Accidents in the Netherlands involving heavy motor vehicles

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An analysis concerning underrun protection of rear ends, compared to the sides and the front ends

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Summary

On behalf of the RDW Vehicle Technology & Information Centre, SWOV analysed accident data concerning heavy vehicles.
Heavy vehicles are all motor vehicles with a total weight of more than 3500 kg (in EU-terms: all N2, N3, M2 and M3 vehicles, including their trailers). The question was whether accidents involving these heavy motor vehicles gave specific reason for concern regarding other road users with respect to underrun protection (the rear end compared to the sides and the front).

SWOV used accident data of the Dutch Ministry of Transport and analysed them in detail, focussing on two-vehicle accidents.
Selected accidents were grouped according to collision type (rear, side, front and not classifiable) and vehicle type (lorry, semi-trailer tractor and bus), as well as to type of opponent vehicle (car, van, motorcycle, moped, cycle and other heavy vehicles).

The injury risk in accidents involving heavy vehicles appears to be far greater for occupants of opponent vehicles than for occupants of the heavy vehicles. This is clearly illustrated by the fact that only 5% of the drivers of heavy vehicles were injured at all, against 87% of the drivers of opponent vehicles, 32% of whom were severely injured (fatal or hospitalized).
Buses seem to be less aggressive than lorries and semi-trailer tractors, the latter type causing the largest share of seriously injured drivers of opponent vehicles. This difference in aggressiveness explained by different accident circumstances of the three heavy vehicle types. Buses, mainly public transport vehicles, had most of their accidents within city limits. However, a large share of accidents involving semi-trailer tractors took place in rural areas or on highways, where accident severity is greater due to higher driving speeds.
As far as collision type is concerned, the percentage of severely injured drivers of opponent vehicles was 27% for accidents involving the rear end of heavy vehicles. The percentages for heavy vehicles hit at the side and hit at the front were 32% and 35% respectively.

There is a slight decrease in the overall number of accidents involving heavy vehicles over the years 1985 to 1997, although the number of heavy vehicles on the road and the number of vehicle kilometres travelled have increased.

The absolute number of accidents involving heavy vehicles with rear-end damage is far lower than the number of heavy vehicles with side damage. The number of heavy vehicles with frontal damage is the highest of the three. The same order applies to the numbers of casualties in opponent vehicles.
This does not necessarily mean that improvement of front underrun protection should have priority above improvement of side underrun protection or rear underrun protection. To reach this kind of decision, it is recommended to gather additional data, especially about cost and effectiveness of devices for underrun protection at the different sides of heavy vehicles.

Contents

1. Introduction

At the request of the Department of Vehicle Standard Development of the RDW Vehicle Technology & Information Centre, SWOV analysed accident data concerning all types of heavy motor vehicles with a total weight of more than 3,500 kg.
SWOV investigated whether the collision involving the rear end of heavy vehicles, including their trailers and semi-trailers, is a serious problem to other road users, compared to collisions involving the front end and the sides of these vehicle types. SWOV also examined how the number of heavy vehicle accidents have developed over the years 1985 to 1997.
This investigation was done, since it should be decided by EEVC whether rear underrun protection of heavy vehicles need specific attention, as compared to side and front underrun protection.

To answer these research questions, the following set-up was chosen:
1. Analyse the number of heavy vehicle accidents in the years 1985 to 1997 and compare these numbers with exposure data (number of vehicles and vehicle kilometres travelled).
2. Analyse the accident circumstances to be able to detect a possible difference between different types of heavy vehicles. (Data of 1997) .
3. Analyse the injury severity of drivers involved in accidents with different types of heavy vehicles and with the different collision modes: rear, side and front. (Data of 1997).

The different types of heavy motor vehicles are derived from the appropriate EU-Directive on masses and dimensions of vehicles (97/27/EU). This study distinguishes the following types:

Lorry
N2 or N3 type motor vehicle, designed for the conveying of goods. This type of vehicle may tow a trailer.

Semi-trailer tractor (S-t tractor)
N2 or N3 type motor vehicle, designed for the towing of semi-trailers, officially called a semi-trailer tractor.

Bus
M2 or M3 type motor vehicle, designed for the carriage of seated, or seated and standing passengers.

Trailer
O type vehicle, designed to be towed by a motor vehicle.

Semi-trailer
O type vehicle, designed to be towed by a s-t tractor.

HGV
Term used in this study to describe all N2 and N3 vehicles and their trailers or semi-trailers.

Heavy vehicle
Term used in this study to describe all N2, N3, M2 and M3 vehicles and their trailers or semi-trailers.

2. The data source used

The data source used for the purpose of this study, is the Dutch National Accident Registration from the Ministry of Transport, of which the (yearly) results are available at SWOV.
These data were registered by the police and give relevant information about the accidents, the types of vehicles involved, the occupants of the vehicles and the severity of their injuries.
Based on various studies concerning representativeness and completeness of accident data in the Netherlands, SWOV concluded that Dutch accident data concerning *motor vehicles* (including heavy vehicles) are almost 100% complete and therefore representative, as far as both fatal accidents and accidents resulting in hospital admittance is concerned.
For less severe accidents, like those resulting in admittance to an emergency department of a hospital (A&E), those resulting in visits to a physician outside a hospital, or those of even less severity, the completeness is far less than 100%, though their representativeness may still be good.
Therefore, we feel that the use of Dutch national accident data for this study is fully justified, if we keep in mind that the numbers of less severe accidents and their casualties are underestimated.

