TNO report

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Real-world fuel consumption of passenger cars based on monitoring of Dutch fuel-pass data

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Samenvatting

Inleiding

TNO monitort sinds 2008 het praktijkbrandstofverbruik van personenauto's in Nederland op basis van tankpasdata van Travelcard Nederland BV. Brandstofverbruik en de daarmee samenhangende uitstoot van CO_2 zijn in de praktijk doorgaans hoger dan de waarden die door de fabrikant worden opgegeven op basis van de typekeuringstest. Opeenvolgende rapporten hebben laten zien dat het verschil tussen het brandstofverbruik in de praktijk en de typekeuringswaarden de laatste tien jaar geleidelijk is toegenomen. Oorspronkelijk lieten vooral zuinige voertuigen in de segmenten van kleine en middenklasse voertuigen een groeiend verschil zien, maar de laatste jaren is deze ook toegenomen voor grotere voertuigen. Als gevolg daarvan dalen het gemiddelde praktijkverbruik en de gemiddelde CO_2-emissies van personenauto's minder hard dan de gemiddelde typekeuringswaarden. Dit vermindert de effectiviteit van verschillende beleidsmaatregelen die ingezet worden om de broeikasgasemissies van de transportsector te verlagen, zoals de Europese CO_2-normen voor lichte voertuigen en het Nederlandse fiscale stimuleringsbeleid voor zuinige personenvoertuigen.

Uit verschillende technische analyses is duidelijk geworden dat de belangrijkste oorzaken voor het groeiende verschil tussen praktijk en typekeuringstestwaarden gezocht moeten worden in:

- de toegenomen uitnutting door fabrikanten van zogenoemde "testflexibiliteiten", d.w.z. bandbreedtes en onduidelijkheden in de voorgeschreven testprocedures en testcondities, om lagere CO_2-emissiewaarden op de typekeuringstest te realiseren zonder aanpassing van het voertuig;
- de toepassing van brandstofbesparende technieken die op de typekeuringstest een groter effect hebben dan in de praktijk, en
- het toegenomen gebruik in de praktijk van energie gebruikende auxiliaries zoals dagrijverlichting en airconditioning.

Het feit dat het snelheids-tijdprofiel van de NEDC en andere testcondities bij de typekeuringstest niet representatief zijn voor de dagelijkse praktijk op de weg veroorzaakt een min of meer statisch verschil tussen het brandstofverbruik op de typekeuringstest en in de praktijk.

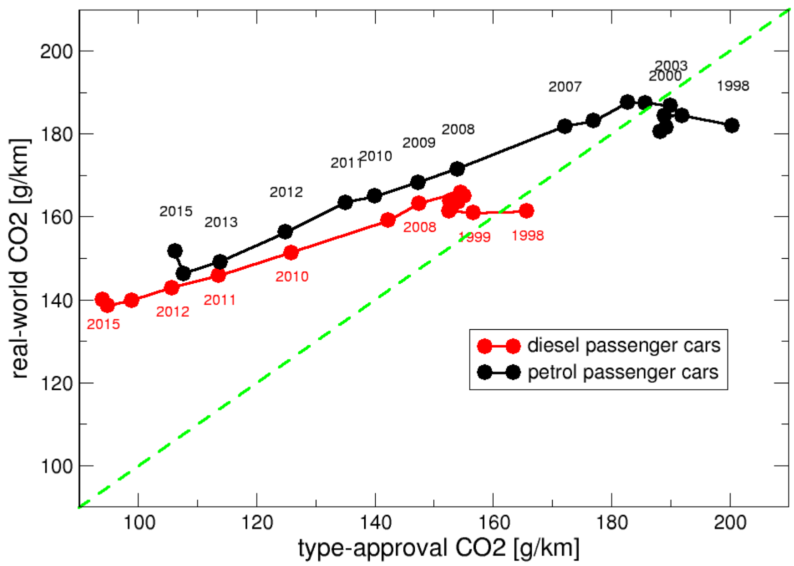
Dit rapport analyseert tankpasdata van Travelcard Nederland BV over de periode 2004 tot Q1 2016 voor in totaal 436 duizend voertuigen[1]. Een analyse van de jaarkilometrages laat zien dat de database niet alleen stereotype zakelijke rijders bevat. Er is een grote spreiding in jaarkilometrages en de database bevat ook een grote groep voertuigen met een relatief gering jaarkilometrage. Rond de 45% van alle nieuw verkochte personenauto's in Nederland zijn leaseauto's. Omdat deze leaseauto's gemiddeld een hoger jaarkilometrage hebben dan auto's in particulier bezit, bepalen deze leaseauto's in grote mate het gemiddeld brandstofverbruik van de Nederlandse personenautovloot. De resultaten van de monitoring worden daarom in grote mate representatief geacht voor de gehele Nederlandse vloot.

[1] Plug-in hybrides (PHEVs) zijn hierin niet meegenomen. Het praktijkverbruik van PHEVs wordt onderzocht in een aparte studie [TNO 2016a].

Resultaten

Over de hele vloot in de tankpasdata voor de periode januari t/m december 2015 is het relatieve verschil tussen de CO_2-emissie in de praktijk en de typekeurings-waarden ongeveer 35%. Voor voertuigen die in 2015 op kenteken zijn gezet is het absolute verschil ongeveer 45 g/km, wat neerkomt op een relatief verschil van 45%.

Gemiddeld groeit het relatieve verschil tussen praktijk en typekeuring voor elk volgend bouwjaar met 1,5%[2]. Dit is equivalent met een jaarlijkse absolute groei van het verschil in CO_2-emissies met 2 g/km. Wanneer voertuigen die verkocht werden in 2015 worden vergeleken met die uit 2014 dan is bij verschillende segmenten van voertuigen met een vergelijkbare typekeuringswaarde een groter dan gemiddelde toename van het verschil zichtbaar. Dit kan een tijdelijk effect zijn dat samenhangt met de introductie in 2015 van een groot aantal nieuwe modellen die aan de Euro 6 norm voldoen.



Figuur NS1 Gemiddelde CO_2 emissies in de praktijk versus de gemiddelde typekeuringswaarde voor nieuwe benzine- en dieselvoertuigen, uitgesplitst naar het jaar van introductie / registratie in Nederland.

De ontwikkeling in de tijd van het brandstofverbruik en het resulterende verschil tussen praktijk en typekeuring voor voertuigen van hetzelfde jaar van introductie / registratie[3] laat voor recente jaren een dalende trend zien. Van 2012 op 2013 is er een duidelijke afname zichtbaar in het verschil van 6 tot 8 g/km voor de meeste groepen van voertuigen van hetzelfde jaar van introductie / registratie in de vloot. Uit een analyse in [TNO 2014] kwam de combinatie van een zachte winter, een zeer laag niveau van congestie in 2013 als gevolg van de economische crisis en de oplevering van nieuwe infrastructuur, en de introductie van dynamische snelheids-limieten en spitsstroken in 2012-2013 naar voren als een waarschijnlijke oorzaak voor de waargenomen afname van het verschil tussen praktijk en typekeuring. Dit samenvallen van tijdelijke oorzaken lijkt nog steeds een plausibele verklaring.

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[2] procentpunt

[3] Wat grosso modo neerkomt op hetzelfde bouwjaar.

Na 2013 stabiliseert het verschil tussen praktijk en typekeuring weer voor de meeste groepen voertuigen van hetzelfde jaar van introductie in de vloot. Onafhankelijk van de waargenomen ontwikkeling in de tijd voor voertuigen die al op de weg zijn, is het verschil altijd groter voor nieuwere voertuigen dan voor oudere.

Voor voertuigen van een gegeven jaar van introductie blijkt er een redelijk lineair verband te zijn tussen de gemiddelde praktijkemissies van CO_2 en de typekeurings-waarden. Voor in 2014 en 2015 verkochte voertuigen kunnen deze correlaties als volgt geschreven worden:

2014: $RW_{CO_2} = 0.79 \cdot TA_{CO_2} + 61$

2015: $RW_{CO_2} = 0.96 \cdot TA_{CO_2} + 48$

met RW_{CO_2} (real-world = praktijk) en TA_{CO_2} (type approval = typekeuring) in [g/km]. Voor nieuwe voertuigen in 2015 is dit een voorlopige schatting aangezien nog niet voor al deze voertuigen een heel jaar data beschikbaar is in de database.

De variatie in praktijkemissies tussen verschillende bestuurders en voertuigen van dezelfde CO_2-typekeuringswaarde is typisch +/- 15 g/km. De variatie wordt kleiner bij lagere gemiddelde typekeuringswaarden. Gegeven dat het verschil tussen praktijk en typekeuring gemiddeld zo'n 45 g/km bedraagt, is het aantal voertuigen (of bestuurders) dat een praktijkverbruik realiseert dat in de buurt komt van de typekeuringswaarde zeer laag.

Impact van veranderingen in de methodologie

De in dit rapport gepresenteerde resultaten zijn afgeleid uit de database van Travelcard Nederland BV met een methodologie die enigszins gewijzigd is ten opzichte van eerdere rapporten. In plaats van door middeling van het per tankbeurt bepaalde verbruik over de tankbeurten, wordt nu het gemiddelde brandstofverbruik (en de daarmee corresponderende gemiddelde CO_2-emissiewaarde) per voertuig of per groep van voertuigen bepaald door de som van alle getankte liters te delen door de som van alle gereden kilometers. Dit is equivalent met een over de per tankbeurt gereden kilometers gewogen middeling van het per tankbeurt bepaalde brandstofverbruik per kilometer.

