Volvo Trucks. Driving Progress

VOLVO TRUCKS SAFETY REPORT 2017

Volvo Trucks Accident Research Team

There is only one acceptable number of accidents in traffic. Zero.

Foreword

Every year about 1,2 million people are killed in road traffic accidents worldwide. This is a well-known fact. If we want to change this figure we need to understand why traffic accidents occur.

Volvo Trucks Accident Research Team has studied and analysed more than 1,700 accidents involving trucks since 1969. This work is ongoing and the information gained is used as a basis for the development of our products to become as safe as possible.

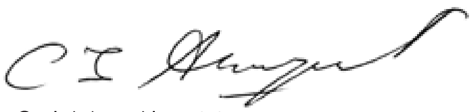
As traffic accidents are a global concern we want to share our findings with society. We are aware that our products are part of the concern but we are also confident that we are part of the solution.

This second public report combines thorough review of research up until today with our knowledge and experience. It provides input for further understanding of accidents involving trucks.

ART's hope is that this publication will be used by authorities and academia. We believe that sharing knowledge and further broaden the understanding of accident causation with trucks is one of the keys to a safer traffic environment.

Together we can reduce the risk of traffic related accidents.

Gothenburg, 3 May 2017



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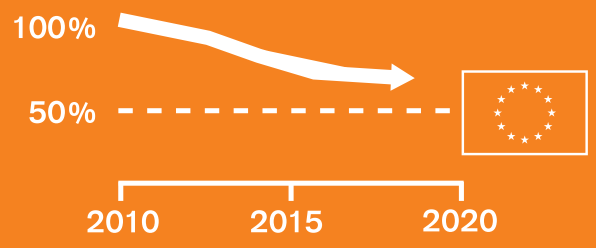
Executive Summary

Today there are approximately
26,000
road fatalities in the EU each year.

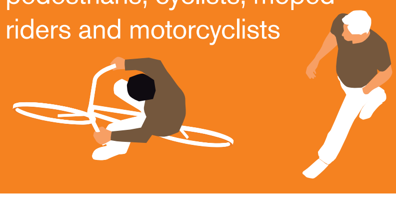
15%
of these are HGV-related.



The EU target is to reduce traffic fatalites by 50% between 2010 and 2020. The pace of reduction has stagnated and the target is currently in jeopardy.

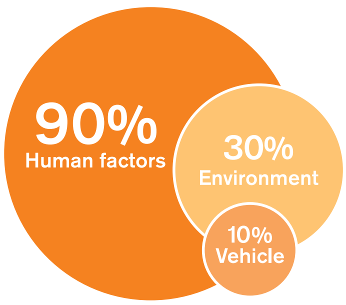
HGV – heavy goods vehicle

VRU – vulnerable road users
pedestrians, cyclists, moped riders and motorcyclists



Research since 1969

Volvo Trucks Accident Research Team (ART) has investigated truck accidents since 1969. This knowledge in combination with deep understanding of European accident statistics is important in the development of safer traffic solutions.



Accident-causing factors

Accident scenarios are complex – an accident seldom has one single cause.

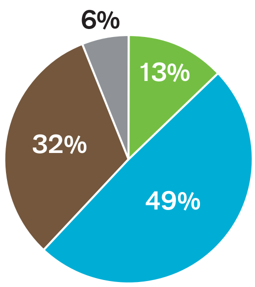
The interacting factors that lead up to an accident can be grouped into three categories: Human factors, Environment and Vehicle.

Smartphones steal attention

17% of all pedestrians use their smartphones while crossing roads and fail to pay attention to the traffic situation.

HGV-related fatalities

The number of fatalities in HGV accidents totalled 3,863 in 2014.



499 fatalities	Accidents causing fatalities to heavy goods vehicle occupants
1,898 fatalities	Accidents causing fatalities to car occupants
1,230 fatalities	Accidents causing fatalities to vulnerable road users
236 fatalities	Other HGV-related fatalities

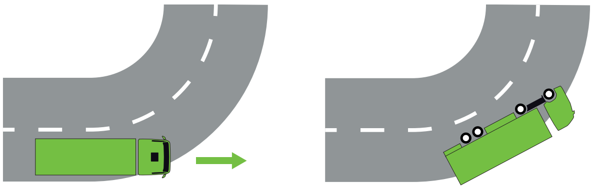
Of the 1,230 VRU fatalities:
53% involved pedestrians
22% involved cyclists
25% involved moped riders or motorcyclists

50%
of non-belted HGV occupants would have survived if their seat belts had been properly used.

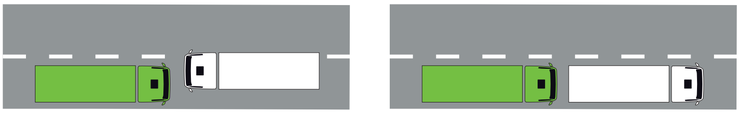
Although drink-driving is a concern and remains a priority, research shows that it is a bigger challenge with car drivers than with HGV-drivers.

ART's official statistics

Type A accidents — Accidents causing fatalities or severe injuries to heavy goods vehicle occupants — 10-20%



55–60% single accidents



20–40% collision with another HGV

weather conditions	72%	17%	11%
accident locality	25%	75%	
time of day	72%	27%	1%

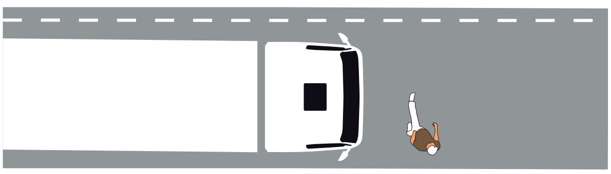
Type B accidents — Accidents causing fatalities or severe injuries to car occupants — 50-55%

35–45% oncoming accidents

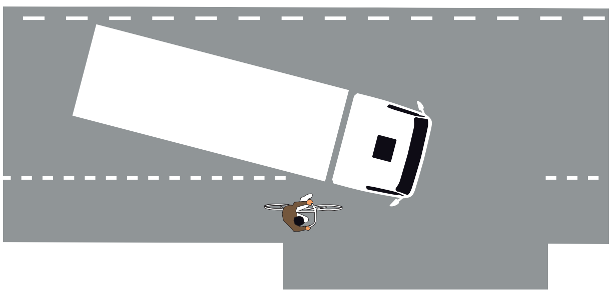
15–25% intersection accidents

weather conditions	74%	17%	9%
accident locality	30%	60%	10%
time of day	84%	15%	1%

Type C accidents — Accidents causing fatalities or severe injuries to vulnerable road users — 30-35%



30% crossing accidents



20% involve an HGV making a turn

weather conditions	79%	8%	13%
accident locality	50%	45%	5%
time of day	85%	15%	

Prioritised areas for improved traffic safety

- **Increase seat belt usage.**
- **Secure driver awareness as well as direct and indirect visibility from the cab.**
- **Enable driver coaching services that provide direct feedback to the driver.**
- **Develop active safety systems, for example:**
  - Advanced Emergency Braking System (AEBS). The currently legislated AEBS is designed to mitigate or avoid rear-end accidents. In the future it would be beneficial to include scenarios involving VRUs, for example crossing accidents.
  - Detection systems that identify VRUs in close proximity to the HGV.
  - Cooperative Intelligent Traffic Systems (C-ITS). Enable communication between vehicles and infrastructure.

Contents

Volvo Trucks aims to decrease the number of accidents involving HGVs until it reaches zero. This report is one way to drive this process.

1. Introduction

Volvo Trucks Accident Research Team regularly compiles the European Accident Research and Safety Report. This report provides a thorough overview of traffic accidents involving heavy trucks with a gross weight above 3.5 tonnes (Heavy Goods Vehicles or HGVs).

The report summarises statistics from EU countries and discusses types and causes of accidents involving HGVs of all makes. With this report, Volvo Trucks Accident Research Team aims to highlight areas of improvement and set the agenda for future development in the area of accident reduction and prevention.

