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TNO report

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Composition and payload distribution of the on-road heavy-duty fleet in the Netherlands

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Summary

Introduction
Heavy-duty vehicles form an important source in the Dutch national emission inventory and are under constant scrutiny. This study was carried out to improve the underlying data for the determination of the emissions of trucks and tractor-trailer combinations. Moreover, information was collected to see whether the current approach has lacunas with respect to, for example, the fraction of foreign vehicles on the Dutch roads and the varying distribution of heavy-duty vehicles, both in size as in age on motorways, rural roads and urban roads.

Approach
A complete picture of heavy-duty transport on the Dutch motorways was created by combining *Weighing in Motion* (or WiM) data with data from licence plate scans. The data of the month November of 2013 was used to determine a multitude of properties of the heavy-duty vehicle fleet on the road.

Conclusions

Composition of the Dutch heavy-duty vehicle fleet
The heavy-duty vehicle fleet in the Netherlands is dominated by large trucks and tractor-trailer combinations. The numbers are large and they carry most of the goods. Small trucks seem to be a remand of the past, and they are now split into vans and 20-tonne GVW distribution trucks. Therefore, these smaller trucks have a different age distribution than modern trucks and tractor-trailers which have a typical economical age up to 5 years.

Vehicle weights and payloads
Most vehicle combinations have a total empty weight of around 15 tonnes. The payloads of heavy-duty vehicles are quite low. Even the largest trucks, which can carry up to 25 tonne of goods, carry only 10 tonnes on average. This includes empty trips. It shows that total payload weight is in many cases not the restriction in the operation of heavy-goods vehicles.

Foreign trucks
Approximately 20% of the heavy-duty vehicles are foreign trucks. This is a significantly higher share than assumed by CBS in 2012.

Vehicle age
A substantial amount of the light trucks are old, although the average age is quite similar for all categories. The tractor-trailer has an average age of 3.5 years, while the light truck with trailer has the highest average age of 5.8 years. Notably, the light trucks with a trailer is a large group, were the average weight is also higher than the average of all light trucks with trailers. Clearly, this is a group of specialized transport retaining older vehicles.

Urban heavy-duty fleet
Tractor-trailers make up 31.5% of the total urban heavy-duty fleet, excluding busses and refuse trucks from the heavy-duty fleet. Together with the heavy trucks with a GVW over 20 tonnes and three or more axles, they comprise 53% to the total.

The small trucks, typically associated with urban driving, are only a minor group in the truck fleet. All trucks below 20 tonnes are 47% of the heavy-goods vehicles and, with 35%, the typical distribution truck in the range 10 - 20 tonnes is the larger group. The small trucks, at a GWV between 3.5 and 10 tonnes, form the remaining 12%.

Based on licence plate data collected in Amsterdam in November 2013, a preliminary investigation was made into the actual urban distance travelled by heavy-duty vehicles. The results are shown in Table 1.

Table 1 The split in urban, rural and motorway driving for each vehicle category.

GVW	**motorway**	**rural**	**urban**
3.5-10 tonne	37.7%	33.4%	28.9%
10 - 20 tonne	57.8%	23.1%	19.0%
over 20 tonne	67.2%	18.4%	14.5%
tractor-trailers	86.9%	8.3%	4.8%

Contents

1 Introduction

1.1 Background and goal

Heavy-duty vehicles form an important source in the Dutch national emission inventory and are under constant scrutiny. This study was carried out to improve the underlying data for the determination of the emissions of trucks and tractor-trailer combinations. Moreover, information was collected to see whether the current approach has lacunas with respect to, for example, the fraction of foreign vehicles on the Dutch roads and the varying distribution of heavy-duty vehicles, both in size as in age on motorways, rural roads and urban roads.

Heavy-duty vehicles can generally carry more goods than their own weight. Consequently, the total vehicle weight of a heavy-duty vehicle on the road can vary between its empty weight to about 2.5 times its empty weight for the large bulk transport. This has large consequences for the associated emissions. As a rule of thumb, it is assumed that the emissions increase proportionally with the weight. However, there are notable exceptions. For example, in the case of Euro-V trucks, the SCR aftertreatment system may not be warm enough to function properly if the payload is too low. It is observed that the NO_x emissions decrease with increasing vehicle weight.

