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TNO report

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Travelcard Nederland BV data source document: fuel consumption of Dutch passengers cars in business use 2004-2012

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Contents

1 Summary

Travelcard Nederland BV handles the fuel transactions for many passenger cars in The Netherlands. Data from 2004 till 2012 provide information about the real-world fuel consumption of these vehicles. The real-world fuel consumption is shown in many cross-sections, per market segment, per brand, for different years, and for the type-approval values themselves. Also the variation among different drivers with the same make and model car is shown. Other aspects, such as fuel prices and weather, are studied as well.

Many trends in the period 2004-2011 are plotted. However, the overall trends are the same for different brands and segments. It can be summarized in three statements:

1. For the period from 2004 till about 2007 the difference between type-approval fuel consumption and real-world fuel consumption is larger for the lower type-approval values.
2. From about 2008 the difference between type-approval fuel consumption and real-world fuel consumption increases for all makes and models.
3. The differences among different market segments and manufacturers can be explained as variation with the type-approval fuel consumption of the respective groups

Additional conclusions:

- there is little evidence of correlation of the real-world fuel consumption with other aspects than the vehicle and ambient temperature.
- The variation among drivers is large (which shows the need for a sufficient sample of vehicles)
- Real-world fuel consumption varies rapidly, continuous monitoring seems essential to keep track of the year-by-year changes.

This document is a source document of a wide variety of analyses carried out, and the results are used, for example, in the ICCT report [Mock et al, 2013].

2 Introduction

2.1 Description

Travelcard Nederland BV[1] offers a fuel card system that can be used at any gas station in the Netherlands and at more than 33,000 fuel stops across Europe. Travelcard is part of LeasePlan Corporation N.V. About 200,000 vehicles, out of the 8 million total in the Netherlands, regularly fill up with petrol or diesel using Travelcard. Typically, the fuel is paid for by the employer since many employees in the Netherlands have a company car as part of their job benefits. The support of Travelcard Nederland BV, by making the data available, is gratefully acknowledged.

The data concerns the Dutch situation only. It should be noted that The Netherlands has a tax regime based on CO_2 which led to a massive introduction of fuel-economic vehicles in the last years. The average type-approval for the cars sold in 2012 is already below 120 g/km. Furthermore, Dutch roads are crowded and many motorways in densely populated areas have reduced speed limits of 100 km/h and 80 km/h. This leads to uniform driving. One of the few important aspects of driving style which is not controlled by the traffic flow is the gear shifting, of which little information is available.

For this study, detailed fuel consumption data for more than 260,000 Travelcard vehicles for the years 2004–11 were analyzed by TNO on behalf of ICCT. ICCT requested and received permission to analyze the data from Travelcard BV. TNO has had a lot of experience with this data, and were asked by ICCT to perform the analyzes. The current report, and contributions to [Mock et al. 2013] are the result of this collaboration. The recent data of 2012 became available during the project, and is included in some of the analyses. In total, about 20 million individual filling events—after a thorough quality check—were used for the analysis. The following brand/manufacturer classification was applied: BMW (BMW), Daimler (Mercedes-Benz), Fiat (Alfa-Romeo, Fiat), Ford, General Motors (Opel), PSA (Peugeot, Citroën), Renault, Toyota, Volkswagen (Audi, Seat, Skoda, VW). Even though not separately analyzed, other brands (such as Mini, smart, Nissan, Lexus) are included in the calculations for overall average fleet values.

The analyses in this report provides a complete as possible picture of the fuel-consumption of passenger cars. The different cross-sections allow for a broad insight in the data. The present report provides the background information, which is used, for example, in the ICCT large review [Mock et al. 2013]. Several assumptions, such as relation with weather and fuel prices are tested. However, in many cases no correlations were discovered.

Among the distinct characteristics of the Travelcard dataset, about 50 percent of the vehicles are powered by diesel fuel. This is about twice as much as for the Dutch vehicle fleet taken as whole. Given that—taking into account Dutch vehicle taxes and fuel prices, a diesel-operated vehicle is more economical above an annual mileage of about 20,000 km—diesel vehicles are very popular among business users. This is precisely the case for the Travelcard fleet, consisting mostly of

[1] See http://www.travelcard.nl/en/homepage. The data used for this analysis were accessed in October/November 2012.

company cars that have a higher annual mileage than average private vehicles. Automatic transmission is not common among Travelcard drivers; only about 8 percent of their vehicles make use of this technology, as opposed to about 18 percent on average in the Netherlands. Therefore, the amount of data on such vehicles is limited, and a separate analysis for automatic transmission vehicles was not carried out. At the manufacturers/brands level, BMW and Volkswagen are overrepresented in the Travelcard dataset compared with the Dutch fleet overall, while Daimler and Fiat are underrepresented. Small and mini models are also underrepresented in the Travelcard fleet. The average CO_2 emission value for model-year 2010 vehicles in the Travelcard dataset was 135 g/km, slightly lower than the average for new passenger cars in the Netherlands in that same year (137 g/km), despite the underrepresentation of small cars, owing to the larger share of diesel vehicles in the select group.

This report provides the background information and data which is used the the review of European results.

3 Methodology

The Travelcard data already includes manufacturers' type-approval fuel consumption data for each vehicle as well as the real-world fuel consumption values determined by analysing pair of consecutive fuelling events, with proper mileage data on both occasions, for each vehicle. Therefore, the dataset could be analysed as it stands without linking to other data sources first. When aggregating the individual vehicle data to fleet averages, the Travelcard vehicle count was used as a weighting factor for the results. One data entry per licence.

As for the spritmonitor.de data [Mock et al., 2012, Mock et al., 2013], fuel consumption reported by Travelcard is not based on laboratory measurements but reflects in use fuel consumption experience by a large number of customers. The values are therefore considered as a good representation of real-world CO_2 values. Furthermore, the homogeneous group of users allow for a comparison between brands and make, with limited demographic variations.

Since the fuel is paid for by the employer, the driver is not likely to be much restricted in driving style by fuel saving motives. However, many employers now included the fuel consumption and vehicle use in the appraisal of the employees. Furthermore, in The Netherlands many motorways in the densely populated western part of the country have reduced speed limits of 100 km/h and 80 km/h. The speed limits in combination with congestion on the Dutch roads makes excessive driving styles unlikely. However, a reduced velocity compared with the speed limit, as some drivers use, may be less likely for the group of Travelcard motorists. Recently, the speed limits on the motorways have increased, which may affect the 2011 data somewhat. Overall, the drivers are a more homogeneous group, which are responsible for large mileages as part of an economic activity. They might be on the higher side of the fuel consumption due to the driving style, but on the lower side due to the vehicle usage: longer trip distances and limited urban driving. Note, that in the first four to five years, passenger cars drive about half the total distance of the total lifetime, which is about 200 000 km for petrol cars, and 300 000 km for diesel cars. In Table 1 the average numbers per market segments are given. In Chapters 2 and 8 the detailed figures are provided.

Table 1 The number of vehicles per market segment, combined with the average CO2 emission and the bandwidth

		diesel			Petrol	
	number	Average	stdev	number	Average	stdev
1 (Mini)	234	115.1	14.3	8431	124.4	17.9
2 (Small)	16944	121.9	14.8	25701	150.7	13.4
3 (Lower Medium)	90986	142.1	15.4	67870	165.0	28.6
4 (Medium)	67344	155.3	15.1	39945	190.8	21.2
5 (Upper Medium)	11950	184.9	26.0	8859	225.9	27.1
6 (Luxury)	300	225.3	21.8	576	288.8	44.5
7 (Sport)	267	173.1	17.2	1503	213.6	45.1
M (MPV)	7961	168.3	16.8	1167	180.6	14.5
F (Off road)	5919	215.7	39.5	132	195.1	4.8

The Travelcard data consists of fuel transactions. Fuel type, vehicle registration, time, date and location are automatically logged. The mileage is added by the driver during the transaction. Often wrong numbers are entered. There are several other reasons to ignore certain transactions:

1. Rounding mileages: to the nearest 500 or 1000 kilometres
2. Missing fuelling: near double double distance on the same amount of fuel indicates a fuelling outside the transactions data
3. Wrong fuel: borrowed fuel pass, not up-to-date records
4. Double fuelling: two transactions several minutes apart.
5. Half tank fuelling and fixed amount fuelling: typical usage is the fill the tank. Some drivers have a habit to fuel bit by bit, the content of the tank is unclear, and leads in combination with the other items to faulty records

Eventually the fuelling data of the more constant drivers, who keep proper track of the mileage is selected.

The vehicle data contains brand, make, model, weight, fuel consumption: urban, rural, and combined. The analysis is performed on the basis of litres per 100 km. The conversion to CO_2 is done with fixed factors: 26.5 and 23.7 [g/km]/[l/100km] for diesel and petrol, respectively. In recent years the factor for petrol shifted from 23.7 to 23.6 [g/km]/[l/100km].

3.1.1 Faulty data removal

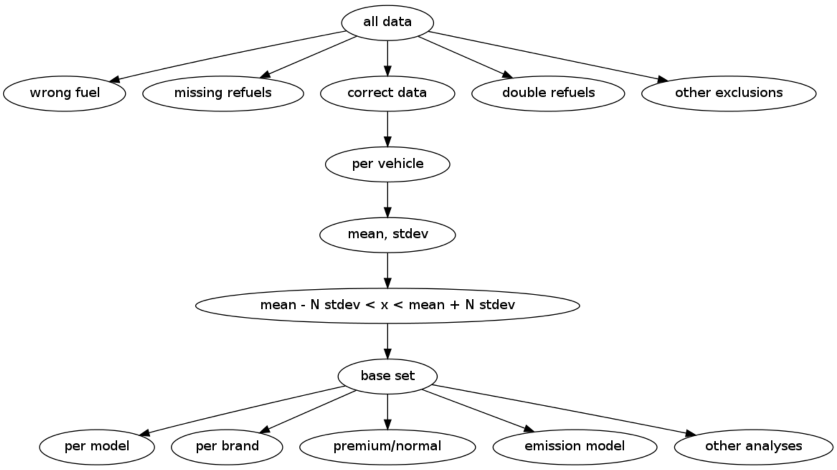


Figure 1 The algorithm to remove faulty or unusable records from the fuelling data.

The algorithm consists of several stages. Obviously wrong data is removed. If possible two consecutive fuelling are used to drop the faulty middle mileage record. From this data, a profile of a vehicle is established, in terms of the average fuel consumption and the variation, or standard deviation. With this information per vehicle the dataset is analysed again, dropping the records which lie outside the range of common usage of the vehicle. The typical setting to remove all the faulty records due to missing fuelling records is three times the standard deviation. The algorithm is visualized in **Error! Reference source not found.**.

4 General results

The discrepancy between CO_2 emission values reported by Travelcard and manufacturers' type-approval values increased from 11 percent in 2004 to 28 percent in 2011. For the years prior to 2004 no data is available. The generic increase is similar for diesel vehicles and petrol vehicles. Furthermore, the lower type-approval fuel consumption typically have a larger deviation between real-world and type approval. This is certainly the case in relative numbers, but also for the absolute difference, i.e., actual litres per 100 kilometre, the deviation is larger for the fuel efficient models. This effect is also visible in the market segments. The compact, fuel-efficient cars show a larger effect.

In the last couple of years, say after 2009, the trend has changed. Nowadays, all models have an increasing deviation between type-approval and norm. In particular for petrol vehicles for the most recent models, one can add 45-50 g/km to the type-approval CO_2 emission, to arrive at the real-world CO_2 emission.

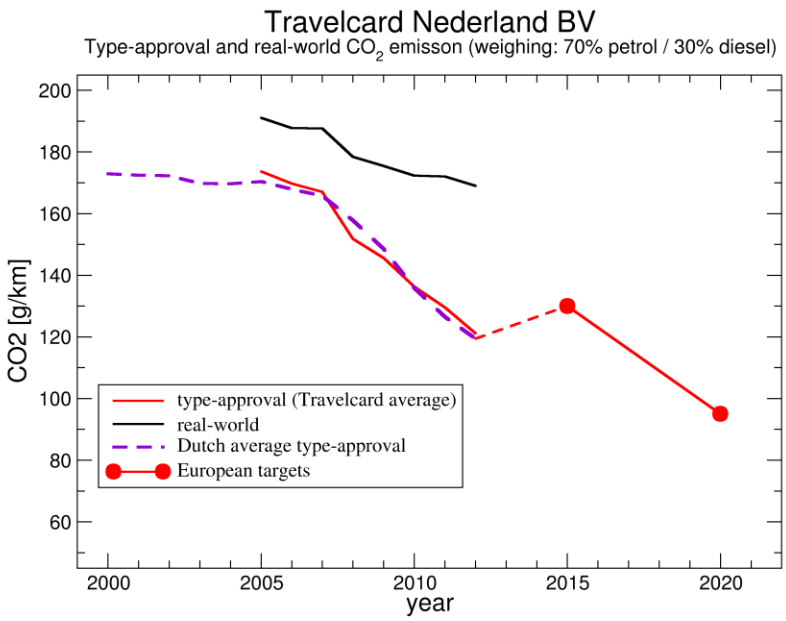
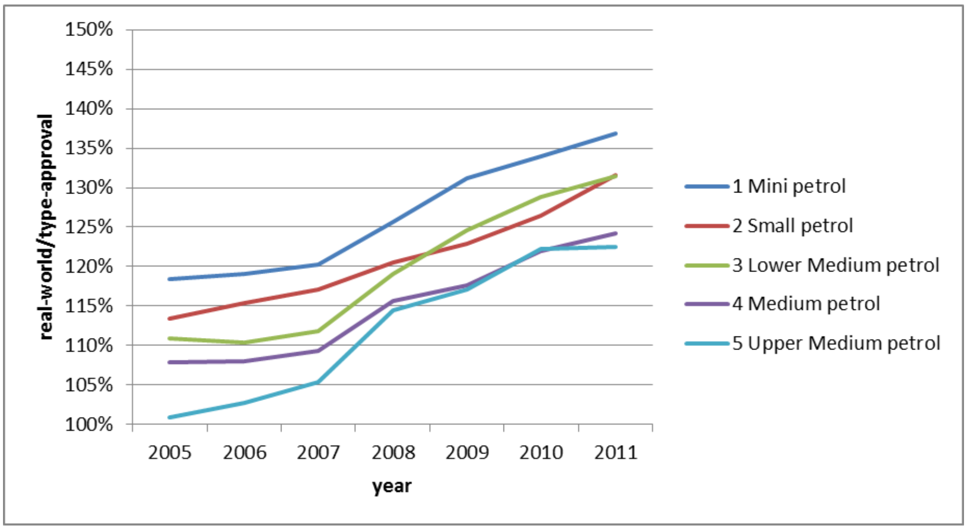


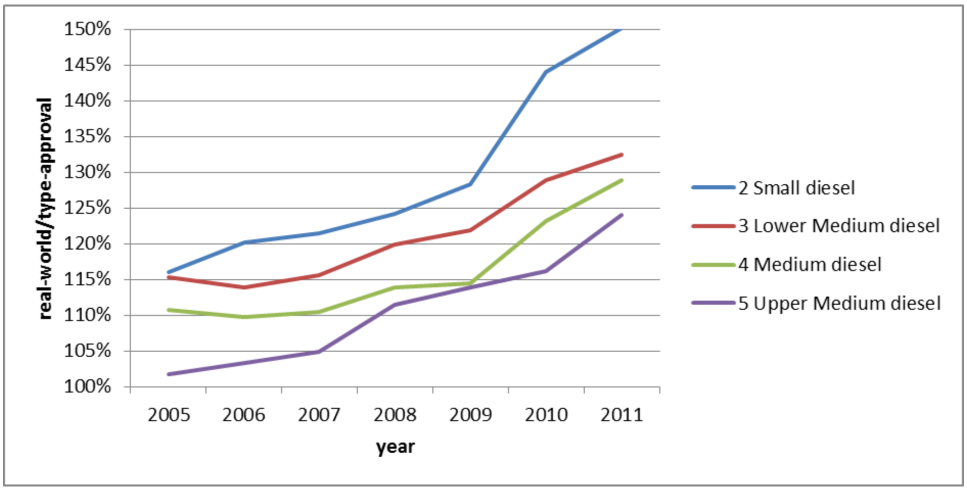
Figure 2 The general trends, based on the weighing of petrol and diesel according to current sales.

4.1 Market segments

ICCT has provided the market segments of the models present in the database. It is therefore possible to present the trends over the years for each market segment separately, removing a bias from the shift in sales between segment. The vehicle sales have dropped dramatically in the last couple of years. In the lease market it seems that drivers are expected to last longer with the same vehicle, moving the age span from 2-3 to 4-5 years.



Figuur 3 The real-world fuel consumption of petrol cars, as percentage of the type-approval fuel consumption, for each market segment.



Figuur 4 The real-world fuel consumption of diesel cars with the years, for each market segment. The small diesel vehicle are compact cars with very low type approval values: Volkswagen Fox and Lupo, Citroen C1 and C2, and Seat Arosa, with fuel consumption between 4.1 and 5.0 l/100km.

Within each segment the difference between the type approval value and the real-world fuel consumption has increased over the year of type approval. The years 2008-2009 has very low business sales, which generate a small bias in the data, for the vehicles sold, in particular diesel vehicles. In the analysis per segment this effect is hardly visible.

Table 1 For petrol cars the generic information per year and market segment, the real-world CO_2 factor, and the real-world CO_2 values.

segments	1 Mini	2 Small	3 Lower Medium	4 Medium	5 Upper Medium	6 Luxury	7 Sport
center value	**120.40**	**147.17**	**156.31**	**184.75**	**218.46**	**279.94**	**197.80**
RW/TA	**1.26**	**1.18**	**1.16**	**1.12**	**1.07**	**1.03**	**1.11**
(urban-rural)/combi	**0.38**	**0.50**	**0.45**	**0.59**	**0.64**	**0.71**	**0.61**
Annual mileage	**21146**	**25291**	**27313**	**26470**	**27939**	**31794**	**23389**
RW/TA [%]							
2005	118.4%	113.5%	110.9%	107.8%	100.9%	107.4%	108.4%
2006	119.1%	115.3%	110.4%	108.0%	102.7%	101.0%	107.5%
2007	120.2%	117.1%	111.9%	109.3%	105.4%	NA	108.7%
2008	125.7%	120.6%	119.0%	115.7%	114.4%	NA	108.4%
2009	131.2%	122.9%	124.5%	117.6%	117.1%	NA	115.7%
2010	133.9%	126.4%	128.9%	122.0%	122.2%	NA	124.2%
2011	136.8%	131.6%	131.4%	124.2%	122.5%	NA	NA
average RW	g/km	g/km	g/km	g/km	g/km	g/km	g/km
2005	162.1	173.2	191.9	209.2	238.5	303.8	230.6
2006	160.1	175.4	190.6	208.1	238.1	290.3	230.3
2007	156.8	174.2	192.1	207.8	235.6	NA	228.0
2008	149.2	174.2	172.8	207.4	234.5	NA	220.8
2009	147.1	172.5	169.2	204.3	226.0	NA	204.3
2010	145.2	167.4	169.3	201.2	227.5	NA	194.2
2011	144.1	169.8	174.2	200.1	228.8	NA	NA

The annual mileage of diesel vehicles is higher than petrol vehicles due to the road tax difference making between petrol and diesel vehicles. It should be noted that except for a very small group of mini vehicles, the annual mileage is relatively constant across the segments.

Table 2 For diesel cars, the generic information per year and market segment, the real-world factor, and real-world CO_2 values

segments	**1 Mini**	**2 Small**	**3 Lower Medium**	**4 Medium**	**5 Upper Medium**	**6 Luxury**	**7 Sport**
center value	**120.22**	**117.89**	**139.79**	**153.12**	**182.42**	**224.08**	**167.99**
RW/TA	**1.25**	**1.24**	**1.18**	**1.12**	**1.07**	**1.03**	**1.06**
(urban-rural)/combi	**0.38**	**0.38**	**0.42**	**0.48**	**0.52**	**0.61**	**0.50**
annual mileage	**29596**	**32046**	**37013**	**37928**	**38465**	**40567**	**35773**
RW/TA							
2005	NA	116.1%	115.3%	110.8%	101.7%	NA	104.9%
2006	116.0%	120.2%	113.9%	109.8%	103.3%	NA	107.7%
2007	NA	121.5%	115.6%	110.4%	104.9%	NA	NA
2008	NA	124.2%	119.9%	113.9%	111.5%	NA	NA
2009	NA	128.3%	121.8%	114.5%	113.9%	NA	NA
2010	NA	144.0%	128.8%	123.2%	116.1%	NA	NA
2011	NA	150.2%	132.4%	128.8%	124.0%	NA	NA
average RW	g/km	g/km	g/km	g/km	g/km	g/km	g/km
2005	NA	147.7	164.9	174.0	196.2	NA	180.2
2006	142.4	148.4	165.1	174.2	200.2	NA	189.1
2007	NA	148.8	167.2	174.3	198.7	NA	NA
2008	NA	148.7	165.5	172.7	197.2	NA	NA
2009	NA	144.7	160.4	167.1	186.1	NA	NA
2010	NA	137.9	156.0	162.8	184.8	NA	NA
2011	NA	138.3	156.8	161.1	184.9	NA	NA

4.2 Complete fleet

From the Travelcard dataset was in 2009 established that the deviation of real-world fuel consumption increases for lower type-approval values. [Ligterink, De Lange, and Passier, 2009, Ligterink & Bos 2010] For type-approval values of 250 g/km or more there is little deviation. For type-approval values of 120 g/km or less, the deviation is 35% or more. The initial observation that some brands have larger deviation could be traced back to the market segment, and the corresponding type approval values.

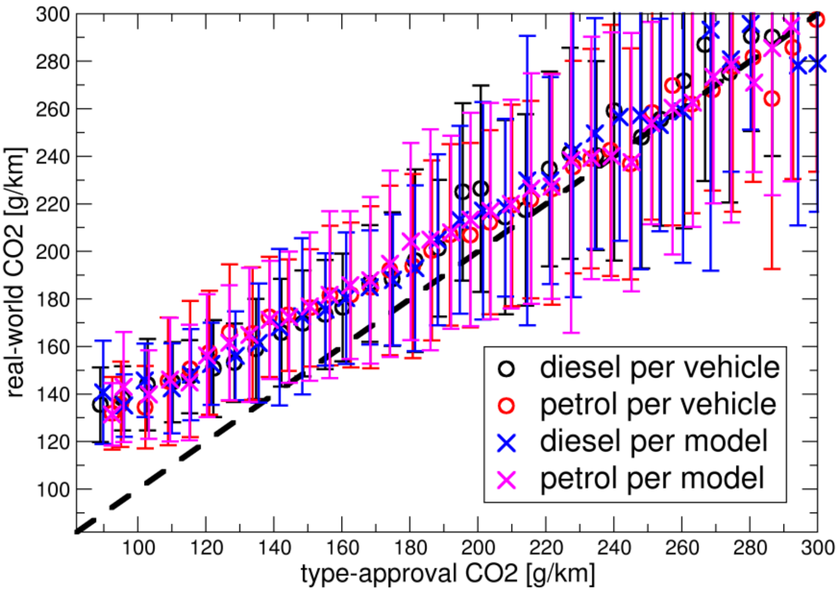
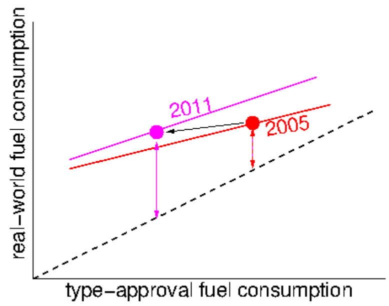


Figure 5 The difference between type-approval and real-world CO2 emissions increased with decreasing type-approval values. Analyses per vehicle and per model show little variation of the effect with popular and less popular models. The plot include all the data over the years 2004-2011, such that the higher deviations are actual higher value for lower type-approval value and a shift with years toward lower type-approval values.

Currently, more data from Travelcard BV is available. In this report the above statement is made more precise, and small deviations among brands and models can be observed. Furthermore, the aspect of variability between drivers can be examined in full.



Figuur 6 The increasing gap between type-approval fuel consumption and real-world fuel consumption depends on two aspects: the decreasing type-approval value and the increasing difference between a given type-approval and the real-world value

A number of models with a large market share are very common in the Travelcard database. Hence for these models different comparisons can be made. The analyses of technology and fuel are carried out on a number of common models. The inclusion of a model is solely based on the amount of data available. No other selection criteria are used.

Generally, it can be observed that new technology and newer models have a lower type-approval value. The lower value resorts only a limited effect in the real-world fuel consumption. In a few cases higher type-approval values are observed for recent years. In all cases the underlying cause is a shift toward larger, heavier vehicle models for the particular manufacturer or market segment. For example an increase in the sales of SUV's.

By analysing the change in type-approval values in more depth, the gain in type-approval fuel consumption is mainly due to a lower urban fuel consumption: the UDC (urban drive cycle) part of the test. [Ligterink & Bos 2010, Ligterink & Smokers 2013] A measure of the difference between the urban and extra-urban part of the test has changed substantially is the last couple of years:

$$T = \frac{FC_{urban} - FC_{extra-urban}}{FC_{combined}}$$

The value of *T* for the modern cars ranges between 0 and 0.55 for petrol, and between 0.25 and 0.4 for diesel. Hybrid vehicles have a *T* of close to zero. From older vehicles, around 2005 and before. The factor *T* is typically 20% higher than for 2012. The gains in fuel saving for urban usage, in particular on the UDC test, with long idling and low engine load, are expected to have limited impact in the case of real-world driving.

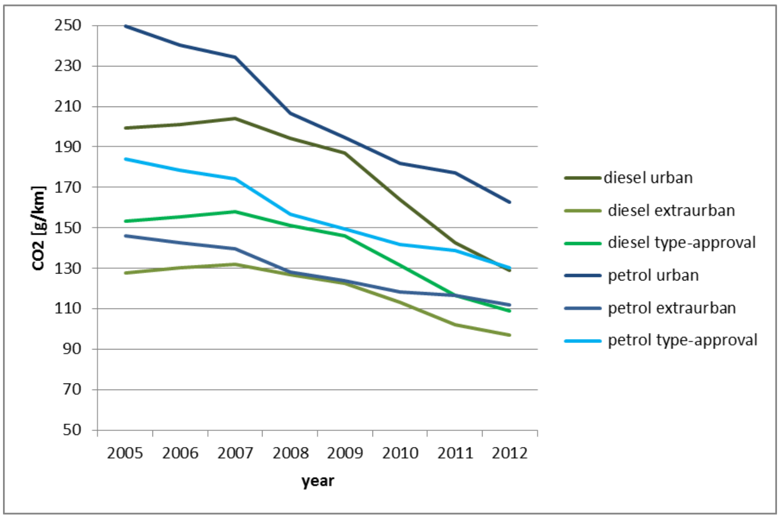
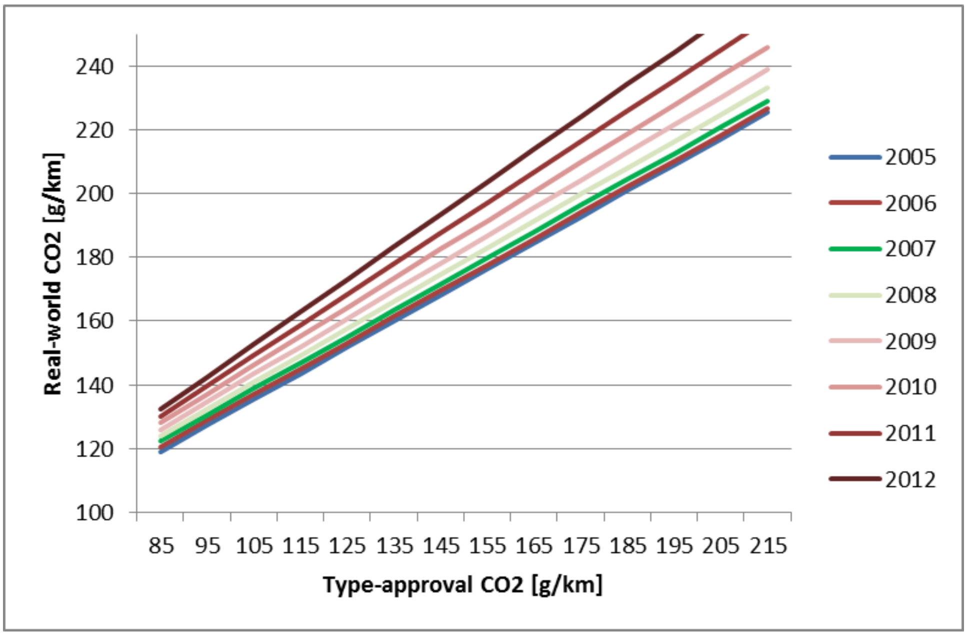
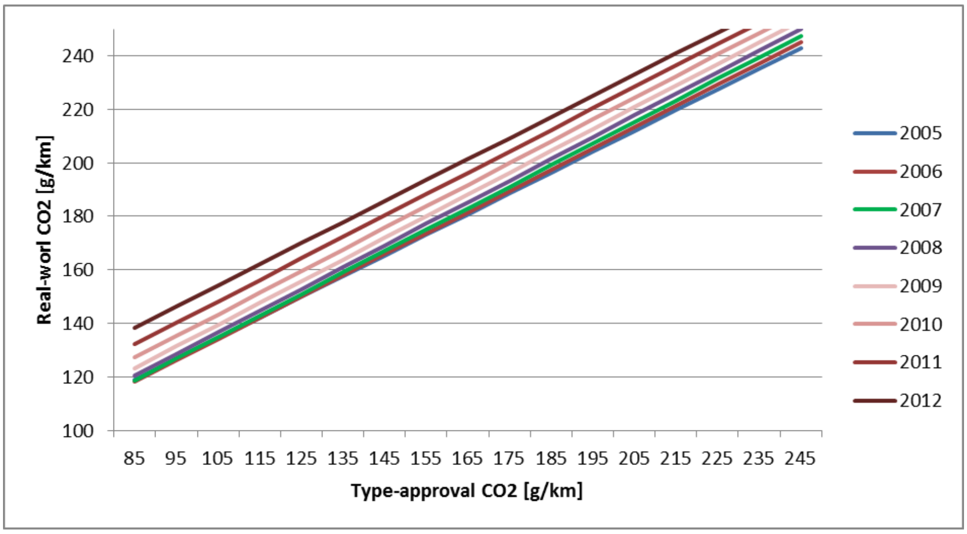


Figure 7 The decrease of the fleet-average urban and extra-urban part of the type approval values. Both for petrol and diesel the urban fuel consumption has dropped with 35%, while the extra-urban fuel consumption decreased with 23%. The combined reduction is 29%.

