Volvo Trucks. Driving Progress

EUROPEAN ACCIDENT RESEARCH AND SAFETY REPORT 2013

VOLVO TRUCKS

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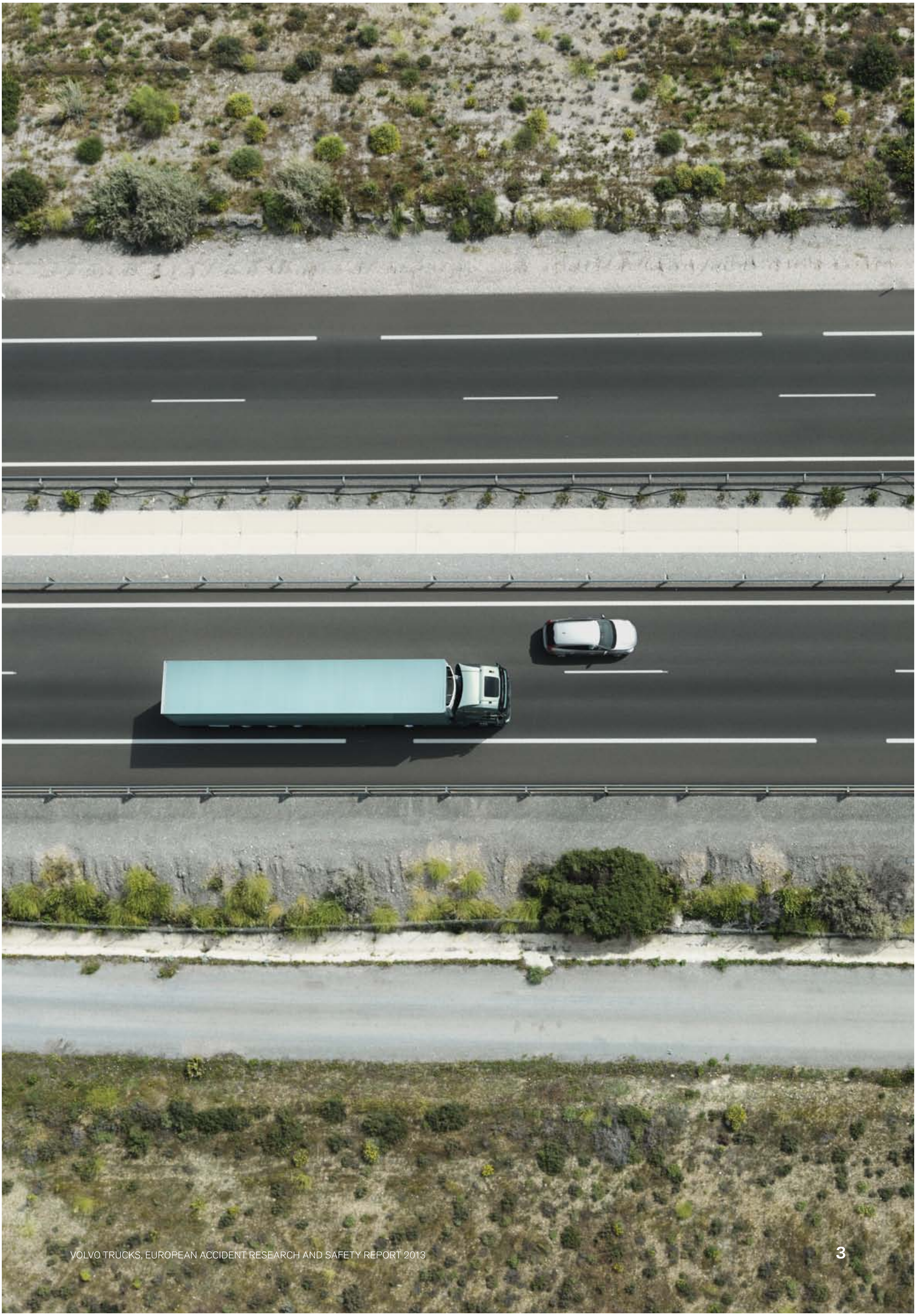

Foreword.

Every year about 1.2 million people are killed in road traffic accidents worldwide. As global traffic volumes increase, there is an evident risk that the number of serious traffic accidents will continue to rise. However, this trend can be reversed by increasing driving, road and vehicle safety levels as demonstrated by the trend in the EU countries, where fewer fatal traffic accidents happen today than 20 years ago. A more detailed understanding of how and why traffic accidents happen can make both the traffic environment and vehicles safer.

Volvo Trucks has studied and analysed a large number of accidents involving trucks since 1969. The information gained has been, and still is, one of the most important bases for the design and development of Volvo trucks. Volvo's in-house research, along with statistics and research findings from European authorities and academics, form the basis of this report. In addition to providing a tool for Volvo's development and safety work, we hope this report will contribute to broadening our understanding of accidents involving trucks, thereby helping to reduce the risk of traffic related accidents and injuries.

Gothenburg, 09 January 2013

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Executive summary.

The bi-annual report of Volvo Trucks Accident Research Team provides an overview of European heavy truck accidents. It tries to explain why these accidents occur and identifies priorities for future development.

In the EU27 countries, 2009 faced about 35,500 fatalities in traffic accidents. This was a 10% decrease from the previous year, 2008, which coincides with the positive trend that has been ongoing for the last 20 years. Heavy trucks are involved in about 17% of the fatalities and 7% of all casualties.

Human error is involved in as many as 90% of all accidents. The two most common human factor related factors that contribute to heavy truck accidents are failure to look properly and failure to judge another person's path or speed. When the vehicle contributes to the accident, the most common cause is limited visibility due to blind spots.

- Only 15% to 20% of those killed or seriously injured in heavy truck accidents are truck occupants. 50% of these accidents are single accidents and 30% are collisions with another heavy truck.
- Seatbelt usage is still unacceptably low. At least 50% of the fatally injured non-belted heavy truck occupants would have survived if they had used a seatbelt.
- 55% to 65% of those killed or seriously injured in heavy truck accidents are car occupants. Car occupants are often injured due to major deformation of the car compartment.
- 15% to 25% of the victims in heavy truck accidents are unprotected road users, i.e. pedestrians, cyclists and motorcyclists. Many of these accidents occur at low speed and here again limited visibility is one of the main causes. In more than 75% of the fatal accidents involving pedestrians and cyclists, the unprotected road user is run over by one or more of the truck wheels.
- The main accident pattern is similar between medium duty (Volvo FL) and heavy duty (Volvo FH/FM) trucks in most respects, but in the case of medium duty trucks, accidents involving unprotected road users are more common and single accidents less common.
- There is no indication that long vehicle combinations are less safe than regular vehicle combinations.
- 10% of all heavy truck accidents are run of road accidents and 12% are due to the truck colliding with the rear of another vehicle.
- About 20% of all heavy truck accidents occur during night hours.
- 15% to 25% of all road accident fatalities are associated with alcohol impairment. This problem is larger among passenger car drivers than heavy truck drivers. Only 0.5% of all heavy truck drivers involved in accidents with personal injury have an illegal blood alcohol level.

Based on the above, the main priorities for further development are:

- Active safety systems, targeting: headway support, lane keeping support, driver awareness, communication, vehicle stability and visibility support.
- Passive safety systems and driver training, including: seatbelt usage, protection of head and upper body in nearside rollover and frontal collisions, compatibility of front and rear of truck and prevention of runover of unprotected road users.

The Haddon matrix

The work to increase traffic safety will as in the past be guided by the Haddon matrix, which has been developed by William Haddon in 1970 (Haddon 1970). Haddon divides factors affecting accident into attributes of the involved drivers, vehicles and the environment before, during and after an accident.

This model helps to visualize the needed measures to

- Reduce risk exposure and prevent accidents from occurring,
- Reduce the severity of injuries in the vent of a crash and
- Reduce the consequences of injury by post-collision measures.

1. Introduction.

Good quality information about the road traffic environment is the basis of effective and efficient product development. An understanding of road traffic safety performance, including active and passive safety systems, is essential for identifying potential areas of development and improving levels of road traffic safety for trucks.

This report presents an overview of road traffic accident patterns involving heavy trucks in Europe. It tries to recognise the specific causes of such accidents and identify the main priorities for future development. Its findings are based on results and information gained from:

- The in-depth investigation of road traffic accidents.
- The results of research projects – both internal Volvo projects and those undertaken with external partners.
- The research and analysis of external statistics and reports.

Traffic safety work at Volvo is a constant cyclic process of analysing the road traffic environment, setting safety performance related targets for product development, testing and manufacturing Volvo Group trucks and following up the safety performance of Volvo Group truck products in the market. The Volvo Accident Research Team operates on a global stage, investigating and supporting all Volvo Group truck brands.

Volvo Accident Research Team

Founded in 1969, Volvos Accident Research Team has been delivering the expertise that makes Volvo Trucks the safest trucks in the world ever since. Investigations are conducted at accident sites, their aim being to understand the sequence of events that resulted in the crash. Vehicles are investigated in depth to understand their crash performance in non-standard situations. These investigations have resulted in a multitude of safety related improvements and provide invaluable up to date insights, significantly adding to the knowledge gained from standard tests.

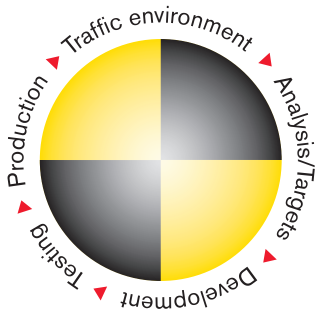


Figure 1: Development of traffic safety is a never-ending process.

Figure 2: An illustration showing the knowledge gained from crash tests (crash facility testing, full scale test of new FH, pendulum testing) and a picture showing the investigation of an accident in the field.

Volvo's Accident Research Team, with its mission to understand the causes and outcomes of accidents, is a major contributor to the Volvo Group's zero vision: zero accidents involving Volvo Group products.

