Central Laboratories Report : 529277.00

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September 1999

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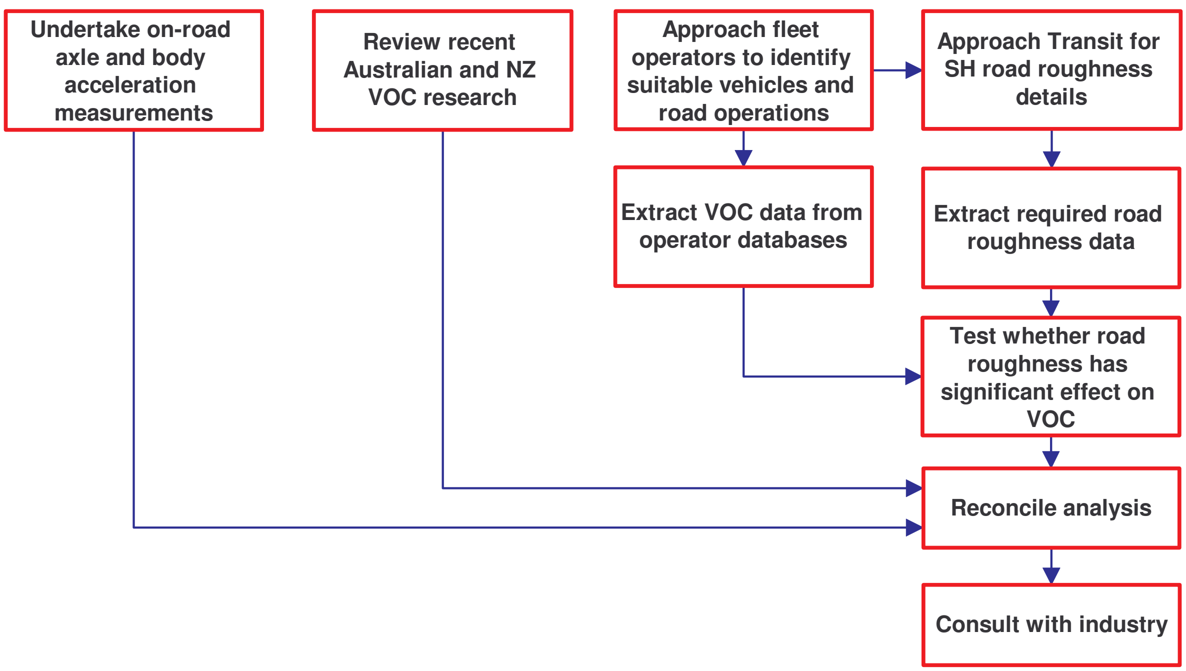
EXECUTIVE SUMMARY

The approach adopted to review passenger car and truck (HCV-I) vehicle operating cost (VOC)-roughness costs tables and graphs contained in Transfund New Zealand's Project Evaluation Manual (PEM) is summarised in the flowchart below. The important aspects of the approach were:

- a selective survey of commercial vehicle fleet operators whose activities were limited to certain road networks so that the recorded operating costs could be related to road condition;
- an on-road measurement programme to establish how vehicle response to road roughness varies with operating speed and vehicle age;
- a literature review of latest Australian and New Zealand VOC research to supplement the findings of the operator surveys; and
- wide consultation with the New Zealand motor industry to confirm outcomes regarding vehicle operating expenses.



On the basis of component VOC data acquired as part of the review, it is apparent that the base repairs and maintenance cost is being overestimated by the NZVOC model used to generate cost tables for the PEM. As a result, base car operating costs given in Tables A5.1 and A5.2 appear to be a factor 1.7 too great. Because most of the roughness related costs in the PEM are attributed to repair and maintenance costs, these are also being significantly over-estimated by a factor of about

1.9. A ¾ reduction in the repairs and maintenance cost component from 16.7c/km to 4.3 c/km would see the PEM provide VOC-roughness predictions that are consistent with motor industry expectations and in agreement with the calibrated ARRB TR VOC model.

By comparison, base HCV-I operating costs given in Tables A5.7 and A5.8 of the PEM appear to be a factor of around 1.3 too great resulting in the roughness related costs being overestimated by a factor of about 3-4. A $^{1}/_{3}$ reduction in the repairs and maintenance cost component from 28.5 c/km to 19 c/km would see the PEM provide HCV-I VOC predictions which match road transport industry expenditures not only in terms of magnitude but also relativities between the component costs.

The identified over-estimation has been attributed to the process of simply applying price and cost indices to update repairs and maintenance costs observed in the late 1970's,early 1980's. As a result, the effect of improved vehicle technology, improved operating practices, and changing fleet makeup have not been adequately accounted for.

Therefore, the principal outcome of the review is the need for annual or biennial quantification of base component VOC's comprising fuel and oil, tyres, repairs and maintenance, and depreciation due to use. This will require standardisation and automation of procedures used for this quantification. Updating of PEM VOC tables can then take place as originally envisaged by the developers of the NZVOC model.

Given the serious omissions and errors identified with NZVOC version 3.3 during the course of this review, a detailed calibration of NZVOC is also warranted to ensure the integrity of running cost and speed cycle cost tables presented in Appendix A5 of the PEM.

The review was instrumental in identifying a number of significant knowledge gaps which, if addressed, will lead to more efficient allocation of scarce road funds. These knowledge gaps, listed in perceived order of priority, are:

- effect of horizontal curvature on VOC ;
- effect of roughness on the annual utilisation and service lives of vehicles;
- speed-roughness relationships applicable to New Zealand motorists;
- safety benefits derived from roughness reduction; and
- quantification of VOC's specific to unsealed roads.

CONTENTS

1 INTRODUCTION

In order to optimise the allocation of financial resources, Transfund New Zealand has adopted benefit-cost analysis for ranking roading related projects for funding. The methodology is documented in the Project Evaluation Manual (PEM) (Transfund New Zealand, 1997) which is continuously being updated as new information comes available. The PEM is currently applied to all improvement projects (except minor safety projects less than $50,000) and also to shape correction (pavement rehabilitation) projects. Costs in the benefit-cost analysis are the costs (or savings) affecting the roading agency and the funding organisation. Benefits are tangible benefits, positive or negative, affecting the public. Benefits are changes in vehicle operating costs, travel time costs, and crash costs. The New Zealand Vehicle Operating Costs Model (NZVOC) forms the basis of vehicle operating cost tables and graphs in the PEM. A comprehensive description of NZVOC can be found in Bennett (1989a).

NZVOC provides vehicle operating costs (VOC) as a function of mean speed and road gradient for six individual vehicle classes or for four road classes (i.e. urban arterial, urban other, rural strategic and rural other). Input resource costs include petrol, tyres, parts, labour and the part of depreciation that is related to vehicle use.

The following relationships are incorporated within the NZVOC model:

- fuel consumption – the mechanistic fuel consumption model, ARFCOM, developed by the Australian Road Research Board (ARRB) (Biggs , 1988) is used to calculate fuel costs;
- tyre consumption – the HDM III Brazil relationships (Watanatada et al, 1987);
- maintenance parts – the HDM III Brazil relationships partially calibrated to New Zealand conditions;
- maintenance labour – estimate of labour costs relative to parts costs;
- depreciation – New Zealand study of depreciation (Bennett, 1989b);
- oil consumption – HDM III relationships modified in line with New Zealand practices.

Additional vehicle running costs due to road roughness are also calculated by the NZVOC model and are presented in Appendix 5 of the PEM for each vehicle and road class. However, concern as to the validity of the PEM's VOC-roughness costs tables and graphs has been growing. This concern is the result of recent Australian and New Zealand research findings (Symonds, Travers, Morgan and Cox, 1996, McLean and Foley, 1998, and Opus International Consultants and Beca Carter Hollings and Ferner Ltd, 1998) and the International Study of Highway Development and Management Tools (ISOHDM) (N.D. Lea International Ltd, 1995) which all suggest benefits from reducing road roughness are significantly being over-estimated by the PEM. In particular, questions have been raised as to the applicability of the HDM III relationships to the range of roughness levels typical of a maintained surfaced road network and vehicle technology of the last decade which contrasts with the 1970's technology that forms the basis of the HDM III Brazil relationships.

Given that accurate determination of VOC is so critically important for the proper economic assessment of Transfund New Zealand's investment in road construction, a review was undertaken by Opus Central Laboratories in association with the Transport Research Laboratory (TRL) to establish whether or not the PEM VOC-pavement roughness relationships for passenger cars and heavy commercial vehicles are valid for typical New Zealand operating conditions. This report presents the findings of this review along with the areas identified as requiring further research.

The review is reported in three parts. The first part (Part A) considers the results of an on-road measurement programme designed to establish how vehicle vibrations vary with vehicle speed and road roughness, and the critical roughness level below which roughness has no impact on VOC. The choice of this critical roughness level has a substantial effect on VOC benefits calculated from any reduction in pavement roughness. The PEM places a 60 NAASRA roughness counts/km (NRC) cutoff, with VOC remaining constant for lower levels of roughness.

The second part (Part B) analyses VOC data acquired from a survey of fleet lease and transport operators in the context of NZVOC modelling approaches while the third part (Part C) discusses the implications of the findings of Parts A & B with respect to existing PEM roughness evaluation procedures and future research needs.

PART A

Relationship Between Vehicle Speed, VOC, and Road Roughness

2 RELATIONSHIP BETWEEN VEHICLE SPEED, VOC AND ROAD ROUGHNESS

2.1 Introductory Comments

The quality of a vehicle's ride is known to vary with the travel speed, the dynamic characteristics of the vehicle, and the spectral characteristics of the roughness of the road (Paterson and Wantanatada, 1985). In quantifying costs for highway network planning and pavement management, this fact raises the question as to whether VOC on a road of a given roughness varies with the vehicle speed. The answer determines whether it is necessary to use a statistic that accounts for vehicle response instead of the road roughness as a determinant of vehicle costs.

The VOC-roughness cost tables and graphs presented in Appendix A5 of the PEM are speed independent. To test the validity of this assumption, the interactions between vehicle speed, road roughness, and vertical axle (unsprung mass) and body (sprung mass) accelerations were determined for three vehicle classes : passenger car, medium commercial vehicle (MCV), and heavy commercial vehicle (HCV–I). Root-mean-square (RMS) axle and body accelerations were selected as the measure of vehicle response because these accelerations are directly related to the load input from the road surface into various suspension and body components. This load in turn impacts on component durability and normal tyre forces, and hence repair and maintenance, fuel, tyre, and depreciation costs.

A description of the on-road test programme precedes the discussion of results.

2.2 Acquisition of Vehicle Response Data

2.2.1 Test sites

Five, chipseal surfaced, test sites varying in length from approximately 600 to 700m were utilised. All these sites were straight and reasonably level, and located on local authority roads in the southern Wairarapa. Road profile data for each site was obtained with an ARRB two-laser profiler operated by Info 2000, from which lane NAASRA roughness values, based on a 10m averaging length, were derived. The 10m lane-roughness data was further averaged to yield 100m lane-roughness values. Details of the test sites are summarised in Table 1, and Figure 1 provides a distribution of the 100m lane-roughness values.

Table 1 : Location and Roughness Details of Test Sites

Site No	Location	Range of 100m Roughness Level (NRC)[1]
1	Western Lake Rd, (south of Featherston)	37 to 111
2	Western Lake Rd, (south of Featherston)	42 to 103
3	Camp Road (east of Featherston)	47 to 115
4	Wards Line (east of Featherston)	34 to 52
5	Kahutara Road (south-east of Featherston)	60 to 133

[1] NRC = NAASRA roughness count

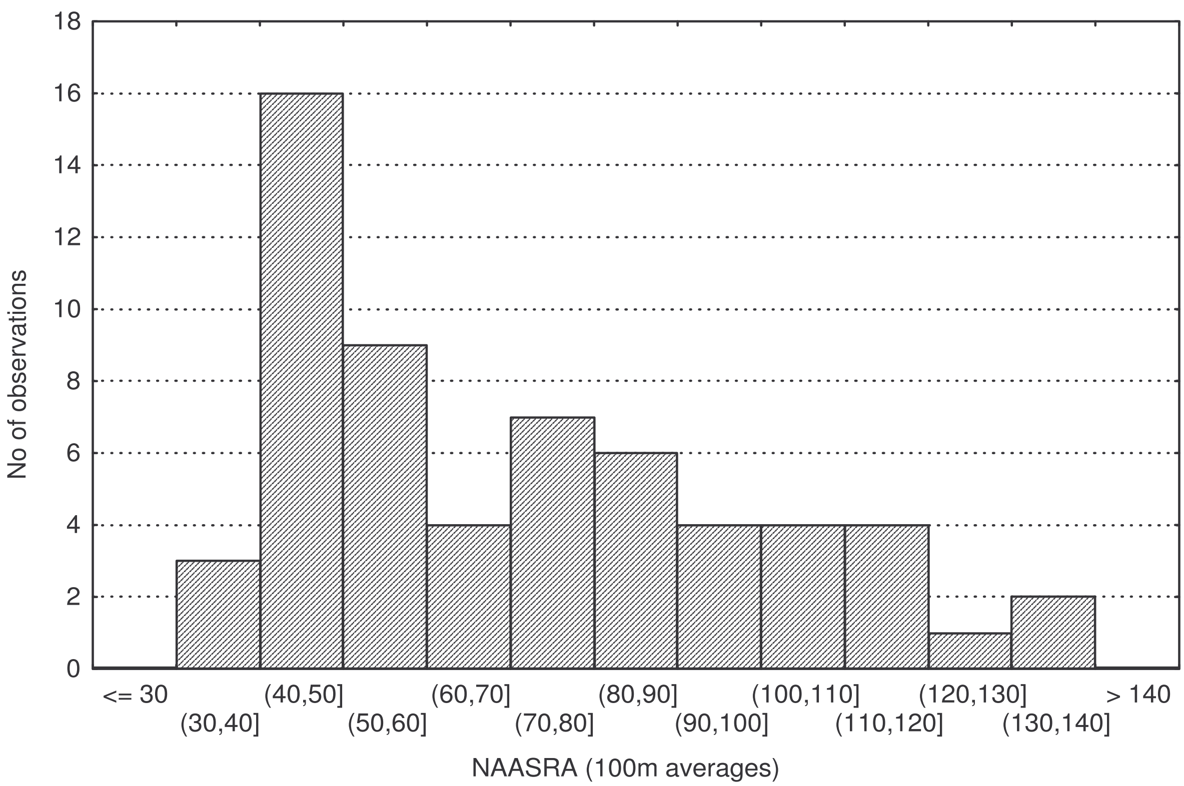


Figure 1 : Distribution of 100m Lane-Roughness Levels Over All Test Sites

2.2.2 Test Vehicles

Table 2 summaries the test vehicles used for the on-road test programme. Both cars were tested with a driver, but no passengers. The MCV was also tested with the driver only and laden to 2.5 and 3.5 tonnes on the front and rear axles respectively. The HCV-I was tested with the driver and one passenger, laden to 4.1 and 12.0 tonnes on the front and rear axles respectively.

Table 2 : Make and Model Details of Test Vehicles

Vehicle No.	PEM Vehicle Type	Make and Model	Registration Plate No.
1	Car	1984 Nissan Pulsar SSS (hatchback)	MK116
2	Car	1999 Nissan Pulsar GL (hatchback)	XS5195
3	Truck (MCV)	1996 Hino Model FD	TW5589
4	Truck (HCV)	1999 Isuzu Model FVZ	YE2433

The 1984 Nissan Pulsar SSS is Transit New Zealand's instrumented test vehicle. It has travelled only 39,500 km and is carefully maintained. Therefore, the availability of a 15 year old vehicle with comparatively low mileage offered the opportunity to gauge advances in suspension technology by comparing RMS body acceleration levels with the latest version of the same vehicle.

Almost 90% of New Zealand's car fleet is less than 18 years old (LTSA, 1999) and so the extremes of the age profile of interest in economic assessments are represented by the two test cars. Sideviews of the test cars are given in Figure 2 and Figure 3 for the test trucks.

2.2.3 Measurement of Vertical Axle and Body Accelerations

"10g" strain gauge accelerometers were employed because of their excellent frequency response range (0 – 120 Hz) and low signal to noise ratio. By comparison, body bounce/pitch and wheel hop frequencies of vehicles lie between 1.5 and 4 Hz and 8 and 15 Hz respectively. For the cars, an accelerometer was fixed to the rear axle, as close to the wheel assembly as possible. Another was firmly fixed to the boot floor, as close as possible to being directly over the axle accelerometer. For the MCV and HCV, an accelerometer was fitted to the rear axle and another immediately above on the cargo tray. An additional accelerometer was fitted to the front steering axle for the HCV.

By mounting the axle and body accelerometers in close proximity to each other, the degree to which roughness induced axle vibrations were transmitted to the vehicle body could be determined.

1984 Nissan Pulsar SSS

1999 Nissan Pulsar GL

Figure 2 : Sideviews of Test Cars

1996 Hino Model FD (MCV)

1999 Isuzu 1400 Model FVZ (HCV-I)

Figure 3 : Sideviews of Test Trucks

2.2.4 Data Acquisition and Associated Processing

A PC based data acquisition system was used to record the output from the accelerometers. For this test programme a sampling rate of 60 samples per second was employed. The output from the accelerometers was first passed through a low-pass filter prior to sampling to remove all acceleration components above 30 Hz.

Software routines were developed to extract the acceleration data for the actual test sections, split it into 100m sections, remove any transducer drift in the data, and calculate the RMS values for each 100m section. These were tabulated into a spreadsheet of NAASRA roughness values and RMS axle and body accelerations for subsequent statistical and graphical analyses.

2.2.5 Programme of Testing

The two cars were driven at four test speeds, 40, 60, 80 and 100 km/h, over each of the five test sites whereas the HCV-I was driven at test speeds of 40, 60 and 80 km/h.

Testing was performed in both directions with two runs being performed at each speed in each direction. An event marker was utilised to flag the start and end points of the test length while data acquisition was in progress.

The MCV was tested as described in Cenek and Jamieson (1999).

The date the tests were carried out and associated weather conditions are tabulated in Table 3.

Table 3 : Test Timetable and Associated Weather Conditions

	Test Vehicle	Date of Testing	Weather Conditions
1	Car – Old	21/6/99	Fine, light winds
2	Car – New	23/6/99	Fine, overcast, moderate northerly winds
3	MCV	18/3/99	Fine, high cloud, light to moderate winds
4	HCV	1/7/99	Fine, high cloud, moderate northerly winds

2.3 Relationships Between NAASRA Roughness and Vehicle Vibrations

Plots of the RMS axle and body accelerations versus corresponding lane NAASRA roughness values are given in Appendix A for each of the test vehicles. Least squares linear regression lines have been included to aid comparison of the resulting roughness slopes. The derived relationships of RMS axle and body accelerations to roughness are summarised in Tables A1 and A2 of Appendix A respectively.

Linear correlations between RMS axle and body accelerations (m/s^2), vehicle speed (km/h) and NAASRA roughness (NRC) are tabulated in Table 4 for ready reference. A natural logarithmic transformation was used to test if a non-linear relationship would be more appropriate. The transformation produced correlations which were, in the main, similar or slightly lower than the linear correlations.

Table 4 : Significant Correlations with Vehicle Accelerations

Test Vehicle	RMS Acceleration	Coefficient of Correlation (r)		
		Vehicle Speed	Roughness	Vehicle Speed & Roughness
1985 Nissan Pulsar	Axle	0.62 (0.70)	0.37 (0.36)	0.71 (0.75)
	Body	0.51 (0.55)	0.65 (0.66)	0.88 (0.87)
1999 Nissan Pulsar	Axle	0.51 (0.57)	0.45 (0.43)	0.71 (0.69)
	Body	0.54 (0.59)	0.64 (0.65)	0.89 (0.87)
1996 Hino	Axle	0.37 (0.37)	0.57 (0.59)	0.72 (0.70)
	Body	0.41 (0.41)	0.53 (0.52)	0.69 (0.66)
1999 Isuzu	Front Axle	0.54 (0.60)	0.56 (0.58)	0.81 (0.83)
	Rear Axle	0.57 (0.71)	0.42 (0.47)	0.73 (0.80)
	Body	0.43 (0.37)	0.41 (0.41)	0.63 (0.56)

Bracketed figures pertain to natural logarithmic transformation correlations.

The important features of the RMS acceleration versus roughness relationships are as follows:

- The rate of increase of both the RMS axle and body accelerations with roughness is clearly speed dependent, increasing with increasing speed. This result is at odds with the PEM which indicates additional VOC due to roughness is independent of speed.

- Axle accelerations are more sensitive to both roughness and vehicle speed than body accelerations. This is expected as the basis of vehicle suspension design is to absorb road load inputs to protect the vehicle and vehicle occupants from variations in the travelled surface. These differences in sensitivities between axle and body accelerations become more pronounced as the speed increases and is a result of the non-linear behaviour of suspension components.

- For vehicle speeds greater than 40 km/h, there is evidence of a linear correlation between RMS axle and body accelerations and NAASRA roughness over the 35 to 135 NRC range investigated. The degree of linear correlation between vehicle response and roughness improves with increasing speed and is greater for cars than trucks.

- At a vehicle speed less than 30-40 km/h, axle and body accelerations appear not to be affected by roughness, irrespective of vehicle type. This result suggests that there is no VOC related benefit in reducing roughness levels of sealed pavements if the vehicle speed is less than 30-40 km/h because any surface irregularities can be readily absorbed by the vehicle's suspension system.

- The RMS body accelerations of the 1985 and 1999 Nissan Pulsars demonstrated identical sensitivity to increasing roughness. Furthermore, the RMS body acceleration levels were of the same magnitude. This result suggests that, for popular New Zealand passenger car models, advances in suspension technology over the past 10 to 15 years have tended to revolve around improved handing rather than improved ride quality. Therefore, only one VOC-roughness relationship is necessary for the PEM's car class as it will apply across the 16 to 18 year vehicle-age profile used for the economic assessment of roading projects.

- When vehicle speed and roughness are multiplied together, the linear correlation with vertical body acceleration is considerably improved when compared with the correlations obtained with these parameters individually. Table 5 tabulates the coefficient estimates of the regression line of RMS acceleration on the combined vehicle speed–roughness parameter for the test vehicles corresponding to the plots given in Figures A9 to A16 of Appendix A. With reference to Table 5, about 40 to 80% of the variability observed in the vertical body accelerations and about 50% of the variability observed in the vertical axle accelerations can be explained by the combined vehicle speed-roughness parameter.

Of all the above findings, the most significant with regard to the PEM is the speed dependent nature of a vehicle's response to increasing roughness. The PEM provides VOC as a function of NAASRA road roughness. Therefore, the effects of speed on vehicle response are implicitly included as well as the constraint of maximum tolerable ride severity in limiting the vehicle speed. An alternative, more fundamental approach, is to estimate VOC as a function of the combined vehicle speed-roughness (VR) parameter for each vehicle category. This VR parameter can be considered to be a measure of "bumps per unit time".

Table 5 : Coefficient Estimates for Vehicle Response Model, Acc = aVR + b,

where: Acc = 100m averaged RMS axle or body acceleration (m/s^2)
V = Vehicle Speed (km/h)
R = 100m averaged lane NAASRA roughness

Vehicle	RMS Acceleration	Coefficients		Statistics	
		Slope (a)	Intercept (b)	r^2	Standard Error of Estimate
1985 Nissan Pulsar	Axle	0.00028 ($1.3x10^{-5}$)	0.90 (0.07)	0.50	0.68
	body	0.000106 ($5.8x10^{-6}$)	0.13 (0.04)	0.76	0.16
1999 Nissan Pulsar	Axle	0.00043 ($2.0x10^{-5}$)	1.78 (0.11)	0.50	1.09
	Body	$9.65x10^{-5}$ ($2.2x10^{-6}$)	0.32 (0.01)	0.79	0.12
1996 Hino	Axle	0.00035 ($2.06x10^{-5}$)	0.98 (0.13)	0.52	0.66
	Body	0.000114 ($9.1x10^{-6}$)	1.13 (0.05)	0.48	0.23
1999 Isuzu	Axle	0.00098 ($5.1x10^{-5}$)	-1.08 (0.23)	0.53	1.77
	Body	$9.48x10^{-5}$ ($6.6x10^{-6}$)	0.82 (0.03)	0.39	0.22

Bracketed figures pertain to standard error of the coefficient.

2.4 VOC Model Form

Intuitively, we can expect the components of VOC such as fuel consumption, tyre wear, and repairs and maintenance to increase with surface roughness. Empirical studies have found relationships between VOC and surface roughness to be either linear or exponential. However, these studies have generally covered large roughness levels typically associated with poorly maintained sealed roads or the difference between unsealed and sealed roads. Questions remain as to the applicability of these relationships to the range of roughness levels typical of a properly maintained sealed road network (Lay, 1999).

Axle and body vertical accelerations are directly related to the road surface induced random loading of vehicle components. Therefore, the mechanisms contributing to the increase of these accelerations with increasing roughness must also cause increases in the various VOC components.

For speeds greater than 40 km/h, the vertical and axle body accelerations were shown to increase linearly with roughness, even at very low roughness levels (less than 60 NRC). This result suggests that a linear model is appropriate for predicting VOC over roughness ranges typically associated with a maintained sealed network.

2.5 Roughness Effects on Travel Speeds

Recent studies on the Newell Highway by ARRB Transport Research indicate that pavement roughness does not affect travel speeds until a pavement roughness of 120 NRC is reached (Symonds Travers Morgan and Cox, 1996). Similarly, Paterson and Watanatada (1985) show that at low roughness levels (less than 160 NRC), travel speeds are relatively insensitive to roughness, with safety and speed limit considerations tending to dominate.

Delanne and Daburon (1999) have attempted to relate vertical accelerations at the seat sliding rail to different ride comfort levels. These RMS vertical accelerations are reproduced in Table 6.

Table 6 : Comparison of Ride Comfort Related Acceleration Limits Applying to Light Passenger Cars

Ride Comfort Rating	RMS Vertical Acceleration at Seat Sliding Rail (m/s^2)		
	TRRL (UK)	**ISUR (UK)**	**LCPC (FRANCE)**
Not uncomfortable	<0.55	<0.54	<0.50
A little uncomfortable	0.55 to 0.93	0.54 to 0.94	0.50 to 079
Rather uncomfortable	0.94 to 1.37	0.95 to 1.18	0.80 to 1.09

With reference to Table 6, the highest acceleration level reached before an attenuating effect on travel speed occurs is about 1.4 m/s^2. Applying the body acceleration relationship given in Table 5 for the 1985 Nissan Pulsar, results in a threshold roughness level of about 120 NRC for a 100 km/h speed zone for roughness to cause a reduction in travel speed. This is in close agreement with ARRB's Newell Highway Study. To put this threshold roughness level in perspective, less than 5% of New Zealand's sealed State Highway network exceeds 120 NRC based on 1998, 100m lane roughness values. Similarly, predicted threshold roughness levels for 50, 70 and 80 km/h speed zones are 240 170 and 150 NRC respectively.