The actual vehicle weight of heavy-duty trucks on the road is therefore essential information for the pollutant emissions. It is also important for the CO_2 emissions, which typically increase with the vehicle weight. Generally, about half of the total CO_2 emissions can be directly attributed to the vehicle weight. Hence, the emissions per tonne good transported over a kilometre will vary greatly with the payload of the vehicle. At best for each tonne goods about 40 g/km CO_2 can be reduced by carrying all the goods in large fully-loaded trucks. This can go up to 100 g/km or more in the more generic case.

A full picture of vehicle fleet, payload and distance travelled will also assist in establishing how effective policies for the reduction of heavy-duty vehicle emissions can be achieved. Some vehicles have a low fraction in the total fleet, and some vehicles are already used efficiently. Neither of these groups of vehicles are candidates for stimulation programs. Generally, there is little known about the actual vehicle usage, since this kind of information is commercially sensitive. The monitoring of vehicle weight on the road shows that the payload is typically lower than is normally assumed.

1.2 Approach

A complete picture of heavy-duty transport on the Dutch motorways was created by combining *Weighing in Motion* (or WiM) data with data from licence plate scans. The data of the month November of 2013 was used to determine a multitude of properties of the heavy-duty vehicle fleet on the road.

Weighing in Motion data alone truncates the dataset based on the vehicle length. Using licence plate scan data and vehicle data from the Dutch road authority (RDW), the vehicles with a gross vehicle weight (GVW) of 3.5 tonne and above can be selected. The total weight of a tractor-trailer combination may be above 3.5 tonne, whereas the tractor's GVW is in fact under 3.5 tonnes. Vehicles with a GVW of under 3.5 tonnes, such as passenger cars, vans, and BE-tractors, are designated light-duty vehicles.

This study is a follow-up of an earlier study on the basis of the same measurement systems. [Kuiper & Ligterink 2013][1] In that study, more details of the WiM system and the resulting data can be found.

1.3 Structure of this report

This report covers the following subjects with respect to the Dutch heavy-duty vehicle fleet. After presenting the Dutch CBS vehicle categories that are used throughout this report in chapter 2, the study gives an insight into the number of foreign trucks driving in the Netherlands in chapter 3. Chapter 4 then informs the reader of age of the heavy-duty fleet, which is an important factor in determining the emissions of heavy-duty vehicles. Chapter 5 details findings on the payload of trucks in the Netherlands, after which chapter 6 takes a closer look into the heavy-duty vehicle fleet in Dutch cities. Chapter 7 sets out the most important findings of the study.

[1] Kuiper, E. & Ligterink, N.E. (2013). Voertuigcategorieën en gewichten van voertuigcombinaties op de Nederlandse snelweg op basis van assen-combinaties en as-lasten. (TNO 2013 R12138). Delft: TNO

2 Heavy-duty vehicles divided into CBS categories

The measured heavy-duty fleet is divided into different vehicle categories, which are deemed relevant for the total emission as reported internationally. These categories are based on the fleet composition as available from the Dutch road authority (RDW). In the emission inventory, the CBS (National Bureau of Statistics) provides the standard vehicle categories with the reference properties. It is important to match the measured data against these categories.

CBS has standardized heavy-duty vehicle categories based on the gross vehicle weight (GVW). Tractor-trailers are a separate category, which includes a few percent of light-duty tractors below 3.5 tonne gross vehicle weight. According to the RDW, however, they are excluded here.

Table 2 The average properties of the vehicles in the respective CBS categories.

Vehicle	**Trailer**	**Weight**	**Empty**	**Power**	**fraction**	**payload**
GVW [tonne]		**[kg]**	**[kg]**	**[kW]**	**[%]**	**[kg]**
<10		5751	4669	121	1.77	1082
10-20		11195	8820	187	11.11	2376
>20		21071	15583	281	5.14	5489
<10	X	10461	6947	124	0.21	3514
10-20	X	22712	15605	252	2.37	7107
> 20	X	31683	18379	320	7.51	13304
Tractor-trailer	X	27485	15729	310	71.53	11756

The tractor-trailer vehicle is dominant on the Dutch motorways. More than 70% of the heavy-duty vehicles are of the tractor-trailer type. Moreover, from this data, the fraction of rigid trucks towing trailers can be determined. Table 3 shows the fraction of trailers in the total mileage.

