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NZ Vehicle Emissions Test Database Report

Prepared for:

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1 Table of Contents

2 Introduction

Over the years in which it has operated, the Energy and Fuels Research unit has performed thousands of emissions tests as part of various projects. This report describes the collation of the data from these tests into a database of emissions from vehicles within the New Zealand fleet, and compares the results in this database to the Vehicle Emissions Prediction Model (VEPM).

3 Database Overview

The database is heavily biased toward petrol light duty vehicles (LDVs), with 117 vehicles in this category compared with 25 diesel LDVs and 6 diesel heavy duty vehicles (HDVs). This is representative of the New Zealand fleet, where petrol LDVs make up approximately 81% of the fleet, diesel LDVs 15% and HDVs about 4%[1].

In total there are 4107 emissions factors for petrol LDVs, 445 for diesel LDVs and 190 for diesel HDVs.

The average age of vehicles in the database is 20 years for petrol LDVs, 16 years for diesel LDVs and 15 years for HDVs. This is much older than the NZ fleet's average age, which is 13.3 years for LDVs and 15.5 for HDVs [1]. Most of the tests in the database were performed during two large projects – one in 1996 and the other in 2004, which is the main reason why the average age in the database is relatively old. The distribution of year of manufacture is shown in Figure 1.

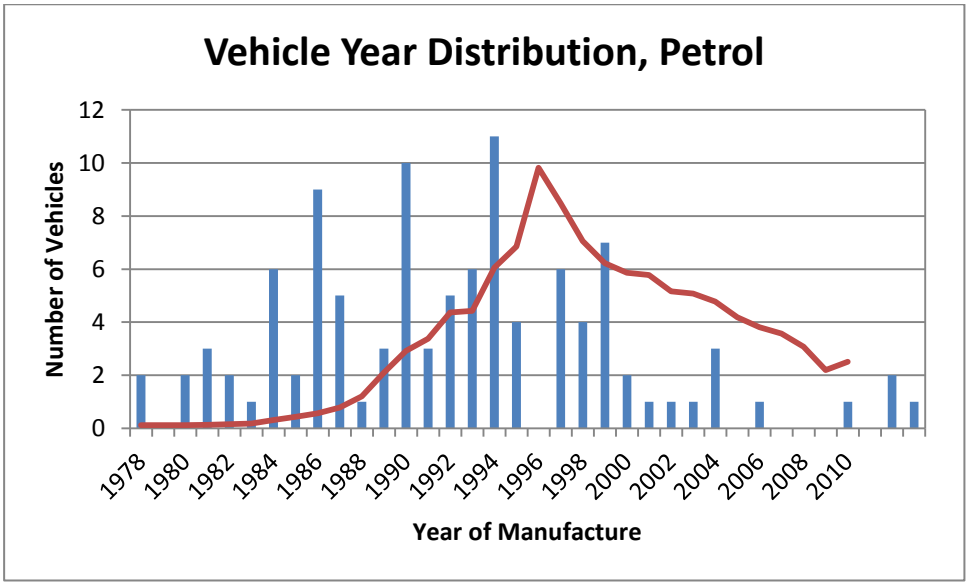


Figure 1 – Number of vehicles per year of manufacture in database, with 2010 NZ fleet overlaid

Also shown in red is the New Zealand petrol car fleet in 2010; this clearly shows that the database is lacking in representation of modern vehicles.

3.1 Repeat Tests

In many cases, a vehicle has been tested once, a service or repairs performed on the vehicle, then it has been retested. In these situations the two lots of testing are entered as separate entries into the database; this mimics the diversity that is likely to occur in the fleet where some vehicles may be well maintained and lower emitting in comparison to poorly maintained vehicles. Where the same vehicle was tested on multiple occasions, but with no significant changes made to the vehicle between runs, the results were averaged to provide a single result for the database

3.2 Heavy Duty Vehicles

Unlike LDVs, which are tested on a dynamometer which allows simulation of vehicle inertia and road-load and therefore can simulate a road driving cycle, HDVs tested by the EFRU have been restricted to fixed load and/or fixed speed testing, due to the limitations of the heavy vehicle test facility. Results that have been obtained from this testing are not readily comparable between vehicles or with VEPM due to the unknowns of how the load and speed scenarios on the dynamometer relate to actual driving conditions. Available results have been collated into the database, but further work would be required to make comparisons to VEPM.

4 Emissions Categories

The intention was to organise vehicles within the database into the same categories they would be in VEPM, this proved more difficult than expected. VEPM uses MOT data to categorise vehicles based on country of origin, as this should directly reflect the emissions standards they have been built to meet, and the emissions control technology used to achieve those standards. However for many vehicles in the database there is insufficient information to determine the country of origin. In many cases it has been noted whether the vehicle was NZ New or imported, but this is insufficient information to categorise vehicles.

4.1 Emissions Class Equivalencies

In VEPM, vehicles of Japanese origin are divided into their respective Japanese emissions classes, and equivalencies are drawn between those classes and European ones (details in [2]). These equivalencies differ for each emission specie – e.g. a J86 car is classed as Euro 1 for CO emissions, but Euro 2 for CO_2, HC, NO_X and fuel consumption. This same method is used in the database.

New Zealand and Australian vehicles have direct equivalencies to European standards that are the same for all species.

4.2 NZ New Vehicles

Most vehicles sold new in NZ originate from Australia, Europe or Japan; however, simply knowing the manufacturer is not sufficient to determine which region the vehicle originates from. As an example, some Japanese manufacturers build cars in Australia, specifically for the Australian market – presumably with technology to meet Australian standards, which are then sold new in NZ. These should be classed as Australian origin vehicles, but some models from the same manufacturer may built to Japanese specifications. This means for instance an NZ new Toyota could potentially be

classified as of Australian or Japanese origin, and even as an NZ manufactured vehicle for the years when cars were assembled in NZ.

4.3 Second Hand Imported Vehicles

Given that the vast majority of vehicles imported to NZ come from Japan, it appears to be reasonable to assume that imported cars made by Japanese manufacturers are from Japan and therefore meet Japanese standards. Imported vehicles from European manufacturers are not so clear – they could either be imported from the European market or from the Japanese market.

4.4 Approach Taken

In some cases the registration plate of the vehicle could be looked up on the CarJam [3] website and the country of origin ascertained; however in many cases the cars are no longer registered or no plate number was recorded. For vehicles whose country of origin couldn't be found, it was decided that due to lack of any better information they would simply be allocated by the country of the manufacturer and assumed to meet the emissions standards applicable in that country at the time of manufacture.

This approach places 60 of the 117 petrol LDVs in the Japanese J86 emissions class, which is equivalent to Euro 2 for all emissions species except CO, where it is equivalent to Euro 1. If these vehicles were of Australian origin, they would be classed as Euro 1. The difference between Euro 1 and 2 is minimal for fuel consumption, but for HC and NO_X the Euro 2s are between 30 and 80% lower: this shows the ability to compare between the database and VEPM will be quite sensitive in some areas to correct allocation of cars to countries of origin.

Table 1 compares the country of origin breakdown between the actual fleet for the years represented (1978-2010) and the database as allocated using the methodology above. The similarity in the compositions provides support for the methodology used.

