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The fleet composition on the Dutch roads relevant for vehicle emissions

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Summary

The average emission per vehicle on a particular road depends on the fleet composition on the road. From the Dutch Pollutant Release and Transfer Register (PRTR) there is an interest in these variations and the way they affect the total emissions of road transport in the Netherlands. The PRTR has commissioned this study to update the fleet composition (per road) and road-type distribution (per vehicle) for the emission factors used for national emission reporting and air quality modelling in the Netherlands. The past assumptions regarding the road-type distributions of different vehicles categories is based on a study from 2010[1]. Current study is meant to update these assumptions including changes in the vehicle fleet, as seen on the road in 2016.

In September 2016 fifteen licence plate cameras collected each two weeks of data in order to establish the typical fleet composition on the different Dutch roads: city, rural and motorways. The licence plate scans are the best way to determine the fleet composition on a particular road. For the vast majority of vehicles from the licence plate information the technical data of the vehicles can be recovered from the RDW (road authority). This data is used, together with the total mileages of each of the vehicle categories as supplied by the Bureau Statistics Netherlands (CBS) to determine the representation of the different vehicle categories on the different roads. Both the age of the vehicles and the fraction of diesel and heavy duty vehicles affect the emissions at that location. The average emission based on the average fleet composition, based on the total mileages alone, does not fully suffices for an accurate determination of the vehicle emissions.

Results

1. The vehicle passages on the representative locations combined with the total annual mileages of Statistics Netherlands are used to derive the road type distributions of each vehicle category.
2. This study included explicitly measurements of rural roads, which have been an area with limited information. This generated some shifts in distance assignment for rural roads.
3. Heavy duty traffic is less in cities than estimated before and also more evenly distributed over rural roads and motorways.
4. In principle, the annual mileages of individual vehicles seem the best estimator of the distribution over urban, rural, and motorway distances. Vehicles with low to moderate annual mileage dominate the urban fleet composition, while high mileages are driven mainly on the motorway.
5. It is recommended that individual vehicle annual mileages are used as a basis for road type assignment, as the most accurate method, with the advantage that emissions can be assigned bottom-up to the correct sources.

[1] Onderzoek naar de wegtype-verdeling en samenstelling van het wegverkeer (2010), Robert van den Brink, Luuk Brederode, Menno Wagenaar (Goudappel-Cofeng).

Contents

1 Introduction

In September 2016 fifteen licence plate cameras collected each two weeks of data in order to establish the typical fleet composition on the different Dutch roads: city, rural and motorways. This data is used, together with the total mileages of each of the vehicle categories as supplied by the Bureau Statistics Netherlands (CBS) to determine the representation of the different vehicle categories on the different roads. Both the age of the vehicles and the fraction of diesel and heavy duty vehicles affect the emissions at that location. The average emission based on the average fleet composition, based on the total mileages alone, does not fully suffices for an accurate determination of the vehicle emissions.

The average emission per vehicle on a particular road depends on the fleet composition on the road. From the Dutch Pollutant Release and Transfer Register (PRTR) there is an interest in these variations and the way they affect the total emissions of road transport in the Netherlands. The PRTR has commissioned this study, since they expect this fleet composition to cause a large variation in emissions. In particular, heavy duty vehicles have different emissions than light duty vehicles. Among light duty vehicles, the fraction of diesel cars will have direct consequences for the average emissions of NO_x in particular. Among petrol cars, the typical age of the vehicles will affect the emissions. Notably, older cars are more used for domestic tasks driving shorter distances within residential areas and are therefore overrepresented on urban roads.

It is complex to recover the complete picture of vehicle use on all road types. Not all roads are covered, since the study is restricted to a particular location on a limited number of vehicles. Often the large group of vehicles with a low mileage are not interesting to monitor, due to the limited data and limited contribution per vehicle. But it’s vehicle use, reflected in the fraction of urban, rural, and motorway use of each individual car, is relevant for two key aspects of the consequences of vehicle emissions. First of all, the driving behaviour varies with the road type, and with it varies the emissions. Hence, the same car with a higher urban usage will have a higher average emission per kilometre, than a car with more rural usage (because urban driving is at lower velocity with more stops causing higher emissions per kilometre than rural driving). This is reflected in the total national emission estimates, the emission inventory, which is reported internationally by the Netherlands. A second important aspect of the variation of the fleet composition per road type lies in the modelling of (future) air quality. Higher emissions are predicted for motorways because of the large share of diesel passenger cars on these roads. Diesel passenger cars have on average high annual mileages which are associated with motorway usage. The result is a local effect, associated with the road types in the neighbourhood of a high concentration of pollutants associated with traffic.

For large cities in the Netherlands the fleet composition is well known, because such cities implemented low emission zones in recent years. The impact of this measure was assessed by carrying out fleet composition studies. But for rural roads, motorways, and other cities little information is available. Moreover, a lot of information from standard monitoring systems is biased, since it is often based on vehicle lengths from induction loops. A passenger car with a trailer is often over 7 metres long and therefore classified as heavy-duty traffic in most studies.

The licence plate scans are the best way to determine the fleet composition on a particular road. A relatively small group of foreign vehicles cannot be identified and a very small fraction of misidentifications occur. For the vast majority of vehicles, from the licence plate information the technical data of the vehicles can be recovered from the RDW (road authority). This study has been carried out to update the fleet composition (per road) and road-type distribution (per vehicle) for the emission factors used for national emission reporting and air quality modelling in the Netherlands.

The past assumptions regarding the road-type distributions of different vehicles categories is based on a study from 2010.[2] Current study is meant to update these assumptions including changes in the vehicle fleet, as seen on the road in 2016.

[2] Onderzoek naar de wegtype-verdeling en samenstelling van het wegverkeer (2010), Robert van den Brink, Luuk Brederode, Menno Wagenaar (Goudappel-Cofeng).

2 Time and locations of the licence plate scans

Typical traffic is considered outside the holiday period. Since many roads have traffic all day around and also in the weekend, the licence plates scans where carried out over a period of two full weeks before the Dutch Autumn holidays, from 1 to 14 October 2016. The locations were chosen to be representative for local situations across the whole of the Netherlands. In principle, it was intended to cover the four quarters of the Netherlands for motorways, rural roads and urban roads in mid-size towns. One city in the west withdrew her consent a few days ahead of the project. It was not possible to arrange a new urban location on such short notice. Consequently, the city locations are only three in number, while the rural and motorway locations are four each.