Volvo Group Safety Vision

The Safety Vision points out the direction for our work. The vision of Zero accidents is a way of thinking, a mental image of an optimum future state. We are committed to always strive towards zero accidents with Volvo Group products.

It is a fact that most accidents involve factors that are out of our control. Therefore, cooperation with other concerned stakeholders in society will be needed to reach our vision.

As long as there is a risk of accidents occurring, Volvo will strive for this vision through high quality, innovative products that reduce the frequency of accidents as well as their consequences.

Accident Research Team Mission

As long as there are road traffic accidents, ART will investigate and try to understand causing factors and consequences of road traffic accidents to further improve **Volvo Group products** and strive for the Safety Vision.

ART globally

- identifies road traffic safety related areas of improvements for our products
- delivers knowledge and research results
- provides a link between Research, Advanced Engineering and Product Development

"Zero accidents with Volvo Group products"

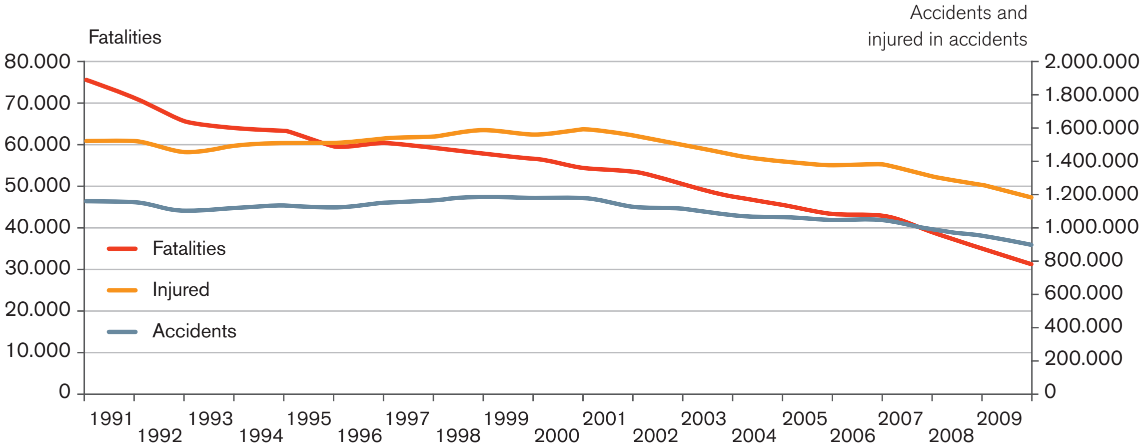
Volvo Group Safety Vision

2. Why do traffic accidents happen?

2.1 Accidents in Europe

2010 saw about 31,100 road traffic fatalities in the EU 27 countries [EC2012], which was a decrease of 11% compared to 2009. This trend has been positive for the last 20 years, thanks to significant improvements in infrastructure and vehicle safety, and not the least in the improved behaviour of road users, such as increased seat belt usage, less speeding and less driving under the influence of intoxicants. The reduction in road traffic fatalities by almost 60% in the EU 27 countries is impressive evidence of the concerted efforts of the automotive industry, politicians, public authorities and consumer organisations. However, further efforts are necessary to continue this reduction in road fatalities.

Table 1: Evolution of accidents, fatalities and injured in EU



In the EU 27 countries from 2005 to 2008 about 1,700,000 people on average were slightly, seriously or fatally injured in all types of traffic accidents each year.

Table 2: Traffic Accident Casualties in EU 27 countries, average values 2005 to 2008.

	All vehicles	Buses >3.5 tonnes		Trucks >3.5 tonnes	
		Number of cases	Proportion of all vehicles	Number of cases	Proportion of all vehicles
Fatalities	43,500	1,200	3%	7,200	17%
Seriously injured	298,400	6,500	2%	21,900	7%
Slightly injured	1,386,100	44,300	3%	83,900	6%
All casualties (∑)	1,728,000	52,000	3%	113,000	7%

2.2 Accident causes

The factors contributing to road traffic accidents are commonly grouped into three categories – causes attributed to the environment, to the vehicle or to the driver.

Analysis shows that in about 30% of cases contributing factors could be attributed to the environment, slippery roads, bad visibility etc. Only 10% of contributing factors are attributed to technical issues related to the vehicles involved; tyre explosions or poor maintenance for example. However, in 90% of cases the major contributing factor is human error. A significant proportion of accidents are caused by a combination of the three categories. For example slow driver reactions during adverse weather conditions (speeding when visibility is low).

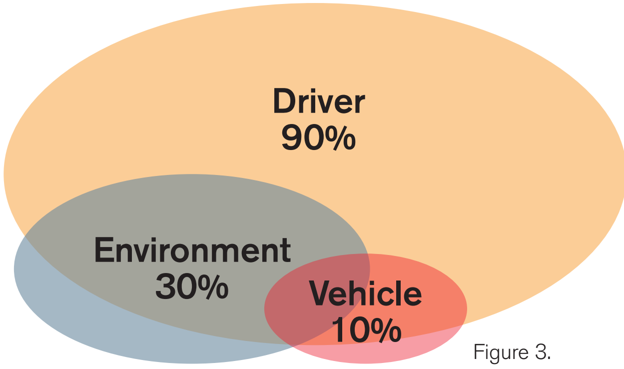


Figure 3.

- Distraction
- Speed
- Risk awareness

- Limited visibility
- Road design
- Weather

- Blind spots
- Tire explosion
- Technical error

2.2.1 Factors related to environment

The traffic environment is usually very complex and requires the constant attention of drivers. Occasionally, environmental conditions such as restricted visibility due to road layout or weather, unexpected changes in road friction (e.g. black ice) cause situations in which the driver can no longer react appropriately.

According to the available statistics from the United Kingdom [DfT 2008], the two most common environmental factors contributing to accidents involving heavy trucks are "Slippery road (due to weather)" and "Road layout (bend, hill, narrow carriageway etc.)".

2.2.2 Vehicle related factors

If the vehicle is found to be the main contributing factor to a road traffic accident, a more detailed classification shows that the issue is related to neglected maintenance, technical faults in subsystems or to conceptual shortcomings.

According to the Department for Transport (DfT 2008), the most common factor when a heavy truck is a contributory factor in an accident is "vehicle blind spots".

In general, three main areas of blind spots can be identified (see also figure 4):

- The sides of the vehicle. Mainly on the passenger side, particularly relevant during lane changes and turning manoeuvres.
- The rear end of the truck or trailer, particularly when reversing, usually at low speed.
- The front of the truck, particularly when starting to move forward or during slow turning manoeuvres.

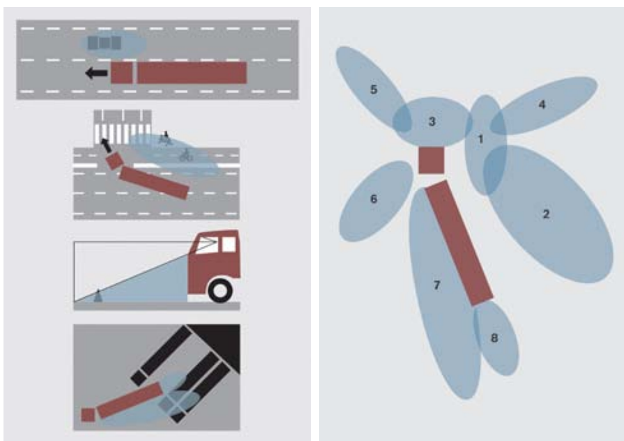


Figure 4. Truck seen from above. The numbered fields, 1–8, show areas that can be difficult for the driver to see.

2.2.3 Human factors

Human error contributes to accidents in 90% of cases. It is either the driver of the truck or the other road user that makes the mistake that contributes to the accident. The main problem areas identified in accidents where the truck driver was the cause of the accident are:

- Inattention (Section 4.5).
- Misjudgement of speed, causing instability and resulting in a rollover in a bend, jackknifing when braking or swinging out on a slippery road.
- Misjudgement of the risk in a particular traffic situation.

The two most common human factors that contribute to accidents involving heavy trucks are “Failure to look properly” and “Failure to judge another road user’s path or speed”.

The fact that such a high proportion of accidents are in whole or in part caused by human error shows the great need for driver support systems that can help drivers to better negotiate today’s complex traffic situations.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3. What do road traffic accidents look like?

3.1 Accident and conflict taxonomy

One approach to understand accident severity is to investigate the relative frequency of accident severity. This concept can be visualised as a pyramid, where fatal accidents constitute the top of the pyramid. These accidents are relatively rare. Traffic conflicts, i.e. interactions between road users that do not result in an accident, form the base of the pyramid. The levels in between consist of accidents resulting in severe and slight injuries, as well as accidents that only result in property damage.

Modern traffic safety research cannot limit itself to the upper layers of the pyramid, instead all levels of traffic interaction must be analysed. Specifically, the analysis of traffic conflict is becoming ever more relevant to future traffic safety work. If we are able to understand how traffic conflicts lead to accidents, we can better tailor modern active safety systems to support drivers in negotiating today's rather complex traffic situations in a safe and efficient way.

However, the most important task is to reduce the number of road traffic fatalities and severe injuries. Passive safety systems, such as the safety cage of truck cabs, form the backbone of in-vehicle safety, protecting the driver and other road users against injury. However, active safety systems are aimed at preventing accidents, and are a precursor to increasing safety. Finally, measures such as driver training and behaviour based safety techniques are the very first step that needs to be addressed when reducing the number of road traffic accidents. These measures aim to reduce the number of traffic conflicts.