Table 1 – Country of origin comparison, petrol LDVs

Country of Origin	Percentage in fleet	Percentage in database
NZ	5%	1%
Australia	21%	22%
Japan	58%	64%
Europe	16%	13%

4.5 Emissions Class Representation

Table 2 shows the number of petrol vehicles within each emissions category and engine size bracket

Table 2 – Number of petrol LDVs in each emissions category

	No. Of Cars (CO)	No. Of Cars (CO_2, HC, NO_X and FC)
ECE 15.02		
1400-2000	1	1
2000+	2	2
ECE 15.03		
1400-2000	4	4
2000+	1	1
ECE 15.04		
1400-2000	1	1
2000+	5	5
Euro 1		
<1400	10	2
1400-2000	55	17
2000+	24	9
Euro 2		
<1400	1	9
1400-2000	2	40
2000+	3	18
Euro 3		
1400-2000	1	1
2000+	1	1
Euro 4		
1400-2000	2	2
2000+	1	1
Euro 5		
1400-2000	3	3

The high concentration of vehicles within the Euro 1 and Euro 2 classes is largely due to the fact that Japanese vehicles from 1986 to 2000 are in those classes, and these vehicles make up a large proportion of the database.

Table 3 - Number of diesel LDVs in each emissions category

	Number of vehicles per category			
	CO, CO2, FC	**HC**	**NO_X**	**PM**
Pre Euro				
<2000cc				3
>2000cc				10
Euro 1				
<2000cc	4	1	3	1
>2000cc	18	1	4	5
Euro 2				
<2000cc		3		
>2000cc		17		
Euro 3				
<2000cc			1	
>2000cc			14	3

Table 3 shows considerable differences between the number of vehicles in each emissions category for each emissions specie. This is because the vast majority of diesel LDVs are of Japanese origin, and the equivalencies with European standards vary between species.

5 Test Cycles

The drive cycles over which emission testing has been performed are a combination of legislative cycles, real-world cycles and steady speeds. Table 4 summarises the attributes of each cycle and the number of vehicles tested on each. The two highlighted cycles involve a cold start.

Table 4 - Drive cycle statistics

Urban Cong	7.7	481	1.03	93		
Suburb Free	38.2	370	3.94	34		
Suburb Int	23.4	928	6.04	34	3	
Suburb Int Agg.	31.8	357	3.16	31		
Suburb Cong	17.6	461	2.26	33		
M'Way Free	101.2	310	8.75	32		
M'Way Int.	69.4	362	6.99	31		
M'Way Int Agg.	68.2	260	4.93	30		
M'Way Cong	32.9	591	5.4	34		
Rural Free	101.2	310	8.75	32		
Rural Int	79.2	460	10.13	28		
Rural Cong	66.9	645	12	27		
DT80	N/A	N/A	N/A		19	6
ECEEUDC	33.5	1180	10.997		4	
ECEEUDC warm	33.5	1180	10.997		2	
Jap 10.15	22.7	660	4.17		23	
FTP 505	41.1	505	5.78		1	
30 km/h	30	N/A	N/A	28		
50 km/h	50	N/A	N/A	37		
60km/h	60	N/A	N/A	60		
80 km/h	80	N/A	N/A	28		
100 km/h	100	N/A	N/A	29		

6 Mileage Normalisation

As a vehicle ages, its emission performance deteriorates, particularly in the case of vehicles fitted with exhaust catalysts. The base emissions factors in VEPM 5.0 are normalised to 50,000km; in order to allow a balanced comparison between VEPM and the database, the database results have also been normalised to 50,000km. In VEPM degradation is accounted for by a degradation factor, which is based on the accumulated mileage of the vehicle - for vehicles with more than 50,000km this

factor is greater than 1, and less than 1 for vehicles below 50,000km. In order to normalise the values in the database, the degradation factor for each vehicle was calculated based on its emission class and mileage when tested, the result is then divided by this factor to obtain the result with a degradation factor of 1. For a small number of vehicles the mileage when tested was not recorded, in these situations the mileage is estimated, based on age, using average annual mileage data from MOT.

7 VEPM Comparisons

The following plots compare the averaged results for each drive cycle from each emissions category with predictions from VEPM 5.0. Categories with a high number of vehicles and with results for many drive cycles were selected for these comparisons. As VEPM has a variety of input options which affect the outputs, it should be noted that the results presented in this section are the basic emissions factors for each category, without the application of penalty factors for deterioration or cold start.

7.1 Petrol LDVs

In the following figures, the data point highlighted red is the FTP 75 cycle, the only one in these data that includes a cold start.

7.1.1 Carbon Monoxide (CO)

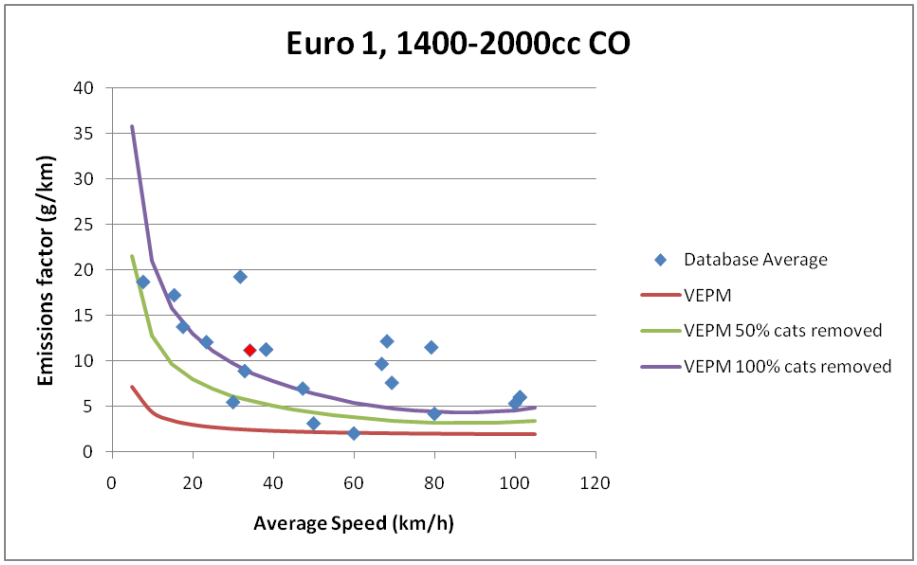


Figure 2 - Comparison between database and VEPM CO results for Euro 1, 1400-2000cc petrol LDVs

As is shown in Figure 2, the correlation between results predicted by VEPM and those for vehicles in the database Euro 1 vehicles is relatively poor. Closer analysis of the vehicles within this category showed that about half were listed as not having catalysts – which is a similar proportion to that observed in a Ministry of Transport study, which found in a sample of 92 of Japanese import vehicles that 55% had had their catalysts removed [4]. As VEPM provides a method for estimating the effect

of catalyst removal [**Error! Bookmark not defined.**], results were also generated for catalyst removal rates of 50 and 100 percent.