De combinatie van de aangepaste methodologie en de waargenomen afname in het verschil tussen praktijk en typekeuring tussen 2012 en 2013 zorgt ervoor dat het in dit rapport berekende absolute verschil tussen de CO_2-emissies in de praktijk en de typekeuringswaarden lager is dan wat in eerdere rapportages werd berekend. Voor voertuigen met lage CO_2-typekeuringswaarden valt het verschil tussen praktijk en typekeuring zo'n 6 tot 8 g/km lager uit dan de waarden in [TNO 2014]. Voor voertuigen met een hoge CO_2-typekeuringswaarde scheelt het 10 tot 14 g/km. Overall trends, die in de data waargenomen kunnen worden, blijven echter nagenoeg onveranderd.

Summary

Introduction

Since 2008 TNO is monitoring the real-world fuel consumption of passenger cars in the Netherlands based on fuelling data obtained from Travelcard Nederland BV. Fuel consumption and CO_2 emissions in real-world driving are generally higher than the type approval figures provided by the manufacturer. Successive reports show that the average gap between real world fuel consumption and the type approval value has been gradually increasing over the last decade. Initially this was mainly the case for fuel efficient vehicles in the small and medium-size segments. In recent years the gap has also increased for larger vehicles. As a consequence the average real-world fuel consumption and CO_2 emissions of passenger cars are decreasing much more slowly than the average type-approval values. This significantly reduces the effectiveness of various policies for reducing greenhouse gases from transport, such as the European CO_2 regulation for light-duty vehicles and national fiscal measures to stimulate the uptake of fuel efficient vehicles.

From various technical analyses it has become clear that the main causes for the increasing gap between real world fuel consumption and the type approval values are:

- the increasing exploitation by manufacturers of so-called “test flexibilities”, i.e. bandwidths and ambiguities in the prescribed test procedures and conditions, to achieve lower CO_2 emission values on the type approval test without changing the vehicle;
- the application of CO_2-reducing technologies that yield higher reductions on the type approval test than under real-world driving conditions, and
- the increased use in real-world driving of energy consuming auxiliaries such as air conditioning and day-time lighting, which are not switched on during the type approval test.

The fact that the NEDC speed-time profile and other test conditions are not representative of real-world driving partly causes a more or less static difference between type approval and real-world fuel consumption.

This report analyses tank pas data, obtained from Travelcard Nederland BV, covering the period 2004 to Q1 2016 and a total number of 436 thousand conventional vehicles[4]. An analysis of the annual mileages of vehicles in the database shows that the database does not only contain stereotypical business drivers. There is a large spread in annual mileages and the database also contains a significant share of vehicles with relatively low annual mileages. Around 45% of all new cars sold in the Netherlands are leased vehicles . As these leased vehicles on average also have higher annual mileages than privately owned vehicles, these leased vehicles to a large extent determine the average real-world fuel consumption of the Dutch passenger car fleet. The results of the analysis are therefore considered meaningful for the entire Dutch passenger car fleet.

[4] Plug-in hybrids (PHEVs) are excluded. The real-world fuel consumption of PHEVs is assessed in a separate study [TNO 2016a].

Results

Over the whole fleet included in the tank pass data for the period January to December 2015 the relative difference between the average real-world and type approval CO_2 emissions is around 35%. For vehicles entering the Dutch fleet in 2015 the absolute difference is about 45 g/km, which means that the relative difference is around 45%.

On average the relative gap is found to grow with 1.5%[5] for every consecutive year of construction. This is equivalent to an annual increase of around 2 g/km in the absolute gap of new vehicles. A larger than average increase of the gap between new vehicles sold in 2015 and 2014 can be observed in many segments of vehicles with similar type approval CO_2 emissions. This may be a temporary effect caused by the introduction of a large number of new vehicle models in 2015 that meet the Euro 6 standard.

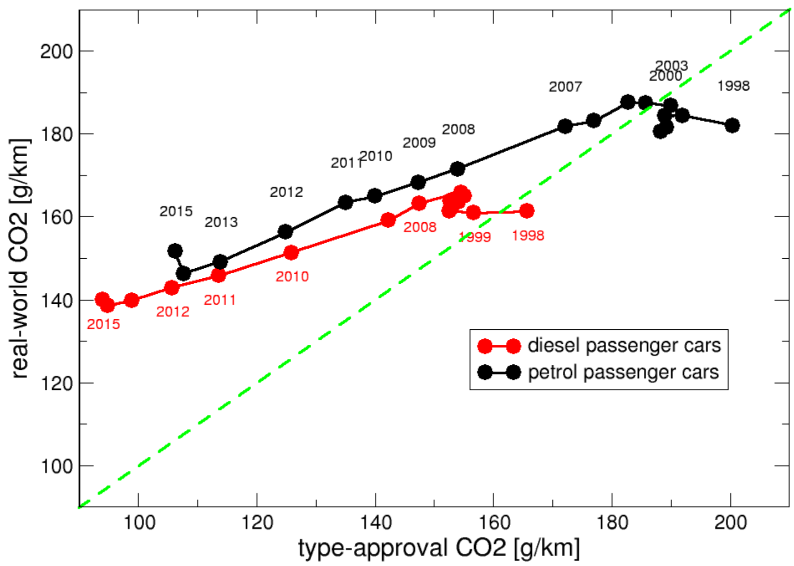

Figure S1 Average real-world CO_2 emissions versus the average type approval value of new petrol and diesel cars, differentiated by the year of introduction / registration in the Netherlands.

Looking at the development over time of the gap for vehicles with the same year of year of introduction / registration, a declining trend is observed in the data for recent years. From 2012 to 2013 a distinct drop in the gap of around 6 to 8 g/km is seen for most groups of vehicles of the same year of introduction into the fleet. From an analysis in [TNO 2014] the combination of mild winter weather, the low levels of congestion in 2013 due to the economic crisis in combination with improved infrastructure, and the introduction of dynamic speed limits in 2012-2013 in combination with extra lanes on the motorway ("spitsstroken") was considered a plausible cause for the observed reduction of the gap. This coincidence of temporary causes still appears to be a plausible explanation.

After 2013 the average gap stabilizes again for most groups of vehicles of the same year of introduction into the fleet. Independent of the observed changes over time, the gap is always larger for newer vehicles than for older vehicles.

[5] percent point

A fairly linear relation is found between the average real- world CO_2 emissions and the type approval value. For new vehicles sold in 2014 and 2015 these correlations can be written as:

2014: $RW_{CO_2} = 0.79 \cdot TA_{CO_2} + 61$

2015: $RW_{CO_2} = 0.96 \cdot TA_{CO_2} + 48$

with RW_{CO_2} (real-world) and TA_{CO_2} (type approval) in [g/km]. For new vehicles sold in 2015 the relation is preliminary as not for all vehicles a complete year of data is available in the database.

There is a typical variation of +/- 15 g/km between different drivers and vehicles of the same type approval CO_2 segment. This variation is decreasing with lower type-approval values. Given an average gap of 45 g/km, the number of modern vehicles which have (or stated differently: the number of drivers that realise) a real-world fuel consumption close to the type-approval value is very small.

Impacts from a change in assessment methodology

The results presented in this report have been derived from the Travelcard Nederland BV database using a methodology that has changed compared to the methodology used in previous reports. Instead of by averaging over tank events, average fuel consumption figures (and corresponding CO_2 emission values) per vehicle and for groups of vehicles have now been determined by dividing the sum over all tanked litres by the sum over all driven kilometres. This is equivalent to a weighted averaging of the average fuel consumption per tank event over the kilometres driven per tank event.

As a result of the combination of the updated methodology and the observed drop in the gap from 2012 to 2013 the results for the absolute difference between real-world and type-approval CO_2 emissions of petrol and diesel passenger cars presented in this report is smaller than the values presented in previous reports. For vehicles with low type approval CO_2 values the gap is around 6 - 8 g/km lower, while for vehicles with high type approval CO_2 values the values are 10 - 14 g/km lower compared to the results from [TNO 2014]. Overall trends observed from the data, however, remain generally unaffected.

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1 Introduction

1.1 Context

The use of fossil fuels in road vehicles is a significant source of greenhouse gas emissions. Reducing these emissions therefore is important to meet national and international climate goals, such as reiterated in the Paris COP21 Agreement. Improving the fuel efficiency of cars is one of the main instruments for reducing CO_2 emissions from road transport in the short to medium term.

The total CO_2 emissions of road transport can be determined from the amount of fuel sold and the carbon content of the fuel. In trends observed in fuel sales, however, the contributions from different vehicle categories cannot be distinguished and the impacts of e.g. increasing mobility, changes in the total distance travelled, and vehicle choice (trends in vehicle sales) cannot be separated from impacts of changes in the fuel efficiency of the vehicles (amount of fuel consumed per unit of distance travelled). Analysis of fuelling data of large groups of vehicles, as is done in the current study, gives insight in the improving energy performance of vehicles and the extent to which reductions observed in the CO_2 emissions and fuel consumption as measured on the type approval test translate into reductions in fuel consumption and CO_2 emissions on the road.

To reduce CO_2 emissions from road transport the European Commission has implemented CO_2 legislation for light duty vehicles. This legislation demands that the average CO_2 emissions of newly sold passenger cars, as measured on the type approval test, does not exceed 130 g/km from 2015 onwards. From 2021 onwards the target is 95 g/km. This is equivalent to a fuel consumption of 3.6 litre of diesel or 4.0 litre of petrol per 100 kilometre. In the Netherlands various vehicle taxes are differentiated on the basis of CO_2 emissions, as measured on the type approval test, since 2008. As a result of this policy the average CO_2 emissions of new vehicles in the Netherlands have decreased from a value above the EU average to a level that is significantly below that. Results of the analyses presented in this report provide useful insights in the effectiveness of these and other related policy instruments, and can also be used as input for efforts to improve procedures for testing and type approval of vehicles.