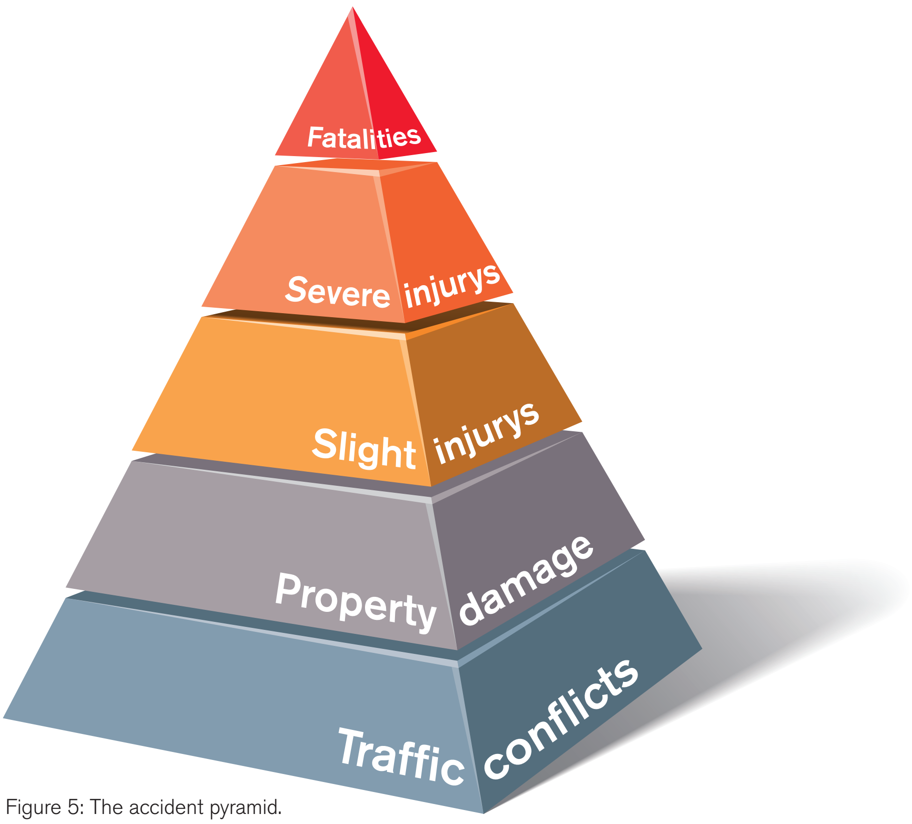


Figure 5: The accident pyramid.

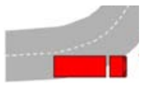
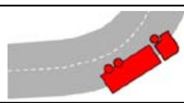
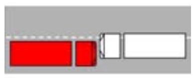
3.2 Type Accidents

On average about 7,200 people are killed and more than 100,000 people are injured in accidents involving heavy trucks (>3.5 tonnes) each year in the European Community (EU 27). In order to classify these accidents, and to describe their frequency, Volvo's Accident Research Team has defined the Type Accidents presented here. This classification scheme reflects potential development areas from the perspective of a truck manufacturer, and helps internal research activities, product planning and product development to focus on areas with the greatest potential benefit. The numbers presented provide a rough overview of the distribution of accidents but are detailed enough to correctly target research and development efforts.

Accident types are updated when new facts come to light. The updated Type Accidents in Figure 6 are based on information from the Lyon and Gothenburg Accident Research teams, as well as from external sources.

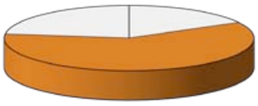
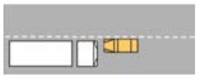
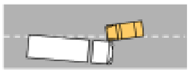
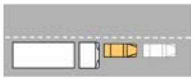
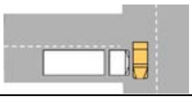
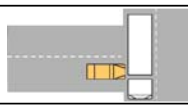
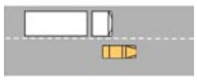
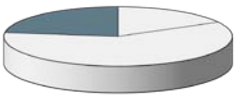
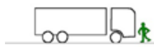
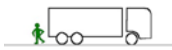
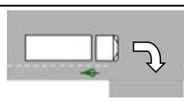
Figure 6: Type Accidents (as defined by Volvo's Accidents Research Team)

Traffic Accidents Involving Heavy Trucks Causing Serious to Fatal Injuries
– WESTERN EUROPÉ

	Road user Group	Type Accident			Frequency	
17%	**A. Truck Occupants 15–20%** 	A1	Truck single Driving off road (with or without rollover)		35%	
		A2	Truck single Roll or yaw instability on road		15%	
		A3	Truck- truck collision, oncoming traffic Front vs. front		10%	
		A4	Truck- truck collision, traffic ahead in same direction Front vs. rear		20%	
		A5	Truck-car collision, all collision types (if they cause injuries also to the truck occupants)		5%	

Traffic Accidents Involving Heavy Trucks Causing Serious to Fatal Injuries

– WESTERN EUROPÉ

	Road user Group	Type Accident			Frequency
60%	**B. Car Occupants 55–65%** 	B1	Truck- car collision, oncoming traffic Truck front vs. car front,		35%
		B2	Truck- car collision, oncoming traffic, Truck side vs. car front/ side (Sideswipe)		10%
		B3	Truck- car collision, oncoming traffic Truck front vs. car side		5%
		B4	Truck- car collision, traffic ahead in same direction Truck front vs. car rear		10%
		B5	Truck- car collision, intersection Truck front vs. car side		15%
		B6	Truck- car collision, traffic ahead in same direction Car front vs. truck rear		10%
		B7	Truck- car collision, intersection Car front vs. truck side		10%
		B8	Truck- car collision, lane change accident Truck side vs. car side		5%
23%	**C. Unprotected road users 15–25%** 	C1	Truck- unprotected collision, truck front vs. unprotected when taking off		5%
		C2	Truck- unprotected collision, truck vs. unprotected when reversing		5%
		C3	Truck- unprotected collision, unprotected that suddenly crosses the direction of truck, e.g at cross road		25%
		C4	Truck- unprotected collision, truck front/side vs. unprotected when turning		20%
		C5	Truck- unprotected collision, truck side vs. unprotected, lane driving		10%
		C6	Truck- unprotected collision, meeting accident		10%
		C7	Truck- unprotected collision, unprotected drives into truck		10%

3.3 Accidents resulting in injury to truck occupants (type A accidents)

Only 15% to 20% of the road users that are seriously injured or killed in accidents involving heavy trucks are truck occupants. The following conclusions can be drawn from the analysis of accident statistics and experience gained in Volvo's own investigations:

- Two main groups of accidents can be identified:
  - About 50% are single vehicle accidents with only one truck involved (types A1 & A2).
  - About 30% are collisions between two trucks (types A3 & A4).
- About 45% of the accidents include a rollover, either in the initial phase, or later as a consequence of specific driving manoeuvres.
- The majority of the accidents causing injury to truck occupants occur in rural areas, on rural roads and on highways, i.e. roads with speed limits of 70 km/h or higher.

Unbelted truck occupants run the risk of being thrown about inside the cab, or even ejected from it. As a result they can suffer serious injuries even in quite minor accidents such as a relatively simple 90 degree rollover.

Together with the seat belt, to protect the occupants in an accident the most important characteristic of a cab is its structural strength. Cabs that pass the Swedish impact test [VVFS 1994:22] have been demonstrated to provide good protection for the occupants in most types of rollover accidents. Volvo continues to design its cabs according to the requirements of the Swedish impact test.

Doors are a commonly underestimated but vitally important part of the overall structure of the cab. It is vital that doors do not open during a collision sequence. If they do, the strength of the cab is effectively reduced, increasing the risk of severe cab deformation and usually resulting in a significantly reduced survival space for the occupants of the vehicle.

Figure 7: The roof hatch in the new FH functions as escape path in case of a vehicle roll over accident.

- Approximately 5% are collisions between a truck and a car. Injuries to truck occupants normally occur in a secondary accident sequence, where the truck runs off the road and/or rolls over.

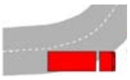
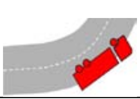
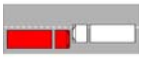
Belted truck occupants are well protected inside the cabs of heavy trucks. In severe collisions (mainly with other heavy trucks, or with roadside obstacles) truck occupants suffer injury as a result of intrusion into the cab or a hard contact with the truck interior as a consequence of major acceleration during the accident sequence. In near side rollovers (driver's side) even belted drivers can suffer injuries as a result of the upper body being subject to impact during contact with the ground.

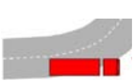
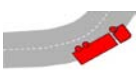
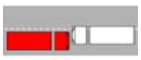
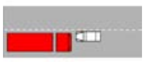
Steering wheel airbags provide additional protection to the truck driver in severe frontal collisions. However, they are – as in passenger cars – regarded as a supplemental restraint system, relying on the safety belt as the primary restraint system. Steering wheel airbags in heavy trucks do not deploy as easily as in passenger cars. The reason for this is that the free area around the driver is greater in a truck than in a car and therefore the driver's chest and head will only come in contact with the steering wheel (and hence, need the airbag) in more severe collisions. Besides, there are many minor (for the truck driver) accident types where it is important that the driver can maintain control over the truck (steer and brake) after the initial collision, and this is not possible if the airbag deploys. One example of such an accident is a frontal collision with a car.

Furthermore, it is important to ensure that the occupants can evacuate the cab as easily as possible following an accident. In trucks where the windscreen is roped in (not bonded), the windscreen often pops out in severe accidents, opening up a large area through which the occupants can often escape. In trucks where the windscreen is bonded, and therefore often stays in position throughout the accident, it is important to ensure that there are other possibilities for the occupants to get out. Following a rollover, when the final position of the truck is on its side, it can be particularly difficult to escape through the doors. The latest generation of the Volvo FH with bonded windshields is provided with an escape route through a roof hatch.

Figure 8 provides a detailed overview of Type A accidents.

