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TNO report

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Dutch CO_2 emission factors for road vehicles

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Summary

Road traffic is a large source of CO_2 emissions and it's emission levels depend on a constantly changing fleet composition and driver behavior. In order to quantify the emissions, representative CO_2 emission factors are required for different vehicle categories and different driving circumstances. Representative CO_2 emission factors are directly linked with the real-world fuel consumption. The present study aims to determine the CO_2 emission factors described above for different vehicle categories.

TNO annually provides emission factors to the Pollutant Release and Transfer Register (PRTR) and the Dutch Ministry of Infrastructure and the Environment. These are consequently used for different purposes, such as estimating and reporting the annual emissions from road transport, air quality modeling and the evaluation of abatement measures. CO_2 emission factors are not part of this annually published set, since emission factors for air pollutants are used for other purposes than those for CO_2. In addition, the decrease of air polluting emissions of vehicles is driven by other European legislations than for CO_2 emissions. For this reason, air pollutant emissions primarily depend on the Euro Classes (construction year) and fuel type whereas CO_2 emissions strongly depend on the vehicle's energy demand: its speed, vehicle weight, driving habits and construction year.

In the reporting to international organizations such as UNFCCC and the EU, CO_2 emissions of road transport are determined solely on the basis of fuel sales. However, in order to evaluate the effect of reduction measures, such as changing the speed limit on motorways, it is necessary to have emission factors which distinguish between different speed limits, construction years and vehicle categories.

Determining the average CO_2 emission for different conditions across the fleet requires knowledge of the following items:
1. the real-world fuel consumption of all relevant vehicle categories,
2. the shares of these vehicles in traffic vehicle-kms, and
3. the variation of the CO_2 emissions with different driving habits and road types.

The fleet specific emission is determined with the combination of these three items.

In this study, real-world CO_2 emission factors for Dutch roads are determined using the following information sources:
- emission measurements on vehicles (derived from test programs carried out for the Ministry of Infrastructure and the Environment),
- monitoring data on the fuel consumption, and
- statistical data on the development of the fleet.

The emission factors are determined in line with the PRTR, SRM-I and SRM-II (Standard Calculation Method for air quality) which is used to determine emission factors of air pollutants. The emission factors are determined for 2015, 2020, and 2030 (relevant for the assessment of reduction measures).

For 2015, the emission factors on the motorways are given in the table below.

Table 1 Real-world CO_2-emission factors on the motorway (SRM-II) in the year 2015 (MSH: strong enforcement) to show the relative effect for different velocities

Real-world CO_2 emission factors [g/km]	**speed limits [in km/h] / level of enforcement [none/MSH]**						
Vehicle category	**Congestion**	**80 / MSH**	**80**	**100 / MSH**	**100**	**120**	**130**
Light-duty	266	143	164	163	167	184	192
Medium-duty	772	444	449	444	444	444	444
Heavy-duty	1527	750	748	750	750	750	750

Table 2 The real-world CO_2 emission factors (SRM-I) for the period 2015-2030, based on the 2015 prognoses of the future fleet composition. The 2030 values are based on the European 2020 target of 95 g/km. No further targets are assumed.

CO_2 [g/km]	Year	2015	2020	2030
Road type	Vehicle classes			
urban congestion	Light-duty	350	313	275
	Busses	1013	998	989
	Medium duty [10-20 ton]	1138	1128	1097
	Heavy duty	2356	2441	2440
urban normal	Light-duty	232	212	189
	Busses	1013	998	989
	Medium duty [10-20 ton]	783	728	690
	Heavy duty	1542	1540	1527
urban free flow	Light-duty	223	201	179
	Busses	1013	998	989
	Medium duty [10-20 ton]	611	535	493
	Heavy duty	1149	1105	1086
rural	Light-duty	142	137	127
	Busses	664	624	602
	Medium duty [10-20 ton]	520	507	504
	Heavy duty	994	1028	1038
Motorway average	Light-duty	183	168	156
	Busses	563	508	478
	Medium duty [10-20 ton]	451	431	420
	Heavy duty	768	787	792

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Appendices

1 Introduction

1.1 Background

The total CO_2 emission of road transport and the reduction thereof is a delicate balance between the increasing mobility over the years combined with more fuel efficient vehicles, and a shift towards motorway driving. Moreover, these aspects depend indirectly on the economic development. So far it has been difficult to pinpoint different aspects as the total CO_2 emissions from road transport are determined based on the amount of fuel sold, which means little differentiation is available of these CO_2 emission totals towards mileages, vehicle types and road types.

On motorways, in November 2011, plans to increase the speed limit on the several Dutch road sections to 130 km/h were estimated to result in an increase of 0.4 Mtons of CO_2. According to TNO the difference in CO_2 emissions between a speed limit of 120 km/h and 130 km/h is roughly 5% [Lange, 2011]. This estimate was provided based on monitoring data from four pilot trajectories. This CO_2 emission is only part of the total CO_2 emission of road transport. Also urban and rural traffic contribute to the total.

Meanwhile, research has been performed on the possibility to reduce the number of alternating speed limits. The maximum speed on the HWN (main roads network of motorways and regional roads) also has effect on CO_2 emissions. In order to calculate these CO_2 emissions based on the velocities driven in 2015, it is necessary to have the CO_2 emission factors for the fleet of 2015 at different speeds.

TNO annually publishes the emission factors of various pollutants emitted by road transport vehicles; amongst others for the use in the Dutch Pollutant Release and Transfer Register (PRTR) and air quality models [Hensema et al., 2013]. In the same process CO_2 emission factors are also determined, however the values are normally not published because they have not been validated. In a recent collaboration with Statistics Netherlands (CBS), CO_2 emissions from passenger cars and light and heavy duty trucks have been determined "bottom-up" using the characteristics of the Dutch vehicle fleet [Staats, 2014], [Willems, 2014] and validated “top-down” with the amount of annual fuel sales [CBS, 2014].

In addition, TNO is involved in several national and international monitoring programs in which the impact of CO_2 policies are evaluated. Through these studies, there is good understanding of the differences between type approval “laboratory” and the practice “real-world” values. Recent TNO research showed that “real-world” CO_2 emissions fall less rapidly than “laboratory” values and the difference between the two is increasing over the years. Therefore, national and European policies have less effect on the reduction of CO_2 emissions than might be expected based on the reported values from manufacturers [Ligterink, 2009], [Ligterink, 2010], [Ligterink, 2012a], [Ligterink, 2012b], [Ligterink, 2013a], [Ligterink, 2013b], [Ligterink, 2014], [Mock, 2013], [Ntziachristos, 2014].

1.2 Aim

The aim of this study is to determine and validate the real-world CO_2 emission factors for road transport. These emission factors are in line with the monitoring programs of fuel consumption, but contain sufficient detail to assign CO_2 emission to different vehicle categories and traffic situations.

1.3 Approach

Real-world CO_2 emission factors are determined in four steps:
1. CO_2 emission factors are determined using TNO's emission model VERSIT+.
2. An estimate is made of the development of the vehicle fleet composition, taking into account the current (stimulus) policy for fuel efficient cars.
3. Real-world emission factors are determined by calibrating the VERSIT+ emission factors with scaling factors. The scaling factors are based on independent observations of the real-world emission totals, i.e. from fuel consumption data. This offsets the CO_2 emissions for the mostly unknown circumstances, which are not included in the chassis tests but are visible in practice, such as extra weight, low temperatures, precipitation, low tyre pressure, etc.
4. The emission factors are aggregated to the level of light, medium and heavy-duty vehicles according to the SRM methodology.

1.4 Structure of the report

In Chapter 2, the method for determining real-world CO_2 emission factors is described. Chapter 3 provides insights from several monitoring programs which are used later on in the calibration process (chapter 6). Chapter 4 and chapter 5 describe the determination of CO_2 emission factors with VERSIT+ and fleet development respectively. The emission factors are aggregated to SRM-I and SRM-II levels in chapter 7. Chapter 8 discusses the effects of driving behavior and uncertainties on the overall emissions. Final conclusions are provided in chapter 9.

2 Method for determining real-world CO_2 emission factors

The approach set out in Section 1.3 is expanded upon here.

2.1 Step 1 – VERSIT+ emission model

In step 1, CO_2 emission factors are determined using TNO's emission model VERSIT+. The CO_2 emission factors are based on, mainly, laboratory tests, which in general reproduce the emissions, and the variation therein with driving behavior. However, the is a small underestimation of the real-world emissions compared to monitoring data. This can have many causes: different driving resistance, vehicle maintenance, payload, auxiliary use, road surface, ambient temperature, etc. For more information on the VERSIT+ emission factors step can be found in [CBS, 2014]. In the cases that vehicles are tested on the road, the differences between the emission tests and the monitoring data is smaller, down from 15% to a few percent.