Given such high roughness levels before limiting of travel speeds occurs, it is imperative that additional VOC due to roughness be related to travel speed.

PART B

Analysis of Fleet Operator Surveys

3 ANALYSIS OF FLEET OPERATOR SURVEYS

3.1 Resource Vehicle Operating Costs

The PEM's roughness related VOC's comprise fuel, tyres and tubes, repairs and maintenance, oil and the proportion of depreciation associated with vehicle use. These VOC's are given in resource costs terms. Therefore, they are exclusive of duties and indirect taxation, such as excise and other taxes on fuel, import duty on built-up vehicles, and Goods and Services Tax (GST) on all cost inputs. The procedures adopted in deriving 1998 component VOC estimates from databases provided by fleet operators are detailed below for ready reference.

3.1.1 Fuel and Oil

Two independent factors determine fuel cost, namely price and consumption. For this review it has been assumed that all cars use petrol and all commercial vehicles use diesel. During 1998, the pump prices were 82.4c/litre and 44c/litre for petrol and diesel respectively. Removing the 12.5% GST component reduces these prices to 73.244c/litre and 39.111c/litre. The duty, taxes and levies applying as at 15 May 1998 are 34.985c/litre for petrol and 0.355c/litre for diesel (Ministry of Commerce, 1999). The resource cost of petrol and diesel therefore are calculated to be 38.259c/litre and 38.756c/litre respectively.

Whenever fuel consumption has been recorded as either a cost or quantity in the fleet database, this is divided by the corresponding distance travelled and, in the case of quantity, multiplied by the resource cost, to provide fuel cost in terms of cents per kilometre. In the absence of any specific fuel consumption data, default fuel cost values tabulated in Table 7 have been employed. These default values have been derived from latest annual car operating costs published by the New Zealand Automobile Association (Directions, 1999) and fuel expense data obtained by the Road Transport Forum (RTF) through surveys of its members.

The cost of lubricants is also included in RTF's values. For cars, the AA recommends a provision of 1 litre of oil per 2,500 km be made irrespective of engine capacity. Assuming the resource cost of oil is $6.729 per litre, this translates to a running cost of 0.269c/km.

Table 7 : Default Resource Fuel and Oil Costs

Vehicle Type	Fuel and Oil Cost (c/km)			
Cars	0-1300cc	1301-1600cc	1601-2000cc	Over 2000cc
Petrol	2.716	2.908	3.329	4.055
Oil	0.269	0.269	0.269	0.269
Total	2.985	3.177	3.598	4.324
Trucks	HCV-I (6x4)		HCV-II (8x4)	
Diesel & Oil Combined	16.278		20.541	

3.1.2 Tyres

Tyre cost data contained in fleet databases have been converted to resource cost by removing the 12.5% GST component. Up until 1998, there was an additional 12.5% excise tax on truck tyres so this has also been removed.

For cars, tyre sizes are generally linked to engine capacity, the smaller the engine capacity, the smaller the wheel rim size. Tabulated in Table 8 are the best selling tyre sizes in 1998, corresponding to the engine capacity categories adopted by the AA, and their associated resource costs. Using weightings derived from first time registration of cars by engine capacity over the 5 year period 1992 to 1998, the resource cost for car tyres representative of the New Zealand car fleet was calculated to be $96.93c.

Table 8: Resource Cost of Car Tyres

Engine Capacity (cc)	Best Selling Tyre Size @ 1998	Tyre Resource Cost (1998$)	Fraction of NZ Car Fleet (1993-98)`	Weighted Tyre Resource Cost (1998$)
0-1300	155 R13	61.33	0.037	2.27
1301-1600	175/70 R13	84.44	0.304	25.67
1601-2000	185/70 R14	96.89	0.384	37.21
>2000	205/65 R15	115.56	0.275	31.78
			Σ=1.000	Σ=96.93

The AA estimates an average tyre life of 40,000 km for cars, giving tyre running costs per year ranging from 0.6c/km for cars with an engine capacity less than 1300cc to 1.2c/km for cars with an engine capacity over 2000cc.

For an inter-city line haul operation, the corresponding tyre life value for a R22.5 sized truck tyre is 82,500 km for the front tyres and 77,500 km for the rear tyres. Front tyres are not recapped. Assuming resource prices of $409 for a new tyre and $203 for a recapped tyre results in a typical HCV tyre running cost figure of 3.09c/km (comprising 2 front tyres at 0.496c/km /tyre and 8 rear tyres of 0.262c/km /tyre).

3.1.3 Repairs and Maintenance

This item comprises those costs of repairs and maintenance incurred as a result of normal wear and tear. Repair costs necessitated by crashes are not included. In addition, care has been taken to exclude vehicles which are under three or more years warranty service contract such as offered by Daewoo and Mazda, as this is not yet standard industry practice. The 12.5% GST component has been removed to derive the resource repair, and maintenance cost.

3.1.4 Depreciation Due to Use

There are three different causes of depreciation. A vehicle may wear out through use on the roads, it may wear out through age, or it may become obsolete as a result of newer and better vehicles being produced. Therefore depreciation comprises time and distance components. However, only the distance component is a running cost.

The depreciation cost for vehicles has been derived by using the approach adopted in NZVOC whereby a proportion of yearly vehicle capital cost is allocated to running costs (Bennett, 1989a). For cars, 30% of the yearly vehicle capital cost is assumed to be due to use whereas for other vehicle classes this reduces to 15%.

The commercial capital costs of running a vehicle include depreciation and interest charges. Depreciation is the decline in value of the asset. Therefore, over its service life, depreciation must equal the asset value (less adjustments for scrap value and tyres). Interest charges represent the time value of money. In an economic analysis, both components need to be taken into account but economic prices (i.e tax excluded and adjustments for inflation) have to be used.

In calculating yearly vehicle capital cost, NZVOC converts the purchase price of a vehicle, less GST and tyres, to a uniform annual cost using the capital recovery factor (CRF) (Lu, 1969). The residual value of the vehicle is also converted to a uniform annual cost using the sinking fund deposit factor (SFDF) (Lu, 1969). For simplicity, NZVOC assumes that the residual value is 5% of the purchase price of the vehicle, less GST and tyres. The difference between the two annual costs represents the yearly vehicle capital cost. Mathematically this can be expressed as:

$$\mathrm{VCC} = \mathrm{VPP} \cdot \mathrm{CRF}_{i-n} - 0.05 \cdot \mathrm{VPP} \cdot \mathrm{SFDF}_{i-n} \tag{1}$$

where:

	VCC	=	vehicle capital cost (\$/year)
	VPP	=	vehicle purchase price less GST and tyres (\$)
	CRF	=	capital recording factor = $i\,(1 + i)^n/((1 + i)^n - 1)$
	SFDF	=	sinking fund deposit factor = $i\,/((1 + i)^n - 1)$
	i	=	economic discount rate = 10%
	n	=	service life in years

Simpler approaches for calculating yearly vehicle capital cost are to:

(1) calculate depreciation as the purchase price less residual value of the vehicle divided by its service life and interest costs as half the purchase price multiplied by the discount rate i.e:

$$\mathrm{VCC} = \mathrm{VPP}\left(\frac{0.95}{n} + 0.5i\right) \tag{2}$$

(2) divide the purchase price of the vehicle less its residual value by the sum of the discount factors over the life of the vehicle i.e.:

$$VCC = \frac{VPP\left(1 - 0.05\right)}{USPWF_{\ i-n}} \tag{3}$$

where: USPWF = uniform series present worth factor
$= (l + i)^n - 1/i\ (l + i)^n$

Equations 1 and 3 are preferred as they take better account of the effect of time on capital when compared to equation 2. With reference to Table 9, all three methods give comparable values of yearly vehicle capital cost.

Table 9 : Comparison of Methods for Calculating Yearly Vehicle Capital Costs (service life = 16 years, discount rate = 10%)

Vehicle No	Purchase Price (exc GST)	Tyres (exc GST)	Vehicle Capital Cost ($/year)		
			Eq.1	Eq.2	Eq.3
1	20,503.71	500	2,528	2,188	2,429
2	45,507.16	500	5,689	4,923	5,465
3	142,222.22	5,010	17,344	15,008	16,660
4	195,555.55	6,058	23,952	20,726	23,009

Equations 1, 2 and 3 show that yearly capital costs are dependent on the service life. Vehicle lives are a reflection of a host of factors including the rise in direct maintenance costs, the costs of finding spare parts for obsolete vehicles, interest charges, technical progress, fashion, and the costs associated with a breakdown.

If vehicle repair and maintenance costs can be reduced by road investment, the vehicle service life will be increased, so there will be a capital cost saving. Ideally, service life should be a function of roughness, but it is not clear from Bennett (1989a) if such a function has been incorporated in NZVOC.

In calculating the depreciation cost due to use, the asset list price recorded in the fleet database is required for application of equation 1. From this price is subtracted the GST component and tyre costs which are calculated as follows:

for cars,	5 tyres @ resource cost $100[1]	= $500
for HCV's,	front tyres @ resource cost	= $409
	rear tyres @ resource cost	= $524

1 Resource cost of $96.93 derived in section 3.1.2 has been rounded to $100.

As an example, a 6x4 truck has 10 tyres giving a total tyre cost of $5,010.

In applying equation 1, a discount rate of 10% has been used and service life and annual utilisation values selected to match those in NZVOC for the car and HCV classes so as to allow direct comparisons with the PEM's component VOC's. Therefore for cars, the annual utilisation was taken to be 14,000 km with a corresponding service life of 18 years and for HCV's the corresponding figures were 40,000 km and 16 years. These service lives were taken to be invariant with roughness based on the opinion of industry that the roughness levels experienced on New Zealand's sealed state highway network are insufficient to effect maintenance costs and vehicle re-sale values.

With reference to motor registration statistics for 1998 (LTSA, 1999), 89.2% of the car fleet has an age of 18 years or less and 81.1% of the truck fleet has an age of 16 years or less suggesting that the NZVOC service lives are still applicable. The corresponding mean ages of the fleets are 11.2 years for cars and 11.7 years for trucks.

The yearly vehicle capital cost is converted to a running cost using the following equation:

$$DR = f \cdot VCC \cdot 100/AKM \tag{4}$$

where:
- DR = use related depreciation (c/km)
- VCC = vehicle capital cost ($/year)
- f = amount of depreciation due to use as a decimal
  = 0.3 for cars, 0.15 for HCV's
- AKM = average annual utilisation in km (=14000 for cars, 40000 for HCV's)

The depreciation cost given by equation 4 is very sensitive to service life and annual utilisation. For example, decreasing the service life from 18 to 16 years and annual utilisation from 14,000 to 12,000 km will increase the depreciation cost by a factor of 1.22. Therefore, it is necessary to confirm the currency of the NZVOC service life and annual utilisation figures, especially given the impact of used imported vehicles on the market. For 1998, used imported vehicles accounted for 64.9 % and 42.4% of car and truck registrations respectively.

3.2 Fleet Databases

A selective survey of commercial vehicle fleet operators was conducted over June-July 1999. The critical requirement was to identify companies/agencies who predominantly operated their vehicles on the same network of roads. State highway operations were preferred, such as intercity line haul, because road condition and geometry details could be readily extracted from Transit New Zealand's RAMM database. Approaches were therefore limited to companies/agencies who were known from a previous survey of vehicle repair and maintenance costs (Opus–BCHF 1998) to have not only vehicles that operated consistently on the same roads, but also maintained databases that could provide the required disaggregated VOC information.

3.2.1 Car Database

All car VOC data was extracted from Fleetlease's (formerly NAFA Asset Management Limited) vehicle management database. Fleetlease carries out active management and cost recovery for over 5,000 fleet cars and light commercial vehicles. For each vehicle entry in the database, there are details associated with purchase and disposal dates and prices, first NZ registration date, engine capacity and fuel type, cumulative mileage, costs by expenses including crash repairs, general repairs and maintenance, routine servicing, and tyres and costs by component (e.g. steering, suspension, transmission, electronics etc.).

Sorting of the vehicle records by routine service location and selected company clients (e.g. stock and station agents) was possible allowing the effects of regional difference and unsealed road operation on VOC to be investigated. It was assumed, that for the time histories recorded in the database, the vehicle operated predominately on state highway roads in the region where routine servicing occurred, and so the VOC should reflect the effect of road conditions in each of these regions. The road roughness assigned to each region was derived from the mean values supplied by Transit New Zealand and tabulated in Table 10.

Vehicles either involved in a crash, under warranty service contact, having a cost history less than a year, or still under active lease were excluded. These exclusions resulted in 569 car records and 102 light commercial vehicle (LCV) records available for analysis. Of the 569 car records, 554 were leased to companies operating predominately on state highway and sealed urban roads (designated "on-road" in the subset database). About 20% (108) of the "on-road" cars were purchased second hand under a sale and leaseback arrangement (designated "used" in the subset database). Only 15 car records pertained to cars operating on a combination of unsealed and sealed roads (designated "off-road" in the subset database). The corresponding LCV distributions were 67 "on-road" records, 31 "used" records and 4 "off-road" records. For both cars and LCV's, all "off-road" vehicles were purchased new.

The resulting mileage, vehicle age and engine capacity distributions for the car class are shown as histogram plots in figures 4 to 6. Features to note are:

- a normal distribution of vehicle mileages over a range of 10,000 to 180,000 km with a mean of 80-90,000 km;
- an age range of 1 to 7 years, with the majority of cars being disposed of after 3 or 4 years;
- over 50% of the cars have an engine capacity of greater than 2 litres.

Table 9 : Mean Roughness by Transit New Zealand Region

Region	100m NAASRA Roughness by Year				
	1994	1995	1996	1997	1998
Northland	72	72	70	72	74
Auckland	65	65	61	60	59
Waikato	72	71	70	74	75
Bay of Plenty	72	71	70	72	74
Gisborne	82	82	82	87	91
Hawkes Bay	73	71	69	72	73
Taranaki	75	75	72	76	78
Wanganui/Manawatu	74	73	72	73	75
Wellington	63	61	60	59	62
Nelson/Marlborough	65	63	61	63	67
Canterbury	58	57	56	58	60
West Coast	69	68	67	69	72
Otago	63	62	61	62	65
Southland	60	57	58	58	61

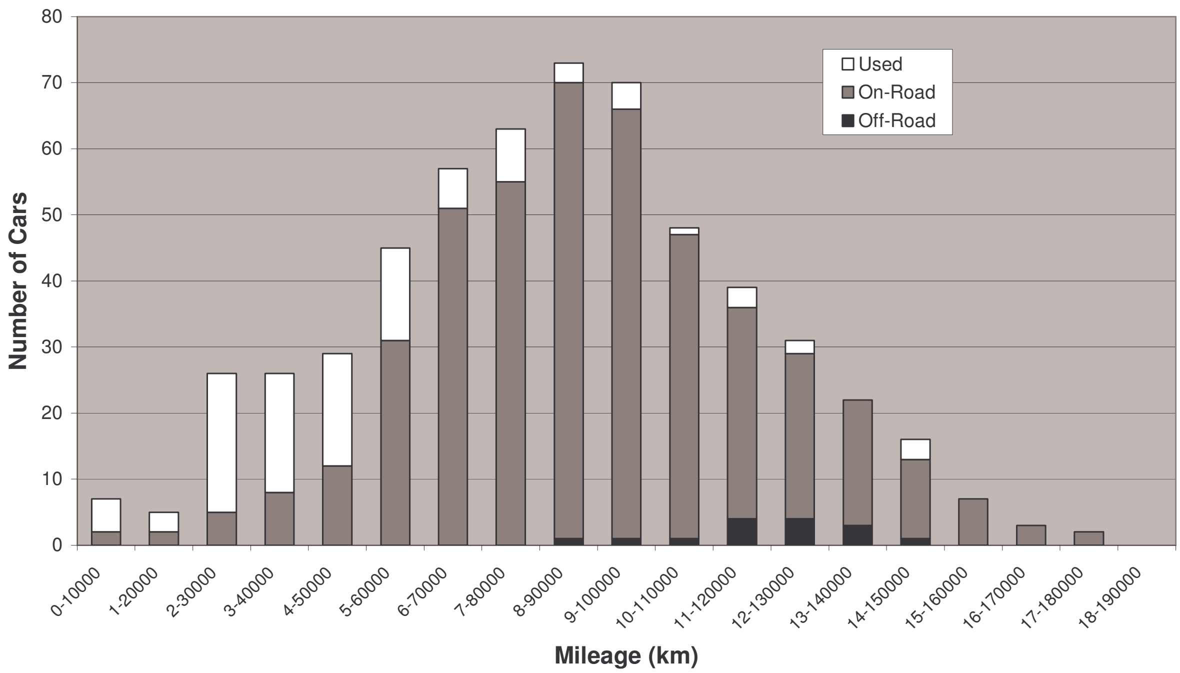


Figure 4 : Fleetlease Subset Car Fleet Database – Mileage Distribution

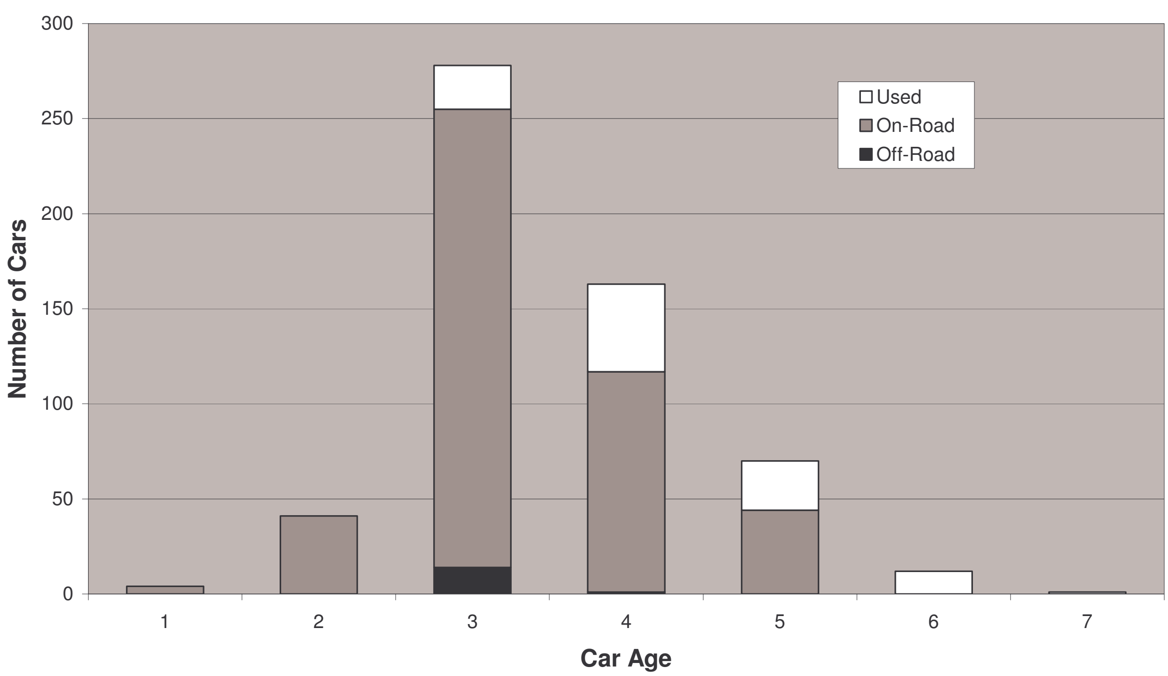


Figure 5 : Fleetlease Subset Car Fleet Database – Age Distribution

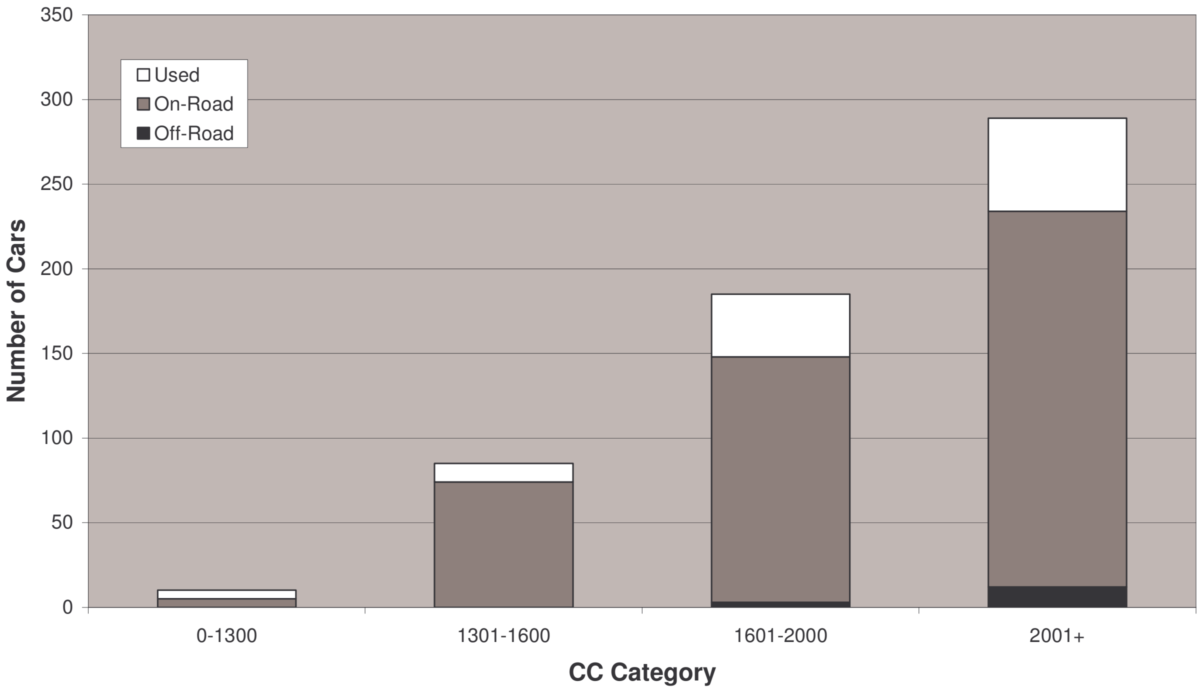


Figure 6 : Fleetlease Subset Car Fleet Database – Engine Capacity Distribution

3.2.2 Truck Database

The truck VOC database, comprising 65 records, was derived from data supplied by five private transport operators who were able to provide comprehensive cost records for vehicles which were consistently driven over the same routes or region. Because four of the five transport operators have requested confidentiality, they have been designated as companies, A to E in the database.

Of the 65 records, 39 pertained to an oil company's tanker fleet which travelled on a mix of state highways and local sealed and unsealed roads (company A) and 19 pertained to the fleet used by NZ Post for intercity mail deliveries (company C). For all records it was possible to derive a mean roughness for the route or region from the RAMM database. The mean roughness levels ranged from 59 to 139 NRC.

The truck database used in this review is reproduced in full in Appendix B. HCV-I's (rigid trucks) account for 79% (51) of the records and HCV-II's (tractor units) account for 21% (14). Unlike the car/LCV database, actual rather than inferred fuel costs were available for 22 of the 65 records (companies C and D). With reference to Appendix B, there are several cases of the same vehicle type being operated on different routes enabling the effect of road condition (bendiness and roughness) to be examined.

3.3 Analysis of Passenger Car VOC

3.3.1 Component VOC

Means of component costs contained in the subset Fleetlease database were derived in terms of "off-road", "on-road", "used", engine capacity and PEM vehicle class (i.e. passenger car and LCV) categories to identify any significant differences or trends. Summaries of the resulting mean component costs and associated dispersion and error statistics of standard deviation (SD), coefficient of variation (CoV), and standard error (SE) are presented in Tables 11 and 12. The originity data for these tables is presented in Appendix C.

With Reference to Tables 11 and 12, the inferred fuel and oil and depreciation costs display significantly less variation than the actual recorded tyre and repairs and maintenance costs as expected. This variation in tyres and repairs and maintenance costs is significant with the coefficient of variation ranging from 0.5 to 2 and reflects differences in important factors such as driving style, proportion of urban versus rural running and general care the vehicle receives.

Table 11 : Passenger Car Component VOC by Engine Capacity as Derived from Fleetlease Database

Engine Capacity (cc)	Sample Size	Statistic	Component VOC (c/km)				
			Fuel & Oil	Tyres	Repairs & Maintenance	Depreciation	Total
0-1300	**10**	**Mean**	**2.99**	**0.76**	**1.68**	**5.46**	**10.87**
(%1993-98		SD	0	0.73	0.78	0.41	1.48
Reg = 3.7%)		CoV	0	0.96	0.46	0.08	0.14
		SE	0	0.23	0.15	0.13	0.47
1301-1600	**85**	**Mean**	**3.18**	**0.59**	**1.16**	**6.38**	**11.31**
(%1993-98		SD	0	0.47	0.54	0.56	1.04
Reg = 30.4%)		CoV	0	0.80	0.47	0.09	0.09
		SE	0	0.05	0.06	0.06	0.11
1601-2000	**185**	**Mean**	**3.60**	**0.87**	**1.25**	**7.82**	**13.54**
(%1993-98		SD	0	1.11	0.69	0.77	1.90
Reg = 38.4%)		CoV	0	1.27	0.55	0.10	0.14
		SE	0	0.08	0.05	0.06	0.14
>2000	**289**	**Mean**	**4.32**	**1.15**	**2.04**	**9.35**	**16.85**
(%1993-98		SD	0	2.71	4.85	2.23	7.97
Reg = 27.5%)		CoV	0	2.46	2.38	0.24	0.47
		SE	0	0.16	0.29	0.13	0.47
Total average	569	-	3.89	0.96	1.64	8.34	14.84
NZ car fleet weighted average	**569**	-	**3.65**	**0.8**	**1.45**	**7.71**	**13.67**

SD = Standard Deviation, CoV = Coefficient of Variation, SE = Standard Error, Reg = New Registrations

Table 12: Passenger Car and LCV Component VOC by Use

Vehicle Use	Sample Size	Component VOC (c/km)					
		Fuel & Oil		Tyres	Repairs & Maintenance	Depreciation	Total
Off-road Car	15	Mean	4.18	0.64	1.48	8.60	14.89
		SD	0.30	0.17	0.59	0.69	1.52
		CoV	0.07	0.27	0.40	0.08	0.10
		SE	0.08	0.04	0.15	0.18	0.39
LCV	4	Mean	4.32	0.64	1.60	2.53	9.09
		SD	0.0	0.37	0.78	0.10	1.22
		CoV	0.0	0.58	0.49	0.04	0.13
		SE	0.0	0.19	0.39	0.05	0.61
On-road Car	446	Mean	3.88	0.85	1.50	8.29	14.52
		SD	0.46	2.17	3.86	1.65	6.51
		CoV	0.12	2.55	2.57	0.20	0.45
		SE	0.02	0.10	0.18	0.08	0.31
LCV	67	Mean	4.01	0.64	1.31	2.52	8.48
		SD	0.36	0.44	0.52	0.47	1.17
		CoV	0.09	0.69	0.40	0.19	0.14
		SE	0.04	0.05	0.06	0.06	0.14
Used Car	108	Mean	3.90	1.48	2.26	8.52	16.16
		SD	0.47	1.54	1.72	3.19	4.98
		CoV	0.12	1.04	0.76	0.37	0.31
		SE	0.05	0.15	0.17	0.31	0.48
LCV	31	Mean	4.21	2.12	2.02	2.54	10.88
		SD	0.35	1.70	1.20	0.49	2.45
		CoV	0.08	0.80	0.59	0.19	0.22
		SE	0.06	0.31	0.22	0.09	0.44
Total Average:							
Car		569	3.89	0.96	1.64	8.34	14.84
LCV		102	4.08	1.09	1.54	2.52	9.24

However, the general trend of increasing tyre and repairs and maintenance costs with increasing engine capacity shown in Table 11 is consistent with the car operating cost tables annually published by the Automobile Association and widely used as the basis for reimbursing employees who use their own vehicle on company business (Directions, 1999). This check provides some confidence in the reliability of the subset Fleetlease database. The anomalous result for the 0-1300 cc class can be discounted on the grounds of the small sample size (10 records) compared to the other engine capacity classes.