Furthermore, it should be noted that the difference in type-approval value between petrol and diesel is mainly in the urban part of the test. Diesel vehicles perform better in in low-load situations. Hybridization is therefore more relevant for petrol than for diesel vehicles, to reduce the fuel consumption on the NEDC test.
Including all the data per type-approval year, the trend for different type-approval values can be recovered with enough statistical significance. Some minor variations exists. However, before 2007 the lower type-approval values yielded the higher deviations. Nowadays for all models have increasing deviations. Furthermore, the deviation are increasing in recent years. Particularly, after 2009 the yearly increase is significant.



Figuur 8 Linear fits per year of the relation between type-approval CO2 emission and real-world CO2 emission for petrol cars, based on all available data



Figuur 9 Linear fits per year of the relation between type-approval CO2 emission and real-world CO2 emission for diesel cars, based on all available data.

Table 2 The real-world CO_2 emission as a factor of type-approval CO_2 emissions for petrol cars. Each cell contains at least 50 vehicles.

Year **petrol**

Range [g/km]	2005	2006	2007	2008	2009	2010	2011	2012
85-90	-	-	-	-	148.2%	146.5%	146.6%	149.4%
90-95	-	-	-	-	145.0%	144.9%	153.6%	151.5%
95-100	-	-	-	-	-	-	163.5%	144.6%
100-105	129.9%	122.9%	126.0%	127.7%	128.8%	137.3%	135.1%	142.1%
105-110	-	127.6%	128.2%	133.1%	135.5%	133.0%	137.6%	149.3%
110-115	139.1%	-	-	-	137.3%	139.9%	134.6%	138.3%
115-120	-	-	129.6%	131.0%	130.6%	134.0%	137.3%	139.7%
120-125	-	-	-	-	-	133.0%	137.0%	140.8%
125-130	-	122.8%	118.9%	123.7%	127.8%	131.9%	134.1%	139.3%
130-135	111.9%	-	-	125.6%	129.8%	132.2%	133.0%	135.3%
135-140	116.6%	119.6%	123.9%	123.5%	126.9%	126.8%	130.3%	135.6%
140-145	115.7%	119.4%	120.2%	126.1%	125.5%	127.9%	130.0%	133.9%
145-150	116.0%	118.3%	118.0%	120.9%	121.9%	126.1%	130.6%	133.4%
150-155	113.5%	116.2%	115.4%	117.5%	120.7%	125.7%	128.0%	131.3%
155-160	113.0%	115.0%	115.3%	118.9%	119.1%	120.4%	124.8%	130.6%
160-165	111.8%	112.5%	112.6%	116.4%	117.3%	120.1%	125.1%	130.7%
165-170	111.3%	110.8%	111.7%	115.9%	116.4%	119.7%	123.5%	126.2%
170-175	109.7%	110.1%	110.8%	113.8%	116.3%	118.5%	123.6%	122.6%
175-180	110.3%	108.3%	109.5%	112.1%	116.1%	119.1%	124.1%	126.4%
180-185	109.1%	109.0%	108.6%	109.1%	114.9%	120.1%	124.7%	-
185-190	109.6%	106.2%	108.3%	111.5%	111.2%	117.5%	124.8%	-
190-195	110.1%	109.6%	111.4%	107.4%	109.2%	118.3%	125.8%	-
195-200	106.5%	105.7%	105.9%	112.8%	113.8%	119.3%	127.6%	-
200-205	107.1%	107.1%	111.1%	106.2%	103.9%	-	-	-
205-210	105.2%	107.0%	108.0%	105.2%	110.8%	118.7%	-	-
210-215	106.6%	102.2%	105.8%	107.3%	105.7%	-	-	-
215-220	102.5%	102.6%	103.5%	103.3%	-	-	-	-
220-225	102.2%	105.7%	104.1%	108.4%	105.9%	-	-	-
225-230	97.3%	102.5%	105.8%	105.4%	108.9%	-	-	-
230-235	105.1%	103.3%	102.6%	100.1%	-	-	-	-
235-240	102.9%	103.3%	-	-	-	-	-	-
240-245	101.2%	107.3%	107.4%	109.6%	-	-	-	-

Table3 real-world CO_2 emission as factor of the type-approval CO_2 emission, for diesel vehicles. Each cell contains at least 50 vehicles.

Year **diesel**

Range [g/km]	2005	2006	2007	2008	2009	2010	2011	2012
85-90	-	-	-	-	-	153.1%	155.4%	156.1%
90-95	-	-	-	-	-	-	147.6%	164.1%
95-100	-	-	-	136.4%	135.9%	144.6%	150.1%	157.3%
100-105	-	-	-	-	145.2%	143.9%	142.9%	138.7%
105-110	-	-	-	-	128.2%	136.7%	136.5%	138.0%
110-115	125.3%	-	-	-	132.6%	131.7%	136.3%	139.2%
115-120	122.6%	122.3%	124.5%	131.0%	129.0%	131.8%	135.8%	137.9%
120-125	121.9%	121.7%	122.9%	122.7%	123.0%	126.5%	133.1%	135.2%
125-130	121.5%	121.9%	121.9%	123.4%	120.5%	123.3%	127.7%	132.5%
130-135	117.1%	119.8%	119.1%	119.9%	120.3%	125.7%	129.2%	133.4%
135-140	116.7%	114.8%	117.8%	115.2%	115.9%	122.6%	127.3%	135.0%
140-145	115.8%	115.8%	115.4%	119.7%	117.5%	120.9%	122.5%	125.5%
145-150	115.3%	114.0%	113.8%	116.7%	114.9%	117.3%	126.2%	131.3%
150-155	111.4%	111.5%	112.2%	112.7%	115.1%	116.3%	121.3%	125.1%
155-160	111.6%	109.7%	111.8%	114.5%	113.3%	116.5%	122.6%	128.0%
160-165	109.7%	110.8%	110.7%	112.4%	112.6%	116.4%	119.3%	-
165-170	107.5%	107.5%	108.3%	113.5%	115.6%	114.6%	-	-
170-175	106.7%	105.4%	109.3%	110.4%	110.9%	114.5%	-	-
175-180	106.0%	107.2%	109.9%	110.3%	110.1%	111.6%	115.2%	-
180-185	110.6%	105.7%	105.7%	110.2%	110.9%	-	-	-
185-190	106.3%	105.2%	105.1%	105.6%	106.4%	-	-	-
190-195	104.7%	106.5%	106.7%	107.3%	107.0%	-	-	-
195-200	99.7%	100.8%	109.9%	109.8%	107.1%	123.2%	-	-
200-205	102.7%	105.1%	-	-	-	-	-	-
205-210	98.7%	101.7%	101.6%	-	-	-	-	-
210-215	105.3%	106.3%	107.5%	-	-	-	-	-
215-220	-	-	107.1%	109.4%	106.5%	-	-	-
220-225	106.4%	103.2%	103.8%	-	-	-	-	-
225-230	102.0%	101.5%	108.3%	-	-	-	-	-
230-235	-	-	108.1%	-	-	-	-	-
235-240	-	109.1%	108.2%	-	-	-	-	-
240-245								

5 Influencing parameters

From the RDW (vehicle registration authority) the actual type-approval date is available. Vehicles are sold and introduced slightly later than type-approved. For older vehicles the type-approval date is not available, hence most of the analyses is performed with the introduction date. Fuel prices in The Netherlands are available from the CBS website. The weather information is available from the KNMI web site.

5.1.1 *The effect of weather*

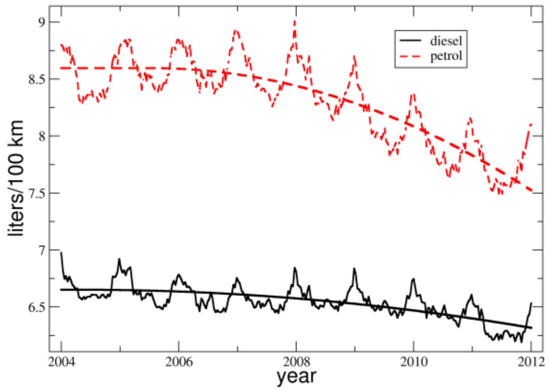


Figure 10 the variation of the average fuel consumption over time. Annual trends, a decreasing fuel consumption, and holiday periods are clearly visible.

There is a clear distinction between summer and winter in the fuel consumption of vehicles. Also the holiday periods show up as an increased fuel consumption. [Ligterink, Kraan & Eijk, 2012] The annual variation is very likely the result of fuel density variations between summer and winter fuel. The fuel norms allow for variation of diesel density between 820 and 845 g/litre [3%]. Petrol can vary between 720 and 775 g/litre [8%] The type-approval test are performed with fuel in a smaller range diesel: 833-837 g/litre and petrol: 743-756 g/litre. The density of test petrol has gone down slightly with Euro-5 (2009) due to the fact that 4.7-5.3% ethanol is added to the refinery petrol. The addition of 4.5-5.5% FAME to diesel did not affect the density.

By straight plotting the fuel-consumption of the correct records over the years, the annual fluctuation of about 10% is clearly visible for petrol and diesel. See Figure 11**Error! Reference source not found.**. Attempts to correlate the variations in average fuel consumption over time with variations in the weather: wind and precipitation, have failed. Also the periods of heavy congestion, typically during autumn storms do not show a correlation with the fuel consumption. A correlation may exists but the present data does not provide evidence.

In part the fuel density may explain the annual variation of fuel consumption. Cold ambient air increases the engine efficiency, but also the friction. Furthermore, the cold start in cold weather will increase the, already substantial, fuel penalty.

5.1.2 Fuel prices in the Netherlands

The effect of the variation of the fuel prices (source: CBS – Netherlands Statistic Institute/Travelcard) was correlated with the number of kilometres driven. The effect of weather and year seasons indicated previously can be found again in these plots. By analysing the plots it can be concluded that the effect of the fuel price has an impact on the number of kilometres driven by diesel vehicles. As a matter of fact the number of kilometres driven by diesel vehicles has a reduction that follows the increase of the fuel price for the same period. On the other hand, the evolution of the number of kilometres driven by petrol vehicles is not influenced by the fuel price.

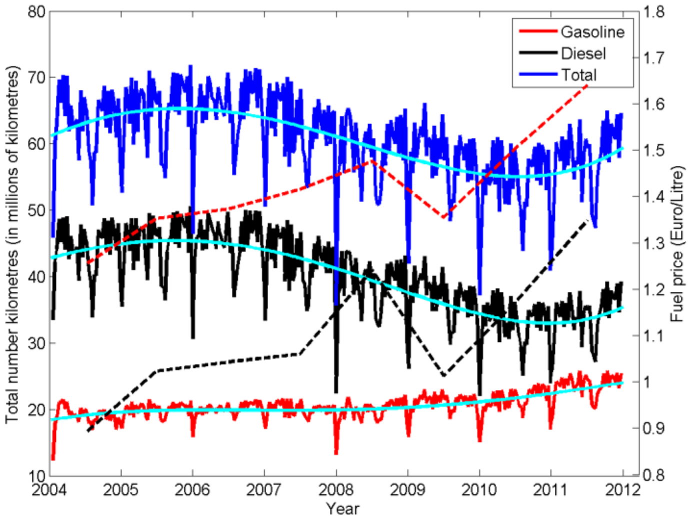


Figure 5 the variation of the fuel price over time related with the number of driven kilometres.

In figure 6 the fuel price variation is depicted with the daily average driven kilometres. Although there is for both fuels a clear descending trend, this evolution does not follow the fuel price variation.

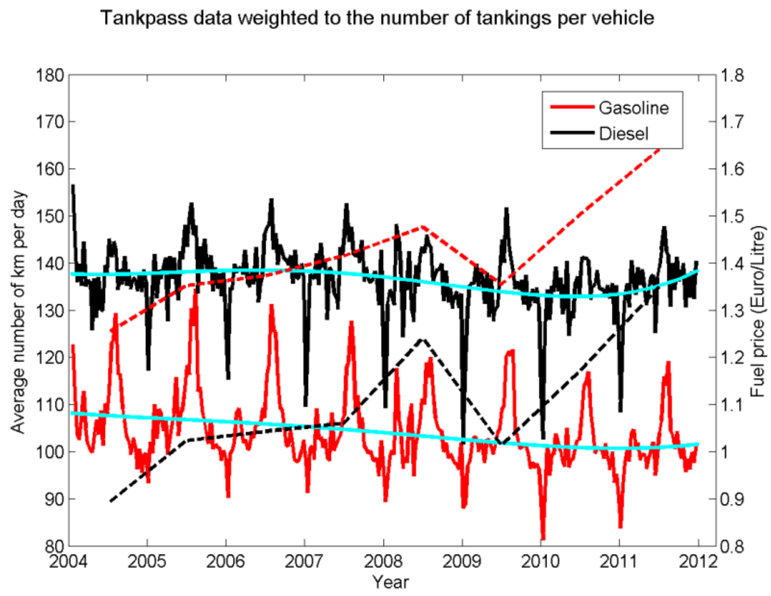


Figure 6 the variation of the fuel price over time related with the average fuel consumption.

The following figure depicts the variation of the average fuel consumption with the evolution of the fuel price. From this figure it can concluded that the fuel consumption does not vary with the fuel price variation.

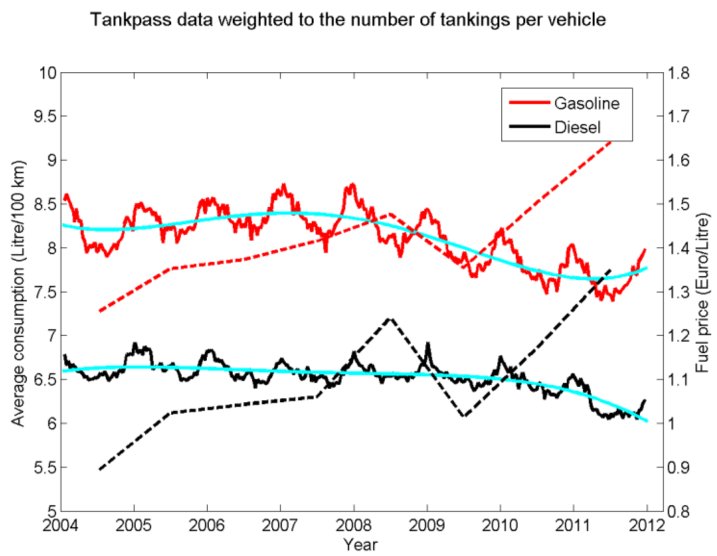


Figure 7 the variation of the fuel price over time related with the average fuel consumption.

5.1.3 *Relation with the evolution of traffic congestion*

The congestion (source: CBS - Netherlands Statistics Institute and KiM – Knowledge Institute for Mobility), measured in time loss, are correlated with the number of kilometres driven. It is not possible to trace a clear trend in the evolution of the two types of data, although the increase of driven kilometres in the years

2011 and 2012 may be in part related with a better traffic control management on the Dutch roads.

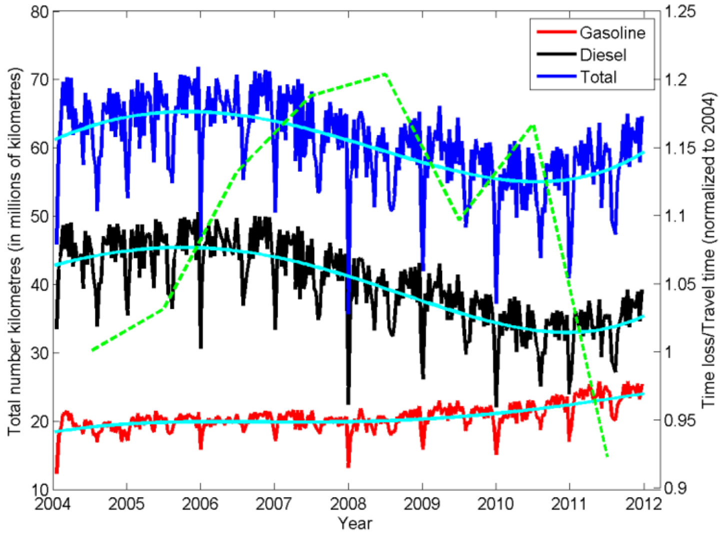


Figure 8 the variation of the fuel price over time related with the queue variation.

The variation of the daily average kilometres over time with the queue evolution is represented in the graphic of figure 9. As for the total kilometres driven (figure 8), it is not possible to indicate a relation between driven kilometres and the variation of queues, except eventually for the years 2010 – 2012.

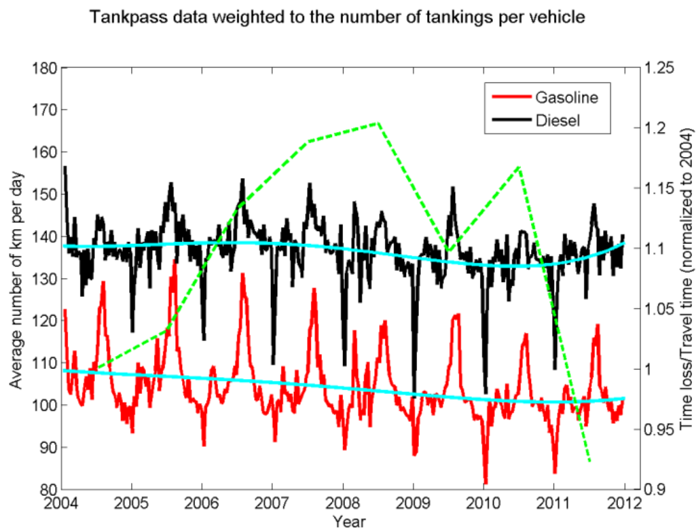


Figure 9 the variation of the average driven kilometres over time related with the queue variation

The following figure depicts the variation of the average fuel consumption with the evolution of the queues on the Dutch roads. From 2008 a descending trend of the dimensions of the queues was registered, which in part due to the economic crisis but also due to better queue management from the Dutch road authorities. The descending trend can also be found in the variation of the fuel consumption although it is not sustained to take any conclusion related with a possible link between these two trends.

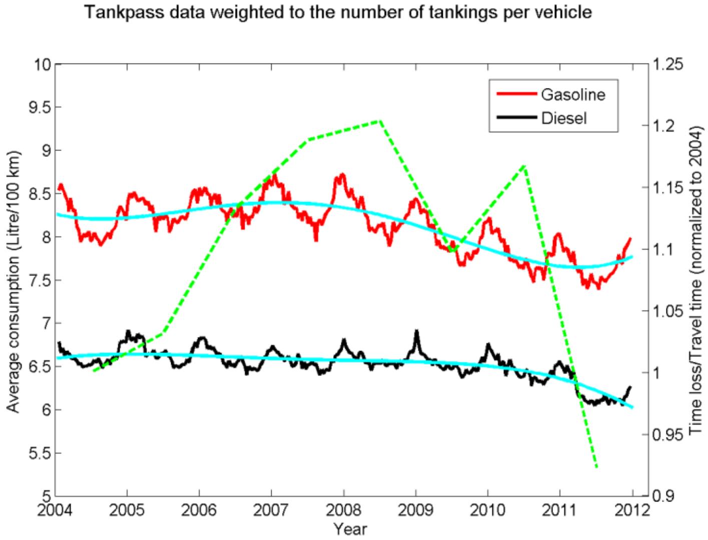
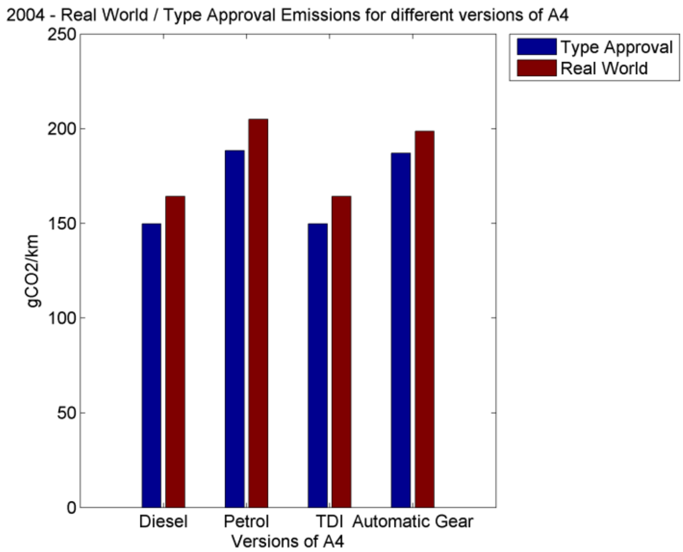


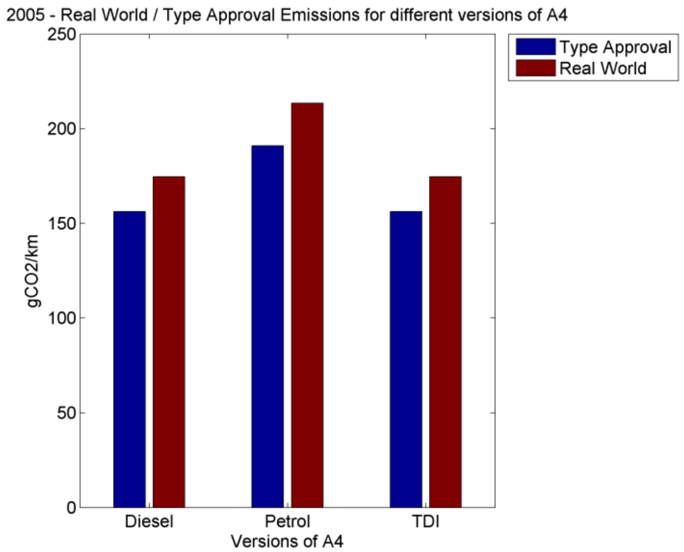
Figure 10 the variation of the fuel consumption over time related with the queue variation.

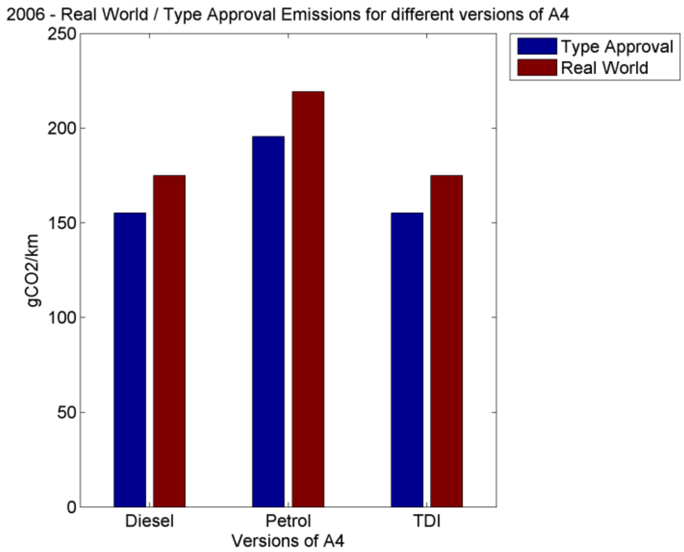
6 Analysis of different versions and technologies of the same vehicle models

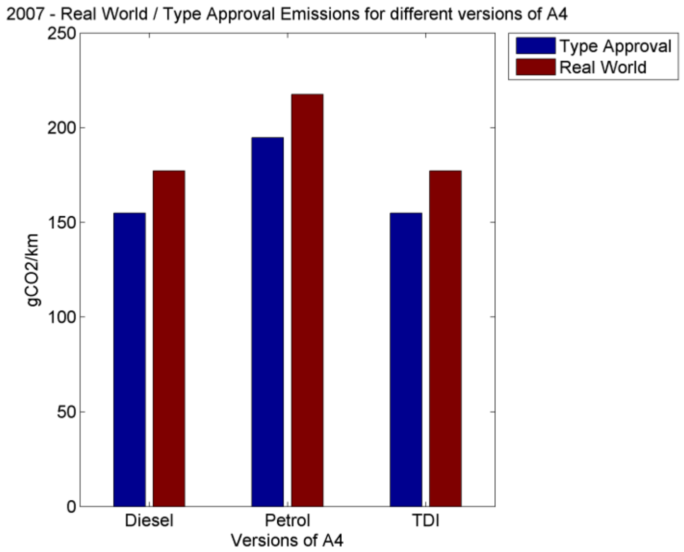
In the following bar graphics different versions of the same model are compared for specific years. The versions under analysis include different fuel types and gearboxes. Also some distinctive motor types are subject to analysis (example, TDI for the A4 or 1.7 CDTI for the Opel Astra). The model names were obtained from the RDW (Dutch road authority). No additional technology assessment than using the technology description in this database is used to generate these results.

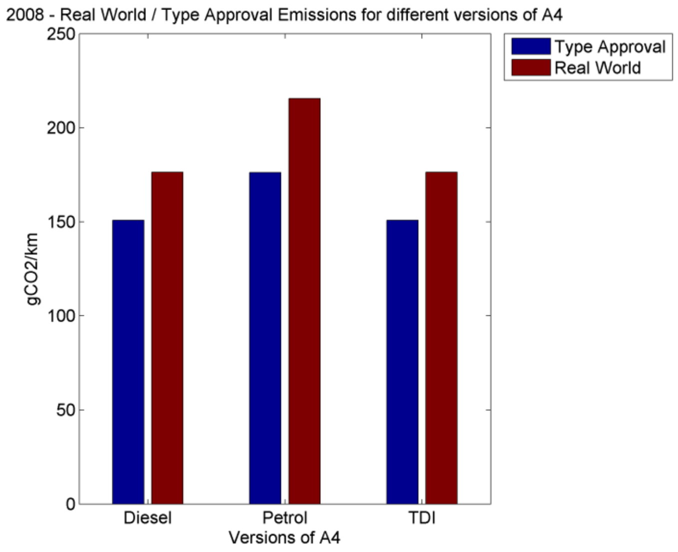
6.1.1 Audi A4 comparison of versions

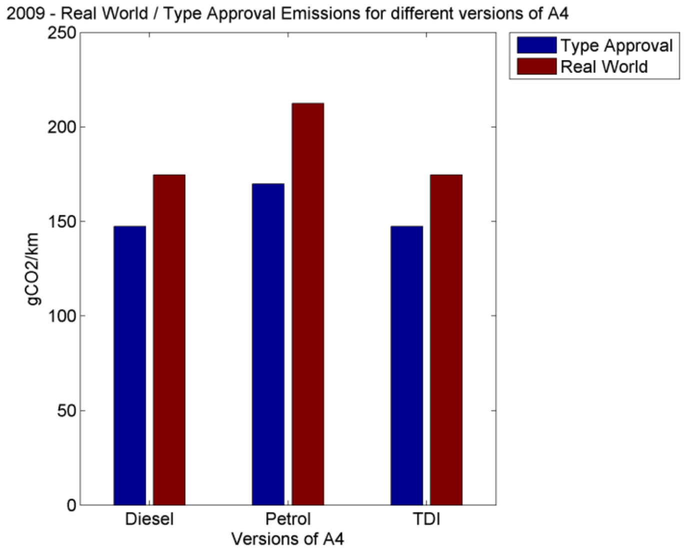


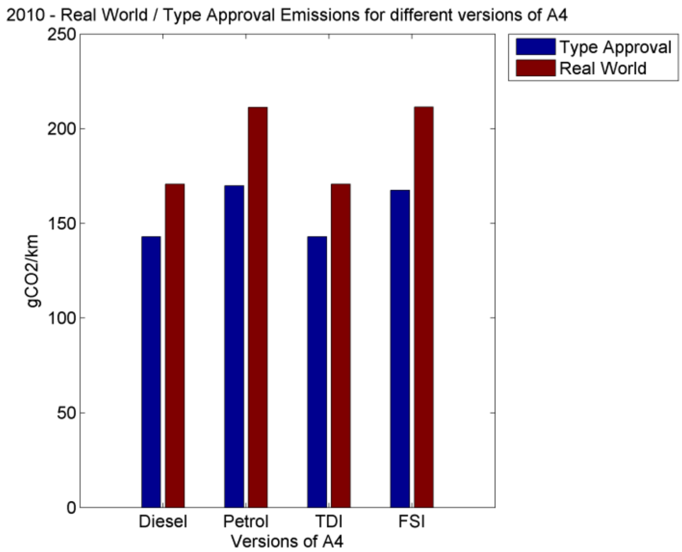

2005 - Real World / Type Approval Emissions for different versions of A4
Type Approval
Real World
gCO2/km
250
200
150
100
50
0
Diesel
Petrol
TDI
Versions of A4

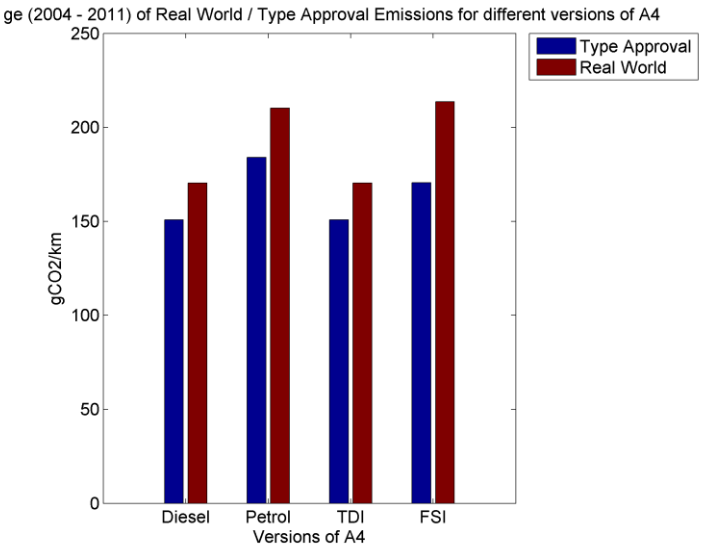

2006 - Real World / Type Approval Emissions for different versions of A4
Type Approval
Real World
gCO2/km
250
200
150
100
50
0
Diesel
Petrol
TDI
Versions of A4


2007 - Real World / Type Approval Emissions for different versions of A4
Type Approval
Real World
gCO2/km
250
200
150
100
50
0
Diesel
Petrol
TDI
Versions of A4