3. Development of accidents over the years

In this chapter we will give you an overview of all accidents involving HGV's and buses in the period of 1985 to 1997. This will give you both an impression of the scale of the problem and of the development of the accident numbers during the years.

Year	Accidents involving HGV's		Accidents involving buses		All injury accidents	
Year	Number	% fatal	Number	% fatal	Number	% fatal
1985	1947	10.1	604	7	42347	3.1
1986	1930	9.8	523	4	43580	3.2
1987	1958	10.8	569	55	42663	3.2
1988	1853	10	520	5.2	41859	3
1989	2046	11.4	577	6.1	44061	3
1990	2104	9.6	566	3.9	44915	2.8
1991	1980	9.8	541	4.3	40703	2.8
1992	1812	8.9	528	5.3	41051	2.9
1993	1751	7.5	506	5.1	40218	2.9
1994	1827	10.6	454	4.2	41391	2.9
1995	1908	10.3	485	3.1	42641	2.9
1996	1801	9.8	486	4.5	41041	2.7
1997	1813	8.3	455	5.9	41036	2.6

Table 1. *The number and severity of all accidents involving HGV's and buses, as well as all Dutch injury accidents in the years 1985 to 1997.*

Table 1 shows that the number of accidents did not change much during the last 13 years. For either of the three accident groups a slight decrease may be observed. In 1997, accidents involving HGV's account for 4.4% of all accidents, while bus accidents account for 1.1% of all accidents. These percentages also did not change much over the last 13 years.
The percentages showing a fatal outcome differ considerably between the three accident groups. Within the accident groups the percentages of fatal outcome did not change much over the years.
Accidents involving HGV's give about three times as much fatal outcome as the average of all accidents, while accidents involving buses do so about two times.
The numbers of accidents shown in *Table 1* include all types of collisions. In later chapters we will show data of the period 1985 to 1997, distinguishing several different collision types.

In order to reach conclusions about the traffic safety of heavy vehicles, the number of accidents should be related to exposure data, such as the number of vehicles and their mileage. These exposure data are presented below, in *Figures 1 and 2*. The data are based on statistics from Statistics Netherlands (CBS).

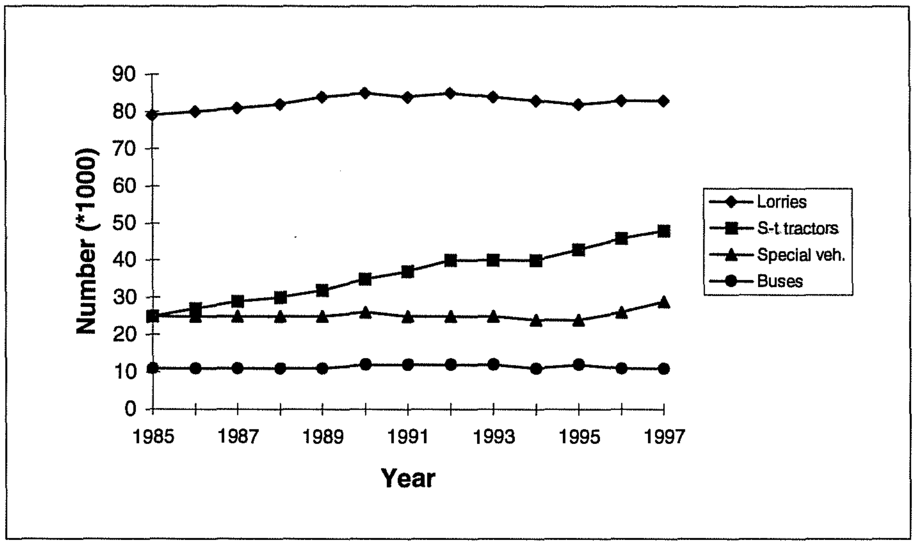

Figure 1. *The number of HGV's and buses in the Dutch vehicle park in the years 1985 to 1997 (CBS).*

Figure 1 shows that he number of lorries in the Dutch car park has been fairly stable over the years (currently slightly less than 85,000 vehicles). Also, the number of buses remained stable (around 11,000).
The number of special vehicles (including fire engines, garbage vehicles etc.) also remained fairly stable, though it has increased to about 29,000 during the last few years.
The number of semi-trailer tractors, however, has increased considerably from 11,000 in 1985 to 48,000 in 1997.
The total park of heavy vehicles in the Netherlands has increased from about 140,000 in 1985 to about 170,000 in 1997, a total increase of 22%.

Figure 2 shows the development of vehicle kilometres of heavy vehicles during the years 1985 to 1997. Comparing *Figure 1* and *Figure 2*, most vehicle categories show more or less the same development in the amount of vehicle kilometres as in the number of vehicles. Especially semi-trailer tractors show the same large increase over the years of vehicle kilometres travelled.