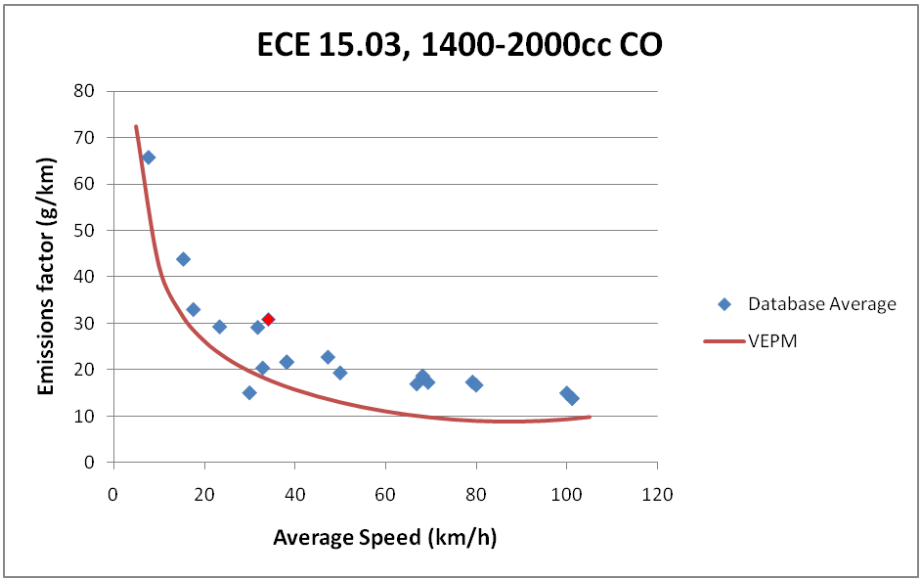


Figure 3 - Comparison between database and VEPM CO results for ECE 15.03, 1400-2000cc petrol LDVs

The results shown in Figure 3 show a much closer agreement between the database and VEPM. Note, however, that this is a much smaller sample size, with only four vehicles in this group. Vehicles within this emissions category do not have exhaust catalysts, so they should exhibit less deterioration in emissions performance and there is no issue relating to catalyst removal as with the previous plot.

7.1.2 Hydrocarbons (HC)

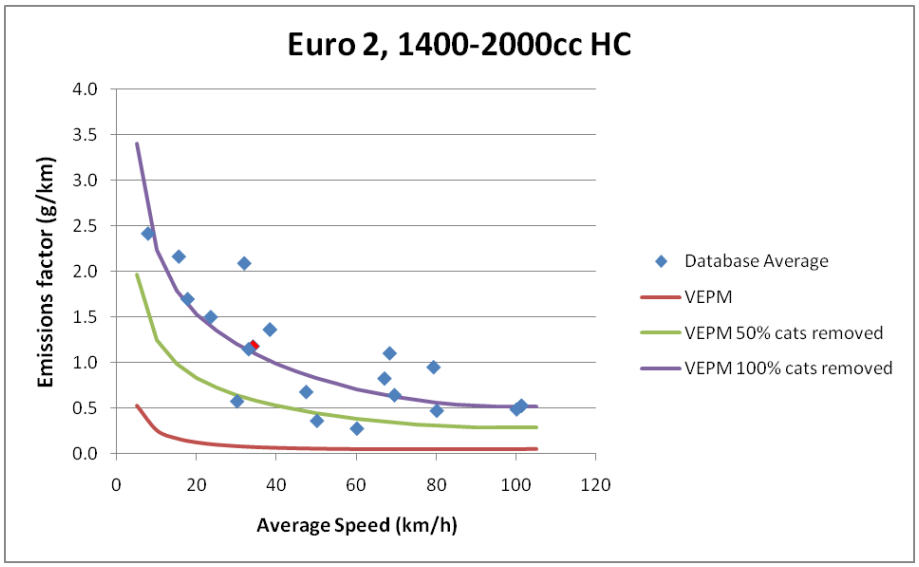


Figure 4 - Comparison between database and VEPM HC results for Euro 2, 1400-2000cc petrol LDVs

Figure 4 shows very similar trends to Figure 2, and again this emissions class had approximately half the vehicles listed as having no catalyst. As can be interpreted from Table 2, the vehicles represented in Figure 4 are largely the same group as Figure 2. This appears to show that the emissions performance of these vehicles is much closer to non catalyst-equipped vehicles than the Euro classes into which they are grouped.

7.1.3 Oxides of Nitrogen (NO_X)

Of all the emissions species, results for NO_X show the most discrepancy between VEPM and the database, often showing completely different emission-speed trends: Figures 5 and 6 show typical results.

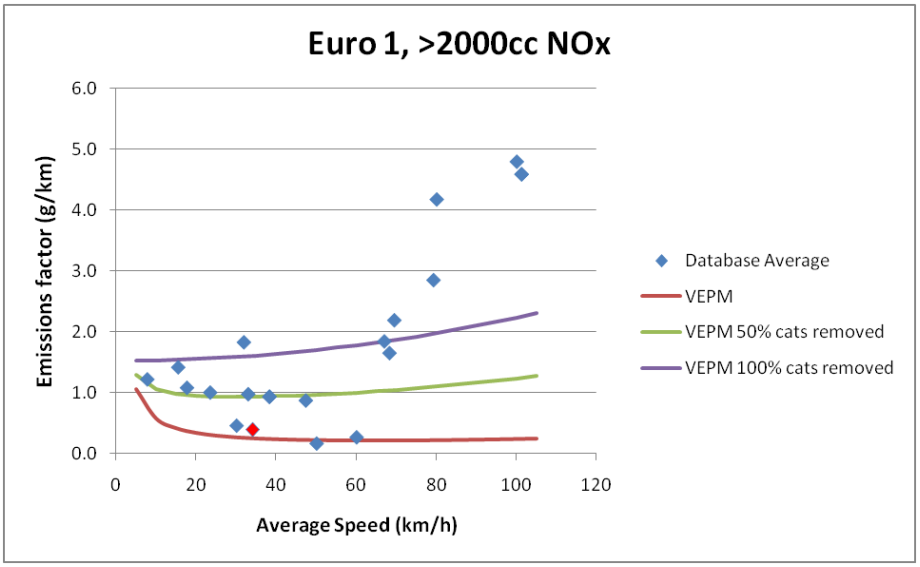


Figure 5 - Comparison between database and VEPM NO_X results for Euro 1, >2000cc petrol LDVs

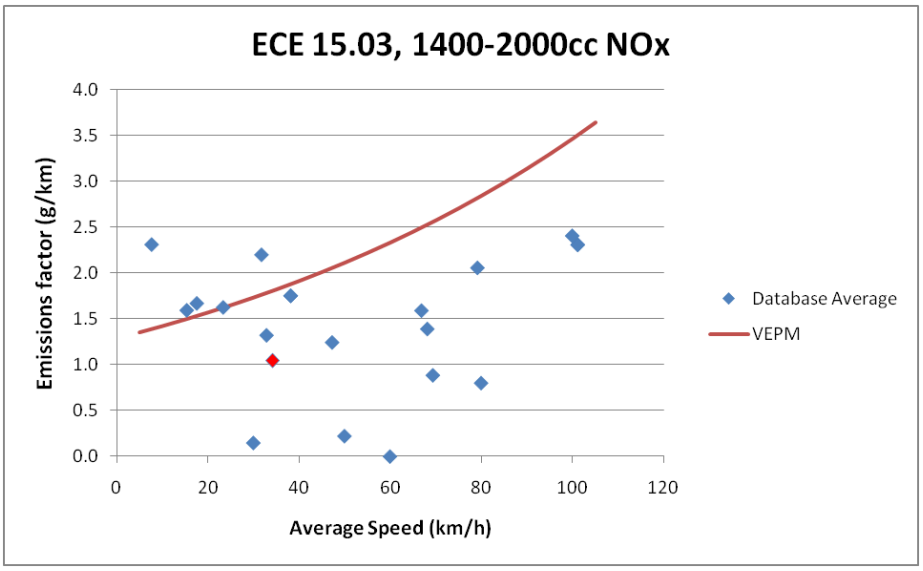


Figure 6 - Comparison between database and VEPM NO_X results for ECE 15.03, 1400-2000cc petrol LDVs