Previous studies by TNO and other parties have shown that the real-world fuel consumption of passenger cars is decreasing much more slowly than the type-approval fuel consumption values of the same cars. The current study adds results from vehicles sold in 2014 and 2015 to the existing picture.

1.2 History of this research

Since 2008 TNO is monitoring the real-world fuel consumption of passenger cars in the Netherlands based on fuelling data obtained from Travelcard Nederland BV. Successive reports[6] show that the average gap between real world fuel consumption and the type approval value has been gradually increasing over the

[6] See e.g. [TNO 2010], [TNO 2013a] and [TNO 2014], available at: https://www.tno.nl/nl/over-tno/dossiers-in-het-nieuws/praktijkverbruik-van-personenautos

last decade. Initially this was mainly the case for fuel efficient vehicles in the small and medium-size segments. In recent years the gap has also increased for larger vehicles.

A growing gap between real-world fuel consumption and type approval values is also observed in other European countries, based on research using different types of databases. For different groups of users and/or vehicles, that are monitored, there are some differences in the observed trends, but the overall picture is very consistent. Recent overviews, published by ICCT[7], include results from the Dutch research and compare these to results obtained on the basis of data from other countries.

From various technical analyses it has become clear that there are different causes for the increasing gap between real world fuel consumption and the type approval values:

- Over the last decade vehicle manufacturers have increasingly exploited so-called “test flexibilities”, i.e. bandwidths and ambiguities in the prescribed test procedures and conditions, to achieve lower CO_2 emission values on the type approval test. These flexibilities exist in the procedure for the roller bench test in the laboratory as well as in the coast down test, carried out on a test track, that is used to determine the vehicle resistance factors needed for setting the road load that is simulated by the roller bench (see e.g. [TNO 2012]). Utilisation of test flexibilities allow OEMs to achieve lower type approval CO_2 values without technical modifications to the vehicles.
- At the same time some of the technologies that manufacturers have started to apply to reduce fuel consumption and CO_2 emissions of cars yield higher reductions on the type approval test than under real-world driving conditions.
- The increased use of energy consuming auxiliaries such as air conditioning and day-time lighting, which are not switched on during the type approval test but are used on the road, may also have contributed to an increasing gap.

The fact that the NEDC speed-time profile and other test conditions are not representative of real-world driving causes a more or less static difference between type approval and real-world fuel consumption.

1.3 Database and filtering

The database used by TNO for monitoring real-world fuel consumption contains fuel transaction data made available by Travelcard Nederland BV. Per fuelling event both the amount of tanked fuel and the odometer setting are recorded as well as the time and date of the fuelling event. In total 52 million diesel fuel transactions and 29 million petrol fuel transactions are in the database. From these data less than half are complete and plausible records.

The odometer settings are entered manually by the drivers and as a consequence this data contains many errors and missing records. The data is therefore rigorously filtered to remove implausible records[8]. On the remaining records a number of analyses are performed to establish main trends and important effects.

[7] See [ICCT 2013], [ICCT 2014] and [ICCT 2015].
[8] See [TNO 2013b] for a description of the filtering process.

By matching the Travelcard Nederland BV database with the registration database from the Dutch road vehicle authority RDW for each vehicle in the database the type approval fuel consumption and CO_2 values and various other technical characteristics of the vehicles are known.

In total 697 thousand vehicles are in the database. After filtering of the data eventually for 188 thousand petrol vehicles and 265 thousand diesel vehicles a real world fuel consumption could be determined and compared to the type approval value. With a total of 436 thousand the majority of vehicles in the database are passenger cars with a type-approval CO_2 emission above 50 g/km. By filtering out type approval values below 50 g/km plug-in hybrids (PHEVs) are excluded from the analysis[9].

1.4 Methodology

By combining data from consecutive fuelling events the distance driven between two fuelling events is calculated. Fuel consumption is calculated by dividing the amount of tanked litres by the driven distance.

The method of deriving average fuel consumption figures from the data per fuelling event has changed compared to previous reports. The differences are explained below. Impacts of this change in methodology are discussed in section 2.5.

Method used in previous reports for calculating average fuel consumption

In previous analyses the average fuel consumption (overall, or e.g. per bandwidth of type approval CO_2 values for a given fuel) was determined by first calculating the average fuel consumption per tank event (amount of fuel tanked divided by the distance driven since the previous fuel event) and then averaging these results over the total number of tank events in the selection for which the average was determined. This approach, however, was found to undervalue the impact of fuel events resp. vehicles with a lower than average real-world fuel consumption on the overall average, when viewed from a fleet perspective. This artefact has become particularly apparent in the evaluation of the real-world fuel consumption of plug-in hybrid vehicles (PHEVs), which show a much larger variation in the kilometres driven per litre due to the large variation in the share of electrically driven kilometres resulting from large differences in charging behaviour of the vehicle users (see [TNO 2016a]).

Method used in this report

In the current report the average fuel consumption (overall, or e.g. per bandwidth of type approval CO_2 values for a given fuel) is determined by dividing the sum of all tanked litres by the sum of all kilometres driven for the selection of tank events for which the average is determined. This produces the average over a selection of vehicles whereby the results for individual fuel events or vehicles are weighted over the kilometres driven.

This approach increases the impact of vehicles with low real-world fuel consumption on the overall average and reduces the contribution of vehicles with relatively high real-world fuel consumption. In addition the new approach is found to improve the

[9] The real-world fuel consumption of PHEVs is assessed in a separate study [TNO 2016a].

accuracy of calculated averages, among other things by eliminating rounding errors associated with the fact that vehicle users do not consistently fill the tank to the same level at every tank event. As a result of both effects, the average fuel consumption values as calculated with this new approach are lower than the values based on the approach followed in previous reports, leading to a lower estimate of the gap between real-world fuel consumption and type approval values. A brief evaluation of the impact of the change in methodology is presented in section 2.5.

For the results presented in this report the new approach has been applied to the complete Travelcard database containing data from 2004 up to 2016. The resulting trends over time are therefore not affected by the change in methodology.

From fuel consumption to CO_2 emissions

Fuel consumption can be directly related to the “direct” CO_2 emissions of a vehicle, i.e. the CO_2 emitted through the exhaust[10]. The amount of CO_2 emitted per litre of fuel, related to the carbon content of the fuel, is more or less fixed. Per litre of petrol about 2370 gram CO_2 is emitted, while for diesel this value is 2650 gram CO_2 per litre. These values, as well as the energy content of the fuels, have been assumed constant for the period over which data are available.

With the admixture of biofuels these numbers change only slightly. Due to the different energy content of biofuels, however, it is to be expected that a little more fuel is needed to provide the same amount of energy when biofuels are blended into petrol and diesel.

1.5 Representativeness of the results

The suggestion is often made that the analyses based on tank pass data from Travelcard Nederland BV is biased for a particular group of users and a particular type of use. Tank passes are used by “business drivers” who mostly drive a leased car provided by their company. As their fuel bill is paid for by the company, these drivers are considered not have an incentive to drive in a fuel efficient manner. So some bias towards higher than average fuel consumption values may indeed be expected. However, an analysis of the annual mileages of vehicles in the database (see Figure 1) shows that the database does not only contain stereotypical business drivers. There is a large spread in annual mileages and the database also contains a significant share of vehicles with relatively low annual mileages.

It is clear from Figure 1 that the average mileage of vehicles in the database is well above the average for the entire Dutch passenger car fleet, which is around 13.000 km/year[11]. For petrol the average mileage in the database is significantly higher than the national averages for new cars (≤ 2 years), which in 2014 was 14.198 km. For diesel the national average in 2014 was 33.869 km[12], which is quite similar to the average in the Travelcard database.

[10] This report only analyses direct CO_2 emissions. This is different from some definitions of “Tank-to-Wheel” emissions in which the direct CO_2 emissions resulting from biofuels are counted as zero, and from “Well-to-Wheel” emissions which include the CO_2-equivalent value of all greenhouse gases emitted in the production chain of the fuel.
[11] Source CBS, see e.g.: http://download.cbs.nl/pdf/2015-transport-en-mobiliteit-2015.pdf
[12] See: http://statline.cbs.nl

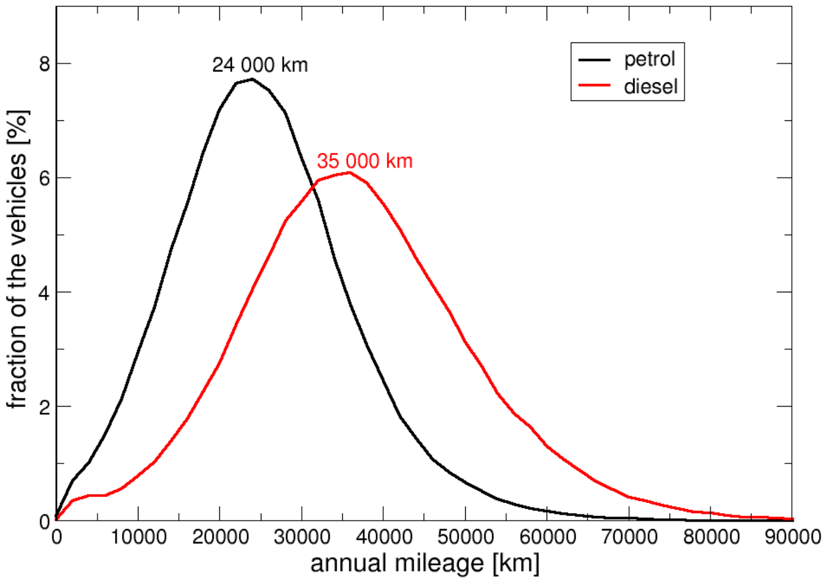

Figure 1 Distribution of the annual mileages of vehicles in the Travelcard database.