Since the previous report from 2013, there has been an increase in the proportion of accidents involving vulnerable road users such as pedestrians and cyclists (VRUs). Therefore, this issue of Volvo Trucks Safety Report has extra focus on accidents between HGVs and VRUs.

Volvo Trucks' hope is that this report and its findings will provide increased understanding of traffic safety and guidance in prioritising future development. Sharing these insights can improve traffic safety all over the world. Because it is not only about HGV manufacturers and vehicle technology; it is also about policies and regulations, education and awareness, research and cooperation.

To reach zero accidents, we all need to work together.

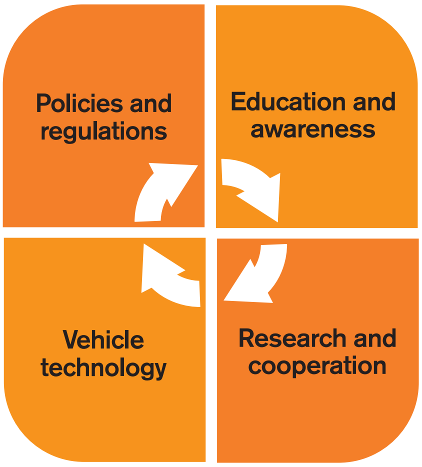


Figure 1: Accident prevention collaboration

Volvo Trucks Accident Research Team

Since the start of Volvo Trucks Accident Research Team (ART) in 1969, it has been one of the main driving forces behind increased traffic safety at Volvo Trucks. ART is also a main actor in the drive to reach Volvo Trucks vision: No product from Volvo Trucks should be involved in an accident. ART's findings and analyses are not only important components in taking Volvo Trucks to a leading position with regards to safety – sharing these insights can contribute to safer traffic for everyone.

VRU – vulnerable road users
pedestrians, cyclists, moped riders and motorcyclists

HGV – heavy goods vehicle

In-depth knowledge about the traffic environment is crucial for effective product development. To improve traffic safety involving HGVs, it is essential to understand how the current products perform in the field. ART investigates accidents involving HGVs by the means of safety impact assessments and forensic engineering. To understand the causes of accidents, ART looks at normal driving and driver behaviour, situations that cause conflicts in traffic, and pre-crash scenarios. When crashes occur, ART analyses the crash scenario and conducts post-crash investigations, both on-site and off-site.

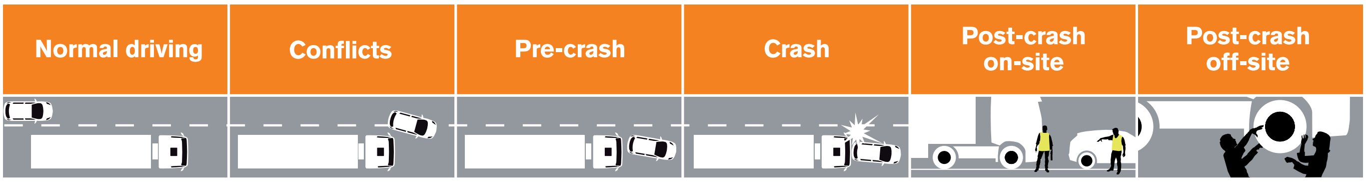


Figure 2: Methods for determining accident causes

Furthermore, ART analyses statistics from national and European databases. An understanding of the full picture is important to set the correct safety requirements for new products. It is equally important to make sure that the requirements are met – both during and after development.

ART is an important player in the never-ending process of traffic safety: traffic environment analysis, development and testing of products, production, and then back to safety analysis, new development, new products and so on.

Figure 3: Development of traffic safety is a never-ending process

TYPE ACCIDENTS

Based on ART's research, Volvo Trucks has classified accidents involving Heavy Goods Vehicles into three categories:

Type A accidents	**Accidents causing fatalities or severe injuries to heavy goods vehicle occupants**
Type B accidents	**Accidents causing fatalities or severe injuries to car occupants**
Type C accidents	**Accidents causing fatalities or severe injuries to vulnerable road users**

Sources

All findings regarding ART´s type accidents are based on analyses of official data and ART's own findings and experience.

The contents of this report are based on results and knowledge gained from:

- Analyses of external statistics and reports
- Participation in various research projects together with external parties
- Own investigations of traffic accidents

The information in this report covers all HGV brands (i.e. not only Volvo-branded HGVs) and the available data has been compiled with the purpose to represent Europe as a whole.

External Databases and Reports

To compile this document, ART has extracted data from various reports and databases. The most important sources are:

ETSC (non-profit organisation that monitors 32 countries in Europe, compiles data and publishes reports) (1)
CARE (database that presents data for 27 EU countries) (2)
STRADA (Swedish open and wide-ranging database) (3)
Other traffic safety databases such as **GIDAS** (Germany) (4), **STATS19** (Great Britain) (5), **SWOV** (the Netherlands) (6), **ONISR** (France) (7)

Furthermore, analyses of the increased number of Naturalistic Driver Studies (NDS) are included in this report. Such studies record normal driver behaviour as well as driver behaviour during conflicts, pre-crash scenarios and accidents. Examples of NDSs are the 100-car study (8), EuroFOT (9) and SHRP2 (10). NDSs continuously provide valuable new insights into why accidents happen.

When it comes to validating data from the different sources, there are a number of challenges. Accidents involving HGVs are complex. The available information varies in quality and the amount of data differs between countries. Furthermore, different reports bring up different aspects of accidents and use varying numbers and severity scales.

For example, data is often presented for HGV collisions with the second party only defined as another vehicle, without specifying what kind of vehicle, and vice versa. Moreover, the statistics are often presented as HGVs and buses/coaches combined.

Naturalistic Driver Studies continuously provide valuable new insights into why accidents happen.

ACTIVE AND PASSIVE SAFETY SYSTEMS

The foundation for protecting both HGV occupants and other road users is passive safety. That includes safety features like the seat belt, airbag and front underrun protection. It also includes the exterior and interior design of the cab, for example the body in white, the steering wheel and seat.

In addition to passive safety, active safety systems can make a big difference. These systems aim to support the driver in difficult situations, firstly through warnings and, as a last resort, active safety systems can take control of the vehicle by braking. Real-life accidents and statistics can be used to develop both active and passive safety along with simulations and crash tests.

2. Accident Statistics

In 2015 there were about 26,300 road fatalities in the EU countries, an increase of 1% compared to 2014 and 2% compared to 2013. Despite this slight increase, the trend over time is that traffic fatalities are decreasing. (11)

The EU target is to reduce road fatalities by 50% between 2010 and 2020. The target is more ambitious than the results so far.

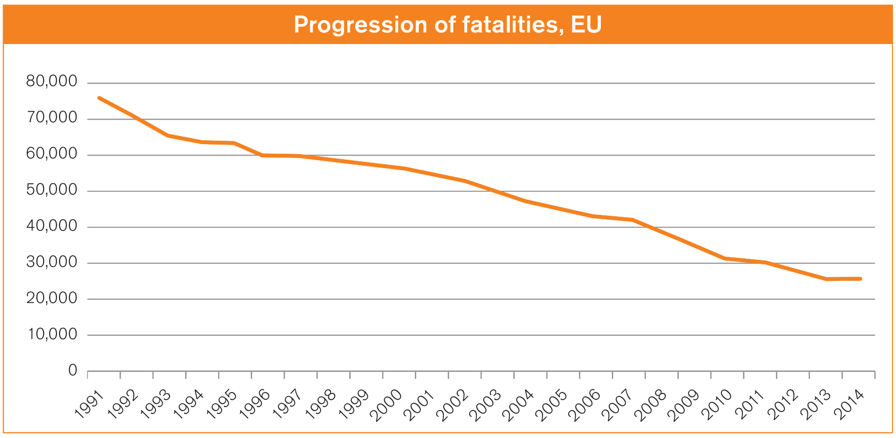


Table 1: Progression of fatalities in the EU (12)

To improve road safety so far, a lot of work has been invested in infrastructure and vehicle safety. Campaigns to improve road users' behaviour regarding seat belt usage, speeding and driving under the influence of alcohol have also been important.