2.2 Step 2 – Determining real-world CO_2 emission factors

The fuel consumption and CO_2 emission of road transport depends on many factors. Vehicle weight, driving speed, and driving dynamics (the amount of acceleration and deceleration) are the three main aspects. In addition, other factors are also important for accurate estimates of CO_2 emissions. Changing weather and temperature conditions cause an annual variation of nearly 7% in CO_2 emissions per kilometer. Improved vehicle technology, in particular more efficient engines, can reduce CO_2 emissions, however in practice, the positive effect of the development is often (partly) counteracted by higher power specifications and weight gain for the same vehicle. For trucks, only half of the reductions achieved at motor level remain in practice on the road.

Using the amount of tanked fuel as a benchmark for total fleet emissions
Total and average CO_2 emissions can be most accurately determined using the vehicle's fuel consumption. Because the total amount of tanked fuel is monitored in the Netherlands, the total amount of emitted CO_2 emissions is known and available for independent verification. Assigning those emissions to specific vehicles and specific conditions is much more difficult.

The direct link between fuel consumption and CO_2 emissions helps to calibrate the emission factors determined in step 1 with the practice on the road. As a rule of thumb the following values are used, from linking official type-approval values for CO_2 and fuel consumption:

- Diesel 1:00 [l/100km] = 26.5 [g/km] CO_2
- Petrol 1:00 [l/100km] = 23.7 [g/km] CO_2

For petrol, this conversion factor needs to be adjusted according to the blending of biofuels. A value of 23.6 is common after 2010. With diesel, the change in fuel density compensates the lower carbon fraction of the bio-blending.

2.3 Step 3 – Vehicle fleet development

Since the year 2000, reducing CO_2 emissions has been a key objective of the European Union, national and local governments and companies with green and sustainable ambitions. As a result, over the years a strong development has been observed in the composition of the vehicle fleet and the applied automotive technologies.

For passenger cars, hybrid vehicles have become a substantial share of the fleet, specifically in the Netherlands. In general, hybrid vehicles have a lower fuel consumption and therefore emit less CO_2 emissions. Effectively, the Netherlands have one of the lowest average fuel consumptions of new passenger cars sold in Europe. In the last ten years, the average type approval value has sunk from 175 g/km to 105 g/km, which in in terms of the type approval is a large step. However, in practice the effects are much smaller as is apparent from monitoring programs.

Also, truck engines are rapidly becoming more efficient, at a rate of roughly one percent per year since 1990. However, on average the rated engine power of vehicles also increases which results in larger engine losses. Effectively, only 50% of the efficiency gain is observed in practice. On average, internal engine losses are about 3% of the rated engine power, which for a typical tractor-trailer on the motorway results in CO_2 emissions of about 65 g/km. 10 percent more powerful engines thus translate to about 7 g/km. For passenger cars, there are similar trends going on, but these are more difficult to distinguish from other developments, because there is no separate engine test. For passenger cars, it is expected that increased power between 2000 and 2015 has led to about 2.5 g/km of additional CO_2 emissions.

2.4 Step 4 – the SRM-I, SRM-II methodology

For harmful emissions, there is a long term program [PRTR and air quality monitoring at RIVM] to annually determine and report the emission factors of road traffic. The same SRM methodology is used to aggregate the real-world CO_2 emission factors for the urban roads, rural roads and the motorway.

3 CO_2 emission measurements

CO_2 emissions are directly related to the vehicle's fuel consumption which is the result of the power demand of the motor. In order to provide a consistent image of the fleet's CO_2 emissions, various data sources must be compared with each other. The CO_2 emission factors produced in this study are calibrated with the most reliable and recent data on fuel consumption. In this chapter, some important data sources are briefly discussed.

3.1 Real world fuel consumption

Before the currently legislated NEDC test cycle was introduced for determining the type approval value, the fuel consumption in the city (ECE / UDC, approximately 18 km/h) was determined, combined with fuel consumption at constant speeds of 90 km/h and 120 km/h. The values for these categories of city, 90 and 120 km/h were respectively around 9, 6 and 8 l/100km for conventional petrol cars in the late eighties, for these three cases. The few Diesel vehicles that were around had a significantly lower fuel consumption. The improvements in type approval (TA) fuel consumption values ever since have mainly been a result of reduced fuel consumption in urban driving rather than at higher speeds and lower dynamics. In recent years, the standard TA fuel consumption decreased rapidly, see Figure 1.

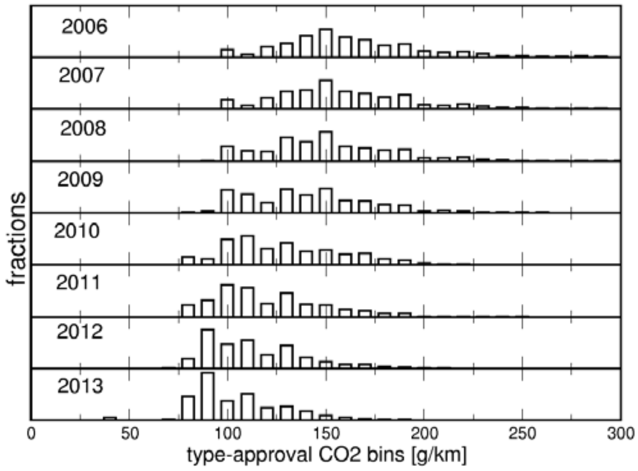


Figure 1: Distribution of type approval CO_2 emissions of new passenger cars (shares of the total sales volume per year) [Ligterink, 2014]

3.2 Previous studies on CO_2-emissions of road transport

In the past, TNO has done some calculations for the Dutch road agency Rijkswaterstaat in which the CO_2 emissions from road transport have been determined. In all cases, however, only relative effects have been properly determined.

The determination of the total amount of CO_2 emissions, which is the basis of this study, provides for the first time an overall picture in which all relevant vehicle categories and situations have been taken into account.

3.3 Modeling CO_2-emissions of heavy duty vehicles

Around 1995, TNO created a simple model for the determination of heavy-duty fuel consumption on the basis of physical properties: rolling resistance, air resistance, etc. The fuel consumption was a function of weight and speed. This model has been and is still used by multiple parties, despite the changes in technology ever since [Ntziachristos, 2014].

In 2009, the model was updated based on the latest available measurements on Euro V trucks on the road [Ligterink, 2012a]. The data for average driving behavior and the related driving dynamics have been included in the model for different average speeds. The main conclusion was that the engine power, in addition to vehicle weight, has an important influence on the practical usage of the vehicle. This does not follow from the official test, because the test is adjusted to the engine's power: a larger engine is more heavily loaded in the test, but not on the road. The equation for the CO_2 [g/km] emissions at average speed and normal driving dynamics is:

$$CO_2 = (465*M+48.1*P)/v+32.4*M+0.89*P-(0.48*M+0.0256)*v+(0.000889*M+0.00041)*v^2$$

v [km/h] is the velocity, M [ton] the total vehicle weight, en P [kW] the rated power.

From this formula it can be deduced that a higher power leads to a higher fuel consumption. This is partly due to the lower efficiency at low loads, but probably a higher specific power (kW/ton) also leads to more dynamic driving with effectively a higher fuel consumption per ton weight. The fact that a heavily loaded truck (10 kW/t and less) has its optimal speed at 85 km/h and a lighter truck at 70 km/h already gives an indication that lower driving dynamics at high speeds on the motorway works mainly in favor of the heavily loaded trucks.

3.4 Fuel consumption based on monitoring program *truck-of-the-future*

The monitoring program truck-of-the-future, which has been running for several years, has independently confirmed the effect of vehicle mass and engine power on fuel consumption which was previously found [TVDT] . As a rule of thumb it can be said that trucks consume about 0.5 l/100 km per ton mass. Every extra kW of engine power is equivalent to about 0.05 l/100 km. For example, a heavy tractor-trailer combination with a gross vehicle mass of 30 tons and a rated engine power of 300 kW consumes on average 30 l/100 km or about 800 gCO_2/km. A light truck with 12 ton and 220 kW consumes about 17 l/100 km (450 gCO_2/km).

Figure 2 contains the fuel consumption data of several hundred trucks at different trips. The red line shows the rule of thumb described above, which on average represents the trend in the data remarkably well. The variation between individual trips of about 15% is caused by the difference in driving dynamics at different trips. This spread is smaller than for passenger cars.