Table 1 The camera locations at the specific kilometres as denoted by the road signs.

	camera location
urban	City Oss Raadhuislaan direction Lievekamplaan
	City Leeuwarden Keizersgracht direction Oosterbrug
	City Hengelo Marskant direction Deldenerstraat
rural	Through road Achterhoek N18-235k direction Groenlo
	ringway Alkmaar N9-81k direction Heiloo
	Through road N381-60k direction A28
	Through road Zeeland N57-57k direction Serooskerke
two-lane motorway	A1-129k direction Hengelo
	A2-171k direction Eindhoven
	A28-64k direction Harderwijk
	A44-2k2 direction Amsterdam

Urban roads
The urban roads are busy roads in the inner cities of mid-size towns, which are expected to attract also regional traffic. The cities should supply an average result for urban traffic, between large cities and small towns. The variation between the different locations yield an indication of regional variations for similar towns.

Rural roads
During the night (20:00-5:00) the N18 near Groenlo in the Achterhoek was closed for roadworks during a few days of this study. It is assumed to have that this a minor influence on the final results. On the days the road was open about 1000 vehicles passed in this period, on a total of 100,000 vehicles on this road in total. The locations were chosen to have a distribution across the country, for and appropriate average results for Dutch urban, rural and motorway roads, not affected particularly by international transport or specific local traffic or conditions.

Motorways
The motorway locations were also selected to be two-lane motorways in each direction to restrict the number of cameras needed for the motorway locations. Two lane motorways are the lower intensity motorways. They may not represent the average fleet on the motorway, but the variation among four locations will give an indication of expected accuracy. All the roads were monitored only in a single direction. From earlier studies, it is noted that for a full day the total traffic is the same for both directions. The traffic in the morning rush hour will go the opposite direction in the evening.

The typical round-trip routes, where a direction is for example chosen to avoid congestion may generate difference between the directions. However, these effects are expected to be smaller than the observed variations among locations.

3 Results of the scans

In total 2.4 million passages were recorded in the two weeks of operation. During that period of time 1.23 million unique licence plates were recorded. A total of 808,389 licence plates were recorded only once by a camera, indicating a single passage. The number of vehicles recorded more than once was much smaller. See Figure 1. This is rather surprising, as with a large number of commuters it is expected that many vehicles pass a given location frequently.

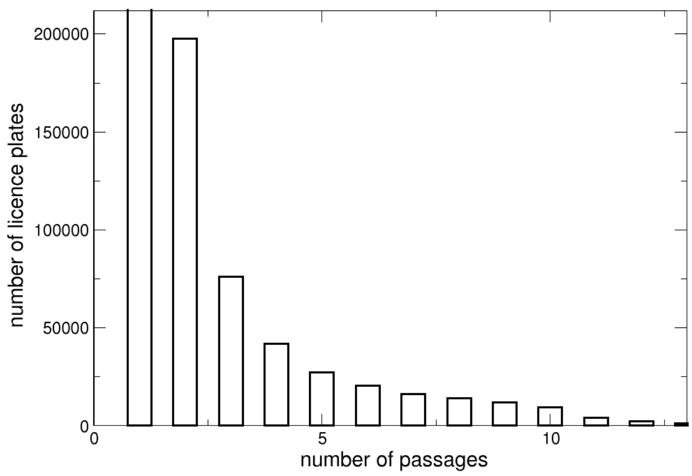

Figure 1 The number of passages for each licence plate. Most licence plates (808,389, i.e., 66%) are recorded only once in the two week period (out of scale).

Most passages are recorded on the motorway. See Table 2. Motorways are busy all day and the road capacity is larger than of rural and urban roads.

Table 2 The number of passages in the two weeks at each of the locations, for motorways separate lanes (first: right, second: left).

location				
urban	Oss	66251		
	Leeuwarden	70064		
	Hengelo	76786		
rural	N18	100658		
	N9	148959		
	N381	60343		
	N57	44992		
		first lane	second lane	total
motorway	A1	223170	217419	440589
	A2	328114	230975	559089
	A28	250500	208905	459405
	A44	230923	174553	405476

From the total number of licence plates only the Dutch licence plates can be linked to a particular vehicle using the Dutch vehicle registry. From the 2.4 million passages, 77 thousand leads to a licence plate which does not exist according to the RDW registry. Since most combinations of digits are non-existent as licence plate, it gives an indication of the number of wrong readings in the order of 3%. Foreign licence plates are collected, and per location the fraction of foreign vehicles, on the basis of their licence plates is determined. Most foreign licence plates are German (3.8%) followed by Belgian (2.1%). In total 9.4% of the licence plates are foreign. The high fraction of German vehicles seems to suggest that holidaymakers are a larger fraction of the foreign traffic in the Netherlands. In particular the large fraction of German vehicles on the N57 near the sea supports this hypothesis. In 2016 the German autumn holiday period was from 4 to 27 October. Hence, some bias of German passenger cars, compared to the annual average, can be expected in the scan period from 1 to 14 October. This may generate some bias in the average fraction of foreign vehicles at all locations.

Table 3 The fraction of foreign licence plates and the dominant group of foreign vehicles (at least 0.5% of all vehicles).

location		foreign	dominant
urban	Oss	2.6%	Polish
	Leeuwarden	2.3%	German
	Hengelo	2.5%	German
rural	N18	4.6%	German
	N9	7.6%	German/Belgian
	N381	4.8%	German
	N57	22.4%	German
motorway	A1	17.6%	German
	A2	12.1%	Belgian
	A28	6.1%	mix
	A44	3.8%	German

Fractions of different vehicle categories

Per road type the distribution of different Dutch vehicle categories can be determined from the license plate information. The fractions of heavy-duty vehicles and vans on urban roads are smaller than usually observed from scans of large cities access roads, as used, for example, for the assessment of low emission zones in Amsterdam, Utrecht and Rotterdam. The separation in three categories: urban, rural, and motorway may not suffices to cover the variation encountered in larger cities.

Table 4 The distribution of vehicle categories per road type, based on all passages road type. Petrol passenger cars are dominant, but diesel passenger cars and diesel vans are substantial groups relevant for the total emissions.

vehicle category		urban	rural	motorway
passenger cars	petrol	71.09%	53.82%	49.81%
	CNG	0.06%	0.11%	0.16%
	Diesel	19.48%	25.00%	30.87%
	LPG	0.40%	0.38%	0.35%
vans	petrol	0.14%	0.12%	0.11%
	CNG	0.22%	0.05%	0.03%
	Diesel	7.94%	13.52%	11.95%
	LPG	0.08%	0.09%	0.07%
rigid trucks	light [< 10 ton]	0.22%	0.66%	0.51%
	medium [10-20 ton	0.18%	0.67%	0.59%
	heavy [> 20 ton]	0.11%	1.32%	0.97%
tractor	light [< 3.5 ton]	0.02%	0.11%	0.07%
	heavy	0.06%	4.17%	4.51%

Motorway: Left and right lane
Another notable effect is the uneven distribution of vehicles on the right (slow) and left (fast) lane on the motorway. Trucks are more common on the right lane. Only about 2% of the trucks are on the left lane, except for light trucks, below 10 ton gross vehicle weight, which are up to 9% on the left lane. But for other vehicles an even distribution of right and left lane is to be expected. However, diesel passenger cars dominate the left lane. It is 61%-68% more likely a diesel or CNG passenger car drives on the fast left lane than on the right lane. Petrol vehicles are distributed even over both lanes. This raises concern about the assumption of the driving behaviour underlying the emission factors. It is currently assumed that all passenger cars have the same average driving behaviour. The fact that diesel passenger cars are predominantly on the left lane means they drive faster than petrol passenger cars, which might result in higher average emission levels.