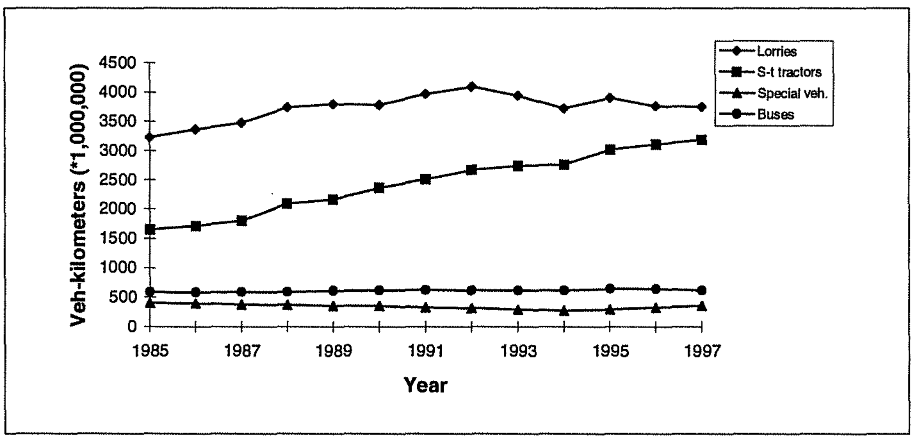

Figure 2. *The number of vehicle kilometres travelled by heavy vehicles in the years 1985-1997 (CBS).*

For lorries, the development shows a pronounced increase of vehicle kilometres travelled over the years up to 1992, after which the number decreased slightly.

The total amount of vehicle kilometres travelled has increased gradually from about 5,900 million in 1985 to about 7,900 million in 1997, a total increase of 35%.
Lorries averagely travelled 52% of the total amount of vehicle kilometres in the period of 1985 to 1997. S-t tractors travelled 34%, buses 9% and special vehicles 5% of that total. We will refer to these shares in chapter 5.

4. Selection of relevant cases

4.1. Selection criteria

In this study only accidents involving lorries, s-t tractors and buses are selected, their total amounting to about 5.5% of all registered Dutch accidents that resulted in injuries (chapter 3). In absolute numbers, this concerns 2,000 to 2,500 accidents per year.

Other selection criteria concerned the number of vehicles involved and the type of opponent vehicle.Only accidents involving two vehicles were selected. Opponent vehicles in these accidents were all types of motor vehicles, as well as bicycles.
This excluded multiple-vehicle collisions, however relevant these might have been for the study of the problem. In these accidents the police data available do not allow proper reconstruction of the sequence of colliding vehicles and their impact points.
Further exclusions were single vehicle collisions, collisions against non-selected opponent vehicles, such as trains and trams, and collisions against pedestrians, animals and fixed obstacles.

In *Table 2* we give an overall view of the numbers of selected and non-selected accidents specified by accident type. This table shows that 68% of all accidents involving lorries, 64% of those involving s-t tractors, and 72% of all accidents involving buses remained in the final selection.

Accident types	Accidents involving			Accidents
	Lorry	S-t tractor	Bus	Total
Selected cases	*954*	*263*	*329*	*1546*
Non-selected cases:	1400	413	455	2268

Table 2. *Number of selected and non-selected accident types, 1997 data.*

4.2. Selected cases and collision type

The accident cases selected were divided into groups of the same collision types: rear, side and front.

Rear collisions are accidents in which the rear end of the heavy vehicle is hit by the front end of the opponent vehicle.
Side collisions are accidents in which a side of the heavy vehicle (or their trailer) is hit by the front of the opponent vehicle.
Front collisions are accidents in which the front end of the heavy vehicle is involved. This includes pure frontal collisions (involving the front of the opponent vehicle), front to side collisions (in which the side of the opponent vehicle is hit) and front to rear collisions (in which the rear of the opponent vehicle is hit).

In the present analysis distinction with respect to collision type is based on the combination of two variables: type of accident and damaged area of the vehicle.
Since every side of the vehicle is divided into three areas (centre and two corners) a rather fine distinction in collision type can be made.
However, in certain cases a corner of both vehicles is involved. In these cases it is practically impossible to distinguish a rear, a side or a frontal collision.
Therefore, some relevant cases are not specified one of the three main collision types, but still remain in the sample named 'Other collision type'.

Table 3 shows the number of accidents in the four main collision categories, specified by for the three selected accident types

Collision type	Lorry		S-t tractor		Bus		Total	
	number	%	number	%	number	%	number	%
Rear	85	*8.9*	27	*10.3*	16	*4.9*	128	*8.3*
Side	274	*28.7*	91	*34.6*	88	*26.7*	453	*29.3*
Frontal	393	*41.2*	94	*35.7*	152	*46.2*	639	*41.3*
Other	202	*21.2*	51	*19.4*	73	*22.2*	326	*21.1*
Total	954	*100%*	263	*100%*	329	*100%*	1546	*100%*

Table 3. *Number and percentage of accidents with lorries, s-t tractors and buses, specified in collision type, 1997 data.*

Table 3 shows that accidents involving lorries represent more than 60% of all selected accident cases, while accidents involving s-t tractors (and their semi-trailers) amount to a share of 17%, leaving a share of 21% for bus accidents.
The table also shows some interesting differences between lorries, s-t tractors and buses as far as distribution of collision types is concerned.
Rear-end damage is more common in s-t tractor and lorry accidents (9% to 10%) than in bus accidents (5%).
Side damage appears to be more common in s-t tractor accidents (35%) than in both other types (29%).
Frontal damage is more common for buses (46%) than for lorries (41%) or s-t tractors (36%).
In general, accidents of the frontal damage type amount to 41% of all accidents in the sample, while those involving side damage amount to 30% and rear-end damage represents 8% of all cases.