7.1.4 Fuel Consumption (FC)

Fuel consumption predicted by VEPM very closely matches the database results; the agreement shown in Figure 7 is typical of all emissions categories.

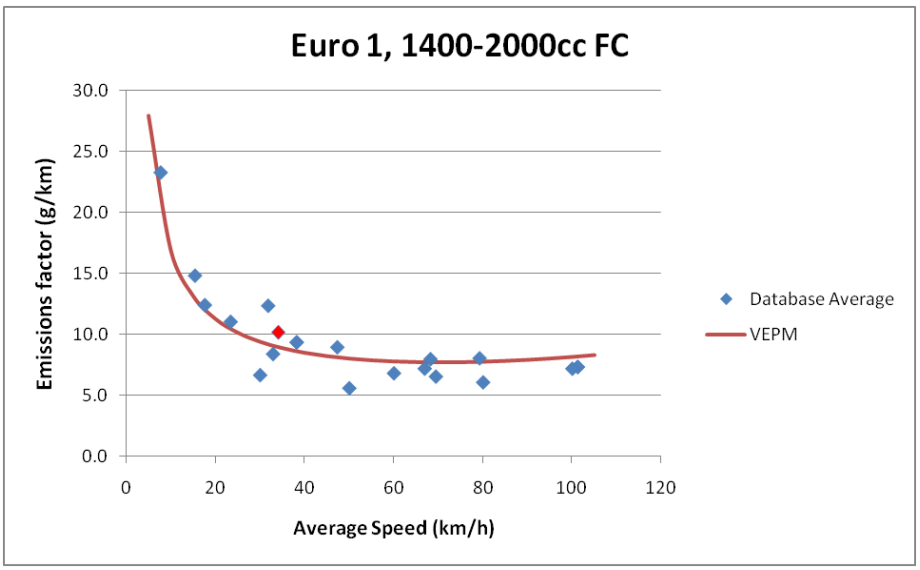


Figure 7 - Comparison between database and VEPM fuel consumption results for Euro 1, 1400-2000cc petrol LDVs

7.2 Diesel LDVs

Due to not having been included in the extensive test programmes that many petrol vehicles were, the data for diesel vehicles comes from only a small number of drive cycles, covering a smaller average speed range than that of the petrol cars.

Figure 8 shows a very good correlation between the database results and those predicted by VEPM. It is important to note, as shown in Table 4, that only two of the data points (average speeds of 23 and 47km/h) represent the average of a significant number of vehicles, with others being four or fewer. As with the petrol LDVs, the cold start cycle is highlighted with a red marker.

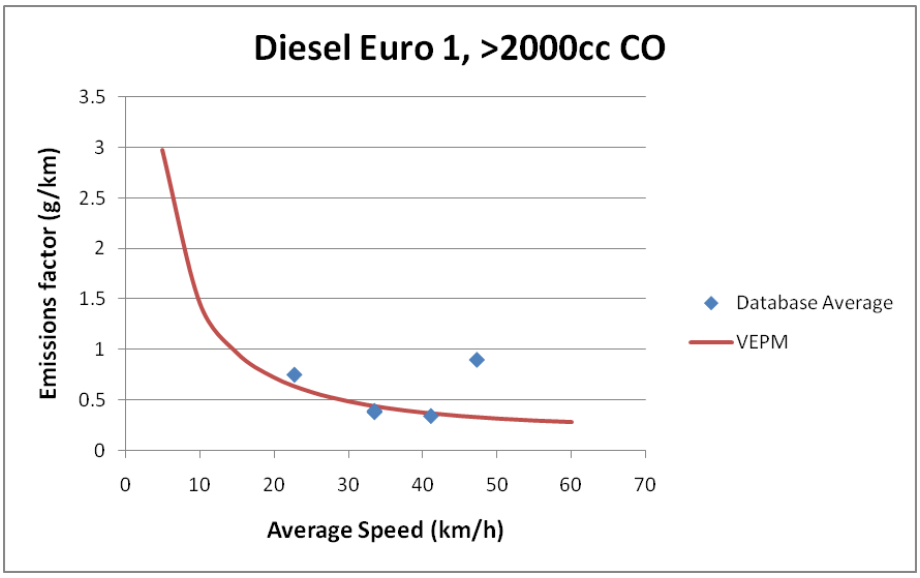


Figure 8 - Comparison between database and VEPM CO for Euro 1, >2000cc diesel LDVs

Figures 9-12 generally demonstrate a good correlation between VEPM and the database, albeit with a limited data set.

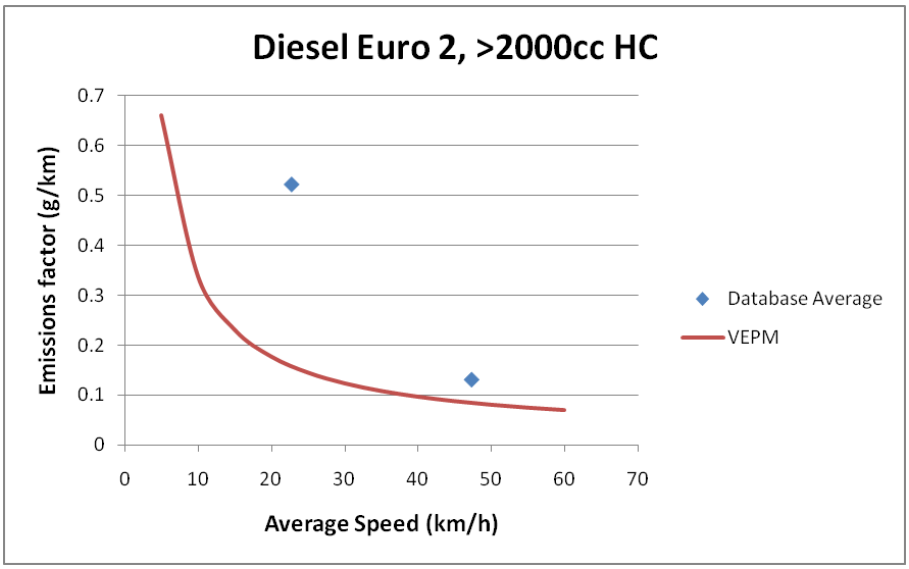


Figure 9 - Comparison between database and VEPM HC for Euro 2, >2000cc diesel LDVs