Older light duty diesel vehicles are more dominant in less densely populated areas
Another interesting feature from the current scans is the proportion of older diesel passenger cars and older diesel vans. In the North, both in the city Leeuwarden as on the provincial road between Friesland and Drenthe, the fraction of older light-duty diesel vehicles is higher than at other locations. Possibly this is linked to the typical distances covered in the less densely populated North of the Netherlands. In the variations of the fleet composition at different locations this was one of the few notable systematic effects. The data for the same road type in different locations is combined in a single result assuming the collective data is representative for the Dutch average. Local variations do exist with significant effects on the average emission.

The difference between rush hour traffic intensities and the traffic during the day is quite limited. In principle busy traffic occurs from 6:00 till 19:00. See Figure 2.

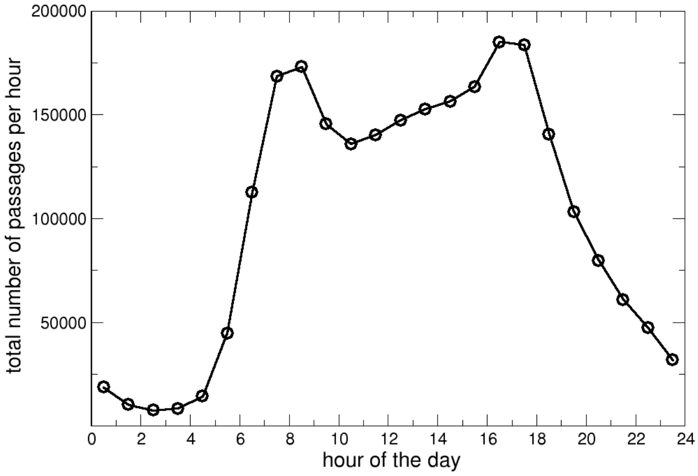

Figure 2 The hour-by-hour distribution of the passages over the day.

4 Age distribution of vehicles on the road

The age distribution of vehicles on the road is of particular interest for the emissions. Older vehicles typically have higher emissions, since every four years the emission limits which new vehicles must comply have become more stringent. These are the Euro-class vehicle categories based on emission legislation, introduced from 1992.

Newer vehicles typically drive longer distances, which is associated with a larger fraction of motorway driving. Especially new diesel cars, up to four years old and annual mileages of around 30,000 km, drive much more on the motorway than in the city. See Figure 3.

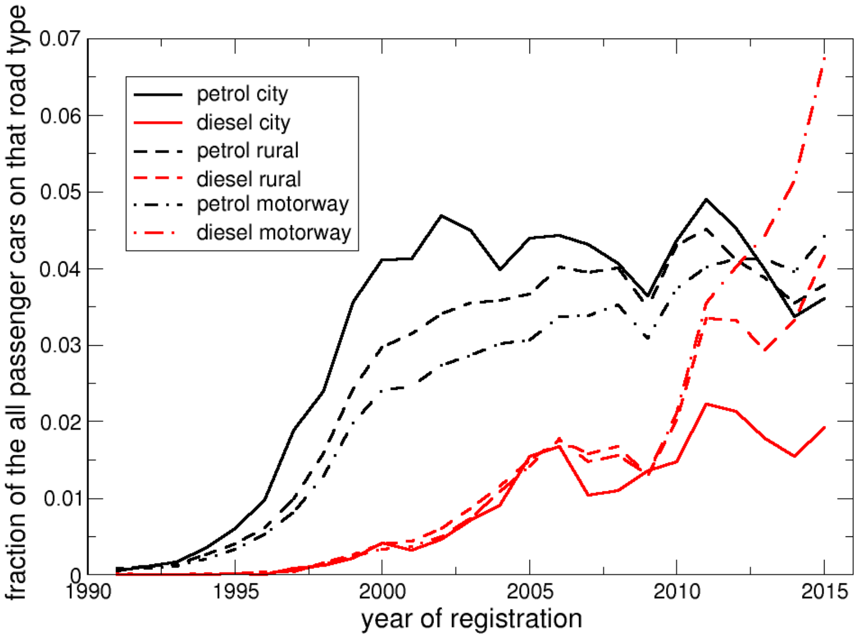

Figure 3 The age distribution of diesel and petrol cars in the total of all passenger cars on that road type. Except for modern diesel cars on the motorway, there are more petrol cars for all ages and road types.

Age distribution of vehicle park on different road types
The age distribution is more or less dominated by the age distribution of the Dutch fleet. The fraction of older vehicles observed on the road is foremost the result of the number of vehicles in the fleet. A second order effect is the variation in annual mileages. Especially in business use, which is mainly diesel vehicles, vehicles have a limited lifetime in the Netherlands, which shows up in the road-side observations. Both trucks and diesel passenger cars are exported in large numbers after 4 to 6 years. Hence, the smaller fraction on the road is the result of a smaller fraction in the fleet. It is rather surprising that the urban age distribution in Figure 3 follows the number of petrol vehicles in the fleet, while the age distribution on the motorway follows roughly the total mileage of the diesel vehicles.

At the moment petrol cars are scrapped at an age of 17 years, which means that vehicles from 1999 and older rapidly decline in numbers, at the time of this study. This is reflected in the urban age distribution in Figure 3. On the other hand, if vehicles have a higher mileage they seem to do the additional kilometres mainly on the motorway, and partly on the urban roads. It is therefore interesting to make a road type-distribution, like above, based on the actual annual mileage of the vehicle.

Distribution of vehicles on different road types based on annual mileage
The low mileages show an even more clear dominance on urban roads. In Figure 4, the distribution of annual mileages is plotted per road type and age, using the data of vehicles with registered annual mileage. The annual mileages above 30,000 km are less common, and belong in most cases to diesel passenger cars, while older vehicles and petrol passenger cars have the lower annual mileages.