Alternative databases generally also have some sort of bias. Databases containing fuel data that are recorded voluntarily by participating vehicle owners / drivers will e.g. tend to have a bias towards lower than average fuel consumption values as only people that care about their fuel consumption or fuel costs will spend time recording their fuelling data.

An important advantage of using tank pass data, is the homogeneity of the group of drivers. These drivers do change their cars every couple of years but not their use patterns. Hence the trends over time are well-established, and are not disturbed by changes in the underlying use patterns. These trends over time are the most important outcome of the study. Within the database it can be seen that for individual drivers the deviation between real-world fuel consumption and the type-approval value is strongly related to their specific use pattern and driving style, but it is not to be expected that this use pattern and driving style will change much over time. Nevertheless some influence of variations in the level of congestion, e.g. related to the economic crisis in recent years or national measures to increase road capacity, on the fuel consumption of vehicles in the database cannot be excluded.

An additional argument in favour of using tank pass data is that 45% of all new cars sold in the Netherlands are leased vehicles[13]. As these leased vehicles on average also have higher annual mileages than privately owned vehicles, these leased vehicles to a large extent determine the average real-world fuel consumption of the Dutch passenger car fleet.

[13] Source: www.vna-lease.nl

2 Results

2.1 Overall trends

Figure 2 shows the evolution of the relative difference between the average real-world fuel consumption and the type approval values of vehicles in the database since 2004. It is clear that the gap between real-world fuel consumption and the type approval value is not yet stabilizing, but instead has increased further with the introduction of new passenger cars on the Dutch roads. The average gap now varies around 30% with a larger gap for diesel vehicles than for petrol vehicles. Also visible in Figure 2 is a large seasonal variation, between the highest fuel consumption over the winter period in December and January, and the lowest fuel consumption just after the summer holidays.

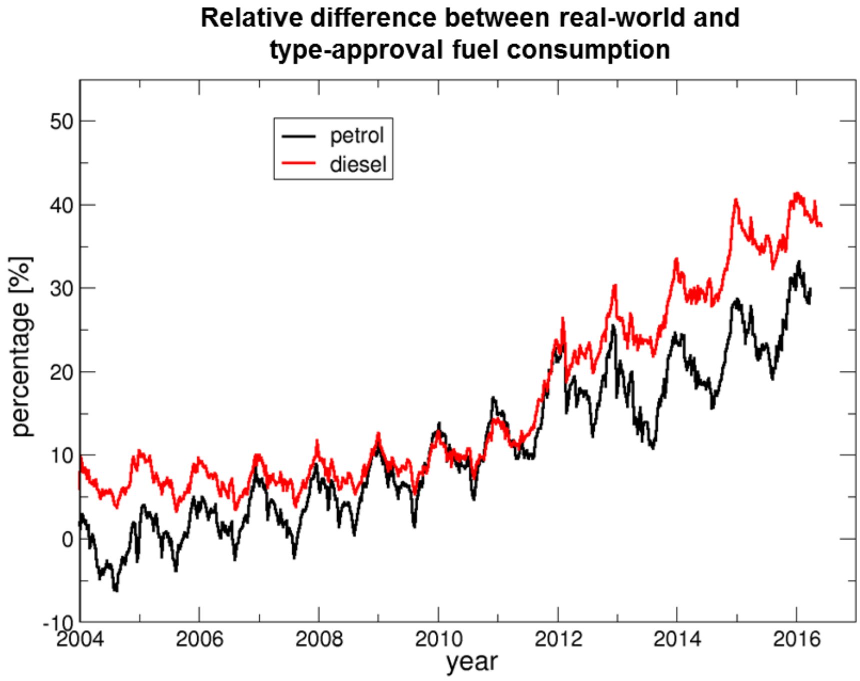

Figure 2 The evolution of the relative difference between the fleet average real-world fuel consumption and the average type-approval value, based on weekly averages of the fuelling data: the total amount of fuel and the total distance. This data is based on a fleet of vehicles, all using Travelcard tank passes, which consists mainly of vehicles younger than four years.

Looking at the gap between real-world and type-approval in more detail in Figure 3, one can observe that the average real-world fuel consumption decreases much more slowly than the average type-approval value. Despite this growing gap, the real-world fuel consumption nevertheless continues to decrease. Initially the gap was larger for petrol than for diesel. This seems to result mainly from the fact that the onset of the drop in type-approval values, visible for petrol vehicle around 2008, predates the drop for diesel cars. The later reduction for diesel cars, however, is more substantial leading to the gap being larger for diesels than for petrol vehicles in recent years.

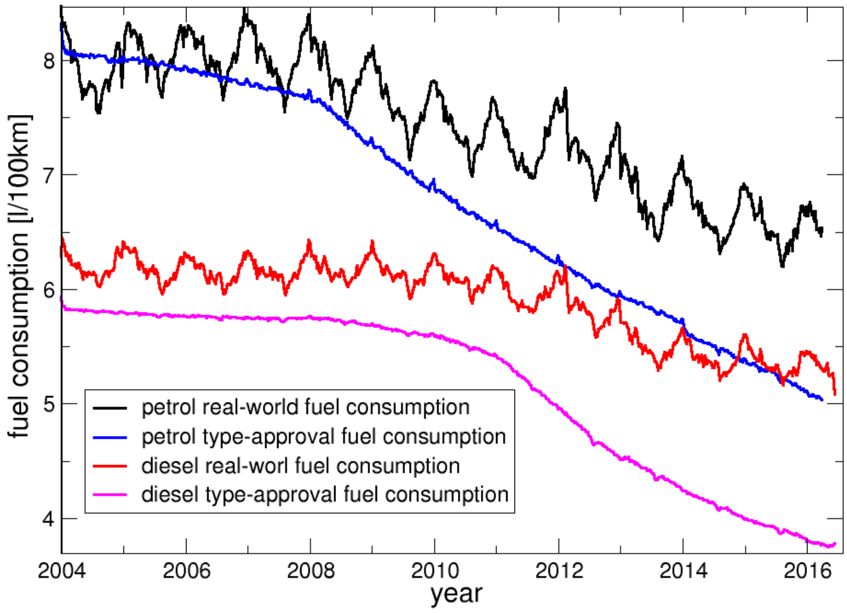

Figure 3 Average real-world and type approval fuel consumption of the vehicles in the database. Both the real-world and the type-approval fuel consumption have reduced since 2004. The different rates of reduction result in an increasing gap.

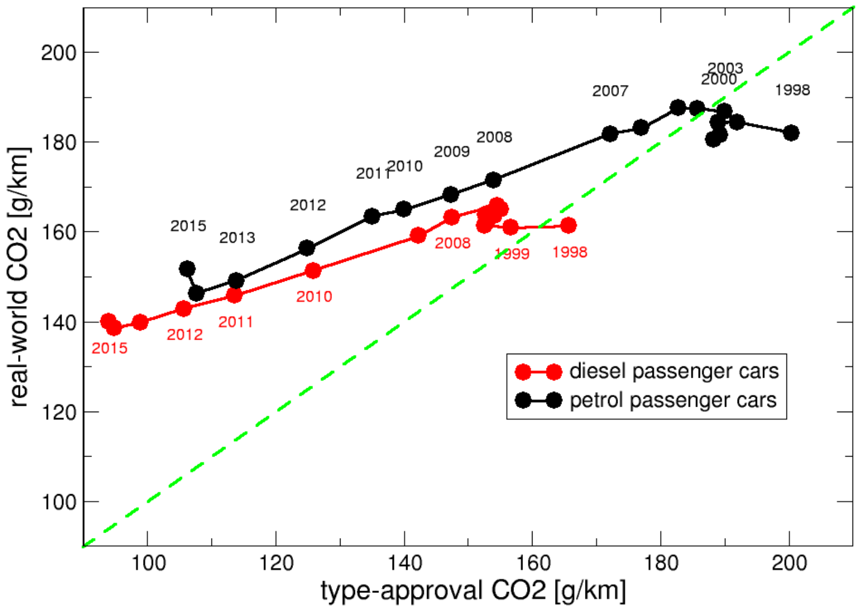

Figure 4 Average real-world CO_2 emissions versus the average type approval value of new petrol and diesel cars, differentiated by the year of introduction / registration in the Netherlands.

The results in Figure 2 and Figure 3 are for the total vehicle fleet, which at any moment in time includes vehicles of different ages. Representing the results in this manner allows determination of seasonal effects and overall trends at the fleet level. This fleet, however, changes over time. Changes in the characteristics of new vehicles over time are best determined by looking at the average fuel consumption as function of the year of introduction of the different vehicles in the fleet (date of registration). Figure 4 shows the real-world CO_2 emission as function the average type approval value for petrol and diesel passenger cars of different years of introduction / registration in the fleet. Per year of introduction data have been averaged over the entire period that vehicles are present in the database. This representation more clearly shows the how the gap evolves over time for new vehicles. Over the last 10 years for petrol vehicles and 7 years for diesels the reduction in real-world CO_2 emissions has been smaller than - but proportional to - the reduction in the average type approval CO_2 emissions. As a result the gap has continuously increased. The small “wiggles” for the 2015 vehicles are artefacts resulting from the fact that for most vehicles not yet an entire year of data is available so that seasonal variations are not averaged out.