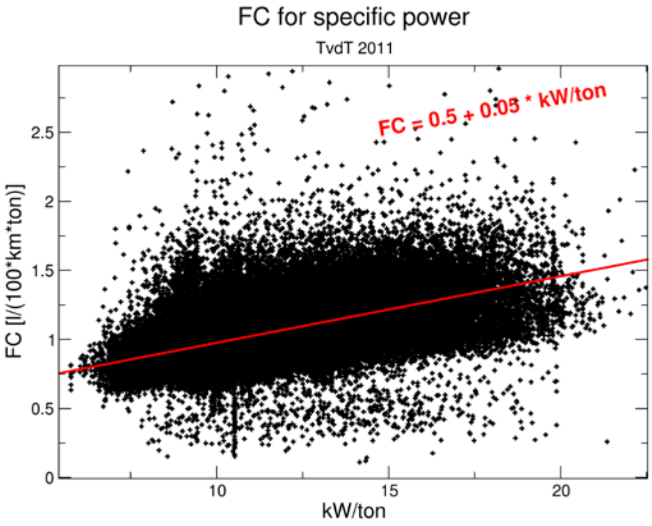


Figure 2 Relation of specific engine power per gross vehicle mass (kW/ton)to and fuel consumption [TvdT]. The resulting trend is visible. The spread of 15% around the line is related to different driving (urban, long distance, etc.).

3.5 Research on the increase of the speed limit to 130 km/h

A previous study on CO_2 emission factors on the motorway [Lange, 2011] compared CO_2 emissions at different velocities. The study showed that the emissions of light duty vehicles increase by 5% when the speed limit increases from 120 to 130 km/h, which a smaller increase in average vehicle veloctiyThe results were combined with the expected fleet development to derive emission factors over time for 2015, 2020 and 2030, see Table 4.

Table 3: Light duty CO_2 emission factors at 130 km/h [Lange, 2011].

	2010	**2015**	**2020**	**2030**
CO_2[g/km]	180	173	161	154

Since then, the fleet development has gone much faster. The current study provides a lower emission factor for 130 km/h for light traffic in 2015: 166.2 g/km. The difference between a 130 km/h and a 120 km/h speed limit is also smaller: 3.7% instead of 5% that was previously determined. The downward trend in the fleet average CO_2 emission factor is also estimated to be smaller though than previously with the recent monitoring data.

Since 2011, many new technologies (start-stop, hybridization, downsizing, six gear, ubiquitous turbo, etc.) have been added to vehicles that are now important on the road. In particular, there is a smaller difference in CO_2 emissions from modern diesel cars between 120 km/h and 130 km/h velocity profiles.

In this study the newly developed velocity profiles for emission factors are used. This gives some change in the overall emission factors, as apparently the dynamics on the different road types is higher than previously assumed.

3.6 Travelcard tank pass analyses

Since 2008, Travelcard Netherlands BV shares its data from tank passes of a large group of vehicles with TNO for analysis [Ligterink, 2009], [Ligterink, 2010], [Ligterink, 2013], [Ligterink, 2014]. The group of vehicles with tank passes belongs to commercial drivers with possibly a slightly higher average speed and more aggressive driving style than the average motorist. On the other hand, the same group of vehicles has a larger annual mileage such that they represent a relatively large share of the total mileage. They drive more than average on the motorways, less in cities and less with a cold engine. These factors could lead to a lower average fuel consumption. There are therefore several reasons that explain a higher than average fuel consumption in this group but also a number of reasons that explain a lower than average fuel consumption. Given the limited visible impact of the annual mileage on the fuel consumption, it can be argued that the group is representative for the different usage for the average fuel consumption of vehicles of a certain age. For the car in the fleet, the fuel consumption does not show hardly any correlation with annual mileage, where high annual mileage is related to a lrager share of motorway driving and longer trips. Travelcard data show relatively big differences in fuel consumption per km compared to other European countries. This is the result of the low type-approval values in the Netherlands, which means that an absolute difference of 50 g/km, with a type-approval value of 100 g/km leads to 50% increase while for a typical 140 g/km type-approval value for, e.g., German cars the same absolute difference leads to a 36% relative difference.

The Travelcard data spans the period from 2004 to May 2014. The trends in fuel consumption, combined with the technological developments, and the lower standard consumption can therefore be monitored. This leads to an important adjustment of the real-world fuel consumption over time, from year-to-year. The real-world fuel consumption is decreasing, however this reduction is not linearly related to the decrease shown by type approval values.

3.7 CO_2 emission factors

CO_2 emission factors, based on the laboratory emission measurements for real world driving, have been derived for many years at TNO with the same methodology as for harmful emissions. But these numbers have not been published for analysis. The monitoring program in which the measurements are performed is intended to get a good picture of the harmful emissions in practice. The vehicles are selected for relevance to harmful (air pollutant) emissions. The group of selected vehicles to monitor harmful emissions is not necessarily representative of the Dutch fleet in terms of CO_2 emissions. This has one simple reason: new vehicles sold in a given year must all comply to the same limits (Euro Class) for harmful emissions. This implies that all vehicles are equal in terms of harmful emissions. For CO_2, the *average* of all new cars sold in Europe in 2015 must comply to 130 g/km. As a result, in modern vehicles, there is a bandwidth of emissions between 85 g/km and 200 g/km. Measuring several dozen vehicles within a certain Euroclass provides a spread in average CO_2 of approximately 25 g/km, which is unacceptable given the desired accuracy in CO_2 emissions of a few grams per kilometer.

A second reason why the use of the CO_2 emission factors from the measurement program is unsuitable for practice are the test conditions.

The measurements from the program were performed in the laboratory under ideal conditions with a low weight, no wind, high temperatures, proper tyre pressure, etc. From practical usage data it is known that the real-world figures are higher than the results of the laboratory tests for the same behavior, but with a large variation in mostly unknown circumstances. This means that the CO_2 emission factors from “laboratory” measurements should be scaled in order to account for “real-world” conditions.

Emission factors currently used in European studies (HBEFA, as used in the latest version of the STREAM report, and COPERT) underestimate the CO_2 emissions of passenger cars. Emission factors which were in the past available through the Statistics Netherlands (CBS) on the other hand overestimated CO2 emissions, since developments in engine technology were not included. The CBS numbers result in average CO_2 emissions around 175-180 g/km for passenger cars with a limited trend. Currently, the detailed results reported here are in line with the average emissions available from the CBS.

3.8 CBS-TNO bottom-up CO_2 calculations

The amount of petrol sold throughout the Netherlands is most likely used for petrol cars, as the amount used for lawnmowers, outboard motors, etc. is negligible in the total sales. Based on the information that annually 67 billion kilometers are driven on petrol and the petrol sales totaled 5.3 billion liters, it can be deduced that the CO_2 emissions are on average around 187 g/km. The petrol sales in recent years remained virtually constant. The number of kilometers driven by passenger cars in the Netherlands has increased from 57 billion kilometers in 1995 to 67 billion in 2012. It can be concluded that petrol cars in this period have been 15% more efficient. This corresponds well with the results from other sources, such as Travelcard.

In 2013, CBS and TNO jointly examined the CO_2 emissions of cars and light and heavy duty trucks based on the mileage of individual vehicles and the expected fuel consumption of these vehicles [Staats, 2014], [Willems, 2014]. For petrol vehicles, this approach corresponds well with the amount of petrol sold. For diesel, fuel sales were larger than expected based on the average fuel consumption and annual mileages of individual vehicles. Further research is being carried out to explain the differences.

Passenger cars

The recent development of the real-world fuel consumption of cars has shown that this real-world consumption depends primarily on the type approval value and the construction year of the vehicle. These relationships were used by CBS to link the kilometers driven with the expected real-world use of such vehicles. For petrol cars, where the practical fuel consumption can be compared to the sold amount of petrol and to the total annual mileages, there is limited difference between bottom-up determination of total fuel and the fuel-sold result. Diesel passenger cars are by no means the only consumers of diesel. Therefore such a comparison is not possible for this group neither for light commercial vehicles.

Trucks and tractor-trailers

The fuel consumption of heavy goods vehicles is strongly dependent on the degree of loading, or the weight of the vehicle combination on the road. The measurement data from TNO have shown that weight and power are two decisive aspects for the fuel consumption. The technological improvements provide a small but steady decline in the type approval fuel consumption of the same engine of approximately 1% per year since 1995 [Ligterink, 2012a], [Kuiper, 2013].

TNO and CBS have linked the different annual mileages of trucks in 2013 to the technical properties and typical loads. The evaluated vehicle weights are the result of analysis of WiM data (Weighing in Motion) on the motorway [Kuiper, 2013]. With this analysis, the CO_2 emissions of heavy goods transport were determined for the first time for different vehicle categories. The difference between the amount of diesel sold and the expected consumption raises questions for further examination. Refueling outside of the Netherlands and vice versa, fueling in the Netherlands and driving abroad, are the most likely causes for the difference between the amount of fuel sold and the overall diesel fuel consumption.