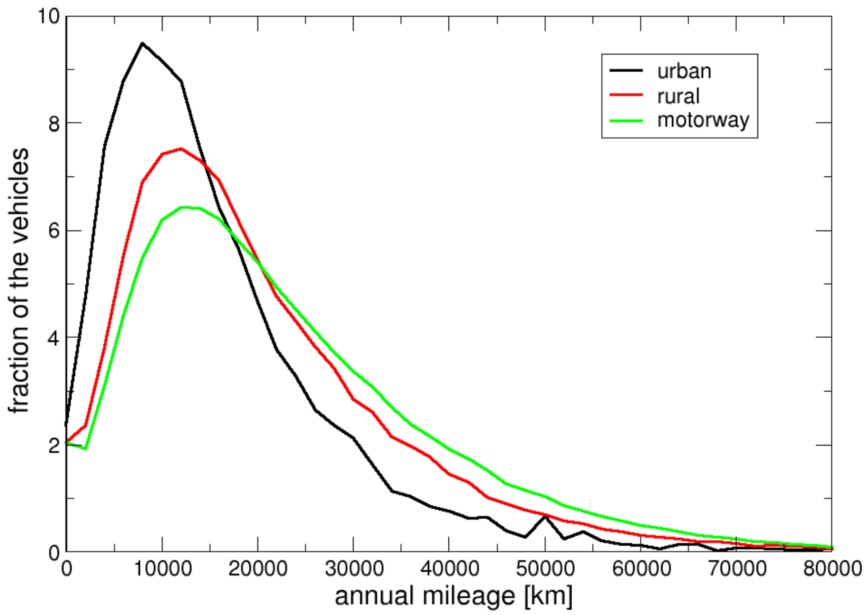

Figure 4 The distribution of annual mileages per road type of passenger cars and vans.

The distribution over distances for road types as function of annual mileage is closer to the vehicle usage, than a distribution on the basis of vehicle age. A low mileage is associated with short trips and possibly low vehicle velocity. Interestingly, for the very low mileages, below 2000 kilometres a year, the vehicle seems not to be used for short urban trips anymore. The annual mileage is more even distribution among the types, which is might be associated with longer daytrips. Probably, this is the typical use of vintage cars. One can expect these vehicles to be used only for pleasure trips a couple of weekends per year, rather daily domestic use. This would explain both the annual mileage as the road-type distribution.

Conversely, it is half as likely to encounter a vehicle with high annual mileages on urban roads than it would be based on their contribution to the total.

The crossover lies at 15,000 km per year. Simply said, urban fleet composition is based on the number of vehicles in the fleet, each doing an equal urban distance. Motorway fleet composition is based on the fraction of the total annual mileage travelled, i.e., the extra mileages. This holds for light-duty vehicles, but not for heavy-duty vehicles which are fewer in numbers and have higher annual mileages. The tractor-semi-trailers are 0.7% of the total motorized fleet, and about one-tenth of that in the urban traffic, as can be inferred from Table 4. For heavy-duty vehicles, the newer vehicles are more common in the urban environment, while for vans the older vehicles are more common in the urban environment. Seemingly, vans follow more the pattern of diesel passenger cars, while designated new trucks do urban delivery. Very likely, older trucks are not in urban distribution, but in building, road-works, etc. and they have less reason to drive into town.

5 Vehicle usage and road type distribution.

The observation of the traffic on each road type, from the previous chapters, gives a good picture of the contribution of a vehicle category to the traffic on that typical road type. However, it does not give a good overview of the vehicle usage per vehicle category. In particular the fraction of urban, rural, and motorway driving per vehicle category cannot be inferred. This requires some additional analyses, which is described in this chapter.

Each passage of a vehicle can be associated with a certain distance driven in the Netherlands. The associated distance will vary from location to location. But given national total mileages from Statistics Netherlands (CBS), the mileages associated with each passage can be estimated by fitting the total mileage of all vehicles with the urban, rural, and motorway passages. Because older vehicles drive more on urban roads, and newer vehicles more on the motorway, this fit can be performed. The increase in urban passages at the expense of motorway passages is linked to a decrease in the total distance travelled of the vehicles as observed from odometer readings. Hence with urban passages a smaller total distance is associated. The rural roads are somewhat more complex as the distances on rural roads are in between the urban and the motorway distribution. The driving on rural roads is correlated both to the urban and the motorway driving.

If older vehicles are included in the fit, more noise is introduced in the results, but more data is used to fit. Excluding older vehicles leads to poorer results because of the more homogenous vehicle usage, with fewer discernible characteristics, which are needed to perform the fit. Eventually, it is chosen to use the average results of different fits to determine the fraction of distance of light-duty vehicles per road type. The average of the fits for vehicles from 1995 onwards, from 1998 onwards, and from 2000 onwards give a road-type distribution of 26.1% urban, 32.9% rural, and 41.0% motorway. Compared with other estimates the fraction of motorway is somewhat smaller, at the benefit of more rural distance in this study. However, be aware, the distances here are determined via an indirect method, of fitting distributions per road type with the totals as reported by the CBS.

This distribution of light-duty vehicles is the reference of the mileage distribution of vehicles, since traffic is dominated by the light-duty vehicles. In the subsequent chapters this fraction is used to infer vehicle category specific results. It should be noted however, the results depend only weakly on this assumption. Eventually, the distribution of traffic at each location has clear characteristics in the sense of the fractions light-duty and heavy-duty, and the fraction diesel passenger cars among the diesel vehicles.

The 26.1% urban, 32.9% rural, and 41.0% motorway split of all the vehicles is used in the subsequent analyses to arrive at the road-type distributions per vehicle. Simply said, given the total distance driven is 100%, the urban distance drive of vehicle category x is the fraction of all urban passages of category x multiplied by the fixed fraction of 26.1% urban kilometres in the total distance. Performing the same exercise for rural and motorway passages, the road-type distribution of vehicle category x can be determined.

6 Road type distribution per build year

If every year of build is included in the analysis, the amount of data is limited for the older vehicles, which leads to some scatter in the result. However, general trends can be distilled from looking at a year by year fleet composition of the different vehicle categories. The number of vehicles in a category is first expressed as a fraction of all the vehicles on a given road type. Subsequently, this fraction is multiplied with the road-type distribution (urban/rural/motorway: 26.1%/32.9%/41.0%) derived in the previous Chapter. This gives the road-type distribution for each vehicle category and age. See Figure 5. For older vehicles the number of vehicles is limited, which introduces a large variation in the results. For heavy duty vehicles, there is hardly a discernible trend with age, while for passengers cars, diesel and petrol, the trends are quite distinctive with large motorway fractions for new vehicles.