However, the EU target of a 50% reduction in road fatalities between 2010 and 2020 is more ambitious than the results so far. The slight increase and slow overall annual reduction show that further efforts are needed.

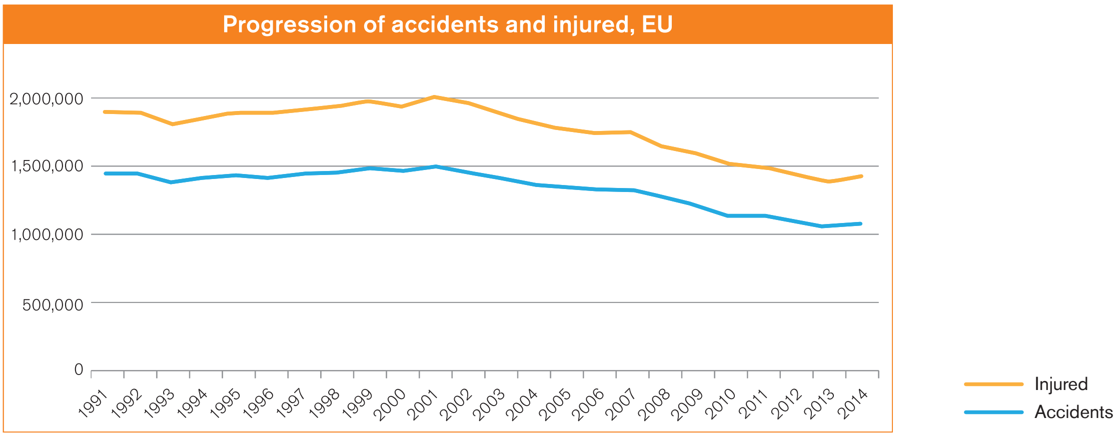


Table 2. Progression of accidents and injured in the EU (12)

If you look at accidents as a whole they are also decreasing, but at a slower pace (2010–2014, fatalities down 17%, whereas accidents decreased by 4.5%). Furthermore, there is a decreasing trend when it comes to people injured in traffic. (12)

When taking a closer look at the different kinds of road users, car occupants show the greatest reduction in fatalities even though they remain the largest group. However, travelling by car is the most common means of transportation, so that is not surprising.

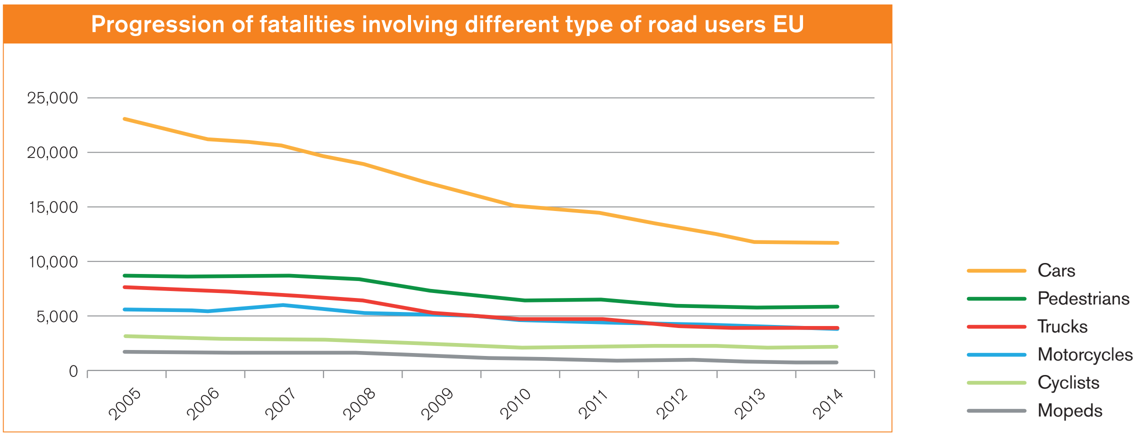


Table 3: Progression of fatalities involving the different types of road users in the EU (13) (14) (15)

Between 2005 and 2014, the number of fatal accidents involving HGVs decreased by 50%. While the total number of traffic fatalities has declined, the proportion of fatalities involving HGVs has remained fairly constant (17% in 2005 compared to 15% in 2014) (14). Of the 25,939 fatalities in 2014, 3,863 were fatalities involving HGVs (15%) (15). In the table below, the distribution of fatal accidents is shown.

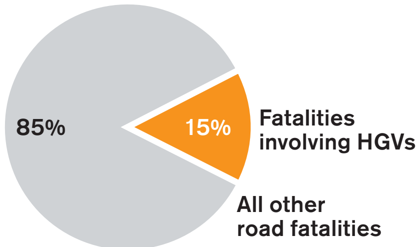


Figure 4: The proportion of fatalities involving HGVs

	All traffic fatalities	All HGV-related traffic fatalities
HGV occupant fatalities	499	499
Car occupant fatalities	11,733	1,898
VRU fatalities	12,500	1,230
Other fatalities	1,203	236
Total:	25,939	3,863

Table 4: Distribution of fatal accidents 2014 (11) (13) (14) (15) (16) (17) (18) (19)