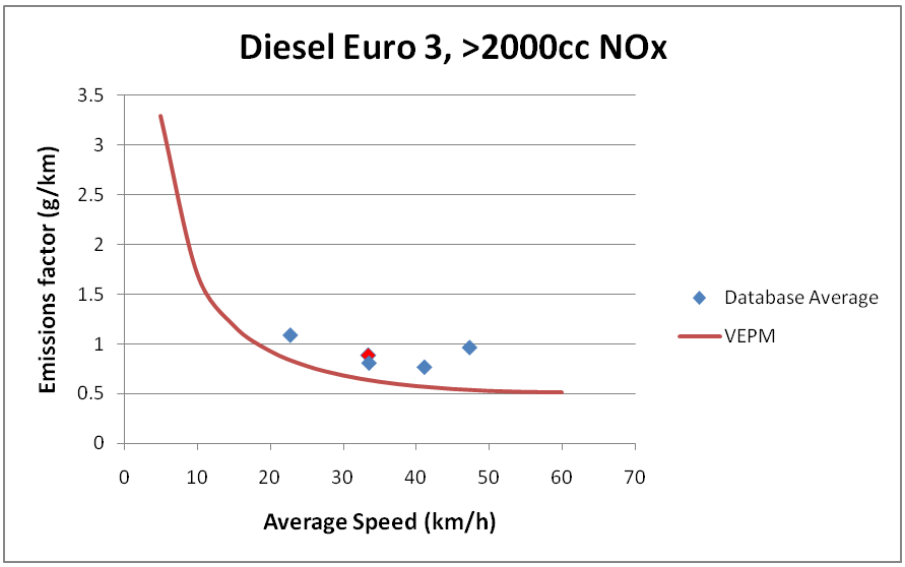


Figure 10 - Comparison between database and VEPM NOx for Euro 3, >2000cc diesel LDVs

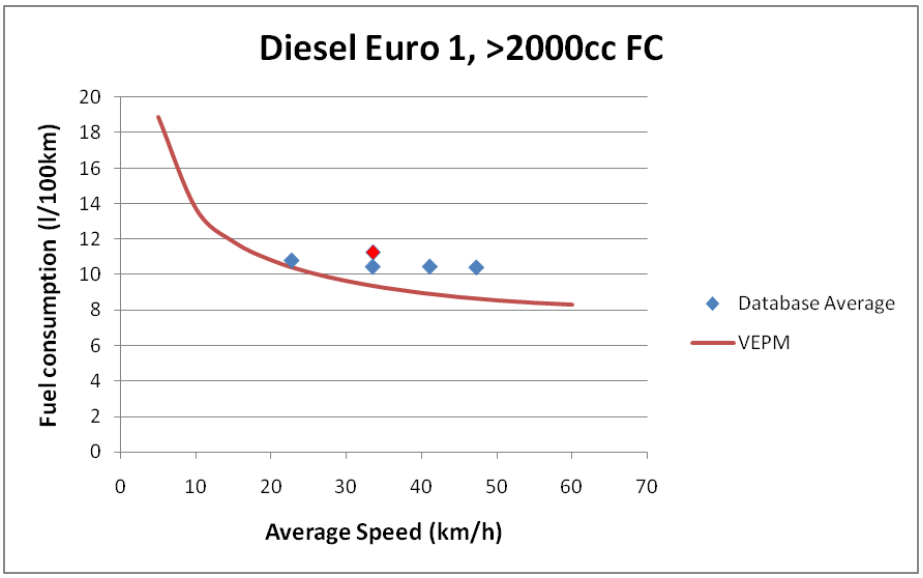


Figure 11 - Comparison between database and VEPM fuel consumption for Euro 1, >2000cc diesel LDVs

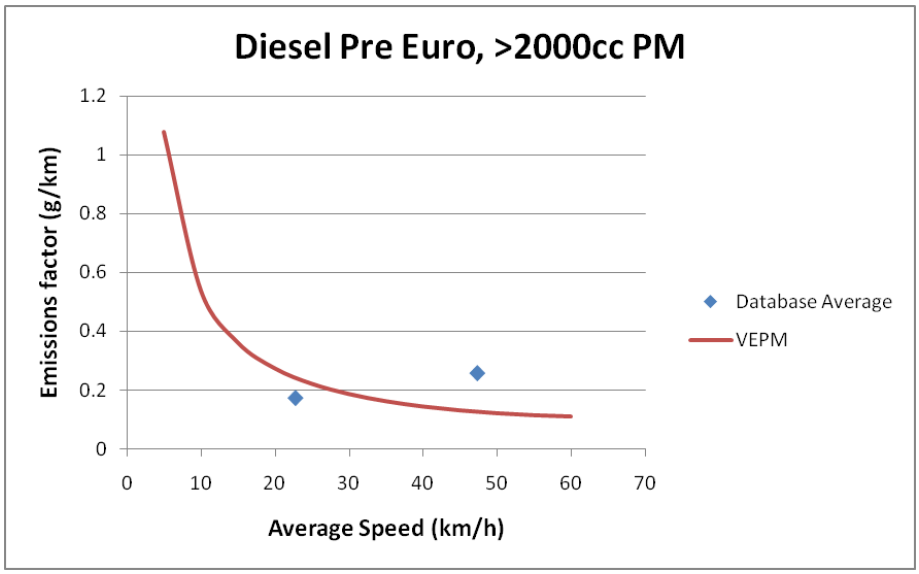


Figure 12 - Comparison between database and VEPM PM for Pre Euro, >2000cc diesel LDVs

7.3 Diesel HDVs

As noted in Section 3.2, comparison with VEPM is not currently possible for the results in the HDV database.

8 Australian Data – NISE2

Test data is available from the NISE2 programme undertaken in Australia – many vehicles from this testing would also be found in the New Zealand fleet. Many of the cars will however be built to different emissions standards than the equivalents found in New Zealand, and the make-up of the fleet will be quite different to the NZ fleet. For these reasons, the data hasn't been included into the database sheets, but is provided in an additional spreadsheet in the event that it can be of use for a particular situation.

9 Conclusions

1) A database of over 4,500 emissions factors has been assembled from New Zealand vehicle testing
2) The average age of vehicles in the database is 2-7 years older than the New Zealand fleet, with very few vehicles manufactured after 2000 having been tested.
3) Although there is some difficulty in allocating vehicles to emissions categories to match VEPM, there is a reasonable correlation between results in the database and those predicted by VEPM. In general, the output from VEPM is lower than the results in the database
4) The frequency of vehicles without catalysts in emission categories where they would be expected to be present is much higher than the default setting in VEPM. Removal rates around 50% are found, whereas the default in VEPM is 15%. Further investigation into this would potentially be very worthwhile, as it could significantly change predicted emissions for a large portion of the fleet.