Table 3 The fraction of trucks towing trailers, per truck category.

truck size	**with trailer**
<10 tonne	10.6%
10-20 tonne	17.6%
>20 tonne	59.4%

Multiplying the mileages of vehicles by the number of vehicles in the fleet determines the fraction in the overall vehicle usage. This is the measure of their representation on the road. Such data can be compared with the actual counts on the road. The CBS and current estimates for the Dutch heavy-duty vehicle representation in the Netherlands is given in Table 4.

Table 4 Fractions of the different Dutch vehicles on the Dutch road, with and without trailer combined. The WiM data is for motorway, hence higher percentages of the heavier vehicles are expected.

	CBS 2012	**WiM 2013**
<10 tonne	4.0%	1.98%
10-20 tonne	15.5%	13.5%
> 20 tonne	16.3%	12.7%
Tractor-trailer	64.2%	71.5%

The higher fraction of tractor-trailers might be due to the different usage or mission profiles of these vehicles. These vehicles are normally used for long-haulage, which means they make more distance on the motorway than the average heavy-duty vehicle. This is further analysed in Chapter 6.

3 Foreign vehicles

The number of foreign heavy-duty vehicles on the Dutch road is increasing year by year. An accurate value is difficult to obtain by any other means than licence plate scans. The WiM equipment includes the country code scan. From this data, a 22% fraction of foreign heavy-duty vehicles on the motorway is found. This depends strongly on the location of the scans.

Table 5 The overview of vehicles and their country, based on the front licence plates. A large number of missing licence plates, possibly biased for foreign licence plates, leads to a higher worst-case estimate.

Number of vehicles	**Country**	**Percentage**
91662	Belgium	5.56%
18939	Bulgaria	1.15%
101274	Germany	6.15%
2894	France	0.18%
14613	Hungary	0.89%
1284697	**Netherlands**	**77.97%**
130059	Poland	7.89%
3460	United Kingdom	0.21%
Total foreign:		**22.03%**
Worst case total foreign:		24.66%

If the combination of the licence plate in front and at the back is combined, an equal fraction of Dutch front and Dutch rear is found: about 6% for each case. For foreign licence plates there is no check if the vehicle is actually a heavy-duty vehicle in the legal sense of more than 3.5 tonne GVW. It could, e.g., include some passenger cars with caravans. However, the average total weight of foreign vehicles is higher than of Dutch vehicles. For German vehicles with a German trailer, the average weight is somewhat lower, and caravans might contribute. About 6% of the vehicle combinations with a German-German licence plate combination weights less than 4.5 tonne. For Polish-Polish vehicle combinations this is almost identical.

In 2012, CBS estimated 9.8% of the heavy-duty vehicles on the Dutch roads to be foreign vehicles, which is substantial lower than the estimate for motorways found here. Assuming motorways to be half of the total distance travelled, the CBS estimate is still lower than what is determined from WiM data.

The percentage of foreign vehicles varies greatly over the locations. From almost 50% of foreign vehicles on the A67 near Eindhoven to 10% on the A12 (between The Hague and Utrecht). The distance to the border is an indicator for this difference, however does not explain the large variation. Likely, the international transport has a number of corridors along which many trucks move between the major industrial and commercial centres. The A1 and the A67 can be such corridors from the Randstad to Germany and from Eindhoven and Antwerp to Germany, respectively.

Table 6 The percentages of foreign vehicles for each of the location, and direction, and approximate distance to the border for this route.

location	left	right	distance
A1	27.2%	29.3%	90 km
A2	27.8%	24.0%	40 km
A12	10.7%	10.3%	100 km
A15	12.3%	13.5%	100 km
A16	15.6%	15.1%	40 km
A27	17.3%	22.4%	50 km
A28	13.5%	12.7%	90 km
A67	49.4%	47.4%	50 km

The distance to the border for some part determines the fraction of foreign vehicles. More accurately, it should be matched with industrial areas on both sides of the border and urban activity. Generally the transport goes in both directions, except for the A27 where the different directions show a substantial difference. The cause is unknown, but may lie in the accuracy of the equipment, or the congestion avoidance of outgoing transport.

Given the lower percentages in Table 6 as representative for average Dutch heavy-duty fleet composition, additional investigation is needed to explain the different findings, which seem to be inconsistent. A priori there is no reason to assume it will have a large impact on the total emissions, as foreign transport companies in Europe rely on similar business usage, and will likely be using modern vehicles. As with the Dutch fleet, the smaller trucks are likely to be older and more important for the emissions.