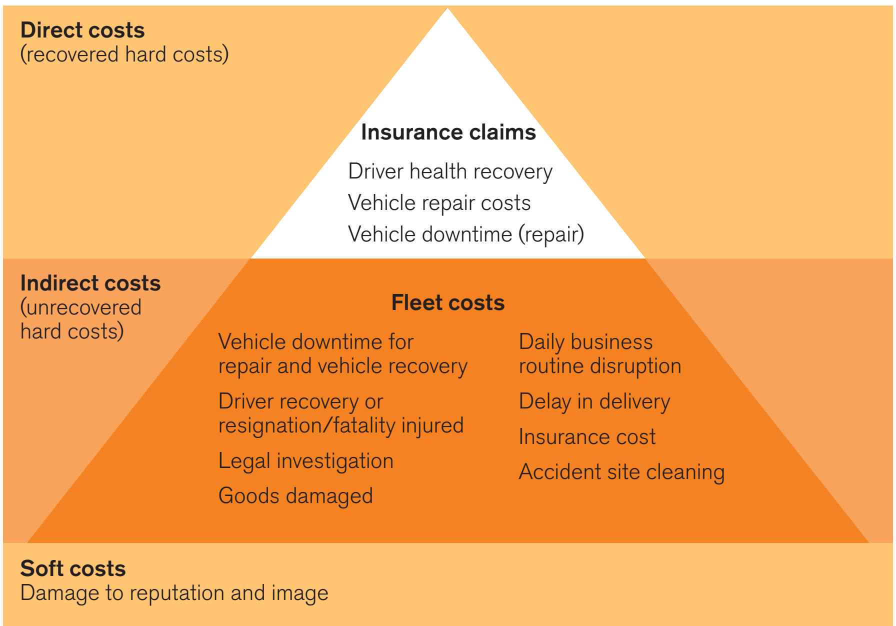
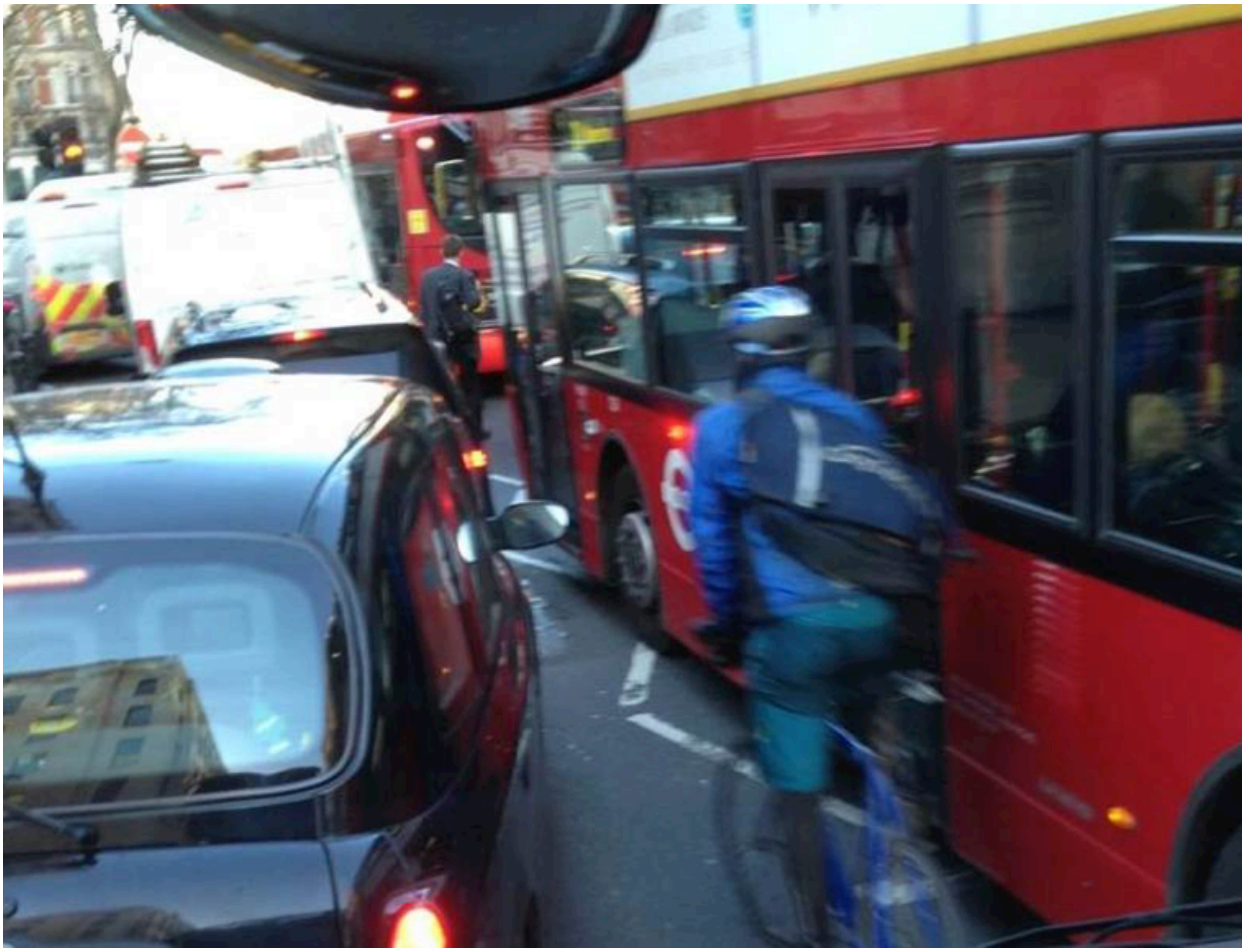


Figure 5: Accident-related costs (20)

SAFETY AS A COST SAVER

Unfortunately, accidents involving HGVs sometimes lead to fatalities and severe injuries. But even minor accidents have consequences – not only to the people involved but also to the transport companies and society.

The direct costs – driver health recovery, vehicle repair costs and vehicle downtime (repair) – are easy to measure. However they represent only a small proportion of the total. Indirect costs are often considerably higher as illustrated in the figure to the left.



The front view from an HGV cab in the London traffic

3. Causes of Accidents

Traffic is a complicated environment where a number of different actors meet and interact. Potentially dangerous situations constantly arise, but thanks to technical safety solutions and the skill of the humans involved, most conflicts do not lead to accidents. But unfortunately, some do.

To reduce the number of traffic accidents, and minimize injuries and damage when they actually happen, it is important to understand the scenarios leading up to accidents. Research in this area has developed considerably in recent years. New technology enables continuous logging of large vehicle fleets. For instance, technical data such as speed and sensor readings are collected and analysed. Video recordings of the driver and the surroundings during normal driving provide new insights over a long period of time.

Normally, an accident is caused by a set of factors that interact in an unfortunate way.

Research shows that accident-causing scenarios are complex, and it is difficult to determine one single cause. Normally it is a set of factors that interact in an unfortunate way. Looking at the contributing factors from the viewpoint of the available research they can be grouped into three categories: Human factors, Environment and Vehicle.

It is seldom vehicle technical failure or infrastructure solely that causes an accident. Human factors are involved in approximately 90% of all cases.

However, human factors are not necessarily the same as human errors. For instance, if you look in the side mirror for a split second and the car in front of you suddenly stops, you may not react in time to apply the brakes.

And let us not forget that all road users actually avoid accidents all the time. This is especially important to remember when developing active safety systems. They interact closely with the driver of the vehicle, and a poorly designed system could potentially have a negative impact on safety.

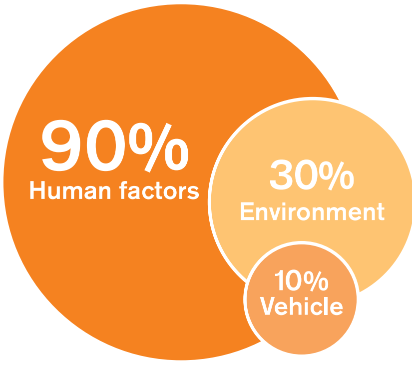


Figure 6: The approximate split between accident-causing factors

Environment

The infrastructure for pedestrians and cyclists differs considerably between different countries in Europe. Generally, the traffic environment is not always adapted to all the different road users. For example, intersections may have poor visibility for one or several road users as they approach.

In old cities, traffic is often more optimised for motor vehicles than for cyclists and pedestrians, which is problematic since there is a shift towards more VRUs in a modern urban society. Urban traffic planning is an important tool for preventing accidents and unnecessary risks in the interaction between drivers of motor vehicles and VRUs.

When it comes to accidents involving HGVs and cars it would be beneficial if all rural roads had central road barriers separating oncoming traffic. However, that is not always feasible.

Issues linked to slippery roads, bad weather and poor light conditions are also part of the environment category.

- **Road design**
- **Traffic planning**
- **Weather**

Example of central road barrier

Different types of road users interact in the traffic environment

Vehicle

For HGVs, visibility for the driver is often an issue. Mirrors and sometimes cameras complement direct vision, but even so there are limitations.

Active safety systems that inform or warn the driver of potential obstacles or other road users, or systems that actually brake or steer the HGV to avoid or mitigate an accident, have great potential for further reducing the numbers. It is important that such systems are designed to work along with the driver and not cause distraction or annoyance by issuing unnecessary warnings or causing false interventions. And most importantly, systems like these must not miss a warning or intervention. The consequences would be unacceptable.

Vehicle malfunctions such as technical failures and tyre explosions may also figure in accident scenarios.

- **Limited visibility for the driver**
- **Tyre explosion**
- **Technical failure**

Human Factors

Human factors contributing to accident prevention have not been investigated in the same way as human factors that cause accidents. However, human errors may be seen as a symptom (not a cause) in a system of vehicles, infrastructure and interaction that needs to be re-designed. More research is needed to understand how such a system should be designed in order to best support HGV drivers in accident prevention and avoidance.

- **Inattention**
- **Lack of risk awareness**
- **Misjudgement of complex traffic environment**

Accidents Related to Inattention

It is difficult to know exactly how many accidents are caused by inattention. Research suggests it is a common cause, one that has been increasing over the past few years.

The traffic situation often changes rapidly. To handle these changes and to foresee them as early as possible it is of utmost importance that all road users – pedestrians and cyclists as well as drivers of motor vehicles – pay full attention to the task at hand. A reduced attention level increases the risk of incidents and accidents.

Driving under the influence of alcohol or drugs naturally causes impaired attention, and most drivers never put themselves in this position. Having said that, it is more difficult to detect drowsiness and driving while fatigued is unfortunately a more common occurrence. It is often difficult to know for sure that an accident was caused by drowsiness – it is very unusual for a driver to admit to having fallen asleep.

