180,000pa**		**$180,000pa**	

For laboratory grade emissions analysis instruments instead of I/M grade, an additional $100,000 should be allowed for.

7.4 For a Fixed System - two lane operation

EQUIPMENT DESCRIPTION	LIGHT DUTY		HEAVY DUTY	
Dynamometer, computer, etc (heavy duty dyno includes dual axle capability for heavy-duty)	2@ $190,000	$380,000	2@ $350,000	$700,000
Emissions Measuring Equipment (I/M grade)	2 @ $90,000	$180,000	2@ $95,000	$190,000
Software licenses and database/comms design	1@ $120,000	$120,000	1@ $120,000	$120,000
Building Areas: • Test cell 20m x 6m x 6m (HD), 12m x 5m x 3m (LD) • Office 6m x 6m • Amenities 2m x 4m • Gas store 2m x 4m • Equipment/tool store 4m x 6m • Customer waiting area & transaction counter 6m x 4m Soundproof Enclosure/lane	220m^2 at $1,000/m^2 2@ $100,000	$220,000 $200,000	340m^2 at $1,000/m^2 2@ $200,000	$340,000 $400,000
Operations staff for a two position lane 1 x vehicle reception 4 x lane operators 2 Admin 1 x Manager	@40K @45K @35K @50K	$340,000pa	@40K @45K @35K @50K	$340,000pa
Calibration equipment		$20,000		$20,000
Reference gases & consumabless		$20,000pa		$20,000pa
TOTAL (CAPITAL)	**$1,120,000**		**$1,770,00**	
TOTAL (RECURRING)	**$360,000pa**		**$360,000pa**	

8 CONCLUSIONS

Conclusions are made under the following three headings.

1. The effectiveness of repair action
2. The emission performance of the diesel fleet
3. The performance of the test and equipment as a Diesel IM test protocol.

8.1 Repair Effectiveness

1. Significant reductions in PM emissions can be achieved from minor repair activity. Repairing ~30% of the fleet will provide a 38% reduction in PM emissions.
2. The rigid truck category benefited most from repair with an average reduction of 57%.
3. The data suggests there are two groups of vehicles within the fleet - those above 25 tonnes and those below 25 tonnes. The following provides the summary details of each group but it is clear that the light to medium vehicle group (<25t) have a better cost/benefit ration than the larger (>25t) group.

	<25tonne	**>25tonne**
Ave Cost of repair	$978	$1,324
Ave PM change	-40%	-11.9
Ave NOx change	9.5%	13.4%
Ave Smoke change	-8.1%	2.1%

4. Generally repairs carried out to reduce PM or smoke increased NOx emissions. The increase was up to 13.4% however, where a vehicle was repaired specifically for a high NOx result then NOx reductions of the same order were achieved.
5. Some vehicle groups such as the Rigid Trucks benefited from repair action well below the category average suggesting that a percentage of vehicles would fail a reasonable cut point.
6. The most common repairs carried out were injector related (35%) followed by poor fuel filters (35%) and fuel pump settings (23%). Repairs to inlet manifolds, exhaust pipes, adjustment of tappets and other non-fuel related components also featured and provided significant emission improvements.
7. Fuel adulteration was found to be very high (26%) of cases and found to be a significant cause of poor emissions performance.
8. Component tampering (adjustment of the fuel pump screw) occurred in ~25% of cases diagnosed, higher than anticipated.
9. The cost of repairs ranged from $60 to just below $3,000. On average vehicles less than 25tonne were repaired for $978 and $1,324 for those >25t. However a $60 repair gave the same level of emission improvement as a $1,000 repair. The reduction in emissions being primarily dependent on the type of fault rather than the money spent on repair.

8.2 Emission Profile

1. The characteristics of the fleet is consistent with that reported in Project 2-2; specifically:

   "All age and size categories contain a number of "gross emitting vehicles and that vehicle age and distance travelled do not correlate well with emission performance. However, the Pre ADR70 (1980-1995) age group are generally higher emitters than the Post ADR 70 group (1996-00)."

2. Fleet size, maintenance regime, general vehicle condition and the origin of the vehicles engine provide some indication of where the "gross emitters" residue. However the data suggests that any vehicle if not properly maintained or tuned to manufacturers specifications will generate a high level of emissions whether in a small or large fleet.
3. The majority of high polluting vehicles are in the light to medium duty categories:
   - Pm emissions can be up to 6 times the fleet average
   - NOx emissions are more stable but can still be up to 3 times the fleet average
   - Smoke opacity is generally around 40% but can go as high as 70%.

8.3 Performance of the DT80 test

1. The DT80 short test proved to be applicable for all vehicle ages, sizes and uses. It was able to discriminate between low and high emitters as well as being able to detect a change in emission performance as a result of repair action.
2. The emission measuring system withstood the harsh environment of testing at remote locations and the continuous daily operation as required for IM programs. The 674 tests (initial and after repair tests) were completed within 5 months including sourcing of the vehicles.
3. The system allowed up to 23 vehicles to be tested in any one day. Time to test ranged from 18 to 30mins/vehicle with an average equipment setup time of ~45mins at a new location.
4. In general vehicle owners were happy with the testing and appreciated receiving a result immediately following the test.