10 References

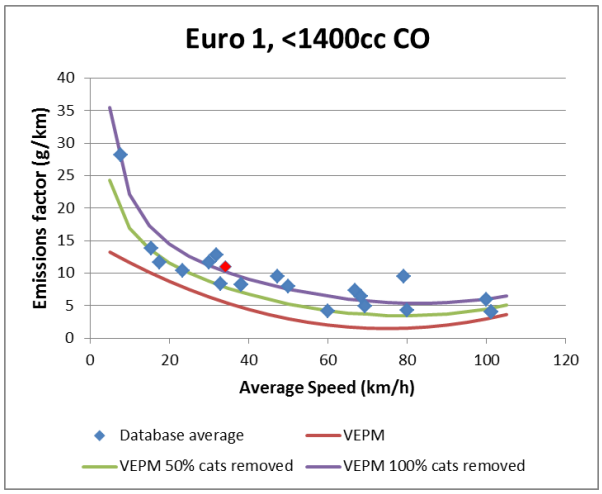
1 2010 New Zealand Vehicle Fleet Data, Ministry of Transport

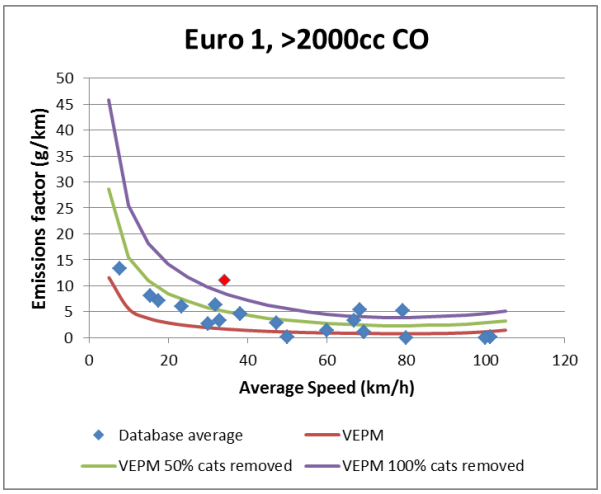
2 Energy & Fuels Research Unit (2008) Development of a Vehicle Emissions Model, Auckland UniServices Ltd

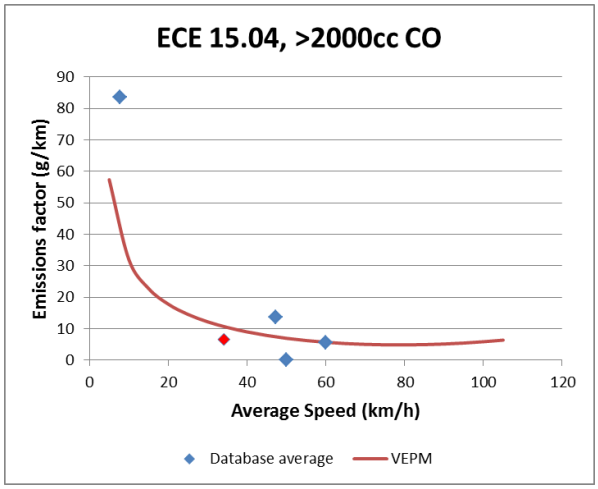
3 CarJam website, http://www.carjam.co.nz

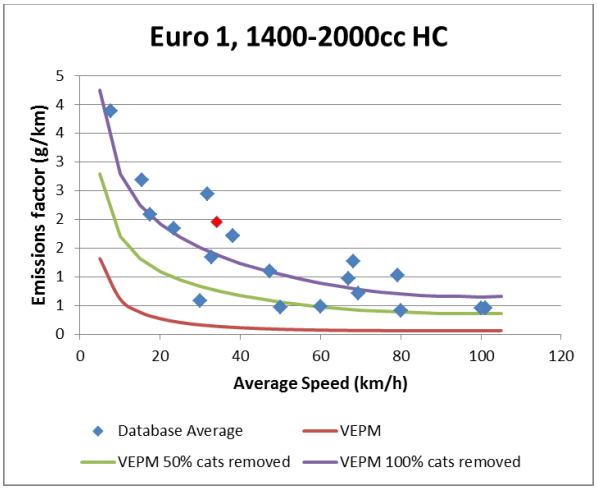
4 Trial Vehicle Scrappage Report (2010), Ministry of Transport

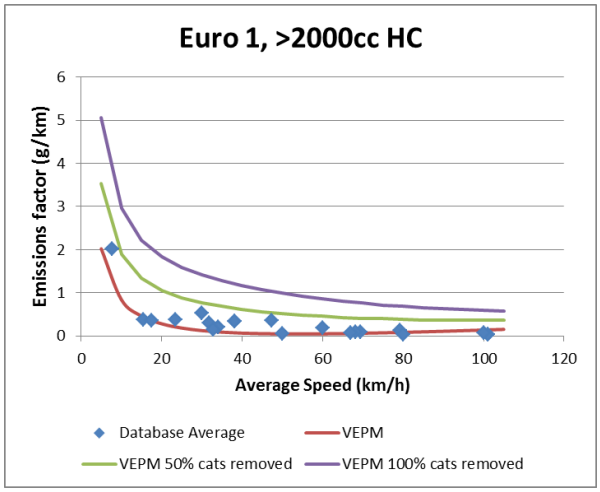
Appendix A - Additional Comparison Plots between VEPM and Database – Light Duty Petrol Vehicles