Table 12 suggests that there is no significant difference between "off-road" and "on-road" use for both car and LCV classes, though not much credence can be placed on this result because of the very small "off-road" sample size (14 and 4 for car and LCV classes respectively). However, there is a statistically significant difference between "on-road" and "used" categories, with the "used" category having a total VOC cost that is 1.6 to 2.4 c/km greater. These "used" vehicles typically have a speedometer reading of 50 to 60,000 km on entering the fleet. Examination of the recorded expenses suggests that these vehicles undergo a comprehensive service, which includes the fitting of a complete set of replacement tyres, before being leased. As a result, tyre costs are a factor of 2-3 times greater than for the new, "on-road" vehicles whereas repair and maintenance costs are 1.5 times greater.

Table 12 also shows that the average VOC of LCV's is 5-6 c/km less than for cars and is entirely due to differences in annual utilisation (20,000 km for LCV's cf. 14,000 km for cars) and the proportion of depreciation assigned to use (15% for LCV's cf. 30% for cars). All things being equal, LCV's therefore have a depreciation cost that is 0.35 that of cars despite an identical service life of 18 years. This result again highlights the sensitivity of PEM VOC to the three factors which dictate the depreciation cost component, these being annual utilisation, service life and the proportion of depreciation that is use related.

3.3.2 Comparison of Passenger Car VOC

Besides the subset Fleetlease database, component VOC data was additionally derived from the 1998 car operating cost table prepared by the Automobile Association (AA) (Directions, 1999) and the 1987/88 car operating cost bulletin prepared by the economics division of the Ministry of Transport (MoT, 1987a). This Ministry of Transport (MoT) data was used to calibrate the NZVOC parts costs model (Opus-BCHF 1998) and also derive weightings so that relativities between the predicted component VOC's were correct when NZVOC version 3.1 was released in 1989.

The component VOC's derived from these sources are compared with those generated by the NZVOC model in Table 13, both in terms of c/km and as a percentage of the total VOC. The NZVOC component VOC's were calculated for a vehicle speed of 100 km/h on a road with 0 gradient and 60 NAASRA counts/km roughness. The NZVOC component costs were updated to 1998 costs using the 1.06 factor given in Appendix A12 of the PEM (Transfund, 1997) to enable direct comparison with the Fleetlease and AA component costs. No attempt was made to update the 1987/88 MoT component costs.

Table 13: Comparison of Resource Component VOC for Car Class Weighted to 1993-98 New Registrations by Engine Capacity

VOC Component	Source of Costs			
	NZVOC (1998c/km)	Fleetlease Database (1998c/km)	1999 AA (1998c/km)	1987/88 MoT (1988c/km)
Fuel and Oil	4.5 (15.1)	3.7 (26.7)	3.7 (17.7)	4.8 (20.1)
Tyres	1.0 (3.2)	0.9 (6.3)	2.1 (10.1)	1.6 (6.9)
Repairs & Maintenance	16.7 (56.6)	1.5 (10.6)	7.6 (36.9)	10.7 (45.4)
Depreciation	7.4 (25.1	7.7 (56.4)	7.3 (35.3)	6.5 (27.6)
Total	29.6	13.8	20.7	23.6

Bracketed figure pertains to percentage of total

With reference to Table 13, the following points are made:

(1) The depreciation costs values are in good agreement. This is not unexpected because the same values of service life (18 years) and utilisation (14,000 km per annum) were used so new vehicle price is the only point of difference.

(2) The difference between the AA and MoT fuel costs are due to differences in petrol pump price (82.4 c/P (AA) cf. 92c/P (MoT)) and fuel consumption (8.7 P/100 km (AA) cf. 9.6 P/100 km (MoT)). Accordingly, the AA figures correctly reflect current fuel prices and technology advances over the past decade related to electronic engine management, lower rolling resistance tyres, improved aerodynamics, and more efficient transmission systems. As the NZVOC model was calibrated against the 1987/88 MoT VOC data, there is no surprise that the fuel costs are in reasonable agreement. Similarly the AA fuel consumption estimates were used to infer fuel costs for the Fleetlease database, hence the perfect agreement.

(3) The expected tyre cost assuming an average tyre life of 40,000 km ranges from 0.6 c/km to 1.2 c/km based on the unit tyre costs given in Table 8. Therefore, NZVOC and Fleetlease values are of the right order whereas the AA's and the MoT's are too high. The higher MoT tyre cost can be explained on account that it has been based on a lower average tyre life of 30,000 km and replacement of the spare tyre in addition to the four wearing tyres. A replacement set of 5 tyres also appears to be assumed by the AA but the tyre resource costs appears to be about 1.7 greater than given in Table 8. This suggests that the AA tyre cost makes a generous provision for tyre fitting, balancing and wheel alignment.

(4) Relative to the AA and MoT repairs and maintenance costs, those of NZVOC appear to be significantly over-estimated whereas those derived from the Fleetlease database are under-estimated. This result is of particular concern because the VOC-roughness costs presented in the PEM are dominated by repair and maintenance costs. Should repairs and maintenance costs be over-estimated in the base cost then the roughness effects will also be over-estimated. Given the importance of a realistic repairs and maintenance cost, a more detailed analysis of the AA, Fleetlease and MoT estimates follows.

3.3.3 Assessment of Car Repairs and Maintenance Costs

Of the four component VOC's for the car class, the largest disagreement between the AA, Fleetlease and MoT estimates occurs for repairs and maintenance. The high MoT estimate cf. 10.7 c/km based on 1987/88 costs can be readily discounted because it has been largely derived from vehicle fleet records kept by Government departments over the 1970's and early 1980's. Therefore, the 1987/88 MoT estimate pertains to fleet vehicles which, in the main, were sourced from the United Kingdom and Australia, and not Japan. Popular fleet cars of the time, such as Vauxhall Chevettes, Ford Escorts, Ford Cortinas and Holden Kingswoods were markedly different to the current fleet in terms of poorer build quality, poorer mechanical reliability, and more frequent routine volume servicing. Unfortunately, the MoT estimate has been used for partial calibration of the HDM-III parts consumption equations incorporated in NZVOC (Bennett, 1989b).

The AA repair and maintenance estimate can be regarded as being representative of vehicles in private ownership. However, when Jim McCutcheon, the AA technical advisor responsible for producing the annual car operating costs tables, was approached, it was discovered that the AA took a very conservative approach in deriving repair and maintenance costs. Anything likely to need replacing because of age was accounted for along with routine servicing. Therefore, the AA estimate includes the replacement of the exhaust system, all rubber parts (e.g. air conditioning hoses, radiator hoses, belts etc.), clutch plate, disk pads, shock absorbers, battery etc. Furthermore, the sample size used by the AA in deriving their car operating costs is only 10 to 14 cars per class.

To test how representative the AA estimate of 8.2 c/km for a vehicle with an engine capacity of over 2000cc is, part costs and target labour hours to carry out routine servicing on a Toyota Camry 220GX sedan up to 252,000 kms along with the age related maintenance suggested by the AA were obtained from Toyota New Zealand. Assuming a resource labour cost of $60 per hour, the total cost of routine servicing over the default service life of the vehicle (18 yeas @ 14,000 km per year) amounts to $2,348.07, corresponding to a running cost of 0.9 c/km. The age related maintenance amounts to a further $3,401.01. Therefore, the expected repairs and maintenance related running cost over the anticipated 18 year service life of the vehicle is 2.3 c/km if the age related maintenance takes place once, say at 125,000 km of 3.6 c/km if twice, say at 85,000 km and 170,000 km. This result suggests that the AA repair and maintenance costs are an over-estimation for latest generation vehicles.

The range of repairs and maintenance costs of 0.9 c/km to 3.6 c/km calculated for the Toyota Camry 220GX falls within the range of values recorded in the Fleetlease database. However, the representatives of the Fleetlease database can be questioned on account that the majority of the cars are 3 to 4 years old, whereas the mean age of the New Zealand car fleet is about 11.2 years. These cars also have very high utilisation which averages at around 30,000 km/year. This is twice the utilisation assumed in the NZVOC model. Some upwards adjustment of the repairs and maintenance cost derived from the Fleetlease database, along the lines suggested by Opus-BCHF (1998), therefore seems appropriate.

In a Swedish study of service and repair costs of cars described in Symonds Travers Morgan and Cox (1996), it was shown that service costs dominate in the early years of a vehicle's life (up to 50,000 km) and remain relatively constant with age. On the other hand, repair costs increase up to 7 ears (100,000 km) and then flatten off, when they can be about 3 times as much as the servicing costs. Therefore, there is an expectation that repair and maintenance costs rise linearly over the first 100,000 km of a vehicle life and then remain reasonably level.

To test this thesis regarding vehicle maintenance-age relationship, a "slice in time" approach was taken whereby repairs and maintenance costs for cars of a certain model were plotted against cumulative distance travelled to obtain an increase in maintenance costs with vehicle age. Figure 7 shows the resulting "slice in time" analysis of the three most popular vehicles in the Fleetlease database : Honda Civic (1600cc), Honda Accord (2200cc), and Holden Commodore (3800cc). With reference to Figure 7, highest repairs and maintenance costs appear to occur early in the life of the vehicle (less than 30,000 km) and then remain fairly constant up to 160,000 km. This suggests that any major mechanical fault with latest generation cars tends to manifest itself within the first one to two years, and once rectified, relatively trouble free motoring can be expected from thereon. Therefore, it can be concluded that the repairs and maintenance costs derived from the Fleetlease database are a true reflection of maintenance costs of 1990's vehicles and so require no adjustment. Such vehicles comprise 31% of the New Zealand vehicle fleet and so the weighted average repair and maintenance cost of 1.45c/km given it Table 11 provides a lower end estimate since it pertains to latest technology.

Table 14 gives average repairs and maintenance costs adopted by a vehicle fleet consultant for different engine capacities. The resulting New Zealand car fleet weighted average using these costs is 3.0c/km. This agrees well with the upper limit value calculated for the Toyota Camry 220GX and suggests provision has been made for regular scheduled replacement of components. Scheduled component replacement is more expensive, but provides greater reliability which is important in some business activities where downtime is critical.

In the absence of any further information, it is recommended that a resource repairs and maintenance cost of 4.3c/km be used for cars. This figure has been derived by weighting the Fleetlease database and 1987/88 MoT repairs and maintenance costs given in Table 13 by 70% and 30% respectively to account for the age profile of the New Zealand car fleet. In obtaining these weightings, it has been assumed that the Fleetlease database value pertains to cars 1986 and younger, whereas the 1987/88 MoT value pertains to cars 1985 and older. However any value of repairs and maintenance between 3 and 5 c/km, as suggested by Bennett (1999) appears reasonable.

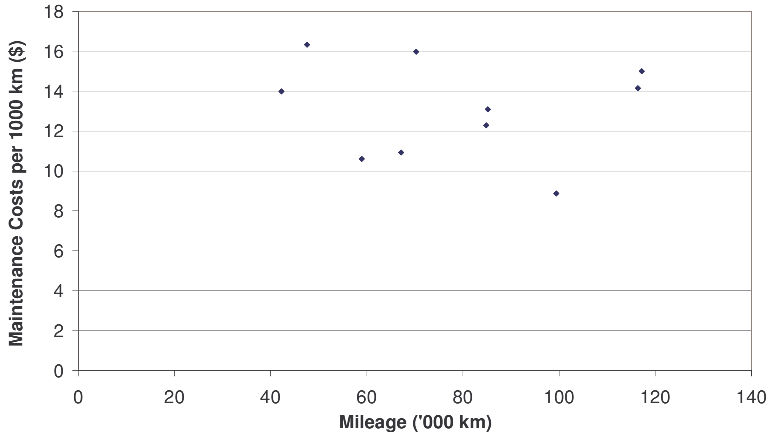
Table 14 : Baseline Repairs and Maintenance Costs as Used by Fleet Managers

Engine Capacity (cc)	Percentage of NZ Car Fleet	Repairs and Maintenance Costs (c/km)
< 1600	29	2.2
1601-2000	39	3.0
2001-3000	22	3.6
>3001	10	4.0
NZ Fleet Weighted Average		3.0

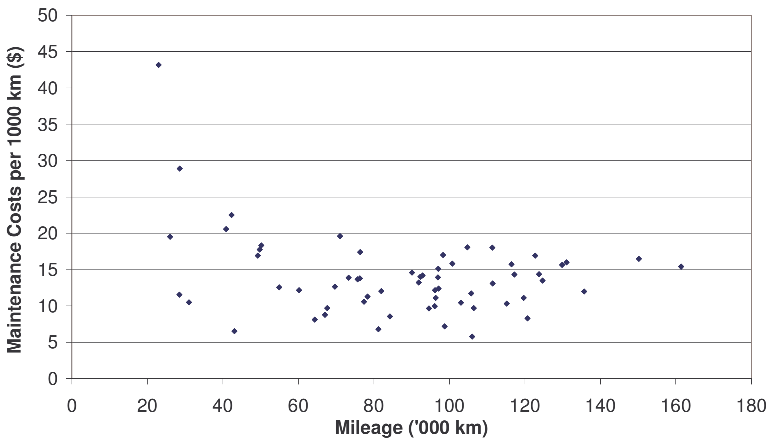
3.3.4 Roughness Dependency

The VOC's recorded in the Fleetlease database covered a range of road roughness from 59NRC to 91NRC. Intuitively, VOC is expected to increase with road roughness. For a change in roughness from 59 to 91NRC, Transfund New Zealand's PEM predicts a change in VOC of 1.45c/km, equating to a sensitivity of 0.46c/km/NAASRA.

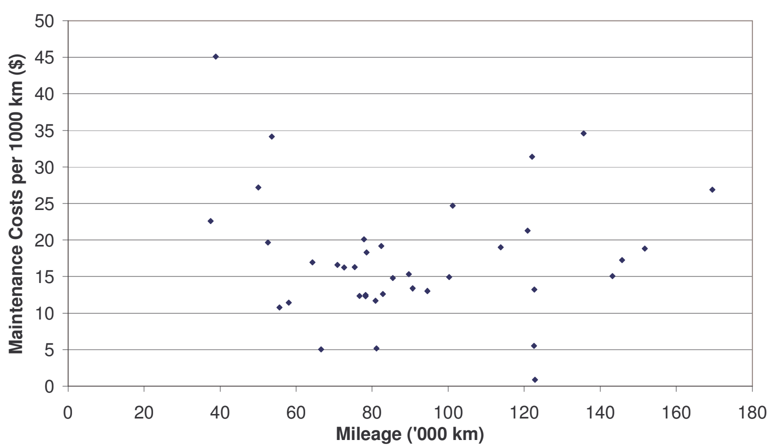
In an attempt to validate the PEM relationship between VOC and road roughness two approaches were taken. The first involved sorting all records in the Fleetlease database by the road roughness assigned to the region where routine servicing took place and calculating the corresponding average VOC. In this manner, the affects of co-factors such as driver behaviour and skill,



Honda Civic Sedan, 1600cc, 5 speed Manual



Honda Accord Sedan 2200cc, 5 speed Manual



Holden Commodore Sedan, 3800cc, 4 speed Automatic

Figure 7: Variation of Maintenance Costs with Vehicle Age as Determined by "Slice in Time" Analysis.

maintenance policies, and route characteristics were minimised through the averaging process. The results of this analysis are presented in Appendix C. No statistically significant difference in VOC between the different roughness values was able to be discerned.

The second approach involved matching records of the same model, age and mileage to determine if there was any difference in VOC as a result of different road roughness. Eleven matched sets were obtained in this manner. However, three of the matched sets showed a decrease in VOC with increasing roughness, whereas the remaining eight produced a range of roughness sensitivity from 0.02 c/km/NAASRA to 0.07 c/km/NAASRA, the average value being 0.037 c/km/NAASRA. Because road conditions pertaining to each car in the matched pair were not precisely known, the difference in roughness attributed to the difference in VOC may not be correct. Therefore not much significance can be attached to these roughness sensitivities, other than they are of comparable magnitude to that of the PEM. Furthermore, the roughness effect on VOC, in certain cases, may be masked by terrain. This inconclusive result serves to highlight the need for as wide a range of roughness as possible and detailed information on operating conditions (e.g. terrain, driving style, maintenance, policy etc.) when investigating the effect of road roughness on VOC.

In order to validate the VOC-roughness relation predicted by the PEM, the following additional sources of information were therefore considered.

3.3.4.1 ARRB TR VOC Model Predictions

The ARRB TR VOC model is based on the structure of the HDM-III VOC sub-model, but employs algorithms based on latest research findings, including those from New Zealand, related to the effect of surface characteristics on fuel consumption and travel speed. The model predictions have been checked against available Australian VOC data (McLean and Foley, 1998). For cars, direct VOC (travel time costs excluded) are calculated by the model to increase by about 22 percent over 40 to 170 NRC, with the baseline VOC being 14.3c/km (Australian currency). This corresponds to a roughness sensitivity of 0.024 c/km/NAASRA, which is about half that of the PEM.

3.3.4.2 Effect of Roughness on Rolling Resistance–New Zealand Experiment

A research programme was undertaken by Opus Central Laboratories between 1988 and 1995 to quantify the influence of pavement surface characteristics of New Zealand roads on tyre rolling resistance (Cenek, 1996). Statistical analysis of the acquired rolling resistance data yielded the resulting regression model:

$$C_O = 0.0124 + 1.64 \times 10^{-5} R_N \times TD^2 \qquad r^2 = 0.75$$

where: C_o = static coefficient of rolling resistance
RN = NAASRA roughness (counts/km)
TD = texture depth (mm) as determined by the sand circle method

This regression model indicates a linear dependency between rolling resistance and roughness.

It is generally accepted that for a car travelling at constant speed, a 5% reduction in tyre rolling resistance will reduce fuel consumption by 1% (Descornet, 1990). For a texture depth of 1.7 mm, which is representative of the state highway network, the above regression model suggests a fuel cost related roughness sensitivity of 0.0017c/km/NAASRA. Therefore, if the view of fleet managers that tyre costs, repairs and maintenance costs, and vehicle depreciation are not affected by roughness over the range typical of maintained New Zealand sealed roads is accepted, then the PEM is over estimating VOC-roughness effects by a factor of 27 (i.e. 0.046 c/km/NAASRA cf. 0.0017 c/km/NAASRA).

3.3.4.3 Willingness to Pay for Access to Smoother Roads

As part of a Public Good Science Fund (PGSF) research programme being undertaken by Opus Central Laboratories, 56 participants were driven in a Toyota Previa 2 to 3 times over 12 sites located between Fielding and Palmerston North. Due to the seating capacity of the vehicle, the 56 participants were grouped into 10. The order of the sites was varied, and different drivers were used for each session. The 12 sites chosen varied in roughness, the smoothest and roughest sites having an average roughness of 29 NRC and 157 NRC respectively. All sites chosen were located in 100km/h speed zones on sealed sections of road. Each site was 500m long and all sites had similar road characteristics with the exception of road roughness.

Participants were informed as to when the site began and ended, and asked to pay particular attention to road roughness while traversing the site at a steady speed of 100 km/h. The vehicle was stopped as soon as practically possible following the site to enable the participants to provide written responses to three questions. The third question asked participants to estimate the additional amount of time they would be willing to take on a 1 hour journey in order to have access to a perfectly smooth road.

Figure 8 gives the averaged results for this question plotted against road roughness. Willingness to spend extra time has been converted to cents per kilometre using non-work related travel time cost of $7.00 per hour as specified in Table A4.1 of the PEM and a travel speed of 100 km/h. The derived relationship is 0.011 c/km/NAASRA. This is about a quarter of the VOC-roughness sensitivity predicted by the PEM for cars.

The extra travel time works out at about 0.17% per NAASRA roughness count. If this increase in travel time was caused entirely by extra maintenance costs, which make up about 25% of all car VOC assuming a baseline repairs and maintenance cost of 4.3 c/km, then this would approximate an increase in maintenance costs of 0.68 % per NAASRA or 0.029 c/km/NAASRA. This value of VOC-roughness sensitivity is in close agreement with that provided by the ARRB TR VOC model.

Symonds, Travers, Morgan and Cox (1996) report a similar willingness to pay for a study conducted in Australia. However, rather than extra time, participants were asked how much extra distance they would be prepared to travel on a smooth road compared to a rough road. This extra travel distance was determined to be about 0.15 to 0.22 % per NAASRA roughness count, which agrees well with the New Zealand study.

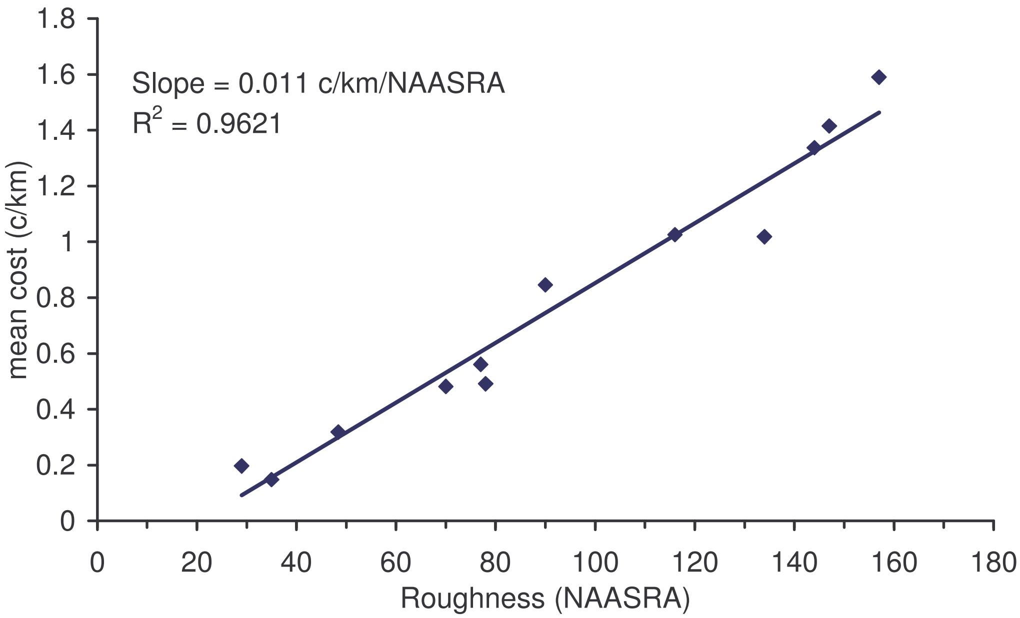


Figure 8: Additional Time Expressed as Cost that New Zealand Motorists are Willing to Take on a One Hour Journey in Order to Have Access to a Perfectly Smooth Road.

This result substantiates the finding that road users are willing to pay to travel on smooth roads, as both sets of results were obtained independently. Therefore the PEM's economic appraisal process should be modified to take appropriate account of road users preference for smoother roads.

3.3.5 Summary of Analysis

On the basis of this review, there is strong evidence that the repairs and maintenance costs predicted by the NZVOC model are significantly over-estimated for the existing car fleet over the range of roughness typical of maintained New Zealand sealed roads. As a result, base car operating costs given in Tables A5.1 and A5.2 of the PEM appear to be a factor 1.7 too great. Because most of the roughness related costs in the PEM are attributed to repair and maintenance costs, these are also being significantly over-estimated by a factor of about 1.9.

A ¾ reduction in repairs and maintenance VOC component cost from 16.7c/km to 4.3c/km would see the PEM provide VOC predictions that are comparable with those of the calibrated ARRB TR VOC model and consistent with motor industry expectations.

3.4 Analysis of Truck VOC

3.4.1 Component VOC

The average resource cost of each VOC component is summarised in Table 15 for heavy commercial vehicle type 1 (HCV-I) and type 2 (HCV-II) classes. The HCV-I class refers to rigid trucks with or without trailers or articulated vehicles with three or four axles in total whereas the HCV-II class refers to articulated vehicles with five or more axles in total. The originating data for Table 15 is given in Appendix B. With reference to Table 15, no statistically significant difference can be seen between the HCV-I and HCV-II classes. This result is not unexpected because, for the HCV-II class, the VOC pertains to the tractor unit only and not to a tractor-trailer combination. For the truck database assembled for this analysis of VOC, the same model HCV-I truck is being used in many instances as the powered unit for the HCV-II tractor-trailer combination.

Table 15: HCV Component VOC as Derived from Operator Surveys

Vehicle Class	Sample Size	Statistic	Component VOC (c/km)				
			Fuel & Oil	Tyres	Repairs & Maintenance	Depreciation	Total
HCV-I	51	Mean	16	6	13	8	43
		SD	2	3	10	1	11
		CoV	0.13	0.5	0.77	0.13	0.26
		SE	0.28	0.42	1.40	0.14	1.54
HCV-II	14	Mean	19	3	13	9	43
		SD	4	2	17	1	17
		CoV	0.21	0.67	1.3	0.13	0.40
		SE	1.07	0.53	4.54	0.27	4.54

SD = Standard Deviation, CoV = Coefficient of Variation, SE = Standard Error

Of the four component VOC's tabulated in Table 15, repairs and maintenance costs show the greatest degree of variation. This variation is a reflection of the maintenance philosophy adopted by the vehicle's owners, namely scheduled replacement of components whether broken or not (preventative maintenance) or non-scheduled repairs when a part is broken (reactive maintenance). Furthermore, there is influence of the varying quality of vehicles that may, in all other respects, be identical. Even in fleets of vehicles which are more or less identical in type and employed on similar work, the repairs and maintenance charges may vary considerably. Therefore, because of the small sample size of 65, the repairs and maintenance costs given in Table 15 should be regarded as only indicative.