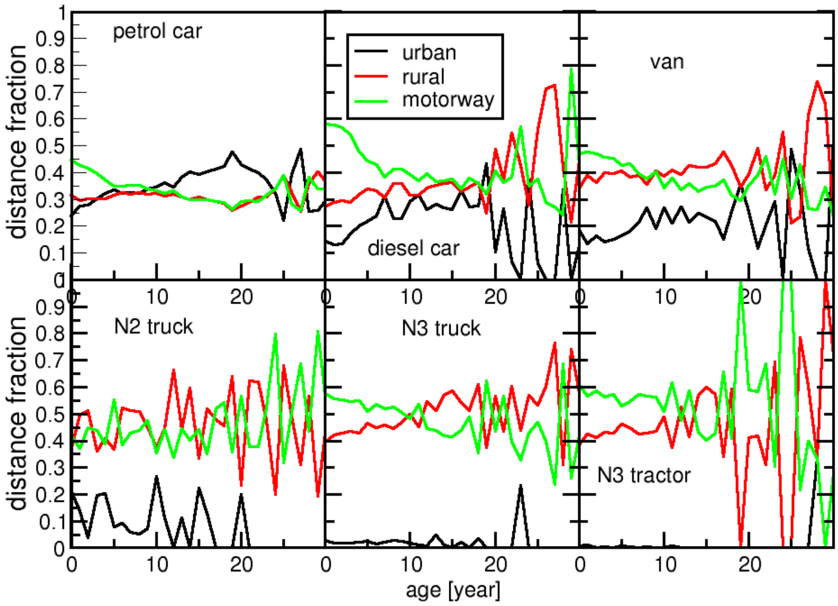

Figure 5 The road type distribution of different vehicles at different ages. For all vehicles, except petrol passenger cars, the amount of data of vehicles older than ten years is somewhat limited, yielding large variations.

To compensate for the limited statistics, a linear fit can be made, assuming a constant fraction after a certain age combined with a linear increasing or decreasing fraction with age for the newest vehicles. For all except petrol cars, a constant fraction is assumed after eight years. For petrol cars, it is assumed that the fraction is linearly dependent on age up to twenty years. These assumptions about the global trends are based on the results in Figure 5. The results are represented in Table 5. The fraction is interpolated smoothly over the first 8 years, and kept constant for vehicles of 8 years and older. Except for petrol passenger cars, with the road-type fraction varying to the useful age of 18 years, and constant beyond the age of 18 years.

Table 5 The road type distribution of different vehicles. A linear change from the age of 0 to the age of 8 years is used, except for petrol cars where the linear change is to the age of 18 years, after which the distribution is constant.

road-type distribution	age	0 years	8 years	18 years
petrol passenger cars	urban	27.24%	34.06%	42.59%
	rural	33.03%	31.05%	28.57%
	motorway	39.72%	34.88%	28.83%
diesel passenger cars	urban	12.57%	27.15%	...
	rural	28.51%	34.11%	...
	motorway	58.92%	38.74%	...
LPGpassenger cars	urban	33.9%	27.8%	...
	rural	35.1%	30.9%	...
	motorway	31.0%	41.3%	...
vans (mainly diesel)	urban	11.32%	24.05%	...
	rural	37.48%	39.86%	...
	motorway	51.19%	36.10%	...
light trucks <12 ton	urban	18.4%	10.2%	...
	rural	39.8%	47.2%	...
	motorway	41.7%	42.6%	...
medium trucks 12-20 tor	urban	14.7%	8.2%	...
	rural	34.9%	46.8%	...
	motorway	50.4%	44.9%	...
heavy trucks > 20 ton	urban	5.6%	2.5%	...
	rural	41.1%	56.0%	...
	motorway	53.3%	41.5%	...
tractor-semi-trailer	urban	0.7%	0.3%	...
	rural	41.2%	45.0%	...
	motorway	58.1%	54.7%	...

Current results deviate for all categories somewhat from the previous findings from 2010 by Van den Brink et al.. See Table 6. In particular the use of heavy-duty vehicles on rural roads is higher in this study than previously estimated.

It should be noted that there is a substantial variation of road type distributions with age. In particular for heavy-duty vehicles, older vehicles are less frequent in the urban environment, while older light commercial vehicles are more frequent in the city. Such variations may have substantial consequences for the emissions of each vehicle group, given that older vehicles typically have higher emissions. In Table 6, Table 7 and Table 8, are the respective results of previous study from 2010, the current study, and the results prior to 2010. The age dependence is more pronounced than before.

It should be noted that especially rural roads were in earlier study considered as a remainder. The licence plate scans in current study do cover the rural roads explicitly. From these results the rural roads are no longer a remainder, but it shows that the rural roads interpolate between the urban fleet composition and the motorway fleet composition. Rural roads are the closest resembling the national averages based on the total from odometer readings.

Table 6 The summary results of previous study (2010) of the road-type distribution per vehicle category.

	urban	rural	motorway
passenger cars	22.6%	35.9%	41.5%
vans	18.3%	33.3%	48.4%
trucks	14.9%	21.8%	63.3%
tractor-trailer	5.7%	19.8%	74.5%
total	21.3%	34.8%	43.9%

Table 7 The aggregated results per fuel type and weight class of current study, weighted over age.

		urban	rural	motorway
passenger cars	petrol	34.9%	30.9%	34.3%
	diesel	21.1%	31.8%	47.0%
	LPG	30.0%	32.4%	37.6%
	average	30.5%	31.1%	38.4%
LCV	diesel	19.5%	39.3%	41.2%
	average	20.1%	39.0%	40.9%
heavy duty	light trucks	12.4%	45.1%	42.4%
	medium trucks	9.4%	43.5%	47.1%
	heavy trucks	3.6%	51.1%	45.3%
	tractor-trailer	0.48%	43.6%	55.9%

Table 8 The road type distribution prior to 2010 of different vehicle categories based on accident statistics.

pre-2010		passenger cars			LCV	trucks	tractor-trailer	bus
accident statistics		petrol	diesel	LPG				
urban	0-2 year	17%	12%	8%	40%	12%	20%	38%
	3-5 year	18%	13%	13%				
	6-8 year	23%	18%	18%				
	9-11 year	32%	22%	18%				
rural	0-2 year	30%	12%	8%	30%	31%	19%	25%
	3-5 year	45%	34%	34%				
	6-8 year	46%	45%	45%				
	9-11 year	37%	40%	45%				
motorway	0-2 year	53%	77%	85%	30%	57%	61%	37%
	3-5 year	37%	53%	53%				
	6-8 year	32%	37%	37%				
	9-11 year	32%	37%	37%				

6.1 Annual mileage as a basis for road-type distribution

The annual mileages can be used to determine a road type distribution of each vehicle on the basis of their mileage.

Based on Figure 4 the road type distribution for a passenger car with a given annual mileage can be estimated, according to the same principles used in the case of the age distribution. This shows, below in Figure 6, that vehicles with a low annual mileage drive mainly in urban traffic. A unique crossover point at 9500 km per year, all road types have equal distance. Afterwards, the reduced urban distance is mainly replaced by motorway distance. It is twice more likely to encounter a vehicle with a low annual mileage in urban traffic than it would be based on the contribution in the total passages.