The data in Figure 4 can be further split out into separate results for groups of vehicles with similar type approval CO_2 emissions. As can be seen from Table 1 and Table 2 both the relative and the absolute gap are generally higher for smaller or more fuel efficient vehicles with low type approval CO_2 values than for larger or less fuel efficient vehicles with high type approval CO_2 values. For vehicles within a type approval CO_2 bandwidth the gap increases over time. The increase over time of the average gap for all newly sold vehicles in the database, as seen in Figure 3, can thus be explained by a combination of the increasing gap for individual vehicles with the same type approval CO_2 value and a shift in the sales towards smaller and/or more fuel efficient vehicles with a higher gap. A shift in sales towards vehicles with lower type approval CO_2 values has occurred in the Netherlands as a result of the strong CO_2-differentiation of vehicle taxes since 2008, as analysed e.g. in [PRC 2014] and [PBL 2014].

2.2 A closer look at the evolution of the gap for vehicle with different years of introduction in the Dutch fleet

The average gap for vehicles with different years of introduction / registration in the Dutch fleet as shown in Figure 4 is somewhat smaller than the values reported in previous reports. The same is true for the overall gap as shown in Figure 2 and Figure 3. A first indication of this trend, that for existing vehicles in the fleet the gap appears to reduce over time, was reported and discussed in [TNO 2014][14]. With the additional data available for the period up to Q1 of 2016 this trend can be further analysed.

Figure 5 and Figure 6 show the evolution over time of the monthly average as well as the yearly average gap for petrol resp. diesel vehicles introduced in the fleet between 2008 and the end of 2014[15].

[14] See Figure 2 and 3 of [TNO 2014] and the discussion in chapter 3 of that report.
[15] The data for the complete period are analysed with the same, updated methodology (see sections 1.4 and 2.5), so that changes in the calculation method can be excluded as a cause for the observed effects.

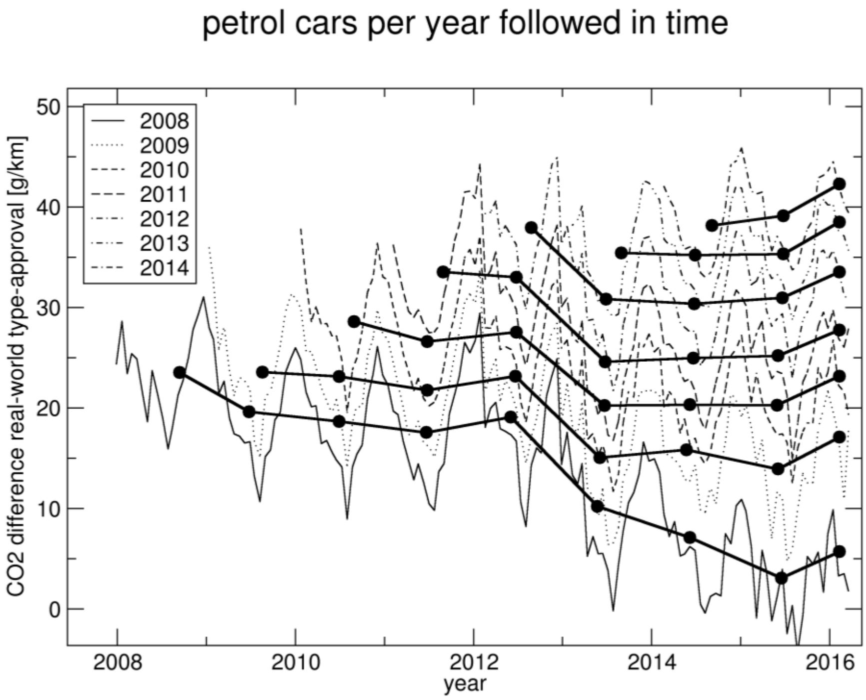

Figure 5 Evolution over time of the gap between real-world and type approval CO_2 emissions for **petrol vehicles** with different years of introduction / registration in the Netherlands. For vehicles from the early years 2008-2010 the number of vehicles in the database is limited in the last two years of monitoring, which may generate some bias.

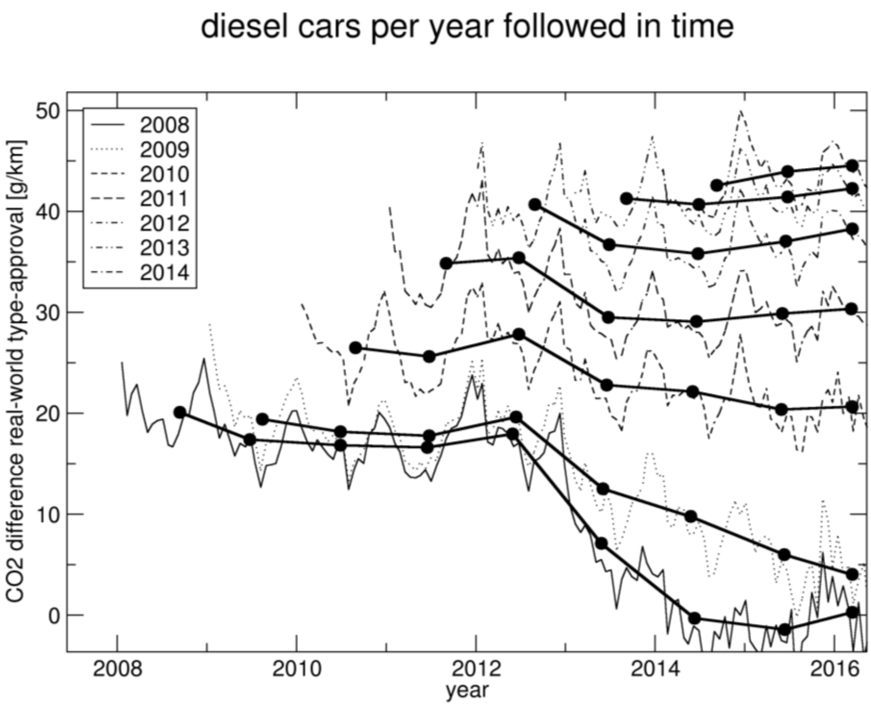

Figure 6 Evolution over time of the gap between real-world and type approval CO_2 emissions for **diesel vehicles** with different years of introduction / registration in the Netherlands. For vehicles from the early years 2008-2010 the number of vehicles in the database is limited in the last two years of monitoring, which may generate some bias.

In Figure 5 and Figure 6 the following trends can be observed:

- Between 2012 and 2013 vehicles of all years of introduction into the fleet show a distinct drop in the gap;
- After 2013 the gap remains largely constant again for petrol vehicles introduced from 2009 onwards and diesel vehicles introduced in 2010 or later;
- For petrol vehicles introduced in 2008 and diesel vehicles introduced in 2008 and 2009 the gap continues to decrease further after 2013;
- Independent of the observed changes over time, the gap is always larger for newer vehicles than for older vehicles. In 2015 the difference in the average gap between vehicles of consecutive years of introduction in the fleet appears to level off for newer vehicles.

The slight increase of the gap from 2015 to 2016 for most years of introduction is caused by the fact that for 2016 not yet a full year of data is available, so that seasonal variations in fuel consumption are not yet averaged out.

Changes over time in the average gap for vehicles of a given year of introduction can be caused by changes in the gap for individual vehicles, e.g. caused by variations in ambient conditions, traffic circumstances and driving styles, as well as by changes in the composition of the group of vehicles with the same year of introduction in the database.

Trends possibly related to changes in fleet composition

A change in the composition of the group of vehicles with the same year of introduction in the Travelcard Nederland BV database is likely to happen three or more years after the year of introduction. Many leased vehicles, for which fuel passes are employed, are used as company car for three to five years, after which they are sold to private owners or exported. It is likely that the vehicles with the highest annual mileages remain in the database for the shortest time. The group of vehicles of a given year of introduction that remains in the fuel pass database after four or five years will thus be smaller than in the first years and will consist of a higher share of vehicles with low annual mileages and driving patterns that differ from those of the group of vehicles with high mileages. Also the average type approval value of the remaining vehicles may be different than the initial average in the year of introduction. That this is a likely explanation for the observed continuing reduction of the gap after 2013 for petrol vehicles introduced in 2008 and diesel vehicles introduced in 2008 and 2009, is proven by the following additional analyses:

- Of the petrol vehicles introduced in the fleet in 2008, the vehicles still present in last two years have an average type-approval CO_2 emission value that is 10 g/km higher than the average for the group of vehicles from 2008 in the years before.
- The evolution of total mileage (per three weeks) of vehicles with different years of introduction, as illustrated in Figure 7 for petrol vehicles, indicates that older vehicles gradually disappear from the database after five years. It is clear that most data is collected in the first five years. After that most vehicles leave the fleet so that average results for later years are based on a smaller group of vehicles.

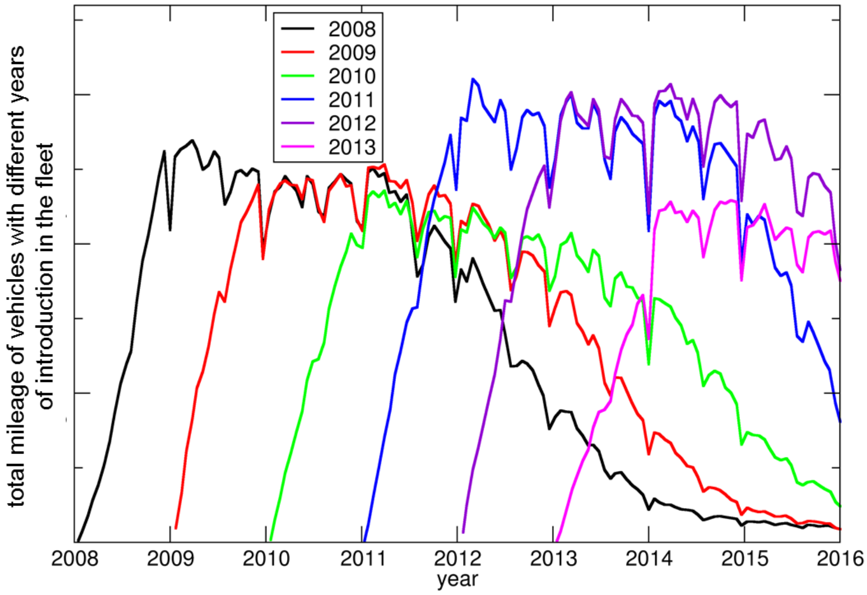

Figure 7 The mileage (per three weeks) over time in the database for petrol vehicles of different years of introduction in the fleet.