3.9 Marginal CO_2 emissions in relation to engine load

Marginal CO_2 emissions are the additional or reduced amount of emissions which are associated with a relative change to the reference situation. For example, lights, air conditioning, battery charging, etc. hardly lead to additional losses in the engine but only increase the engine load. In that case, the additional CO_2 is not proportional to the share of overall work, but lower. This is explained by a higher engine efficiency at higher loads. An important exception is a substantially higher engine speed at high loads. This introduces additional losses, which may yield lower efficiency. This can be compared to a small engine driving with high engine speeds of 4000 rpm on the motorway.

The marginal CO_2-emissions at a small change of the engine load in normal operation is in the order of the CO_2 associated with the optimum motor efficiency.

Petrol passenger cars:	720 Δg/ΔkWh (37% optimal efficiency)
Diesel passenger cars:	680 Δg/ΔkWh (39% optimal efficiency)
Diesel trucks:	650 Δg/ΔkWh (40.5% optimal efficiency)

Light duty

This allows to make estimations of, for example, small changes of speed at constant driving dynamics. In this case the extra work at the wheels directly leads to additional CO_2 emissions. For passenger cars, the baseline is 110 km/h. A speed increase or decrease of 1 km/h is then associated with roughly a 1-to-1 relationship:

- Passenger cars: 1 Δg/km per 1 Δkm/h

This relationship is not suitable for speeds below 100 km/h. In that case, driving dynamics and engine efficiency are important factors that interfere with this relationship. Above 120 km/h air resistance will increase rapidly, so that the same rule of thumb is not suitable above this speed. The consequence is that the average speed is not a good measure of these effects.

For example, the CO_2 emissions of a car at 130 km/h is disproportionately higher compared to a velocity of 110 km/h. If one in fifty cars drive 130 km/h and the remaining cars drive 110 km/h, the average speed of this group is 110.4 km/h (0.36% higher), while CO_2 emissions are 0.56% higher. The average speed is compensated by a second car traveling 90 km/h, but CO_2 emissions are not. For heavy-duty trucks the vehicle weight hardly has an impact on the related change in CO_2 emissions to a change in vehicle speeds.

Heavy duty
Large trucks and tractor-trailers have similar dimensions that influence air drag. A change in velocity of 1 km/h at 90 km/h results in

- Trucks: 4 Δg/km per 1 Δkm/h

These rules of thumb apply in the case of changing velocities at the same driving dynamics, whereas dynamics is defined as an equal variation in engine power. The variation in acceleration (Δa) normalizes at the speed:

$$\text{dynamiek} \sim \Delta a / v_{\text{average}}$$

In contrast to the situation on motorways, driving dynamics at low speeds will result in a larger uncertainty in CO_2 emissions. There are reasons to believe that the driving dynamics are decreasing over the years. For example, through improved infrastructure a more constant velocity of vehicles is created in congestion. But on the other hand, the increased engine power is a reason to assume that the driving dynamics is increasing. Fully loaded trucks with the lowest power-to-mass ratio have the lowest dynamics.

3.10 Verification and accuracy

Harmful air pollutant emissions have a large bandwidth, a) due to unknown factors which affect the functioning of the emission reduction technologies and b) due to the large sensitivity to surrounding conditions. For CO_2 emissions this bandwidth is often not accepted. This is important for three reasons:

1. There is an independent validation of the totals based on fuel consumption.
2. In addition, fuel consumption is associated with physical principles which are deemed to be known.
3. And last, for fuel costs and the assumption that operations are optimized, it is assumed that fuel consumption is as low as possible. This is considered to be a unique number for the deployment of vehicles, purely from an economic point of view.

However, the practice is more complex than these positivist and deterministic assumptions indicate. This is partly due to the large variation in fuel consumption due to external influences and personal driving styles. But with proper design of monitoring programs with sufficient data and analysis, the accuracy of the predicted average real-world fuel consumption deviates less than 5%. This is based on the experience of the last few years, with the available data, and the independent validation.

The assumptions, such as physical principles, which have a limited relation to the absolute emissions, ensure that the relative effects, such as the change of average speed or the influence of the outside temperature, are known with greater accuracy.

4 VERSIT+ emission factors on the basis of emission measurements

4.1 Passenger cars and speed limits

The VERSIT+ emission factors were previously calculated based on velocity profiles and vehicle usages that have been measured in a number of projects throughout the years 2001 to 2011. The latest velocity profiles were measured at a speed limit of 130 km/h [Lange, 2011]. However, in the autumn of 2015 a large program of determining the normal and average driving behavior was carried out in the Netherlands [Ligterink, 2016], which are used in this report.

Previous results showed that the average speed at a speed limit of 130 km/h was only slightly higher than the average speed at a speed limit of 120 km/h. The driving dynamics at a speed limit of 130 km/h is somewhat higher. As an effect, there was only limited difference between the CO_2 emissions at a speed limit of 120 km/h and at 130 km/h. The recent update shows a minor change with respect to this driving behavior. Only the driving dynamics has increased somewhat.

Both trajectory speed controls and low speed limits achieve low driving dynamics which keep emissions low. Emission factors for motorways are therefore distinguished according to:

- congestion ($v_{average}$ < 50 km/h)
- the speed limit, and
- the level of enforcement.

For harmful emissions, the effect of low driving dynamics is larger than for CO_2 emissions. This is specifically the case for modern engines where the engine efficiency is more constant at constant and dynamic engine loads. The control technology for the reduction of harmful emissions, especially in the case of diesel vehicles, is better tuned for constant loads and low dynamics.

4.2 Light commercial vehicles (vans)

Vans are an understudied group, both in legislation and in the monitoring programs. It is common that vans are not fully tested for admission on European roads. There are tables included in the legislation which can be used for determining a standard value for type approval of fuel consumption. These tables often provide more favorable values for vans such that the entire test is preferably not performed for larger vans. These vehicles with standard values represent the largest share in the group of all vans.

There are also developments where vans are used as a tractor for a trailer (BE-combis). The weight of this vehicle combination is often substantially higher than the 3.5 tons that vans may weigh by themselves. Possibly, as a result, especially in the future, the estimation of emissions is higher than on the basis of the van alone.

For the moment the CO_2 emissions of vans should be estimated based on the measured on-road fuel consumption from monitoring programs, differentiated according to the empty vehicle weight which best correlates with the variation in the on-road consumption.

4.3 Heavy duty vehicles and payload

Heavy-duty PEMS tests that have been performed for several years by TNO for the Ministry of Infrastructure and the Environment [Vermeulen 2014], yield the best direct predictions of the CO_2 emissions of different truck combinations, from small to large, from empty to fully loaded. Monitoring programs such as truck-of-the-future confirm these results. The disadvantage of monitoring programs is that they cannot distinguish by type of road and congestion because this information is not known. There is only an average fuel consumption figure, from mileage and fuel sales. But the emission model VERSIT + for heavy duty trucks provides a good prediction for modern trucks. The CO_2-emissions from older trucks are extrapolated on the basis of the improvements in engine efficiency that are visible in the engine testing. After compensating for the increased engine power over the years, a 0.5% improvement per year in fuel consumption remains, such that a modern engine is working at a relatively lower load. Over the period from 1970 to 2012 the average engine power of a tractor has increased annually by 3.3 kW to over 320 kW. Disregarding the technological developments, this autonomous development of the increase in engine power results in additional CO_2 emissions of 0,7 g/km per year.

5 Development of the vehicle fleet

Until 2000, the development of engine technology was approximately in equilibrium with the increase in vehicle weight. The perceived comfort and safety caused the vehicle weight to increase from the eighties until 2005. As an effect, the improvement of technology was roughly eliminated by the increase in vehicle weight. The fuel consumption in this period declined only slightly. After 2005, with weight reductions, the fuel consumption declined rapidly.

5.1 CO_2-targets, energy labelling and legislation

On paper, the largest decrease in fuel consumption is achieved over the last two decades. Given the stakes involved with a low fuel consumption, the limits of the testing procedure were sought. This is especially true for the fuel-efficient cars from 2004 onwards. The difference between the type approval and the on-road fuel consumption has been growing for this group over the last decade. Since 2011 , the difference is growing for all vehicles, including cars with relatively high CO_2 emissions of 150 g/km and more.