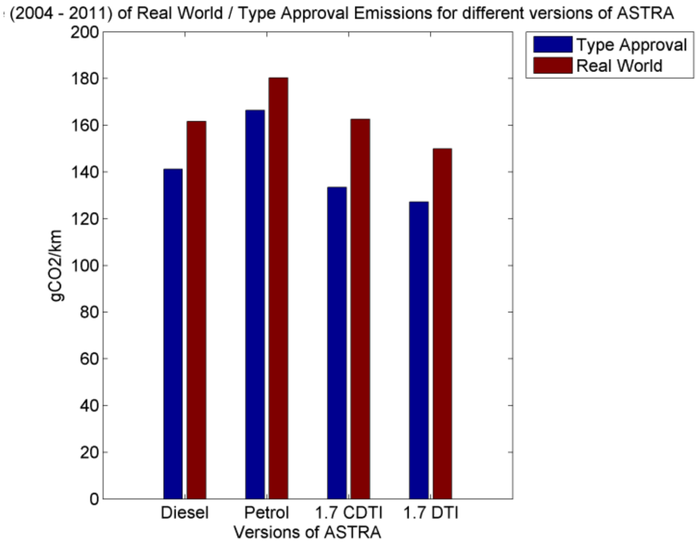

2008 - Real World / Type Approval Emissions for different versions of A4
250
200
150
100
50
0
gCO2/km
Type Approval
Real World
Diesel
Petrol
TDI
Versions of A4

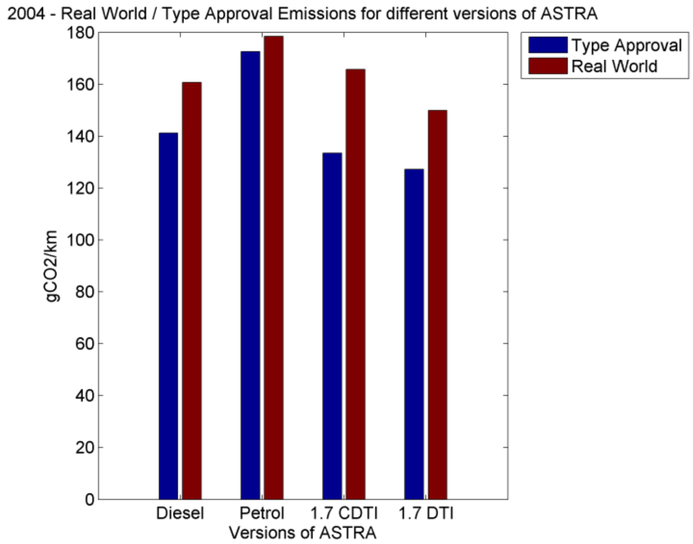

2009 - Real World / Type Approval Emissions for different versions of A4
250
200
150
100
50
0
gCO2/km
Type Approval
Real World
Diesel
Petrol
TDI
Versions of A4

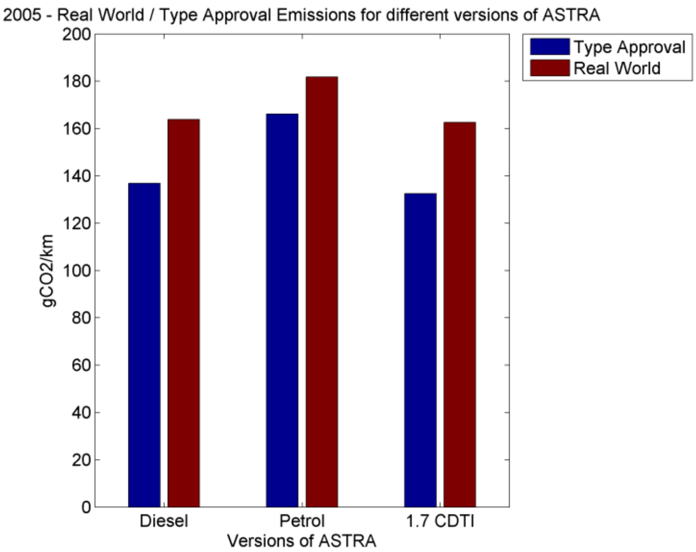

2010 - Real World / Type Approval Emissions for different versions of A4
Type Approval
Real World
gCO2/km
250
200
150
100
50
0
Diesel
Petrol
TDI
FSI
Versions of A4

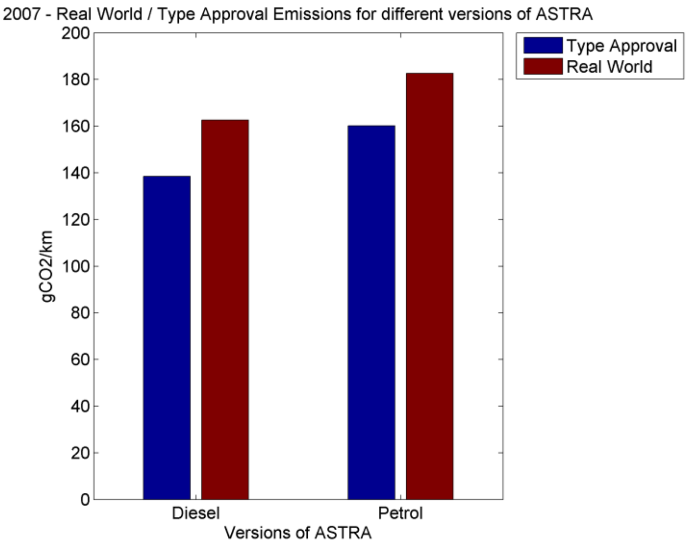

ge (2004 - 2011) of Real World / Type Approval Emissions for different versions of A4
Type Approval
Real World
gCO2/km
250
200
150
100
50
0
Diesel
Petrol
TDI
FSI
Versions of A4

6.1.2 *Opel Astra comparison of versions*

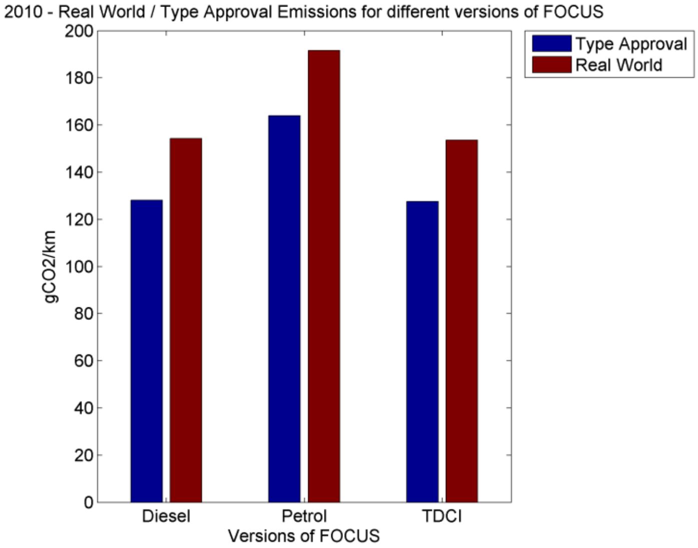


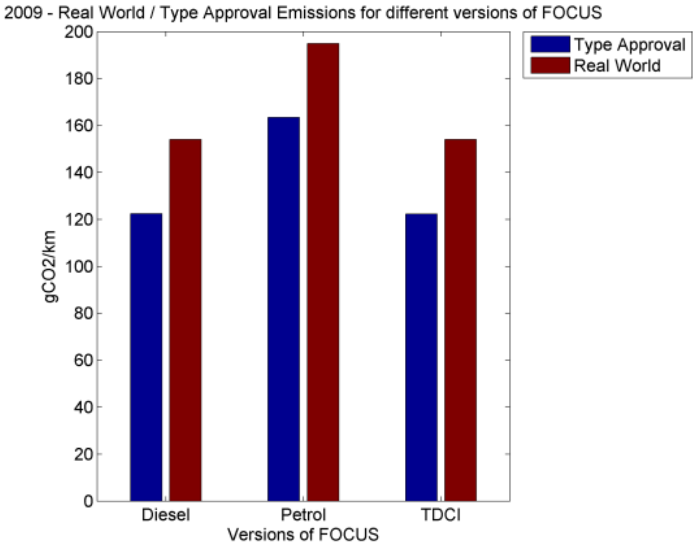


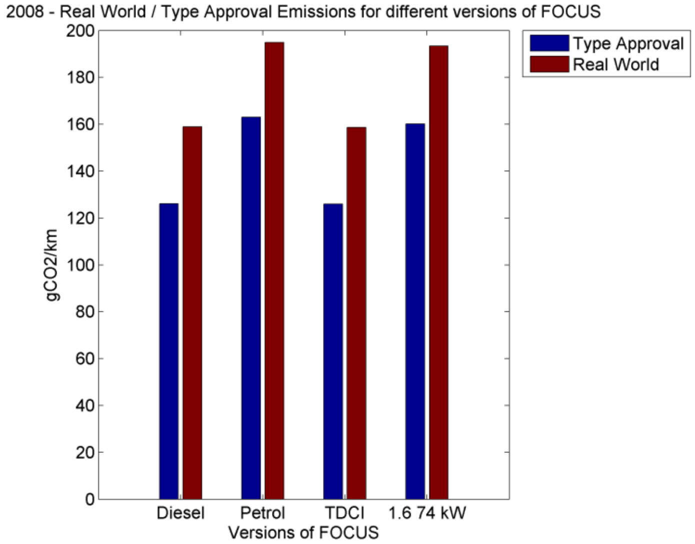

2005 - Real World / Type Approval Emissions for different versions of ASTRA
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
200
Diesel
Petrol
1.7 CDTI
Versions of ASTRA

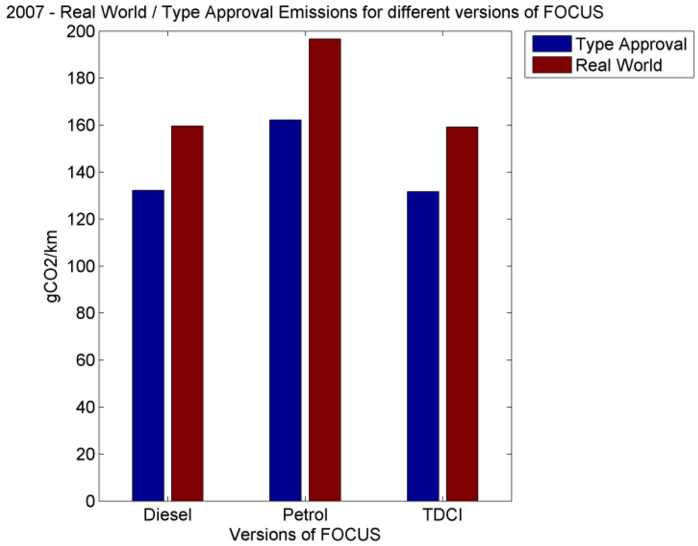

2007 - Real World / Type Approval Emissions for different versions of ASTRA
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
200
Diesel
Petrol
Versions of ASTRA

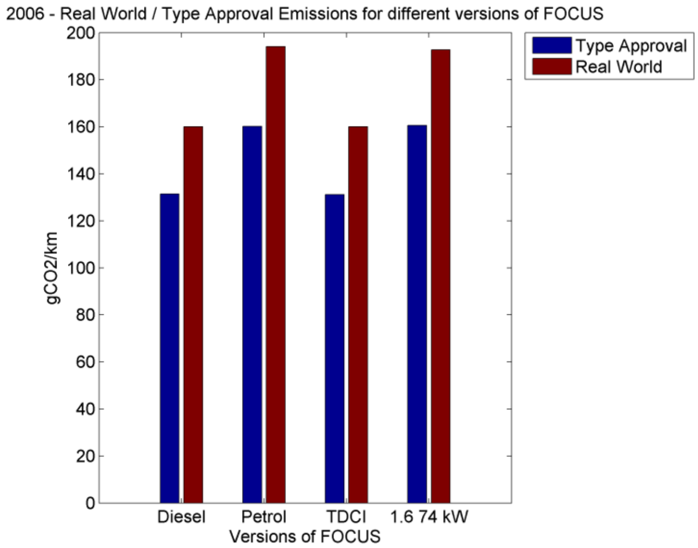
6.1.3 Ford Focus comparison of versions

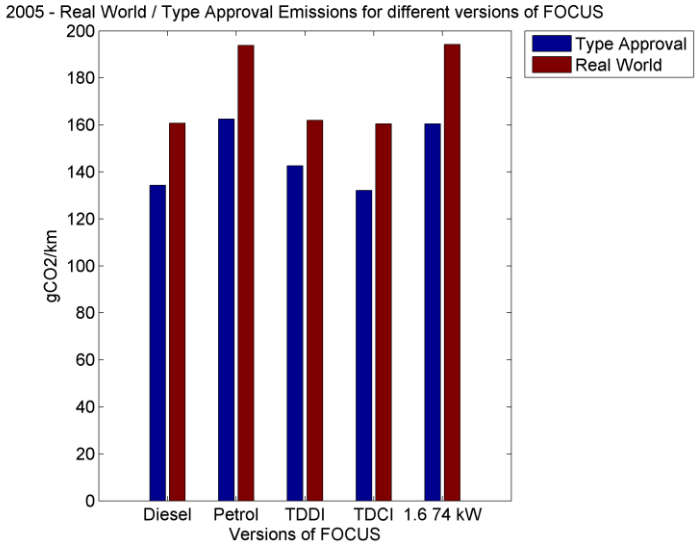


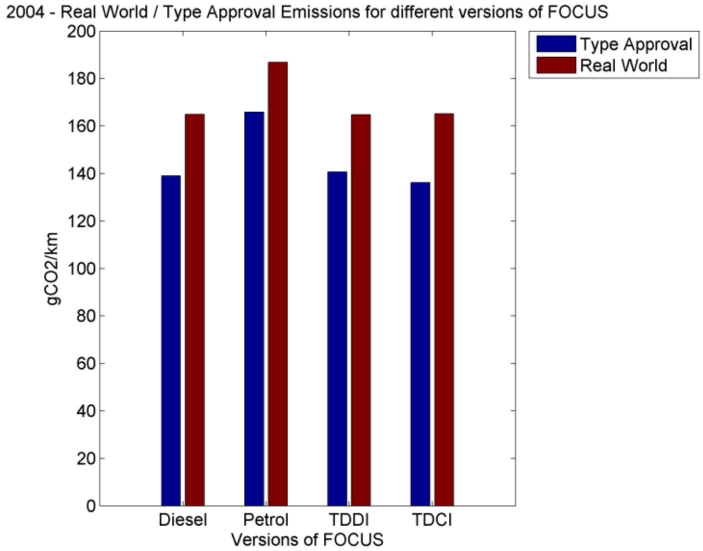


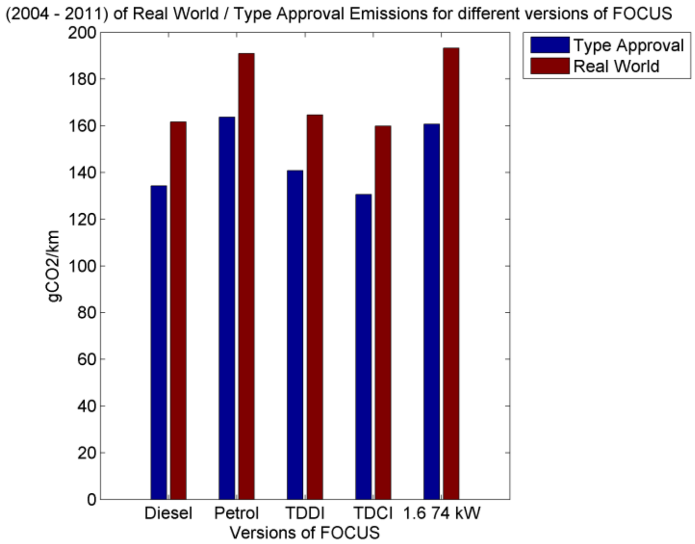

2008 - Real World / Type Approval Emissions for different versions of FOCUS
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
200
Diesel
Petrol
TDCI
1.6 74 kW
Versions of FOCUS


2007 - Real World / Type Approval Emissions for different versions of FOCUS
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
200
Diesel
Petrol
TDCI
Versions of FOCUS

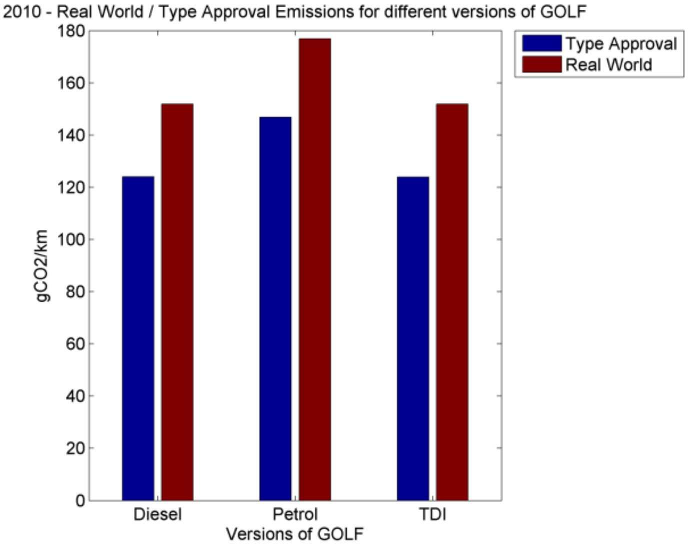

2006 - Real World / Type Approval Emissions for different versions of FOCUS
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
200
Diesel
Petrol
TDCI
1.6 74 kW
Versions of FOCUS

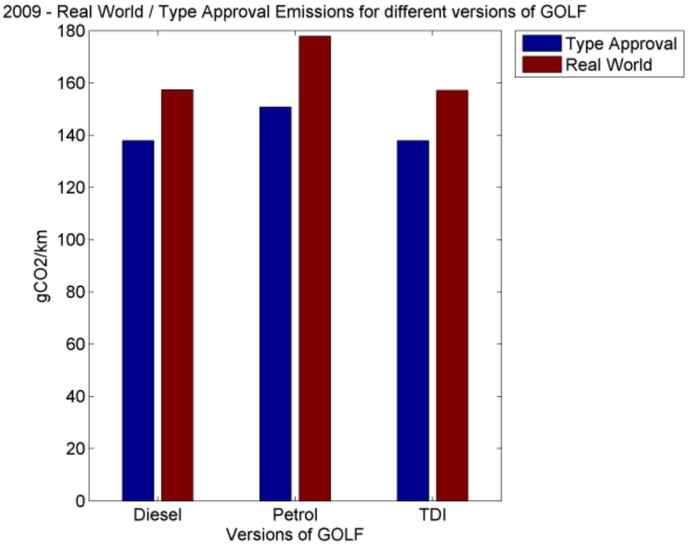

2005 - Real World / Type Approval Emissions for different versions of FOCUS
Type Approval
Real World
gCO2/km
200
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDDI
TDCI
1.6 74 kW
Versions of FOCUS

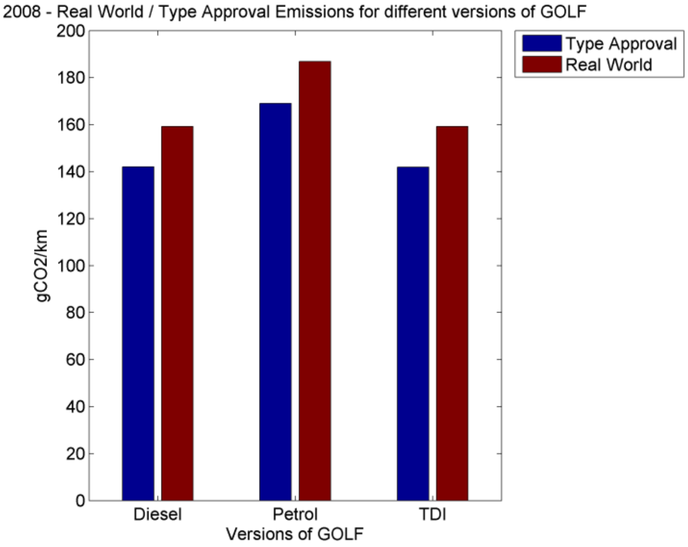

2004 - Real World / Type Approval Emissions for different versions of FOCUS
Type Approval
Real World
gCO2/km
200
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDDI
TDCI
Versions of FOCUS

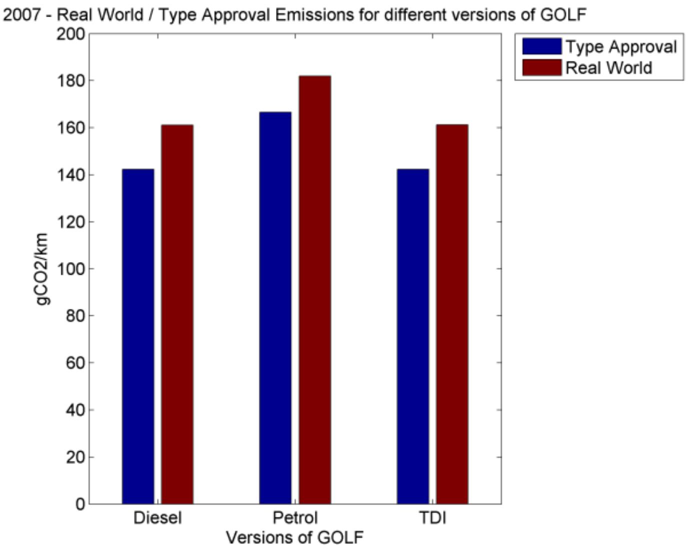

(2004 - 2011) of Real World / Type Approval Emissions for different versions of FOCUS
Type Approval
Real World
gCO2/km
200
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDDI
TDCI
1.6 74 kW
Versions of FOCUS

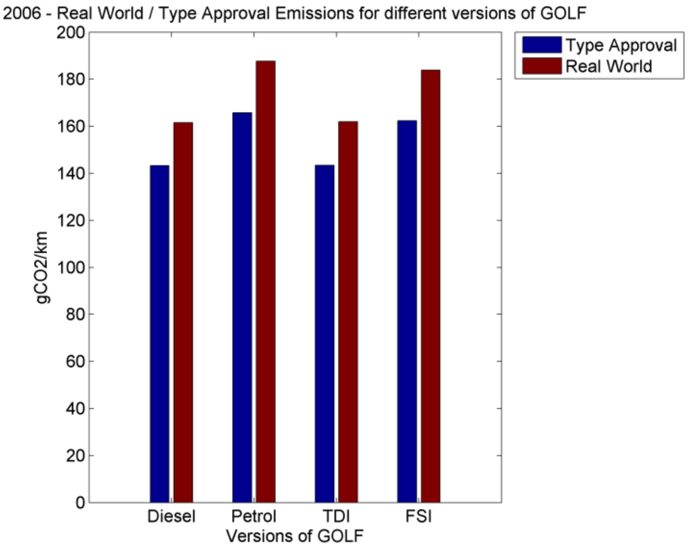
6.1.4 Volkswagen Golf comparison of versions

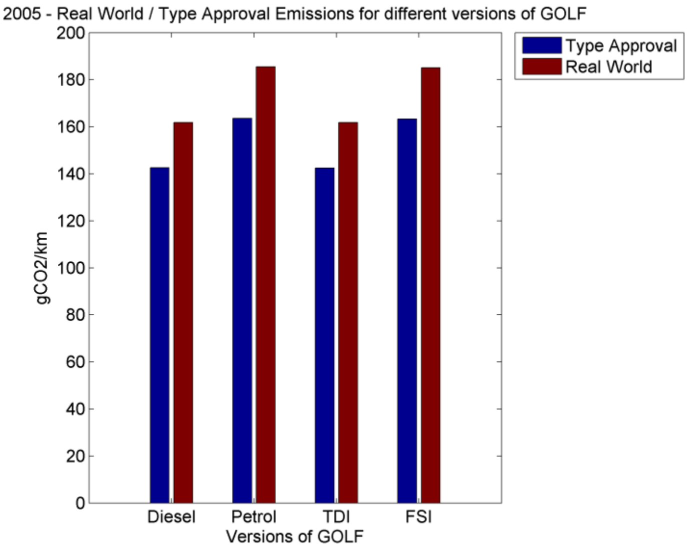


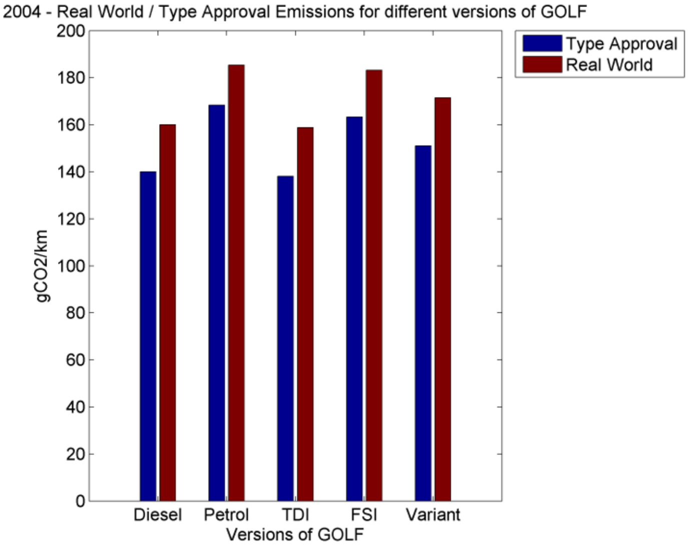


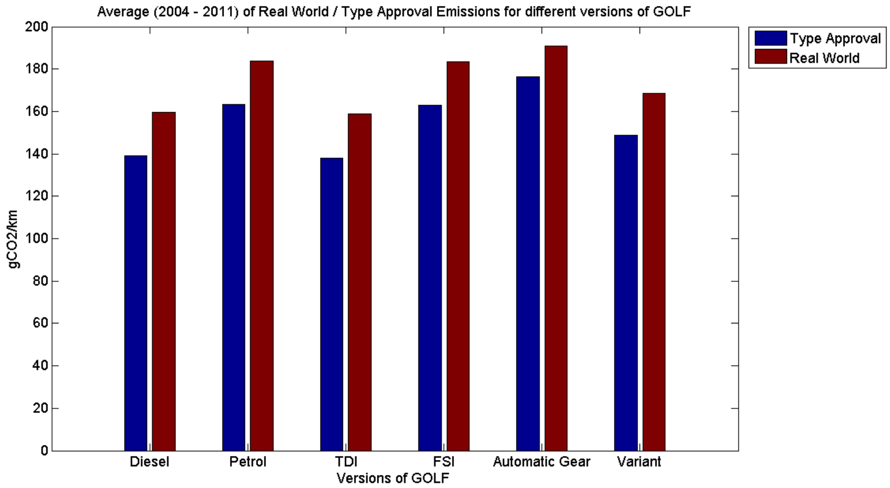



2007 - Real World / Type Approval Emissions for different versions of GOLF
gCO2/km
Type Approval
Real World
Diesel
Petrol
TDI
Versions of GOLF

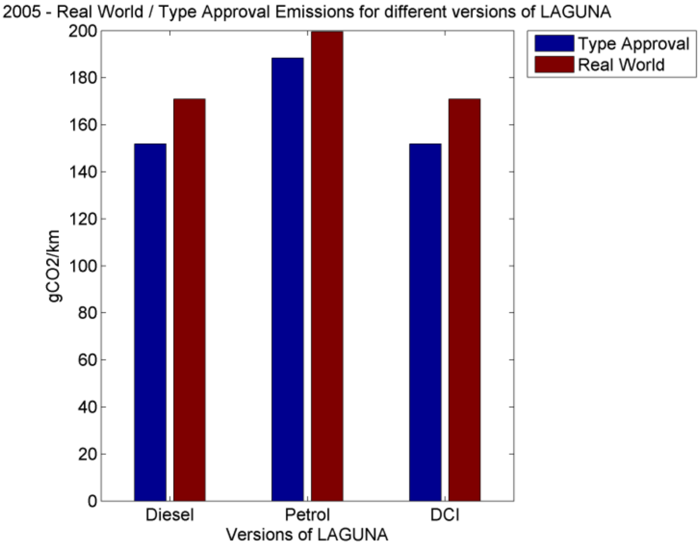

2006 - Real World / Type Approval Emissions for different versions of GOLF
gCO2/km
Type Approval
Real World
Diesel
Petrol
TDI
FSI
Versions of GOLF

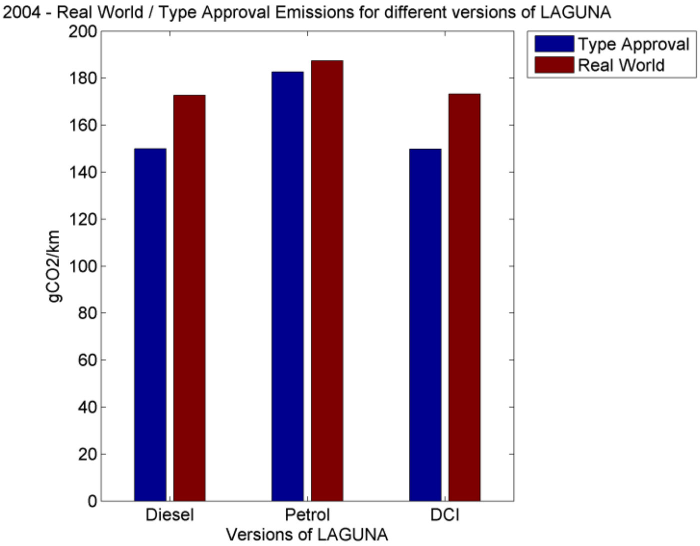

2005 - Real World / Type Approval Emissions for different versions of GOLF
gCO2/km
Type Approval
Real World
Diesel
Petrol
TDI
FSI
Versions of GOLF

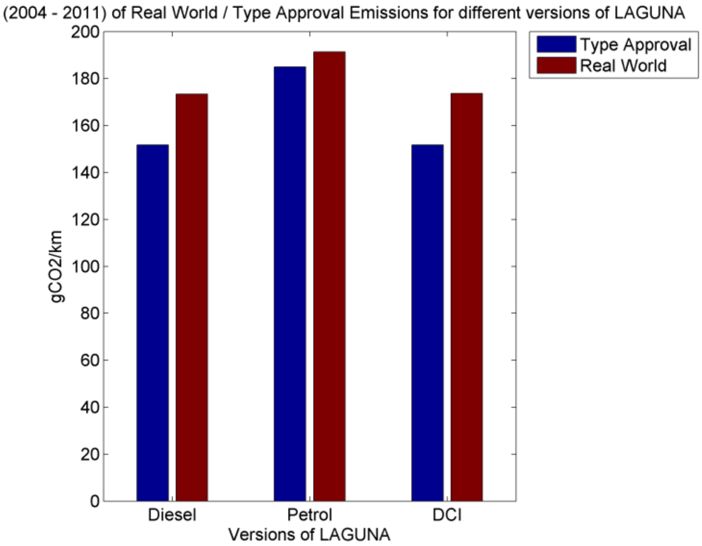

2004 - Real World / Type Approval Emissions for different versions of GOLF
Type Approval
Real World
gCO2/km
200
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDI
FSI
Variant
Versions of GOLF