Figure 8: Type A Accidents (as defined by Volvo's Accident Research Team)

TYPE ACCIDENT			Relative share	DESCRIPTION	Traffic environment	Light condition
A1	Truck single Driving off road (with or without rollover)		35%	Single vehicle accident, truck leaves road, usually followed by a rollover (+-90 deg or more) or collision with object.	Rural road/highway	60–70% daylight, 5–10% twilight/dawn, 25–35% dark
A2	Truck single Roll or yaw instability on road		15%	Single vehicle accident, roll or yaw instability on road. (out of which 12% yaw and 88% roll) Truck may leave lane / drive off road / roll over as a secondary sequence.	Rollovers occur on highway exits/entries or in curves in urban as well as rural areas.	65–80% daylight, <5% twilight/dawn, 20–25% dark,
A3	Truck- truck collision, oncoming traffic Front vs. front		10%	Collision with other oncoming truck, offset and impact angle varies, main impact normally on the driver side.	Rural roads	65–75% daylight, 5–10% twilight/dawn, 20–25% dark
A4	Truck- truck collision, traffic ahead in same direction Front vs. rear		20%	Collision with rear of other truck or trailer. Offset and impact angle varies widely, main impact normally on the passenger side.	Rural road/highway. First truck driving slower uphill, last in queue or parked.	65–75% daylight, 5–10% twilight/dawn, 20–25% dark
A5	Truck-car collision, oncoming traffic Truck front vs. car		5%	Collision with car. Offset and impact angle varies, most common front vs. front. Truck occupant gets injured usually in a later sequence, e.g. driving off road or rollover.	Rural roads, not separated lanes.	40-50% daylight, 30-40% dawn/twilight, 15–20% dark

TYPE ACCIDENT			Relative share	Speed 1st event	Typical cause	Rollover (in any sequence)	Injury causing event
A1	Truck single Driving off road (with or without rollover)		35%	Medium to high	Driver inattention or fatigue	64%	Risk for ejection of unbelted occupant. Mainly upper body parts, due to intrusion and impact to interior. Far side rollover – belted occupant often uninjured. Near side rollover – contact with ground and risk for partial ejection of upper body parts.
A2	Truck single Roll or yaw instability on road		15%	Medium to high	Too high speed, driver inattention, misjudgement, unstable combination, load displacement, slippery road	95%	Risk for ejection of unbelted occupant. Mainly upper body parts, due to intrusion and impact to interior. Far side rollover – belted occupant often uninjured. Near side rollover – contact with ground and risk for partial ejection of upper body parts.
A3	Truck- truck collision, oncoming traffic Front vs. front		10%	High	Driver inattention, curves with bad visibility, slippery roads	<10%	Sometimes very high retardation, due to engagement of chassis frame, risk for ejection of unbelted truck occupant. Risk for injuries to feet and legs due to cab- intrusion.
A4	Truck- truck collision, traffic ahead in same direction Front vs. rear		20%	Medium to high	Driver inattention, bad visibility, bad conspiquity	<10%	Risk for injuries to feet and legs due to cab- intrusion, which can be severe due to usually a high impact above the frame. Risk for ejection of unbelted truck occupant. Chest and head injuries, head hit the radio shelf. Knee and leg injuries due to intrusion.
A5	Truck-car collision, oncoming traffic Truck front vs. car		5%	High	Most often car in wrong lane.	42%	Truck occupants injured due to later sequence in accident, e.g. driving off road or rolling over.

3.4 Seat belt usage

The structural strength of a vehicle can only protect its occupants while they remain inside the cab. The restraint system that ensures this is chiefly the seat belt. However, this is marginal because even today overall seat belt usage in heavy trucks is far too low. A recent report from the Swedish Transport Administration [Trafikverket 2010] confirms that very few truck occupants killed in traffic accidents were wearing a seat belt (5%), and an in-depth investigation [Strandroth 2009] shows that at least 50% of those unbelted truck occupants who were fatalities would have survived had they been wearing a seat belt. A study conducted by NTF Sweden in 2012 confirms these findings.

In several countries seat belt usage among truck drivers is very good. Within several safety-minded companies seat belt usage is also high. The common denominator for such countries and companies are incentives for using a seat belt, and the strictness and enforcement of legislation. While the use of seatbelts is mandatory in all European countries, and many non-European countries, in most of them the risk of being fined for violating the law is low.

Interviews with drivers reveal various reasons for not wearing seat belts. A common explanation is the relative decrease in driving comfort. Common to these interviewees is a significant difference in body length to the average adult male.

The driving position in a heavy truck differs from that of passenger cars. In addition, the seat suspension system results in large vertical movements, even in normal driving conditions. Today most seat belts for truck drivers are integrated into the seat, i.e. the shoulder belt is also attached to the seat, allowing the seat belt to follow the movement of the seat. However, in most cases it is not possible to adjust the attachment point to suit the height of the driver.

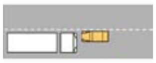
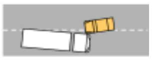
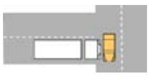
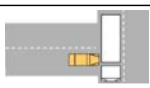
3.5 Accidents resulting in injury to car occupants (type B accidents)

Car occupants are by 55% to 65% the largest proportion of those injured in accidents involving trucks. Based on an analysis of research reports, accident statistics and our own investigations, we can draw the following conclusions:

- About 65% of collisions between trucks and cars involve the front of the truck (accident types B1, B3, B4, B5).
- The most common severe accident is a frontal collision with an oncoming car (type B1). This is mainly due to the high relative speeds and significant difference in the masses involved.
- While the truck driver is usually uninjured or only slight injured, he suffers severe shock.
- In a rear-end impact (type B6), the car sometimes underruns the rear of the truck, either because the rear underrun protection system of the truck or trailer is too weak, or its ground clearance is too high. To some extent trucks or trailers are not fitted with a rear underrun protection system, this results in a high level of intrusion into the car with very severe consequences for its front occupants.
- The most common type of accident between trucks and cars (if accidents resulting in minor injuries are included) in urban areas, is in situations involving lane changing or merging (type B8).
- Car occupants are often injured due to a severe deformation of the car's passenger compartment. The difference in geometry and weight between a heavy truck and a car results in the extreme deformation of the car due to the high collision impact.

Figure 9 provides a detailed overview of Type B accidents.

Figure 9: Details of Type B Accidents (as defined by Volvo's Accidents Research Team) resulting in injury to the occupants of cars.

TYPE ACCIDENT			Relative share	DESCRIPTION	Traffic environment	Relative speed	Typical cause
B1	Truck- car collision, oncoming traffic Truck front vs. car front.		35%	Collision with oncoming car, frontal with different impact angles and offsets.	Rural roads/highways.	High	Most often caused by car:– sliding car– overtaking– inattention of drivers
B2	Truck- car collision, oncomming traffic, Truck side vs. Car front/ side (Sideswipe)		10%	Collision with very small or no overlap on truck front, main deformation on truck is on the side.	Rural roads/highways.	High	Most often caused by car:– sliding car– overtaking– inattention of drivers
B3	Truck- car collision, oncoming traffic Truck front vs. car side		5%	Collision with oncoming car, car slides with side against truck.	Collision on rural roads. Slippery roads common.	High	Caused by sliding car.
B4	Truck- car collision, traffic ahead in same direction Truck front vs. car rear		10%	Collision with rear of passenger car in same direction, with different offsets.	Rural roads/ highways. Traffic ahead in same direction.	Medium	Caused by truck.– inattention - poor visibility– bad car conspicuity
B5	Truck- car collision, intersection Truck front vs. car side		15%	Collision with passenger car at intersection, truck drives into side of car.	Rural and urban roads, at intersections.	Low	Truck or car does not give right of way– inattention– poor visibility– bad conspicuity
B6	Truck- car collision, traffic ahead in same direction Car front vs. truck rear		10%	Collision with passenger car, car drives into rear of truck. 75% of severe collisions have 75-100% overlap.	Truck usually standing or moving at low speed.	Medium	Caused by car:– inattention– poor visibility– bad truck conspicuity
B7	Truck- car collision, intersection Car front vs. truck side		10%	Collision with passenger car at intersection, car drives into side of truck. The average underrun is larger if the car impacts a rigid truck than a tractor and the largest underrun if the car impacts the trailer.	Rural and urban roads, at intersections	Low	Truck or car does not give right of way– inattention– poor visibility– bad conspicuity
B8	Truck- car collision, lane change accident Truck side vs. car side		5%	Collision with passenger car, lane change, merge or cut-in situation. Either truck or car changes lanes.	Highways, ring roads with multiple lanes.	Low	Usually caused by truck.– inattention– limited visibility

3.6 Accidents resulting in injury to unprotected road users

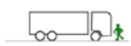
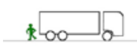
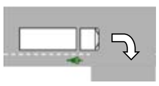
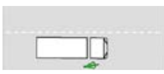
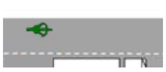
15% to 20% of those killed and seriously injured in accidents involving trucks are unprotected road users, i.e. pedestrians, cyclists and motorcyclists. The relative proportion of unprotected road users in accidents involving trucks is smaller if only trucks with a GCW of more than 12 tonnes are taken into account. In less motorised countries such as Africa or Asia, the proportion is greater.