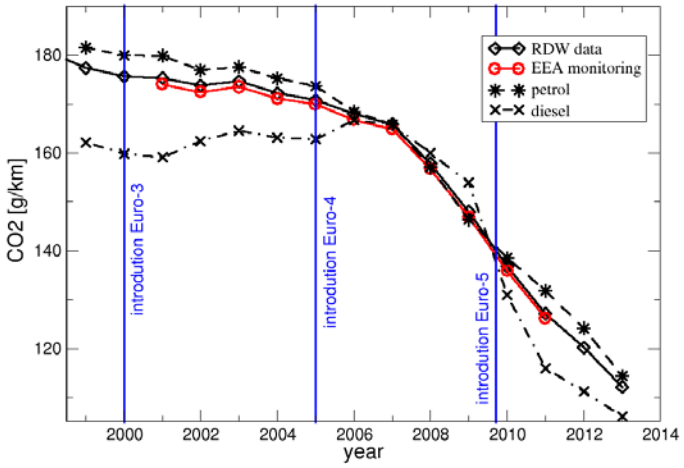


Figure 3 The average type approval fuel consumption of Europe (based on European monitoring) and the Netherlands (based on Dutch monitoring, including imports). The Dutch average is also differentiated for petrol and diesel. De introduction dates of the different Euro Classes are indicated by blue lines. Large reductions have started in 2007 for petrol vehicles and in 2009 for diesel vehicles.

In the Netherlands there is a large shift in the fleet towards low type approval fuel consumption figures. The Netherlands thus belong to the countries with the lowest CO_2 type approval of new vehicles. In 2013 and 2015 there was an extra dimension added by selling substantial numbers of plug-in hybrid electric vehicles, which can charge electrically, but whose type approval fuel consumption values barely have a relationship with the real world.

6 Calibration on the basis of monitoring data

Based on the information briefly described in the previous chapters, the CO_2 emission factors are scaled relative to the values that come directly from the measuring program to the values of the national average. The CO_2 emission factors based on measurement in the laboratory and on the road may show some bias, for example due the weight and temperatures, but the trend with velocity and dynamics is captured by the VERSIT+ emission model. The absolute or total emission levels are determined based on monitoring programs and other independent information. Experience with uncalibrated CO_2 emission factors and fuel consumption monitoring provides the following picture for the calibration of the emission factors:

1. Heavy-duty Euro V emission factors correspond to the monitoring. Older vehicles are scaled on the basis of 0.5% higher consumption per year, back to Euro-II.
2. CO_2 emission factors from petrol and diesel cars both have a systematic bias to the downside. The variation must be compensated by matching Travelcard monitoring data with the Dutch fleet.
3. For vans insufficient data is available for an independent evaluation. Emission factors are scaled based on vehicle weight and the average extra fuel consumption of these vehicles. The effect of CO_2 legislation is still limitedly visible. By lack of better insight the autonomous development is considered equal to the development of heavy-duty trucks.
4. CO_2 emission factors of vehicles with alternative fuels, LPG, CNG and ethanol are scaled based on the carbon content of petrol vehicles as a reference.
5. Alternative powertrains such as plug-in hybrid vehicles, follow the same trend as other fuel-efficient vehicles. The real-world fuel consumption is compensated in this manner. Not enough is known to estimate the future development.
6. Euro-6 passenger cars type-approval real-world difference are scaled according to the development of Euro 4 to Euro 5, with a type approval consumption target for Euro-6 of 95 g/km, which corresponds well to the extrapolation to 2015. The relation between the monitored difference of the type-approval value and the real-world average is used to make a forward prognosis. If more detail is needed, the differentiation with respect to type-approval year must be made.
7. Euro-VI trucks follow the natural trend and are believed to be 2% more economical than Euro-V.

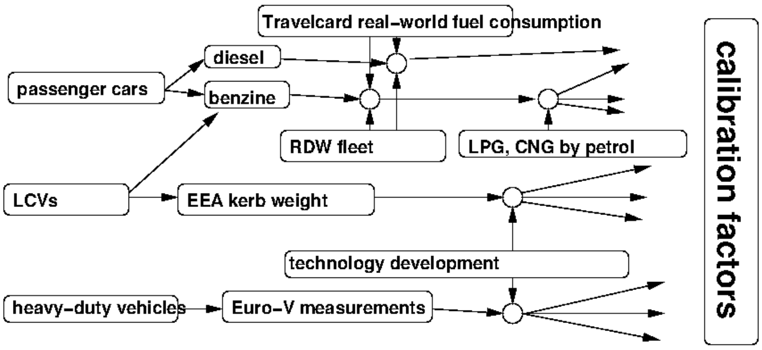


Figure 4 The flowchart of deriving different calibration factors which are used to scale VERSIT+ factors based on “laboratory” measurement

Scaling can only be applied to the totals because monitoring programs generally do not know what the shares are at the different types of roads and congestion degrees. From the SRM methodology, there is an underlying distribution of road types and congestion degrees. The totals from SRM are compared with the totals from the monitoring programs, which results in a scaling factor.

6.1 Calibration passenger cars

SRM is based on passenger cars per Euro class and fuel type. Within a single Euro-class, which comprises approximately four years, recently there have been major changes. It is therefore necessary to weigh the Dutch fleet according to construction year and type approval value in order to produce an average value.

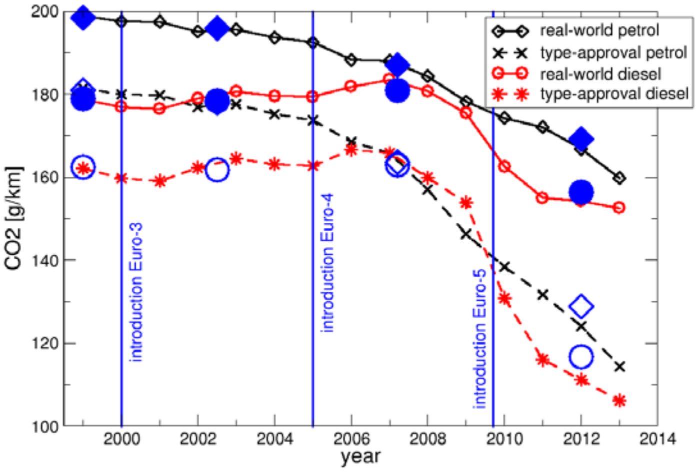


Figure 5 The real-world fuel consumption per construction year of the Dutch vehicle fleet. The Euro Class averages are shown in blue symbols (diamond: petrol, circle: diesel)

The Euro-6 factors assume that the development since 2005 continues on in the same way towards the European targets of 95 g / km standard consumption. This gives rise to a proportional decrease in the real-world consumption.

Tabel 1 The Euroclass averages of the total fuel consumption (in g/km), weighted over urban, rural and motorway driving

	Petrol		Diesel	
	Reality	Norm	Reality	Norm
Euro-0,1,2	198	181	179	162
Euro-3	196	178	178	162
Euro-4	187	164	181	163
Euro-5	169	129	156	117
Euro-6	151	95	141	95

Correction factors for alternative fuels which can be used for this purpose have already previously been determined in [Ligterink 2014b]:

Tabel 2 The CO_2 emission savings associated with alternative fuels relative to petrol, for spark ignition technologies

LPG	Ethanol	CNG
-10.4%	-2.7%	-23.4%

6.2 Calibration light commercial vehicles

Because the understanding of CO_2 emissions from light commercial vehicles is very limited, both in the deployment and in the development over the years, a simple robust approach was chosen to scale emission factors based on the vehicle weight in monitoring programs.

The average weight of the approximately fifty new commercial vehicle models sold per year in the Netherlands is about 1,780 kg. In recent years the weight has remained stable. Based on this, it can be deduced that for the most part Class III vans have been sold. The average type approval fuel consumption is of limited significance, but from 2012 to 2013, this value has reduced 2.8% from 179 g/km to 174 g/km. The reconstructed fuel consumption, a linear function on the basis of weight, and vehicles which are actually tested, would be 190 g/km. In practice, the CO_2 emission is in the order of 230 g/km (fuel consumption of 8.7 l/100 km). The autonomous development of improving engine technology is based on the development of trucks and is taken into account in these numbers. The reference category, for 230 g/km, is the heavy Euro-5 van. The other categories are scaled relative to this category. The engine power of vans has increased in the past, but with CO_2 legislation the growth seemed to have stopped, but may even be reversed.

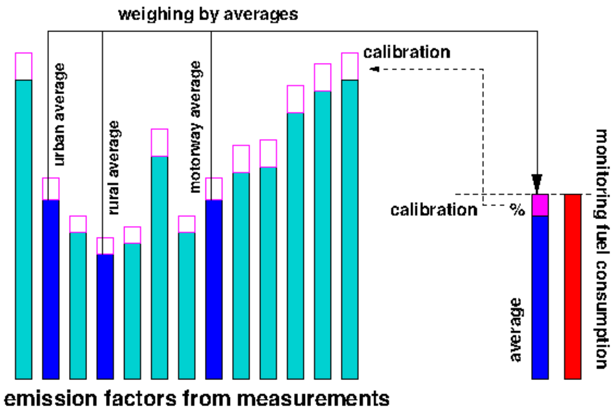
For vans on petrol, LPG and CNG it is assumed that these are all smaller Class I vehicles. For these vehicles the values are equal to those of passenger cars for the reference of Euro-5. This is only a small group of vehicles.