3.4.2 Comparison of Truck VOC

To check the validity of the component VOC's derived from the operator survey, component VOC data was additionally obtained from a fleet consultant, a 1996 survey of truck operators conducted by AGC Finance on behalf of the New Zealand Road Transport Association (now known as Road Transport Forum, RTF), and the 1987/88 truck operating cost bulletin prepared by the economics division of the Ministry of Transport (MoT, 1987b). The Ministry of Transport (MoT) data was used to calibrate the NZVOC parts costs model and to ensure appropriate relativities between the component truck VOC's predicted by NZVOC version 3.1.

The component VOC's drawn from these sources are compared with those generated by the NZVOC model in Table 16, both in terms of c/km and as a percentage of total VOC. The NZVOC component VOC's were calculated for a vehicle speed of 90 km/h on a road with 0 gradient and 60 NAASRA counts/km roughness. The NZVOC component costs were updated to 1998 costs using the 1.06 factor given in Appendix A12 of the PEM (Transfund, 1997) to enable direct comparison with the operator survey and fleet consultant's component cost estimates. No attempt was made to update the 1996 AGC survey or 1987/88 MoT component costs.

Table 16: Comparison of Resource Component VOC for HCV-I Class

VOC Component	Source of Costs				
	NZVOC	**Operator Survey (1998c/km)**	**Fleet Consultant (1998c/km)**	**AGC Survey (1996c/km)**	**1987/88 MoT (1988c/km)**
Fuel & Oil	15.6 (25.3)	16 (37.2)	16 (37.7)	8-16.9 (29.3-37.6)	19.2 (31)
Tyres	8 (13)	6 (14)	3.2 (7.5)	2.4-3.2 (8.8-7.1)	9.2 (5.7)
Repairs & Maintenance	28.5 (46.3)	13 (30.2)	14.5 (34.2)	10.7-13.3 (39.2-29.6)	27.5 (44.4)
Depreciation	9.5 (15.4)	8 (18.6)	8.7 (20.5)	6.2-11.6 (22.7-25.8)	6 (9.7)
Total	61.6	43	42.4	27.3-45	61.9

Bracketed figure pertains to percentage of total

With reference to Table 16, the following points are made.

(1) A range of values are given for the 1996 AGC survey costs which pertain to line haul operators whose haulage activities are mainly between cities and large towns. The lower and upper values are typical costs of large firms (20 or more trucks) and owner-driver firms (1 truck) respectively. Clearly, the large firms benefit from economies of scale, their VOC being about 60% that of owner-drivers.

(2) The difference between MoT fuel and tyre costs and those of the more recent surveys can be partly explained by differences in the unit diesel price (65.3 c/litre (MoT) cf. 38.8 c/litre) and new tyre lives (48,000 km (MoT) cf. 82,500km).

(3) A number of the transport operators approached to provide data for the truck VOC database had also participated in the 1996 AGC survey. Therefore, a likely explanation for the good agreement between the operator survey, fleet consultant, and AGC survey component VOC's is that they have been derived from the same source of operating records. The only significant cost discrepancy relates to tyres. However, the operator survey contained some responses from operators whose transport activities consisted mainly of transport in rural areas, involving tortuous routes where tyre wear can be expected to be greater due to more frequent cornering and braking. For example, the AGC survey produced tyre costs of between 6-10c/km for rural operations compared with 3-

4c/km for inter-city operations. The operator survey tyre cost of 6c/km therefore does not appear unreasonable as a representative value.

(4) As expected, the NZVOC and 1987/88 MoT component VOC's agree well, particularly in regard to repairs and maintenance. However, when compared to the more recently determined component VOC's, these repairs and maintenance costs seem to be significantly over-estimated by about a factor of two. Such a large difference cannot be explained by an allowance for differences in work environments of vehicles. For example, a fleet lease operator contacted allows a factor of 1.5 in repairs and maintenance cost between the easiest state highway conditions (e.g. Canterbury Plains) and hardest (e.g. Northland, West Coast). The corresponding repairs and maintenance costs for a comparatively new (2 years old) HCV-I are 8.4c/km and 12.4c/km respectively with most of the increased cost resulting from additional engine, brakes and suspension maintenance. It can also be argued that the records in the truck VOC database, with the exception of 3, pertain to trucks that are less than 9 years old, and so are providing a biased sample. However, a "slice-in-time" analysis of the most popular truck model in the database, the Scania P113M, shows no trend of increasing repairs and maintenance cost with mileage/age (refer Figure 9). Furthermore, the three oldest vehicles in the database (registration dates 1984, 1986 and 1989) have repairs and maintenance costs which are comparable to the newer trucks and are by no means the highest in the database. Therefore, it can be concluded that the operator survey derived repairs and maintenance costs are fairly representative of the 16 year age profile that is the basis of the PEM's economic evaluation procedures for trucks. The NZVOC model has been calibrated against the 1987/88 MoT repairs and maintenance estimate for trucks of 27.5c/km. However, this figure pertains in the main to late 1970's early 1980's UK sourced trucks which bear little resemblance to the current Japanese dominated (greater than 80 %) truck fleet in terms of mechanical reliability and servicing requirements. Therefore, some reduction in the repairs and maintenance cost predicted by NZVOC appears justifiable to account for the improved technology of latest generation trucks.

(5) The Road Transport Forum in their publication "Road Transport Facts" suggest a typical expenditure profile for a seven year old truck of 39.5 % an fuel and lubrication, 46.8 % on repairs and maintenance, and 13.7 % on tyres if depreciation is not considered. The corresponding NZVOC and operator survey relativities are 29.9 %, 54.7 % and 15.4 % and 46 %, 27 % and 17 % respectively. This indicates that truck repairs and maintenance costs are being over-estimated by the PEM and under-estimated by the operator survey. Given that there is not much difference in fuel and oil and tyre costs between NZVOC and the operator survey, a repairs and maintenance cost of 19 c/km will generate component costs relativities which matches the Road Transport Forum's. This equates to a 33 % reduction in the NZVOC repairs and maintenance cost. The resulting baseline VOC for trucks therefore becomes 49 c/km if the more current operator survey component costs are used and represents a 20 % reduction over the existing PEM value.

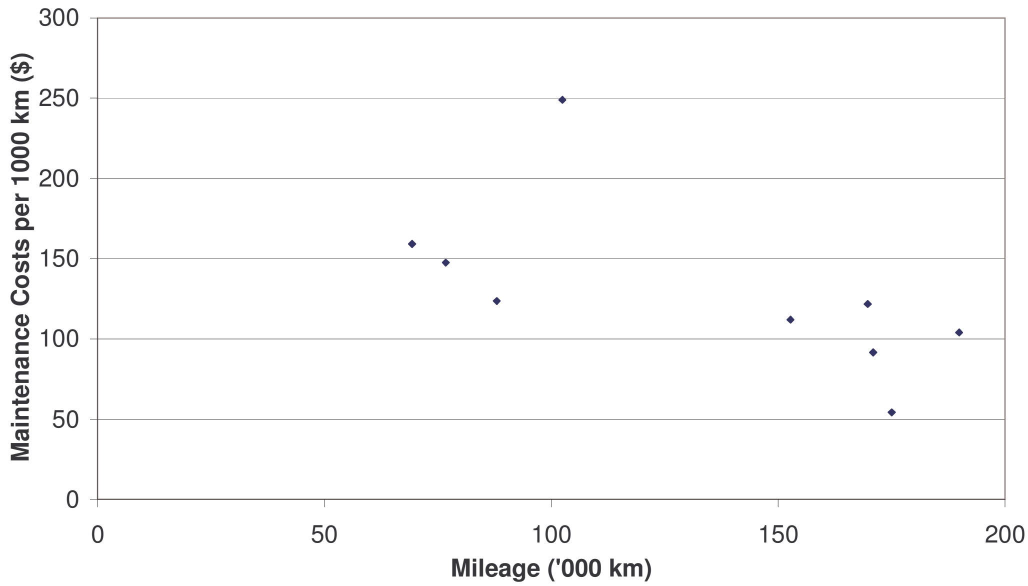


Figure 9: Variation of Maintenance costs with Vehicle Age as Determined by "Slice-in-Time" Analysis for Scania Model P113M, 8 x 4 Rigid Truck

3.4.3 Roughness Dependency

The same analysis procedure as described in Section 3.3.4 was applied to the truck-VOC database to establish a relationship between VOC and road roughness. However, the likelihood of a successful outcome was better in this case because:

(1) most vehicles in the truck-VOC database were dedicated to specific inter-city routes and so more confidence could be attached to the roughness value assigned to the VOC records; and

(2) the range of roughness covered was greater (59 NRC to 170 NRC) enabling differences to be better highlighted.

Sorting the records in terms of roughness as presented in Appendix C, enabled VOC's to be conveniently aggregated into two distinct groups, those pertaining to a moderate roughness level of 70 NRC (26 records) and those pertaining to a high roughness level of 141 NRC (25 records). The corresponding mean and standard deviation (SD) VOC's were calculated to be 39.2 c/km (SD=9.12) and 45.9 c/km (SD=12) respectively. Therefore, the differences in mean VOC between the two groups of 6.7 c/km is significant at the 0.05 level. The resulting roughness sensitivity is calculated to be 0.099 c/km/NAASRA.

For the same roughness levels, the PEM gives a difference in VOC of 28.8 c corresponding to a roughness sensitivity of 0.411 c/km/NAASRA. This is a factor of 4 greater than indicated by the operator survey findings.

No statistically significant difference in VOC could be established when truck records of the same model, age and mileage but different mean route roughness were directly compared. A most likely explanation for this result is that roughness effects are being masked by road curvature and road gradient effects. This hypothesis could be simply tested by regressing VOC against distance averaged measures of curvature, gradient and roughness whenever the route information permits.

The following additional sources of information were considered as independent confirmation of the lower HCV-I VOC-roughness dependency derived from the operator survey.

3.4.3.1 ARRB TR VOC Model Predictions

The ARRB TR VOC model described in section 3.3.4.1, calculates direct VOC (travel time costs excluded) for articulated trucks (HCV-II) to increase by about 24 % over 40 to 170 NRC, with the baseline VOC being 64.2 c/km (Australian currency). This corresponds to a roughness sensitivity of 0.118 c/km/NAASRA which is in close agreement with the operator survey derived value of 0.099 c/km/NAASRA.

3.4.3.2 New Zealand Truck Fuel Consumption – Roughness Measurements

A Public Good Science Fund (PGSF) study is being undertaken by Opus Central Laboratories to determine the relative contributions of road surface texture, road surface roughness, and pavement deflection on fuel consumption of trucks. The results of on-road fuel consumption measurements made with a Nissan CM 180 rigid truck under clam wind conditions showed that a roughness change from 44 NRC to 113 NRC, representing a 156 % change, produced only a 2 % increase in fuel use from 11 ℓ/100km to 11.2 ℓ/100km for a steady travel speed of 70 km/h (Jamieson and Cenek, 1999). This suggests a fuel cost related roughness sensitivity of only 0.0011 c/km/NAASRA. The magnitude of car and truck fuel costs-roughness sensitivities is therefore comparable (refer section 3.3.4.2).

In conducting the fuel consumption measurements, special care was taken to exclude other road related factors so that only roughness effects would be evident. Accordingly, the test sites were selected to have similar pavement deflection, road surface texture and road gradient but different longitudinal roughness.

The same approach was adopted in considering the effect of pavement deflection on fuel consumption. An increase in average pavement deflection from 0.33 mm to 0.475 mm, representing a 41 % increase, was shown to produce a 4 % increase in fuel consumption for a constant travel speed of 70 km/h on smooth (.45 NRC) road surfaces. Therefore the fuel consumption of trucks is much more sensitive to changes in pavement deflection than pavement roughness. This result suggests that in previous studies of the influence of road surface characteristics and condition on truck fuel consumption, pavement deflection effects may have been incorrectly attributed to roughness.

3.4.4 Summary of Analysis

As for the car class, the NZVOC model is over-estimating repairs and maintenance costs for the HCV-I class over the range of roughness typical of maintained New Zealand sealed roads. As a result, base HCV-I operating costs given in Tables A5.7 and A5.8 of the PEM appear to be a factor of around 1.3 too great. Because most of the roughness related costs in the PEM are attributed to repair and maintenance costs, these are also being significantly over-estimated by a factor of about 3 to 4.

A $^{1}/_{3}$ reduction in repairs and maintenance VOC component cost from 28.5 c/km to 19 c/km would see the PEM provide VOC predictions that are comparable with those of the calibrated ARRB TR VOC model and component VOC relativities which match road transport industry expenditure profiles.

PART C

Implications of Review Findings and Future Research Needs

4 IMPLICATIONS OF REVIEW FINDINGS AND FUTURE RESEARCH NEEDS

4.1 Implications

4.1.1 NZVOC

On the basis of component VOC data acquired as part of this review, it is apparent that the base repairs and maintenance cost is being significantly over-estimated by the NZVOC model for both passenger car and HCV-I classes. This appears to reflect the process of updating repairs and maintenance costs observed in the late 1970's, early 1980's, using appropriate price and cost indices. As a result, the effects of improved vehicle technology and operating practices associated with the current vehicle fleet have not been accounted for. However, NZVOC has a specified updating procedure which does not appear to have been followed since the late 1980's. This requires unit costs used to derive the base component VOC's to be requantified annually and the model rerun. The current year's VOC tables are then compared to those in the PEM and an appropriate VOC updating factor calculated.

Table 17 summarises the 1998 unit resource costs derived as part of this review. These unit resource costs should be compared with those incorporated in NZVOC version 3.3 to establish whether or not unit resource cost discrepancies are the main reason for observed differences between predicted and surveyed base VOC's.

Table 17: 1998 Unit Resource Costs

Cost Component	Unit Resource Costs ($)	
	Passenger Cars	**Trucks (HCV-I)**
New Vehicle Price	28,600*	188,000
Fuel	0.3826/P	0.3876/P
Oil	6.73/P	6.73/P
Tyres : New Recapped	97* -	409 203
Labour	60	60

* NZ Fleet Average Weighted by Engine Capacity

If the specified updating procedure is to be readopted, it is essential that a standard procedure be put in place for quantifying the unit resource costs for input to the NZVOC model to ensure equivalency.

The "best estimate" base component VOC's for the passenger car and HCV-I classes as determined from this review are given in Table 18. The resulting relativities should be compared with the output from NZVOC when the 1998 unit resource costs of Table 17 are input as a check on the integrity of the software. In this regard, three major errors were identified with NZVOC version 3.3 during the course of the review related to:

(1) incorrect removal of benefits from roughness reduction below 75 NRC on fuel consumption;

(2) the commercial vehicle tyre model does not take appropriate account of speed and gradient effects;

(3) no relationship between roughness and service life has been implemented and so the depreciation component of VOC is invariant with roughness.

These errors are discussed in greater detail by Bennett (1999) and serve to highlight the urgent need for a full calibration of NZVOC version 3.3.

Table 18: "Best Estimate" Component VOC's for Passenger Car and HCV-I Classes

Component VOC	PEM Class			
	Passenger Car		HCV-I	
	(c/km)	(% of Total)	(c/km)	(% of Total)
Fuel and Oil	3.7	22.3	16	32.7
Tyres	0.9	5.4	6	12.2
Repairs and Maintenance	4.3	25.9	19	38.8
Depreciation	7.7	46.4	8	16.3
Total	16.6	-	49	-

4.1.2 PEM VOC-Roughness Relationships

The results of the operator surveys undertaken as part of this review suggest a base VOC of 16.6 c/km and a roughness sensitivity of 0.024 c/km/NAASRA is appropriate for passenger cars. The corresponding values for trucks (HCV-I) are 49 c/km and 0.1 c/km/NAASRA.

Figures 10 and 11 illustrate the resulting reductions in roughness effects when compared to the current PEM predictions converted to 1998 dollar values for the passenger car and HCV-I classes respectively Superimposed is the output from the NZVOC model modified to give base VOC and component VOC relativities which matched preliminary estimates derived from an initial analysis of the operator surveys (refer Bennett, 1999). The close agreement between operator survey and modified NZVOC relationships indicates that NZVOC can correctly predict roughness sensitivity so long as it is calibrated to give a realistic estimate of base component VOC, in particular, repairs and maintenance.

Two x-axis have been plotted, one roughness and the other roughness times travel speed to account for the effect of the speed dependent nature of a vehicle's response to increasing roughness as determined from on-road tests conducted as part of this review. For example, the VOC benefit from reducing roughness from 160 NRC to 80 NRC in a 50 km/h zone is therefore shown to be only half that achieved in a 100 km/h zone. The roughness times travel speed axis in this case was simply generated by multiplying the roughness axis by the speed the VOC pertained to. This speed was taken to be 100 km/h for cars and 90 km/h for trucks.

Before such speed sensitive VOC-roughness relationships can be incorporated in the PEM, additional research is first required to better quantify the effects of pavement roughness on travel speed.

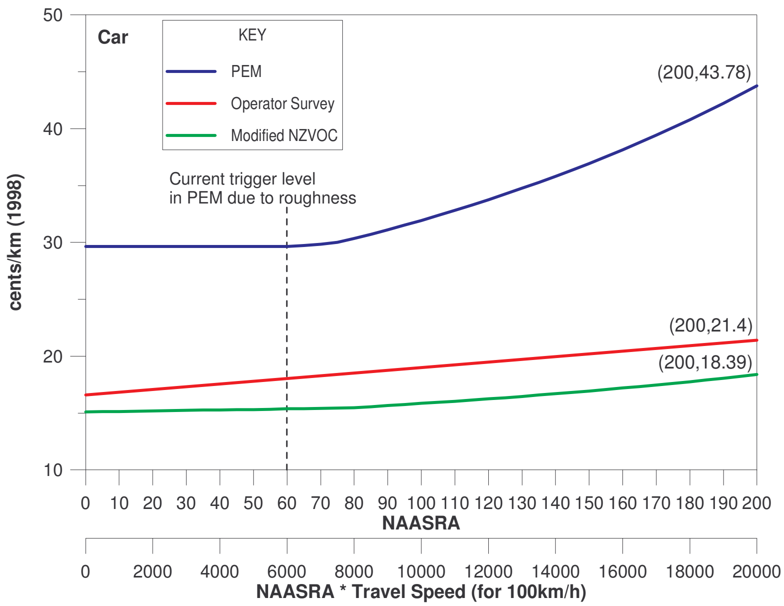


Figure 9: Comparison of Passenger Car VOC-Roughness Relationships.

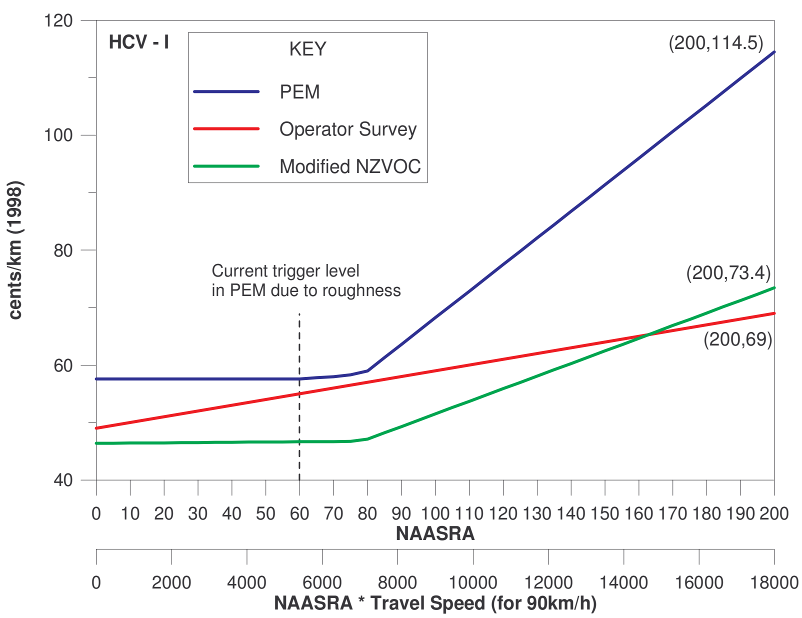


Figure 10: Comparison of HCV-I VOC-Roughness Relationships.

4.2 Future Research Needs

This review of the PEM's VOC-pavement roughness relationship for passenger cars and heavy commercial vehicles has identified the need for the following complimentary studies, which are given in priority order. Successful completion of these studies will result in improved procedures for economic assessment of road projects.

4.2.1 Effect of Horizontal Curvature on VOC

It is well known that horizontal curvature has a significant effect on fuel consumption, tyre wear, and repairs and maintenance. Anecdotal evidence from fleet operators indicates that horizontal alignment is more of an issue than roughness in regard to repairs and maintenance costs because of increased duty on the driveline, brakes, and engine through deceleration and acceleration cycles and suspension components through weight shifts that occur during cornering. Results from a limited survey of Australian fleet operations conducted by ARRB indicated that a tortuous route can increase repairs and maintenance costs by between 9-12.5 % (Thoresen, 1998).

At present, the only facility in the PEM for accounting for the effect of horizontal curvature on VOC is through speed change cycle costs (refer figures A5.19b-A5.28b of the PEM). Therefore, a desk study supplemented by operator surveys and limited on-road tests utilising cars and trucks instrumented to measure fuel consumption and associated road load should be performed to establish whether or not increase in VOC due to more demanding road alignment conditions is adequately predicted by the PEM. In addition, regression studies should be carried out on state highway road condition and road geometry databases to determine if there are any significant correlations between roughness and curvature. The findings of these studies will confirm the need or otherwise to explicitly consider horizontal curvature in the PEM.

4.2.2 Effect of Roughness on Use Related Depreciation Costs

Use related depreciation costs calculated by the NZVOC model are presently independent of roughness. However, one would expect that if a vehicle has been subjected to rougher treatment, higher operating costs can be expected by any given vehicle age or distance travelled leading to a reduced service life and therefore higher use-related depreciation costs. New Zealand specific research is required to establish the effect of roughness on the annual utilisation and service lives of vehicles and their interaction so that the resulting relationships can be incorporated in NZVOC.

4.2.3 Speed-Roughness Relationships

New Zealand specific research is required to quantify the effects of roughness on free operating speeds and speed change cycles induced by surface defects. Road roughness serves to decrease ride comfort. It is therefore important to determine the roughness level that has an attenuating effect on operating speeds for different speed zones as this will confirm the need or otherwise to explicitly consider operating speed when calculating roughness related VOC. At present, the PEM provides VOC as a function of only NAASRA roughness so the effects of speed on vehicle response are implicitly included as well as the constraint of maximum tolerable ride severity in limiting the operating speed. The PEM approach has to be tested in light of improved vehicle suspension design. Recent Australian field research reported in McLean and Foley (1998) shows negligible decrease in speed with roughness for cars up to about 130 NRC and articulated trucks up to about 78 NRC. This suggests that New Zealand road users are likely to be very roughness tolerant over the roughness range typical of rural arterial roads.

Roughness is an average measure of surface condition, typically over 100m or 500m of lane. However, these average roughness values do not necessarily present uniform surface condition over the sample interval and particularly at the high roughness end, may reflect discrete roughness elements such as broken surface or potholes. Infrequent, discrete, roughness elements will induce speed change cycles as drivers slow to minimise the impact of, or avoid, the roughness element, and then accelerate to a speed they consider appropriate for the general condition of the road. VOC's predicted by NZVOC assume steady state running. Therefore, the implication of this assumption for high roughness roads (greater than 130 NRC), where the likelihood of discrete roughness elements is greater, merits investigation.

4.2.4 Safety Benefits Derived from Roughness Reduction

The PEM presently takes no account of potential safety benefits resulting from roughness reduction. However, road roughness influences the actual useable friction that is provided by the road surface and tyre by adding a random vertical force applied to the tyre which can result in friction variations during turning and braking manoeuvres. Overseas research has shown a linear relationship between short wavelength (less than 3 m) roughness and car stopping distances, with an increase in amplitude of only 1 mm resulting in an increase in stopping distance of about 6 %. This corresponds to an extra 5 metres at 100 km/h. Research is required to determine relationships between roughness and cornering and braking performance of cars and trucks and to develop a benefit-cost methodology for assessing road roughness/road user safety trade-offs for incorporation in the PEM should this be warranted.

4.2.5 VOC Specific to Unsealed Roads

Th PEM makes no distinction between a vehicle operating on sealed and unsealed roads when determining VOC'S. However a gravel surface is likely to result in higher repairs and maintenance costs due to clogged air filters and broken windscreens and higher fuel costs as loose surface material can increase tyre rolling resistance by as much as 40 to 70% depending on the depth of loose surface material relative to the tyre size (Jamieson and Cenek, 1999).

One of the four tangible benefit categories in the PEM associated with sealing roads is vehicle operating cost savings due to reduced roughness. These savings will be substantially reduced if the NZVOC model is modified to reflect findings of this review making it more difficult to justify seal extensions. It is therefore imperative that VOC's specific to unsealed roads are accurately quantified so that true socio-economic optimisation of unsealed roads can take place.

4.3 Concluding Remarks

The main outcome of this review is the realisation that base component VOC's must be re-quantified annually or biennially and not simply updated using price and cost indices ,as is common economic practice, if the effects of improved vehicle technology and changing operating practice are to be properly reflected in Transfund New Zealand's PEM. This will require standardisation and documentation of procedures used to derive unit input costs and base component VOC's. Ideally, these procedures will be automated and designed to interface with vehicle fleet databases maintained by industry.

The New Zealand Automobile Association (AA) and Road Transport Forum (RTF) regularly survey the vehicle operating expenses of their members. Since the demise of operating cost tables produced by the Economics Division of the Ministry of Transport, these surveys are the main source of cost data regarding vehicle ownership and operation. It therefore will be advantageous for Transfund New Zealand to have an involvement in the design and execution of the AA and RTF surveys so that the information obtained is better targeted to the needs of the PEM.

Provision to interrogate Fleetlease's vehicle management database on a biennial basis would also be beneficial as this will enable lower bound estimates of component VOC's for passenger cars and light commercial vehicles to be obtained. Furthermore, because of the vehicle age profile of the database, advance warning of any major shifts in VOC component relativities caused by improving vehicle technology can be derived through time series analysis. This advance warning will enable proactive policy analyses to be carried out leading to more efficient allocation of funding.

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Paul Carroll,	Parts Manager, Toyota New Zealand Ltd.
Alan Court,	NZ Post.
Phil Herbert,	Esanda Fleet Partners.
Craig Johnston,	Assistant General Manager, Fleetlease.
Jim McCutcheon,	New Zealand Automobile Association Inc.
Bill Prebble,	Product Development Manager, South Pacific Tyres NZ Limited.
Russell Walsh,	Fleet Consultant.