More characteristics of the selected accidents are shown in chapter 5.

5. Main characteristics of the selected accidents

5.1. Vehicle type

Since we are interested in all different types of lorries, s-t tractors and buses, we specified eight different heavy vehicle categories within our selection. *Table 4* shows the distribution of accidents over these categories.

Type of heavy vehicle	Percentage of total selected cases
Lorry (single)	49.7
Lorry and trailer	8.3
Other lorry	3.5
S-t tractor (single)	0.9
S-t tractor and semi-trailer	15.3
Other s-t tractor	0.9
Bus for public transport	20.2
Other type of bus	1.2
Total	100 (N=1,546)

Table 4. *Percentage distribution of heavy vehicle accidents over different heavy vehicle types, 1997 data.*

Of all lorries involved in the selected accidents, single lorries are by far the most common type, namely 50% against 8% lorries with trailer and 4% other lorry types.
S-t tractors with semi-trailer is the most important type of S-t tractor involved in the selected accidents: 15% against 1% single and 1% other type of s-t tractor.
Nearly all buses involved in accidents are public transport buses.

Comparing *Figure 2* and *Table 4*, we see that the accident involvement of lorries represent more or less the relative amount of vehicle kilometres travelled. The same is the case for the special vehicles.
However, in a similar comparison, s-t tractors appear to be under-represented in accidents by a factor two, whereas buses are over-represented by a factor two. This might well be explained by other characteristics, such as the purpose for which the specific vehicles are used. (See also paragraph 5.5).

5.2. Involvement of trailers or semi-trailers

Table 4 shows that in 24% of all cases, a heavy vehicle towing a trailer or semi-trailer was involved. However, only in 10% of all these accidents the trailer or semi-trailer was actually hit, either in side collisions or in rear-end collisions.
Other data show that there was almost no difference in injury outcome for the driver of opponent vehicles when they hit either the towing vehicle or the trailer.

For these reasons we will combine the data of 'trailer accidents' with the accident data of the towing vehicles without further distinction.

5.3. Type of opponent

Opponent vehicles of HGV's and buses are divided in seven categories in *Table 5*. This table shows the distribution of heavy vehicle accidents over these opponent categories.

Type of opponent vehicle	Type of heavy vehicle			Average %-age
	Lorry	S-t tractor	Bus	
Car	50	51.7	38.3	47.8
Van	5.5	10.3	5.8	6.3
Motorcycle	2.8	3	3.6	3
Moped	15.1	10.7	16.7	14.7
Bicycle	23.9	18.3	33.4	25
Other HGV or bus	2.7	6.1	2.1	3.2
Total	N=954	N=263	N=329	N=1,546

Table 5. *Percentage distribution of heavy vehicle accidents over the opponent categories, 1997 data.*

Cars are by far the most common opponents of both HGV's and buses, accounting for nearly half of all selected accidents, although their shares differ somewhat. Cycles are more common opponents for buses than for lorries and s-t tractors, and their total share is 25%, ranking second. Mopeds rank third with a 15% total share. Vans rank fourth (6%).
Motorcycles and other HGV's or buses play a minor role as opponents.
The most prominent difference between HGV and bus accidents is the shares of cars (about 50% for HGV's and 38% for buses) compared to the shares of bicycles (around 20% for HGV's and 33% for buses).

Accidents involving two heavy vehicles of the same type were counted only once in this study. In these cases the heavy vehicle first appearing in a specific accident record was assigned as the relevant vehicle. The other vehicle was assigned as the opponent vehicle and was not counted as a heavy vehicle.
In this way the number of accidents used in this study will be correct, since only one vehicle per accident is counted.
On the other hand, since only one heavy vehicle is counted where two heavy vehicles are involved, the real number of relevant heavy vehicles is slightly higher than the heavy vehicles that appear in this study..

5.4. Severity of the accidents

In the following table, *Table 6*, the measure of accident severity is the most severely injured occupant of either of the two vehicles involved.
While the average share of fatal accidents is 7%, accidents involving s-t tractors appear to be more severe than average (11%). Bus accidents, on the other hand, appear to be less severe than the other two categories, both regarding the share of fatal accidents and the share of hospital admittance.