6.3 Calibration heavy duty

The large PEMS (Portable Emissions Measurement Systems) measurement program for Euro V trucks is a good basis for the valuation of absolute CO_2 emission factors [Ligterink, 2012a]. The fuel consumption levels of these vehicles are independently confirmed by the fuel monitoring programs and data provided by the distribution companies. The organic development of vehicle technology is the only calibration that must be performed on these emission factors. That can be done in two ways: Include the development of engine power into the development of the fleet, or effectively including it in the calibration. In the CBS / TNO bottom-up analysis [Staats 2014, Willems 2014] the first way was followed to calculate the total CO_2 emission based on the mileage. However, since there are no good CO_2 measurements available for older vehicles, it has been decided to include the change in engine power and the relative impact on the engine losses at equal absolute engine load into the calibration. In practice this means that CO_2 emissions for each class prior to Euro-V are assumed to be 2% higher, e.g. Euro-IV 2%, Euro-III 4% Euro-II 6% and so on.

6.4 Stratification other categories: independent effects

The most important assumption for the determination of CO_2 emission factors is that the totals on the basis of the detail emission factors may be scaled on the basis of the totals based on the monitored fuel consumption. So, if the difference between fuel consumption and CO_2 emission factor is 10%, the detail emission factors, like urban, rural and motorways can all be scaled by the same percentage. Since in general these percentages are small, the possible errors that arise in the individual emission factors are small.



Figuur 1 The calibration applied to a vehicle category: the average fuel consumption based on reweighting the individual emission factors is scaled to the real-world fuel consumption that is monitored. All emission factors per vehicle category are scaled with the same calibration factor.

The weighing of CO_2 emission factors to an average over all road types is done with a standard distribution for each vehicle type based on the mission profile of this type of vehicle.

The fact that the improvements in vehicle technology are particularly harvested at low engine loads and at high congestion levels is already visible in the lower CO_2 emissions. This shift is unrelated to the calibration of the total emissions. In most cases, the calibration factors are smaller than the variations in the CO_2 emission factors themselves.

The calibration factors vary with the different categories of vehicle and fuel types. For light traffic the calibration factors are almost always positive, as expected. Petrol has calibration factors between 15% and 30%. For diesel these are slightly larger. LPG and CNG have lower factors, because in the past especially larger vehicles have been measured in these categories. For heavy duty transport the calibrations are smaller. The measured values are more in line with practice. The range lies between -15% to 5%.

7 Emission factors Emission Inventory and SRM

7.1 Methodology SRM-I and SRM-II

For harmful emissions, there is a long term program [PRTR, RIVM] to determine the emission factors of road traffic. The program covers several aspects:

1. Legislation classes of vehicles on which the relevant vehicle categories are based.
2. Driving behavior of vehicles, in different ways, and at different degrees of congestion.
3. Shares of the different categories of vehicles on the road.

Every year, the emission factors are determined and adjusted based on new findings if necessary. These are used in the air quality models such as the NSL (‘Nationaal Samenwerkingsprogramma Luchtkwaliteit’). In general, new measurements on vehicles are the main reason to adjust numbers. Changes in the methodology and reference vehicles and situations also occur, but less frequently and with minor adjustments as a result.

7.2 Results SRM-I and SRM-II

The emission factors for 2015 on the motorway are given in the tables below.

Table 4 Real-world CO_2-emission factors on the motorway in the year 2015 (MSH: strong enforcement, frequent trajectory speed control)

Real-world CO_2 emission factors [g/km]	**speed limits [in km/h] / level of enforcement [none/MSH]**						
Vehicle category	**Congestion**	**80 / MSH**	**80**	**100 / MSH**	**100**	**120**	**130**
Light-duty	266.5	143.6	164.1	163.0	167.0	184.9	192.0
Medium-duty	772.0	444.3	449.2	444.3	444.3	444.3	444.3
Heavy-duty	1527.9	750.4	748.0	750.4	750.4	750.4	750.4

At average speeds of 120 km/h and 130 km/h CO_2 emissions are relatively high. This has to do with the higher driving dynamics and especially the older cars and petrol cars. Variations in power at high engine loads apparently give extra high emissions. For more modern technology the gap is narrowing.

Plotted against the speed limit itself, the effect is only small. The difference in the emission factor for light duty traffic (i.e. passenger cars and vans) at 120 km/h and 130 km/h is 3.6%. This is small compared to the difference in CO_2 emissions at an actual change in velocity of 120 km/h to 130 km/h, which is of the order of 11% - 13%. The small effect is explained by the actual average speed at the 120 and 130 speed limits which has only gone up slightly and remains well below the speed limit itself [Lange, 2011]. The same effect is still present in the new driving behavior [Ligterink,2016]. The average velocity is not much higher, but the dynamics are.

With the recent update of the driving behavior in 2015 some changes in driving behavior are observed but the effect on the CO_2 emissions for the different road types and congestion levels is limited. The fact that the additional emissions are now lower than previously estimated is mainly the result of new emission measurements of Euro-5 diesel vehicles. These vehicles apparently only have marginally higher CO_2 emissions due to the higher dynamics. This suggests that the engine is optimized at a low fuel consumption at high speeds and dynamics.

Table 5 The real-world CO_2 emission factors (SRM-I) voor 2015-2030, based on the fleet composition based on 2015 prognoses

CO_2 [g/km]	**Jaar**	**2015**	**2020**	**2030**
Road type	**Vehicle classe**			
urban congestion	Light-duty	350	313	275
	Busses	1013	998	989
	Medium duty [10-20 ton]	1138	1128	1097
	Heavy duty	2356	2441	2440
urban normal	Light-duty	232	212	189
	Busses	1013	998	989
	Medium duty [10-20 ton]	783	728	690
	Heavy duty	1542	1540	1527
urban free flow	Light-duty	223	201	179
	Busses	1013	998	989
	Medium duty [10-20 ton]	611	535	493
	Heavy duty	1149	1105	1086
Rural	Light-duty	142	137	127
	Busses	664	624	602
	Medium duty [10-20 ton]	520	507	504
	Heavy duty	994	1028	1038
Motorway average	Light-duty	183	168	156
	Busses	563	508	478
	Medium duty [10-20 ton]	451	431	420
	Heavy duty	768	787	792

The effect of increasing CO_2 emissions in time for the heavy duty vehicles is partly related to an observed change in vehicle usage. The modern tractor-trailer combinations (Euro-V/VI) are separated in two categories: about a third are fully loaded with almost 40 tons GVW. Apart from that all other categories show a substantial CO_2 reduction over the years.

8 Effects of driving behavior and uncertainties

8.1 The impact of driving behavior on CO_2 emissions

Speed and dynamics (acceleration and deceleration) are the key components in driving behavior that affect fuel consumption and resulting CO_2 emissions per kilometer. On the basis of physical principles - the aerodynamic resistance force increases quadratically with the velocity - the air drag is the most important aspect in the CO_2-emissions above speeds of 100 km/h. At 100 km/h around three quarters of the power is needed to overcome aerodynamic drag. Effectively, when going from 100 km/h to 120 km/h, air drag increases by 44% and the required engine power increases approximately by 33%. Smaller engines often need higher speeds to drive at this velocity, so fuel consumption is relatively higher. Big engines have large power reserves, which means the extra fuel consumption is possibly lower.

Since trucks are equipped with speed limiters, trucks do not drive faster than 90 km/h. In addition, the air drag has a lower share in the total power demand, because the mass and therefore the inertia is higher [Kuiper, 2013]. The effect of an increased velocity is therefore smaller. Between 80 km/h and 90 km/h the increase in CO_2 emissions is approximately 12%, since air drag is only about half of the total power demand.

The discussed rules of thumb are based on differences in constant driving speeds, when all other conditions remain the same. The influence of weight is thus minimized, and only plays a role in the rolling resistance. The rule of thumb for the rolling resistance is around 16-20 g/km CO_2 emissions per ton vehicle weight for all vehicles. Heavier, newer vehicles with diesel engines are closer to the low number whereas smaller, older vehicles with petrol engines are closer to the large number. Absolute CO_2 emissions for heavy vehicles are higher per kilometer, but slightly lower per unit weight. In the claimed effect, different driving behaviors are not included.