One growing problem regarding inattention is the use of smartphones and other devices. In a situation where the driver cannot focus on driving the best solution is to stop until it is safe again. If all road users were fully focused on their primary task – to move safely and be aware of the traffic situation – the number of accidents would decrease.

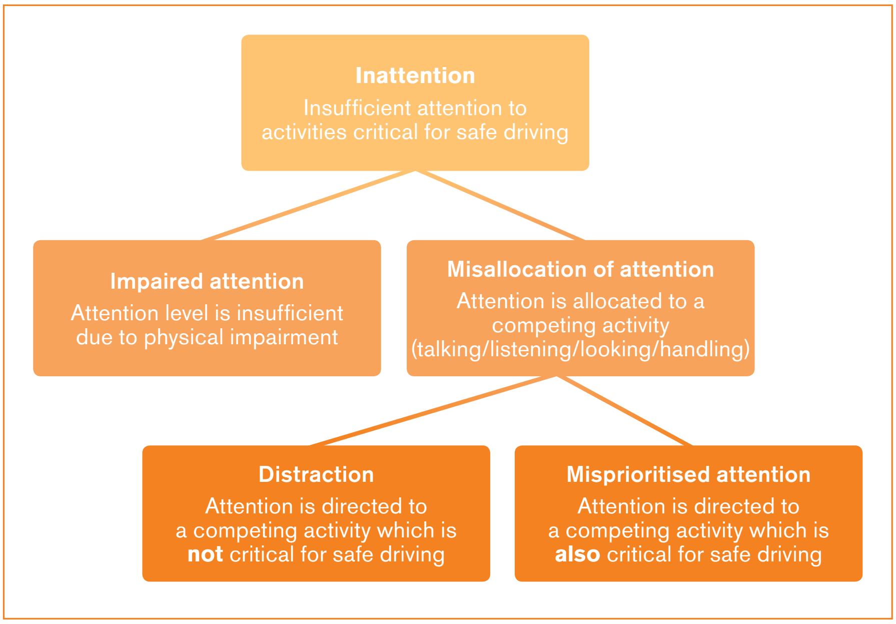


Figure 7: Inattention categories

One growing problem in traffic is the use of smartphones.

Solutions such as alco-locks are important tools that address drink-driving

ALCOHOL-RELATED ACCIDENTS

Approximately 25% of all traffic fatalities in Europe are alcohol-related. Nonetheless, only 2% of all driven mileage is covered by someone with alcohol in their blood. Drivers under the influence of alcohol are highly overrepresented in fatal road accidents (21). It is important to point out that this data is valid for all drivers and fatalities, not only those involving HGVs. In fact, HGV drivers are under-represented when it comes to drink-driving.

To solve the issue of drink-driving all parts of society need to work together. One example is the alco-gate pilot that was implemented at the Port of Gothenburg in 2013. Driving off the ferries the drivers had to undergo a sobriety test. 0.3% of car drivers were found to be under the influence of alcohol, and 0.05% of HGV drivers (22). (NB: The HGV drivers had received information about the gate in advance, the car drivers had not, which may or may not have affected the result.)

Recent European data on alcohol and drug usage related to traffic accidents involving HGVs is limited (2010–2015). The lack of data suggests that this issue is not as prioritised as it should be.

Drivers under the influence of alcohol are highly overrepresented in fatal road accidents.

4. Accidents Involving Heavy Goods Vehicles

Type Accidents According to ART

Volvo Trucks Accident Research Team (ART) has investigated accidents involving heavy goods vehicles (HGV) since 1969. ART's mission is to utilise the accumulated knowledge to find areas of improvement and drive development of safety solutions within the industry.

Based on this knowledge and systematic analysis of statistical data covering all HGV brands, Volvo Trucks has classified HGV accidents into three categories:

Type A accidents	**Accidents causing fatalities or severe injuries to heavy goods vehicle occupants**
Type B accidents	**Accidents causing fatalities or severe injuries to car occupants**
Type C accidents	**Accidents causing fatalities or severe injuries to vulnerable road users**

Type B accidents are the most common with just over half of the total (50–55%), followed by type C with about a third (30–35%). Type A accidents form the smallest category, representing just 10–20% of the total. As can be seen below, the overall distribution between the accident categories has changed between the ART reports of 2013 (23) and 2017. A comparison shows that type C shows a relatively increasing share of HGV accidents that result in fatalities or severe injuries.

	ART report 2013		ART report 2017
Type A accidents	15–20%	→	10–20%
Type B accidents	55–65%	↘	50–55%
Type C accidents	15–25%	↗	30–35%

Table 5: Accident type trend according to ART

The different types of accidents are divided into sub-categories focusing on accident scenario and frequency. A systematic overview and a better understanding of accidents – including knowing how dangerous different types of accidents are for the different road users – make it possible to invest the right resources in future development of safety systems.

This report provides an overview of European accident statistics. There are differences between countries, for example due to infrastructure and climate.

A few examples are Germany, where A4 accounts for 40% of all type A accidents, and northern countries where A1 and A2 are more common than in the rest of Europe.

ART has drawn conclusions based on its own findings and official data. As a result, there are differences between the ART and EU data.

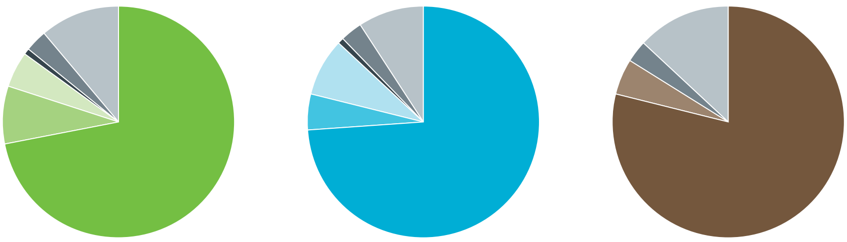
Driving Circumstances

A vast majority of all severe accidents occur during daytime in fair weather.

There are more HGVs and cars on the road during daytime. As a consequence type A and B accidents are more frequent during the day. The same apply for type C accidents: more people walk, cycle or use PTWs during daylight. In addition, VRUs are probably more cautious when weather conditions are visibly poor.

A vast majority of all severe accidents occur during daytime in fair weather.

Weather, severe accidents A type (n=142) | **Weather, severe accidents B type (n=436)** | **Weather, severe accidents C type (n=192)**



72% fair weather	74% fair weather	79% fair weather
8% rain	5% rain	5% rain
5% snowfall	8% snowfall	0% snowfall
1% sleet	1% sleet	0% sleet
3% fog	3% fog	3% fog
11% unknown/not specified	9% unknown/not specified	13% unknown/not specified

Figure 8: Weather conditions (3)

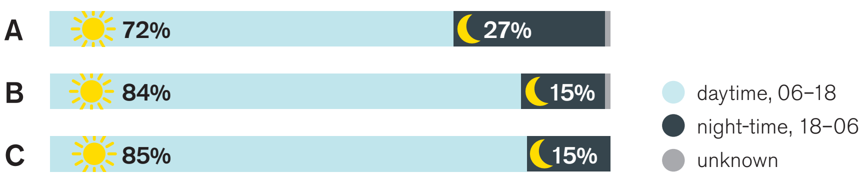


Figure 9: Time of day (3)

Dry roads are, perhaps surprisingly, the most prevalent road conditions for all type accidents – which correlates with the fact that most accidents occur in fair weather.