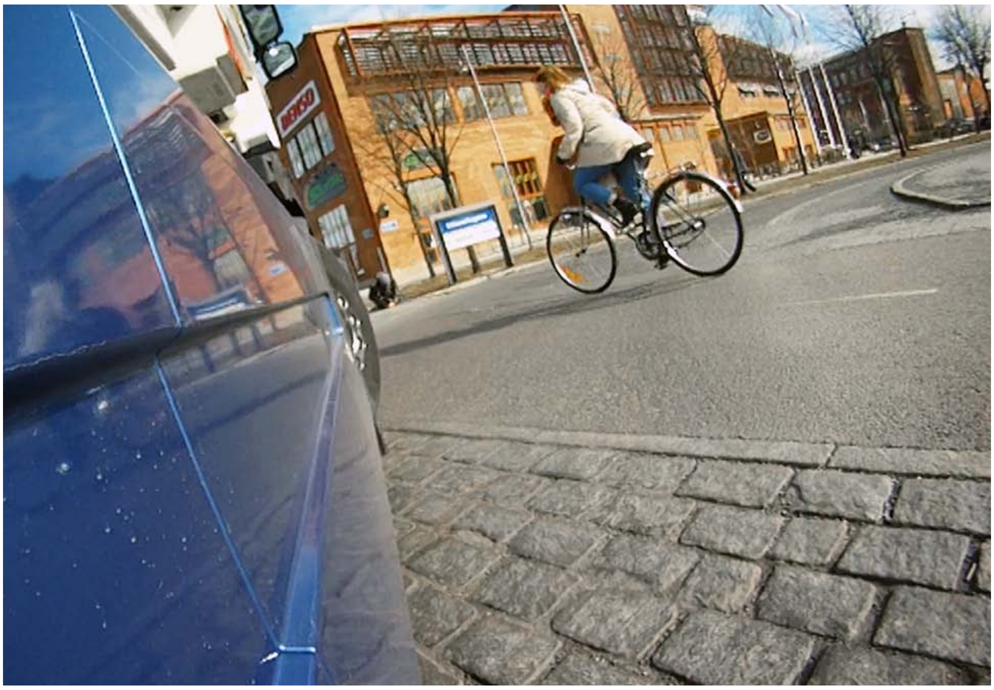
Again, based on an analysis of statistical material, reports and the work of ART, the following conclusions can be drawn:

- The consequences for unprotected road users in a truck collision are usually very severe. Serious injuries are more frequent than slight injuries.
- Truck drivers are usually not physically injured but generally suffer from shock.
- Most accidents between trucks and unprotected road users take place in urban areas, in daylight and where road conditions are good.
- 60% of collisions between trucks and pedestrians or bicycles occur in urban areas.
- The opposite applies to motorcyclists; two thirds of accidents between trucks and motorcycles occur in rural areas.
- Many of the victims in reversing accidents (type C2) are elderly people, who often move slowly and have poor hearing.
- Many of these accidents occur during low speed manoeuvres (C1, C2, C4). Limited visibility is one of the main causes of accidents. It would seem that blind spots around trucks are unfamiliar to other road users (and sometimes to the truck drivers as well).

Descriptions and some details of typical accidents causing injury to unprotected road users are summarised in Figure 10.

Figure 10: Details of accidents resulting in injury to unprotected road users.

TYPE ACCIDENT			Relative share	DESCRIPTION	Traffic environment	Truck speed	Typical cause
C1	Truck- unprotected collision, truck front vs. Unprotected when taking off		5%	Collision with unprotected, frontal part of truck in low speed manoeuvring or starting from stationary e.g. at crossroads or pedestrian crossings. (mostly pedestrians)	Urban areas, daylight.	Low	- Limited visibility; front of cab, right or left side of cab. - Limited driver knowledge of blind spots. - Lack of communication with other road user. - Driver stressed, inattentive or distracted.
C2	Truck- unprotected collision, truck vs. Unprotected when reversing		5%	Collision with unprotected, rear parts of truck/trailer in low speed reversing. Distribution trucks when delivering goods/ garbage collectors. (mostly pedestrians)	Urban areas, daylight. Most often elderly people, but also children	Low	- Limited visibility rear of truck. - External acoustic warning signal not enough. - Working routines not good enough. - Lack of knowledge. - Driver stressed, inattentive or distracted.
C3	Truck- unprotected collision, unprotected that suddenly cross the direction of truck, e.g at cross road		25%	Collision with unprotected at intersection, moderate or high speed. (pedestrians, bicycles, mopeds)	Urban areas. The driver is often surprised and not prepared for the sudden situation.	Low, Medium, High	Other road user: - Lack of judgement. - Misjudgement of speed of truck. Truck: Inattention, limited visibility
C4	Truck- unprotected collision, truck side vs. Unprotected when turning		20%	Collision with unprotected, most often right turn. (pedestrians, bicycles, mopeds)	Urban areas, low speed, narrow city streets, often a parallel bicycle lane or a zebra crossing.	Low	- Limited visibility side of truck. - Lack of knowledge about the blind spots. - Driver stressed, inattentive or distracted
C5	Truck- unprotected collision, truck side vs. Unprotected, lane driving		10%	Collision with unprotected. Lane driving, e.g. lane change, merge, cut in, not keep in lane. (bicycles, mopeds, motorcycles)	Urban areas.	Medium	- Lack of visibility- Driver stressed, inattentive or distracted.
C6	Truck- unprotected collision, meeting accident		10%	Collision with oncoming unprotected road user - mainly motorcycle or moped.	Rural areas	Low, Medium, High	- Truck or unprotected leaves lane - Truck misjudges distance to unprotected when making turn
C7	Truck- unprotected collision, Unprotected drives into truck		10%	Collision where an unprotected road user drives into the truck - either from the rear or from the side.	Urban and rural areas, often at intersections.	Low	- Lack of attention from unprotected - Bad conspicuity of truck

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4. The analysis of specific accident types.

4.1 Medium duty trucks as compared to heavy duty trucks

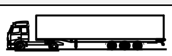
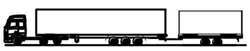
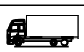
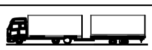
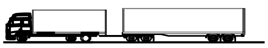
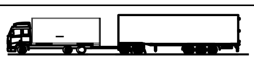
Based on STRADA data (Swedish Traffic Accident Data Acquisition), a comparison of accident patterns involving heavy duty trucks and medium duty trucks has been carried out [ER-614170]. Through chassis numbers, STRADA provides information about the make and model of the vehicles involved. The analysis was limited to FH and FM vehicles representing the heavy duty segment, and FE vehicles representing the medium duty segment. FE vehicles were not represented in the sample, probably as a result of their quite recent introduction to the market in relation to the period of the sample (2003 to 2007).

In most respects the pattern of accidents involving medium and heavy duty vehicles is similar. However, some there are some significant differences which can be attributed to the different transport applications of heavy and medium duty trucks and the differences in traffic environment that result from this.

The main differences in the sample were:

- Unprotected road users account for 22% of those killed and seriously injured in accidents involving medium duty trucks and only 13% in accidents involving heavy duty trucks.
- More than 70% of accidents involving heavy duty trucks occur in rural areas, whereas for medium duty trucks the ratio between rural and urban areas is equal.
- More than 55% of injuries to the occupants of heavy duty trucks are the result of single accidents. For the medium duty section of the sample this figure is less than 35%.
- Almost 30% of injuries to truck occupants in accidents involving medium duty trucks are the result of collisions with cars. For heavy duty trucks this figure is much lower (under 15%).
- Frontal collisions cause over 30% of injuries to car occupants in accidents involving heavy duty trucks, and less than 20% in accidents involving medium duty trucks.
- No type C1 accident was identified for medium duty trucks (10% for heavy duty trucks).
- Reversing accidents (unprotected road users) are much more frequent for medium duty trucks (more than 10%) than for heavy duty trucks (2% to 3%).

Figure 11: Truck vehicle combinations in European countries and their respective lengths.

Truck combination		Typical length
	Tractor + semitrailer	16.5 m
	Tractor + semitrailer + centre axle trailer	25.25 m
	Tractor + B-double	25.25 m
	Rigid	Varies
	Rigid + centre axle trailer	18.75 m
	Rigid + drawbar trailer	24 m
	Rigid + dolly + semitrailer	25.25 m

4.2 European modular system

Sweden and Finland allow vehicle combinations of 25.25 m with a maximum weight of 60 tonnes, provided they are standard vehicles (trucks and trailers) compliant with EU standards.

In the rest of Europe, the maximum permitted truck combination length is 18.75 m for rigid trucks with trailers. The most common truck combination in Europe is a tractor with one semi-trailer, with a typical total vehicle length of 16.5 m. In Sweden and Finland, both 24 m (typically a rigid truck with a drawbar trailer) and 25.25 m combinations (see Figure 9 for different combinations) are seen on the roads. Both 24 m and 25.25 m combinations are considered to be long combinations in the context presented here. Results are based on an analysis of STRADA data with a sample covering the period 2003 to 2009 [Wrige 2010].

There is generally no indication that long vehicle combinations are less safe than regular vehicle combinations. However, the dynamics of long vehicle combinations are more complex than those of standard combinations, which emphasises the importance of even load distribution.

In most respects the general pattern of accidents is similar for long vehicle combinations and regular vehicle combinations. However, there are some differences in accident distribution, most of which are probably attributable to the different transport applications and traffic environments in which these combinations usually operate.

Accidents involving regular vehicle combinations are equally frequent in urban and rural areas, while accidents involving long vehicle combinations predominantly occur in rural areas (75%).

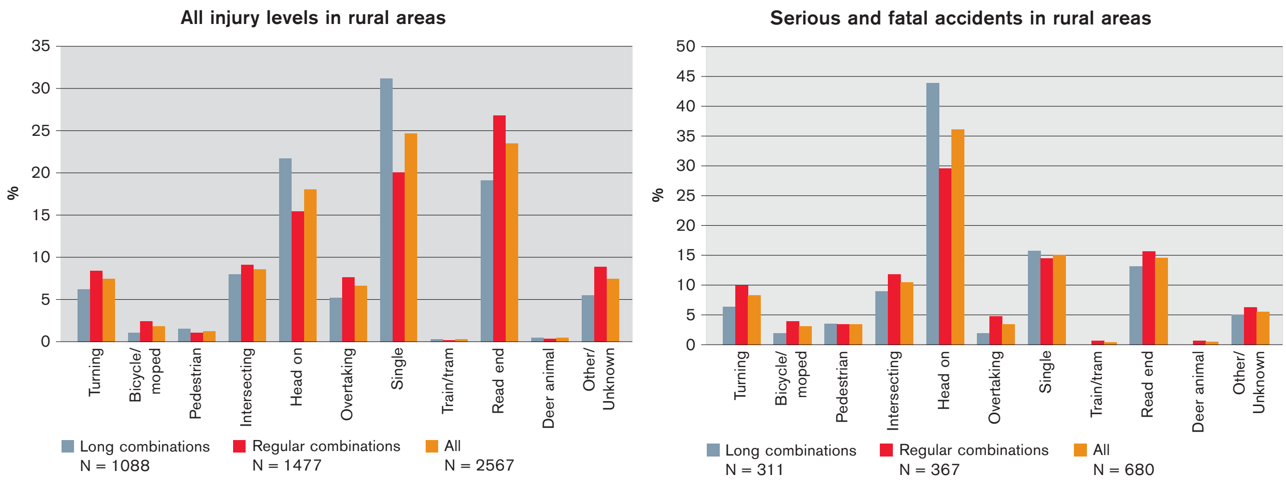
Head on collisions constitute 22% of accidents involving long combinations compared to 15% for regular combinations (rural areas, all levels of injury). This is probably because long vehicle combinations are largely driven on rural highways.