Average (2004 - 2011) of Real World / Type Approval Emissions for different versions of GOLF
Type Approval
Real World
gCO2/km
200
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDI
FSI
Automatic Gear
Variant
Versions of GOLF

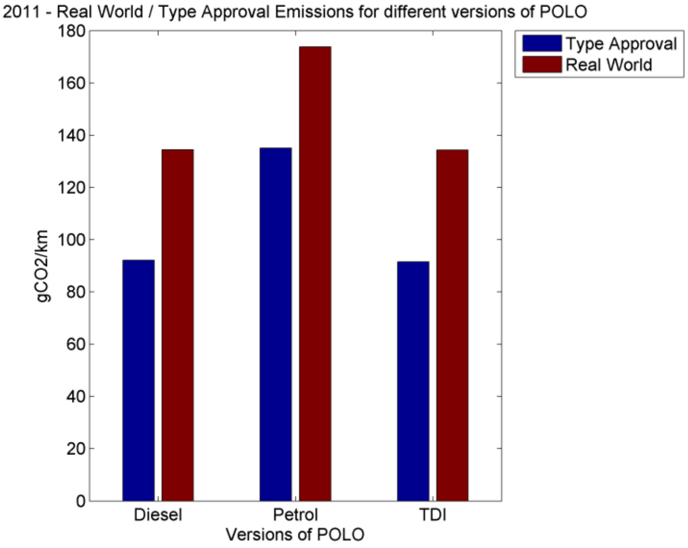
6.1.5 Renault Laguna comparison of versions

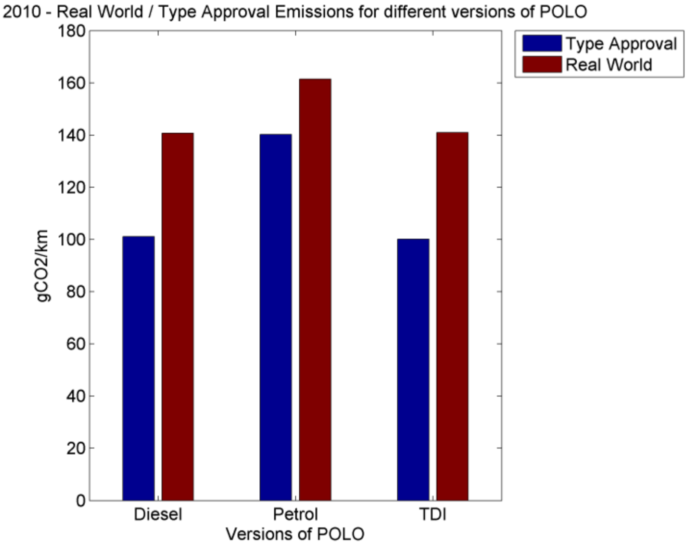


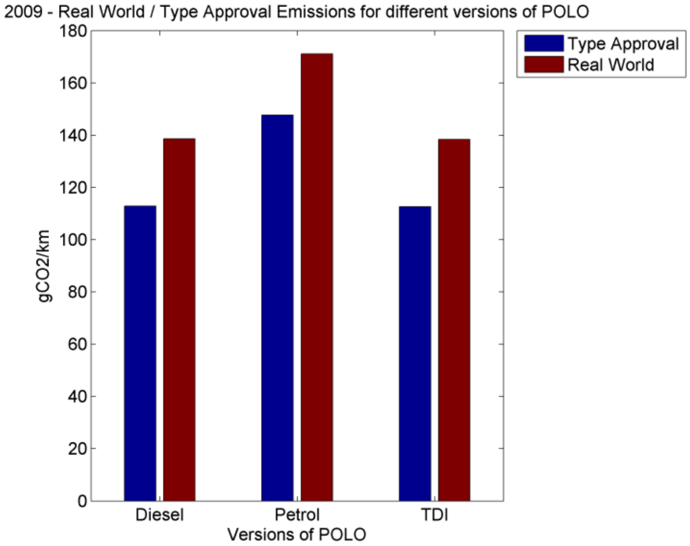


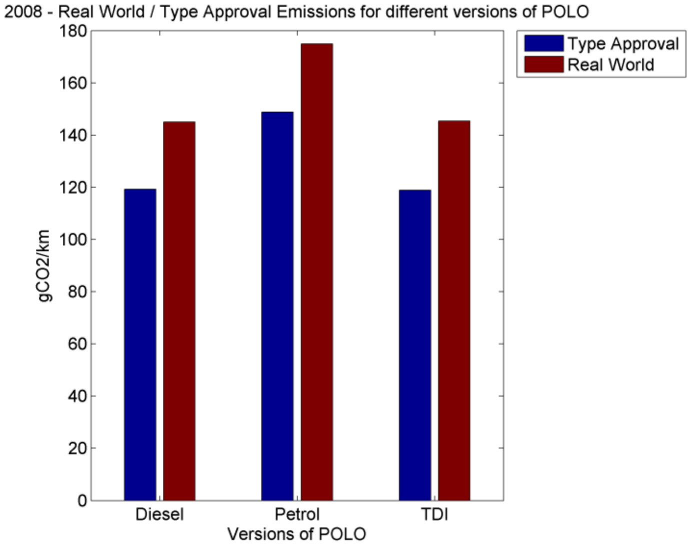

(2004 - 2011) of Real World / Type Approval Emissions for different versions of LAGUNA
Type Approval
Real World
gCO2/km
200
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
DCI
Versions of LAGUNA

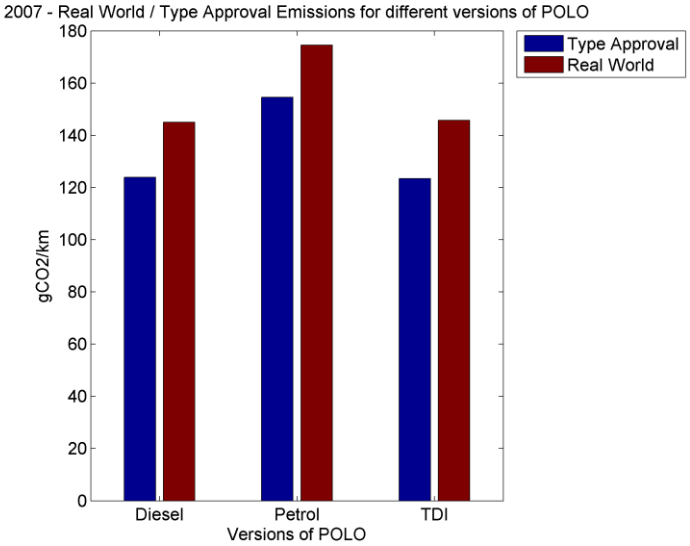
6.1.6 *Volkswagen Polo comparison of versions*

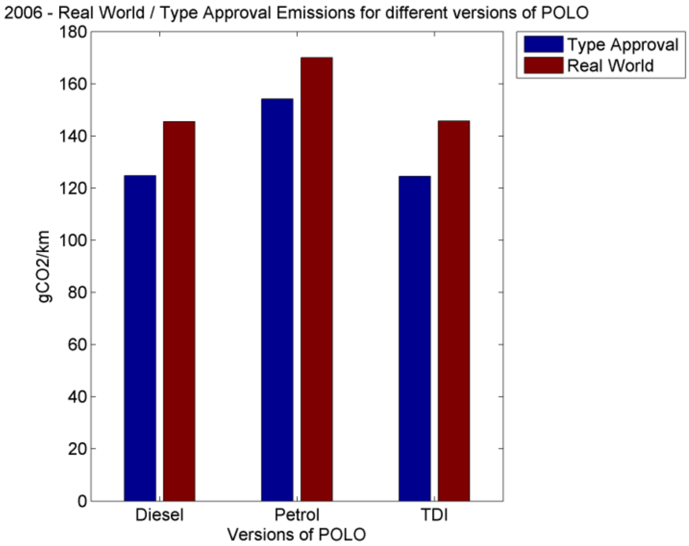


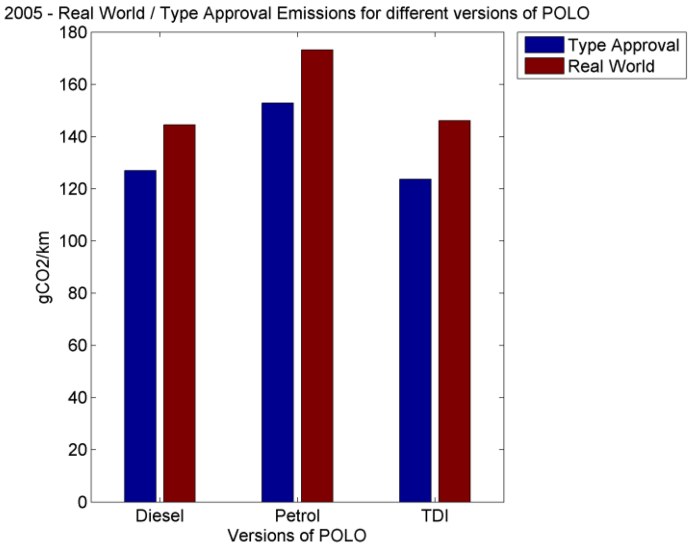


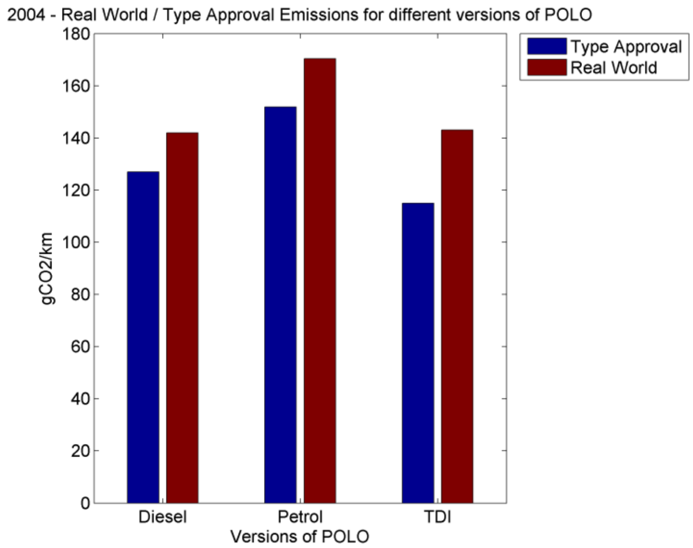

2009 - Real World / Type Approval Emissions for different versions of POLO
gCO2/km
180
160
140
120
100
80
60
40
20
0
Type Approval
Real World
Diesel
Petrol
TDI
Versions of POLO

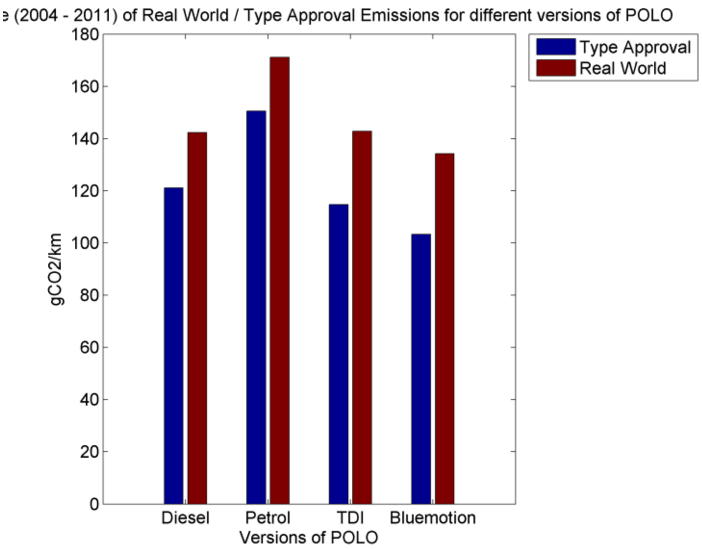

2008 - Real World / Type Approval Emissions for different versions of POLO
gCO2/km
180
160
140
120
100
80
60
40
20
0
Type Approval
Real World
Diesel
Petrol
TDI
Versions of POLO


2007 - Real World / Type Approval Emissions for different versions of POLO
gCO2/km
180
160
140
120
100
80
60
40
20
0
Type Approval
Real World
Diesel
Petrol
TDI
Versions of POLO

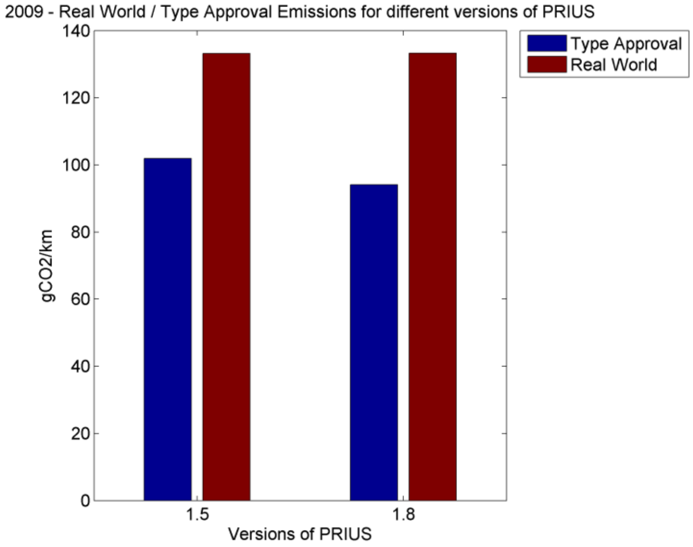

2006 - Real World / Type Approval Emissions for different versions of POLO
Type Approval
Real World
gCO2/km
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDI
Versions of POLO

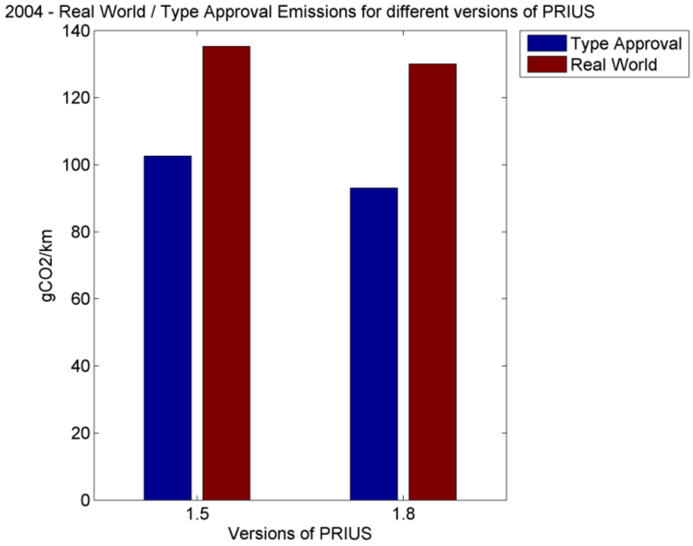

2005 - Real World / Type Approval Emissions for different versions of POLO
Type Approval
Real World
gCO2/km
180
160
140
120
100
80
60
40
20
0
Diesel
Petrol
TDI
Versions of POLO

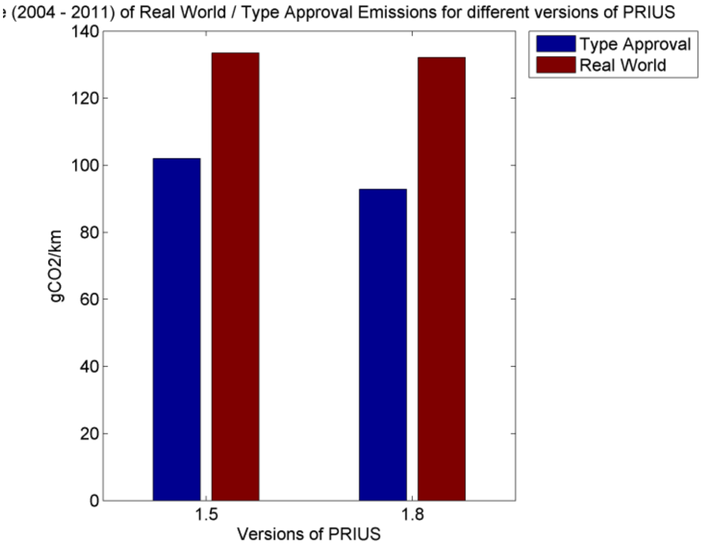

2004 - Real World / Type Approval Emissions for different versions of POLO
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
Diesel
Petrol
TDI
Versions of POLO


(2004 - 2011) of Real World / Type Approval Emissions for different versions of POLO
Type Approval
Real World
gCO2/km
0
20
40
60
80
100
120
140
160
180
Diesel
Petrol
TDI
Bluemotion
Versions of POLO

6.1.7 Toyota Prius comparison of versions







7 Evolution 2004 – 2011 for different manufacturers

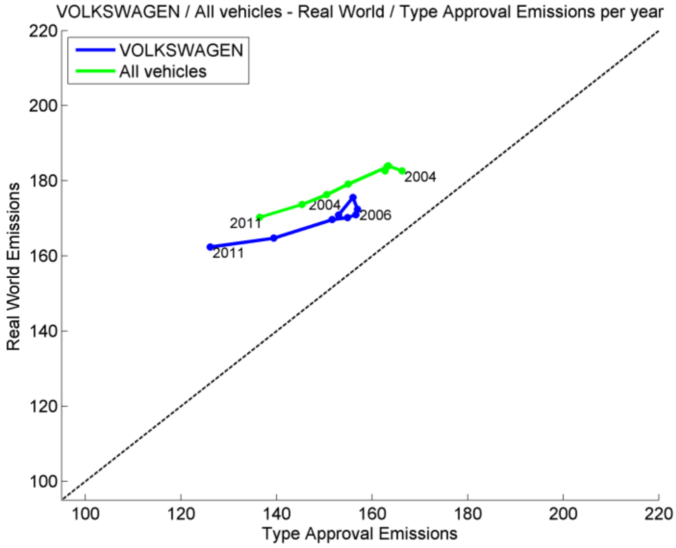
The following graphics depict the evolution in the ratio Real World emissions with Type Approval emissions. In the same graphic the evolution in the relation Real World emissions with Type Approval emissions for the whole vehicles of the Travelcard database is presented.

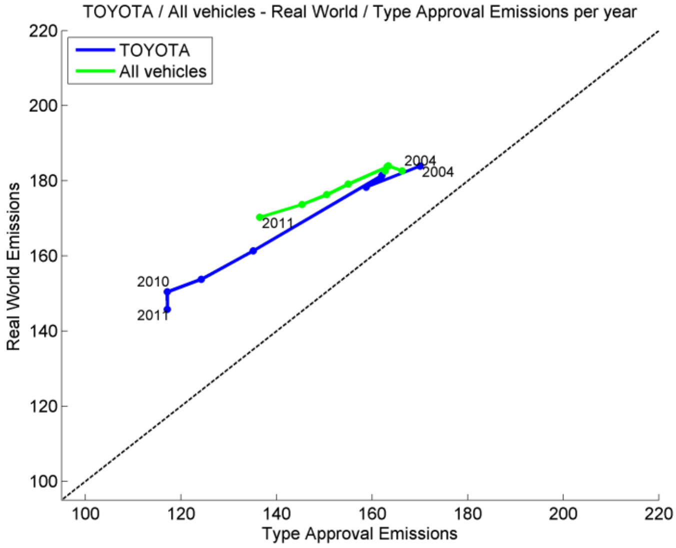
In the graphs, apart from the year-by-year evolution of the particular brand, also the evolution of the whole dataset is presented and a line where type approval is identical to the real-world fuel consumption. All brands more or less follow the same trend to lower fuel consumption, where the real world value decreases less than the type approval value. Some lines are below or above the average line. This means the vehicles perform better or worse than the average. Other lines a shifted along the average line, to the left or right. This means the average fleet of this manufacturer have on average lower, or higher, type approval values, but follow in basis the same trend. The notable example of the latter is Fiat which has a very low average type approval for 2011. However, the line in overlapping with the lower end of the average line.

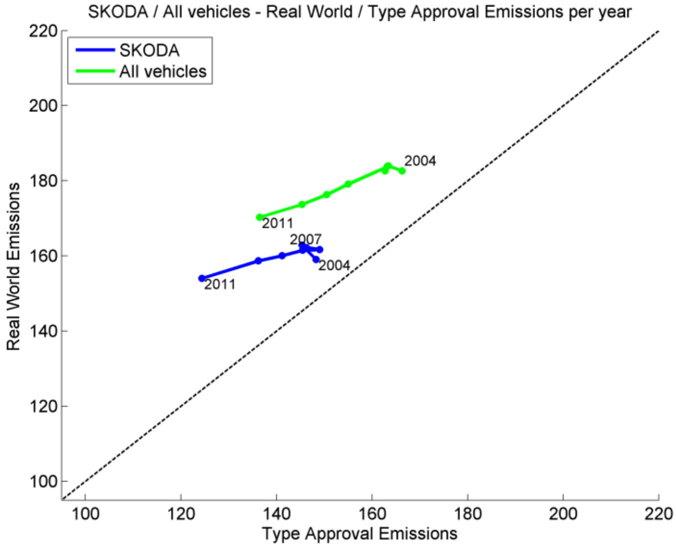
In essence, the trend of Fiat is the same as the average, except that in the Travelcard fleet a large number of small Fiats are present, i.e. Panda, Punto, 500, and Stilo. These Fiat vehicle also dominate the small vehicle market segment and show a large deviation associated with low type-approval values.

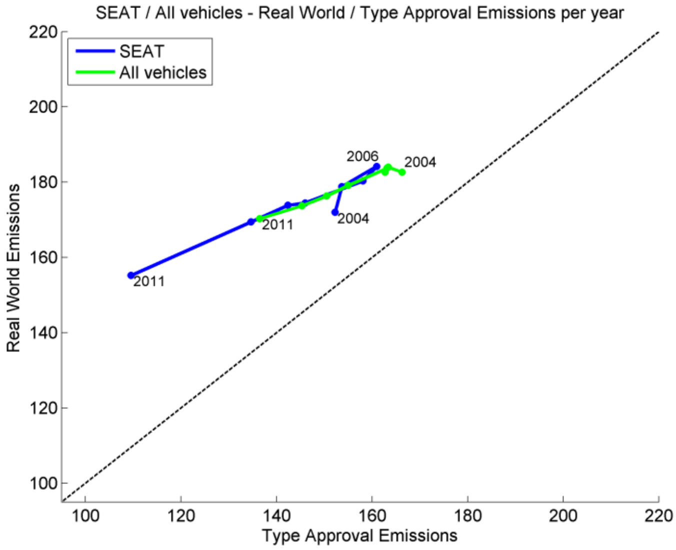
Another notable trend is for Mercedes. Only a few vehicles are available. Furthermore, there is a shift in the models over the years. Therefore, there is no clear trend visible over the years for Mercedes.

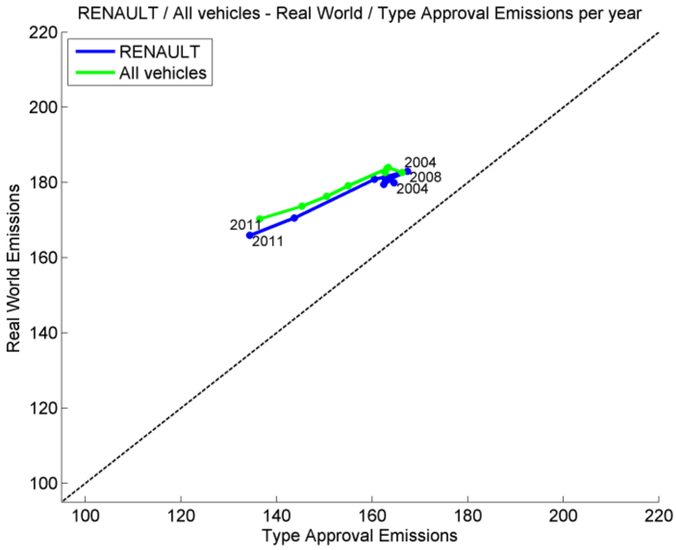
The last model year of the Citroen C5 has only limited vehicles underlying the data. Possibly the 2011 value is a outlier.

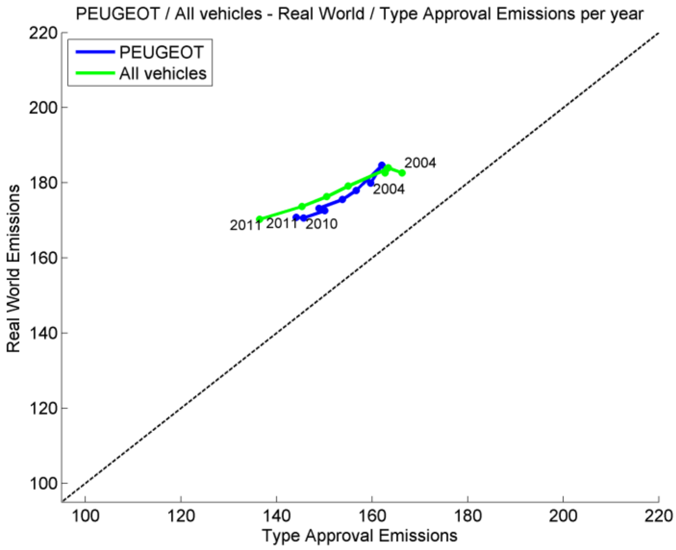

VOLKSWAGEN / All vehicles - Real World / Type Approval Emissions per year
VOLKSWAGEN
All vehicles
2004
2004
2006
2011
2011
Real World Emissions
Type Approval Emissions

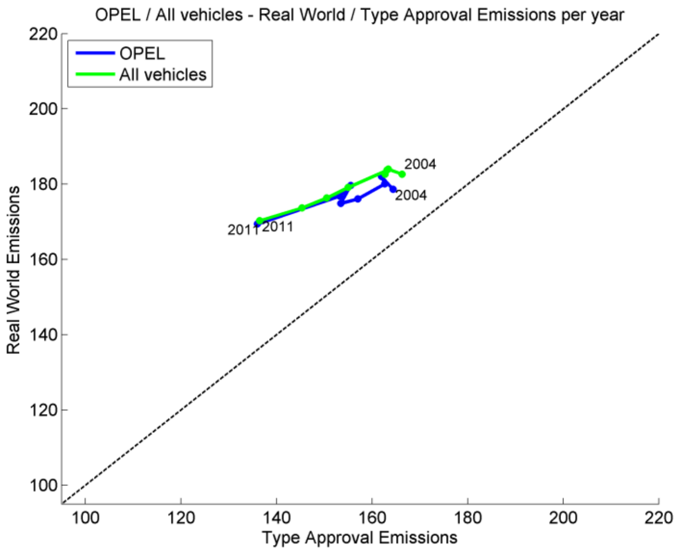

TOYOTA / All vehicles - Real World / Type Approval Emissions per year
TOYOTA
All vehicles
2004
2004
2011
2010
2011
Real World Emissions
Type Approval Emissions

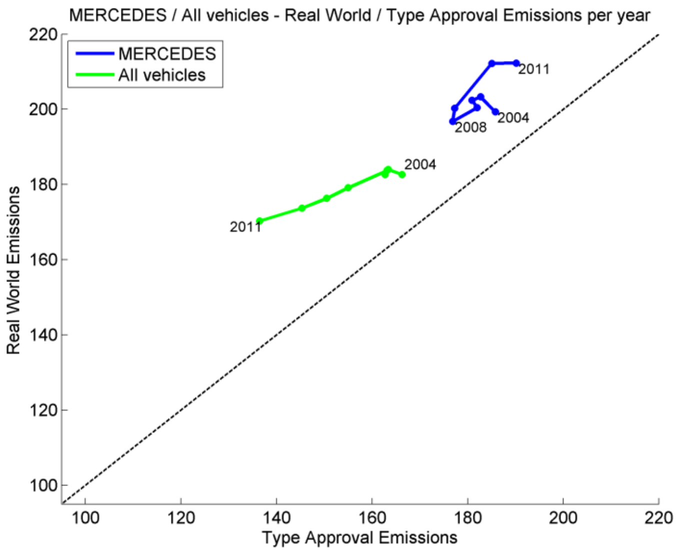

SKODA / All vehicles - Real World / Type Approval Emissions per year
SKODA
All vehicles
2004
2011
2007
2004
2011
Real World Emissions
Type Approval Emissions

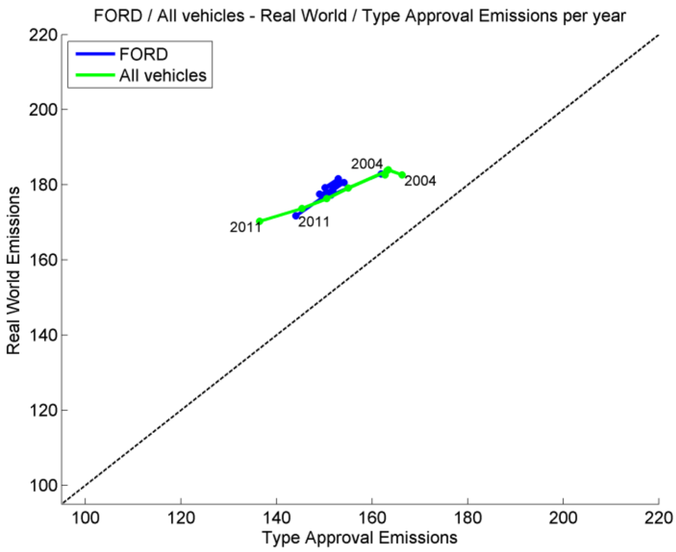

SEAT / All vehicles - Real World / Type Approval Emissions per year
SEAT
All vehicles
2006
2004
2011
2004
2011
Real World Emissions
Type Approval Emissions
220
200
180
160
140
120
100
100
120
140
160
180
200
220