Trends possibly related to changes in ambient conditions and traffic circumstances

The distinct drop in the gap between 2012 and 2013 is around 6 to 8 g/km for most groups of vehicles of the same year of introduction into the fleet. The apparent size of the drop may be somewhat exaggerated by the slight increase of the average gap over 2012 compared to 2011. From an analysis in [TNO 2014] the combination of mild winter weather, the low levels of congestion in 2013 due to the economic crisis in combination with improved infrastructure, and the introduction of dynamic speed limits in 2012-2013 in combination with extra lanes on the motorway ("spitsstroken") was considered a plausible cause for the observed reduction of the gap. This coincidence of temporary causes still appears to be a plausible explanation.

The large infrastructural changes, with additional lanes and dynamic speed limits, were completed around 2013. The new situation combined with the economic recession led to a reduction of the congestion, with a limited increase in overall free-flow velocity. This may, in part, be the cause of the reduced fuel consumption. More recently the reduced congestion has also led to higher free-flow velocities. This could explain why the initial effect does not lead to a further reduction in CO_2 emissions beyond the effect observed in 2013 [TNO 2016b]. Both congestion and higher free flow velocities above 80 km/h lead to an increase in fuel consumption. That one is traded for the other over the years explains the limited change in fuel consumption between periods of low and high congestion, as observed in 2014.

The fuel composition may play a role, but the findings are not consistent with the expected effect for, mainly, petrol. In particular, the energy density of petrol is not fully constant [TNO 2016c]. A few percent variation is possible between one petrol sample to the next. Moreover, between summer and winter petrol there are also variations in the energy density. There is limited information that this has changed over the years. On the other hand, the admixture of biofuels does have an effect on energy content per litre of fuel. However, from the increased bio-admixture in the

period 2010-2015 the fuel consumption in litres per kilometre would be expected to increase rather than decrease, as is observed in Figure 5 and Figure 6 for the period 2012 - 2013.
In a previous study [TNO 2013b] the relation between fuel prices and fuel consumption of this group of vehicles has been assessed. No correlation was found in this study, despite large variations in fuel prices. For the group of drivers, using new cars and with the fuel being paid for, high fuel prices may generate little incentive to adapt driving behaviour.

The soft winters and high ambient temperatures in the summer of the last years will have affected the fuel consumption of the vehicles. It is expected that one degree ambient temperature increase will lead to about 0.4% decrease in fuel consumption and vice versa [TNO 2016b]. The magnitude of the effect is related to the relatively large share of motorway driving with the vehicles in the database.

2.3 A closer look at the gap for different vehicle classes

The large amount of vehicles in the database allows for a reliable determination of the difference between real-world and type-approval CO_2 emissions for vehicles with (ranges of) different CO_2 type-approval values and different years of introduction. For years of introduction and CO_2 emission classes for which the database contains more than 50 vehicles the average relative difference is given in Table 1. Both for later years and for lower type-approval CO_2 values a larger relative gap can be observed. Interestingly, petrol and diesel vehicles follow the same trend. Even the magnitude of the relative differences based on the CO_2 emission classes is very similar.

The large increase of the difference between real-world and type approval CO_2 emissions as function of the type approval value is somewhat exaggerated in the relative numbers in Table 1. For a lower type-approval CO_2 emission the same amount of additional CO_2 emissions represents a larger relative gap. In Table 2, which presents the absolute difference in type-approval and real-world CO_2 emissions, trends in the year-by-year change of the gap are more clear. Both for petrol and diesel the gap has increased annually by 1 to 3 g/km for vehicles with similar type approval CO_2 emissions. There does not seem to be a slowing down of this increasing difference. As matter of fact, a larger than average increase can be observed in many CO_2-segments between new vehicles sold in 2015 and 2014. This may be a temporary effect caused by the introduction of a large number of new vehicle models in 2015 that meet the Euro 6 standard.

Furthermore it can be seen from Table 2 that the absolute gap was initially most prominent in vehicles with low type approval values and small or absent for larger and less fuel efficient vehicles. In more recent years, however, it has become substantial over all type approval CO_2 segments. Finally it can be seen that especially for diesels the shift towards vehicles with lower type approval CO_2 values is accompanied by a clear narrowing of the bandwidth of CO_2 values.

Table 1 The relative difference between real-world and type-approval fuel consumption of petrol (upper) and diesel (lower) passenger cars, differentiated for the year of first registration and the type-approval CO_2 emission value and averaged over the entire period that vehicles within a category are present in the Travelcard database.

petrol	**type-approval CO2 [g/km]**												
year	70 - 79	80 - 89	90 - 99	100 - 109	110 - 119	120 - 129	130 - 139	140 - 149	150 - 159	160 - 169	170 - 179	180 - 189	190 - 199
2005				23.4%	30.8%		12.1%	10.2%	7.9%	6.3%	4.2%	3.0%	1.9%
2006				20.9%		17.1%	13.2%	12.6%	9.4%	6.6%	3.1%	1.8%	1.2%
2007				22.2%	22.9%	12.4%	18.5%	12.7%	9.7%	6.8%	3.8%	2.2%	2.6%
2008				26.0%	23.9%	19.5%	18.7%	16.7%	12.7%	9.7%	6.0%	4.0%	2.0%
2009		42.6%	38.2%	27.6%	26.6%	20.4%	20.8%	17.3%	12.5%	9.8%	7.9%	4.9%	3.6%
2010		40.4%	38.9%	27.1%	27.6%	23.9%	20.1%	17.5%	13.4%	11.0%	9.9%	9.6%	8.9%
2011		41.4%	44.4%	28.6%	25.6%	26.6%	20.8%	19.4%	15.1%	12.5%	12.2%	11.7%	11.6%
2012		42.5%	36.4%	34.0%	26.0%	26.4%	22.8%	20.8%	16.6%	13.5%	10.8%	14.9%	10.3%
2013	51.2%	45.8%	39.4%	36.2%	33.2%	25.8%	24.5%	20.7%	20.9%	11.4%	11.2%		6.9%
2014	54.5%	48.2%	40.7%	37.0%	32.8%	28.0%	27.0%	23.3%	21.8%	14.1%			
2015	68.2%	54.8%	45.0%	44.9%	39.8%	34.5%	31.1%	29.7%	26.4%	31.2%			

diesel	**type-approval CO2 [g/km]**												
year	70 - 79	80 - 89	90 - 99	100 - 109	110 - 119	120 - 129	130 - 139	140 - 149	150 - 159	160 - 169	170 - 179	180 - 189	190 - 199
2005					17.5%	17.1%	12.2%	10.7%	6.4%	3.5%	1.0%	2.2%	-3.2%
2006					16.6%	17.4%	12.3%	10.2%	5.2%	3.5%	0.6%	-0.9%	-1.7%
2007					19.6%	17.7%	13.3%	8.8%	6.7%	3.9%	3.7%	-0.7%	0.5%
2008			26.7%	31.6%	25.7%	18.2%	11.6%	11.6%	7.8%	6.2%	4.3%	0.4%	1.3%
2009			27.2%	29.8%	23.7%	16.3%	12.2%	10.5%	7.6%	5.9%	3.3%	1.2%	0.0%
2010		43.8%	40.2%	30.8%	24.7%	18.1%	16.0%	11.8%	8.5%	7.6%	4.4%	2.6%	8.5%
2011		46.1%	40.8%	29.7%	27.8%	22.0%	18.0%	16.0%	12.6%	9.3%	6.9%	8.6%	14.1%
2012		45.3%	49.9%	29.5%	28.7%	22.5%	21.3%	15.3%	12.8%	14.7%	13.2%	12.9%	11.0%
2013		52.1%	40.3%	33.8%	30.7%	24.5%	21.7%	19.0%	16.7%	14.6%	13.4%		
2014		55.6%	43.4%	38.2%	32.3%	25.3%	22.4%	19.3%	17.3%				
2015	58.2%	60.1%	45.3%	40.5%	36.6%	32.4%	29.7%						

Table 2 The absolute difference between real-world and type-approval fuel consumption of petrol (upper) and diesel (lower) passenger cars, differentiated for the year of first registration and the type-approval CO_2 emission value and averaged over the entire period that vehicles within a category are present in the Travelcard database.