Accident severity	Lorry	S-t tractor	Bus	Average %-age
Fatal	6.8	11.4	5.5	7.3
Hospital admittance	28.4	30.8	23.7	27.8
Other injury	64.8	57.8	70.8	64.9
Total	N=954	N=263	N=329	N=1,546

Table 6. *Percentage distribution of accident severity over the type of heavy vehicle, 1997 data.*

5.5. Local speed limit

Table 7 shows the heavy vehicle accidents specified by the local speed limit, the maximum speed allowed at the accident spot.

Speed limit (km/h)	Lorry	S-t tractor	Bus	Average %-age
up to 50	56.1	42.2	82.4	59.2
60-90	34.7	44.9	16.4	32.6
100-120	9.2	12.9	1.2	8.2
Total	N=954	N=263	N=329	N=1,546

Table 7. *Percentage distribution of local speed limit over the heavy vehicle accidents, 1997 data*

Nearly 60% of all accidents take place at roads having a speed limit up to 50 km/hour, which in most cases means that these accidents occur in urban areas.
The difference among the three vehicle types however is considerable, since more than 80% of all selected bus accidents occur at these roads, while on the other hand only some 42% of accidents involving s-t tractors take place on these roads, while lorries show a little higher proportion (56%).
On roads having a speed limit of 60-90 km/hour (mainly so called 80 km/hour roads), also s-t tractors and lorries have a far bigger proportion of accidents than buses.
On roads having a speed limit of 100-120 km/hour (mainly highways), bus accidents only show a proportion of 1%, while lorries and s-t tractors represent 9% and 13% respectively, of the accidents in their groups.

Paragraph 5.1 showed that semi-trailer tractors are under-represented in the accident sample if compared to their share of vehicle kilometres travelled, while at the same time buses are over-represented. This fact may be partially or completely explained by their totally different shares on different road types.
Buses involved are mainly public transport buses, and will therefore travel most of the time within urban areas, where accidents are more likely to occur. On the other hand, semi-trailer tractors travel mainly on highways, where accidents occur less frequently.

5.6. Day of the week

Table8 shows the occurrence of heavy vehicle accidents at the separate days of the week.
We can see that on Saturdays and Sundays far less accidents involving heavy vehicles occur than during weekdays. Bus accidents, however, occur more frequently during weekends than accidents involving HGV's.

Day of the week	Lorry	S-t tractor	Bus	Average %-age
Sunday	1.5	1.1	4.3	2
Monday	19.8	14.8	17.9	18.6
Tuesday	18.3	18.6	14	17.5
Wednesday	19.5	19	16.7	18.8
Thursday	18.1	19.8	16.7	18.1
Friday	19	22.1	19.2	19.5
Saturday	3.9	4.6	11.3	5.5
Total	N=954	N=263	N=329	N=1,546

Table 8. *Percentage distribution of heavy vehicle accidents over the days of the week, 1997 data.*

5.7. Hour of the day

Table 9 shows the distribution of heavy vehicle accidents over the hours of the day.
The three vehicle types show only very small differences in distribution over daytime. Only accidents involving s-t tractors occur a little bit more often in the very late and very early hours of the day than the other types.

Hour of the day	Lorry	S-t tractor	Bus	Average %-age
0-6	3.3	6.1	1.8	3.4
6-10	25.2	23.6	22.5	24.3
10-16	48.8	39.2	45	46.3
16-20	18.6	22.4	24	20.4
20-24	4.3	8.8	6.7	5.6
Total	N=954	N=263	N=329	N=1,546

Table 9. *Percentage distribution of heavy vehicle accidents over the hours of the day, 1997 data.*

5.8. Weather condition

Table 10 contains accident numbers distributed over several types of weather in which the accident occurred.
Some difference between the vehicle types can be observed under raining conditions. The heavy vehicle accidents under raining conditions involve more often HGV's than buses.

Weather condition	Lorry	S-t tractor	Bus	Average %-age
Dry	82.8	82.1	88.8	84
Rain	14.5	15.2	10.6	13.3
Fog	1.5	27	0.6	1.5
Other/unknown	1.3	0.4	-	0.8
Total	N=954	N=263	N=329	N=1,546

Table 10. *Percentage distribution of heavy vehicle accidents over different weather conditions, 1997 data.*

5.9. Driver age

Table 11 shows the distribution of accidents over different age categories of the heavy vehicle driver.

Interestingly, younger heavy vehicle drivers (aged 18 to 34) are much more involved in HGV accidents than in bus accidents. Drivers in the higher age categories (35 to 54), however, are more involved in bus accidents than in accidents with HGV's. This is probably due to the fact that the average age of bus drivers is higher than of HGV drivers.

Driver age (years)	Lorry	S-t tractor	Bus	Average %-age
18-24	11.7	12.6	1.5	9.7
25-34	30.9	38	15.8	28.9
35-44	25.8	23.2	32.2	26.7
45-54	20.9	15.6	39.8	24
55-64	5.8	8.4	8.8	6.9
65 +	0.4	0.4	0.3	0.4
Unknown	4.5	1.9	1.5	3.4
Total	N=954	N=263	N=329	N=1,546

Table 11. *Percentage distribution of heavy vehicle accidents over driver age, 1997 data.*

5.10. Driver sex

The distribution of heavy vehicle accidents between male and female drivers is presented in *Table 12.*

Male drivers represent more than 95% of all heavy vehicles drivers involved in accidents. This is most probably due to the fact that the driving of heavy vehicles still is 'male business'.