4 Old heavy-duty vehicles

Vehicles built before 1992 do not have to comply with Euro-class emission legislation. Some emission limits exist for such vehicles, however, they are less complete as with the 13-mode engine test of Euro-I and Euro-II, or the ESC and ETC engine tests of Euro-III till Euro-V, and the WHSC, WHTC, and PEMS test for Euro-VI. Therefore, it is important to know which old vehicles still represent a large share in the total fleet. Table 7 shows the fractions and deviations from the category average weight. The deviation indicates whether the group of old vehicles within a category is some specialized set.

The age of the vehicle thus strongly affects the emissions. A few older vehicles in the fleet make the total emissions increase significantly. It is therefore important to know which vehicles remain on the road and which are used regularly.

Table 7 Fractions and properties of heavy-duty vehicles built before 1992 (Euro-0) on the Dutch road. In particular, the older smaller trucks remain part of the fleet, and are used for carrying relatively heavy loads. The latter category seems to be replaced by larger trucks in the modern fleet.

category		**in total**	**in category**	**weight**	**average age**
GVW	**trailer**	**[%]**	**[%]**	**[%]**	**[year]**
<10		0.039	2.178	10	4.8
10-20		0.114	1.03	-1	4.1
>20		0.011	0.206	-16	3.8
<10	X	0.094	4.476	**24**	5.8
10-20	X	0.014	0.605	-10	4.7
> 20	X	0.003	0.044	-10	4
Tractor-trailer	X	0.01	0.014	-1	3.5

A substantial amount of the light trucks are old, although the average age is quite similar for all categories. The tractor-trailer has an average age of 3.5 years, while the light truck with trailer has the highest average age of 5.8 years. Both ages are low compared to passenger cars, the average age of which is closer to eight years. Notably, the light trucks with a trailer is a large group, were the average weight is also higher than the average of all light trucks with trailers. Clearly, this is a group of specialized transport retaining older vehicles.

Older vehicles have a much higher PM emission than the younger vehicles. Over the years, there have been substantial and gradual improvements on the PM emissions of heavy-duty vehicles. Prior to 2014, the reduction of NO_x emissions was only limited, and not in line with the ever declining vehicle emission limits.

5 Payload of trucks

If trucks are better loaded, fewer trucks are needed to transport the same amount of goods. This is generally beneficial, for emissions, reducing congestion, and for the transport business. However, it is a hard problem. In all kind of manners it seems difficult to increase the average payload trucks. Understanding the problem starts with understanding the vehicle limitations and general characteristics of the observed payload.

The trucks on the road have a variety of empty weights and maximal weight, or gross vehicle weight (GVW). Typically, the heavier the vehicle, the more it can carry. A light commercial vehicle, or van, weighs 2.2 tonne and has GVW of 3.5 tonne, which means its payload is 60% of its own weight. A tractor-trailer combination weighs 14 tonne, with a GVW of 40 tonne, which yields a maximal payload of 185% of its own weight. Generally, heavy-duty vehicle combinations are not allowed to exceed a GVW of 40 tonnes. Special dispensation exists for 50 tonnes and in some cases such as cranes and the like, even higher GVW's are allowed. The limit of 40 tonne GVW is quickly reached: already from 8 to 9 tonnes, many of the vehicles have an allowed GVW of 40 tonnes. See Figure 1. This means that relatively small trucks in general are capable of carrying the heaviest allowed load.