petrol	**type-approval CO2 [g/km]**												
year	70 - 79	80 - 89	90 - 99	100 - 109	110 - 119	120 - 129	130 - 139	140 - 149	150 - 159	160 - 169	170 - 179	180 - 189	190 - 199
2005				24.4	35.1		16.5	14.9	12.4	10.3	7.3	5.5	3.6
2006				22.4		21.7	18.2	18.1	14.6	10.9	5.4	3.3	2.4
2007				24.1	26.7	15.9	25.6	18.3	15.0	11.2	6.6	4.1	5.0
2008				27.8	28.3	24.8	25.7	24.1	19.8	16.2	10.5	7.4	3.9
2009		37.9	35.3	29.4	30.5	26.0	28.6	25.0	19.6	16.3	13.9	9.2	7.0
2010		36.0	35.9	28.6	31.5	30.0	27.4	25.4	20.9	18.4	17.3	17.9	17.4
2011		36.7	41.5	29.9	29.2	33.0	28.4	28.1	23.6	20.7	21.4	21.6	22.6
2012		37.5	35.0	35.7	30.0	32.9	31.1	30.1	25.9	22.3	18.9	27.6	20.0
2013	40.4	39.6	37.4	37.8	38.3	31.8	33.3	30.1	32.4	18.8	19.7		13.5
2014	42.3	42.0	39.0	39.3	37.7	35.2	36.6	33.8	33.7	23.3			
2015	51.2	46.8	43.3	47.8	45.3	43.2	42.1	42.9	40.9	51.4			

diesel	**type-approval CO2 [g/km]**												
year	70 - 79	80 - 89	90 - 99	100 - 109	110 - 119	120 - 129	130 - 139	140 - 149	150 - 159	160 - 169	170 - 179	180 - 189	190 - 199
2005					20.3	21.4	16.4	15.4	9.9	5.8	1.7	4.1	-6.3
2006					19.5	21.6	16.7	14.7	8.1	5.7	1.1	-1.7	-3.3
2007					23.2	22.1	17.8	12.8	10.4	6.4	6.5	-1.3	0.9
2008			26.4	33.6	30.6	22.9	15.7	16.8	12.1	10.1	7.6	0.8	2.6
2009			26.9	31.7	27.9	20.4	16.5	15.2	11.8	9.6	5.7	2.2	0.0
2010		39.0	38.8	33.1	28.4	22.8	21.8	17.1	13.2	12.5	7.8	4.8	16.7
2011		41.0	38.8	32.1	31.9	27.4	24.5	23.2	19.6	15.3	12.2	16.0	27.6
2012		40.2	45.9	31.9	32.8	28.0	28.8	22.5	19.8	24.5	23.3	24.0	21.5
2013		45.6	39.0	36.1	34.8	30.8	29.4	27.8	26.0	24.4	23.5		
2014		47.1	42.5	40.5	36.3	31.6	30.2	28.2	26.9				
2015	46.0	49.5	43.8	42.8	41.0	40.3	40.2						

Figure 8 shows that there is a fairly linear relation between the average real- world CO_2 emissions and the type approval value. For new vehicles sold in 2014 and 2015 these correlations can be written as[16]:

2014: $RW_{CO_2} = 0.79 \cdot TA_{CO_2} + 61$

2015: $RW_{CO_2} = 0.96 \cdot TA_{CO_2} + 48$

with RW_{CO_2} (real-world) and TA_{CO_2} (type approval) in [g/km]. For new vehicles sold in 2015 the relation is preliminary as not for all vehicles a complete year of data is available in the database.

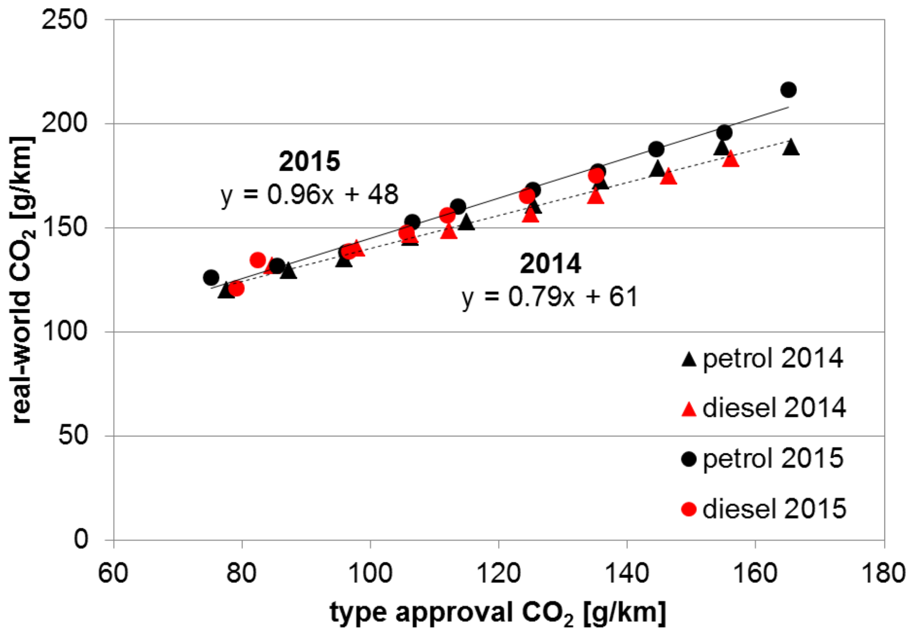

Figure 8 Correlation between absolute real-world CO_2 emissions and the average type approval value per segment, for new vehicles sold in 2014 and 2015.

2.4 Variations between vehicles and drivers

The results in the graphs and tables above are averages based on a large number of vehicles and drivers. This does not mean that individual users all have the same deviation between real-world and type approval CO_2 emissions or fuel consumption. There is a large spread in vehicle use patterns and driving styles, resulting in a substantial spread in fuel consumption and associated real-world CO_2 emissions. As can be seen from Figure 9, diesel vehicles have a smaller spread than petrol cars. Assuming similar underlying variations in use patterns and driving styles for petrol and diesel vehicles, this would mean that for diesel vehicles the fuel consumption is less sensitive to variations in use conditions and driving styles. This is to be expected given the lower sensitivity of a diesel engine's efficiency to variations in engine load.

[16] These relationships differ from the equation $RW_{CO_2} = 0.95 \cdot TA_{CO_2} + 55$, given in [TNO 2015]. This is caused by the change in methodology as discussed in sections 1.4 and 2.5.

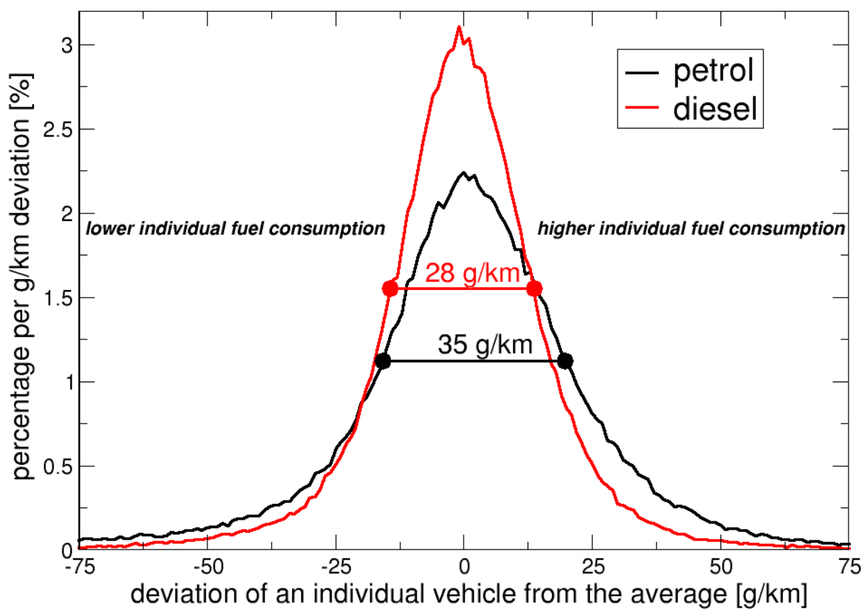

Figure 9 The variation in real-world CO_2 emissions of individual vehicles with respect to the average result for the type approval CO_2-segment in which they are categorised in Table 1 and Table 2, for all 436,000 vehicles in the database.

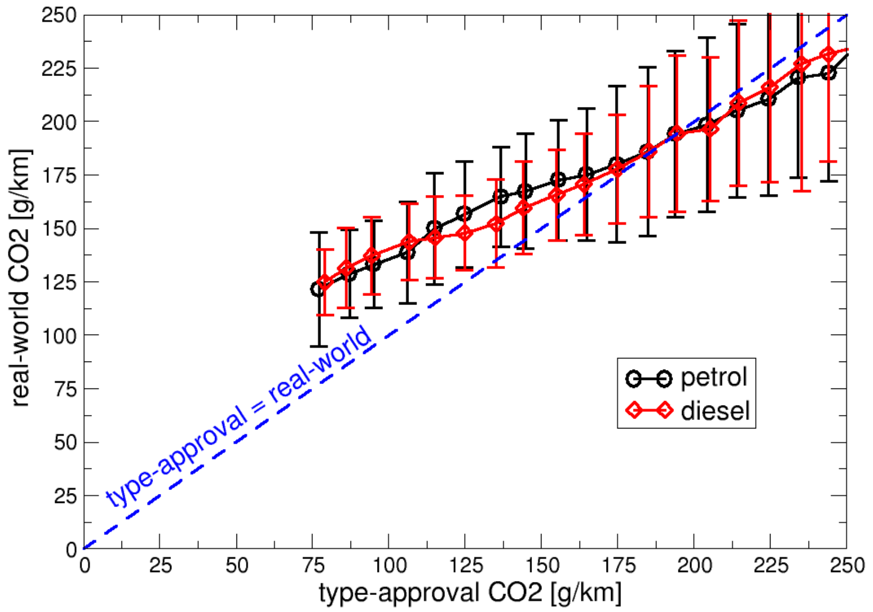

Figure 10 The average real-world CO_2 emission values and associated standard deviations per type-approval CO_2 emission class (as used in Table 1 and Table 2) for all vehicles in the database. For lower type-approval values the gap increases while the variation decreases. The gap is therefore established most accurately for vehicles with a type-approval value below 110 g/km.