Driver sex	Lorry	S-t tractor	Bus	Average %-age
Male	96	97	95.7	96.1
Female	0.5	1.1	3.3	1.2
Unknown	3.6	1.9	0.9	2.7
Total	N=954	N=263	N=329	N=1,546

Table 12. *Percentage distribution of heavy vehicle accidents over driver sex, 1997 data.*

6. Rear-end damage accidents compared to side and frontal damage accidents

6.1. Collision type and injury severity

In view of the specific aim of this study we will now compare the severity of drivers' injury between the three main types of collision (rear, side and front).
We assigned the collision type depending on the *damaged side* of the heavy vehicle. The category 'other' includes all cases in which the damage can not be clearly allotted to front, rear or side. In most of these cases a corner of the heavy vehicle is involved (the police often records this type of cases as 'side').
Injury severity is divided in three categories: serious (fatal and hospitalized), other injured, and not injured.

6.2. Data of drivers only

Data on drivers of both vehicles involved are always available, even if the driver is not injured. Data on passengers are only recorded by the police if the passenger was injured. However, their seating position is not specified in such cases. For this reason we concentrate only on *drivers* of heavy vehicles and their opponent vehicles.
The real number of injured people are therefore higher than the numbers shown in the next paragraphs.

6.3. Injury severity of heavy vehicle drivers and collision type

The injury severity of the heavy vehicle drivers is shown against the type of collision in *Table 13*. Accidents with all types of heavy vehicles are regarded in this analysis.

Injury severity, heavy vehicle driver	Collision type				Average %-age
	Rear	Side	Frontal	Other	
Fatal + hospitalized	-	0.2	1.4	1.2	0.9
Other injured	5.5	2.4	4.4	4.9	4
Not injured	94.5	97.4	94.2	93.9	95.1
Total	N=128	N=453	N=639	N=326	N=1,546

Table 13. *Percentage distribution of injury severity of heavy vehicle drivers, specified in collision type, 1997 data.*

Table 13 shows that drivers of heavy vehicles are almost not at risk in the selected accidents, nearly regardless of collision type. Less than 1% of the drivers is severely injured (fatal plus hospitalized), 4% is less severely injured, while 95% is not injured at all.

6.4. Injury severity of opponent vehicle drivers and collision type

Table 14 shows the injury severity of the opponent vehicle drivers against the type of collision.

Injury severity, opponent vehicle driver	Collision type				Average %-age
	Rear	Side	Frontal	Other	
Fatal + hospitalized	26.6	31.8	35.1	26.4	31.6
Other injured	57	59.8	49.6	58.6	55.1
Not injured	16.4	8.4	15.4	15	13.3
Total	N=128	N=453	N=639	N=326	N=1,546

Table 14. *Percentage distribution of injury severity of opponent vehicle drivers, specified in collision type, 1997 data.*

In contrast to *Table 13, Table 14* shows that drivers of opponent vehicles suffer enormously from accidents involving HGV's and buses. Nearly 32% of the drivers are severely injured, of whom 7% fatally (*Table 6*).
Also far more opponent vehicle drivers than heavy vehicle drivers are injured in another, less severe way. This percentage is 55%, half of which had to be treated at an A&E department.
Only 13% of the opponent vehicle drivers was not injured at all. In these cases probably a passenger in the same vehicle was injured, since all accidents were recorded as injury accidents.

Some difference between the different collision types can be observed, pointing out that collisions with the front of a heavy vehicle result in the highest percentage of severely injured drivers (35%), followed by collisions against the sides (32%), while collisions against the rear end of heavy vehicles still cause severe drivers' injury in 27% of the cases.

In the previous two tables we combined the three types of heavy vehicles, in order to be able to show collision type against injury severity in the same table. Since it might be interesting to see whether there are differences between the three heavy vehicle types, we specify these numbers in *Table 15*. For practical reasons, injury severity is restricted to only one category: the severely injured.

Collision type	Lorry	S-t tractor	Bus	Average %-age
Rear	27.1	33.3	12.5 *	26.6
Side	34.3	34.1	21.6	31.8
Front	33.8	44.7	32.2	35.1
Other	26.2	31.4	23.3	26.4
Average %-age	31.8	37.3	26.4	31.6

* the number of accident cases is only 2 out of 16

Table 15. *Percentage distribution of severely injured opponent vehicle drivers over collision type, specified in heavy vehicle type, 1997 data.*

Table 15 shows that drivers of opponent vehicles suffer most in accidents involving s-t tractors (the average share of seriously injured is 37%), followed by lorries (32%) and by buses (26%).
This order of aggressiveness is also apparent in the distribution over collision type, except for side collisions, in which lorries are as aggressive as s-t tractors.
The reason why buses appear the least aggressive of the three vehicle types, and s-t trailers the most aggressive, may again be attributed to their different accident circumstances, as illustrated in chapter 5. Bus accidents nearly all occurred in urban areas, while a relatively large proportion of s-t tractor accidents took place on highways and other roads in rural areas, where driving speeds are higher and collisions therefore may result in more severely injured.
The fact, that in frontal collisions the share of seriously injured opponent drivers in accidents involving buses does not differ much from that involving lorries (32% and 34% respectively), indicates that in this type of collision buses are equally aggressive as lorries. This may be due to the fact that cyclists are more common opponents of buses than of lorries, whereas cars are more common opponents of lorries than of buses. Since cyclists are far more vulnerable than car drivers, this may explain the equally high percentage of severely injured after frontal collision of buses and lorries.