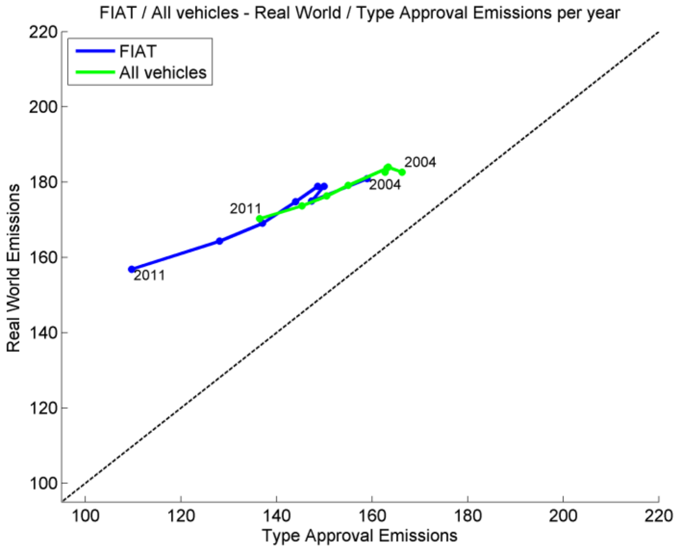

RENAULT / All vehicles - Real World / Type Approval Emissions per year
RENAULT
All vehicles
2004
2008
2004
2011
2011
Real World Emissions
Type Approval Emissions
220
200
180
160
140
120
100
100
120
140
160
180
200
220

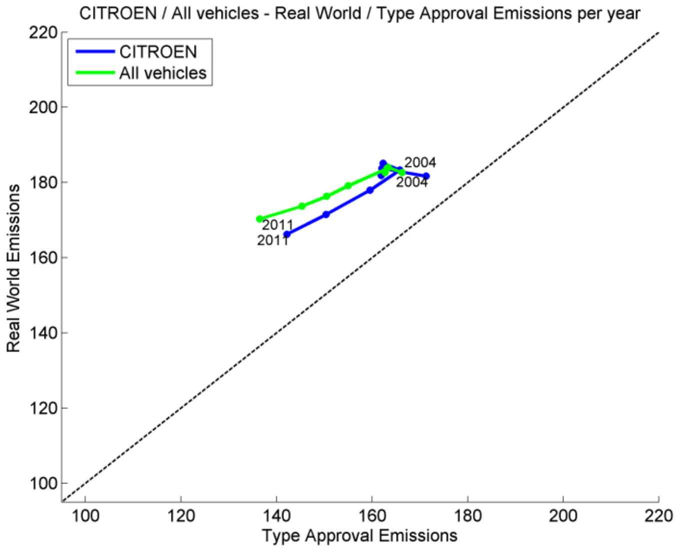

PEUGEOT / All vehicles - Real World / Type Approval Emissions per year
PEUGEOT
All vehicles
2004
2004
2011
2011
2010
Real World Emissions
Type Approval Emissions
220
200
180
160
140
120
100
100
120
140
160
180
200
220

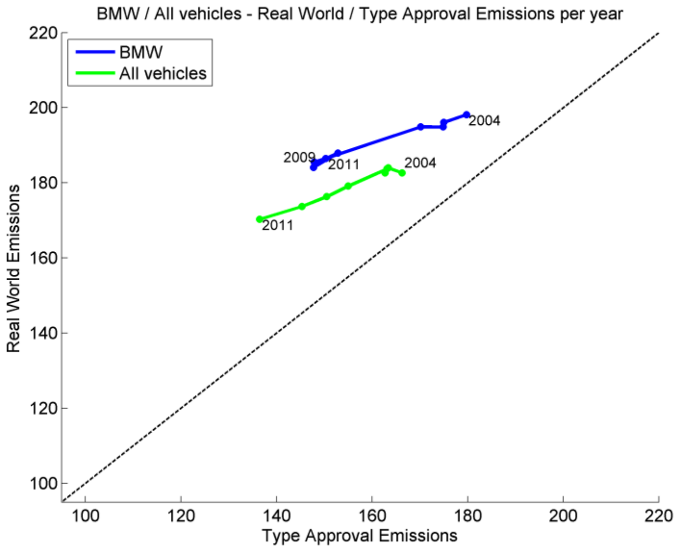

OPEL / All vehicles - Real World / Type Approval Emissions per year
OPEL
All vehicles
2004
2004
2011
2011
Real World Emissions
Type Approval Emissions
100
120
140
160
180
200
220

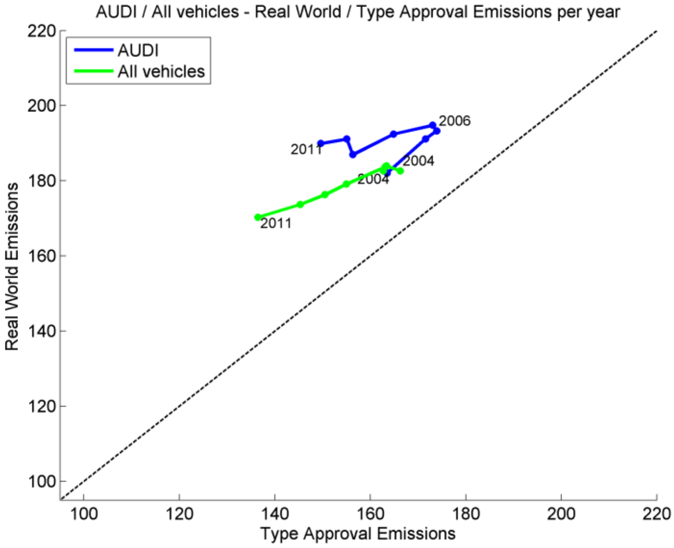

MERCEDES / All vehicles - Real World / Type Approval Emissions per year
MERCEDES
All vehicles
2011
2008
2004
2004
2011
Real World Emissions
Type Approval Emissions
100
120
140
160
180
200
220

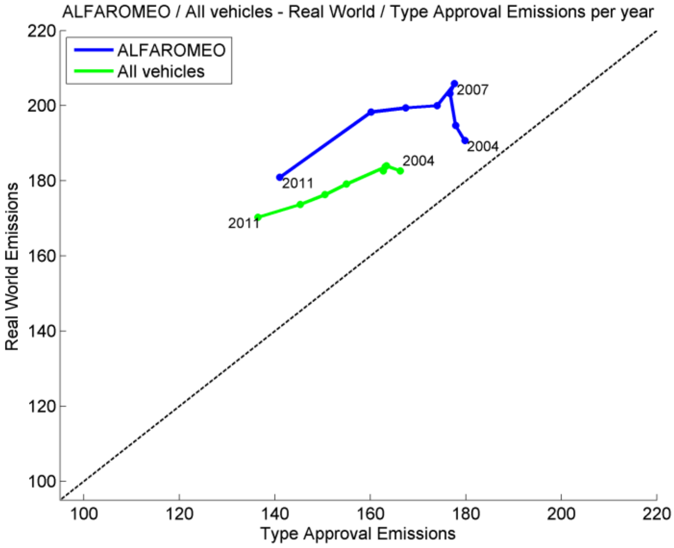

FORD / All vehicles - Real World / Type Approval Emissions per year
FORD
All vehicles
2004
2004
2011
2011
Real World Emissions
Type Approval Emissions
100
120
140
160
180
200
220

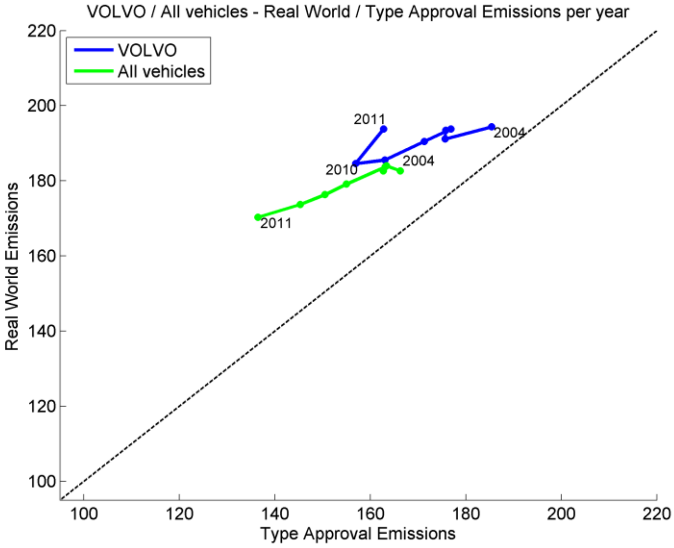

FIAT / All vehicles - Real World / Type Approval Emissions per year
FIAT
All vehicles
2004
2004
2011
2011
Real World Emissions
Type Approval Emissions
100
120
140
160
180
200
220


CITROEN / All vehicles - Real World / Type Approval Emissions per year
CITROEN
All vehicles
2004
2004
2011
2011
Real World Emissions
Type Approval Emissions
100
120
140
160
180
200
220


BMW / All vehicles - Real World / Type Approval Emissions per year
BMW
All vehicles
2004
2009
2011
2004
2011
Real World Emissions
Type Approval Emissions
100
120
140
160
180
200
220

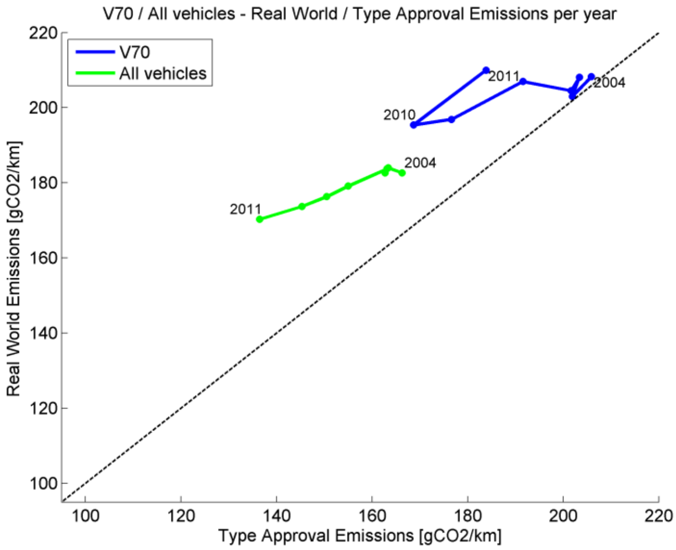

AUDI / All vehicles - Real World / Type Approval Emissions per year
AUDI
All vehicles
2006
2011
2004
2004
2011
Real World Emissions
Type Approval Emissions
220
200
180
160
140
120
100
100
120
140
160
180
200
220

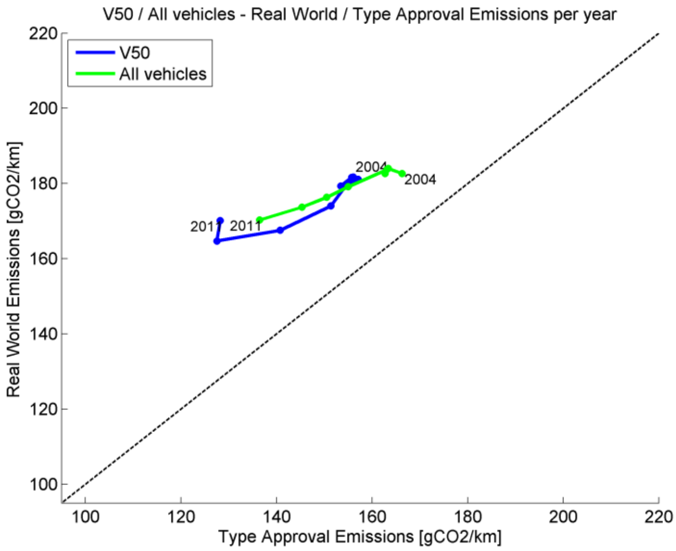

ALFAROMEO / All vehicles - Real World / Type Approval Emissions per year
ALFAROMEO
All vehicles
2007
2004
2004
2011
2011
Real World Emissions
Type Approval Emissions
220
200
180
160
140
120
100
100
120
140
160
180
200
220

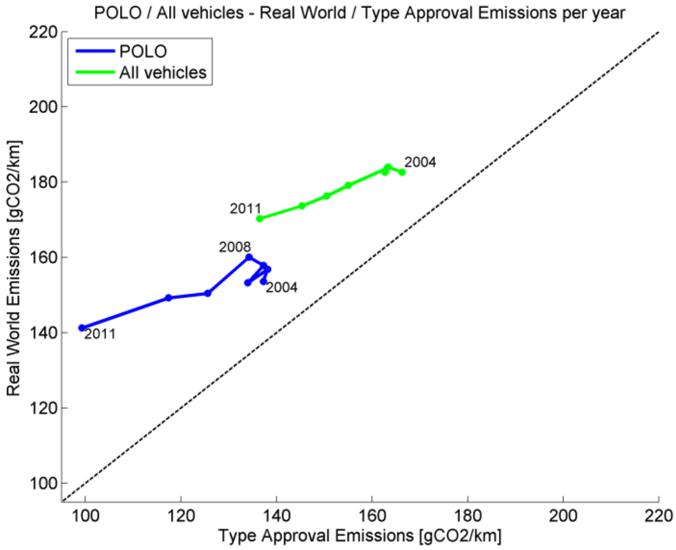

VOLVO / All vehicles - Real World / Type Approval Emissions per year
VOLVO
All vehicles
2011
2004
2004
2010
2011
Real World Emissions
Type Approval Emissions
220
200
180
160
140
120
100
100
120
140
160
180
200
220

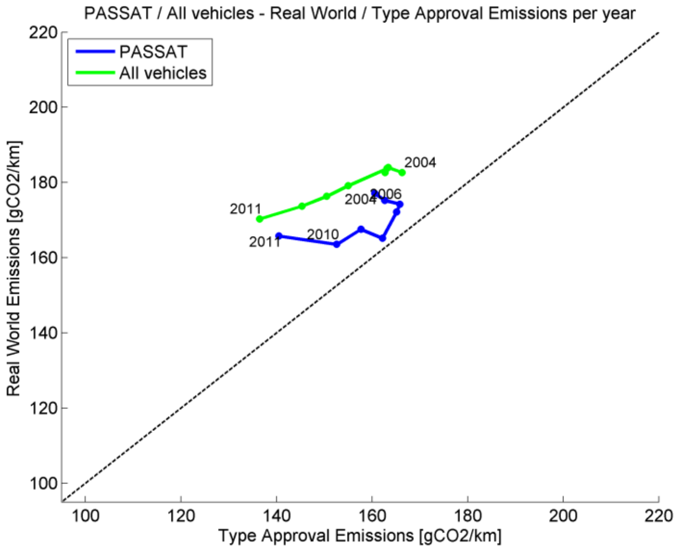
8 Evolution 2004 – 2011 for different models

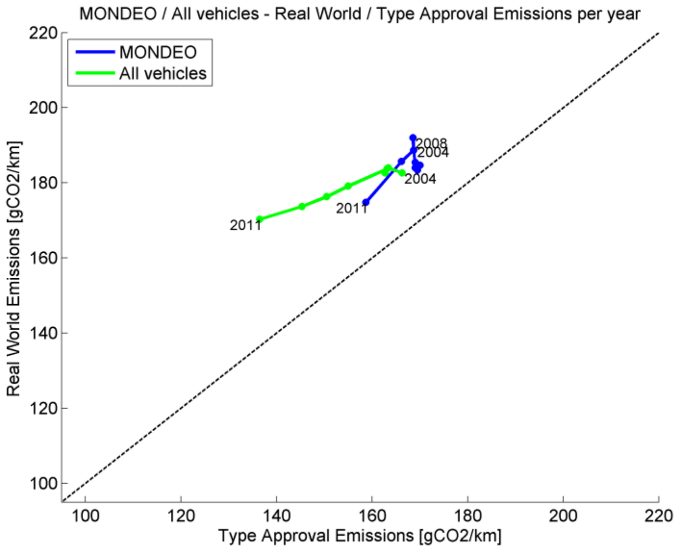
The evolution presented in the previous graphics for the relation real world / type approval models is presented in this section for the top 15 models of the Travelcard database.

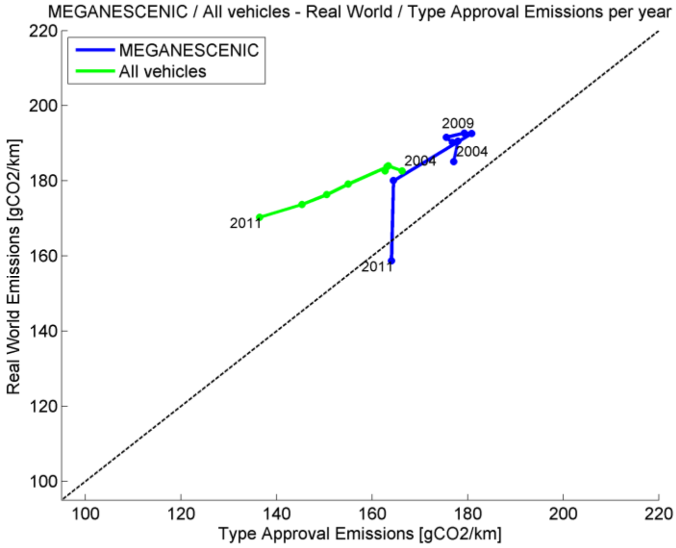


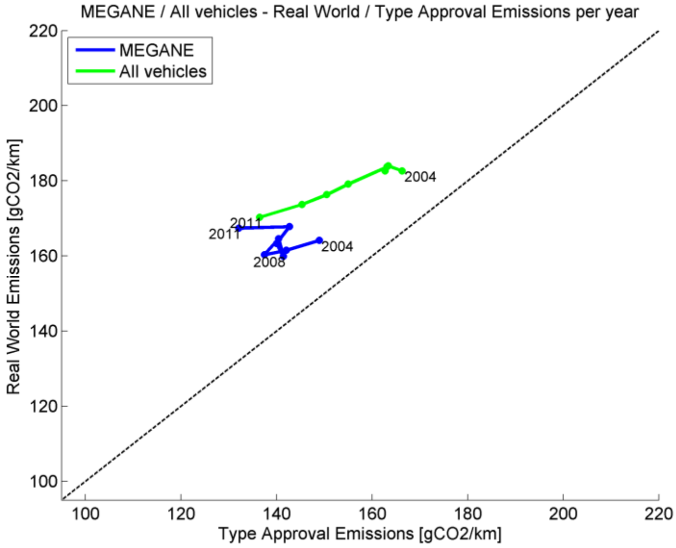


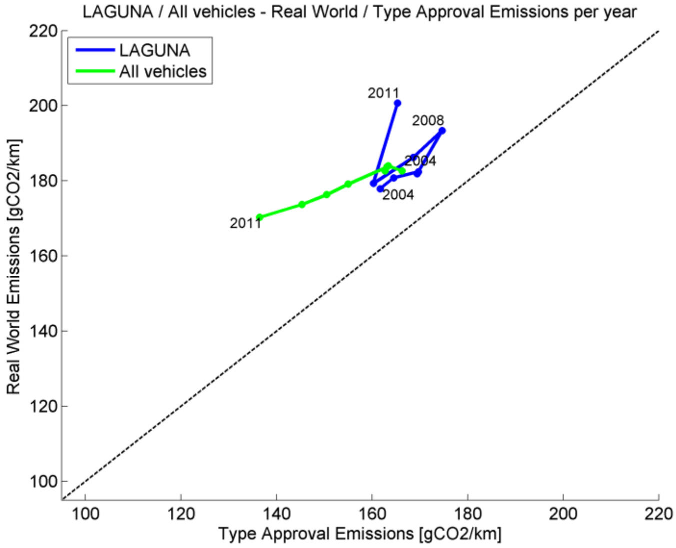

POLO / All vehicles - Real World / Type Approval Emissions per year
POLO
All vehicles
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2008
2004
2011
100
120
140
160
180
200
220

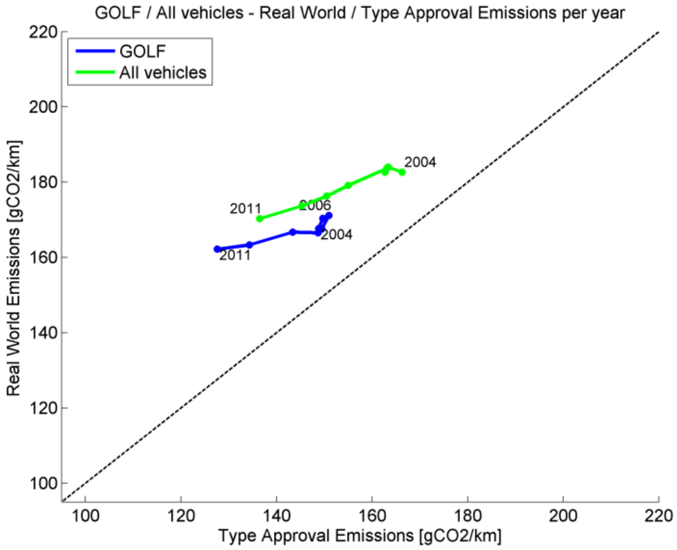

PASSAT / All vehicles - Real World / Type Approval Emissions per year
PASSAT
All vehicles
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2004
2006
2010
2011
100
120
140
160
180
200
220

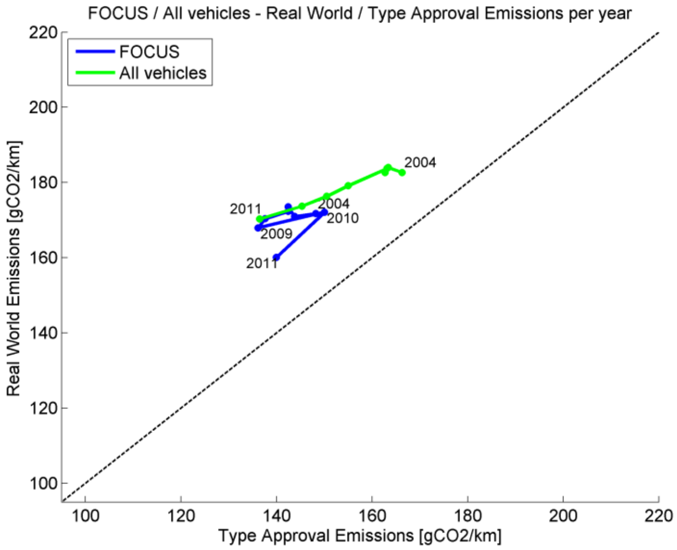

MONDEO / All vehicles - Real World / Type Approval Emissions per year
MONDEO
All vehicles
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2008
2004
2004
2011
2011
100
120
140
160
180
200
220

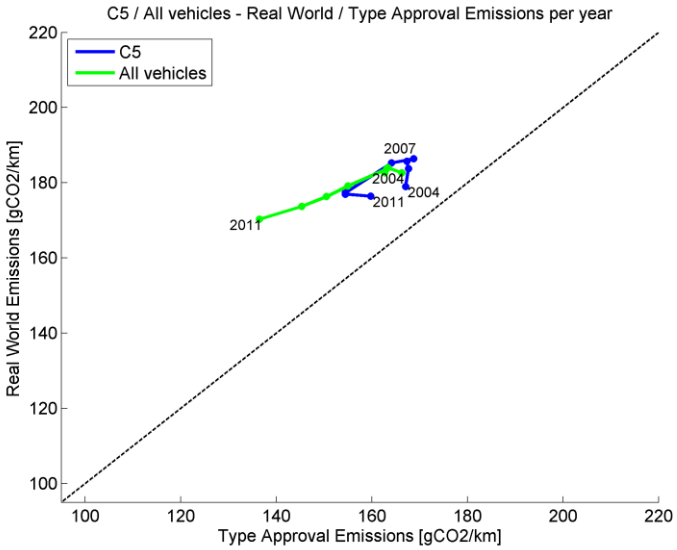

MEGANESCENIC / All vehicles - Real World / Type Approval Emissions per year
MEGANESCENIC
All vehicles
2009
2004
2004
2011
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]

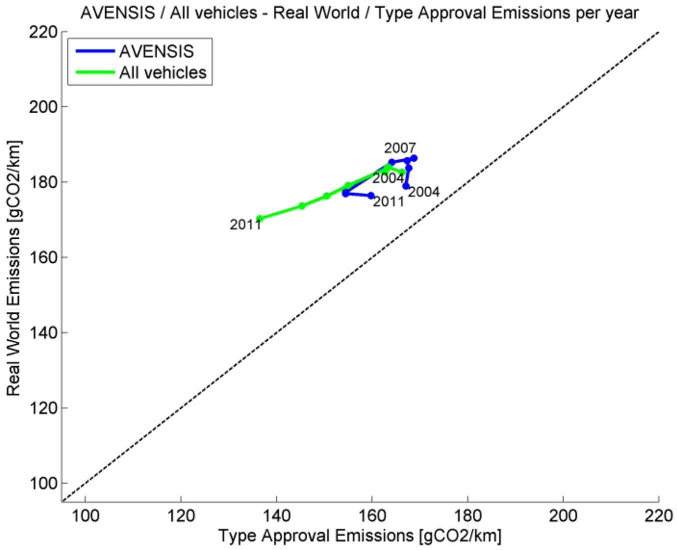

MEGANE / All vehicles - Real World / Type Approval Emissions per year
MEGANE
All vehicles
2004
2011
2011
2004
2008
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]

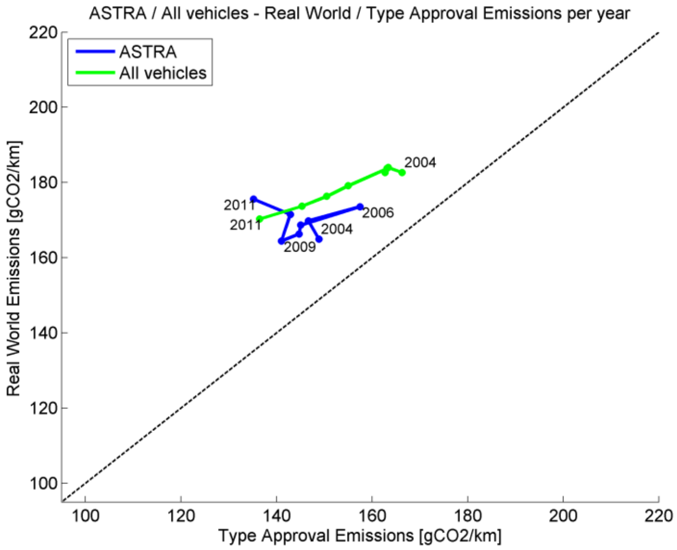

LAGUNA / All vehicles - Real World / Type Approval Emissions per year
LAGUNA
All vehicles
2011
2008
2004
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]

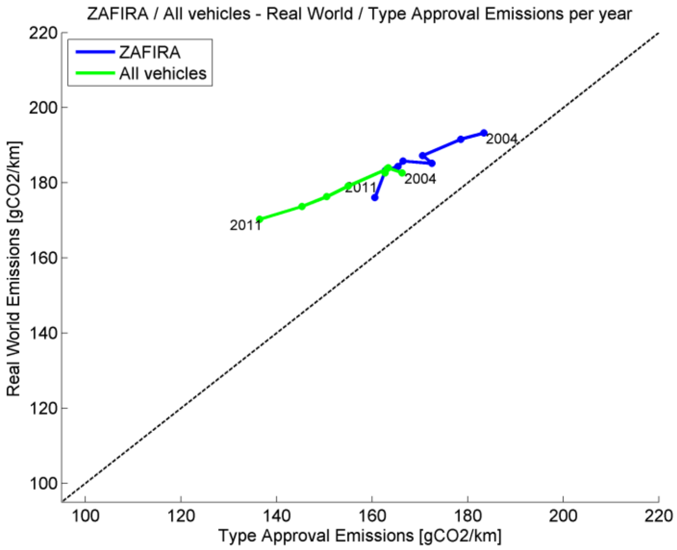

GOLF / All vehicles - Real World / Type Approval Emissions per year
GOLF
All vehicles
2004
2011
2006
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220

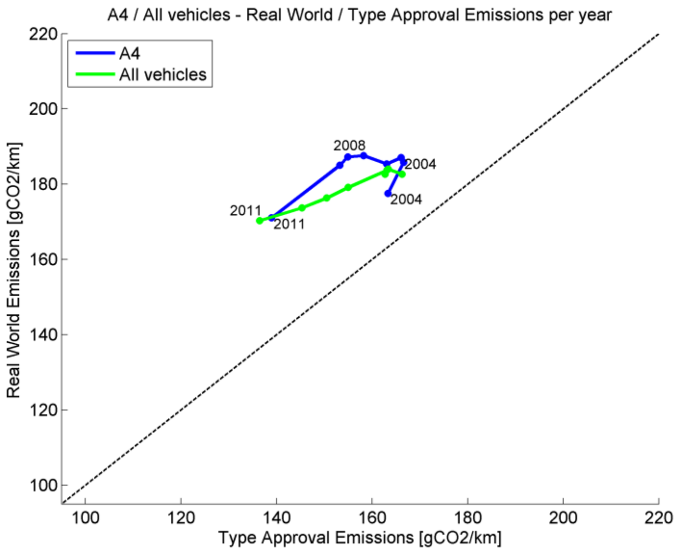

FOCUS / All vehicles - Real World / Type Approval Emissions per year
FOCUS
All vehicles
2004
2011
2004
2010
2009
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220


C5 / All vehicles - Real World / Type Approval Emissions per year
C5
All vehicles
2007
2004
2004
2011
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220


AVENSIS / All vehicles - Real World / Type Approval Emissions per year
AVENSIS
All vehicles
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2007
2004
2004
2011
2011
100
120
140
160
180
200
220

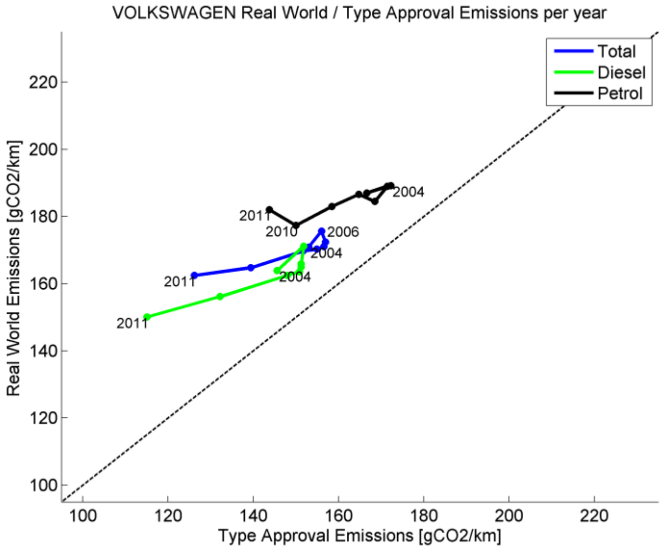

ASTRA / All vehicles - Real World / Type Approval Emissions per year
ASTRA
All vehicles
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2011
2006
2004
2009
100
120
140
160
180
200
220