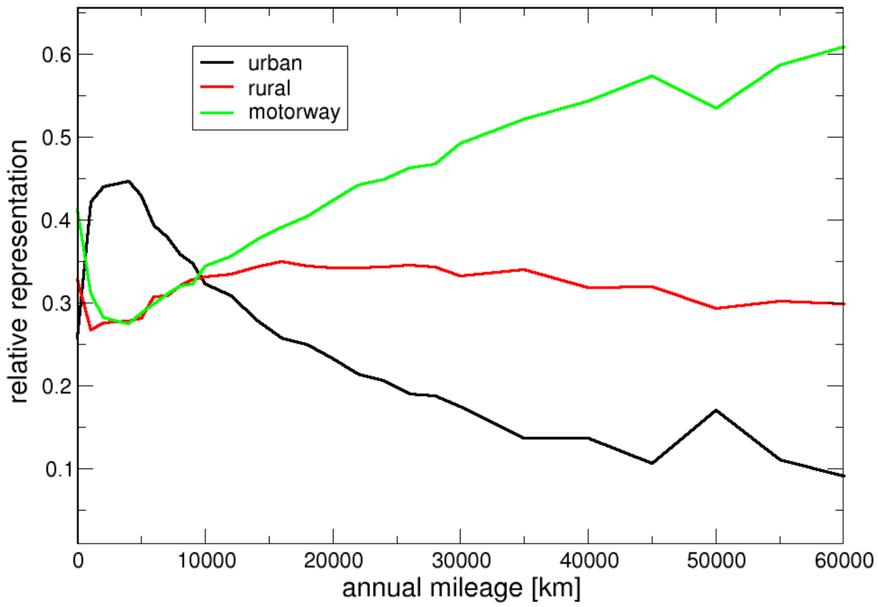

Figure 6 The relative representation of vehicles with a certain annual mileage on each of the different road types. The low mileages are much more common on urban roads than on other roads. On rural roads there is limited variation with annual mileage.

The distinct characteristics of the road type distribution is more pronounced than a differentiation on the basis of age and fuel type. The variation between 45% urban distance to 10% urban distance for the low to the high annual mileages is clearly related to the usage. For 40 000 km per year, one has to spend six hours each working day in a vehicle in urban use, while on the motorway this would be less than two hours. Hence it is unlikely vehicles with high annual mileages drive much in cities.

7 Results of other license plates scans

Three aspects, of variation in the local fleet composition, are of special importance for the vehicle emissions:

1. The fraction of diesel passenger cars among the light duty vehicles
2. The fraction of vans among the light duty vehicles
3. The fraction of heavy-duty vehicles in the total

In a number of studies in Amsterdam, Rotterdam, and Utrecht this was investigated. The studies were carried out mainly to estimate the effect of introducing low emission zones. The results are summarized in Table 9.

Table 9 The results of a number of different studies in Amsterdam, Rotterdam, and Utrecht.

location	year	diesel	vans	heavy-duty
Amsterdam	2012	27.8%	11.6%	1.2%
Amsterdam	2014	36.2%	12.8%	1.7%
Amsterdam	2016	29.7%	7.5%	0.9%
Utrecht	2014	35.0%	9.7%	1.2%
Utrecht	2012	30.2%	11.7%	1.2%
Rotterdam	2015	25.7%	9.9%	1.3%
Rotterdam	2012	25.0%	11.7%	1.2%
current study	2016	21.4%	8.4%	0.6%

The results of the previous studies show systematically higher fractions of diesel passenger cars, vans and heavy duty traffic as compared to the current study (Table 4). When scrutinizing these results in more detail, the locations near large office blocks show a larger fraction of diesel passengers cars associated with commuters. The higher economic activity in larger cities may well explain the higher number of vans and trucks. On the other hand, local car mobility, with older petrol cars, may be reduced because of congestion and parking problems. This can also lead to a greater fraction of business use mobility, associated with diesel.

The average percentage of vans in light duty traffic in the large cities is in the range of 7.5% to 12.8% compared to the 8.4% found in the current study for mid-sized cities. Heavy-duty traffic was in the range of 0.9% to 1.7% and has value of 0.6% in the current study. At specific locations the percentages can easily double the average results for a city in a particular study. Although the age distribution of the vehicles may vary from year to year, it is expected that these key aspects vary only moderately with the year the study was carried out.

The question is, if and how, the deviating results of large cities should be included in the Dutch fleet composition. The difference between these cities and the average is quite large and directly associated with the economic activity. The consequences for the local emissions are significant. The emissions are underestimated up to 30% for locations with high economic activity, due to the deviation of the share of diesel vehicles in the local fleet.

8 Conclusions and recommendations

The complete picture of the distance distribution of all vehicles is complicated. In practice, it is possible to follow a small group all the time, or to determine the fleet composition at specific locations. In this study the latter option is chosen. It gives a good picture of the different locations, which can be extrapolated. The urban, rural, and motorway locations show each a variation, but generally, the differences in the fleet composition among the different road types is larger. Via a bootstrap method, using the total mileages of vehicles different categories from Statistics Netherlands, the effective mileages urban, rural, and motorway can be determined. Assuming a total mileage associated with each passage per road type, the total mileages can be fitted, given the best assigned mileage per road type. The locations can be assigned via the total annual mileages, to 26.1% urban, 32.9% rural, and 41% motorway distances. The underlying road type distributions per vehicle category depend only weakly on these numbers. For example, heavy-vehicles are uncommon in cities, which will not alter with another weighing of the total mileages.

It is expected that different biases will affect the outcomes. For example, local German holidays can be the reason of a larger fraction of German vehicles on the Dutch roads. The choice of mid-size town will have limited business activity, and therefore limited fractions of diesel passenger and heavy-duty vehicles. However, on the other hand the main features of fleet composition per road type are clear. Older vehicles with low annual mileages dominate as large group of vehicles the urban traffic. The high mileages are related mainly with motorway traffic. The rural fraction seems more related to the motorway composition than with the urban composition.

The road-type distribution is most clearly related to the annual mileages for light-duty vehicles. It is recommended that the annual mileages of vehicles are directly related to the road-type distribution per vehicle for the use in emission inventories, or emission averages. This makes the impact of different vehicle categories more clear and robust. If the annual mileages change, with the development of the fleet, the emission inventory will follow automatically.

Specific locations with a higher share of diesel vehicles, light- duty and heavy duty, form a problem translating the national averages to local circumstances. If the share of these vehicles can be linked to economic activity, as opposed to residential areas, it may be possible to have locally adjusted fleet compositions.