Single accidents constitute 31% of accidents involving long combinations, compared to 20% for regular combinations (rural areas, all levels of injury). This is probably because long vehicle combinations are driven longer distances on average than regular vehicle combinations, and are also driven more at night.

Read-end collisions constitute 19% of accidents involving long combinations, compared to 27% for regular combinations (rural areas, all levels of injury).

Figure 12 shows the distribution of accident types for regular and long vehicle combinations.

Figure 12: Accident type distribution for long and regular vehicle combinations, classification of accident type according to the Swedish Road Administration.

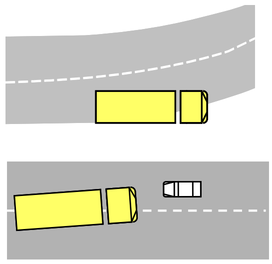


4.3 Lane departure accidents

A lane departure accident occurs when a vehicle leaves its own lane and drifts either into oncoming traffic, or leaves the road.

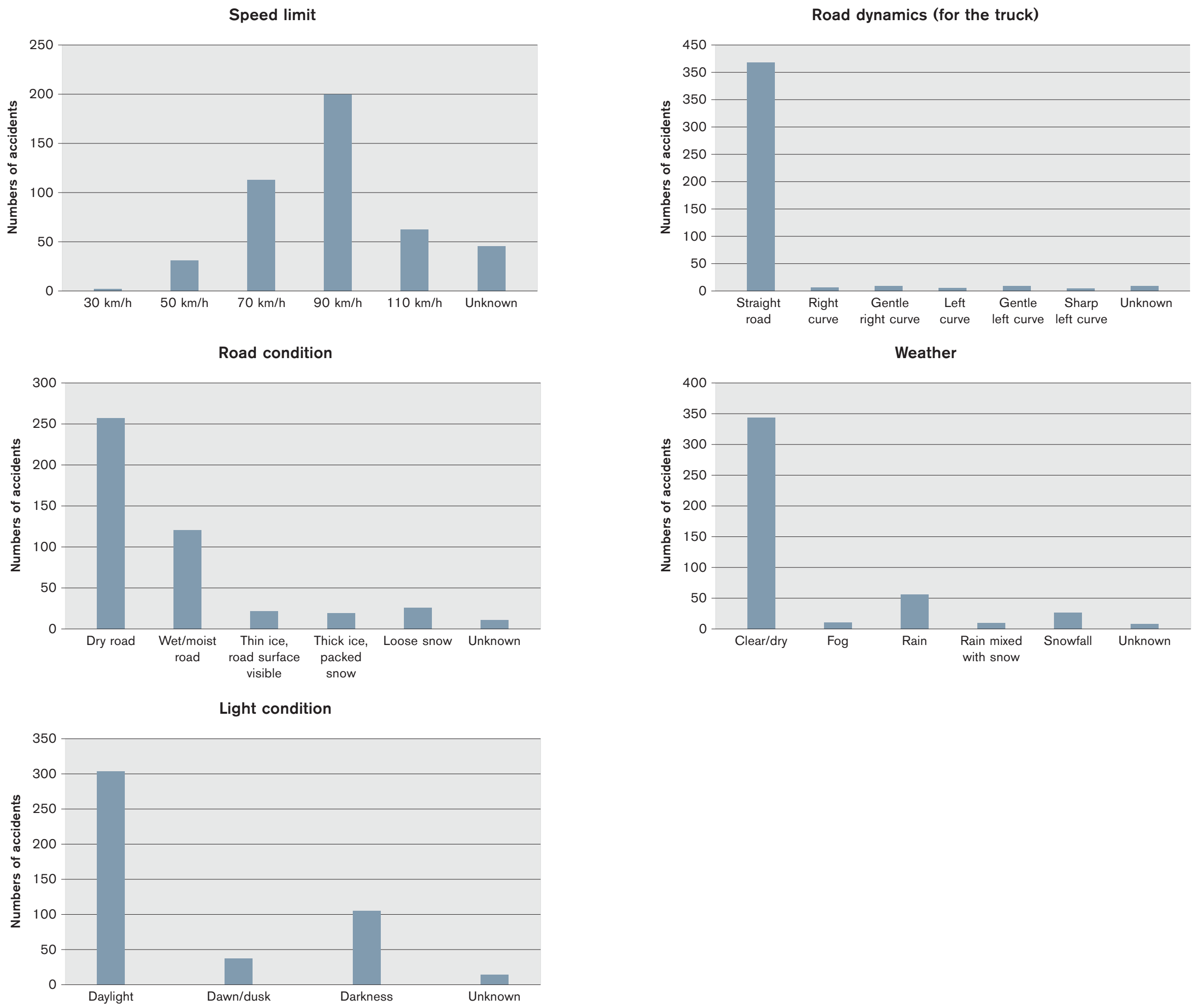
An analysis of STRADA data, focusing on vehicles with a total weight of more than 3.5 tonnes and the period 2003 to 2008, shows that:

- Of the total accident sample, road departure accidents constitute 10% of all accidents involving trucks, and 7% of all accident with severe injuries or fatalities.
- Taking only accidents where the occupants of heavy trucks are seriously or fatally injured, lane departure accidents account for about 40%.
- Road conditions are indicated in about 10% of cases where lane markings may not have been visible (loose snow or thick ice/packed snow).
- In 96% of all lane departure accidents involving vehicles with a weight of more than 3.5 tones, trucks with a weight of about 12 tonnes are involved, and 88% involve a truck that is heavier than 18 tonnes.
- In lane departure accidents involving trucks heavier than 12 tonnes:
  - 80% are rigid trucks and 20% tractors, closely reflecting the population of these vehicle types on the road (23% tractors, 77% rigid trucks).
  - 21% of the trucks are 2 axle combinations, 73% have 3 axles, and 6% have more than 3 axles.
  - In 83% of cases, the speed limit was 70 km/h or greater.
- The most common lane departure accidents occur in conditions of good visibility on a straight road and in good weather and road conditions.



Lane departure accidents.

Figure 13: The characteristics of lane departure accidents, based on an analysis of STRADA data.



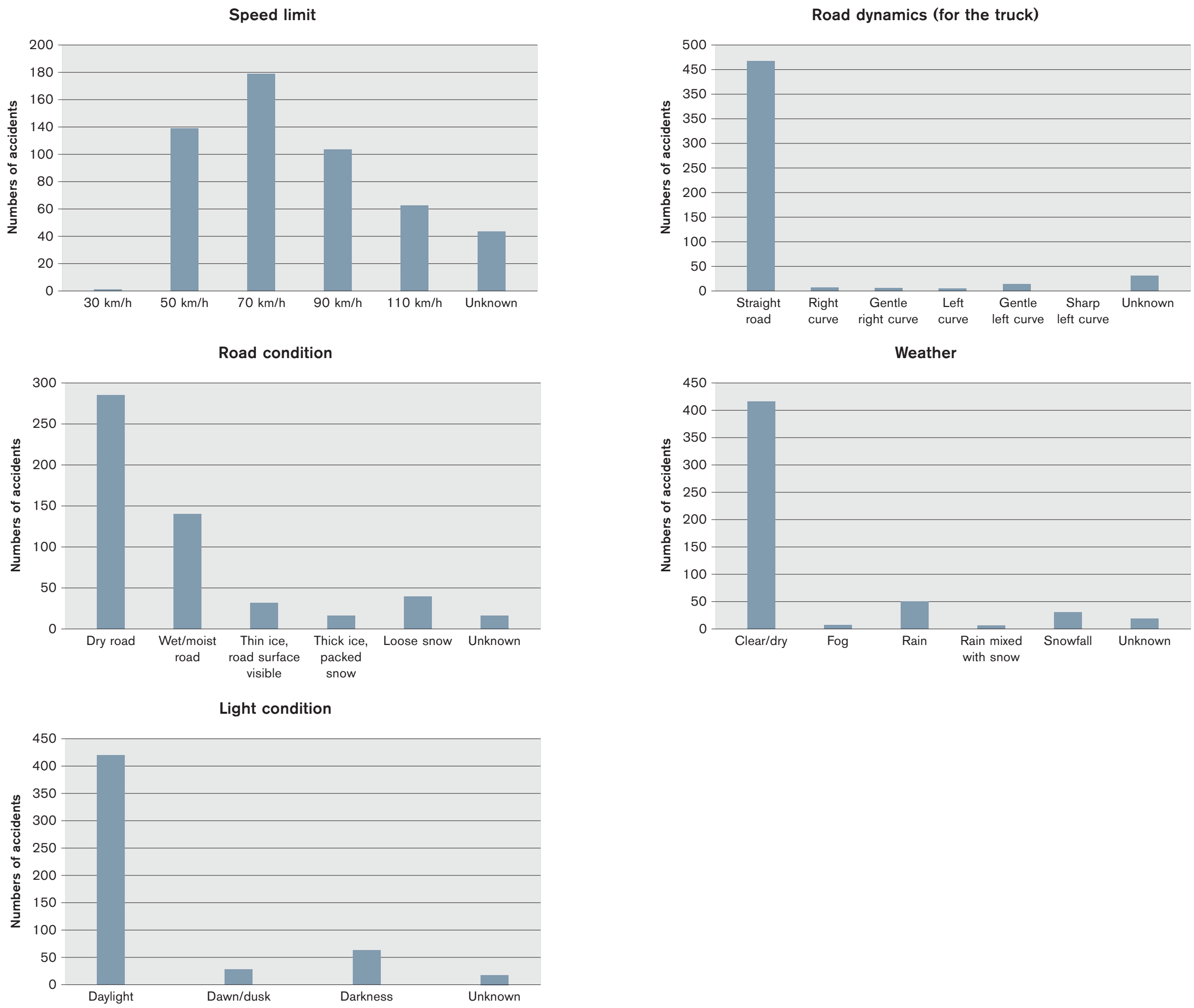
4.4 Rear-end collisions

A rear-end collision is an accident where a vehicle hits the rear of another vehicle, which may be travelling at a lower speed, parked or turning off the road.