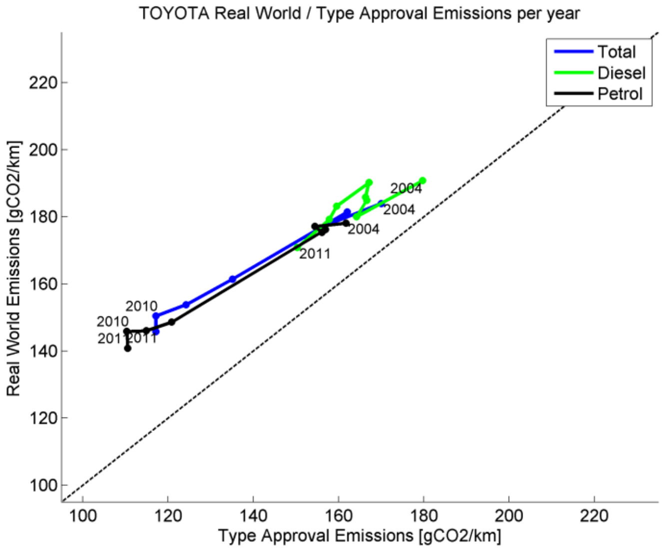

ZAFIRA / All vehicles - Real World / Type Approval Emissions per year
ZAFIRA
All vehicles
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2004
2011
100
120
140
160
180
200
220

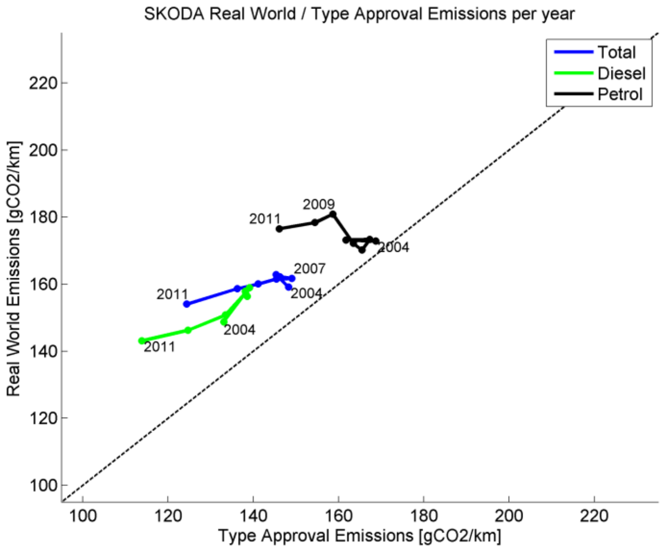


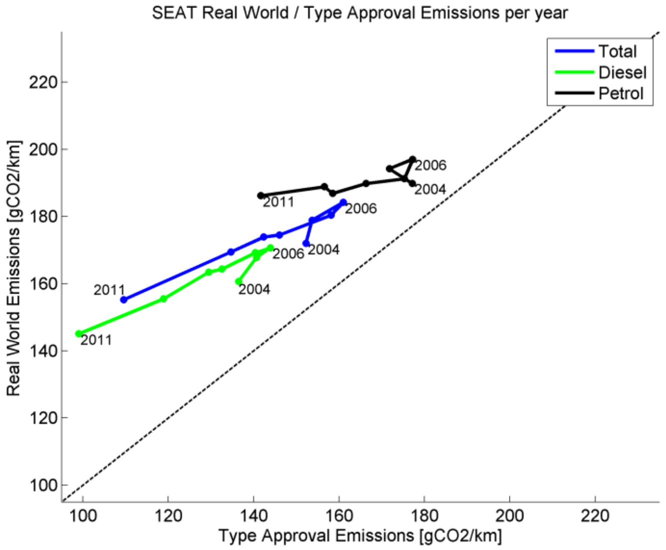
8.1 Evolution 2004 – 2011 of different models and fuel types

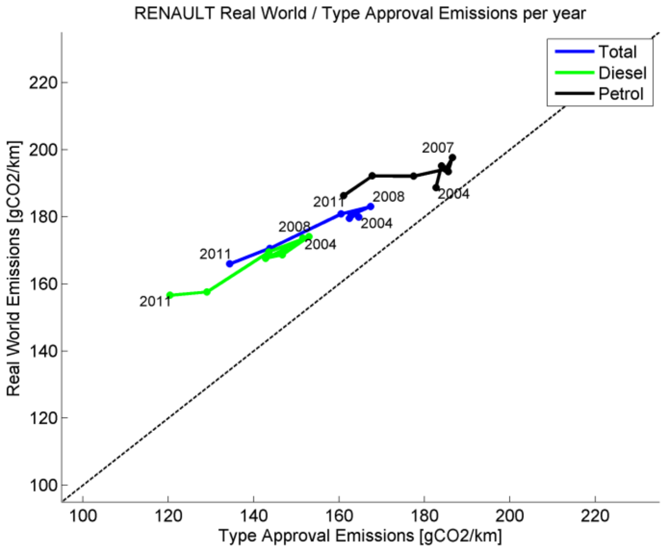
In the following graphics the evolution of the relation real world / type approval emissions is presented for different manufacturers in the period 2004 – 2011. The results also include separate curves for the diesel and petrol vehicles of each of the manufacturers.

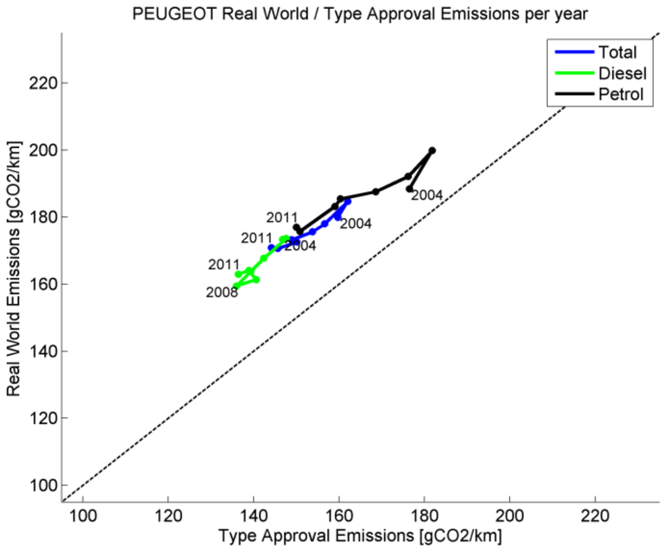

VOLKSWAGEN Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2010
2006
2004
2011
2004
2011

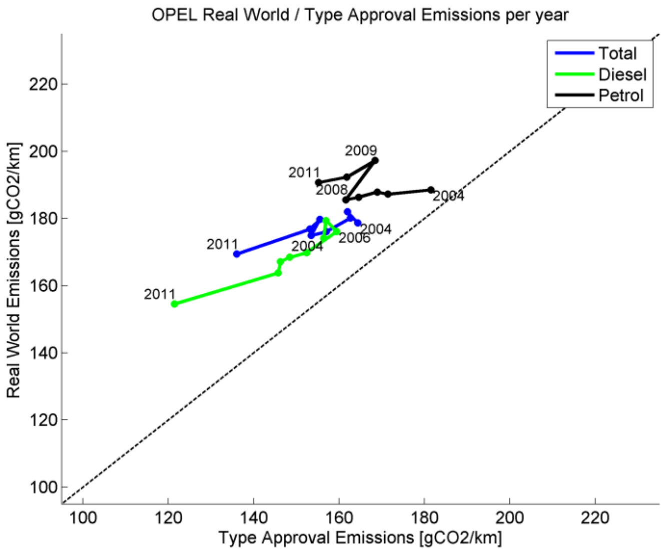

TOYOTA Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2004
2004
2011
2010
2010
2011
2011

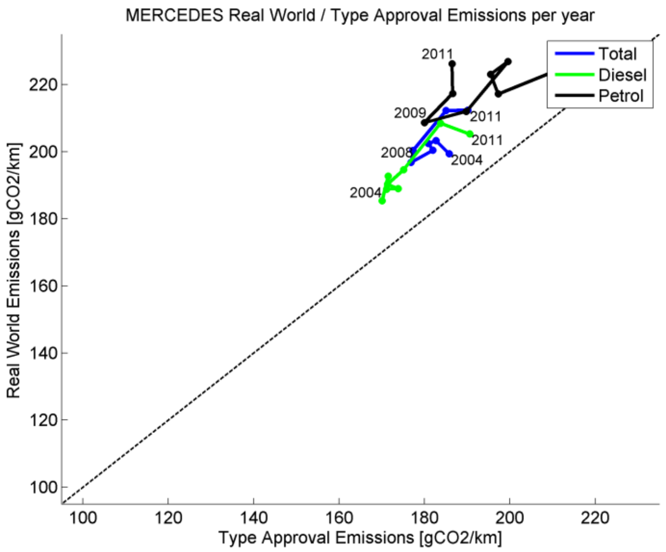

SKODA Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2009
2011
2004
2007
2011
2004
2004
2011

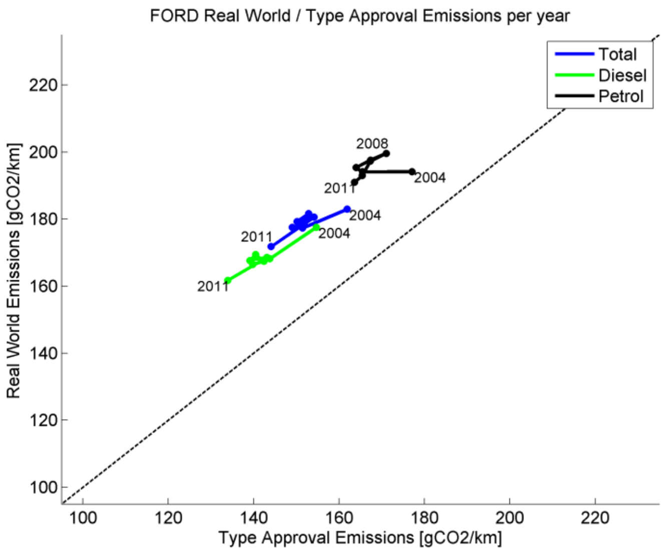

SEAT Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2011
2006
2004
2011
2006
2004
2011
2006
2004
2011

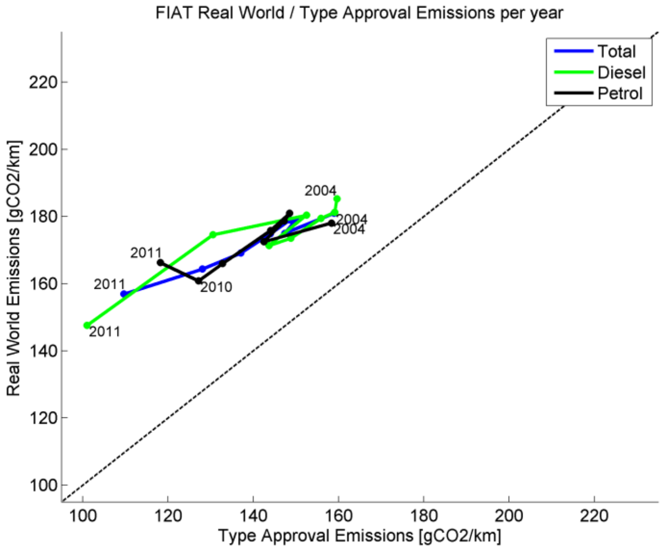

RENAULT Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2007
2004
2011
2008
2004
2008
2004
2011
2011

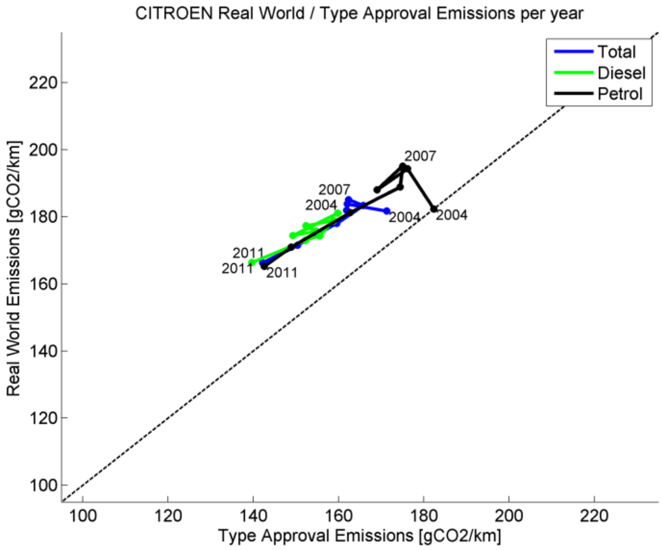

PEUGEOT Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2004
2011
2004
2011
2008

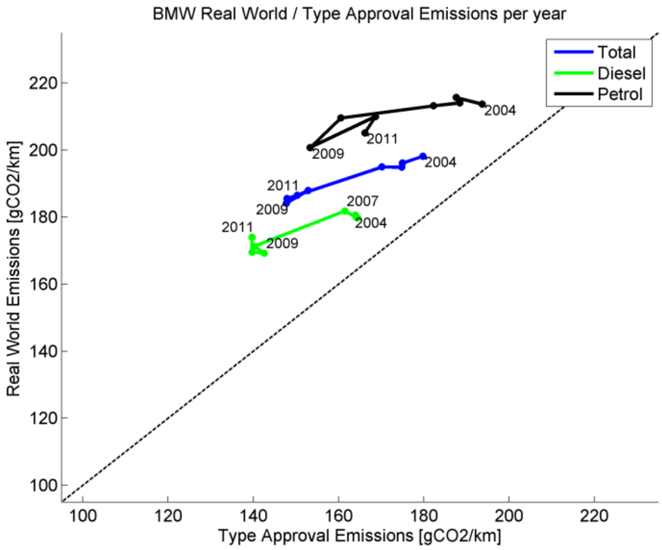

OPEL Real World / Type Approval Emissions per year
Total
Diesel
Petrol
2009
2011
2008
2004
2004
2006
2011
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220

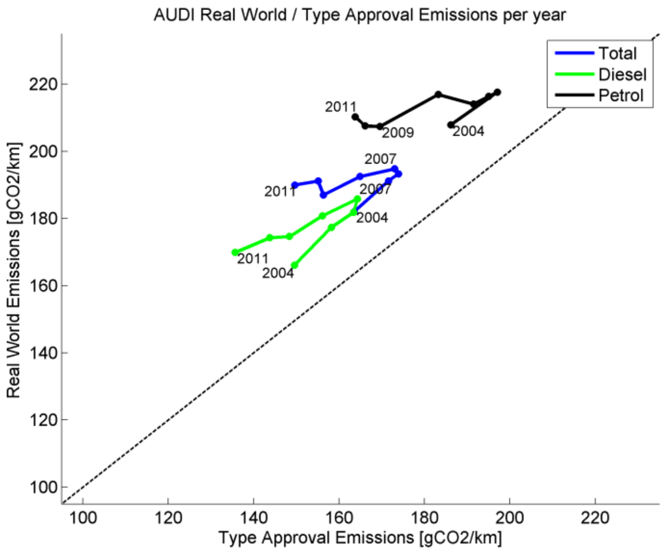

MERCEDES Real World / Type Approval Emissions per year
Total
Diesel
Petrol
2011
2009
2011
2011
2008
2004
2004
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220

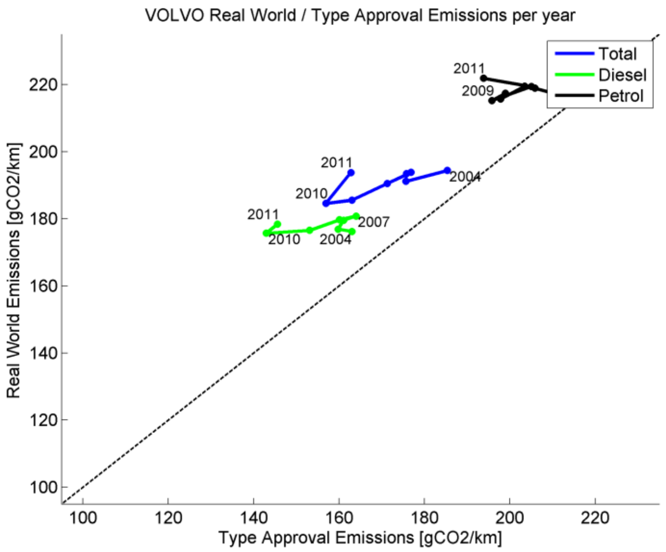

FORD Real World / Type Approval Emissions per year
Total
Diesel
Petrol
2008
2004
2011
2004
2011
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220

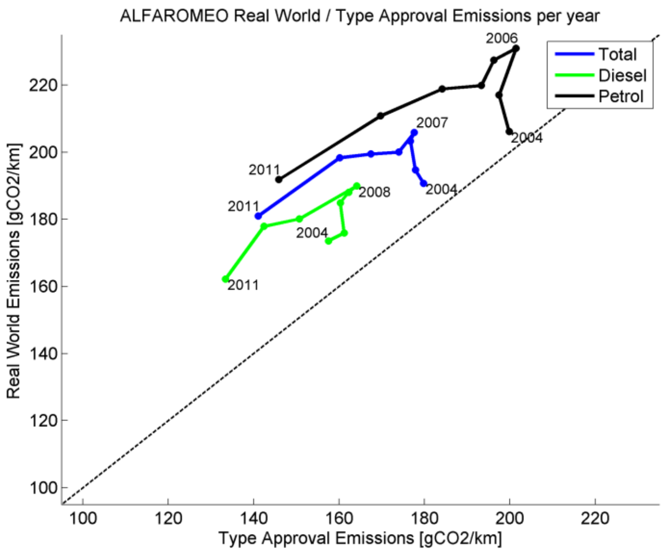

FIAT Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2004
2004
2011
2011
2010
2011
100
120
140
160
180
200
220


CITROEN Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2007
2007
2004
2004
2004
2011
2011
2011
100
120
140
160
180
200
220


BMW Real World / Type Approval Emissions per year
Total
Diesel
Petrol
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
2004
2011
2009
2004
2011
2009
2007
2004
2011
2009
100
120
140
160
180
200
220


AUDI Real World / Type Approval Emissions per year
Total
Diesel
Petrol
2011
2009
2004
2007
2011
2007
2004
2011
2004
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220


VOLVO Real World / Type Approval Emissions per year
Total
Diesel
Petrol
2011
2009
2011
2010
2004
2011
2010
2004
2007
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220

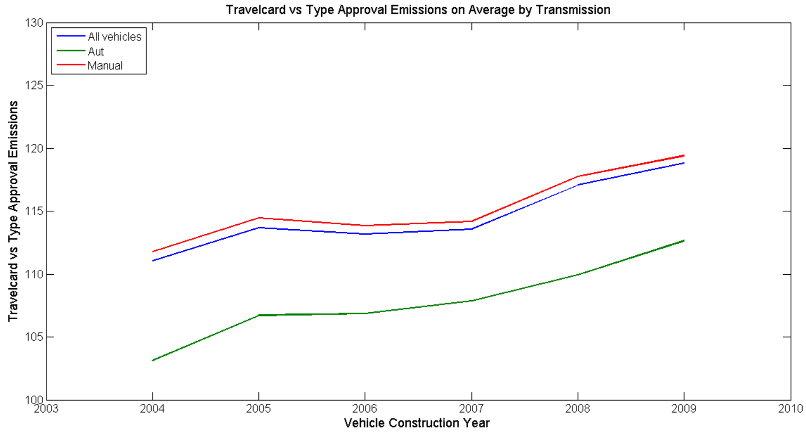

ALFAROMEO Real World / Type Approval Emissions per year
2006
Total
Diesel
Petrol
2007
2004
2011
2011
2008
2004
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
100
120
140
160
180
200
220

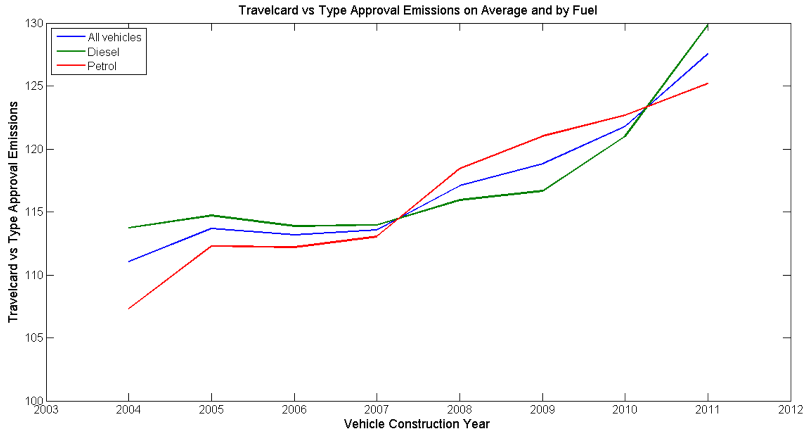
9 General Trends

This section indicates for the global dataset the evolution [in %] of the relation type approval/real world emissions for the different years included in the Travelcard database.

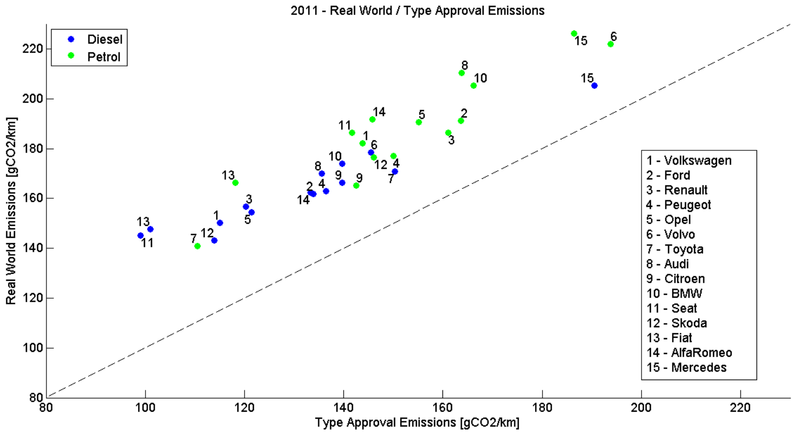
9.1 Automatic transmission

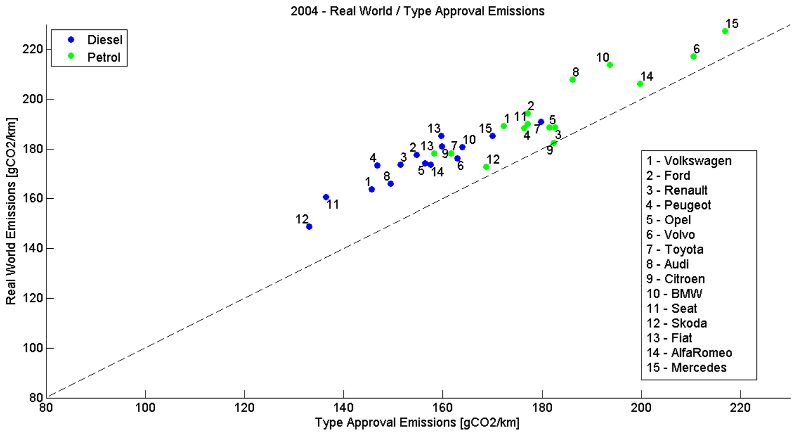
In The Netherlands automatic transmission is rather uncommon: about 8% of the vehicles have automatic transmission. There is a wide range of technology available. The historically large increase in fuel consumption for is absent for the newer vehicles, especially in the higher market segments.

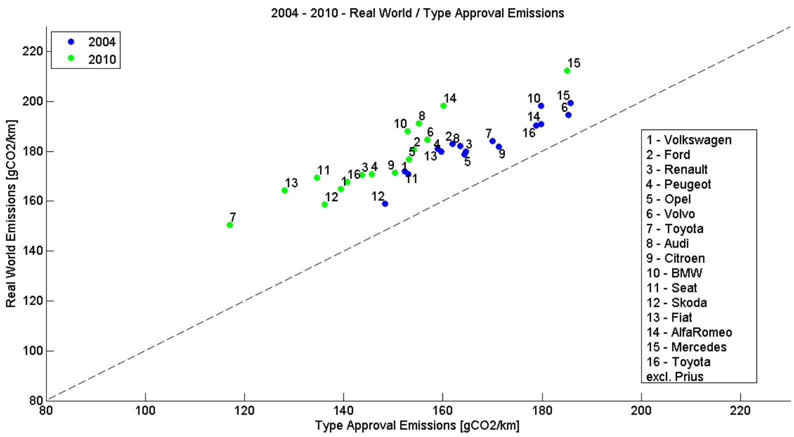


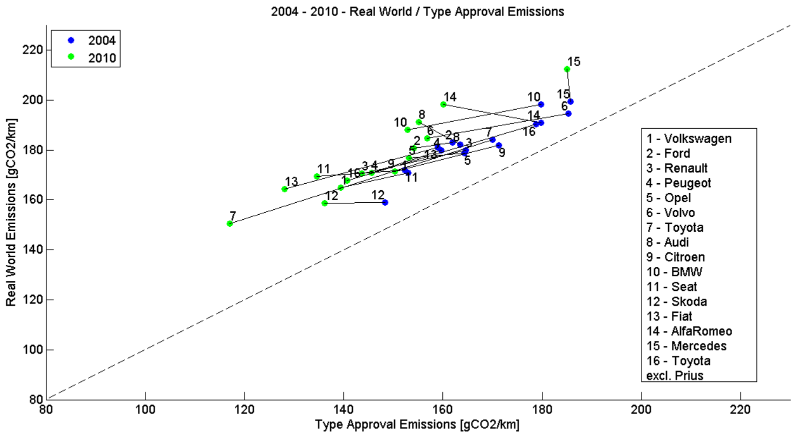


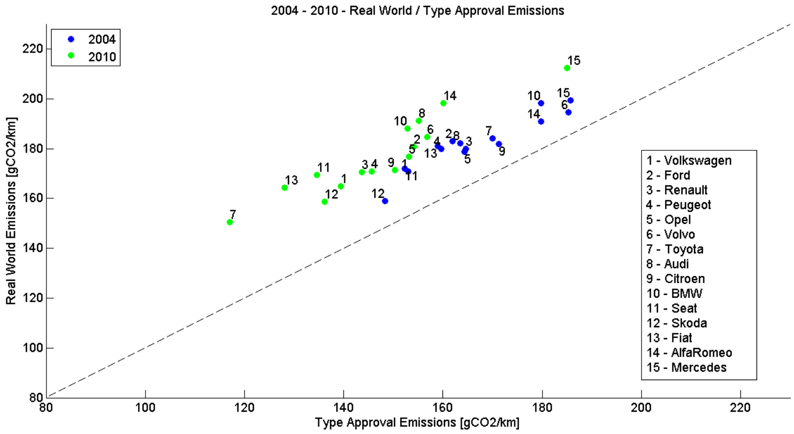
The following scatter plots depict the relation between real world and type approval emissions for the different manufacturers subject to analysis and considering different fuel types. In the case of the manufacturers a separate analysis is performed for the years 2004 and 2011. The global average for each manufacturer was measured in the period 2004 – 2010 due to the reduced sampling of some brands for the year 2011. For the models an analysis was made based on the variation of the relation real world / type approval emissions in the period 2004 - 2011.