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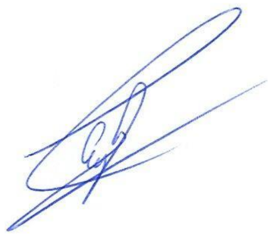

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A Overview of the results

In the tables below the relative frequency of a particular vehicle of a given age from 2000 to 2016 is given per location, compared to the frequency of the vehicle category over all locations. The columns per category span from the oldest vehicles, i.e., 2000 to the newest from left to right. Notable are, for example, the older diesel vehicles in the North of the Netherlands, and the new diesel passenger cars on the fast lane of the motorway.

passenger cars – petrol

location	2000																2016
TNO-9-1-Raadhuislaan-1-W-riLievekamplaan	2.0	1.9	2.0	1.8	1.6	1.7	1.6	1.5	1.4	1.4	1.4	1.5	1.3	1.2	1.1	1.0	0.9
TNO-11-1-Keizersgracht-1-N-riOosterbrug	2.2	2.1	1.8	1.8	1.6	1.4	1.2	1.3	1.2	1.2	1.0	0.9	0.9	0.8	0.7	0.7	0.7
TNO-10-1-Marskant-1-N-riDeldenerstraat	2.1	2.2	1.9	1.9	1.8	1.6	1.5	1.4	1.2	1.4	1.2	1.1	1.1	1.0	0.9	0.9	1.0
TNO-5-1-N18-235k2-1-Z-riGroenlo	1.4	1.4	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.0	0.9	0.8	0.8	0.8	0.9
TNO-6-1-N9-81k6li-1-Z-riHeiloo	1.3	1.3	1.3	1.3	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.1	1.1	1.0	0.9
TNO-7-1-N381-60k0-1-O-riA28	0.8	0.9	0.9	0.9	0.8	0.9	0.9	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.7
TNO-8-1-N57-57k3-1-Z-riSerooskerke	0.7	0.7	0.7	0.9	0.8	0.8	0.9	0.8	0.8	0.9	1.0	1.1	1.0	1.0	0.9	0.9	1.0
TNO-4-1-A1-129k9re-1-O-riHengelo	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
TNO-4-1-A1-129k9re-2-O-riHengelo	0.7	0.7	0.7	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0
TNO-3-1-A2-171k2li-1-N-riEindhoven	1.0	0.9	0.9	1.0	0.9	1.0	0.9	0.9	0.9	1.0	0.9	0.9	0.9	0.9	0.9	0.8	0.9
TNO-3-1-A2-171k2li-2-N-riEindhoven	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1
TNO-1-1-A28-64k0re-1-W-riHarderwijk	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.9
TNO-1-1-A28-64k0re-2-W-riHarderwijk	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1
TNO-2-1-A44-2k2li-1-O-riAmsterdam	1.1	1.1	1.1	1.1	1.2	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.4	1.3	1.3
TNO-2-1-A44-2k2li-2-O-riAmsterdam	0.8	0.8	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.1	1.3	1.3	1.5	1.7	1.7	1.8	1.6

passenger cars – diesel

location	2000																2016	
TNO-9-1-Raadhuislaan-1-W-riLievekamplaan	1.5	1.1	1.1	1.2	1.0	1.3	1.2	0.9	0.9	1.3	0.9	0.8	0.7	0.5	0.4	0.4	0.4	
TNO-11-1-Keizersgracht-1-N-riOosterbrug	2.0	2.1	2.0	1.7	1.5	1.6	1.5	1.0	1.1	1.1	1.0	0.9	0.7	0.6	0.4	0.4	0.4	
TNO-10-1-Marskant-1-N-riDeldenerstraat	1.0	0.6	1.1	0.9	1.1	0.8	0.9	0.8	0.8	0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	
TNO-5-1-N18-235k2-1-Z-riGroenlo	1.1	0.8	1.0	1.2	0.7	0.9	0.9	1.0	0.8	0.9	0.8	0.8	0.7	0.6	0.8	0.7	0.7	
TNO-6-1-N9-81k6li-1-Z-riHeiloo	1.1	1.2	1.1	1.1	1.1	1.0	0.8	0.9	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.5	
TNO-7-1-N381-60k0-1-O-riA28	1.9	1.7	1.7	1.6	1.7	1.7	1.7	1.7	1.8	1.6	1.4	1.5	1.2	0.9	0.9	0.9	0.8	
TNO-8-1-N57-57k3-1-Z-riSerooskerke	0.8	1.0	1.1	0.9	0.9	0.8	0.7	0.8	0.9	0.8	1.1	0.9	0.8	0.8	0.7	0.7	0.7	
TNO-4-1-A1-129k9re-1-O-riHengelo	0.8	0.9	0.8	0.8	0.8	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	slow lane
TNO-4-1-A1-129k9re-2-O-riHengelo	0.9	1.1	0.9	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.7	1.7	1.7	fast lane
TNO-3-1-A2-171k2li-1-N-riEindhoven	0.9	0.9	0.9	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	slow lane
TNO-3-1-A2-171k2li-2-N-riEindhoven	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.3	1.5	1.5	1.7	1.7	fast lane
TNO-1-1-A28-64k0re-1-W-riHarderwijk	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.8	0.8	0.8	0.7	slow lane
TNO-1-1-A28-64k0re-2-W-riHarderwijk	1.1	1.2	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.6	1.8	1.8	1.8	fast lane
TNO-2-1-A44-2k2li-1-O-riAmsterdam	0.8	0.7	0.8	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.8	slow lane
TNO-2-1-A44-2k2li-2-O-riAmsterdam	0.7	0.6	0.7	0.8	0.8	0.8	0.9	0.9	0.9	1.0	1.1	1.2	1.3	1.4	1.3	1.4	1.4	fast lane