6.5. Detailed collision type and its development

In *Table 16* more detailed collision types are presented. This is especially done for the collision types 'side' and 'frontal'.
The first type is divided into the categories 'centre' and 'corner', meaning that the heavy vehicle was hit at the centre part of the side, respectively at the front or rear corner of the side.
Frontal collisions may be divided into three different collision modes: front against front (the front of the heavy vehicle struck the front of its opponent), front against side (the front of the heavy vehicle struck the side of its opponent) and front against rear (the front of the heavy vehicle struck the rear of its opponent).

	Damaged part of the heavy vehicle							
Year	Rear	Side-centre	Side-corner	Front			Other type	Total
	Damaged side of the opponent							
	Front	Front	Front	Front	Rear	Side		
1985	112	346	291	178	100	377	417	1821
1986	110	301	301	151	86	392	407	1748
1987	99	311	335	152	96	374	426	1793
1995	146	295	193	127	141	346	398	1646
1996	122	325	145	103	152	351	358	1556
1997	128	308	145	118	166	355	326	1546

Table 16. *The number of heavy vehicle accidents in the periods 1985-1987 and 1995-1997, against several specified collision types.*

Table 16 shows an overall decrease from 1985 to 1997, also apparent within some of the collision types. However, other accident numbers per collision type increase over the years and some of them only fluctuate.
In order to realize a more stable pattern, we calculated averages for the two three year periods, which are presented in the next table, *Table 17*.

	Damaged part of the heavy vehicle							
Year	Rear	Side-centre	Side-corner	Front			Other type	Total
	Damaged side of opponent							
	Front	Front	Front	Front	Rear	Side		
1985-1987 (A)	*107*	*319*	*309*	*160*	*94*	*381*	*417*	*1787*
1995-1997 (B)	*132*	*309*	*161*	*116*	*153*	*351*	*361*	*1583*
B/A	*1.23*	*0.97*	*0.52*	*0.73*	*1.63*	*0.92*	*0.87*	*0.89*

Table 17. *Average number of heavy vehicle accidents in the periods 1985-1987 and 1995-1997, against several specified collision types.*

Table 17 shows that the average total number of accidents in the 1995-to-1997 period is 89% of the accidents in the period of 1985 to 1987, representing an overall decrease of 11%.

Three specific collision types do not follow this trend:
- Accidents of heavy vehicles with *rear-end damage* have increased with 23%.
- Accidents of heavy vehicles with *damage to the side-corner* have decreased to 52%, while the number of accidents involving the side-centre has remained more or less at the same level.
- Accidents of heavy vehicles with *frontal damage,* that collided against the rear of opponents, have increased with 63%.

This last-mentioned increase, in which cars and vans are the most common opponents, relates to the same problem as has already been reported by SWOV, (Tromp, 1998; Van Kampen, 1997).
These reports mention that due to the increase of the number of cars and vans on the roads, the number of rear-end collisions involving these vehicle types has more than doubled since 1985. Thus, the increase in this type of heavy vehicle accidents is in agreement with the general trend.

6.6. Collision type and type of opponent

It may well be that the type of collision in heavy vehicle accidents depends on the type of opponent vehicle. *Table 18* shows the data to check for such a dependency. Data for the three most frequently occurring vehicle types are shown separately, whereas data of vans and cars are combined in *Table 18.*

Opponent type	Collision type				Average %-age
	Rear	Side	Frontal	Other	
Car and van	82.8	43.2	61.3	43.8	54.1
Bicycle	7	26.5	24.1	31.6	25
Moped	3.9	25.4	8.3	16.6	14.7
Other	6.3	4.9	6.3	8	6.2
Total	N=128	N=453	N=639	N=326	N=1,546

Table 18. *Percentage distribution of heavy vehicle accidents over the type of opponent, specified in collision type, 1997 data.*

From *Table 18*, it is clear that in rear-end collisions cars and vans are by far the most frequent opponent (a share of 83%), while cycles and mopeds score far less than their average share presented in the last column.
In side collisions the shares of cycles and mopeds are relevant as well, since they amount to more than 50%, equally distributed over cyclists and mopeds.
In frontal collisions, apart from cars and vans (61%) the share of cycles is also important (24%), while mopeds represent only 8%, far less than their average share of 15%.