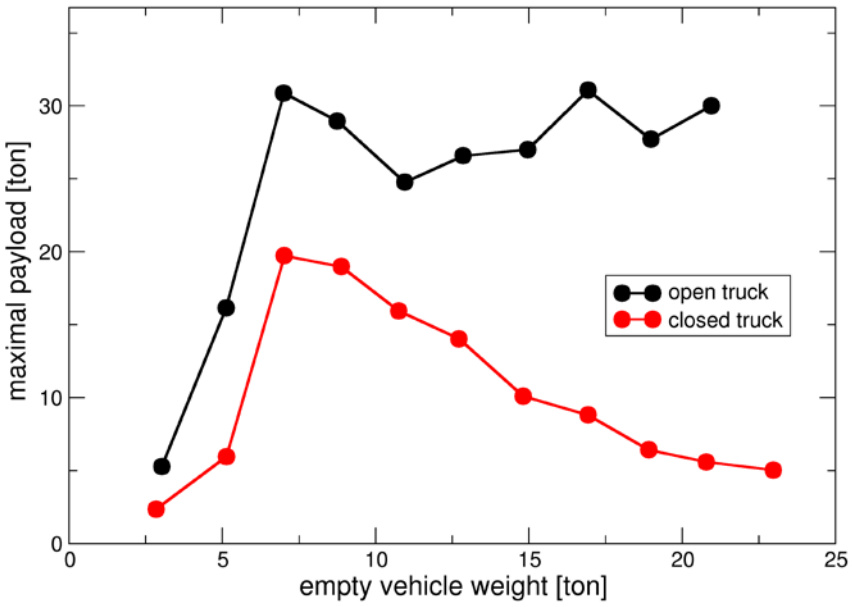

Figure 1 The maximal payload as function of the empty weight, shown for the largest group of registered Dutch trucks (the "open wagen"). Already light vehicles have a high GVW.

The same trend can be observed on the road. The payload set against the empty weight of the vehicle show a similar trend. Only the smallest trucks have a lower payload. Over a large range of empty weights the payload is more or less constant.

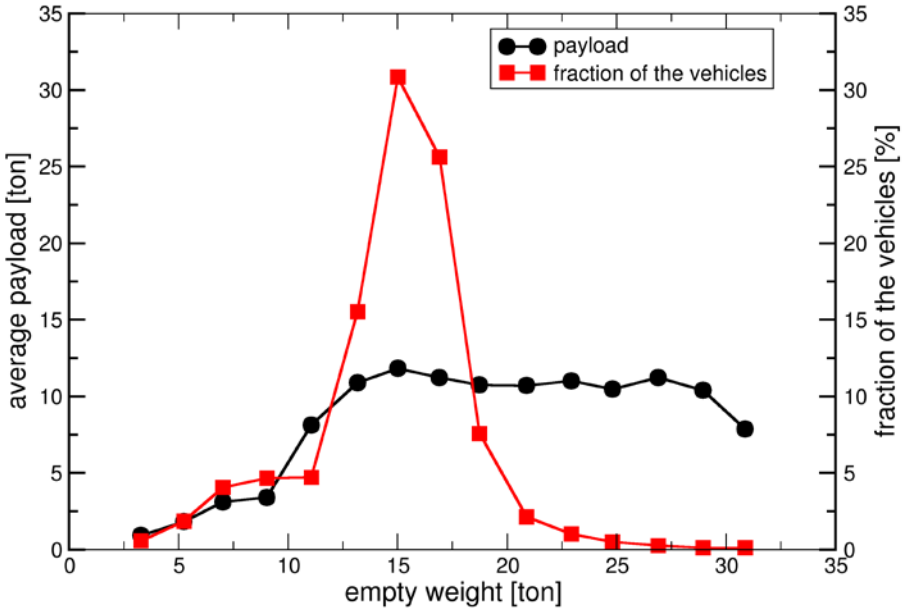

Figure 2 The average payload and fraction of vehicles on the road.

Interestingly, most vehicle combinations have a total empty weight of around 15 tonne; the typical weight of a tractor-trailer combination. Only a smaller fraction of the vehicles have an empty weight below 13 tonnes with a reduced payload, although the vehicle combination have no payload weight restriction as can be seen from Figure 1. Very likely for vehicles between 7 and 13 tonne empty weight there is a volume restriction, leading to a lower average payload.

6 Heavy-duty vehicles in urban situations

Heavy-duty vehicles have much higher emissions than the average light-duty vehicle and therefore still significantly contribute to the total emissions. While in the city they make up approximately 5% of the total urban fleet in a typical Dutch city, they are responsible for about half of the total urban traffic emissions. Busses are important, but heavy-goods vehicles contribute the largest amount.

This 5% share of heavy-duty vehicles on the total urban vehicle fleet is a coarse prediction. Limited information exists on the number of heavy-duty vehicles and the total share in distance covered by these vehicles in the city. In this study, a preliminary investigation was made into the actual urban distance travelled by heavy-duty vehicles, based on licence plate data collected in Amsterdam in November 2013.

Heavy rigid trucks and tractor-trailer combinations, both above 20 tonnes GVW, also are important players in the urban heavy traffic, which clearly follows from the licence plate scans in Amsterdam. Very likely, the average weight is lower than on the motorway. Moreover, tractor-trailers in urban driving are somewhat older: 4.5 years average against 3.5 years on the motorway. Also, the rated power is less: 280 kW against 310 kW for motorway. Hence, the urban tractor-trailers are typically the smaller vehicles.