light commercial vehicles – diesel

location	2000																2016
TNO-9-1-Raadhuislaan-1-W-riLievekamplaan	0.9	1.0	1.1	0.9	1.2	0.8	1.2	0.7	1.1	0.8	0.7	0.6	0.5	0.5	0.6	0.4	0.6
TNO-11-1-Keizersgracht-1-N-riOosterbrug	1.8	1.4	1.5	1.5	1.4	1.1	1.0	0.8	0.8	0.7	0.6	0.8	0.7	0.5	0.8	0.8	0.7
TNO-10-1-Marskant-1-N-riDeldenerstraat	1.6	1.1	0.8	1.1	1.0	0.8	0.9	0.8	0.8	0.8	0.7	0.7	0.8	0.8	0.6	0.6	0.7
TNO-5-1-N18-235k2-1-Z-riGroenlo	1.2	1.5	1.4	1.6	1.5	1.3	1.5	1.4	1.2	1.4	1.3	1.3	1.2	1.2	1.1	1.2	1.0
TNO-6-1-N9-81k6li-1-Z-riHeiloo	1.7	1.3	1.4	1.3	1.1	1.2	1.2	1.0	1.0	1.1	0.9	1.0	1.0	0.9	0.9	0.8	0.7
TNO-7-1-N381-60k0-1-O-riA28	1.4	1.8	2.2	1.6	2.0	1.5	1.4	1.6	1.6	1.5	1.4	1.4	1.3	1.3	1.2	1.5	1.3
TNO-8-1-N57-57k3-1-Z-riSerooskerke	1.2	1.0	0.9	1.0	0.9	1.2	1.1	0.9	0.9	0.8	0.8	1.0	1.0	1.2	0.9	1.0	1.1
TNO-4-1-A1-129k9re-1-O-riHengelo	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	0.9	0.9
TNO-4-1-A1-129k9re-2-O-riHengelo	0.7	0.6	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.3	1.5
TNO-3-1-A2-171k2li-1-N-riEindhoven	1.2	1.3	1.1	1.0	0.9	1.0	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	0.9
TNO-3-1-A2-171k2li-2-N-riEindhoven	0.8	0.8	0.8	0.9	0.8	1.0	1.0	1.0	0.9	0.9	1.1	1.0	1.0	1.2	1.2	1.2	1.2
TNO-1-1-A28-64k0re-1-W-riHarderwijk	1.1	1.0	1.0	1.1	1.2	1.1	1.1	1.0	1.1	1.1	1.1	0.9	1.0	0.9	0.9	1.0	1.0
TNO-1-1-A28-64k0re-2-W-riHarderwijk	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.3	1.5
TNO-2-1-A44-2k2li-1-O-riAmsterdam	1.0	1.1	1.2	1.0	1.0	1.1	0.9	1.1	1.1	1.1	1.0	1.0	0.9	0.9	0.9	0.9	0.8
TNO-2-1-A44-2k2li-2-O-riAmsterdam	0.5	0.5	0.5	0.6	0.7	0.6	0.6	0.7	0.7	0.7	0.9	0.8	0.9	0.8	0.8	0.9	0.7

light trucks – diesel < 12 ton

location	2000																	2016
TNO-9-1-Raadhuislaan-1-W-riLievekamplaan														0.8				
TNO-11-1-Keizersgracht-1-N-riOosterbrug																		
TNO-10-1-Marskant-1-N-riDeldenerstraat														0.6			0.6	
TNO-5-1-N18-235k2-1-Z-riGroenlo							2.2	2.6	2.4	1.8	2.1	2.0	1.0	1.6	0.9	1.7	1.6	1.2
TNO-6-1-N9-81k6li-1-Z-riHeiloo									0.7	1.1	1.0	1.1	0.7	0.9	0.7	0.8	1.2	0.7
TNO-7-1-N381-60k0-1-O-riA28										2.0	1.6	2.6	1.6	2.2	2.0	2.3	2.3	1.6
TNO-8-1-N57-57k3-1-Z-riSerooskerke															1.2		1.4	
TNO-4-1-A1-129k9re-1-O-riHengelo			3.5	2.5	2.3	2.2	1.5	2.0	2.1	1.9	2.3	1.9	2.0	1.7	1.9	1.9	1.8	1.6
TNO-4-1-A1-129k9re-2-O-riHengelo																	0.2	
TNO-3-1-A2-171k2li-1-N-riEindhoven	1.6	1.6	1.4	1.2	2.3	1.4	2.0	2.4	1.7	1.8	1.5	2.1	2.0	1.6	1.6	1.4	1.5	2.0
TNO-3-1-A2-171k2li-2-N-riEindhoven																	0.3	
TNO-1-1-A28-64k0re-1-W-riHarderwijk	2.0	2.0	1.9	1.6		1.9	1.3	1.2	1.4	1.2	1.3	1.3	1.4	2.3	1.8	1.9	1.7	1.7
TNO-1-1-A28-64k0re-2-W-riHarderwijk																0.3	0.2	0.4
TNO-2-1-A44-2k2li-1-O-riAmsterdam					1.5		2.1	1.2	2.0	2.0	1.9	1.3	2.3	1.2	2.0	1.6	1.3	1.6
TNO-2-1-A44-2k2li-2-O-riAmsterdam																		

heavy trucks – diesel > 12 ton

location	2000															2016	
TNO-9-1-Raadhuislaan-1-W-riLievekamplaan								0.1			0.1	0.1	0.1		0.1	0.1	
TNO-11-1-Keizersgracht-1-N-riOosterbrug						0.1	0.2	0.2	0.1	0.1	0.2		0.1	0.1			
TNO-10-1-Marskant-1-N-riDeldenerstraat						0.2	0.1	0.1	0.2	0.2		0.1				0.1	
TNO-5-1-N18-235k2-1-Z-riGroenlo	2.3	2.4	2.3	2.1	2.0	1.7	1.5	1.6	1.6	1.4	1.3	1.2	1.2	1.3	1.1	1.2	
TNO-6-1-N9-81k6li-1-Z-riHeiloo	1.1	1.1	1.0	0.8	0.4	0.7	0.7	0.6	0.6	0.5	0.7	0.7	0.4	0.5	0.7	0.5	
TNO-7-1-N381-60k0-1-O-riA28	2.4	1.8	1.6	2.7	1.5	2.2	1.9	1.6	1.7	1.6	2.2	1.6	2.1	1.7	1.5	1.4	
TNO-8-1-N57-57k3-1-Z-riSerooskerke					0.7	0.9	0.9	0.7	0.8	1.2	1.0	0.9	1.0	1.0	1.0	0.8	
TNO-4-1-A1-129k9re-1-O-riHengelo	1.9	2.5	2.5	2.1	2.4	2.4	2.3	2.3	2.3	2.1	2.5	2.3	2.5	2.5	2.3	2.5	slow lane
TNO-4-1-A1-129k9re-2-O-riHengelo								0.0		0.0	0.0	0.0	0.0	0.0	0.0	0.0	fast lane
TNO-3-1-A2-171k2li-1-N-riEindhoven	1.5	1.4	1.9	1.9	1.9	1.8	2.1	2.1	1.8	2.1	1.9	2.1	2.0	2.0	2.2	2.0	slow lane
TNO-3-1-A2-171k2li-2-N-riEindhoven							0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	fast lane
TNO-1-1-A28-64k0re-1-W-riHarderwijk	2.3	1.9	1.7	2.0	2.2	2.1	2.0	2.3	2.3	2.3	2.3	2.4	2.5	2.5	2.4	2.5	slow lane
TNO-1-1-A28-64k0re-2-W-riHarderwijk						0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	fast lane
TNO-2-1-A44-2k2li-1-O-riAmsterdam	1.3	1.4	1.0	1.2	1.2	1.2	1.2	1.0	1.3	1.2	0.9	1.0	0.9	0.8	0.9	0.9	slow lane
TNO-2-1-A44-2k2li-2-O-riAmsterdam																	fast lane