7. Discussion

As we have seen, accidents involving heavy vehicles contribute disproportionally to the number and severity of traffic casualties.
A more detailed analysis of differences between cars, HGV's and vans focussing on accidents within urban areas is given in van Kampen & Vis (1997). This report also states that there is not much difference between the vehicle types regarding their *involvement* in accidents, given also their exposure in traffic.
This means that most of the injury outcome of accidents between heavy vehicles and other vehicles is caused by the structural properties of heavy vehicles. They are heavier, larger and stiffer than almost all other categories of road vehicles. Besides, their geometrical properties do not match the geometrical properties of opponent vehicles.
It is therefore still quite possible that cars, which are successfully developed for withstanding collisions against solid objects at very high speeds, are badly damaged in collisions against HGV's and buses.

It appears from the analysis in this report that the differences in injury level between drivers of heavy vehicles and those of opponents are still very high. Though the absolute number of collisions between heavy vehicles and other vehicles may have decreased slightly during the last 13 years, the problem of injury mismatch is still very much apparent.
Improved underrun protection, therefore is a necessary element of heavy vehicles, in order to match existing properties of cars (and other categories) and to create a sustainable safe (compatible) situation in case of collisions.

From the selected accident statistics, it seems that only slightly less injuries are caused by rear-end collisions than by side and frontal collisions. However, the numbers of these accidents differ considerably. Front ends of heavy vehicles are involved in far more accidents than sides and rear-ends. Sides collisions are second important and rear-end collisions are third. Differences in injury severity of drivers of opponent vehicles suggest that s-t tractors are more aggressive than lorries, while buses are the least aggressive. These differences may be partially explained by the fact that the buses represented in the accident sample operate mainly in urban areas, while the accidents of the other two heavy vehicle types occur relatively more often in rural areas, where speeds are higher and accidents more severe.

We have also shown that cars are by far the most important opponent in rear-end accidents, while in side collisions both cycles and mopeds are prominent too. In frontal collisions both cars and cycles are the more important opponents.

Considering these results, one could therefore say that front underrun protection deserves more attention than side underrun protection, while rear underrun protection would only be third in this row.
The decision for this kind of priorities may also depend on the costs and effectiveness of protective devices that are available or in development for either of the three heavy vehicle sides.

Therefore, application of rear underrun protection could theoretically become a first priority, if devices of low costs and with high effectiveness could be developed and applied.

8. Conclusions

Accidents involving heavy vehicles have been studied with respect to underrun protection.
Three types of heavy vehicles have been distinguished: lorries, s-t tractors and buses; their shares in the selected accident sample are 66%, 21% and 13% respectively. These shares include lorries and s-t tractors towing a trailer or semi-trailer, available in 24% of all cases.
Only two-vehicle accidents were selected for this purpose, excluding therefore multi-vehicle collissions, collisions against pedestrians, single vehicle accidents and collisions against obstacles.
Furthermore, three collision types have been studied, representing damage to the *rear*, the *sides* and the *front* of these heavy vehicles. In each of these cases, the front part of an opponent vehicle was involved.
Rear-end damage was found in 8%, side damage in 29% and frontal damage in 41% of all selected cases; in the remaining 22% of the cases, no distinction to rear, side or front could be made.

As far as *drivers of the heavy vehicles* are concerned these accidents do not mean a serious injury threats, especially not if compared to the opponent vehicle drivers.
For *drivers of opponent vehicles* these accidents have considerable injury threats. Averagely, 32% of these drivers are seriously injured, and 55% are less severely injured.

Rear-end collisions do cause a little less severe injury than do side and frontal collisions; though the proportion of severely injured drivers is still 27%, compared to side collisions where this proportion is 32%, and frontal collisions where the proportion is 35%.

Almost no differences between the three heavy vehicle types were observed in general characteristics of these accidents. It can be seen however that bus accidents occur far more often within urban areas than accidents involving lorries or s-t tractors. This may be so because buses involved in accidents are almost exclusively public transport buses.

With respect to injury severity of drivers of opponent vehicles, buses appear the least aggressive, while s-t tractors seem somewhat more aggressive than lorries. These differences also seem explainable in view of the different accident circumstances of the three heavy vehicle types, especially regarding the type of road and the local speed limit.

Cars are by far the most common opponent of heavy goods vehicles in the selected two vehicle collisions, followed by cycles and mopeds. Their average shares are 48%, 25% and 15%, respectively.

The number of heavy vehicles in The Netherlands has increased with 22%, and the number of vehicle kilometers travelled increased with 35% in the period of 1985 to 1997. Despite this fact, there appears to be no change in the number of heavy vehicle accidents in this period. In fact, the number of injury accidents has decreased slightly.

Only for certain specific collision types some changes were observed. The number of accidents in which the front of a heavy vehicle hits the rear end of an opponent (mostly car or van) has increased considerably. This may be attributed solely to the increase of cars and vans on the roads, and was already established by SWOV examining the crash safety of occupants of cars and vans.
Also collisions involving the rear of heavy vehicles occur more often in recent years than 13 years ago, while the number of collisions involving the side corner parts of heavy vehicles has decreased.

As far as specific types of opponent vehicles are concerned, attention should at least always be focussed on cars (especially in rear-end collisions) and on two-wheelers (especially in side and in frontal collisions).

It is recommended that data are gathered about costs and effectiveness of measures concerning underrun protection. In this way, the decision about which side of the heavy vehicle needs priority protection will be made possible.

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