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APPENDIX A

Linear Regression Analysis of Roughness Induced Vehicle Axle and Body Accelerations

A1 : Plots of RMS Accelerations against NAASRA Roughness

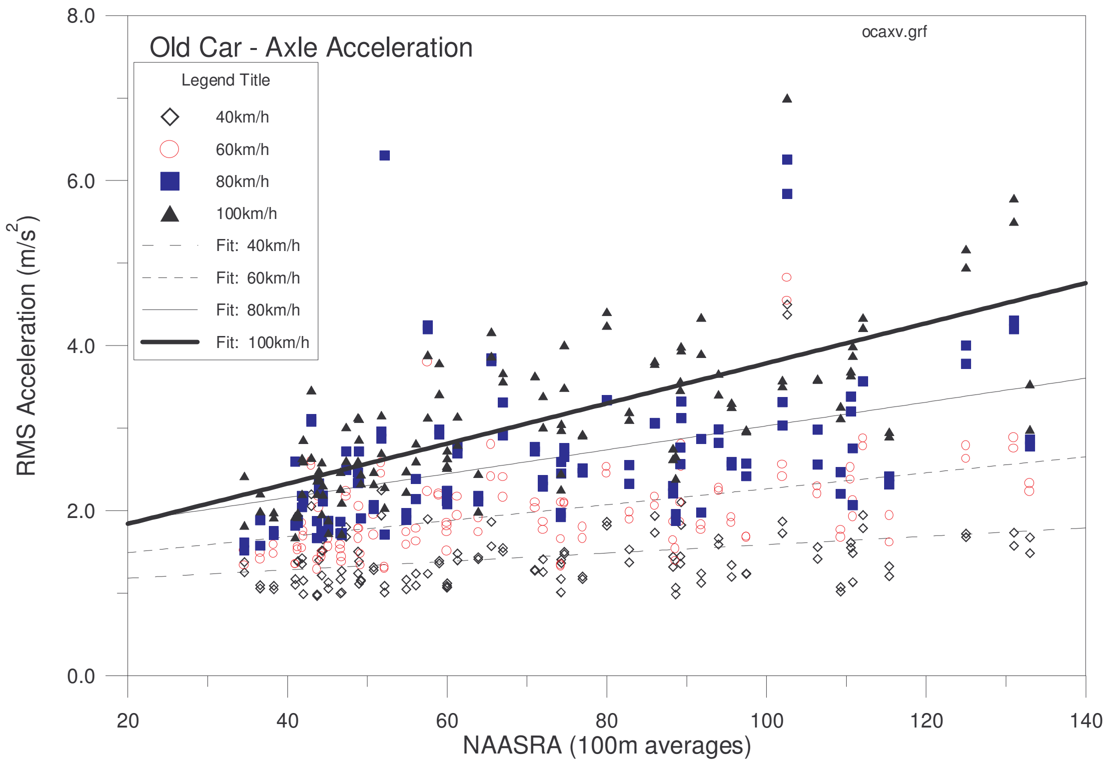

Figure A1 : 1985 Nissan Pulsar – Axle Accelerations

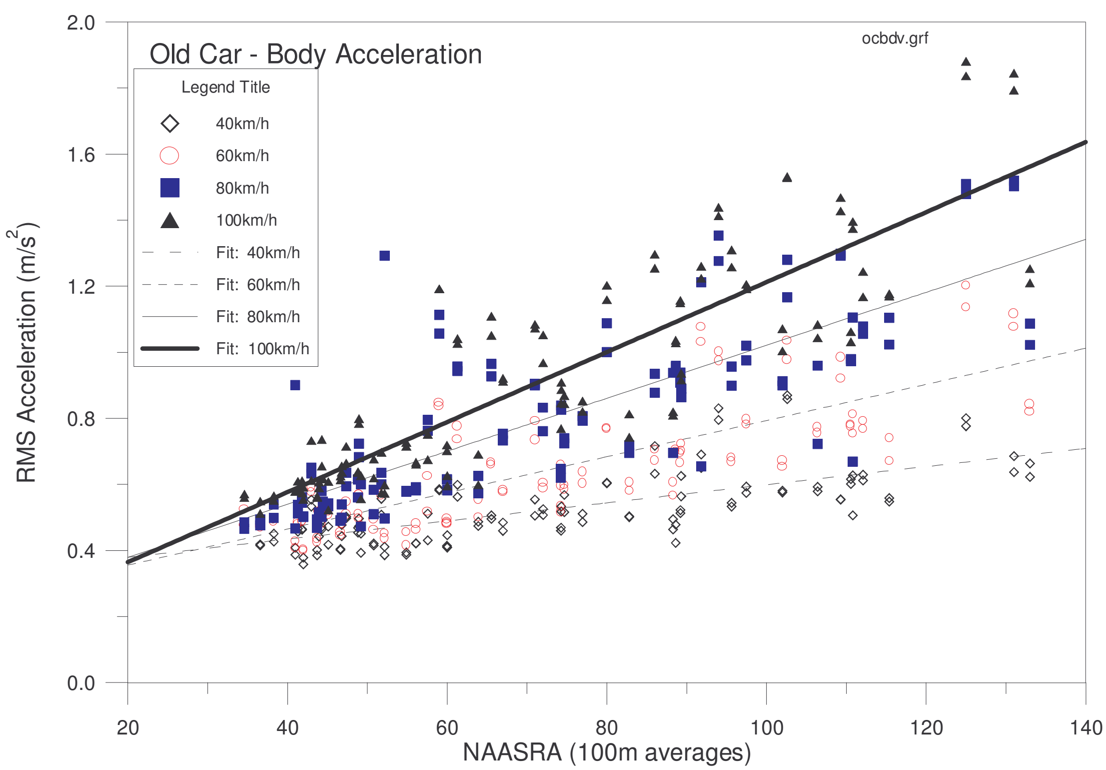

Figure A2 : 1985 Nissan Pulsar – Body Accelerations

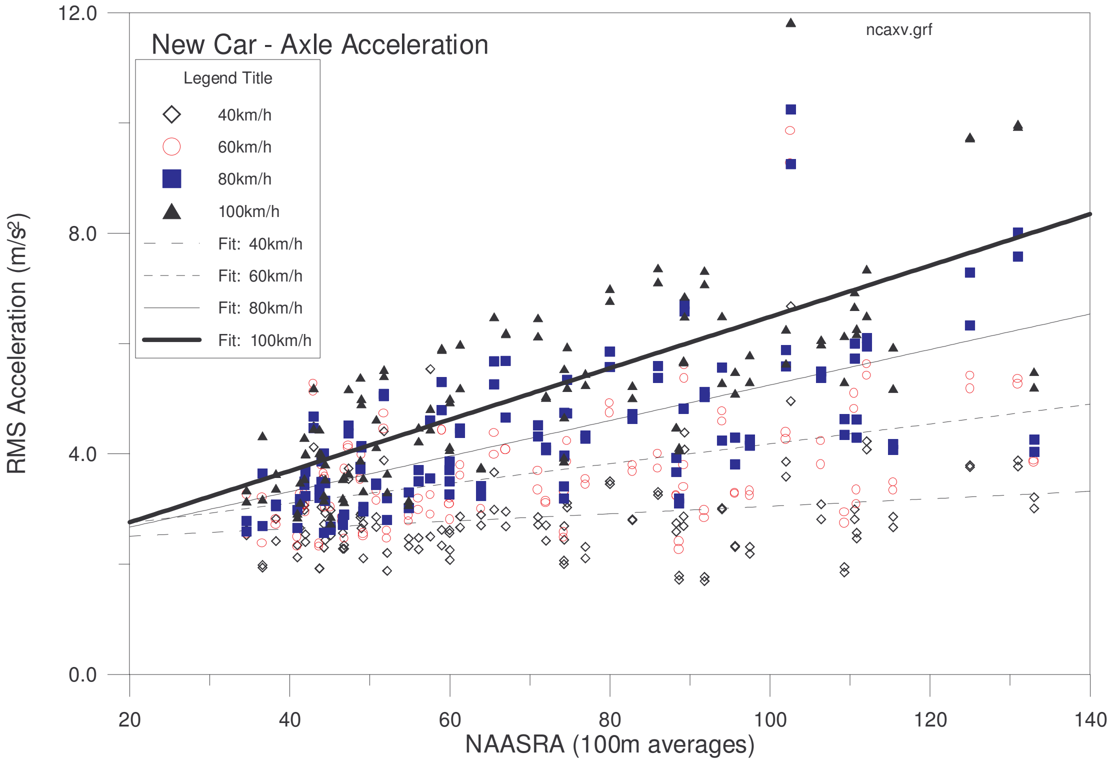

Figure A3 : 1999 Nissan Pulsar – Axle Accelerations

Figure A4: 1999 Nissan Pulsar – Body Accelerations

OPUS

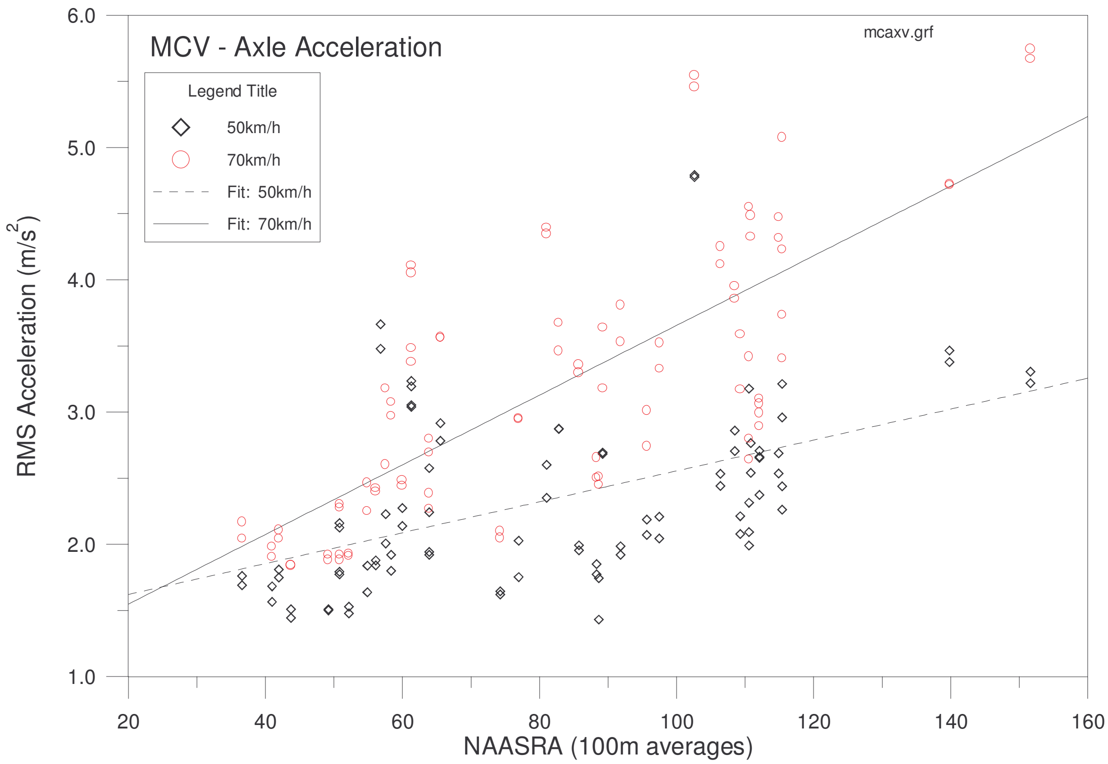

Figure A5 : 1996 Hino (MCV)–Axle Accelerations

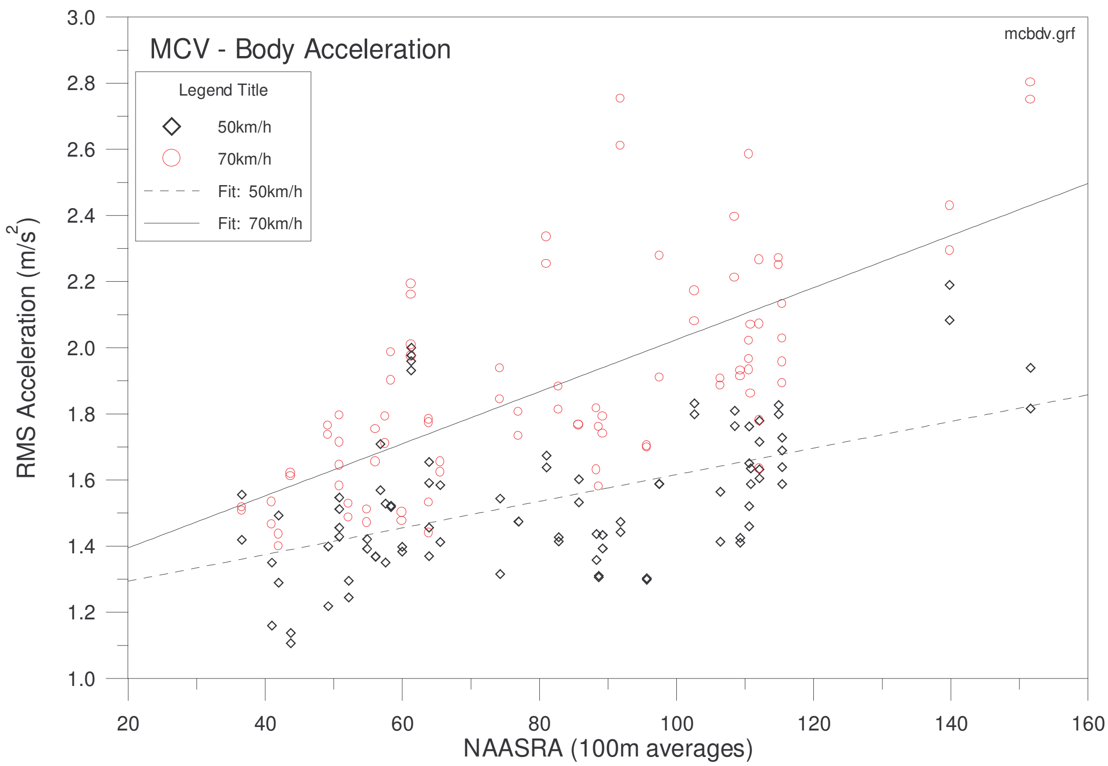

Figure A6 : 1996 Hino (MCV)–Body Accelerations

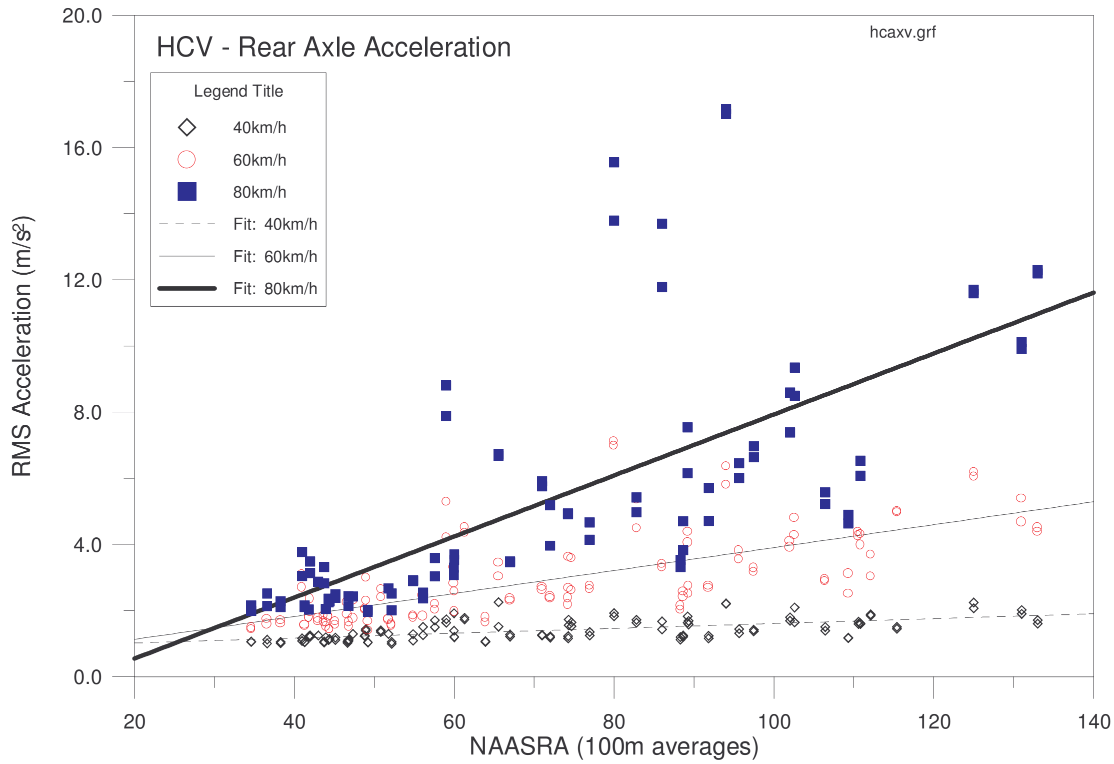

Figure A7 : 1999 Isuzu (HCV-I)–Axle Accelerations

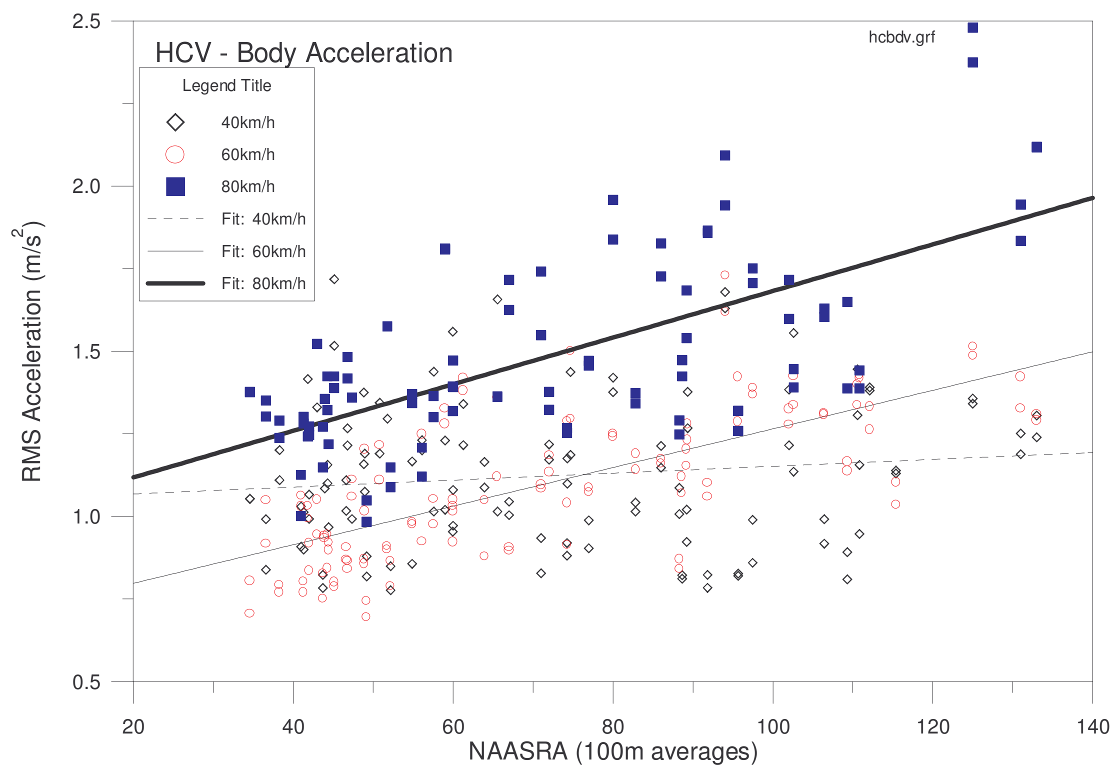

Figure A8 : 1999 Isuzu (HCV-I)–Body Accelerations

A2 : Least Square Regression Lines of RMS Acceleration on NAASRA roughness

The lines of best fit plotted in Figures A1 to A8 have the form:

Acc = aR+b

where: Acc = 100m averaged RMS axle or body acceleration (m/s^2)
R = 100m averaged lane NAASRA roughness
a, b = regression coefficients tabulated in Tables A1 and A2.

Table A1: Regression Coefficients for RMS Axle Accelerations

Vehicle	Speed (km/h)	No. of Observations	Slope (a)	Intercept (b)	r^2	Standard Error of Estimate
1995 Nissan Pulsar	40	120	0.005	1.079	0.08	0.47
	60	120	0.010	1.297	0.21	0.51
	80	120	0.014	1.580	0.21	0.76
	100	120	0.024	1.353	0.46	0.70
1999 Nissan Pulsar	40	120	0.007	2.372	0.05	0.76
	60	120	0.018	2.387	0.18	1.03
	80	120	0.032	2.026	0.42	1.02
	100	120	0.046	1.850	0.51	1.22
1996 Hino (MCV)	50	88	0.012	1.387	0.24	0.59
	70	85	0.027	1.021	0.58	0.65
1999 Isuzu (HCV-I)	40	114	0.007	0.870	0.38	0.25
	60	120	0.034	0.431	0.49	0.95
	80	90	0.092	-1.299	0.47	2.66

Table A2: Regression Coefficients for RMS Body Accelerations

Vehicle	Speed (km/h)	No. of Observations	Slope (a)	Intercept (b)	r^2	Standard Error of Estimate
1995 Nissan Pulsar	40	120	0.003	0.324	0.50	0.07
	60	120	0.005	0.246	0.65	0.11
	80	120	0.008	0.219	0.65	0.16
	100	120	0.010	0.153	0.75	0.16
1999 Nissan Pulsar	40	120	0.003	0.427	0.46	0.07
	60	120	0.005	0.370	0.60	0.12
	80	120	0.008	0.316	0.74	0.13
	100	120	0.010	0.287	0.78	0.15
1996 Hino (MCV)	50	88	0.004	1.213	0.28	0.18
	70	86	0.007	1.237	0.48	0.23
1999 Isuzu (HCV-I)	40	114	0.001	1.047	0.02	0.22
	60	120	0.006	0.680	0.51	0.15
	80	90	0.007	0.977	0.44	0.21

A3 : Plots of RMS Accelerations against Combined Vehicle Speed – Roughness Parameter