An analysis of STRADA data, focusing on the same sample as in Section 6.3 (vehicles with a total weight of more than 3.5 tonnes and the period 2003 to 2008), show that:

- 12% of all accidents involving heavy trucks and 7% of severe accidents involving heavy trucks are due to the truck colliding with rear of another vehicle.
- 91% of all rear-end collisions involve a truck with a weight above 12 tonnes, in 81% of those cases the truck is heavier than 18 tonnes.
- In rear-end collisions involving trucks with a weight above 12 tonnes
  - 82% are rigid trucks, 18% tractors.
  - 27% are vehicles with 2 axles, 68% with 3 axles, and 5% with more than 3 axles.
- The most common rear-end collision is a collision where the truck drives into the back of a car.
- Most rear-end collisions occur in conditions of good visibility on a straight road in daylight and in good weather conditions.
- More than half of these accidents happen on roads with a speed limit of either 50 km/h or 70 km/h.

Figure 14: Characteristics of rear-end collisions based on an analysis of STRADA data.



4.5 Accidents related to inattention

Traffic situations often change rapidly. To handle these rapid changes and anticipate them as early as possible it is important that the driver is paying full attention to his driving.

If the driver's concentration is diminished there is a greater risk of incidents and accidents.

It is difficult to know exactly how many accidents are caused by inattention, but researchers agree that it is a common cause of accidents and one that has increased over recent years.

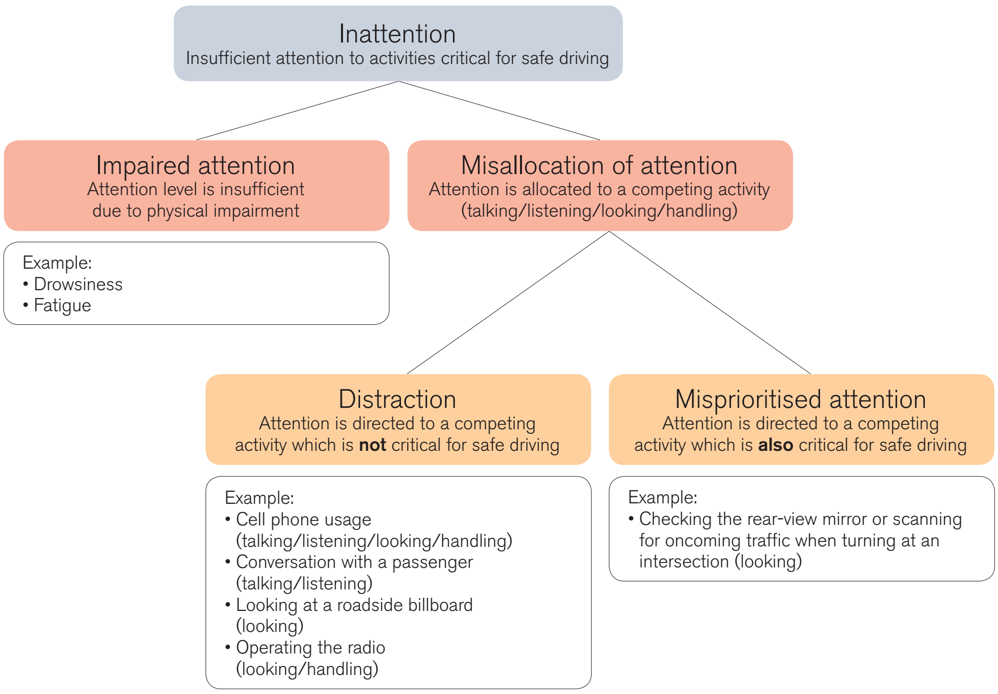
Inattention can be divided into two main categories; diversion of attention and impaired attention. Diversion of attention is when the driver's overall attention level is normal, but focused on something other than driving. Impaired attention is when the driver's overall attention is inadequate due to physiological impairment.

Intoxication (by drugs or alcohol) may lead to both the diversion of attention (due to increased distractibility or impaired judgment when under the influence of alcohol) and impaired attention (due to drug-induced drowsiness).

Even if the outcome of an accident is often the same regardless of the type of inattention that caused the accident, the measures to prevent accidents can differ fundamentally depending on the type of inattention.

Figure 15 gives an overview of the different inattention categories and also gives examples of situations when they can occur.

Figure 15: The taxonomy of inattention.



Early on, Volvo took interest in drowsiness and fatigue, and in recent years there has been an increased focus in general on accidents caused by these factors. It is often difficult to know for sure that an accident was caused by drowsiness, simply because this is only possible by interviewing the driver and interpreting his statements. Understandably drivers rarely admit to being fatigued as this would be considered reckless driving and could have legal consequences. Other explanations, such as an animal suddenly crossing the road or a sneezing attack, are regularly offered and are hard to prove or disprove.

External studies indicate that 10% to 20% of all single accidents are caused by fatigue [Anlund et al 2004]. Swedish accident statistics from 1994 to 2001 indicate a proportion of fatigue related accidents of 3%.

However, though not always present, typical indicators of a single accident caused by drowsiness are:

- No brake or skid marks on the road and/or hard or verge.
- No signs of braking.
- An acute angle between the road and the trajectory.
- The site of the accident is often at the end of a straight, just at the beginning of the following bend.
- A rural road.
- The time of the accident is often close to the end of a driving shift, close to the final destination or during the early hours of the morning. The risk of a single vehicle accident is 13 times higher between 4 and 5 in the morning than during daytime [Åkerstedt et al, 2000].

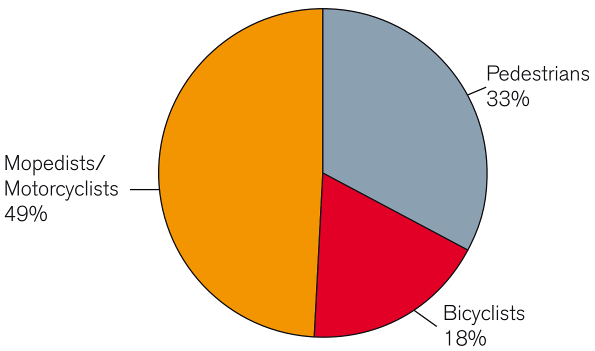
Figure 16: A typical drowsiness related accident, (Type A1) driving off the road in a bend. In this case, the driver confirmed that he had fallen asleep. The driver was only slightly injured but suffered serious shock.

4.6 Accidents involving unprotected road users

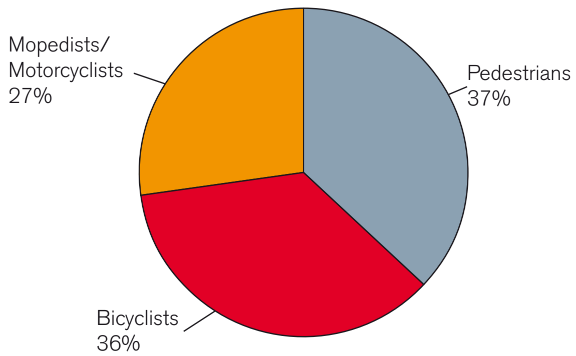
Unprotected road users consist mainly of three types of road user: pedestrians, cyclists and those on moped/ scooters and motorcycles. Distribution between these three groups varies significantly between countries, depending on the infrastructure and culture of each country. In countries like Denmark and the Netherlands cyclists naturally constitute a quite large proportion of unprotected road users injured in accidents involving heavy trucks.

Figure 17 shows the distribution in France and Sweden.

Figure 17: Proportion of unprotected road users seriously injured or killed in accidents involving heavy trucks..



Killed and seriously injured, France 2009



Killed and seriously injured, Sweden 2003–2008

An analysis of all fatal accidents involving heavy trucks and unprotected road users in France in 2006 showed that the fatality was often the result of the unprotected road user being run over by one or more of the wheels of the truck [Desfontaine et al, 2008].

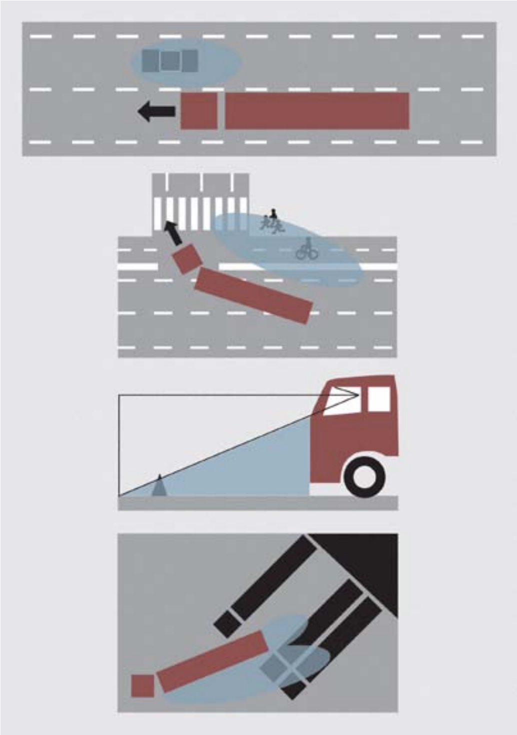
In fatal accidents involving pedestrians older people are overrepresented. More than half of the pedestrians killed in accidents involving heavy trucks in France in 2006 were older than 60.