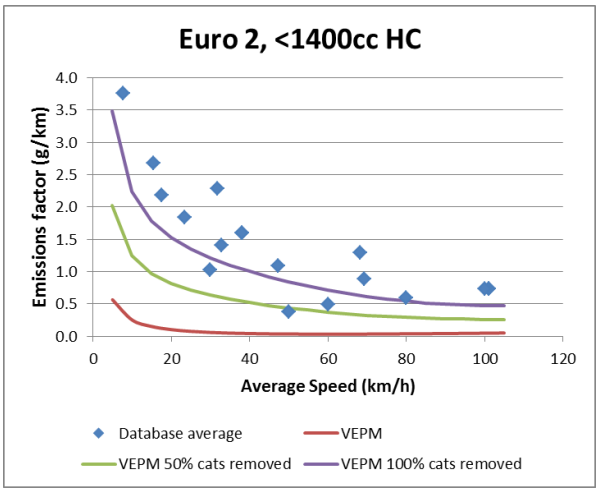


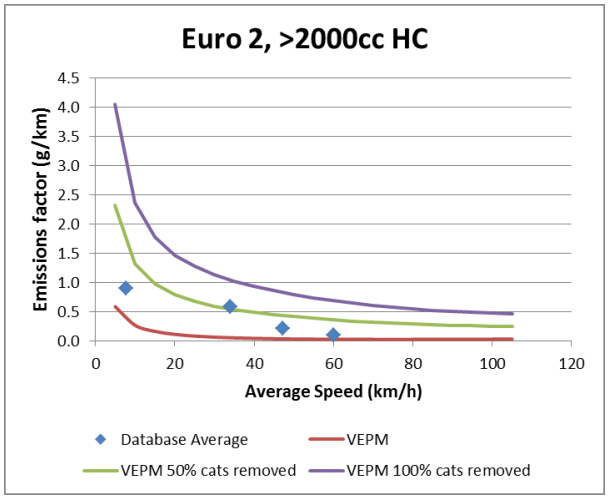


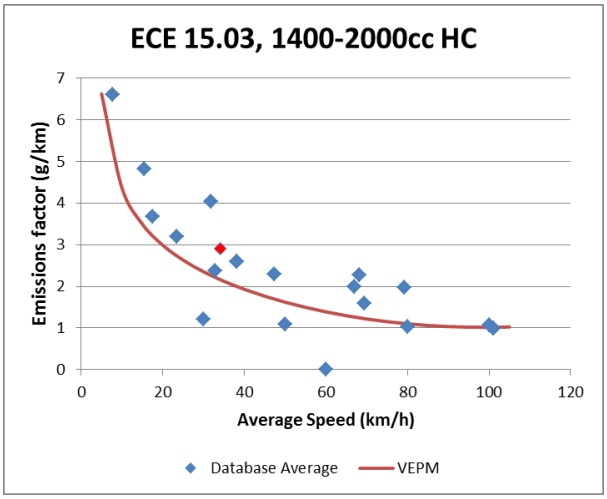


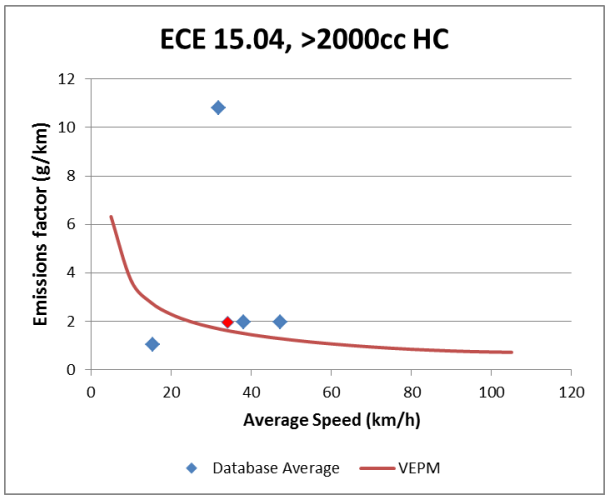


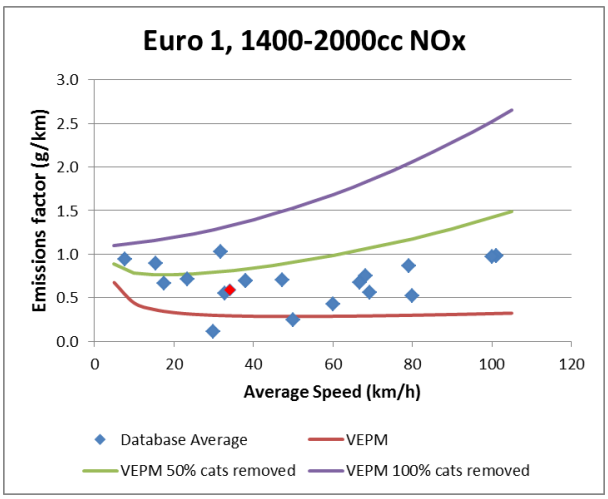


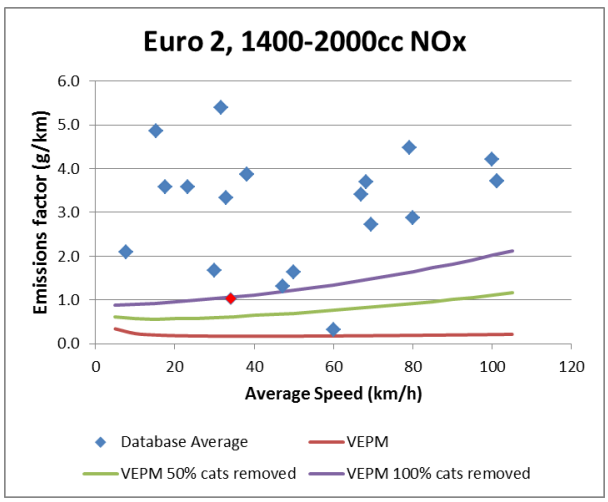


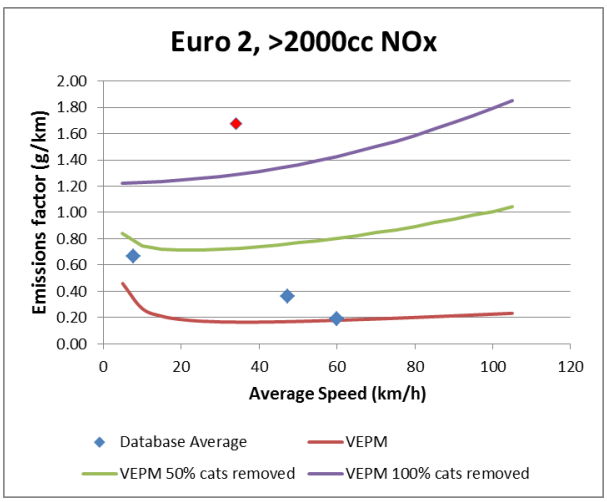

Euro 2, >2000cc HC
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM
VEPM 50% cats removed
VEPM 100% cats removed

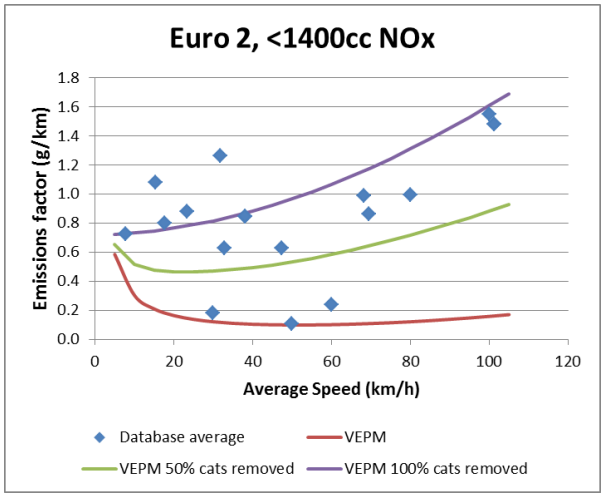

ECE 15.03, 1400-2000cc HC
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM

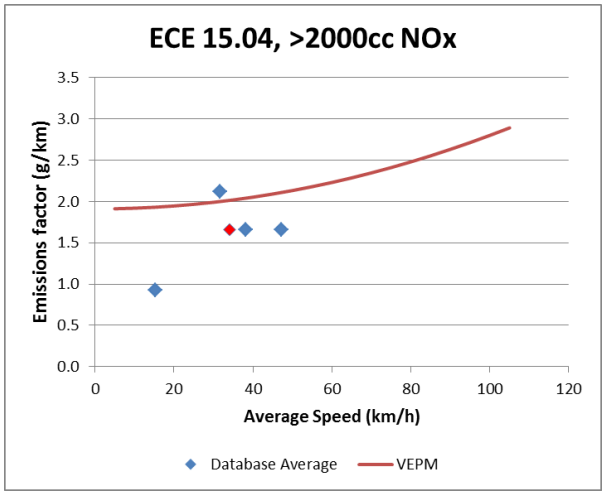

ECE 15.04, >2000cc HC
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM

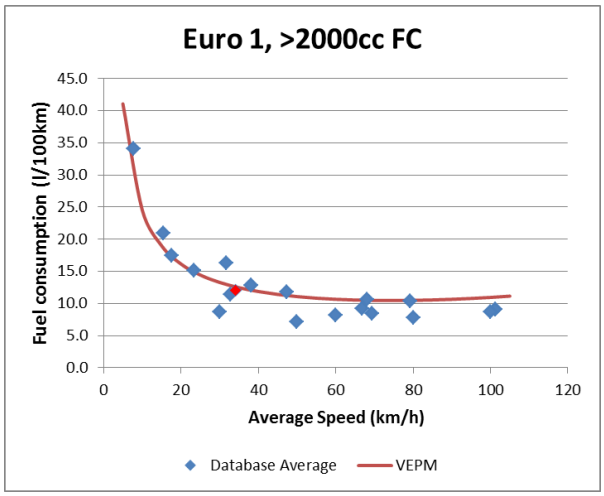

Euro 1, 1400-2000cc NOx
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM
VEPM 50% cats removed
VEPM 100% cats removed