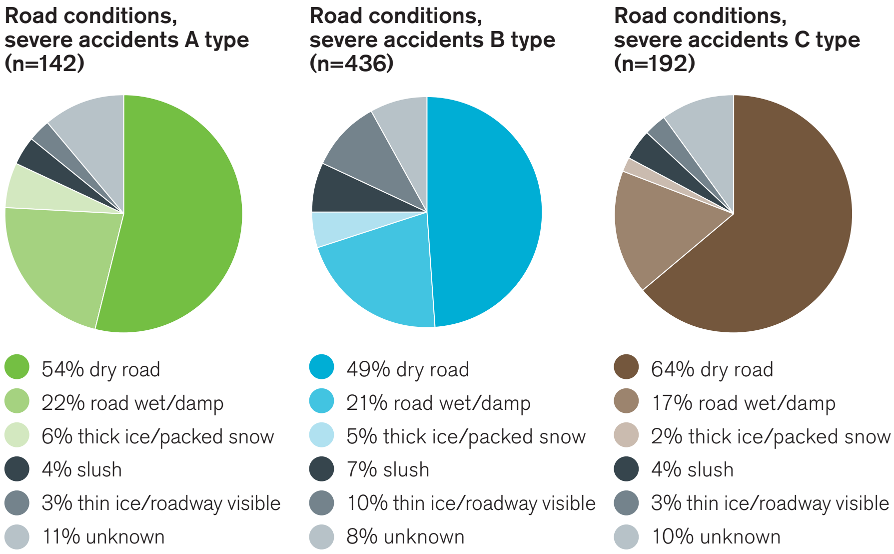


Figure 10: Road conditions (3)

The majority of type A and B accidents occur on rural roads (including motorways). The split when it comes to type C accidents is closer to 50/50, but with a small bias toward urban roads.

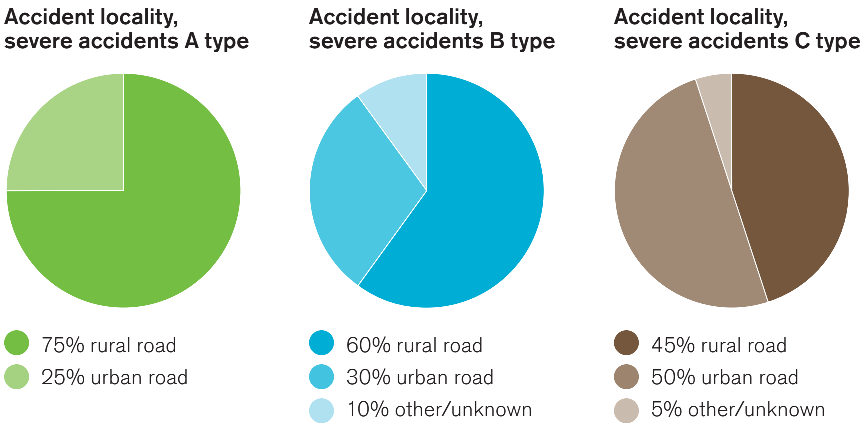


Figure 11: Accident locality (3)

Type A Accidents

These are accidents involving HGVs that cause serious injuries or fatalities to the HGV occupants. The most common types are lane-departure accidents (A1) and rollover or yaw instability on the road (A2). These are both single vehicle accidents and one frequently contributing factor to the serious injuries is the occupant not wearing a seat belt.

10–20% of all HGV accidents are type A accidents

Since November 2015 three systems that can help decrease type A accidents are legally required in Europe:

- Advanced Emergency Braking System (AEBS)
- Lane Departure Warning System (LDWS)
- Electronic Stability Control (ESC)

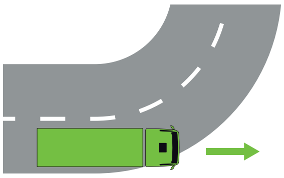
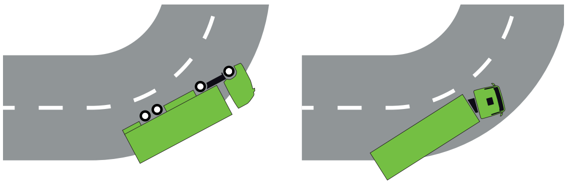
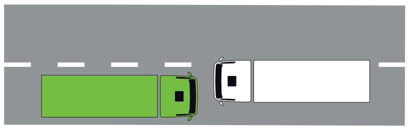
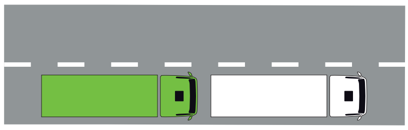
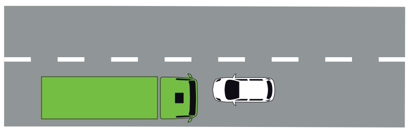
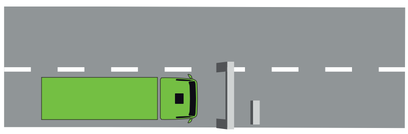
A1 35–40%	**Scenario:** Single truck accident where the truck drives off the road. Often – but not necessarily – followed by rollover or collision with an object. **Typical cause:** Driver inattention or fatigue, driver swerves to the side to avoid an obstacle.	
A2 20%	**Scenario:** Single truck accident due to roll or yaw instability on the road. Often followed by lane departure, driving off the road or rollover. **Typical cause:** Excessive speed, driver inattention or misjudgement, unstable vehicle combination, load displacement, slippery roads, tyre explosion.	
A3 5–10%	**Scenario:** Frontal collision with oncoming truck. Offset and impact angle varies, but main impact normally on driver's side. **Typical cause:** Driver inattention, curves with poor visibility, narrow or slippery roads.	
A4 15–20%	**Scenario:** Collision with another truck going in the same direction (driving into the rear of the truck in front). Offset and impact angle varies extensively, but main impact normally on passenger's side. **Typical cause:** Driver inattention, limited visibility, slippery roads or because the vehicle in front is not conspicuous enough.	
A5 ≤5%	**Scenario:** Frontal collision with an oncoming car. Offset and impact angle varies, but main impact normally front of both vehicles. Injuries to truck occupant normally occur in a secondary scenario, for example rollover or driving off the road. **Typical cause:** Most often car in wrong lane.	
A6 5%	**Scenario:** Truck collides with (drives into) object on the road, for example bridge or bridge pillars. **Typical cause:** Driver inattention or misjudgement of distance or height.	
Other ≤10%	**Example of scenarios:** Collision between trucks at intersection (one drives into the side of the other). Collision between truck and rail-bound vehicle at intersection (train or tram drives into truck side). **Typical cause:** Truck does not give right of way or cannot stop for example due to slippery road or misjudged stopping distance.	

Figure 12: Type A accidents sub-categories – scenario and typical cause

SEAT BELT USAGE

Seat belt usage saves lives. Most people know this and use seat belts in passenger cars. Despite this, drivers of HGVs tend to show lower usage rates, even though strengthened HGV cabs only protect their occupants if they are properly belted. Furthermore, using a seat belt also protects fellow road users. A belted driver can keep greater control of the vehicle if an accident occurs. Research shows (24):

Common reasons for using the seat belt:

- Protection in case of an accident
- It is required by law

Common reasons to skip the seat belt:

- Too much work or takes too long
- Uncomfortable when driving

What would make non-users change their mind-set?

- More comfortable seat belts
- More police checks or higher fines
- Another solution

50% of the non-belted HGV occupants killed in accidents would have survived if their seat belts had been properly used.

The images below shows a sequence of events from a rollover test with crash test dummies. The driver is belted while the passenger is not. The unbelted passenger gets severely injured by several impacts with the cab's interior before hitting the driver. Colliding with each other causes severe injuries to both of them. By the end of the rollover, the passenger is thrown out of the cab (circled).