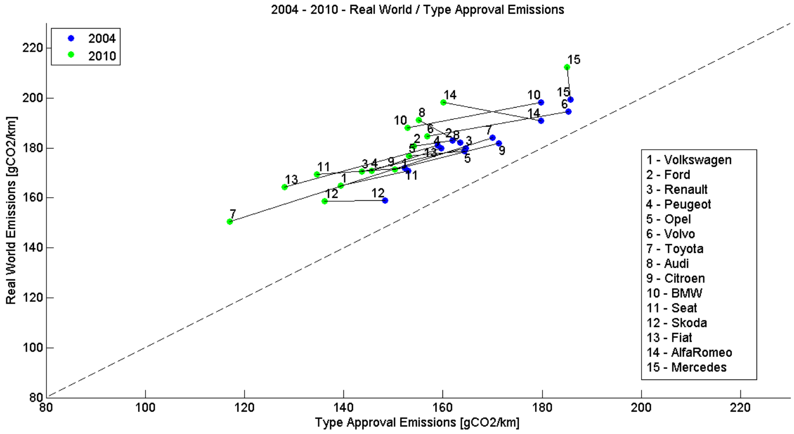


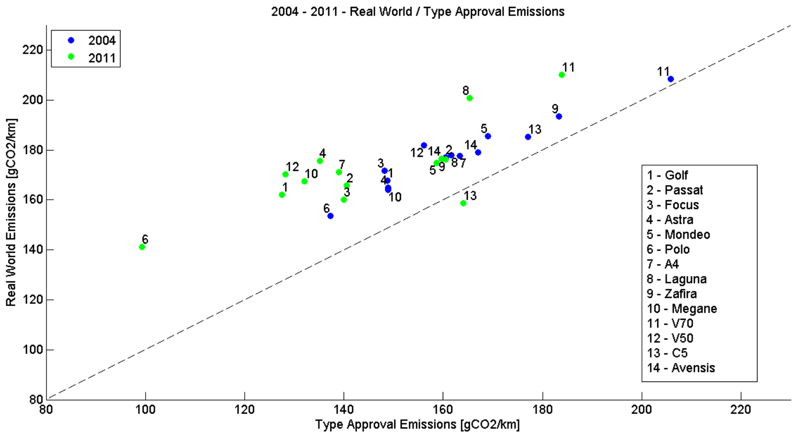


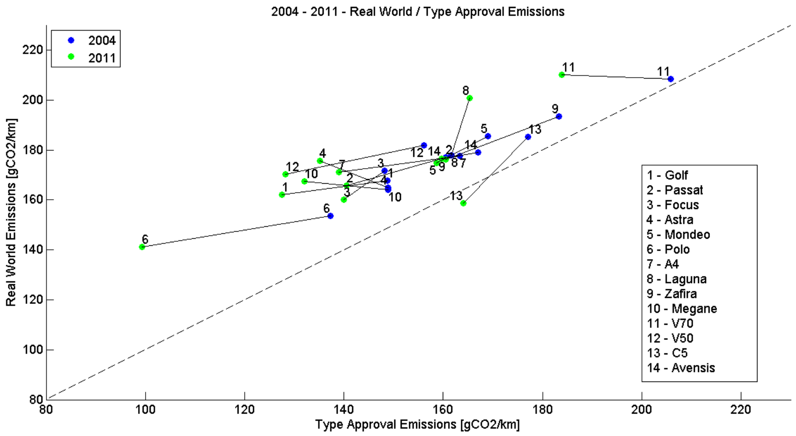



2004 - 2010 - Real World / Type Approval Emissions
2004
2010
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
1 - Volkswagen
2 - Ford
3 - Renault
4 - Peugeot
5 - Opel
6 - Volvo
7 - Toyota
8 - Audi
9 - Citroen
10 - BMW
11 - Seat
12 - Skoda
13 - Fiat
14 - AlfaRomeo
15 - Mercedes
16 - Toyota excl. Prius


2004 - 2010 - Real World / Type Approval Emissions
2004
2010
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
1 - Volkswagen
2 - Ford
3 - Renault
4 - Peugeot
5 - Opel
6 - Volvo
7 - Toyota
8 - Audi
9 - Citroen
10 - BMW
11 - Seat
12 - Skoda
13 - Fiat
14 - AlfaRomeo
15 - Mercedes


2004 - 2010 - Real World / Type Approval Emissions
2004
2010
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
1 - Volkswagen
2 - Ford
3 - Renault
4 - Peugeot
5 - Opel
6 - Volvo
7 - Toyota
8 - Audi
9 - Citroen
10 - BMW
11 - Seat
12 - Skoda
13 - Fiat
14 - AlfaRomeo
15 - Mercedes

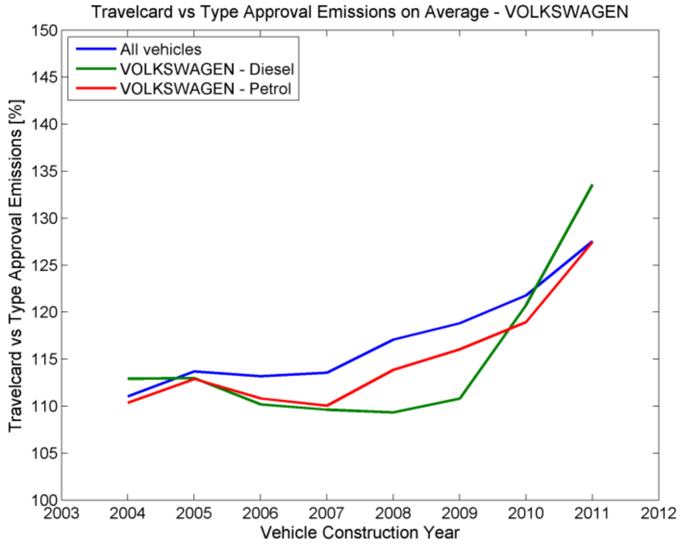

2004 - 2011 - Real World / Type Approval Emissions
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
1 - Golf
2 - Passat
3 - Focus
4 - Astra
5 - Mondeo
6 - Polo
7 - A4
8 - Laguna
9 - Zafira
10 - Megane
11 - V70
12 - V50
13 - C5
14 - Avensis

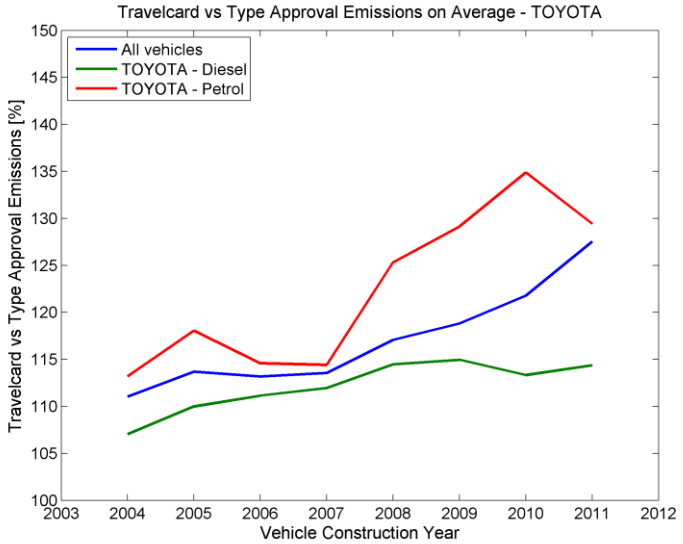

2004 - 2011 - Real World / Type Approval Emissions
2004
2011
Real World Emissions [gCO2/km]
Type Approval Emissions [gCO2/km]
1 - Golf
2 - Passat
3 - Focus
4 - Astra
5 - Mondeo
6 - Polo
7 - A4
8 - Laguna
9 - Zafira
10 - Megane
11 - V70
12 - V50
13 - C5
14 - Avensis

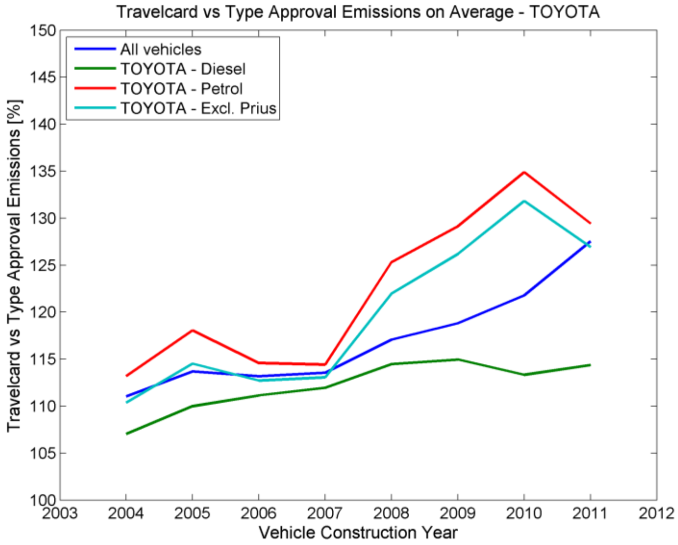
9.1.1 *Individual manufacturer analysis*

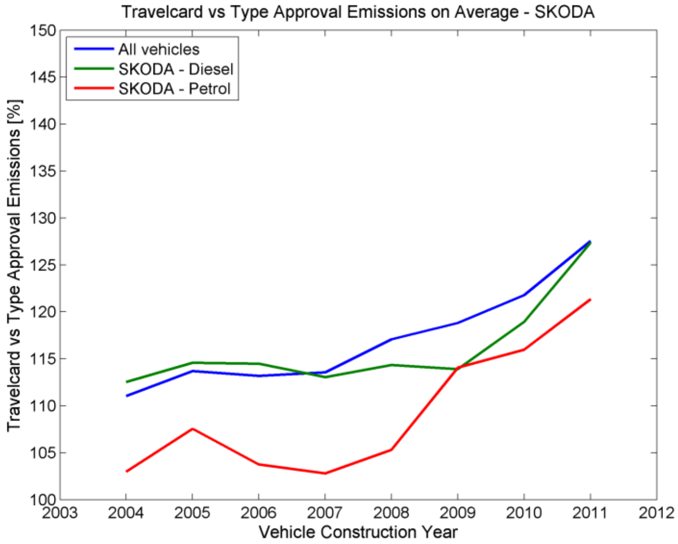
This section includes an analysis on the ratio real world/type approval emissions for each of the manufacturers. In the graphics an analysis is also performed for petrol and diesel vehicles for each manufacturer.

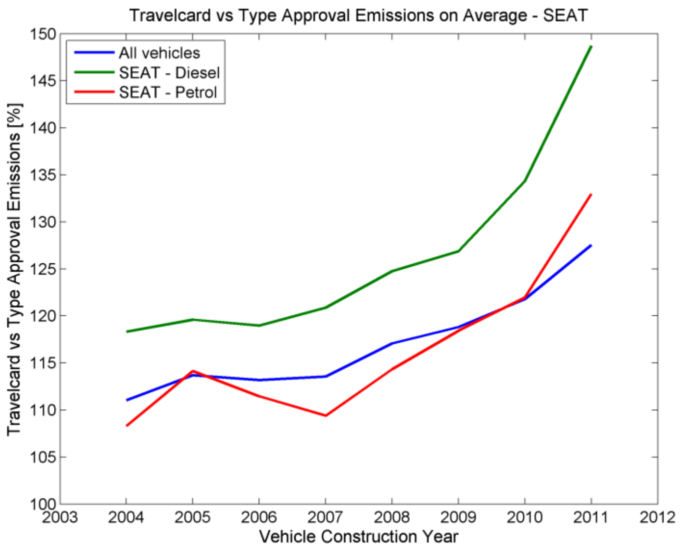
For Toyota, the Prius hybrid vehicle model is a substantial part of the whole dataset. In the analyses it is treated also as a separate group. Mercedes is at the edge of number of vehicles for a robust estimate. Furthermore, for Mercedes there has been a shift in the sales over segments, which affect the trend lines significantly.

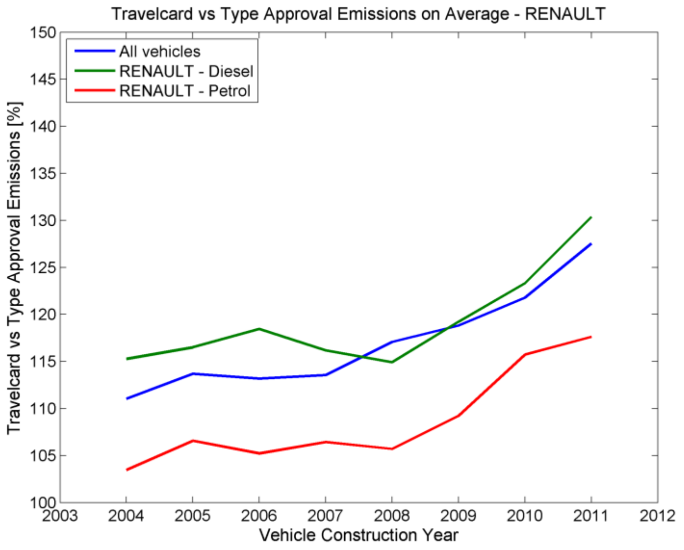


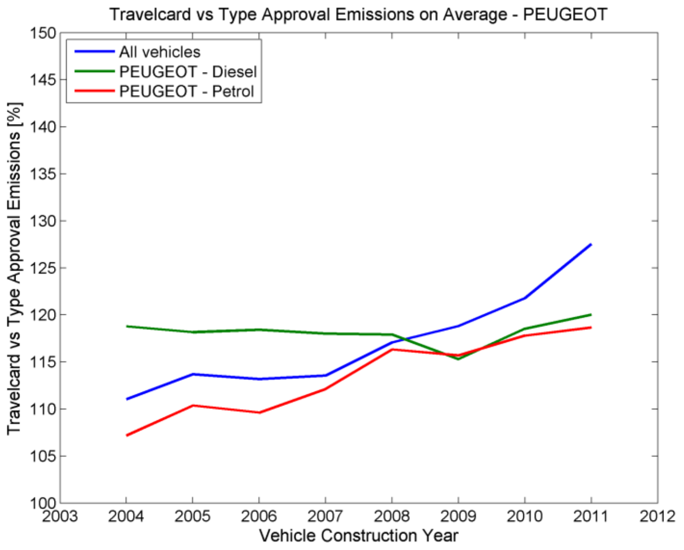


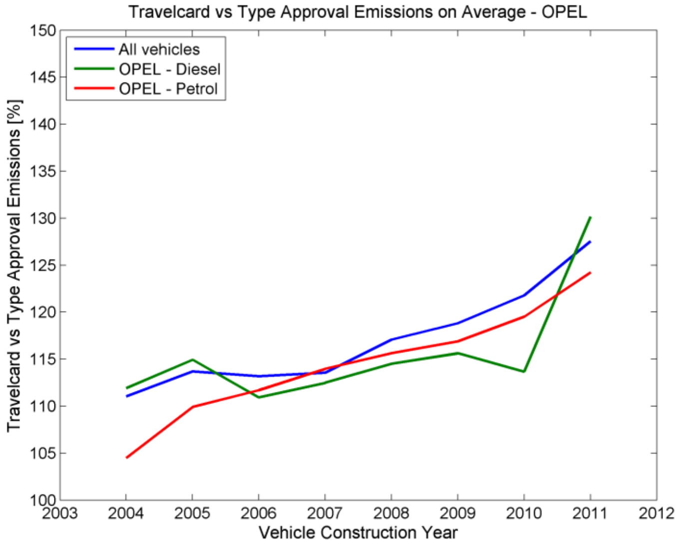

Travelcard vs Type Approval Emissions on Average - TOYOTA
All vehicles
TOYOTA - Diesel
TOYOTA - Petrol
TOYOTA - Excl. Prius
Travelcard vs Type Approval Emissions [%]
150
145
140
135
130
125
120
115
110
105
100
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Vehicle Construction Year

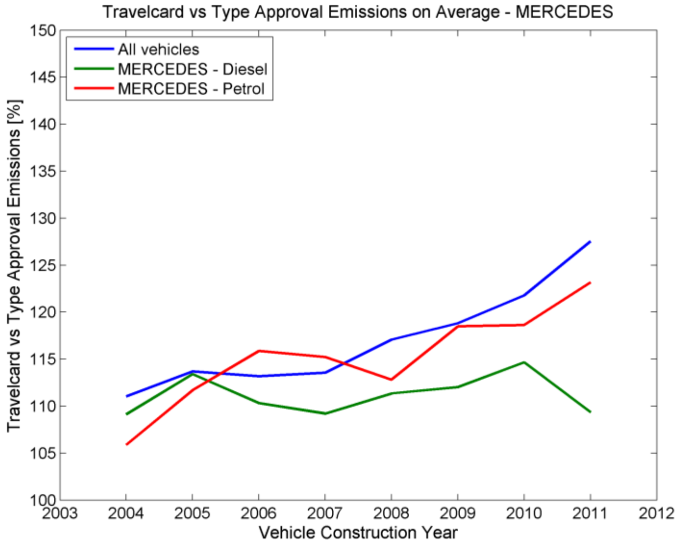

Travelcard vs Type Approval Emissions on Average - SKODA
All vehicles
SKODA - Diesel
SKODA - Petrol
Travelcard vs Type Approval Emissions [%]
150
145
140
135
130
125
120
115
110
105
100
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Vehicle Construction Year


Travelcard vs Type Approval Emissions on Average - SEAT
All vehicles
SEAT - Diesel
SEAT - Petrol
Travelcard vs Type Approval Emissions [%]
Vehicle Construction Year
100
105
110
115
120
125
130
135
140
145
150
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

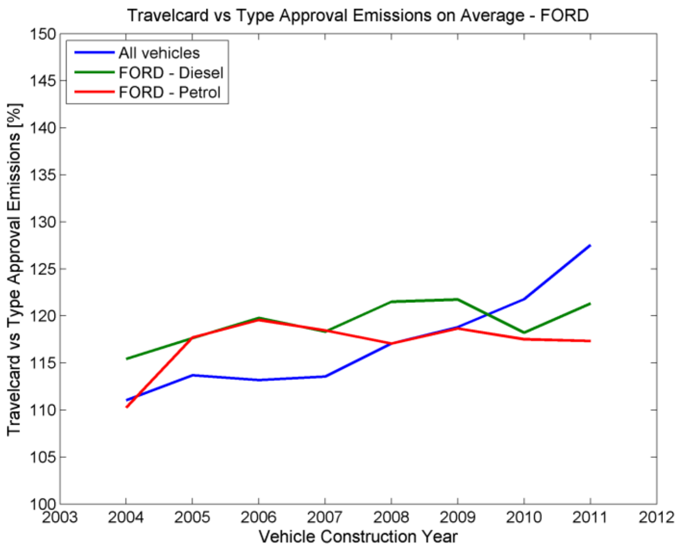

Travelcard vs Type Approval Emissions on Average - RENAULT
All vehicles
RENAULT - Diesel
RENAULT - Petrol
Travelcard vs Type Approval Emissions [%]
Vehicle Construction Year
100
105
110
115
120
125
130
135
140
145
150
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012

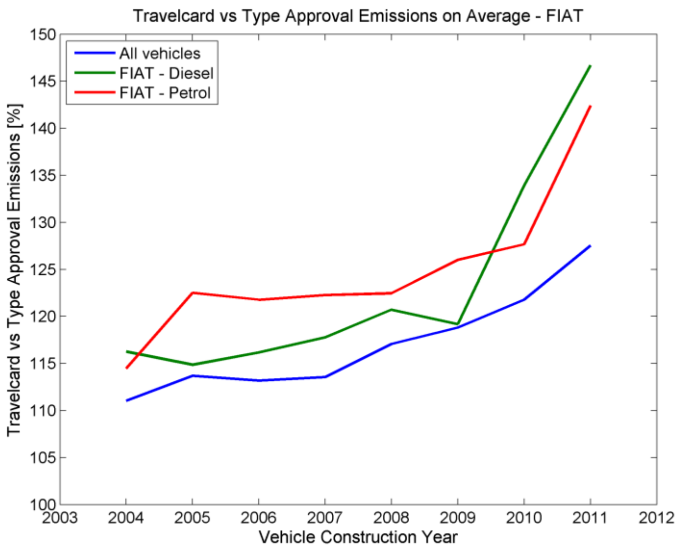

Travelcard vs Type Approval Emissions on Average - PEUGEOT
All vehicles
PEUGEOT - Diesel
PEUGEOT - Petrol
Travelcard vs Type Approval Emissions [%]
Vehicle Construction Year
100
105
110
115
120
125
130
135
140
145
150
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012



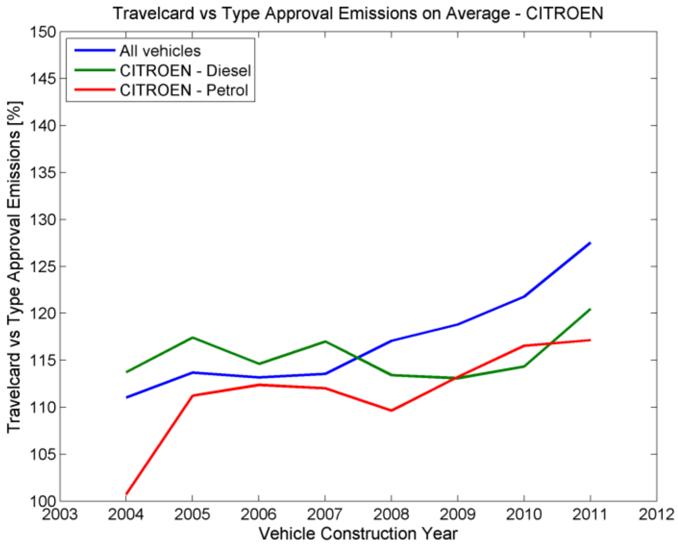


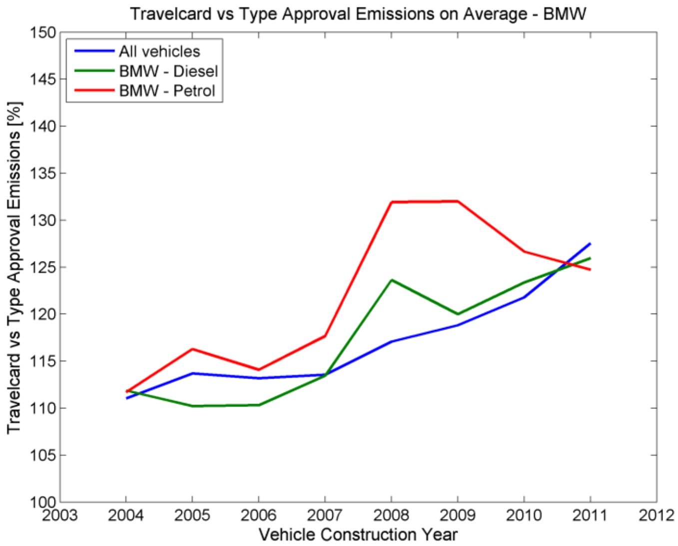
There are only a limited number of Mercedes vehicles in the fleet. Furthermore, the market share of Mercedes has shifted towards the high-end and SUV models. The type approval has increased rather than decreased.

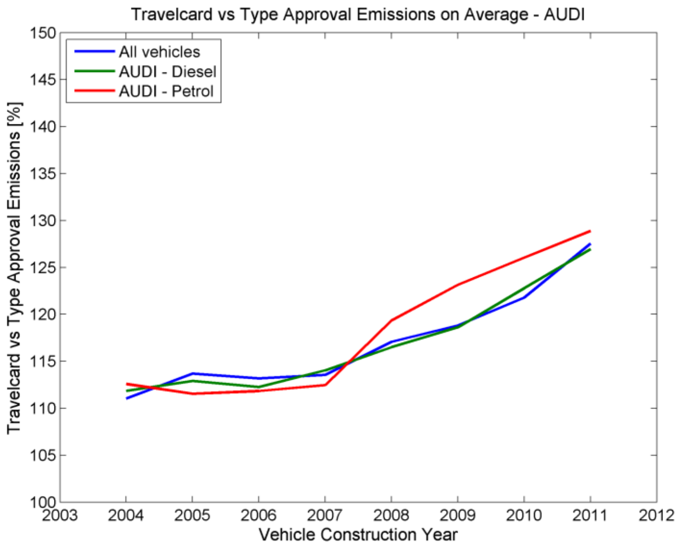


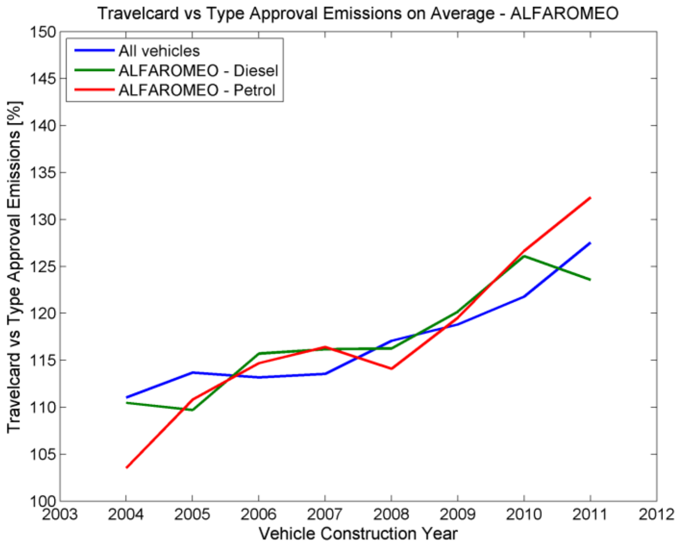


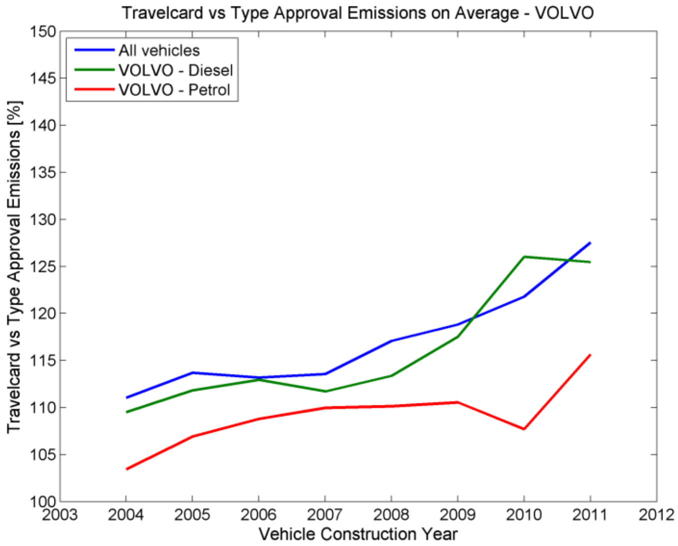
Fiat mainly has small vehicles in the database. The type-approval values are low, which is associated with large deviations, in particular relative to the type approval value. For the group of vehicles with the same type-approval values, Fiat does not significantly deviate from the average.


Travelcard vs Type Approval Emissions on Average - CITROEN
All vehicles
CITROEN - Diesel
CITROEN - Petrol
Travelcard vs Type Approval Emissions [%]
Vehicle Construction Year


Travelcard vs Type Approval Emissions on Average - BMW
All vehicles
BMW - Diesel
BMW - Petrol
Travelcard vs Type Approval Emissions [%]
Vehicle Construction Year


Travelcard vs Type Approval Emissions on Average - AUDI
All vehicles
AUDI - Diesel
AUDI - Petrol
Travelcard vs Type Approval Emissions [%]
Vehicle Construction Year


Travelcard vs Type Approval Emissions on Average - ALFAROMEO
All vehicles
ALFAROMEO - Diesel
ALFAROMEO - Petrol
Travelcard vs Type Approval Emissions [%]
150
145
140
135
130
125
120
115
110
105
100
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Vehicle Construction Year


Travelcard vs Type Approval Emissions on Average - VOLVO
All vehicles
VOLVO - Diesel
VOLVO - Petrol
Travelcard vs Type Approval Emissions [%]
150
145
140
135
130
125
120
115
110
105
100
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Vehicle Construction Year

10 Variation among drivers per manufacturer

For a given vehicle model, the variation in fuel consumption is due to the typical usage and driving style. There is, of course, a substantial variation among the drivers. However, the variation is such that the deviation between type-approval fuel consumption and the real-world fuel consumption is still significant for most models.

From the database the models with sufficient numbers are selected. the variation of the deviation between real-world fuel consumption and type-approval fuel consumption is plotted as cumulative distributions. This shows the fraction of drivers below a certain fuel consumption. In many cases the global figure is similar. In order to show a changing trend the total dataset is divided in two groups: 2004-2006 and 2007-2011. The shift of the line shows the change in the difference between real-world and type-approval value. In part this change is due to lower type-approval values for later years for the same model. A shift, combined with a less steep cumulative distribution, as seen in many of the cases, can be explained by a change dominated by a lower type-approval value.

The following graphics present the cumulative distribution for the different manufacturers of the ratio real world / type approval emissions. This analysis is split in two time period 2004 – 2006 and 2007 – 2011.

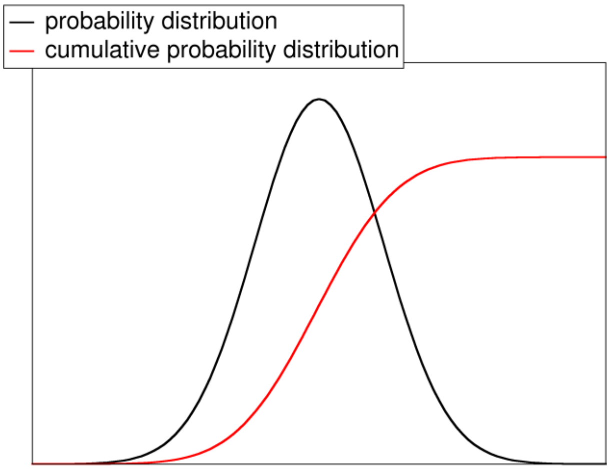
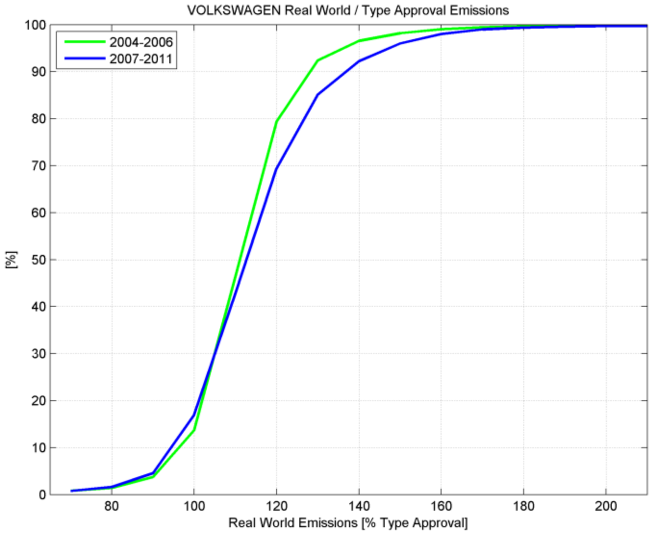
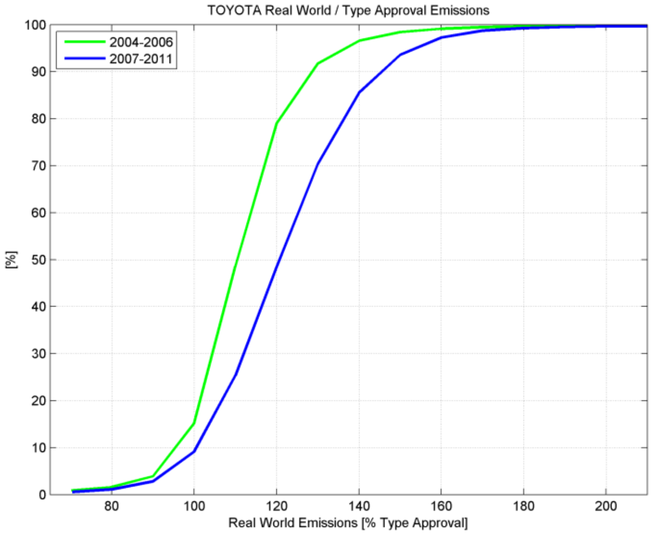
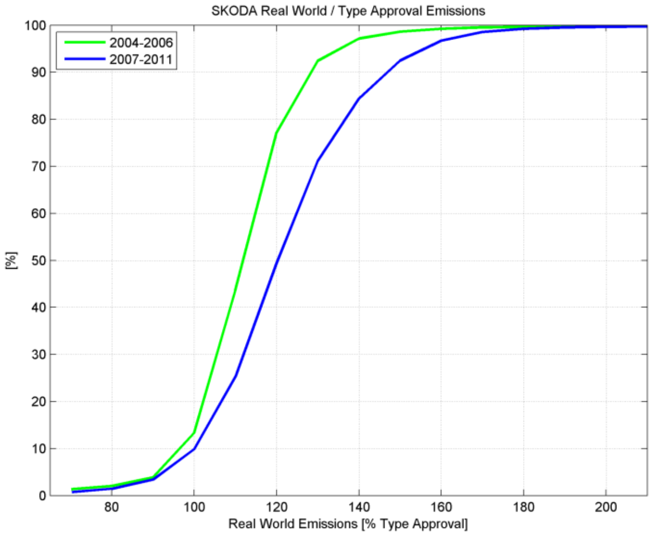
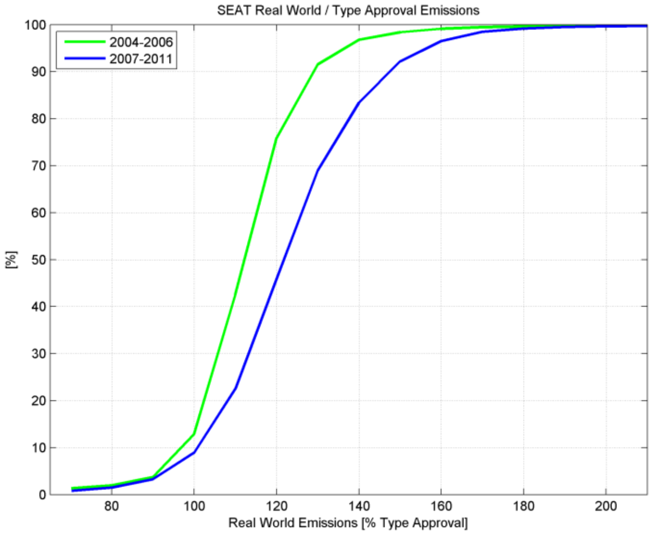


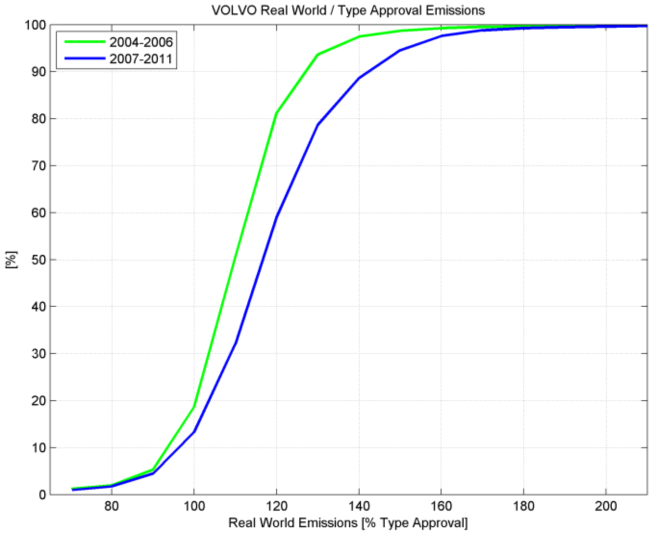
Figure 11 The plotted distributions are the cumulative probability distribution; the integral of the bell curve, or probability density distribution.