The observed average variation of about 30 g/km (i.e. +/- 15 g/km around the average) results in a difference in fuel consumption of about 1 to 2 litre/100km between users with typical high and low fuel consumption with the same vehicle model. Driving 100 km/h or 130 km/h on the motorway yields a larger difference of about 50 g/km. Hence, the magnitude of the observed variations in fuel consumption between different drivers is well within the range of expectations. In total 436.000 vehicles are underlying this analysis, divided into 184,000 petrol passenger cars and 252,000 diesel vehicles.

Given the typical spread of 30 g/km in the real-world CO_2 emissions of similar vehicles means that for an accuracy of 2 - 3 g/km in the average emissions of a group of similar vehicles at least data from 50 individual vehicles are needed. Each of the cells in Table 1 and Table 2 have at least 50 vehicles underlying the presented averages.

The typical variation in real-world CO_2 emissions of +/- 15 g/km around the average, combined with an average gap of around 45 g/km, means that the number of modern vehicles which have (or stated differently: the number of drivers that realise) a real-world fuel consumption close to the type-approval value is very small.

Figure 10 shows that while the gap increases with a decreasing type-approval value, the variation is decreasing for vehicles with lower CO_2 values. In this graph the average real-world CO_2 emission value and the associated standard deviation are visualised for each of the type-approval CO_2 emission classes as used in Table 1 and Table 2. From this analysis it is also clear that there are only minor differences between the trends for petrol and diesel vehicles.

2.5 Evaluation of impacts of the change in methodology

As explained in section 1.4 the results presented in this report have been derived from the Travelcard Nederland BV database using a methodology that has changed compared to the methodology used in previous reports. Instead of by averaging over tank events, average fuel consumption figures (and corresponding CO_2 emission values) per vehicle and for groups of vehicles have now been determined by dividing the sum over all tanked litres by the sum over all driven kilometres. This is equivalent to a weighted averaging of the average fuel consumption per tank event over the kilometres driven per tank event.

This change in methodology has two main impacts:

- In average results per vehicle inaccuracies are eliminated, which are associated with the fact that the tank is not filled to the exact same level at every tank event;
- In average results for groups of vehicles the results for vehicles with a lower than average fuel consumption get a higher weight than in the previously employed method.

As a result of the combination of the updated methodology and the observed drop in the gap from 2012 to 2013, as seen in Figure 5 and Figure 6, the results for the absolute difference between real-world and type-approval CO_2 emissions of petrol and diesel passenger cars as included in Table 2 is smaller than the values presented in previous reports. For vehicles with low type approval CO_2 values the gap is around 6 - 8 g/km lower compared to the results from [TNO 2014], while for vehicles with high type approval CO_2 values the values are 10 - 14 g/km lower. The sole effect of the methodology change is slightly smaller.

An in-depth analysis shows that the largest effect comes from impact 1, listed above. This is illustrated in Figure 11. For all individual vehicles in the database the average CO_2 emissions have been calculated by averaging the results per tank event over all tank events and by dividing the sum over all tanked litres by the sum over all driven kilometres. Figure 11 plots the distribution of the difference between the result obtained with the first method and the second method. The updated methodology leads to average CO_2 emissions per vehicle that are on average 7.5 g/km (for diesel) to 10.5 g/km (petrol) lower than the results obtained with the old method. The shape of the distribution indicates that there is one group of drivers that always fill the tank in (more or less) the same way while another group shows a large variation in the level of filling between tank events, leading to the long tail in the right-hand side of the graph.

The average size of the difference as shown in Figure 11 appears to explain the largest part of the difference in outcome between the old and the updated method. The effect is the largest for vehicles for which the total distance is small, and decreases somewhat if data is available for 30,000 km or more. This may also indicate that the effect is influenced by seasonal variations.

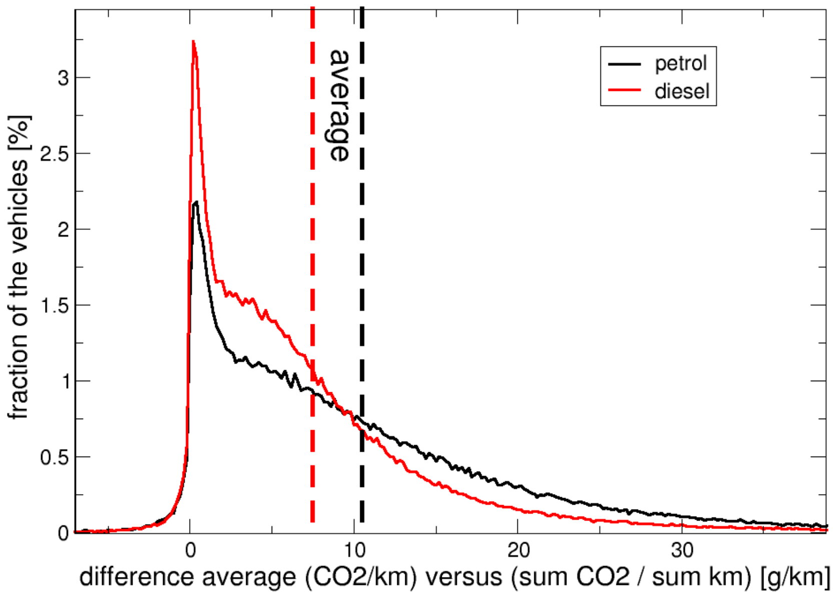

Figure 11 Difference between the average real-world CO_2 emission values determined for individual vehicles by averaging the average CO_2 emissions in g/km determined per tank event over all tank events and by dividing the sum of all CO_2 emissions (in grammes) over all tank events by the sum of all kilometres driven over all tank events.

Separate analyses on the data for impact 2, as listed above, confirm that this mechanism indeed has a significantly smaller effect than impact 1.

3 Conclusions

For many years studies by TNO and other organisations have accumulated evidence that the difference between real-world fuel consumption and CO_2 emissions of passenger cars and their type-approval values (the “gap”) is increasing. As a consequence the average real-world fuel consumption and CO_2 emissions of passenger cars are decreasing much more slowly than the average type-approval values. The analysis of tank pass data from Travelcard Nederland BV, presented in this report, shows that new vehicles sold in 2015 are no exception. But in recent years the picture has become somewhat more complex.

This report analyses tank pas data, obtained from Travelcard Nederland BV[17], covering the period 2004 to Q1 2016 and a total number of 436 thousand conventional vehicles (plug-in hybrids are excluded). An analysis of the annual mileages of vehicles in the database shows that the database does not only contain stereotypical business drivers. There is a large spread in annual mileages and the database also contains a significant share of vehicles with relatively low annual mileages. The results of the analysis are therefore considered meaningful for the entire Dutch passenger car fleet.

Over the whole fleet included in the tank pass data for 2015 the relative difference between the average real-world and type approval CO_2 emissions is around 35%. For vehicles entering the Dutch fleet in 2015 the absolute difference is about 45 g/km, which means that the relative difference is around 45%.

Averaged over the whole period that vehicles are present in the database, the relative gap on average grows with 1.5%[18] per year as function of the year of introduction / registration of the vehicles in the fleet. This is equivalent to an annual increase of around 2 g/km in the absolute gap. A larger than average increase of the gap between new vehicles sold in 2015 and 2014 can be observed in many segments of vehicle with similar type approval CO_2 emissions. This may be a temporary effect caused by the introduction of a large number of new vehicle models in 2015 that meet the Euro 6 standard.

Looking at the development over time of the gap for vehicles with the same year of year of introduction / registration, a declining trend is observed in the data for recent years. From 2012 to 2013 a distinct drop in the gap of around 6 to 8 g/km is seen for most groups of vehicles of the same year of introduction into the fleet. From an analysis in [TNO 2014] the combination of mild winter weather, the low levels of congestion in 2013 due to the economic crisis in combination with improved infrastructure, and the introduction of dynamic speed limits in 2012-2013 in combination with extra lanes on the motorway (“spitsstroken”) was considered a plausible cause for the observed reduction of the gap. This coincidence of temporary causes still appears to be a plausible explanation.

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[17] [TNO 2016a]
[18] percent point

After 2013 the average gap stabilizes again for most groups of vehicles of the same year of introduction into the fleet. Independent of the observed changes over time, the gap is always larger for newer vehicles than for older vehicles.

There is a typical variation of +/- 15 g/km between different drivers and vehicles. This variation is decreasing with lower type-approval values. Given an average gap of 45 g/km, the number of modern vehicles which have (or stated differently: the number of drivers that realise) a real-world fuel consumption close to the type-approval value is very small.

Impacts from a change in assessment methodology

The results presented in this report have been derived from the Travelcard Nederland BV database using a methodology that has changed compared to the methodology used in previous reports. Instead of by averaging over tank events, average fuel consumption figures (and corresponding CO_2 emission values) per vehicle and for groups of vehicles have now been determined by dividing the sum over all tanked litres by the sum over all driven kilometres. This is equivalent to a weighted averaging of the average fuel consumption per tank event over the kilometres driven per tank event.

For the absolute difference between real-world and type-approval CO_2 emissions of petrol and diesel passenger cars the combination of the updated methodology and the drop in the gap observed from 2012 to 2013 leads to results that are around 6 - 8 g/km lower for vehicles with low type approval CO_2 values and 10 - 14 g/km lower for vehicles with high type approval CO_2 values compared to the results from [TNO 2014]. Overall trends observed from the data, however, remain generally unaffected.

4 Literature

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For an overview of all relevant TNO reports on the topic of road vehicle fuel consumption see:

www.tno.nl/brandstofverbruik

www.tno.nl/fuelconsumption

5 Signature

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TNO

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