The test showed that if both had been belted, they would not have suffered any severe injuries in this accident. (25)

Rollover test with crash test dummies (25)

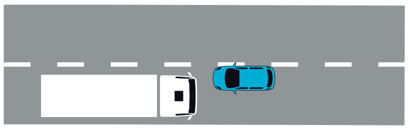
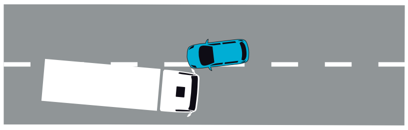
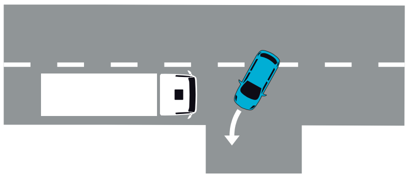
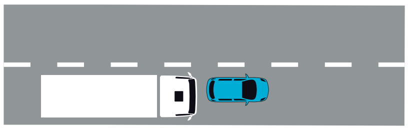
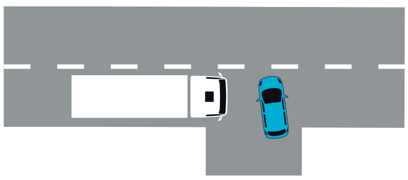
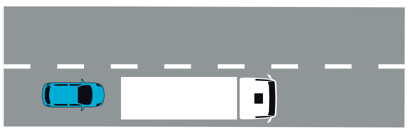
Type B Accidents

These are accidents between cars and HGVs that cause serious injuries or fatalities to car occupants. Car occupants killed in collisions with HGVs account for roughly 16% of all car occupant fatalities.

The most common accident type is frontal collision (B1). High speeds and the differences in mass and geometry between the vehicles lead to high collision impact and considerable deformation of the car. The second most frequent accident type is collision between car front and HGV rear, both vehicles going in the same direction (B6). Again, the mass difference and major deformation cause injuries and fatalities.

Frontal collisions (B1) and car hitting an HGV while crossing the oncoming lane (B3) could be avoided with better infrastructure. One example is central road barriers in rural areas, another is so called "spanish turns".

50–55% of all HGV accidents are type B accidents

B1 25–35%	**Scenario:** Frontal collision with an oncoming car. Offset and impact angle varies. **Typical cause:** Most often caused by car sliding or overtaking, or driver inattention. Sometimes caused by suicide attempts.	
B2 10%	**Scenario:** Collision with an oncoming car, sideswipe (truck front never hits car). Main deformation on truck is at the side. **Typical cause:** Most often caused by car sliding or overtaking, or inattention of the driver.	
B3 ≤5%	**Scenario:** Collision with an oncoming car that turns off the road, directly in front of the truck. The truck hits the car in the side. **Typical cause:** Caused by car turning off the road inattentively, often limited visibility.	
B4 10%	**Scenario:** Collision with car going in the same direction (driving into the rear of the car in front). Offset and impact angle varies. **Typical cause:** Caused by truck, inattention, limited visibility or because the vehicle is not conspicuous enough.	
B5 10–15%	**Scenario:** Collision with car at intersection, truck drives into side of car. **Typical cause:** Caused by truck or car (most often car) failing to give right of way due to inattention, limited visibility or because the truck is not conspicuous enough.	
B6 10–15%	**Scenario:** Collision with car going in the same direction (car drives into rear of truck). **Typical cause:** Caused by car, inattention or limited visibility, or because the truck is not conspicuous enough.	

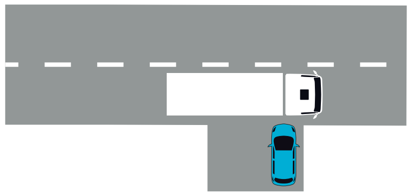
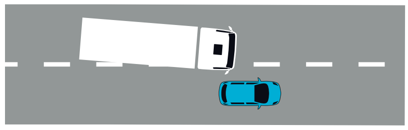
B7 5–10%	**Scenario:** Collision with car at intersection, car drives into side of truck. Impact on tractors has less underrun frequency than impact on rigids. Highest underrun frequency involving impact with trailer. **Typical cause:** Truck or car (most often car) fails to give right of way due to inattention, limited visibility or because the other vehicle is not conspicuous enough.	
B8 15–20%	**Scenario:** Collision with car during lane changing, merging or cutting-in. Could be either the truck or the car that changes lane, so the two vehicles collide side-to-side. **Typical cause:** Most often caused by truck: inattention, limited visibility or swerving.	
Other ≤10%	**Example of scenario:** Collision with car while manoeuvring slowly, parking or reversing. **Typical cause:** Inattention or limited visibility.	

Figure 13: Type B accidents sub-categories – scenario and typical cause

Type C Accidents

These are accidents between vulnerable road users and HGVs that cause serious injuries or fatalities to the VRUs. Almost half of all traffic fatalities in Europe are VRUs, and roughly 10% of all VRU fatalities are caused by accidents involving HGVs.

The three most common accident types resulting in severe injuries and fatalities to VRUs are crossing accidents (C3), accidents where the HGV is turning a corner (C4), and sideswipe accidents (C5). The most common fatal scenario for both pedestrians and cyclists is getting run over by one or more wheels of the HGV, often as a secondary consequence of the accident types mentioned above.

When it comes to moped riders and motorcyclists (powered two wheelers, or PTW) four type C accidents have high frequency: crossing accidents (C3), accidents with turning HGV (C4), collision in lane (C5), and VRU drives into HGV (C7). However, frontal collisions (C6) are the most dangerous type with the highest fatality rate.

VRU accidents are more frequent in southern Europe, possibly due to narrower urban roads and more vulnerable road users such as cyclists and moped riders sharing the streets with other traffic.

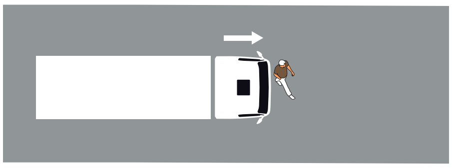
30–35% of all HGV accidents are type C accidents

C1
5%

VRU: Mainly pedestrians.

Scenario: Collision with VRU during low speed manoeuvring or starting at crossroads or pedestrian crossings. Impact with front of truck.

Typical cause: Limited visibility from cab (front, left or right), incorrectly adjusted or lack of front and side mirrors. Lack of communication between VRU and driver. Driver or VRU stressed, inattentive or distracted.

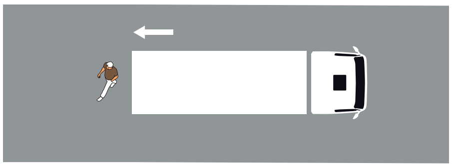


C2
5%

VRU: Mainly pedestrians.

Scenario: Collision with VRU during low speed reversing. Impact with rear of truck or trailer. Typically distribution trucks when delivering goods, or refuse collectors.

Typical cause: Limited visibility at rear of truck. External acoustic warning signal not enough or missing. Poor working routines or lack of knowledge. Driver or VRU stressed, inattentive or distracted.

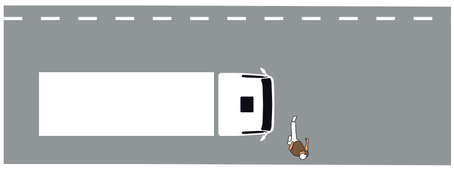


C3
30%

VRU: Pedestrians (most common), cyclists and moped riders.

Scenario: Collision with VRU at intersection, moderate or high speed. VRU suddenly crosses road in front of truck, for example at crossroads.

Typical cause: VRU inattention, lack of judgement or misjudgement of truck's speed. Truck driver inattention or limited visibility.

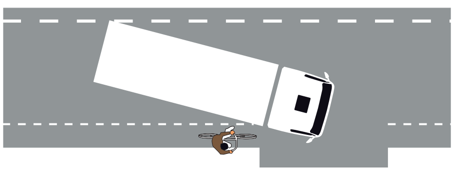


C4
20%

VRU: Cyclists (most common), pedestrians and moped riders.

Scenario: Collision with VRU when turning (right in right hand-traffic and left in left-hand traffic) at low speed. Front or side of truck hits stationary VRU (often at red light or crossing) when turning or cyclist comes at speed hitting the side of the truck.

Typical cause: Limited visibility from cab (passenger side), incorrectly adjusted or lack of passenger side mirror. Lack of communication between VRU and driver or VRU stressed, inattentive or distracted. Cyclist misjudges the truck's speed or direction of travel.