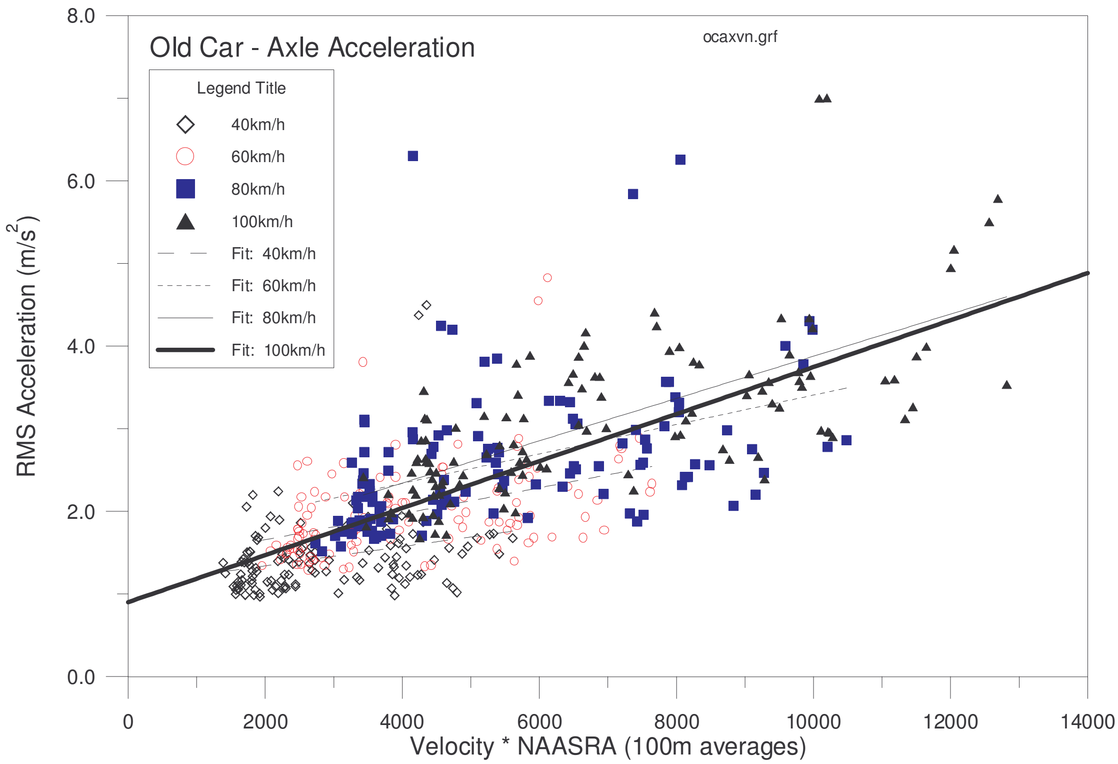

Figure A9 : 1985 Nissan Pulsar – Axle Accelerations as Function of VR Parameter

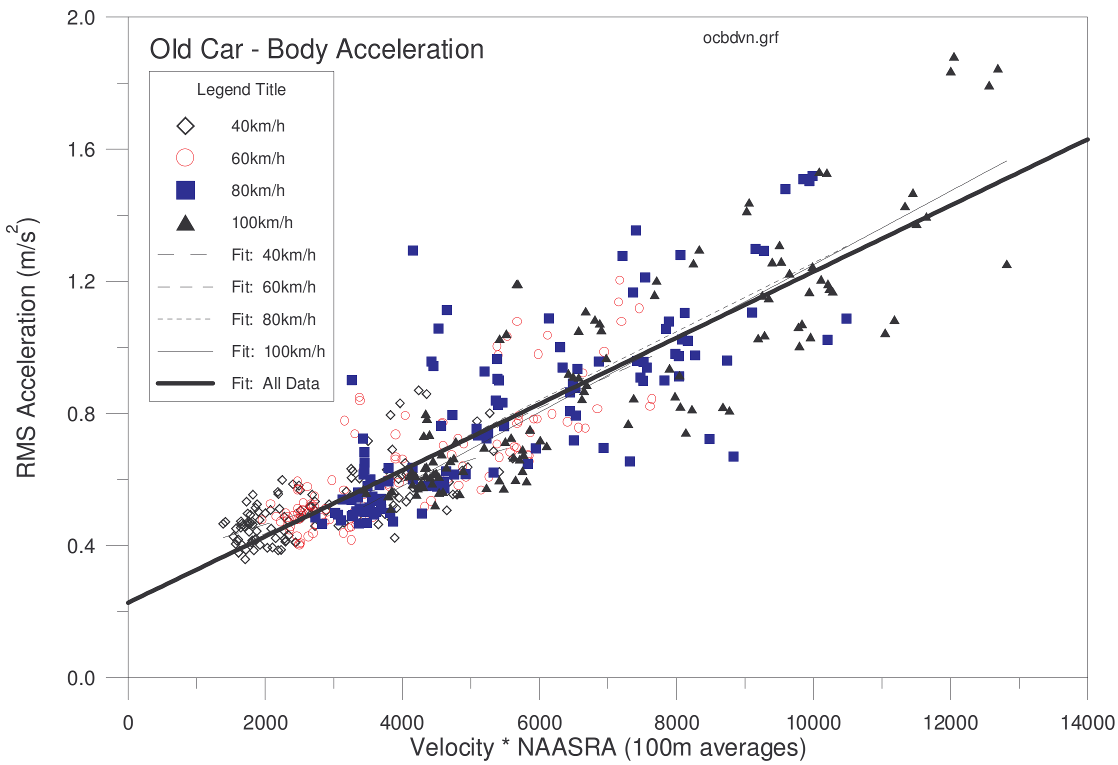

Figure A10 : 1985 Nissan Pulsar – Body Accelerations as Function of VR Parameter

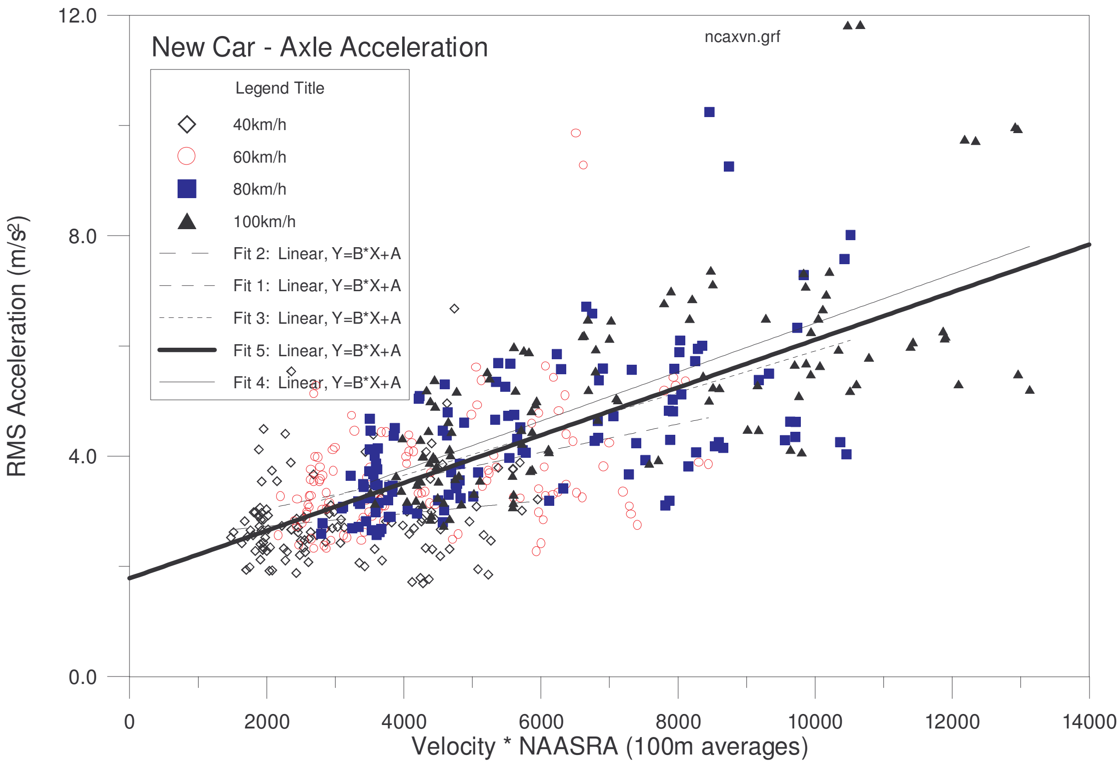

Figure A11 : 1999 Nissan Pulsar – Axle Accelerations as Function of VR Parameter

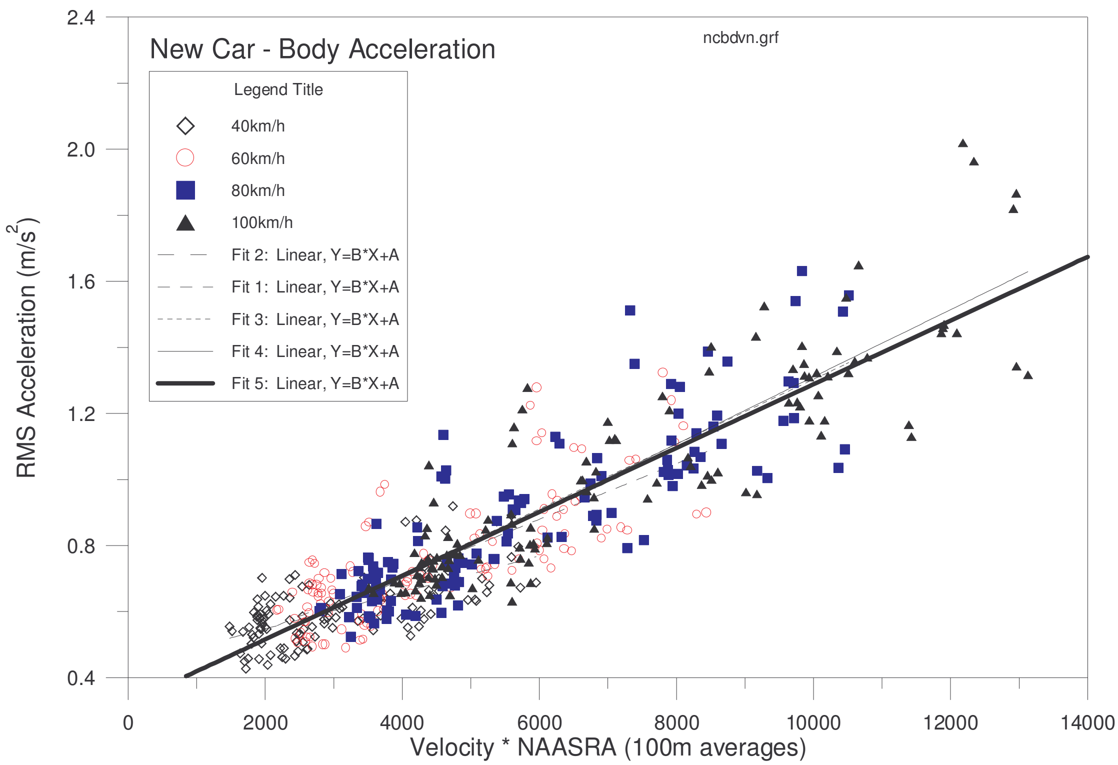

Figure A12: 1999 Nissan Pulsar – Body Accelerations as Function of VR Parameter

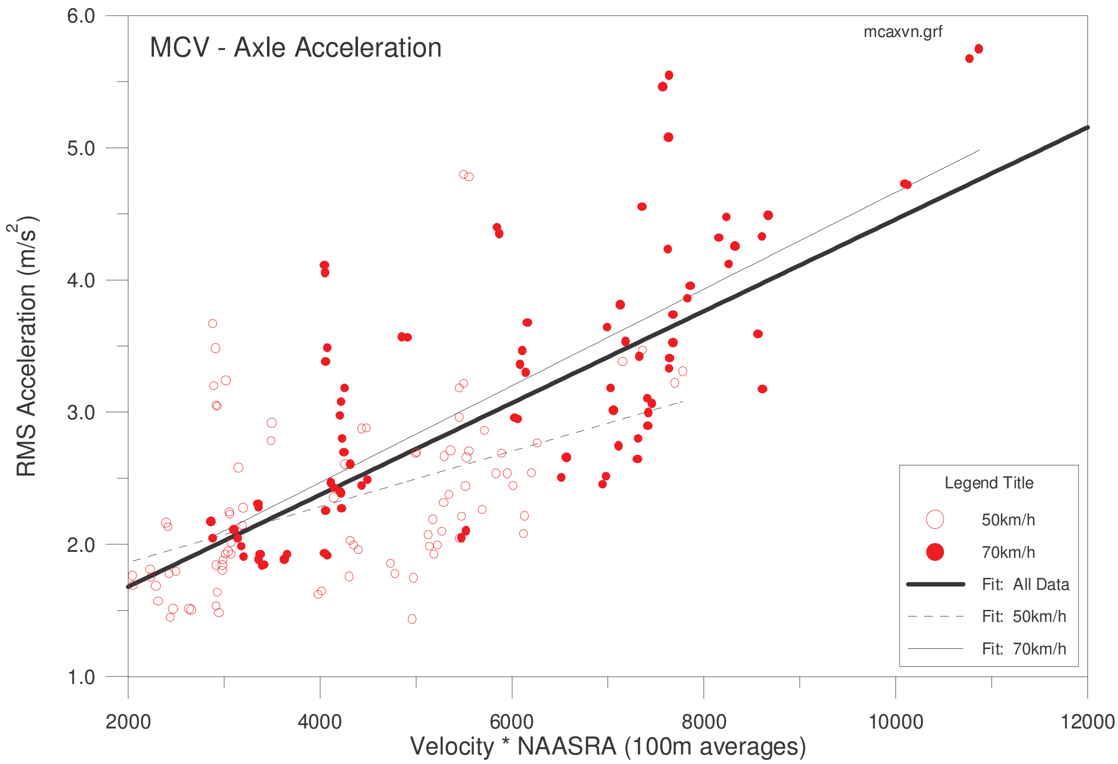

Figure A13 : 1996 Hino (MCV) – Axle Accelerations as Function of VR Parameter

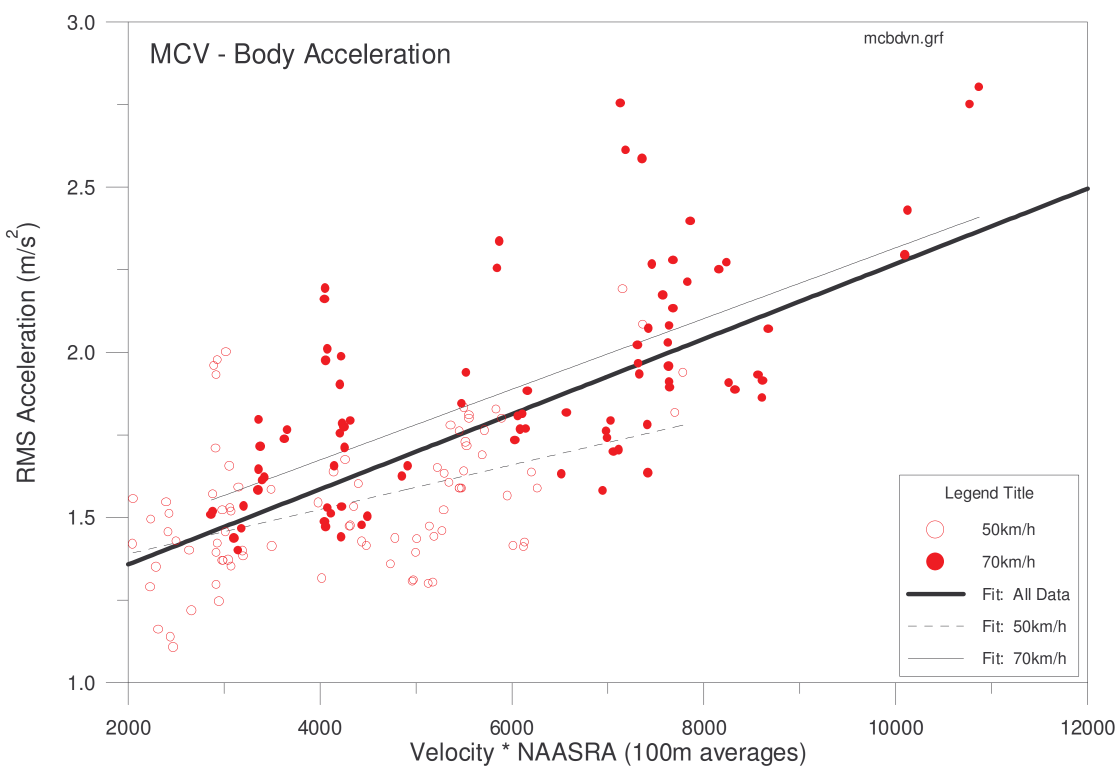

Figure A14 : 1996 Hino (MCV) – Body Accelerations as Function of VR Parameter

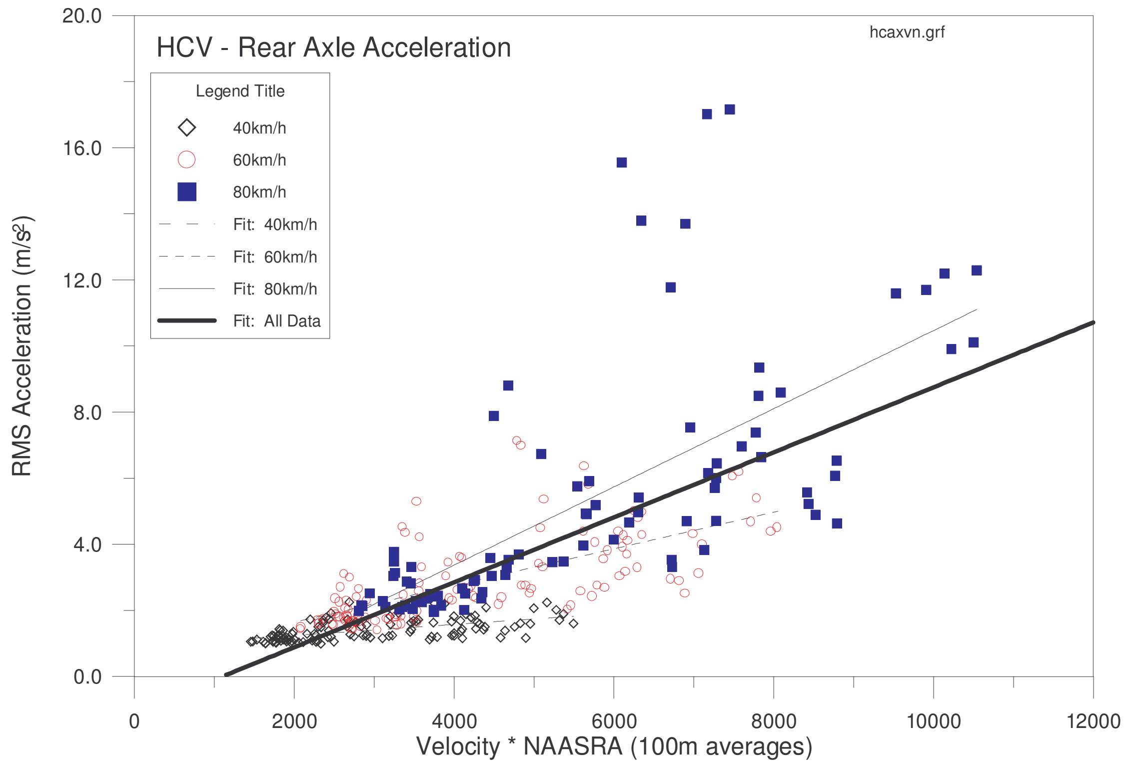

Figure A15 : 1999 Isuzu (HCV-I)–Axle Accelerations as Function of VR Parameter

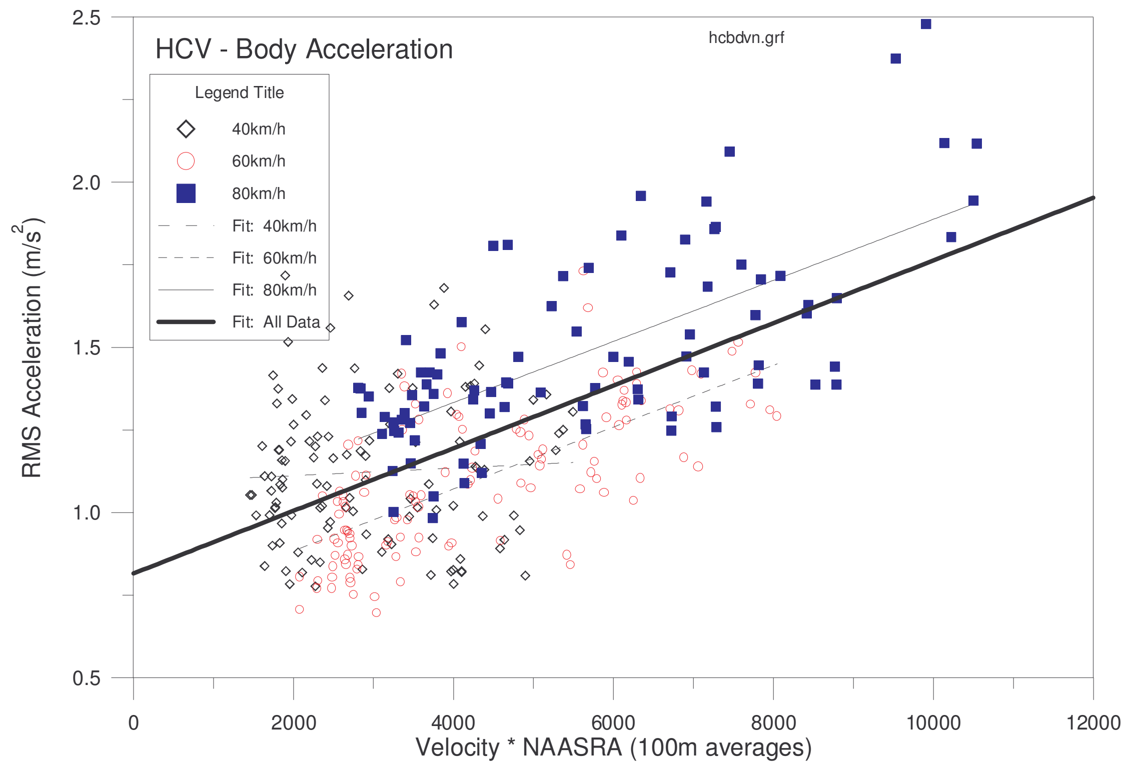

Figure A16 : 1999 Isuzu (HCV-I)–Body Accelerations as Function of VR Parameter

APPENDIX B

VOC Database for Trucks

Table B1: Database Entries

veh_id	company	veh_make	veh_model	veh_year	Veh_type	veh_class	whl_drive	route_region	kms_life	kms_voc	av_roughness	bendiness	underbody_r&m	other_r&m	total_r&m
T823	A	ERF	410	1994	Rigid	HCV-1	8x4	Aucklnad/Waikato		66278	67		0.0750	0.1450	0.2210
T846	A	ERF	405	1997	Rigid	HCV-1	8x4	Hawkes Bay		179127	73		0.0030	0.0610	0.0640
T811	A	ERF	325E	1991	Rigid	HCV-1	8x4	Canterbury		74516	132		0.0140	0.1110	0.1250
T818	A	ERF	405E	1993	Rigid	HCV-1	8x4	Canterbury		78824	132		0.0640	0.2090	0.2730
T815	A	ERF	325	1993	Rigid	HCV-1	8x4	Otago		142915	134		0.0430	0.1380	0.1810
T832	A	ERF	410	1996	Rigid	HCV-1	8x4	Otago		152020	134		0.0130	0.0910	0.1030
T831	A	ERF	410	1996	Rigid	HCV-1	8x4	Hawkes Bay		184248	138		0.0290	0.1460	0.1750
T850	A	ERF	M11	1997	Rigid	HCV-1	8x4	Manawatu		69478	139		0.0020	0.0560	0.0580
T835	A	ERF	405	1997	Rigid	HCV-1	8x4	Wellington		86694	170		0.0230	0.1070	0.1300
B1	B	Hino	380	1996	Rigid	HCV-1	6x4	Wellington		315200	62				0.1850
D1	D	Hino	FM186	1986	Rigid	HCV-1	6x4	Wellington	400000	35000	62				0.2800
US9933	C	Hino	FF2HPKA		rigid	HCV-1	6x2	Kaikohe/Whangarei	111537	74079	67	77.9			0.0790
D2	D	Mitsubishi	FM515	1989	rigid	HCV-1	4x2	Wellington	276000	30000	62				0.0600
TD7224	C	Mitsubishi	FV330		rigid	HCV-1	6x4	Dunedin/Christchurch	610435	194796	65	36.2			0.1190
TQ7468	C	Mitsubishi	FV330		rigid	HCV-1	6x4	Dunedin/Christchurch	717407	312185	65	36.2			0.0870
SU1997	C	Mitsubishi	FM220		rigid	HCV-1	6x2	Hamilton/Taupo	433499	69394	67	56.9			0.0660
TI9613	C	Mitsubishi	FM225M		rigid	HCV-1	6x2	New Plymouth/Palmerston N	593025	173606	67	45.9			0.0840
SU2021	C	Mitsubishi	FM220		rigid	HCV-1	6x2	Hamilton/Thames	441659	80438	70	46.02			0.1350
SD236	C	Mitsubishi	FM220		rigid	HCV-1	6x2	Hamilton/Taumarunui	457199	136899	80	91.46			0.0430
WB9871	C	Scania	R124GB-400	1997	rigid	HCV-1	8x4	Auckland/Tauranga	164973	163525	62	61.0			0.0600
WB9872	C	Scania	R124GB-400	1997	rigid	HCV-1	8x4	Auckland/Whangarei	158767	157984	65	77.86			0.0710
T848	A	Scania	P113	1997	rigid	HCV-1	8x4	Auckland/Waikato		159463	67		0.0020	0.0760	0.0770
T824	A	Scania	P113M	1994	rigid	HCV-1	8x4	Nelson/Marlborough		169734	70		0.0160	0.1210	0.1370
ST515	C	Scania	R113M-380		rigid	HCV-1	6x4	Napier/Taupo	390942	115350	70	82.54			0.1860
T834	A	Scania	P113M	1996	rigid	HCV-1	8x4	Bay of Plenty		170896	75		0.0010	0.1010	0.1030
T836	A	Scania	P113M	1996	rigid	HCV-1	8x4	Bay of Plenty		189855	75		0.0000	0.1170	0.1170
T840	A	Scania	P124	1998	rigid	HCV-1	8x4	Manawatu		41909	75		0.0310	0.0270	0.0580
E1	E	Scania	P123	1997	rigid	HCV-1	8x4	Napier/Gisborne/Taupo	550000		79				0.1000
T822	A	Scania	P113M	1994	rigid	HCV-1	8x4	Canterbury		76739	132		0.0690	0.0970	0.1660
T847	A	Scania	P113MK	1997	rigid	HCV-1	8x4	Canterbury		62769	132		0.0000	0.0470	0.0470
T816	A	Scania	P113	1993	rigid	HCV-1	8x4	Southland		33902	133		0.0240	0.2010	0.2250
T828	A	Scania	P113M	1995	rigid	HCV-1	8x4	Southland		87984	133		0.0160	0.1230	0.1390
T845	A	Scania	P113M	1997	rigid	HCV-1	8x4	Southland		175000	133		0.0080	0.0530	0.0610
T825	A	Scania	P113	1994	rigid	HCV-1	8x4	Auckland/Waikato		39464	135		0.1630	0.5000	0.6630
T809	A	Scania	P113M	1991	rigid	HCV-1	8x4	Nelson/Marlborough		69305	135		0.0110	0.1680	0.1790
T817	A	Scania	P113	1993	rigid	HCV-1	6x4	Taranaki/Wanganui		71862	139		0.0430	0.2180	0.2610
T830	A	Scania	P113	1995	rigid	HCV-1	8x4	Northland		97310	139		0.0110	0.1150	0.1260
T827	A	Scania	P113M	1995	rigid	HCV-1	8x4	Gisborne		152692	139		0.0180	0.1080	0.1260
T820	A	Scania	P113M	1994	rigid	HCV-1	8x4	Gisborne		102394	147		0.0430	0.2370	0.2800
E3	E	Volvo	F12	1992	rigid	HCV-1	8x4	Manawatu/Waiouru/Wairarapa	900000		69				0.2670
T841	A	Volvo	FH12	1998	rigid	HCV-1	8x4	Otago		47352	69		0.0080	0.0500	0.0580
E2	E	Volvo	FH12	1996	rigid	HCV-1	8x4	Nelson/Blenheim/Greymouth	1000000		70				0.1800
T829	A	Volvo	FH12	1995	rigid	HCV-1	8x4	Northland		158860	74		0.0120	0.1640	0.1770
T843	A	Volvo	FL12	1997	rigid	HCV-1	8x4	Taranaki/Wanganui		168378	78		0.0020	0.0600	0.0620
T821	A	Volvo	FH12	1994	rigid	HCV-1	8x4	Canterbury		148630	132		0.0200	0.1220	0.1420
T826	A	Volvo	FH12	1995	rigid	HCV-1	8x4	Wellington		78017	132		0.0230	0.1670	0.1910
T837	A	Volvo	FL1O	1997	rigid	HCV-1	8x4	Canterbury		58128	132		0.0000	0.0610	0.0610
T813	A	Volvo	FL1O	1992	rigid	HCV-1	8x4	Canterbury		68230	132		0.0310	0.0820	0.1130
T838	A	Volvo	FL12	1997	rigid	HCV-1	8x4	Auckland/Waikato		74739	135		0.0810	0.1850	0.2650
T833	A	Volvo	FH12	1996	rigid	HCV-1	8x4	West Coast		155005	138		0.0080	0.1340	0.1420
T849	A	Volvo	FL10	1998	rigid	HCV-1	8x4	Waikato		32480	139		0.0010	0.0380	0.0390
TE6706	C	Ford	Louisville		tractor	HCV-2	6x4	Wellington/Auckland	1227730	107149	66	55.41			0.2530
P400	A	Kenworth		1991	tractor	HCV-2	6x4	Auckland/Waikato		43964	59		0.0030	0.6280	0.6310
P402	A	Kenworth	T400	1995	tractor	HCV-2	6x4	Auckland/Waikato		157631	59		0.0010	0.1670	0.1690
P403	A	Kenworth	T400	1996	tractor	HCV-2	6x4	Wellington		125662	62		0.0180	0.1090	0.1270
D3	D	Mitsubishi	Fuso	1984	tractor	HCV-2	6x4	Wellington/Palmerston	760000	48000	62				0.5000
WD8782	C	Scania	R124GB-400	1997	tractor	HCV-2	6x4	Wellington/Auckland	166920	166196	66	55.41			0.0460
WD8784	C	Scania	R124GB-400	1997	tractor	HCV-2	6x4	Wellington/Auckland	195713	195662	66	55.41			0.0430
UH4978	C	Scania	R143ML-450		tractor	HCV-2	6x4	Wellington/Auckland	525387	296619	66	55.41			0.0290
UH4979	C	Scania	R143ML-450		tractor	HCV-2	6x4	Wellington/Auckland	537151	286570	66	55.41			0.0630
WD9794	C	Volvo	FH12-420	1997	tractor	HCV-2	6x4	Christchurch/Picton	160056	149420	62	93.66			0.0300
WD1105	C	Volvo	FH12-420	1997	tractor	HCV-2	6x4	Christchurch/Dunedin	170002	167083	65	36.2			0.0390
WJ4789	C	Volvo	FH12-420	1997	tractor	HCV-2	6x4	Wellington/Auckland	108430	105624	66	55.41			0.0350
WJ4790	C	Volvo	FH12-420	1997	tractor	HCV-2	6x4	Wellington/Auckland	98100	98100	66	55.41			0.0310
P405	A	Volvo	Fl10 360	1997	tractor	HCV-2	6x4	North Island		63782	73		0.0000	0.0490	0.0490
P401	A	Volvo	NL12	1993	tractor	HCV-2	6x4	Bay of Plenty		112194	74		0.0150	0.1390	0.1540