Clearly, congestion generates the highest CO_2 emission per kilometer. This is a combination of two effects: First, the large amount of braking, dissipating the kinetic energy of the vehicle into heat. This typically contributes about a third of the total CO_2 emission in congestion. Second, the engine losses play a significant role at lower velocity, as the time the engine is operating is central to the engine losses, and at 15 km/h in congestion, the engine is running four minutes for each kilometer driven. This accounts for about 100 grams of CO_2 for a normal passenger car and about 400 grams per kilometer of a truck.

The driving behavior used for the determination of emission factors is based on measurements on the road. The speed is recorded during tests. A number of these mission profiles are also used in order to mimic the situation on the road in the laboratory during an emissions test. The measurements form the basis of the emission factors that are used in the Netherlands. This is the core of the VERSIT+ emission model: the various emission tests are combined into an emission factor per vehicle class and normalized driving [Lange, 2011].

8.2 Unknown driving conditions and the visible effects

Different drivers of the same vehicle achieve different (average) fuel consumptions, with differences of up to 40%. This difference depends on many factors, all of which have a share of a few percent [Ligterink, 2012b]. The interaction between the different factors makes it difficult to properly model the conditions. Therefore, a large data set is needed to average the results across all conditions and variations between the different drivers. This requires data of thousands of vehicles that are followed for a longer time, or the data on fuel sales linked to the mileage of these vehicles. Such data is used to calibrate the results of emission models to the totals. Because so many small effects together give a total effect, there is only a weak link between the relative CO_2 emissions from situation to situation, and the absolute emissions average for all situations. For example, extra weight in all cases results in higher CO_2 emissions. It can be considered independent in first order of driver behavior and road type. Therefore, the emission factors from the measurement program can be calibrated with the totals from the monitoring programs.

9 Conclusions

For the first time a complete set of normalized and a calibrated on-road CO_2 emission factors for the Dutch roads has been derived for the entire Dutch vehicle fleet. This was done for a large number of vehicle categories on the basis of emission measurements and observed fuel consumption. In this way both relative effects, such as differences due to the different speed limits, and absolute levels, such as in emission totals can be determined. The calculation has been done for the year 2013, in order to make a comparison with the monitoring data like Travelcard Nederland BV, and for 2015, in order to calculate the effectiveness of abatement options on the reduction of CO_2 emissions.

The general trend is that the CO_2 emissions increase with speed and decrease with reduced dynamic driving, for example due to strict enforcement of the speed limit. The highest CO_2 emissions per kilometer occur in congestion. The effects, for example on motorways, are smaller than expected with the use of a (simplistic) physical model, e.g. modeling rolling resistance and air drag in combination with the speed limit. There are two reasons for this. First, at higher speed limits, the difference between the speed limit and the actual average speed is greater. Second, for the same level of enforcement generally driving dynamics reduce at higher average speeds. The difference between 120 km/h and 130 km/h is an exception: The average speed is almost the same, but the driving dynamics is greater at 130 km/h. Research undertaken in 2011 showed somewhat larger effects than those provided now. The smaller difference in CO_2 emissions per kilomeer between 120 km/h and 130 km/h has been derived from emission measurements on new vehicles.

On other roads, in particular urban roads, the level of congestion is the main driver of CO_2 emissions. However, it is very likely that CO_2 emissions are also strongly linked with the local road infrastructure which also affect the constancy of driving.

Finally, the driver can play an important role in the CO_2 emission by its vehicle use and driving style. This is poorly known as yet, therefore the derived emission factors are calibrated on real-world usage and PEMS results. Eventually, the aim is that all emission results are in-line: the on-road test programs cover the Dutch situation on road as well as possible. The recent test results coincide already well with the monitoring data, and only a few percent calibration was needed to ensure the sum emissions match the independently derived total emissions from petrol.

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CO_2 emission factors

The CO_2 emission factors for the emission inventory categories are presented in this table

	Urban	Rural	motorway
component	CO_2 [g/km]	CO_2 [g/km]	CO_2 [g/km]
BABBEUR0	1064	709	786
BABCEEV5	1004	672	574
BABCEUR4	1004	675	587
BABCEUR6	984	593	461
BABDEEV5SCR	1004	672	574
BABDEUR0	1064	695	616
BABDEUR1	1064	719	616
BABDEUR2	1064	730	634
BABDEUR2DPF	1064	730	634
BABDEUR2HOF	1064	730	634
BABDEUR3	1044	707	611
BABDEUR3DPF	1044	707	611
BABDEUR3DPFSCR	1044	707	611
BABDEUR3HOF	1044	707	611
BABDEUR4	1065	716	623
BABDEUR4EGR	1045	702	601
BABDEUR4SCR	1024	688	589
BABDEUR5EGR	1004	672	574
BABDEUR5SCR	1004	672	574
BABDEUR6	984	593	461
BABLEUR0	1064	709	786
LBAB1982	272	195	169
LBAB1983	272	195	169
LBAB1984	272	195	169
LBAB1985	272	195	169
LBAB1986	272	195	169
LBAB1987	272	195	169
LBAB1988	272	195	169
LBAB1989	272	195	169
LBAB1990	272	195	169
LBAB1991	272	195	169
LBAB1992	272	195	169
LBABEUR1	277	167	188
LBABEUR2	253	164	197
LBABEUR3	258	155	201
LBABEUR4	246	145	194

LBABEUR5	222	132	175
LBABEUR6	199	118	157
LBABPR82	272	195	169
LBABR3WC	288	141	203
LBACEUR5	173	90	141
LBACEUR6	156	81	125
LBAD1982LCH	246	147	145
LBAD1982ZWA	359	217	214
LBAD1983LCH	246	147	145
LBAD1983ZWA	359	217	214
LBAD1984LCH	246	147	145
LBAD1984ZWA	359	217	214
LBAD1985LCH	246	147	145
LBAD1985ZWA	359	217	214
LBAD1986LCH	246	147	145
LBAD1986ZWA	359	217	214
LBAD1987LCH	246	147	145
LBAD1987ZWA	359	217	214
LBAD1988LCH	246	147	145
LBAD1988ZWA	359	217	214
LBAD1989LCH	246	147	145
LBAD1989ZWA	359	217	214
LBAD1990LCH	246	147	145
LBAD1990ZWA	359	217	214
LBAD1991LCH	246	147	145
LBAD1991ZWA	359	217	214
LBAD1992LCH	246	147	145
LBAD1992ZWA	359	217	214
LBADEUA6LCH	195	145	146
LBADEUA6ZWA	238	198	238
LBADEUC6LCH	195	145	146
LBADEUC6ZWA	238	198	238
LBADEUR1LCH	233	139	157
LBADEUR1ZWA	340	205	231
LBADEUR2LCH	216	123	173
LBADEUR2ZWA	303	174	267
LBADEUR3HOFLCH	200	123	177
LBADEUR3HOFZWA	291	182	261
LBADEUR3LCH	200	123	177
LBADEUR3ZWA	291	182	261
LBADEUR4DPFLCH	198	92	195
LBADEUR4DPFZWA	310	143	272
LBADEUR4LCH	198	92	195

LBADEUR4ZWA	310	143	272
LBADEUR5LCH	187	148	153
LBADEUR5ZWA	243	202	243
LBADPR82LCH	246	147	145
LBADPR82ZWA	359	217	214
LBAE	0	0	0
LBAL1982	283	169	138
LBAL1983	283	169	138
LBAL1984	283	169	138
LBAL1985	283	169	138
LBAL1986	283	169	138
LBAL1987	283	169	138
LBAL1988	283	169	138
LBAL1989	283	169	138
LBAL1990	283	169	138
LBAL1991	283	169	138
LBAL1992	283	169	138
LBALEUR1	289	173	132
LBALEUR2	251	150	163
LBALEUR3	229	151	171
LBALEUR4	223	146	160
LBALEUR5	201	132	145
LBALEUR6	180	118	129
LBALPR82	283	169	138
LBALR3WC	289	173	132
LBEDEUR5	220	119	193
LBEDEUR6	207	118	192
LMFBEUR0	156	88	120
LMFBEUR1	110	90	141
LPAB1982LCH	272	195	169
LPAB1982MED	272	195	169
LPAB1982ZWA	272	195	169
LPAB1983LCH	272	195	169
LPAB1983MED	272	195	169
LPAB1983ZWA	272	195	169
LPAB1984LCH	272	195	169
LPAB1984MED	272	195	169
LPAB1984ZWA	272	195	169
LPAB1985LCH	272	195	169
LPAB1985MED	272	195	169
LPAB1985ZWA	272	195	169
LPAB1986LCH	272	195	169
LPAB1986MED	272	195	169