An in-depth analysis of accidents involving heavy trucks and unprotected road users in urban areas showed that:

- The front of the truck was the impact zone in 62% of the collisions.
- In 81% of the accidents the truck was moving forwards.
- 51% of the trucks involved were rigid trucks, 55% were goods distribution trucks.
- In 44% of collisions with pedestrians, the pedestrian was on the roadway.
- Nearly 24% of injured pedestrians crossed the road-way outside a pedestrian crossing but within 50 m of a pedestrian crossing.
- In 48% of accidents the distance between the final position of the pedestrian and his impact position was less than 5 m, indicating a low impact speed.
- In 60% of cases the pedestrian did not have the right of way.

Table 3: Proportion of vulnerable road users run over in accidents involving heavy trucks.

	Run over
Pedestrian	75%
Bicycle	79%
Moped/Scooter	62%
Motorcycle	35%
Total	67%

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5. What can be done to improve traffic safety?

5.1 Active Safety and Driver Support

In 90% of all cases, human error is a contributing factor to accidents. Driver support is therefore essential for improving traffic safety. While support can be offered by active safety systems, behaviour based safety and driver education are major factors that can contribute to fewer road traffic fatalities globally.

As a result, active safety prioritises support for the driver in complex traffic situations (helps the driver avoid errors due to inattention, the misjudgement of speed or risk).

It should be a priority to develop the following support systems:

- Headway support, ensuring that drivers maintain a safe distance to vehicles ahead. The main accident type targeted is rear-end collisions. It is also important to detect stationary objects.
- Lane keeping support, ensuring that drivers keep the vehicle in the correct lane or on the road.
- Driver awareness support, maintaining the driver's attention levels (despite drowsiness or distraction).
- Communication support, drivers must be capable of conducting a certain amount of communication while driving in a safe manner (keeping their eyes on the road and hands on the steering wheel).
- Visibility support, ensuring that the driver detects obstacles in the blind areas around the vehicle combination. Limited visibility is the cause of many severe accidents as well as many minor accidents and incidents.

Driver education that includes an awareness of risk situations and active driving also has the potential to reduce the risk of most types of accident.

5.2 Passive Safety

Even with excellent active safety systems accidents will continue to happen. It is of vital importance that efforts continue to reduce the injury of road users involved in accidents. Combining active and passive safety systems may also increase the benefits of each type of system, possibly leading to the development of integrated safety systems.

5.2.1 Truck occupants

Low safety belt usage is still an issue and an increase would significantly reduce fatalities among truck occupants.

Good protection for the head and upper body in roll-over accidents would help to prevent injury arising from impact between parts of the body and the ground. There is therefore a need for rollover protection, particularly for nearside rollovers. The same applies to frontal collisions where good head and chest protection would reduce injuries and fatalities.

5.2.2 Car occupants

Better compatibility between the front and rear-ends of trucks and cars will reduce injuries to car occupants. Further work is necessary to align the structure of trucks to the geometry of cars and to absorb as much energy as possible in both frontal and rear-end collisions. The most severe type of accident between trucks and cars is a frontal collision. In this situation the relative speed on impact is very high, and even if the absorption of energy at the front of the truck front is increased significantly, the risk of injury to car occupants will remain high.

5.2.3 Unprotected road users

Accidents where unprotected road users are run over are usually fatal. Measures to prevent these accidents, either through structures to prevent the vulnerable road user ending up under the wheels of the truck, or systems that will detect a vulnerable road user and prevent the truck impacting them, need to be developed and will result in great benefits.

5.3 Attitudes and behaviours

A number of traffic safety issues can probably never be solved by product development. The most obvious example is seat belt usage among truck drivers. Working actively with information, driver education and other ways av changing behaviours will therefore be a vital part in the ongoing work to improve traffic safety.


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6. Sources and references.

Haddon W Jr. (1970). "On the escape of tigers: an ecologic note". Am J Public Health Nations Health 60 (12): 2229–34. www.ncbi.nlm.nih.gov/pmc/articles/PMC1349282/

[EC2012] European Commission 2012; Road Safety Evolution in the EU, http://ec.europa.eu/transport/road_safety/specialist/statistics/index_en.htm, accessed on 28.10.2012

[DfT 2008] Contributory Factors Statistics 2008, Department for Transport, UK http://www.dft.gov.uk/pgr/statistics/datatablespublications/accidents/

[Trafikverket 2010] Bilbältesanvändning i dödsolyckor – en analys av vägtrafikolyckor i Sverige 2005-01-01 till 2009-06-30. Publikationsnummer 2010:70, Trafikverket, 2010

[Strandroth 2009] In-depth analysis of accidents involving heavy goods vehicles – Effects of measures promoting safe heavy goods traffic, J. Strandroth, Publication 2009:2, Swedish Road Administration, 2009

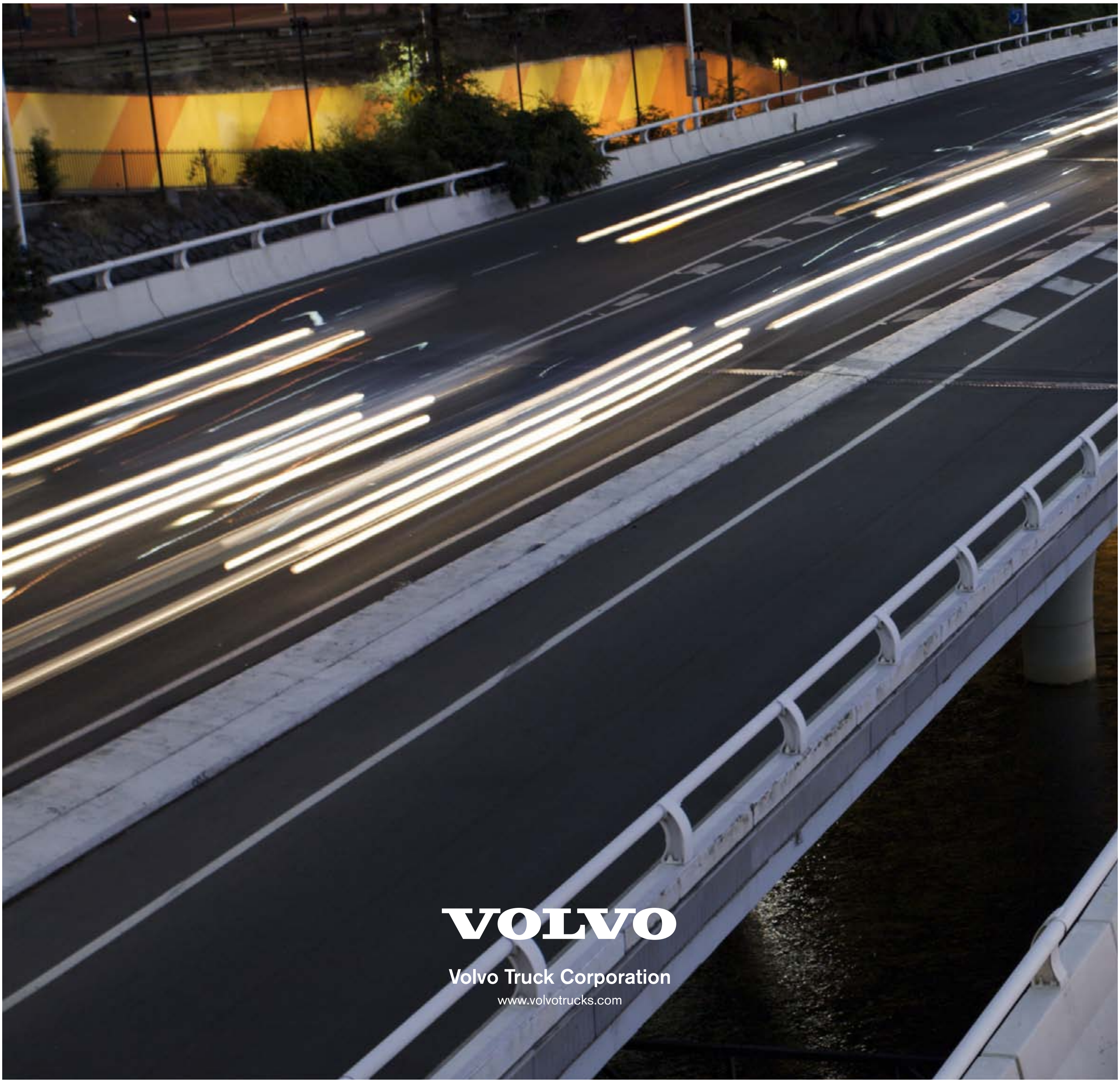
[ER-614170] Wrige, Anna; Engineering Report ER-614170 Accident types – comparison FH/FM trucks and FL/FE trucks, Gothenburg 2009

[Wrige 2010] Wrige, Anna; Long vehicle combinations – accident analysis. Gothenburg 2010.

[Anlund et al 2004] Min trötta resa. VTI report 498-2004, Anlund, Kecklund and Peters.

[Åkerstedt et al, 2000] Trötthet och trafiksäkerhet- en översikt av kunskapsläget, T Åkerstedt, G Kecklund, Publikation 2000:74, Karolinska Institutet + Presentation, M Gillberg, Institutionen för Folkhälsovetenskap, Karolinska Institutet

[Desfontaines et al, 2008] Synthesis report relating to the analysis of several accident data bases, Task 1: Accidentology, PRUDENT – VI Project, H. Desfontaines, P. Beillas, 2008



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