veh_id	fuel	Tyres	total_voc	kms_pur	pur_price	sale_price	under_r&m(less)	other_r&m(less)	total_r&m(less)	fuel(less)	tyres(less)	total_voc(less)	tyre_no	purch-tyres	eco-deprn	NormVOC
T823	0.1628	0.0680	33.94%		220000		0.0667	0.1289	0.1964	0.1628	0.0604		12	189263	0.0897	0.5094
T846	0.1628	0.0300	4.69%		220000		0.0027	0.0542	0.0569	0.1628	0.0267		12	189263	0.0897	0.3361
T811	0.1628	0.0380	11.20%		200000		0.0124	0.0987	0.1111	0.1628	0.0338		12	171485	0.0813	0.3890
T818	0.1628	0.0600	23.44%		220000	69000	0.0569	0.1858	0.2427	0.1628	0.0533		12	189263	0.0897	0.5485
T815	0.1628	0.0440	23.76%		200000		0.0382	0.1227	0.1609	0.1628	0.0391		12	171485	0.0813	0.4441
T832	0.1628	0.0850	12.62%		220000		0.0116	0.0809	0.0916	0.1628	0.0756		12	189263	0.0897	0.4196
T831	0.1628	0.0500	16.57%		220000		0.0258	0.1298	0.1556	0.1628	0.0444		12	189263	0.0897	0.4525
T850	0.1628	0.0700	3.45%		220000		0.0018	0.0498	0.0516	0.1628	0.0622		12	189263	0.0897	0.3663
T835	0.1628	0.0580	17.69%		220000		0.0204	0.0951	0.1156	0.1628	0.0516		12	189263	0.0897	0.4196
B1	0.1628	0.0900			195000		0.0000	0.0000	0.1644	0.1628	0.0800		10	168089	0.0797	0.4869
D1	0.1265	0.0500		240000	180000		0.0000	0.0000	0.2489	0.1265	0.0444		10	154756	0.0734	0.4932
US9933	0.1465	0.0660			180000		0.0000	0.0000	0.0702	0.1465	0.0587		10	154756	0.0734	0.3487
D2	0.1855	0.0500		180000	100000	25000	0.0000	0.0000	0.0533	0.1855	0.0444		6	85742	0.0407	0.3239
TD7224	0.2015	0.0160			180000		0.0000	0.0000	0.1058	0.2015	0.0142		10	154756	0.0734	0.3948
TQ7468	0.1345	0.0230			180000		0.0000	0.0000	0.0773	0.1345	0.0204		10	154756	0.0734	0.3056
SU1997	0.1405	0.0220			160000		0.0000	0.0000	0.0587	0.1405	0.0196		10	136978	0.0649	0.2836
TI9613	0.1265	0.0270			160000		0.0000	0.0000	0.0747	0.1265	0.0240		10	136978	0.0649	0.2901
SU2021	0.1195	0.0390			160000		0.0000	0.0000	0.1200	0.1195	0.0347		10	136978	0.0649	0.3391
SD236	0.1515	0.0270			160000		0.0000	0.0000	0.0382	0.1515	0.0240		10	136978	0.0649	0.2786
WB9871	0.1628	0.0530			200000		0.0000	0.0000	0.0533	0.1628	0.0471		12	171485	0.0813	0.3445
WB9872	0.1628	0.0550			200000		0.0000	0.0000	0.0631	0.1628	0.0489		12	171485	0.0813	0.3561
T848	0.1628	0.0310	2.60%		198000		0.0018	0.0676	0.0684	0.1628	0.0276		12	169707	0.0805	0.3392
T824	0.1628	0.0500	11.68%		198000	60000	0.0142	0.1076	0.1218	0.1628	0.0444		12	169707	0.0805	0.4095
ST515	0.1628	0.0360			180000		0.0000	0.0000	0.1653	0.1628	0.0320		10	154756	0.0734	0.4335
T834	0.1628	0.0450	0.97%		198000		0.0009	0.0898	0.0916	0.1628	0.0400		12	169707	0.0805	0.3748
T836	0.1628	0.0560	0.00%		198000		0.0000	0.1040	0.1040	0.1628	0.0498		12	169707	0.0805	0.3970
T840	0.1628	0.0060	53.45%		198000		0.0276	0.0240	0.0516	0.1628	0.0053		12	169707	0.0805	0.3001
E1	0.1628	0.0800			198000		0.0000	0.0000	0.0889	0.1628	0.0711		12	169707	0.0805	0.4032
T822	0.1628	0.0420	41.57%		198000	60000	0.0613	0.0862	0.1476	0.1628	0.0373		12	169707	0.0805	0.4281
T847	0.1628	0.0980	0.00%		198000		0.0000	0.0418	0.0418	0.1628	0.0871		12	169707	0.0805	0.3721
T816	0.1628	0.2020	10.67%		198000	50000	0.0213	0.1787	0.2000	0.1628	0.1796		12	169707	0.0805	0.6228
T828	0.1628	0.1220	11.51%		198000		0.0142	0.1093	0.1236	0.1628	0.1084		12	169707	0.0805	0.4752
T845	0.1628	0.0380	13.11%		198000		0.0071	0.0471	0.0542	0.1628	0.0338		12	169707	0.0805	0.3312
T825	0.1628	0.0570	24.59%		198000	60000	0.1449	0.4444	0.5893	0.1628	0.0507		12	169707	0.0805	0.8832
T809	0.1865	0.0760	6.15%		198000		0.0098	0.1493	0.1591	0.1865	0.0676		12	169707	0.0805	0.4936
T817	0.1628	0.0990	16.48%		180000	50000	0.0382	0.1938	0.2320	0.1628	0.0880		10	154756	0.0734	0.5561
T830	0.2005	0.0560	8.73%		198000		0.0098	0.1022	0.1120	0.2005	0.0498		12	169707	0.0805	0.4427
T827	0.1305	0.0430	14.29%		198000		0.0160	0.0960	0.1120	0.1305	0.0382		12	169707	0.0805	0.3611
T820	0.1355	0.1360	15.36%		198000	60000	0.0382	0.2107	0.2489	0.1355	0.1209		12	169707	0.0805	0.5857
E3	0.2165	0.1150			215000	60000	0.0000	0.0000	0.2373	0.2165	0.1022		12	184818	0.0876	0.6436
T841	0.1628	0.1060	13.79%		206000		0.0071	0.0444	0.0516	0.1628	0.0942		12	176818	0.0838	0.3924
E2	0.2065	0.1300			215000		0.0000	0.0000	0.1600	0.2065	0.1156		10	185867	0.0881	0.5701
T829	0.1628	0.0710	6.78%		215000	150000	0.0107	0.1458	0.1573	0.1628	0.0631		12	184818	0.0876	0.4708
T843	0.1628	0.0540	3.23%		215000		0.0018	0.0533	0.0551	0.1628	0.0480		12	184818	0.0876	0.3535
T821	0.1628	0.0710	14.08%		215000		0.0178	0.1084	0.1262	0.1628	0.0631		12	184818	0.0876	0.4397
T826	0.1628	0.0520	12.04%		215000	150000	0.0204	0.1484	0.1698	0.1628	0.0462		12	184818	0.0876	0.4664
T837	0.1628	0.0720	0.00%		175000		0.0000	0.0542	0.0542	0.1628	0.0640		12	149263	0.0708	0.3518
T813	0.1628	0.0490	27.43%		175000		0.0276	0.0729	0.1004	0.1628	0.0436		12	149263	0.0708	0.3775
T838	0.1628	0.0630	30.57%		215000		0.0720	0.1644	0.2356	0.1628	0.0560		12	184818	0.0876	0.5420
T833	0.1628	0.0430	5.63%		215000	150000	0.0071	0.1191	0.1262	0.1628	0.0382		12	184818	0.0876	0.4148
T849	0.1628	0.0360	2.56%		175000		0.0009	0.0338	0.0347	0.1628	0.0320		12	149263	0.0708	0.3002
TE6706	0.1605	0.0180			200000		0.0000	0.0000	0.2249	0.1605	0.0160		10	172534	0.0818	0.4831
P400	0.2054	0.0200	0.48%		200000		0.0027	0.5582	0.5609	0.2054	0.0178		10	172534	0.0818	0.8659
P402	0.2054	0.0640	0.59%		200000	75000	0.0009	0.1484	0.1502	0.2054	0.0569		10	172534	0.0818	0.4943
P403	0.2054	0.0220	14.17%		200000	110000	0.0160	0.0969	0.1129	0.2054	0.0196		10	172534	0.0818	0.4197
D3	0.1165	0.0500		615000	180000		0.0000	0.0000	0.4444	0.1165	0.0444		10	154756	0.0734	0.6787
WD8782	0.1775	0.0100			190000		0.0000	0.0000	0.0409	0.1775	0.0089		10	163645	0.0776	0.3048
WD8784	0.1485	0.0260			190000		0.0000	0.0000	0.0382	0.1485	0.0231		10	163645	0.0776	0.2874
UH4978	0.1825	0.0270			190000		0.0000	0.0000	0.0258	0.1825	0.0240		10	163645	0.0776	0.3098
UH4979	0.1895	0.0250			190000		0.0000	0.0000	0.0560	0.1895	0.0222		10	163645	0.0776	0.3453
WD9794	0.1755	0.0170			206000		0.0000	0.0000	0.0267	0.1755	0.0151		10	177867	0.0843	0.3016
WD1105	0.1495	0.0270			206000		0.0000	0.0000	0.0347	0.1495	0.0240		10	177867	0.0843	0.2924
WJ4789	0.2605	0.0140			206000		0.0000	0.0000	0.0311	0.2605	0.0124		10	177867	0.0843	0.3883
WJ4790	0.2635	0.0100			206000		0.0000	0.0000	0.0276	0.2635	0.0089		10	177867	0.0843	0.3842
P405	0.2054	0.0640	0.00%		160000		0.0000	0.0436	0.0436	0.2054	0.0569		10	136978	0.0649	0.3708
P401	0.2054	0.0490	9.74%		206000		0.0133	0.1236	0.1369	0.2054	0.0436		10	177867	0.0843	0.4702

Table B2: Truck component VOC by roughness

		HCV-1				HCV-1 Total	HCV-2	HCV-2 Total	Grand Total
av_roughness	Data	4x2	6x2	6x4	8x4		6x4		
59	Average of total_r&m(less)						0.36	0.36	0.36
	StdDev of total_r&m(less)2						0.29	0.29	0.29
	Average of fuel(less)						0.21	0.21	0.21
	StdDev of fuel(less)2						0.00	0.00	0.00
	Average of tyres(less)						0.04	0.04	0.04
	StdDev of tyres(less)2						0.03	0.03	0.03
	Average of eco-deprn						0.08	0.08	0.08
	StdDev of eco-deprn2						0.00	0.00	0.00
	Average of NormVOC						0.6801	0.6801	0.6801
	StdDev of NormVOC2						0.26	0.26	0.26
	Count of veh_id						2	2	2
62	Average of total_r&m(less)	0.05		0.21	0.05	0.13	0.19	0.19	0.16
	StdDev of total_r&m(less)2	#DIV/0!		0.06	#DIV/0!	0.10	0.22	0.22	0.15
	Average of fuel(less)	0.19		0.14	0.16	0.16	0.17	0.17	0.16
	StdDev of fuel(less)2	#DIV/0!		0.03	#DIV/0!	0.02	0.05	0.05	0.03
	Average of tyres(less)	0.04		0.06	0.05	0.05	0.03	0.03	0.04
	StdDev of tyres(less)2	#DIV/0!		0.03	#DIV/0!	0.02	0.02	0.02	0.02
	Average of eco-deprn	0.04		0.08	0.08	0.07	0.08	0.08	0.07
	StdDev of eco-deprn2	#DIV/0!		0.00	#DIV/0!	0.02	0.01	0.01	0.02
	Average of NormVOC	0.3239		0.4900	0.3445	0.4121	0.4666	0.4666	0.4355
	StdDev of NormVOC2	#DIV/0!		0.00	#DIV/0!	0.09	0.19	0.19	0.13
	Count of veh_id	1		2	1	4	3	3	7
65	Average of total_r&m(less)			0.09	0.06	0.08	0.03	0.03	0.07
	StdDev of total_r&m(less)2			0.02	#DIV/0!	0.02	#DIV/0!	#DIV/0!	0.03
	Average of fuel(less)			0.17	0.16	0.17	0.15	0.15	0.16
	StdDev of fuel(less)2			0.05	#DIV/0!	0.03	#DIV/0!	#DIV/0!	0.03
	Average of tyres(less)			0.02	0.05	0.03	0.02	0.02	0.03
	StdDev of tyres(less)2			0.00	#DIV/0!	0.02	#DIV/0!	#DIV/0!	0.02
	Average of eco-deprn			0.07	0.08	0.08	0.08	0.08	0.08
	StdDev of eco-deprn2			0.00	#DIV/0!	0.00	#DIV/0!	#DIV/0!	0.01
	Average of NormVOC			0.3502	0.3561	0.3522	0.2924	0.2924	0.3372
	StdDev of NormVOC2			0.06	#DIV/0!	0.04	#DIV/0!	#DIV/0!	0.05
	Count of veh_id			2	1	3	1	1	4
66	Average of total_r&m(less)						0.06	0.06	0.06
	StdDev of total_r&m(less)2						0.07	0.07	0.07
	Average of fuel(less)						0.20	0.20	0.20
	StdDev of fuel(less)2						0.05	0.05	0.05
	Average of tyres(less)						0.02	0.02	0.02
	StdDev of tyres(less)2						0.01	0.01	0.01
	Average of eco-deprn						0.08	0.08	0.08
	StdDev of eco-deprn2						0.00	0.00	0.00
	Average of NormVOC						0.3576	0.3576	0.3576
	StdDev of NormVOC2						0.07	0.07	0.07
	Count of veh_id						7	7	7
67	Average of total_r&m(less)		0.07		0.13	0.09			0.09
	StdDev of total_r&m(less)2		0.01		0.09	0.06			0.06
	Average of fuel(less)		0.14		0.16	0.15			0.15
	StdDev of fuel(less)2		0.01		0.00	0.02			0.02
	Average of tyres(less)		0.03		0.04	0.04			0.04
	StdDev of tyres(less)2		0.02		0.02	0.02			0.02
	Average of eco-deprn		0.07		0.09	0.07			0.07
	StdDev of eco-deprn2		0.00		0.01	0.01			0.01
	Average of NormVOC		0.3075		0.4243	0.3542			0.3542
	StdDev of NormVOC2		0.04		0.12	0.09			0.09
	Count of veh_id		3		2	5			5
69	Average of total_r&m(less)				0.14	0.14			0.14
	StdDev of total_r&m(less)2				0.13	0.13			0.13
	Average of fuel(less)				0.19	0.19			0.19
	StdDev of fuel(less)2				0.04	0.04			0.04
	Average of tyres(less)				0.10	0.10			0.10
	StdDev of tyres(less)2				0.01	0.01			0.01
	Average of eco-deprn				0.09	0.09			0.09
	StdDev of eco-deprn2				0.00	0.00			0.00
	Average of NormVOC				0.5180	0.5180			0.5180
	StdDev of NormVOC2				0.18	0.18			0.18
	Count of veh_id				2	2			2
		HCV-1				HCV-1 Total	HCV-2	HCV-2 Total	Grand Total
av_roughness	Data	4x2	6x2	6x4	8x4		6x4		
70	Average of total_r&m(less)		0.12	0.17	0.14	0.14			0.14
	StdDev of total_r&m(less)2		#DIV/0!	#DIV/0!	0.03	0.02			0.02

	Average of fuel(less)		0.12	0.16	0.18	0.16			0.16
	StdDev of fuel(less)2		#DIV/0!	#DIV/0!	0.03	0.04			0.04
	Average of tyres(less)		0.03	0.03	0.08	0.06			0.06
	StdDev of tyres(less)2		#DIV/0!	#DIV/0!	0.05	0.04			0.04
	Average of eco-deprn		0.06	0.07	0.08	0.08			0.08
	StdDev of eco-deprn2		#DIV/0!	#DIV/0!	0.01	0.01			0.01
	Average of NormVOC		0.3391	0.4335	0.4898	0.4380			0.4380
	StdDev of NormVOC2		#DIV/0!	#DIV/0!	0.11	0.10			0.10
	Count of veh_id		1	1	2	4			4
73	Average of total_r&m(less)				0.06	0.06	0.04	0.04	0.05
	StdDev of total_r&m(less)2				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.01
	Average of fuel(less)				0.16	0.16	0.21	0.21	0.18
	StdDev of fuel(less)2				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.03
	Average of tyres(less)				0.03	0.03	0.06	0.06	0.04
	StdDev of tyres(less)2				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.02
	Average of eco-deprn				0.09	0.09	0.06	0.06	0.08
	StdDev of eco-deprn2				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.02
	Average of NormVOC				0.3361	0.3361	0.3708	0.3708	0.3534
	StdDev of NormVOC2				#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.02
	Count of veh_id				1	1	1	1	2
74	Average of total_r&m(less)				0.16	0.16			0.16
	StdDev of total_r&m(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of tyres(less)				0.06	0.06			0.06
	StdDev of tyres(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of eco-deprn				0.09	0.09			0.09
	StdDev of eco-deprn2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of NormVOC				0.4708	0.4708			0.4708
	StdDev of NormVOC2				#DIV/0!	#DIV/0!			#DIV/0!
	Count of veh_id				1	1			1
75	Average of total_r&m(less)				0.08	0.08			0.08
	StdDev of total_r&m(less)2				0.03	0.03			0.03
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				0.00	0.00			0.00
	Average of tyres(less)				0.03	0.03			0.03
	StdDev of tyres(less)2				0.02	0.02			0.02
	Average of eco-deprn				0.08	0.08			0.08
	StdDev of eco-deprn2				0.00	0.00			0.00
	Average of NormVOC				0.3573	0.3573			0.3573
	StdDev of NormVOC2				0.05	0.05			0.05
	Count of veh_id				3	3			3
78	Average of total_r&m(less)				0.06	0.06			0.06
	StdDev of total_r&m(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of tyres(less)				0.05	0.05			0.05
	StdDev of tyres(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of eco-deprn				0.09	0.09			0.09
	StdDev of eco-deprn2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of NormVOC				0.3535	0.3535			0.3535
	StdDev of NormVOC2				#DIV/0!	#DIV/0!			#DIV/0!
	Count of veh_id				1	1			1
79	Average of total_r&m(less)				0.09	0.09			0.09
	StdDev of total_r&m(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of tyres(less)				0.07	0.07			0.07
	StdDev of tyres(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of eco-deprn				0.08	0.08			0.08
	StdDev of eco-deprn2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of NormVOC				0.4032	0.4032			0.4032
	StdDev of NormVOC2				#DIV/0!	#DIV/0!			#DIV/0!
	Count of veh_id				1	1			1

		HCV-1				HCV-1 Total	HCV-2	HCV-2 Total	Grand Total
av_roughness	Data	4x2	6x2	6x4	8x4		6x4		
80	Average of total_r&m(less)		0.04			0.04			0.04
	StdDev of total_r&m(less)2		#DIV/0!			#DIV/0!			#DIV/0!
	Average of fuel(less)		0.15			0.15			0.15
	StdDev of fuel(less)2		#DIV/0!			#DIV/0!			#DIV/0!
	Average of tyres(less)		0.02			0.02			0.02

	StdDev of tyres(less)2		#DIV/0!			#DIV/0!			#DIV/0!
	Average of eco-deprn		0.06			0.06			0.06
	StdDev of eco-deprn2		#DIV/0!			#DIV/0!			#DIV/0!
	Average of NormVOC		0.2786			0.2786			0.2786
	StdDev of NormVOC2		#DIV/0!			#DIV/0!			#DIV/0!
	Count of veh_id		1			1			1
132	Average of total_r&m(less)				0.12	0.12			0.12
	StdDev of total_r&m(less)2				0.06	0.06			0.06
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				0.00	0.00			0.00
	Average of tyres(less)				0.05	0.05			0.05
	StdDev of tyres(less)2				0.02	0.02			0.02
	Average of eco-deprn				0.08	0.08			0.08
	StdDev of eco-deprn2				0.01	0.01			0.01
	Average of NormVOC				0.4216	0.4216			0.4216
	StdDev of NormVOC2				0.06	0.06			0.06
	Count of veh_id				8	8			8
133	Average of total_r&m(less)				0.13	0.13			0.13
	StdDev of total_r&m(less)2				0.07	0.07			0.07
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				0.00	0.00			0.00
	Average of tyres(less)				0.11	0.11			0.11
	StdDev of tyres(less)2				0.07	0.07			0.07
	Average of eco-deprn				0.08	0.08			0.08
	StdDev of eco-deprn2				0.00	0.00			0.00
	Average of NormVOC				0.4764	0.4764			0.4764
	StdDev of NormVOC2				0.15	0.15			0.15
	Count of veh_id				3	3			3
134	Average of total_r&m(less)				0.13	0.13			0.13
	StdDev of total_r&m(less)2				0.05	0.05			0.05
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				0.00	0.00			0.00
	Average of tyres(less)				0.06	0.06			0.06
	StdDev of tyres(less)2				0.03	0.03			0.03
	Average of eco-deprn				0.09	0.09			0.09
	StdDev of eco-deprn2				0.01	0.01			0.01
	Average of NormVOC				0.4319	0.4319			0.4319
	StdDev of NormVOC2				0.02	0.02			0.02
	Count of veh_id				2	2			2
135	Average of total_r&m(less)				0.33	0.33			0.33
	StdDev of total_r&m(less)2				0.23	0.23			0.23
	Average of fuel(less)				0.17	0.17			0.17
	StdDev of fuel(less)2				0.01	0.01			0.01
	Average of tyres(less)				0.06	0.06			0.06
	StdDev of tyres(less)2				0.01	0.01			0.01
	Average of eco-deprn				0.08	0.08			0.08
	StdDev of eco-deprn2				0.00	0.00			0.00
	Average of NormVOC				0.6396	0.6396			0.6396
	StdDev of NormVOC2				0.21	0.21			0.21
	Count of veh_id				3	3			3
138	Average of total_r&m(less)				0.14	0.14			0.14
	StdDev of total_r&m(less)2				0.02	0.02			0.02
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				0.00	0.00			0.00
	Average of tyres(less)				0.04	0.04			0.04
	StdDev of tyres(less)2				0.00	0.00			0.00
	Average of eco-deprn				0.09	0.09			0.09
	StdDev of eco-deprn2				0.00	0.00			0.00
	Average of NormVOC				0.4337	0.4337			0.4337
	StdDev of NormVOC2				0.03	0.03			0.03
	Count of veh_id				2	2			2

		HCV-1				HCV-1 Total	HCV-2	HCV-2 Total	Grand Total
av_roughness	Data	4x2	6x2	6x4	8x4		6x4		
139	Average of total_r&m(less)			0.23	0.08	0.11			0.11
	StdDev of total_r&m(less)2			#DIV/0!	0.04	0.08			0.08
	Average of fuel(less)			0.16	0.16	0.16			0.16
	StdDev of fuel(less)2			#DIV/0!	0.03	0.02			0.02
	Average of tyres(less)			0.09	0.05	0.05			0.05
	StdDev of tyres(less)2			#DIV/0!	0.01	0.02			0.02
	Average of eco-deprn			0.07	0.08	0.08			0.08
	StdDev of eco-deprn2			#DIV/0!	0.01	0.01			0.01
	Average of NormVOC			0.5561	0.3676	0.4053			0.4053

	StdDev of NormVOC2			#DIV/0!	0.06	0.10			0.10
	Count of veh_id			1	4	5			5
147	Average of total_r&m(less)				0.25	0.25			0.25
	StdDev of total_r&m(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of fuel(less)				0.14	0.14			0.14
	StdDev of fuel(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of tyres(less)				0.12	0.12			0.12
	StdDev of tyres(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of eco-deprn				0.08	0.08			0.08
	StdDev of eco-deprn2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of NormVOC				0.5857	0.5857			0.5857
	StdDev of NormVOC2				#DIV/0!	#DIV/0!			#DIV/0!
	Count of veh_id				1	1			1
170	Average of total_r&m(less)				0.12	0.12			0.12
	StdDev of total_r&m(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of fuel(less)				0.16	0.16			0.16
	StdDev of fuel(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of tyres(less)				0.05	0.05			0.05
	StdDev of tyres(less)2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of eco-deprn				0.09	0.09			0.09
	StdDev of eco-deprn2				#DIV/0!	#DIV/0!			#DIV/0!
	Average of NormVOC				0.4196	0.4196			0.4196
	StdDev of NormVOC2				#DIV/0!	#DIV/0!			#DIV/0!
	Count of veh_id				1	1			1

	HCV-1				HCV-1 Total	HCV-2	HCV-2 Total	Grand Total
	4x2	6x2	6x4	8x4		6x4		
Total Average of total_r&m(less)	0.05	0.07	0.17	0.13	0.13	0.13	0.13	0.13
Total StdDev of total_r&m(less)2	#DIV/0!	0.03	0.07	0.10	0.09	0.17	0.17	0.11
Total Average of fuel(less)	0.19	0.14	0.16	0.17	0.16	0.19	0.19	0.17
Total StdDev of fuel(less)2	#DIV/0!	0.01	0.03	0.01	0.02	0.04	0.04	0.03
Total Average of tyres(less)	0.04	0.03	0.05	0.06	0.06	0.03	0.03	0.05
Total StdDev of tyres(less)2	#DIV/0!	0.02	0.03	0.03	0.03	0.02	0.02	0.03
Total Average of eco-deprn	0.04	0.07	0.07	0.08	0.08	0.08	0.08	0.08
Total StdDev of eco-deprn2	#DIV/0!	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Total Average of NormVOC	0.3239	0.3080	0.4450	0.4392	0.4248	0.4233	0.4233	0.4244
Total StdDev of NormVOC2	#DIV/0!	0.03	0.09	0.11	0.11	0.17	0.17	0.12
Total Count of veh_id	1	5	6	39	51	14	14	65