LPAB1986ZWA	272	195	169
LPAB1987LCH	272	195	169
LPAB1987MED	272	195	169
LPAB1987ZWA	272	195	169
LPAB1988LCH	272	195	169
LPAB1988MED	272	195	169
LPAB1988ZWA	272	195	169
LPAB1989LCH	272	195	169
LPAB1989MED	272	195	169
LPAB1989ZWA	272	195	169
LPAB1990LCH	272	195	169
LPAB1990MED	272	195	169
LPAB1990ZWA	272	195	169
LPAB1991LCH	272	195	169
LPAB1991MED	272	195	169
LPAB1991ZWA	272	195	169
LPAB1992LCH	272	195	169
LPAB1992MED	272	195	169
LPAB1992ZWA	272	195	169
LPABEUR1	288	141	203
LPABEUR2	285	143	203
LPABEUR3	255	153	204
LPABEUR4	236	149	195
LPABEUR5	213	135	176
LPABEUR6	191	121	158
LPABO3WCLCH	272	195	169
LPABO3WCMED	272	195	169
LPABPR82LCH	272	195	169
LPABPR82MED	272	195	169
LPABPR82ZWA	272	195	169
LPABR3WC	288	141	203
LPACEUR1	221	108	156
LPACEUR2	218	110	155
LPACEUR3	195	117	156
LPACEUR4	191	99	156
LPACEUR5	173	90	141
LPACEUR6	156	81	125
LPAD1982LCH	240	155	170
LPAD1982MED	240	155	170
LPAD1982ZWA	240	155	170
LPAD1983LCH	240	155	170
LPAD1983MED	240	155	170
LPAD1983ZWA	240	155	170

LPAD1984LCH	240	155	170
LPAD1984MED	240	155	170
LPAD1984ZWA	240	155	170
LPAD1985LCH	240	155	170
LPAD1985MED	240	155	170
LPAD1985ZWA	240	155	170
LPAD1986LCH	240	155	170
LPAD1986MED	240	155	170
LPAD1986ZWA	240	155	170
LPAD1987LCH	240	155	170
LPAD1987MED	240	155	170
LPAD1987ZWA	240	155	170
LPAD1988LCH	240	155	170
LPAD1988MED	240	155	170
LPAD1988ZWA	240	155	170
LPAD1989LCH	240	155	170
LPAD1989MED	240	155	170
LPAD1989ZWA	240	155	170
LPAD1990LCH	240	155	170
LPAD1990MED	240	155	170
LPAD1990ZWA	240	155	170
LPAD1991LCH	240	155	170
LPAD1991MED	240	155	170
LPAD1991ZWA	240	155	170
LPAD1992LCH	240	155	170
LPAD1992MED	240	155	170
LPAD1992ZWA	240	155	170
LPADEUA6	181	135	136
LPADEUC6	181	135	136
LPADEUR1	243	132	187
LPADEUR2	246	136	183
LPADEUR3	231	140	185
LPADEUR3HOF	231	140	185
LPADEUR4	249	129	191
LPADEUR4DPF	249	129	191
LPADEUR5	188	149	153
LPADPR82LCH	240	155	170
LPADPR82MED	240	155	170
LPADPR82ZWA	240	155	170
LPAE	0	0	0
LPAL1982LCH	283	169	138
LPAL1982MED	283	169	138
LPAL1982ZWA	283	169	138

LPAL1983LCH	283	169	138
LPAL1983MED	283	169	138
LPAL1983ZWA	283	169	138
LPAL1984LCH	283	169	138
LPAL1984MED	283	169	138
LPAL1984ZWA	283	169	138
LPAL1985LCH	283	169	138
LPAL1985MED	283	169	138
LPAL1985ZWA	283	169	138
LPAL1986LCH	283	169	138
LPAL1986MED	283	169	138
LPAL1986ZWA	283	169	138
LPAL1987LCH	283	169	138
LPAL1987MED	283	169	138
LPAL1987ZWA	283	169	138
LPAL1988LCH	283	169	138
LPAL1988MED	283	169	138
LPAL1988ZWA	283	169	138
LPAL1989LCH	283	169	138
LPAL1989MED	283	169	138
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LPAL1990LCH	283	169	138
LPAL1990MED	283	169	138
LPAL1990ZWA	283	169	138
LPAL1991LCH	283	169	138
LPAL1991MED	283	169	138
LPAL1991ZWA	283	169	138
LPAL1992LCH	283	169	138
LPAL1992MED	283	169	138
LPAL1992ZWA	283	169	138
LPALEUR1	248	174	150
LPALEUR2	238	131	187
LPALEUR3	232	131	186
LPALEUR4	219	115	186
LPALEUR5	198	104	168
LPALEUR6	179	94	149
LPALO3WCLCH	283	169	138
LPALO3WCMED	283	169	138
LPALPR82LCH	283	169	138
LPALPR82MED	283	169	138
LPALPR82ZWA	283	169	138
LPALR3WC	248	174	150
LPEBEUR5	160	101	132

LPEBEUR6	143	91	118
LPEDEUR5	150	81	131
LPEDEUA6	130	74	119
LPEDEUC6	130	74	119
LPHBEUR4	236	149	195
LPHBEUR5	213	135	176
LPHBEUR6	191	121	158
LPHDEUR5	199	108	175
LPHDEUR6	174	99	159
MVABEUR0LCH	397	265	293
MVADEDE5LCHSCR	448	298	253
MVADEDE5SCRZWA	907	603	503
MVADEUG5EGRLCH	501	301	244
MVADEUG5EGRZWA	1003	609	488
MVADEUG5LCHSCR	447	294	254
MVADEUG5SCRZWA	922	601	502
MVADEUR0LCH	413	280	287
MVADEUR0ZWA	941	607	546
MVADEUR1LCH	366	283	293
MVADEUR1ZWA	906	612	549
MVADEUR2LCH	357	282	294
MVADEUR2ZWA	887	614	551
MVADEUR3DPFLCH	378	268	287
MVADEUR3DPFZWA	948	584	535
MVADEUR3HOFLCH	378	268	287
MVADEUR3HOFZWA	948	584	535
MVADEUR3LCH	378	268	287
MVADEUR3ZWA	948	584	535
MVADEUR4LCH	527	305	248
MVADEUR4ZWA	1055	610	496
MVADEUR6LCH	358	265	243
MVADEUR6ZWA	782	567	462
MVALEUR0LCH	397	265	293
ZTRBEUR0	1527	1018	1126
ZTRDEDE5LCHSCR	1263	839	683
ZTRDEDE5SCRZWA	1976	1308	979
ZTRDEUG5EGRLCH	1373	847	665
ZTRDEUG5EGRZWA	2032	1335	964
ZTRDEUG5LCHSCR	1320	846	673
ZTRDEUG5SCRZWA	2245	1368	924
ZTRDEUR0	1352	908	717
ZTRDEUR1	1371	906	715
ZTRDEUR2	1338	910	719

ZTRDEUR3	1404	873	698
ZTRDEUR3DPF	1404	873	698
ZTRDEUR3HOF	1404	873	698
ZTRDEUR4	1445	836	680
ZTRDEUR6LCH	1208	852	705
ZTRDEUR6ZWA	2246	1460	970
ZTRLEUR0	1092	728	806
ZVADEDE5ANHLCHSCR	1149	740	656
ZVADEDE5ANHSCRZWA	1619	1040	913
ZVADEDE5SCR	1283	852	693
ZVADEUG5ANHEGRLCH	1212	740	647
ZVADEUG5ANHEGRZWA	1704	1040	901
ZVADEUG5ANHLCHSCR	1272	763	632
ZVADEUG5ANHSCRZWA	1843	1077	870
ZVADEUG5EGR	1392	860	674
ZVADEUG5SCR	1344	860	682
ZVADEUR0	1251	881	756
ZVADEUR0ANHLCH	1147	822	695
ZVADEUR0ANHZWA	1546	1172	972
ZVADEUR1	1273	880	753
ZVADEUR1ANHLCH	1120	828	697
ZVADEUR1ANHZWA	1573	1171	968
ZVADEUR2	1248	882	756
ZVADEUR2ANHLCH	1110	831	697
ZVADEUR2ANHZWA	1556	1167	972
ZVADEUR3	1314	838	737
ZVADEUR3ANHDPFLCH	1156	794	681
ZVADEUR3ANHDPFZWA	1606	1119	950
ZVADEUR3ANHHOFLCH	1156	794	681
ZVADEUR3ANHHOFZWA	1606	1119	950
ZVADEUR3ANHLCH	1156	794	681
ZVADEUR3ANHZWA	1606	1119	950
ZVADEUR3DPF	1314	838	737
ZVADEUR3HOF	1314	838	737
ZVADEUR4	1466	848	690
ZVADEUR4ANHLCH	1206	784	656
ZVADEUR4ANHZWA	1686	1095	916
ZVADEUR6	1179	830	684
ZVADEUR6ANHLCH	1085	681	577
ZVADEUR6ANHZWA	1725	1040	853