The dominance of tractor-trailers on the motorway has its effect on the urban heavy-duty fleet composition, with a fraction of 31.5% of the total fleet, excluding busses and refuse trucks from the heavy-duty fleet. Together with the heavy trucks with a GVW over 20 tonnes and three or more axles, they comprise 53% to the total.

Typical urban utility trucks such as refuse trucks, drainage trucks, and large street sweepers make up 3.7% of the total urban heavy-duty traffic. Trucks for building activities are only a small fraction of the fleet. One could consider open trucks, concrete mixers, cranes, and tippers as such vehicles, which is 6% of the fleet. Buses are a large part, but this may depend on the lines and services: buses represent 22% of the total heavy-duty fleet at the locations in Amsterdam.

The small trucks, typically associated with urban driving, are only a minor group in the truck fleet. All trucks below 20 tonnes are 47% of the heavy-goods vehicles and, which 35%, the typical distribution truck in the range 10 - 20 tonnes is the larger group. The small trucks, at a GWV between 3.5 and 10 tonnes, form the remaining 12%.

The urban figures, combined with the total distance per category, suggests a typical trip for specific vehicles. If all heavy-goods vehicles combined drive about 9% of the distance in urban conditions, 20% rural, and 71% on the motorway, this suggests a larger urban contribution for the smaller trucks. The rural mileages is unknown. However, with 15% urban and 85% motorway, the averages are well reproduced in Table 8. The rural mileages are then partly associated with urban driving, and partly with motorway driving.

Simply said: for every two urban kilometres also a rural kilometre is made, and motorway distance is complemented with 20% additional rural distance.

Table 8 Overview of the different heavy-goods vehicle compositions per road type. The average value is based on the CBS figures for Dutch mileages.

	Fraction		
Trucks GVW	average	motorway	urban
3.5 - 10 ton	4.0%	2.0%	12.0%
10 - 20 tonne	15.5%	13.5%	35.0%
over 20 tonne	16.3%	12.7%	21.5%
tractor-trailers	64.2%	71.8%	31.5%

Given the overall 9%, 20%, and 71% split between the total urban, rural, and motorway distances, each vehicle category has a different split. This can be derived from the ratio urban-motorway in Table 8. The percentages in this table multiplied by the overall split yields numbers proportional to the total mileage of each vehicle category, which can be expressed again in a split between urban, rural and motorway per vehicle category, as shown in Table 9.

Table 9 The split in urban, rural and motorway driving for each vehicle category.

GVW	motorway	rural	urban
3.5-10 tonne	37.7%	33.4%	28.9%
10 - 20 tonne	57.8%	23.1%	19.0%
over 20 tonne	67.2%	18.4%	14.5%
tractor-trailers	86.9%	8.3%	4.8%

7 Conclusions

Composition of the Dutch heavy-duty vehicle fleet
The heavy-duty vehicle fleet in the Netherlands is dominated by large trucks and tractor-trailer combinations. The numbers are large and they carry most of the goods. It almost seems that the small trucks are a remand of the past, and they are now split into vans and 20-tonne GVW distribution trucks. Therefore, these smaller trucks have a different age distribution than modern trucks and tractor-trailers which have a typical economical age up to 5 years.

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Most vehicle combinations have a total empty weight of around 15 tonnes. The payloads of heavy-duty vehicles are quite low. Even the largest trucks, which can carry up to 25 tonne of goods, carry only 10 tonnes on average. This includes empty trips. It shows that total payload weight is in many cases not the restriction in the operation of heavy-goods vehicles.

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Approximately 20% of the heavy-duty vehicles are foreign trucks. This is a significantly higher share than assumed by CBS in 2012.

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A substantial amount of the light trucks are old, although the average age is quite similar for all categories. The tractor-trailer has an average age of 3.5 years, while the light truck with trailer has the highest average age of 5.8 years. Notably, the light trucks with a trailer is a large group, were the average weight is also higher than the average of all light trucks with trailers. Clearly, this is a group of specialized transport retaining older vehicles.

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Based on licence plate data collected in Amsterdam in November 2013, a preliminary investigation was made into the actual urban distance travelled by heavy-duty vehicles. The results are shown in Table 10.

Table 10 The split in urban, rural and motorway driving for each vehicle category.

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8 Signature

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