APPENDIX C

Summary Tables Generated From Fleetlease Database

Table C1: Passenger car and LCV component VOC by engine capacity

		CARS			CARS Total	LTCOMM			LTCOMM Total	Grand Total
CC-Cat	Data	Off-Road	On-Road	Used		Off-Road	On-Road	Used		
0-1300	Average of AdjTyres		0.26	1.26	0.76			2.30	2.30	1.01
	StdDev of AdjTyres		0.36	0.68	0.73			0.27	0.27	0.90
	Average of SMLessTyres		1.27	2.09	1.68			1.23	1.23	1.60
	StdDev of SMLessTyres		0.69	0.68	0.78			0.09	0.09	0.73
	Average of FuelCosts		2.99	2.99	2.99			2.99	2.99	2.99
	StdDev of FuelCosts		0.00	0.00	0.00			0.00	0.00	0.00
	Average of EcoDeprn		5.47	5.44	5.46			1.99	1.99	4.88
	StdDev of EcoDeprn		0.40	0.46	0.41			0.00	0.00	1.40
	Average of ActDeprn		13.53	29.93	21.73			36.57	36.57	24.20
	StdDev of ActDeprn		7.48	8.02	11.32			20.42	20.42	13.27
	Average of VOC		9.98	11.77	10.87			8.51	8.51	10.48
	StdDev of VOC		0.86	1.48	1.48			0.36	0.36	1.63
	Average of VOCA		18.04	36.26	27.15			43.08	43.08	29.80
	StdDev of VOCA		7.87	9.13	12.52			20.78	20.78	14.35
	Count of Bus Unit code		5	5	10			2	2	12
1301-1600	Average of AdjTyres		0.51	1.12	0.59					0.59
	StdDev of AdjTyres		0.42	0.46	0.47					0.47
	Average of SMLessTyres		1.09	1.61	1.16					1.16
	StdDev of SMLessTyres		0.42	0.93	0.54					0.54
	Average of FuelCosts		3.18	3.18	3.18					3.18
	StdDev of FuelCosts		0.00	0.00	0.00					0.00
	Average of EcoDeprn		6.35	6.59	6.38					6.38
	StdDev of EcoDeprn		0.58	0.38	0.56					0.56
	Average of ActDeprn		10.26	26.88	12.41					12.41
	StdDev of ActDeprn		4.19	28.42	11.95					11.95
	Average of VOC		11.13	12.50	11.31					11.31
	StdDev of VOC		0.94	0.92	1.04					1.04
	Average of VOCA		15.04	32.79	17.34					17.34
	StdDev of VOCA		3.98	28.91	12.21					12.21
	Count of Bus Unit code		74	11	85					85
1601-2000	Average of AdjTyres	0.52	0.68	1.64	0.87		0.59	4.03	0.70	0.84
	StdDev of AdjTyres	0.26	0.43	2.19	1.11		0.34	#DIV/0!	0.71	1.07
	Average of SMLessTyres	0.50	1.10	1.87	1.25		1.35	3.34	1.41	1.27
	StdDev of SMLessTyres	0.23	0.43	1.09	0.69		0.62	#DIV/0!	0.71	0.69
	Average of FuelCosts	3.60	3.60	3.60	3.60		3.60	3.60	3.60	3.60
	StdDev of FuelCosts	0.00	0.00	0.00	0.00		0.00	#DIV/0!	0.00	0.00
	Average of EcoDeprn	7.44	7.83	7.84	7.82		2.29	2.22	2.28	7.05
	StdDev of EcoDeprn	0.42	0.78	0.76	0.77		0.19	#DIV/0!	0.19	2.05
	Average of ActDeprn	8.67	10.28	24.83	13.16		10.37	30.61	11.05	12.87
	StdDev of ActDeprn	1.47	5.27	24.13	13.04		4.32	#DIV/0!	5.63	12.29
	Average of VOC	12.06	13.21	14.94	13.54		7.82	13.19	8.00	12.76
	StdDev of VOC	0.14	0.99	3.44	1.90		0.95	#DIV/0!	1.35	2.65
	Average of VOCA	13.29	15.66	31.94	18.87		15.91	41.58	16.76	18.58
	StdDev of VOCA	1.82	5.16	26.78	14.29		4.11	#DIV/0!	6.19	13.46
	Count of Bus Unit code	3	145	37	185		29	1	30	215
2001+	Average of AdjTyres	0.67	1.09	1.47	1.15	0.64	0.68	2.03	1.22	1.16
	StdDev of AdjTyres	0.15	3.03	1.17	2.71	0.37	0.50	1.75	1.34	2.50
	Average of SMLessTyres	1.72	1.89	2.68	2.04	1.60	1.29	2.03	1.60	1.95
	StdDev of SMLessTyres	0.32	5.43	2.12	4.85	0.78	0.43	1.21	0.91	4.38
	Average of FuelCosts	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32	4.32
	StdDev of FuelCosts	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average of EcoDeprn	8.89	9.30	9.64	9.35	2.53	2.69	2.59	2.64	8.04
	StdDev of EcoDeprn	0.34	1.54	4.07	2.23	0.10	0.54	0.49	0.50	3.33
	Average of ActDeprn	8.03	13.37	34.30	17.13	8.91	9.49	41.37	22.21	18.12
	StdDev of ActDeprn	0.76	16.94	32.84	22.21	3.47	4.15	59.39	40.48	26.77
	Average of VOC	15.60	16.61	18.11	16.85	9.09	8.98	10.97	9.79	15.48
	StdDev of VOC	0.45	8.63	5.61	7.97	1.22	1.08	2.46	2.00	7.73
	Average of VOCA	14.75	20.67	42.77	24.63	15.47	15.78	49.75	29.35	25.55
	StdDev of VOCA	0.79	24.99	33.54	27.74	4.47	4.32	59.18	40.78	30.71
	Count of Bus Unit code	12	222	55	289	4	38	28	70	359
Total Average of AdjTyres		0.64	0.85	1.48	0.96	0.64	0.64	2.12	1.09	0.98
Total StdDev of AdjTyres		0.17	2.17	1.54	2.05	0.37	0.44	1.70	1.20	1.94
Total Average of SMLessTyres		1.48	1.50	2.26	1.64	1.60	1.31	2.02	1.54	1.63
Total StdDev of SMLessTyres		0.59	3.86	1.72	3.51	0.78	0.52	1.20	0.85	3.25
Total Average of FuelCosts		4.18	3.88	3.90	3.89	4.32	4.01	4.21	4.08	3.92
Total StdDev of FuelCosts		0.30	0.46	0.47	0.46	0.00	0.36	0.35	0.37	0.45
Total Average of EcoDeprn		8.60	8.29	8.52	8.34	2.53	2.52	2.54	2.52	7.46
Total StdDev of EcoDeprn		0.69	1.65	3.19	2.02	0.10	0.47	0.49	0.46	2.80
Total Average of ActDeprn		8.16	11.85	30.10	15.22	8.91	9.87	40.71	19.21	15.82
Total StdDev of ActDeprn		0.92	12.54	28.95	18.26	3.47	4.21	56.51	34.12	21.45
Total Average of VOC		14.89	14.52	16.16	14.84	9.09	8.48	10.88	9.24	13.99
Total StdDev of VOC		1.52	6.51	4.98	6.19	1.22	1.17	2.45	1.98	6.09
Total Average of VOCA		14.46	18.08	37.74	21.72	15.47	15.84	49.06	25.92	22.35
Total StdDev of VOCA		1.15	18.13	30.29	22.16	4.47	4.20	56.32	34.50	24.45
Total Count of Bus Unit code		15	446	108	569	4	67	31	102	671

Table C2: Passenger car and LCV component VOC by use and NAASRA roughness

		CARS			CARS Total	LTCOMM			LTCOMM Total	Grand Total
NAASRA	Data	Off-Road	On-Road	Used		Off-Road	On-Road	Used		
59	Average of AdjTyres	0.48	1.02	1.31	1.07		0.76	2.07	1.10	1.07
	StdDev of AdjTyres	0.34	3.22	0.90	2.94		0.57	2.44	1.39	2.84
	Average of SMLessTyres	0.76	1.83	2.57	1.95		1.50	2.24	1.69	1.93
	StdDev of SMLessTyres	0.52	5.77	2.29	5.32		0.67	1.59	1.00	5.09
	Average of FuelCosts	3.96	3.89	3.91	3.89		3.98	4.32	4.07	3.91
	StdDev of FuelCosts	0.51	0.46	0.43	0.45		0.37	0.00	0.35	0.45
	Average of EcoDeprn	8.38	8.44	9.00	8.53		2.44	2.28	2.40	8.00
	StdDev of EcoDeprn	0.65	1.78	4.77	2.54		0.37	0.45	0.39	2.98
	Average of ActDeprn	7.32	13.08	26.22	15.27		9.52	32.51	15.52	15.29
	StdDev of ActDeprn	0.49	17.87	24.02	19.59		2.62	24.92	15.90	19.27
	Average of VOC	13.58	15.18	16.79	15.44		8.68	10.91	9.27	14.90
	StdDev of VOC	2.02	9.45	6.65	9.00		1.29	2.45	1.89	8.79
	Average of VOCA	12.51	19.82	34.02	22.18		15.76	41.14	22.39	22.20
	StdDev of VOCA	1.87	26.58	25.64	26.81		2.56	25.31	16.74	26.06
	Count of Bus Unit code	2	197	41	240		17	6	23	263
60	Average of AdjTyres		0.78	0.97	0.81		0.36	1.85	0.90	0.83
	StdDev of AdjTyres		0.48	0.71	0.52		0.35	1.66	1.21	0.66
	Average of SMLessTyres		1.34	2.40	1.52		0.91	1.95	1.28	1.49
	StdDev of SMLessTyres		0.50	1.58	0.87		0.67	1.04	0.93	0.88
	Average of FuelCosts		3.95	3.58	3.89		3.81	4.14	3.93	3.89
	StdDev of FuelCosts		0.44	0.63	0.49		0.35	0.36	0.38	0.48
	Average of EcoDeprn		8.32	6.95	8.09		2.60	2.74	2.65	7.30
	StdDev of EcoDeprn		1.41	1.66	1.53		0.57	0.51	0.53	2.40
	Average of ActDeprn		10.69	30.91	14.11		11.77	36.97	20.93	15.10
	StdDev of ActDeprn		3.97	18.77	11.25		7.58	31.74	22.32	13.43
	Average of VOC		14.39	13.90	14.31		7.68	10.68	8.77	13.51
	StdDev of VOC		1.96	3.28	2.21		1.70	2.22	2.35	2.96
	Average of VOCA		16.76	37.86	20.33		16.85	44.91	27.05	21.30
	StdDev of VOCA		3.93	19.36	11.62		7.10	30.32	22.51	13.72
	Count of Bus Unit code		54	11	65		7	4	11	76
61	Average of AdjTyres	0.51	0.32	3.05	0.51		0.74		0.74	0.55
	StdDev of AdjTyres	#DIV/0!	0.25	#DIV/0!	0.74		0.17		0.17	0.68
	Average of SMLessTyres	1.49	0.98	4.08	1.22		1.37		1.37	1.25
	StdDev of SMLessTyres	#DIV/0!	0.35	#DIV/0!	0.86		0.27		0.27	0.79
	Average of FuelCosts	4.32	3.39	4.32	3.51		4.08		4.08	3.61
	StdDev of FuelCosts	#DIV/0!	0.43	#DIV/0!	0.52		0.42		0.42	0.54
	Average of EcoDeprn	8.80	6.56	8.09	6.81		2.31		2.31	6.06
	StdDev of EcoDeprn	#DIV/0!	1.17	#DIV/0!	1.28		0.09		0.09	2.08
	Average of ActDeprn	9.05	12.44	36.41	13.81		6.76		6.76	12.64
	StdDev of ActDeprn	#DIV/0!	3.85	#DIV/0!	7.25		2.65		2.65	7.17
	Average of VOC	15.12	11.24	19.54	12.05		8.50		8.50	11.46
	StdDev of VOC	#DIV/0!	1.83	#DIV/0!	2.86		0.30		0.30	2.93
	Average of VOCA	15.37	17.13	47.87	19.06		12.95		12.95	18.04
	StdDev of VOCA	#DIV/0!	3.57	#DIV/0!	8.64		2.56		2.56	8.23
	Count of Bus Unit code	1	13	1	15		3		3	18
62	Average of AdjTyres	1.04	0.72	2.57	1.16		0.69	1.14	0.79	1.12
	StdDev of AdjTyres	#DIV/0!	0.52	2.99	1.67		0.19	0.21	0.27	1.59
	Average of SMLessTyres	1.33	1.21	2.38	1.48		1.58	1.12	1.48	1.48
	StdDev of SMLessTyres	#DIV/0!	0.39	1.53	0.94		0.25	0.83	0.42	0.90
	Average of FuelCosts	4.32	3.97	3.88	3.95		3.91	4.32	4.00	3.96
	StdDev of FuelCosts	#DIV/0!	0.43	0.46	0.43		0.39	0.00	0.38	0.43
	Average of EcoDeprn	8.22	8.61	8.60	8.60		2.51	2.55	2.52	8.00
	StdDev of EcoDeprn	#DIV/0!	1.55	1.76	1.58		0.44	0.37	0.40	2.37
	Average of ActDeprn	8.74	12.48	41.99	19.27		10.76	17.33	12.22	18.58
	StdDev of ActDeprn	#DIV/0!	8.08	38.19	23.04		6.51	5.60	6.64	22.05
	Average of VOC	14.92	14.50	17.42	15.19		8.69	9.14	8.79	14.55
	StdDev of VOC	#DIV/0!	2.04	5.10	3.23		0.81	0.66	0.76	3.62
	Average of VOCA	15.44	18.38	50.82	25.86		16.94	23.91	18.49	25.13
	StdDev of VOCA	#DIV/0!	8.11	40.97	24.76		6.66	4.57	6.73	23.68
	Count of Bus Unit code	1	62	19	82		7	2	9	91
65	Average of AdjTyres		0.46	1.44	0.89	0.50	0.60	3.97	1.71	1.30
	StdDev of AdjTyres		0.45	1.98	1.36	#DIV/0!	0.66	2.32	2.10	1.77
	Average of SMLessTyres		0.85	2.30	1.50	0.96	1.12	2.53	1.57	1.53
	StdDev of SMLessTyres		0.59	1.52	1.28	#DIV/0!	0.38	1.14	0.96	1.09
	Average of FuelCosts		3.64	3.75	3.69	4.32	4.18	4.32	4.24	3.97
	StdDev of FuelCosts		0.63	0.66	0.60	#DIV/0!	0.32	0.00	0.24	0.53
	Average of EcoDeprn		6.76	8.21	7.41	2.42	2.59	3.32	2.82	5.11
	StdDev of EcoDeprn		1.05	1.75	1.51	#DIV/0!	0.32	0.97	0.66	2.62
	Average of ActDeprn		13.55	50.91	30.15	9.39	11.42	54.73	25.63	27.89
	StdDev of ActDeprn		5.96	39.78	31.60	#DIV/0!	6.75	33.42	27.91	29.02
	Average of VOC		11.71	15.70	13.48	8.21	8.49	14.14	10.34	11.91
	StdDev of VOC		2.50	4.37	3.84	#DIV/0!	1.17	3.37	3.41	3.88
	Average of VOCA		18.50	58.40	36.23	15.18	17.31	65.55	33.16	34.69
	StdDev of VOCA		4.71	40.32	32.60	#DIV/0!	7.60	35.88	30.69	30.75
	Count of Bus Unit code		5	4	9	1	5	3	9	18

NAASRA	Data	CARS Off-Road	CARS On-Road	CARS Used	CARS Total	LTCOMM Off-Road	LTCOMM On-Road	LTCOMM Used	LTCOMM Total	Grand Total
67	Average of AdjTyres		0.96		0.96	1.20	0.00		0.60	0.91
	StdDev of AdjTyres		0.51		0.51	#DIV/0!	#DIV/0!		0.85	0.54
	Average of SMLessTyres		1.21		1.21	2.70	1.03		1.86	1.30
	StdDev of SMLessTyres		0.50		0.50	#DIV/0!	#DIV/0!		1.18	0.61
	Average of FuelCosts		3.89		3.89	4.32	4.32		4.32	3.95
	StdDev of FuelCosts		0.48		0.48	#DIV/0!	#DIV/0!		0.00	0.46
	Average of EcoDeprn		8.30		8.30	2.64	2.72		2.68	7.50
	StdDev of EcoDeprn		1.19		1.19	#DIV/0!	#DIV/0!		0.05	2.32
	Average of ActDeprn		10.14		10.14	13.58	7.93		10.75	10.23
	StdDev of ActDeprn		2.55		2.55	#DIV/0!	#DIV/0!		3.99	2.60
	Average of VOC		14.36		14.36	10.86	8.07		9.47	13.66
	StdDev of VOC		2.26		2.26	#DIV/0!	#DIV/0!		1.97	2.79
	Average of VOCA		16.20		16.20	21.80	13.28		17.54	16.39
	StdDev of VOCA		2.81		2.81	#DIV/0!	#DIV/0!		6.02	3.11
	Count of Bus Unit code		12		12	1	1		2	14
72	Average of AdjTyres		0.66		0.66					0.66
	StdDev of AdjTyres		#DIV/0!		#DIV/0!					#DIV/0!
	Average of SMLessTyres		0.84		0.84					0.84
	StdDev of SMLessTyres		#DIV/0!		#DIV/0!					#DIV/0!
	Average of FuelCosts		3.18		3.18					3.18
	StdDev of FuelCosts		#DIV/0!		#DIV/0!					#DIV/0!
	Average of EcoDeprn		6.96		6.96					6.96
	StdDev of EcoDeprn		#DIV/0!		#DIV/0!					#DIV/0!
	Average of ActDeprn		6.46		6.46					6.46
	StdDev of ActDeprn		#DIV/0!		#DIV/0!					#DIV/0!
	Average of VOC		11.63		11.63					11.63
	StdDev of VOC		#DIV/0!		#DIV/0!					#DIV/0!
	Average of VOCA		11.14		11.14					11.14
	StdDev of VOCA		#DIV/0!		#DIV/0!					#DIV/0!
	Count of Bus Unit code		1		1					1
73	Average of AdjTyres	0.44	0.83	1.03	0.87		0.84	1.45	1.30	0.93
	StdDev of AdjTyres	#DIV/0!	0.46	0.66	0.52		#DIV/0!	1.83	1.53	0.69
	Average of SMLessTyres	1.89	1.39	1.79	1.53		1.18	2.31	2.03	1.59
	StdDev of SMLessTyres	#DIV/0!	0.70	0.39	0.64		#DIV/0!	1.12	1.07	0.70
	Average of FuelCosts	4.32	3.97	3.87	3.96		4.32	4.32	4.32	4.00
	StdDev of FuelCosts	#DIV/0!	0.44	0.38	0.42		#DIV/0!	0.00	0.00	0.41
	Average of EcoDeprn	8.85	8.64	8.69	8.66		2.48	2.47	2.47	7.89
	StdDev of EcoDeprn	#DIV/0!	1.67	2.07	1.73		#DIV/0!	0.29	0.24	2.63
	Average of ActDeprn	8.84	9.77	39.87	18.34		8.59	42.45	33.98	20.29
	StdDev of ActDeprn	#DIV/0!	2.24	55.63	31.59		#DIV/0!	29.98	29.76	31.34
	Average of VOC	15.51	14.83	15.39	15.02		8.83	10.55	10.12	14.40
	StdDev of VOC	#DIV/0!	2.35	2.19	2.23		#DIV/0!	1.10	1.24	2.68
	Average of VOCA	15.50	15.97	46.56	24.69		14.94	50.52	41.63	26.81
	StdDev of VOCA	#DIV/0!	2.86	55.64	31.73		#DIV/0!	30.52	30.62	31.62
	Count of Bus Unit code	1	19	8	28		1	3	4	32
74	Average of AdjTyres	0.70	0.74	1.13	0.78		0.63	0.98	0.67	0.75
	StdDev of AdjTyres	0.03	0.42	0.31	0.40		0.17	#DIV/0!	0.20	0.36
	Average of SMLessTyres	1.84	1.10	1.76	1.24		1.31	2.09	1.40	1.28
	StdDev of SMLessTyres	0.31	0.23	0.18	0.37		0.36	#DIV/0!	0.42	0.38
	Average of FuelCosts	4.32	3.83	4.32	3.93		4.14	4.32	4.16	3.99
	StdDev of FuelCosts	0.00	0.43	0.00	0.43		0.34	#DIV/0!	0.32	0.42
	Average of EcoDeprn	8.85	7.78	9.28	8.04		2.61	2.45	2.59	6.75
	StdDev of EcoDeprn	0.00	1.70	0.42	1.60		0.34	#DIV/0!	0.33	2.74
	Average of ActDeprn	7.73	9.35	11.32	9.38		7.67	11.49	8.10	9.08
	StdDev of ActDeprn	0.71	2.76	5.53	2.98		2.04	#DIV/0!	2.29	2.86
	Average of VOC	15.71	13.44	16.49	13.99		8.69	9.84	8.82	12.77
	StdDev of VOC	0.31	2.07	0.20	2.15		0.72	#DIV/0!	0.78	2.93
	Average of VOCA	14.59	15.01	18.54	15.34		13.76	18.88	14.33	15.10
	StdDev of VOCA	0.86	2.64	6.01	3.06		2.13	#DIV/0!	2.62	2.96
	Count of Bus Unit code	3	23	3	29		8	1	9	38
75	Average of AdjTyres	0.65	0.62	1.29	0.80	0.43	0.63	2.48	1.26	0.92
	StdDev of AdjTyres	0.07	0.36	0.69	0.53	0.01	0.44	1.04	1.13	0.77
	Average of SMLessTyres	1.39	1.20	1.63	1.32	1.37	1.24	1.90	1.48	1.37
	StdDev of SMLessTyres	0.69	0.48	0.85	0.63	0.37	0.45	1.39	0.92	0.72
	Average of FuelCosts	4.08	3.90	4.01	3.94	4.32	4.03	4.06	4.06	3.97
	StdDev of FuelCosts	0.37	0.48	0.44	0.46	0.00	0.37	0.56	0.43	0.45
	Average of EcoDeprn	8.49	8.11	8.27	8.18	2.53	2.53	2.37	2.47	6.59
	StdDev of EcoDeprn	1.05	1.39	1.02	1.27	0.06	0.68	0.22	0.54	2.80
	Average of ActDeprn	8.41	9.71	21.49	12.59	6.33	10.49	25.26	15.29	13.35
	StdDev of ActDeprn	1.10	3.63	9.33	7.57	0.93	2.63	12.83	10.59	8.55
	Average of VOC	14.62	13.83	15.20	14.24	8.65	8.43	10.81	9.26	12.85
	StdDev of VOC	2.04	2.11	1.93	2.12	0.41	1.30	2.64	2.13	3.08
	Average of VOCA	14.54	15.43	28.42	18.65	12.46	16.39	33.70	22.09	19.61
	StdDev of VOCA	0.78	3.70	9.86	8.10	1.29	2.68	13.75	11.81	9.35
	Count of Bus Unit code	6	50	19	75	2	17	10	29	104

		CARS			CARS Total	LTCOMM			LTCOMM Total	Grand Total
NAASRA	Data	Off-Road	On-Road	Used		Off-Road	On-Road	Used		
78	Average of AdjTyres	0.68	0.88	0.93	0.87		0.69	0.72	0.71	0.83
	StdDev of AdjTyres	#DIV/0!	0.33	0.22	0.28		#DIV/0!	1.02	0.72	0.40
	Average of SMLessTyres	2.02	1.35	1.79	1.52		1.59	1.74	1.69	1.56
	StdDev of SMLessTyres	#DIV/0!	0.43	0.55	0.47		#DIV/0!	0.72	0.52	0.47
	Average of FuelCosts	4.32	3.70	3.96	3.83		3.60	4.32	4.08	3.89
	StdDev of FuelCosts	#DIV/0!	0.52	0.51	0.50		#DIV/0!	0.00	0.42	0.48
	Average of EcoDeprn	8.85	7.98	7.88	8.05		2.45	2.68	2.60	6.69
	StdDev of EcoDeprn	#DIV/0!	1.43	0.10	1.17		#DIV/0!	0.15	0.17	2.66
	Average of ActDeprn	7.47	9.97	18.32	11.55		8.35	164.40	112.39	36.76
	StdDev of ActDeprn	#DIV/0!	2.15	13.64	6.45		#DIV/0!	219.42	179.42	89.24
	Average of VOC	15.86	13.91	14.55	14.27		8.33	9.47	9.09	12.98
	StdDev of VOC	#DIV/0!	2.10	1.19	1.84		#DIV/0!	1.89	1.49	2.89
	Average of VOCA	14.49	15.90	24.99	17.76		14.23	171.19	118.87	43.04
	StdDev of VOCA	#DIV/0!	2.66	14.93	7.02		#DIV/0!	217.68	178.62	89.04
	Count of Bus Unit code	1	6	2	9		1	2	3	12
91	Average of AdjTyres		0.63		0.63					0.63
	StdDev of AdjTyres		0.46		0.46					0.46
	Average of SMLessTyres		1.68		1.68					1.68
	StdDev of SMLessTyres		0.72		0.72					0.72
	Average of FuelCosts		3.63		3.63					3.63
	StdDev of FuelCosts		0.55		0.55					0.55
	Average of EcoDeprn		7.71		7.71					7.71
	StdDev of EcoDeprn		1.90		1.90					1.90
	Average of ActDeprn		13.59		13.59					13.59
	StdDev of ActDeprn		8.88		8.88					8.88
	Average of VOC		13.65		13.65					13.65
	StdDev of VOC		2.80		2.80					2.80
	Average of VOCA		19.52		19.52					19.52
	StdDev of VOCA		8.36		8.36					8.36
	Count of Bus Unit code		4		4					4
Total Average of AdjTyres		0.64	0.85	1.48	0.96	0.64	0.64	2.12	1.09	0.98
Total StdDev of AdjTyres		0.17	2.17	1.54	2.05	0.37	0.44	1.70	1.20	1.94
Total Average of SMLessTyres		1.48	1.50	2.26	1.64	1.60	1.31	2.02	1.54	1.63
Total StdDev of SMLessTyres		0.59	3.86	1.72	3.51	0.78	0.52	1.20	0.85	3.25
Total Average of FuelCosts		4.18	3.88	3.90	3.89	4.32	4.01	4.21	4.08	3.92
Total StdDev of FuelCosts		0.30	0.46	0.47	0.46	0.00	0.36	0.35	0.37	0.45
Total Average of EcoDeprn		8.60	8.29	8.52	8.34	2.53	2.52	2.54	2.52	7.46
Total StdDev of EcoDeprn		0.69	1.65	3.19	2.02	0.10	0.47	0.49	0.46	2.80
Total Average of ActDeprn		8.16	11.85	30.10	15.22	8.91	9.87	40.71	19.21	15.82
Total StdDev of ActDeprn		0.92	12.54	28.95	18.26	3.47	4.21	56.51	34.12	21.45
Total Average of VOC		14.89	14.52	16.16	14.84	9.09	8.48	10.88	9.24	13.99
Total StdDev of VOC		1.52	6.51	4.98	6.19	1.22	1.17	2.45	1.98	6.09
Total Average of VOCA		14.46	18.08	37.74	21.72	15.47	15.84	49.06	25.92	22.35
Total StdDev of VOCA		1.15	18.13	30.29	22.16	4.47	4.20	56.32	34.50	24.45
Total Count of Bus Unit code		15	446	108	569	4	67	31	102	671