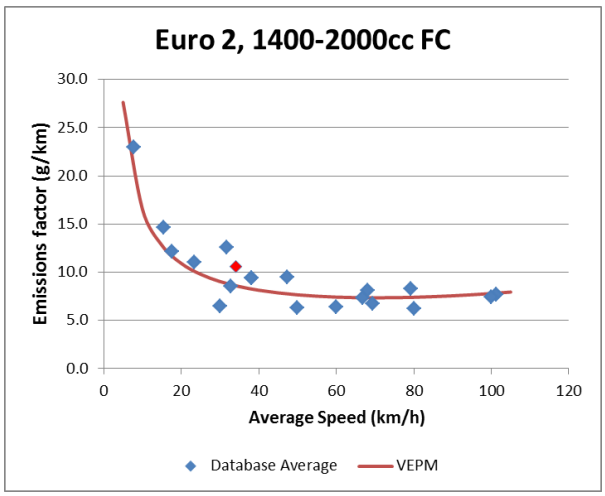

Euro 2, 1400-2000cc NOx
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM
VEPM 50% cats removed
VEPM 100% cats removed

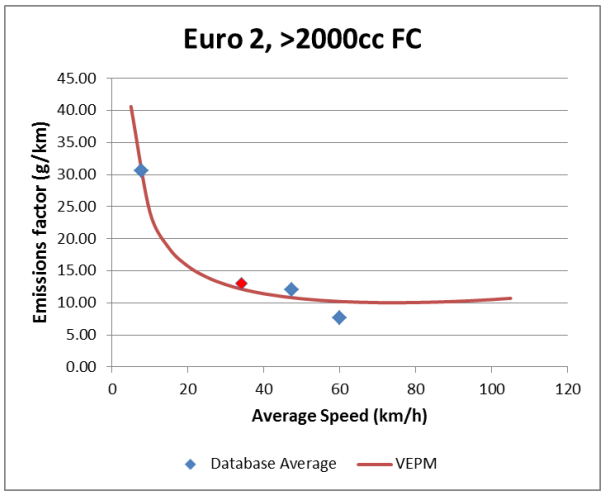

Euro 2, >2000cc NOx
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM
VEPM 50% cats removed
VEPM 100% cats removed

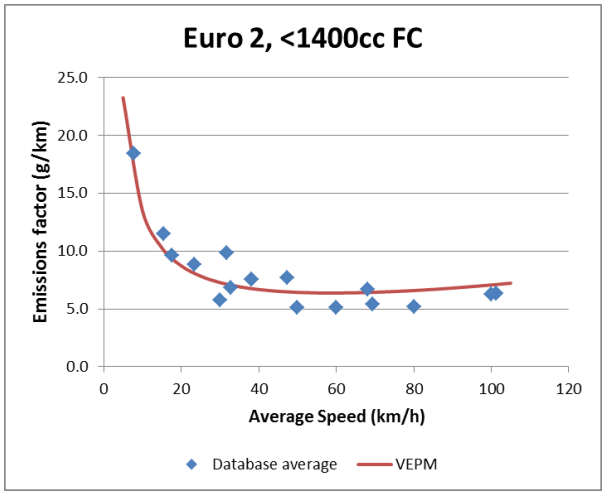

Euro 2, <1400cc NOx
Emissions factor (g/km)
Average Speed (km/h)
Database average
VEPM
VEPM 50% cats removed
VEPM 100% cats removed

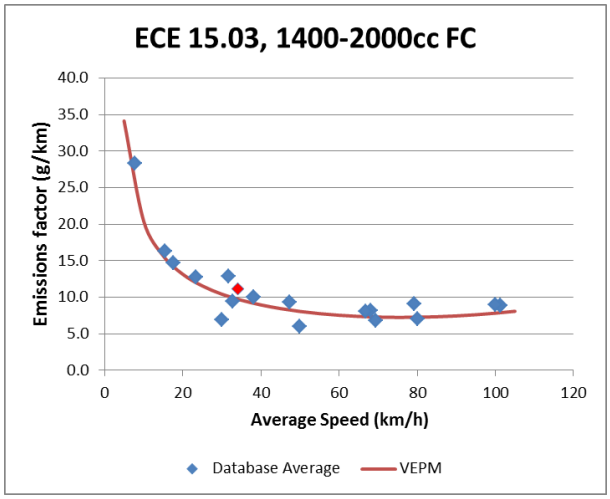

ECE 15.04, >2000cc NOx
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM

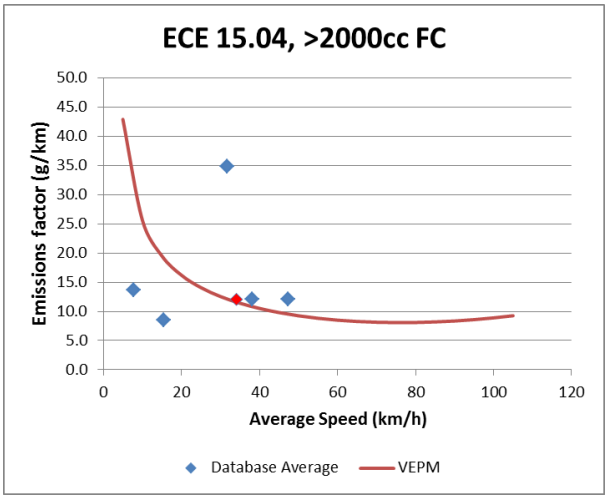

Euro 1, >2000cc FC
Fuel consumption (l/100km)
Average Speed (km/h)
Database Average
VEPM


Euro 2, 1400-2000cc FC
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM


Euro 2, >2000cc FC
Emissions factor (g/km)
Average Speed (km/h)
Database Average
VEPM


Euro 2, <1400cc FC
Emissions factor (g/km)
Average Speed (km/h)
Database average
VEPM


ECE 15.03, 1400-2000cc FC
Emissions factor (g/km)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
20
40
60
80
100
120
Average Speed (km/h)
Database Average
VEPM


ECE 15.04, >2000cc FC
Emissions factor (g/km)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
20
40
60
80
100
120
Average Speed (km/h)
Database Average
VEPM

Appendix B - Additional Comparison Plots between VEPM and Database – Light Duty Diesel Vehicles