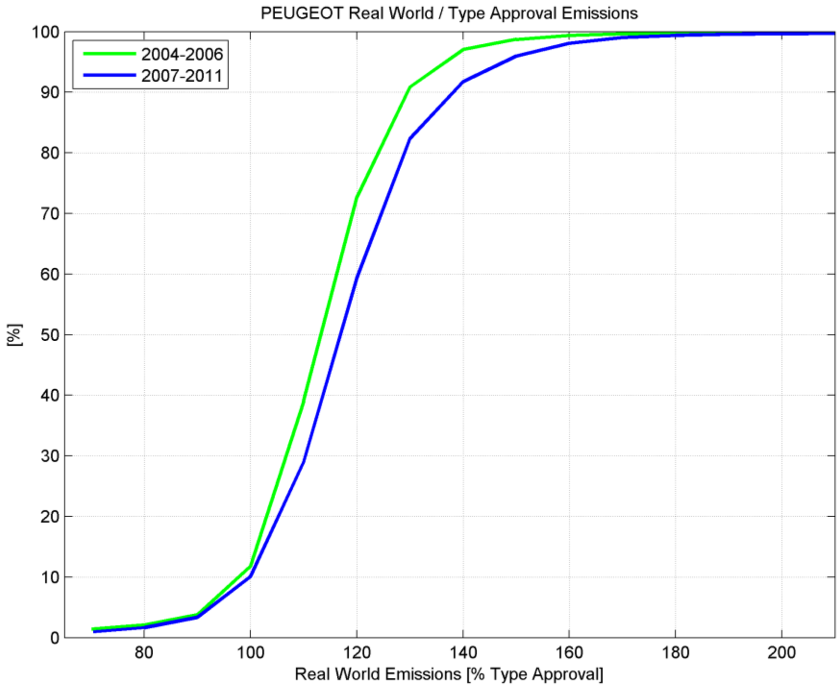

VOLKSWAGEN Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


TOYOTA Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


SKODA Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


SEAT Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


VOLVO Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


PEUGEOT Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
0
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100
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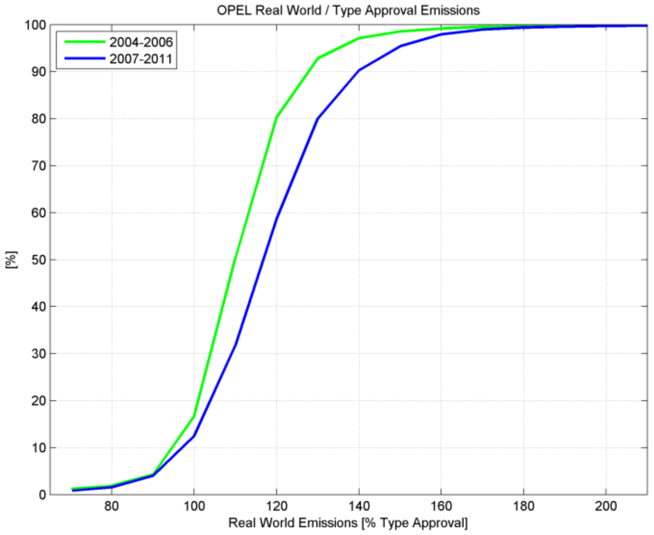
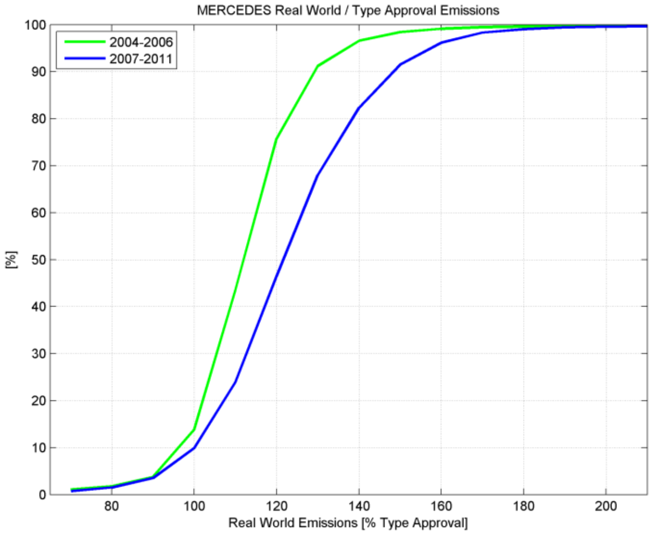
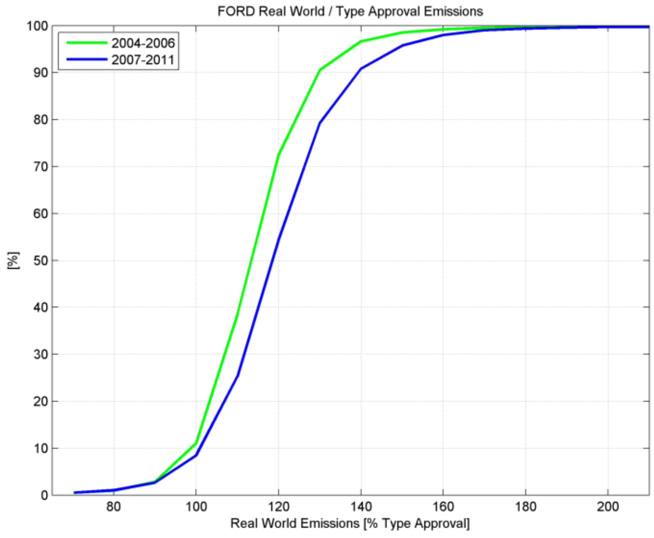
100
120
140
160
180
200
Real World Emissions [% Type Approval]


OPEL Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


MERCEDES Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


FORD Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
0
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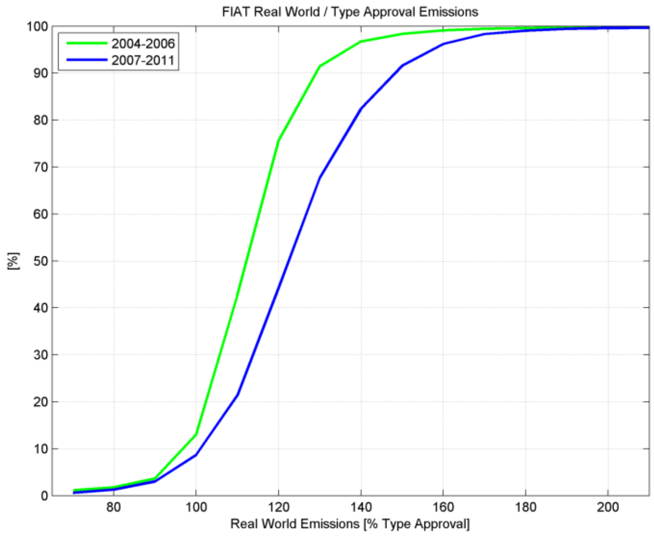
100
120
140
160
180
200
Real World Emissions [% Type Approval]


FIAT Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
0
10
20
30
40
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60
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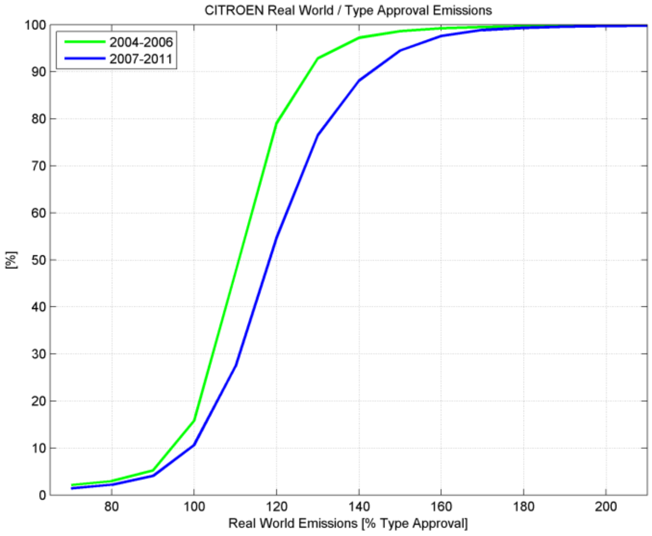
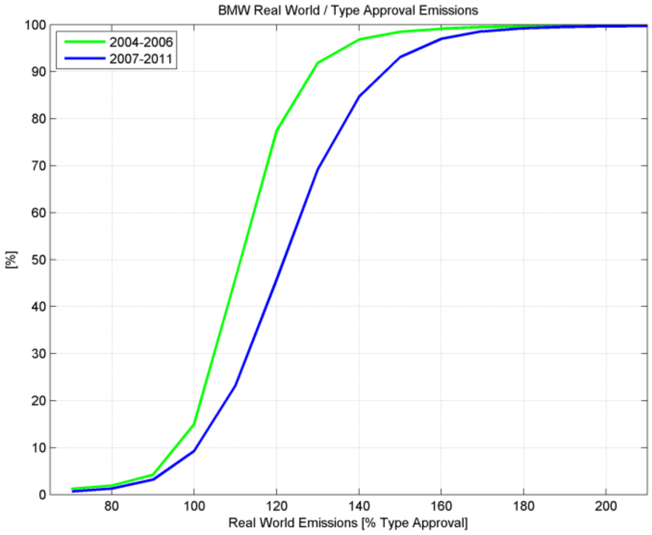
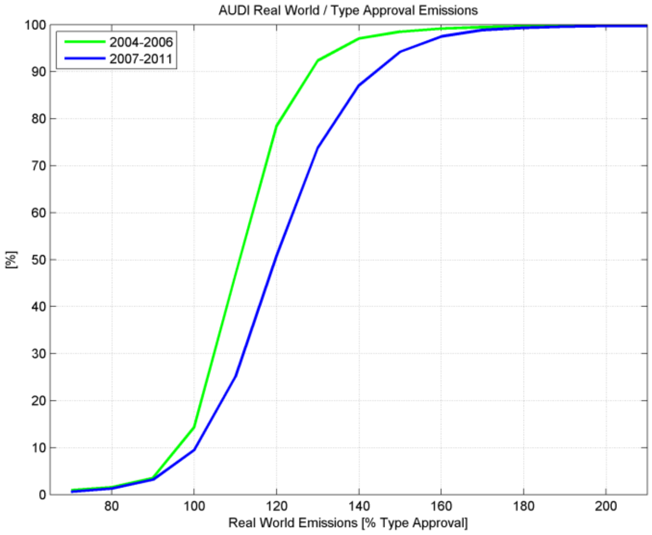
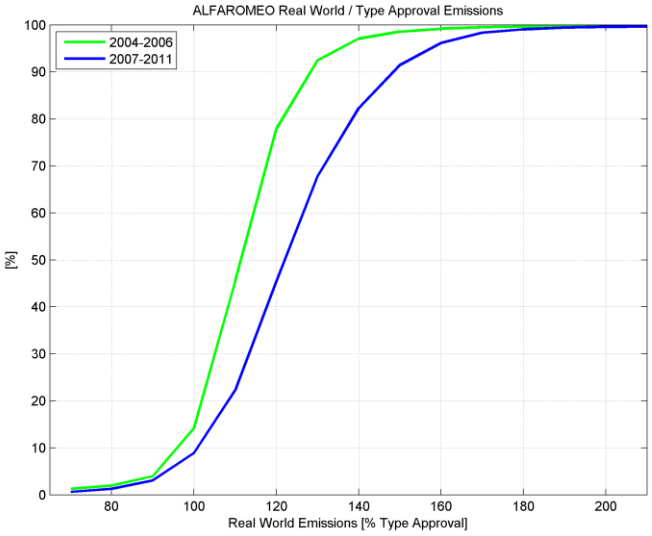
90
100
80
100
120
140
160
180
200
Real World Emissions [% Type Approval]


CITROEN Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


BMW Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


AUDI Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


ALFAROMEO Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]
0
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20
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50
60
70
80
90
100
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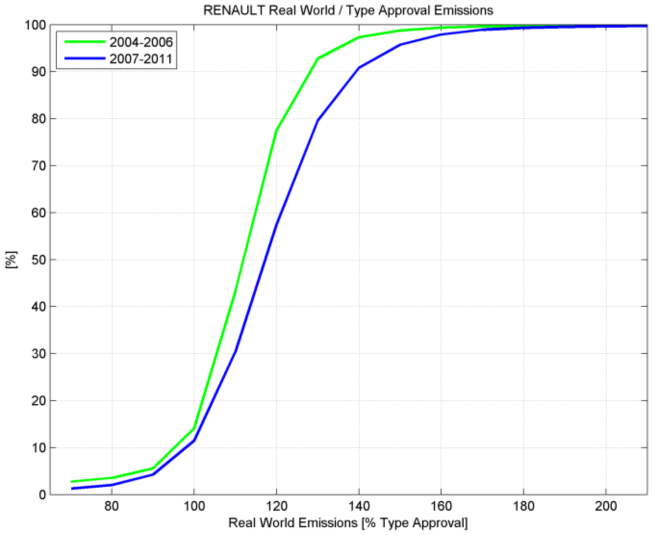
120
140
160
180
200


RENAULT Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]
0
10
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70
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100
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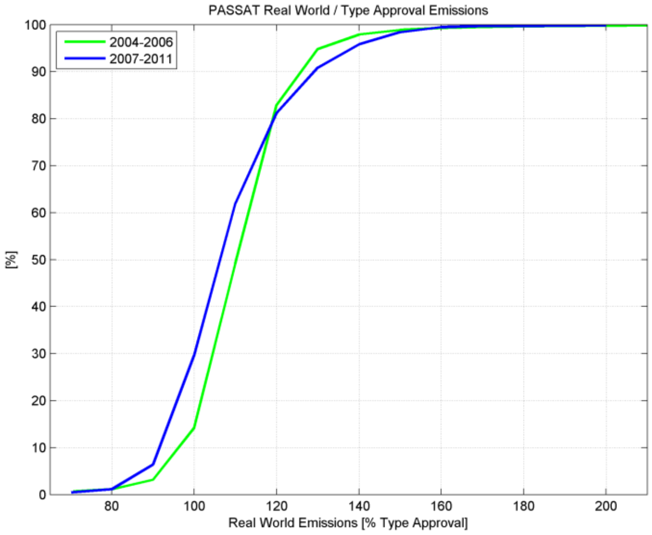
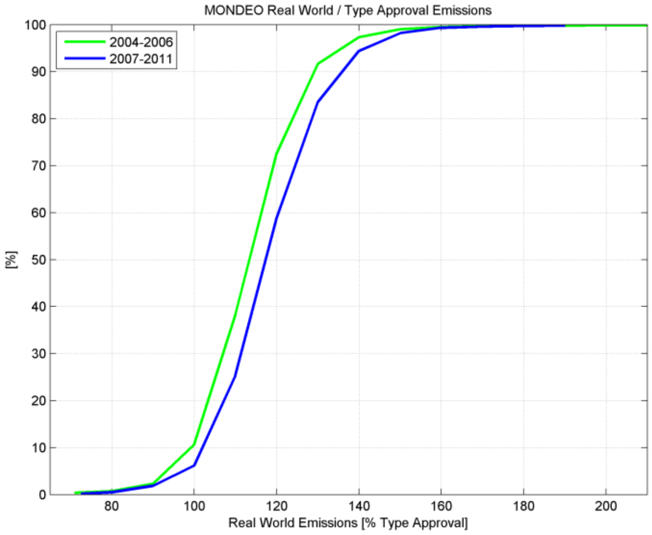
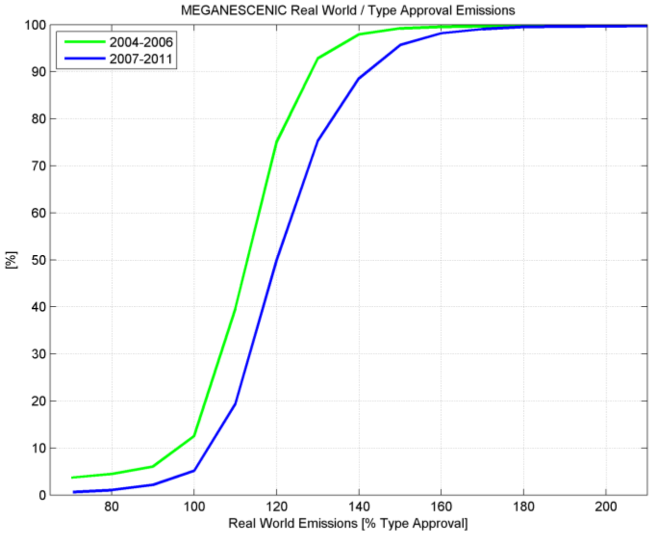
100
120
140
160
180
200

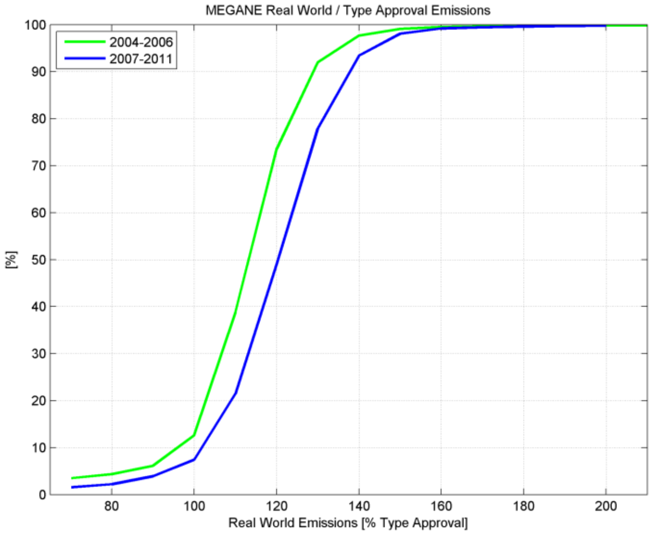
10.1 Variation among drivers per model

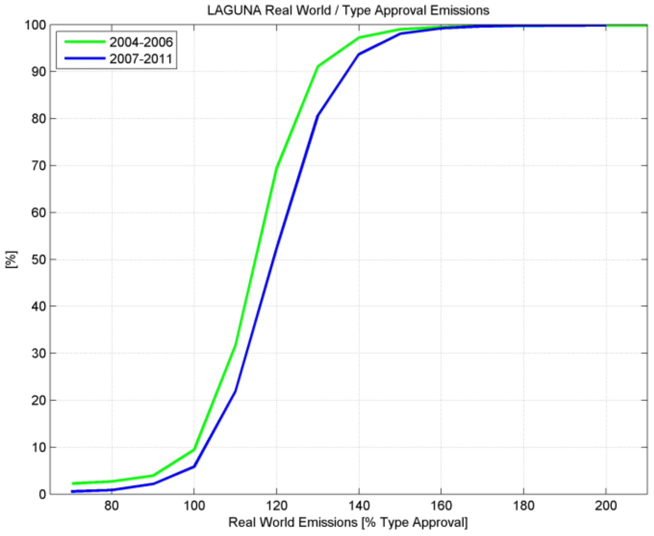
As for the previous section the following graphics depict the cumulative distribution of the ratio real world / type approval emissions but for different models. This analysis is also split in two time period 2004 – 2006 and 2007 – 2011.

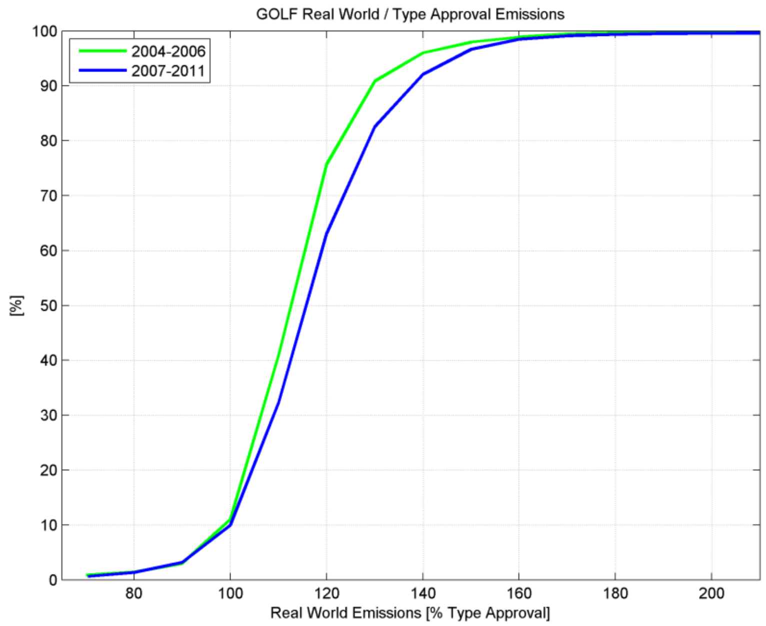


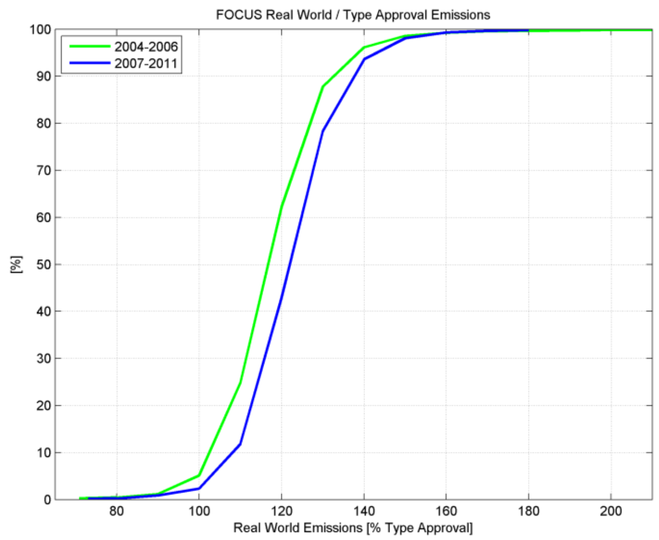


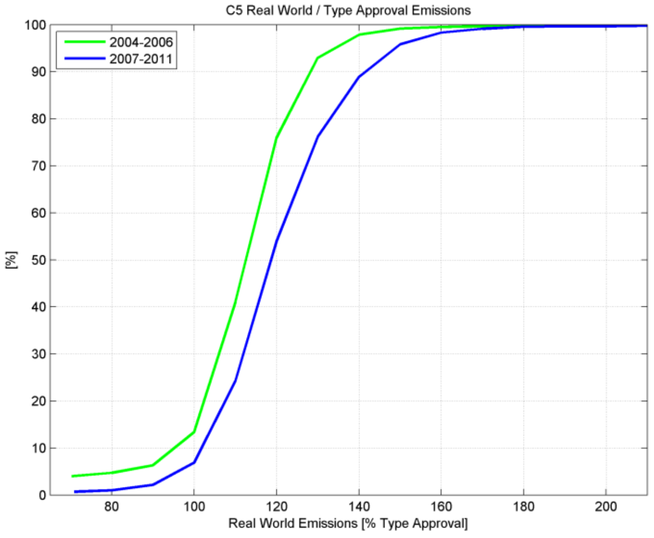

MEGANESCENIC Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]

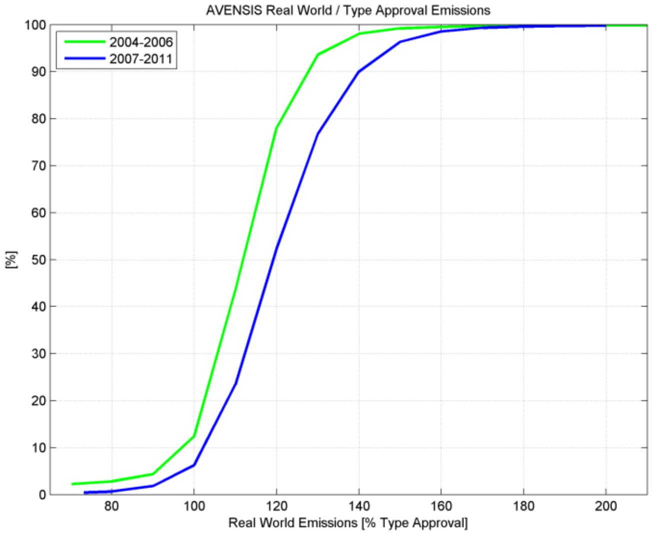

MEGANE Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


LAGUNA Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


GOLF Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


FOCUS Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


C5 Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
100
90
80
70
60
50
40
30
20
10
0
80
100
120
140
160
180
200
Real World Emissions [% Type Approval]


AVENSIS Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
100
90
80
70
60
50
40
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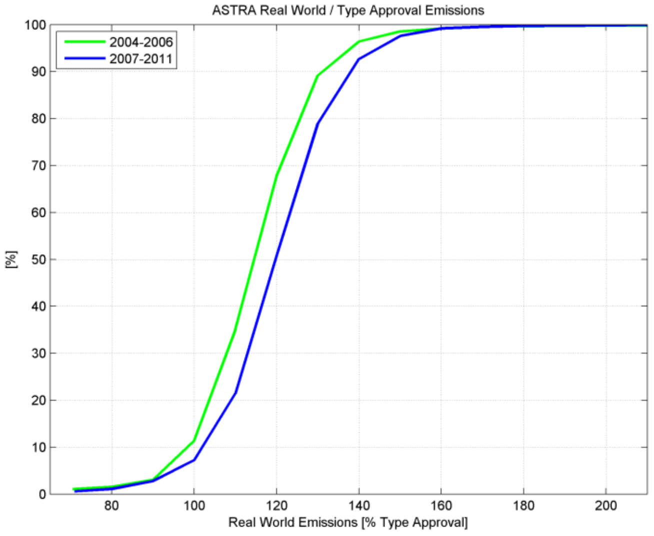
20
10
0
80
100
120
140
160
180
200
Real World Emissions [% Type Approval]


ASTRA Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
100
90
80
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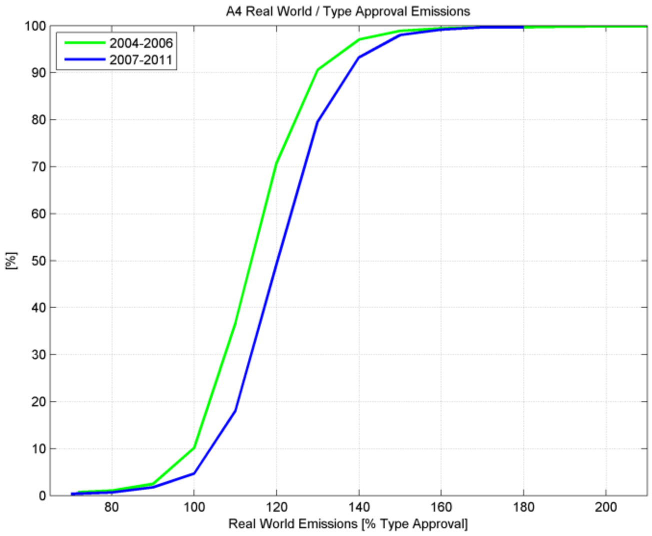
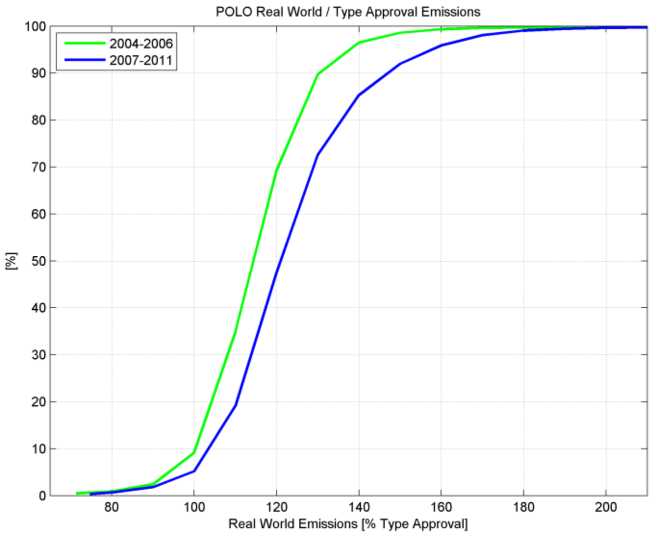
120
140
160
180
200
Real World Emissions [% Type Approval]


A4 Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]


POLO Real World / Type Approval Emissions
2004-2006
2007-2011
[%]
Real World Emissions [% Type Approval]

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12 Signature

Delft, 30 July 2013

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Research Manager

Norbert Ligterink
Projectleader/Author