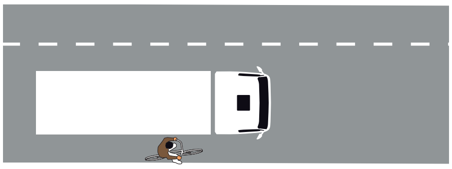
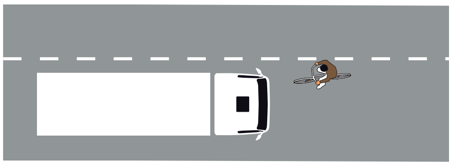
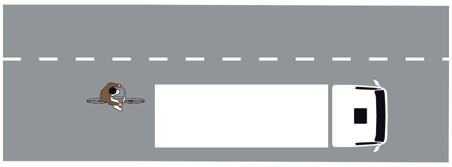
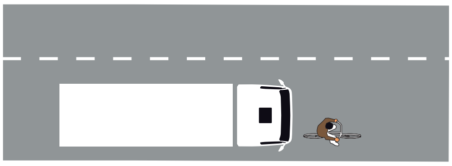
C5 15%	**VRU:** Cyclists, moped riders and motorcyclists. **Scenario:** Collision with VRU in lane at moderate to high speed, for example during lane exit, lane changing, merging or cutting-in. Side of truck hits VRU. **Typical cause:** Lack of visibility, narrow roads with oncoming traffic, driver stressed, inattentive or distracted.	
C6 5%	**VRU:** Mainly moped riders and motorcyclists. **Scenario:** Frontal collision with VRU at all speeds. **Typical cause:** Lane exit of either truck or VRU (most common), overtaking, misjudgement of speed and distance and inattention.	
C7 5%	**VRU:** Cyclists, moped riders and motorcyclists. **Scenario:** Collision where VRU drives into rear or side of truck ahead, truck at low speed and VRU at moderate to high speed. **Typical cause:** VRU lack of attention, misjudgement of truck speed, or because the truck is not conspicuous enough.	
C8 5%	**VRU:** Pedestrians, cyclists, moped riders and motorcyclists. **Scenario:** Collision where truck drives into VRU ahead or other unprotected people on the road such as road-workers or people changing tyres. **Typical cause:** Driver inattention, VRU acts unexpectedly, too short distance to VRU ahead, VRU not conspicuous enough.	
Other **5–10%**	**VRU:** Pedestrians, cyclists, moped riders and motorcyclists. **Example of scenario:** Collision where truck hits VRU while parking or turning slowly (not reversing). Offset differs. **Typical cause:** Limited visibility, distracted driver, distracted VRU, misjudgement of distance. **VRU:** Pedestrians. **Example of scenario:** VRU jumps or lies down in front of truck. **Typical cause:** Suicide.	

Figure 14: Type C accidents sub-categories – scenario and typical cause

5. Vulnerable Road Users and Heavy Goods Vehicles

Accidents involving pedestrians, cyclists and drivers of powered two wheelers (PTWs) are being increasingly discussed due to their severity. The VRUs are unprotected, and their small mass is unfavourable in a collision. Furthermore, they are harder to detect than other road users, and consequently suffer a higher risk of getting injured.

VRU Statistics

Statistics show that severe injuries and fatalities for vulnerable road users are decreasing at a slower rate than for protected vehicle occupants. The decrease in VRU injuries has stagnated over the past few years (26). According to a report by the European Commission, the total road fatality rate between the years 2010–2013 decreased by 18%. The same number for pedestrians is 11%, and for cyclists only 3% (27).

The decrease in VRU injuries has stagnated over the past few years.

Fatalities in accidents involving HGVs in Europe 2014 (n=3,863)

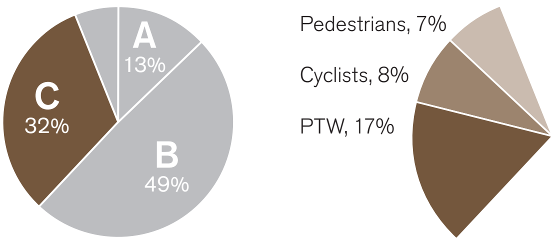
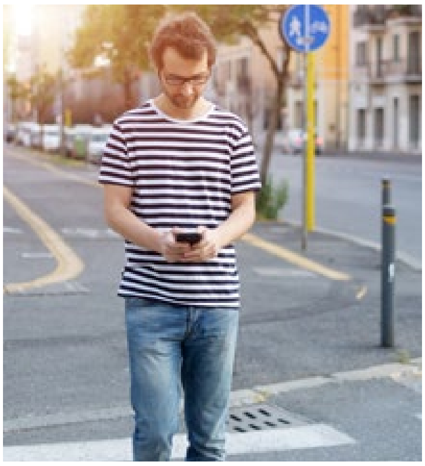


Figure 15: Distribution of VRU-fatalities in HGV-related accidents (15)

Approximately 10% of the VRU injuries and fatalities in traffic involve HGVs. Despite the relatively small share, a large proportion of accidents between VRUs and HGVs produce severe consequences. The distribution of accidents between HGVs and different VRUs varies significantly between European countries. Key factors are the extent to which people travel by cycle or on foot and how the infrastructure is built up. For example, the Netherlands and Denmark are known for their widespread cycling, while in Greece and large parts of southern Europe it is common to use scooters.



VRUs using smartphones is a growing traffic safety problem

Safer VRUs

Accidents involving VRUs are very complex since VRUs are somewhat unpredictable. They can move in ways that leave little room for a vehicle driver to react.
Hence, accidents happen even when the driver is focusing fully on the traffic.

One growing problem in traffic is distraction due to the use of smartphones. It is common to see pedestrians – and even cyclists – moving around listening to music, texting or playing games, with limited awareness of their surroundings. Studies show that almost one fifth (17%) of all pedestrians crossing a road fail to pay attention to the traffic because they are using their smartphone (28).

Safety Systems

To cut the number of accidents with VRUs it is necessary to work on several fronts simultaneously. It is not sufficient to only develop more safety systems for HGVs, even if that is one part of the solution. A lot of different steps need to be taken from society concerning infrastructure planning as well as education on the risks in traffic. In addition, all vehicle manufacturers and the VRUs themselves need to play their part.

There are active safety systems and sensors being developed today which could theoretically decrease the number of VRU accidents. The main problem is that no manufacturer can provide a high enough rate of correct warnings yet. Too many false warnings would lower confidence in the systems, and missed warnings are simply not acceptable.

One example of an active safety system is Advanced Emergency Braking Systems for HGVs (AEBS), which have been required by law since 2015. The systems currently on the market is mainly targeting collisions with vehicles ahead. Further development of both sensors and functionality is needed in order to accurately address VRU accidents.

Looking at passive safety systems, one example is the HGV side underrun protection (required by law in the EU). It is fitted on the side of the truck, between the wheels and is intended to protect other road users from being caught underneath the vehicle. However, this does not always work in favour for VRUs. The law allows the use of two planks with a maximum distance of 30 cm in between. In some cases road users have become stuck in that space, and unfortunately this method of protection is negatively impacting the outcome of these accidents (29).

Methods to reduce VRU accidents include:

- **Development of active and passive safety systems**
- **Infrastructure planning**
- **Education and awareness campaigns**

“Stop, Look, Wave” is now spreading fast around the world

In addition to upcoming technical solutions, educational and awareness-enhancing campaigns could play a major role when it comes to safety for VRUs. With this in mind Volvo Trucks has developed two educational programmes, “Stop Look Wave” and “See and Be Seen”, to teach children, teenagers and young adults how to behave in a safe manner around trucks. Both programmes are free and available for everyone to download (30).

IMPACT ZONES

In the figure below, the areas of impact in accidents between HGVs and cyclists in right-hand traffic (slight and moderate accidents included) are shown. One-third of all impacts occur at the front of the HGV, approximately 40% on the right side and a little more than 10% on the left. The rest is rear or unknown.

The impact frequency is high on the vehicle´s side. One possible solution is an A-pillar camera that is activated when the HGV indicates a turn. It assists the driver by offering a better view to the side.

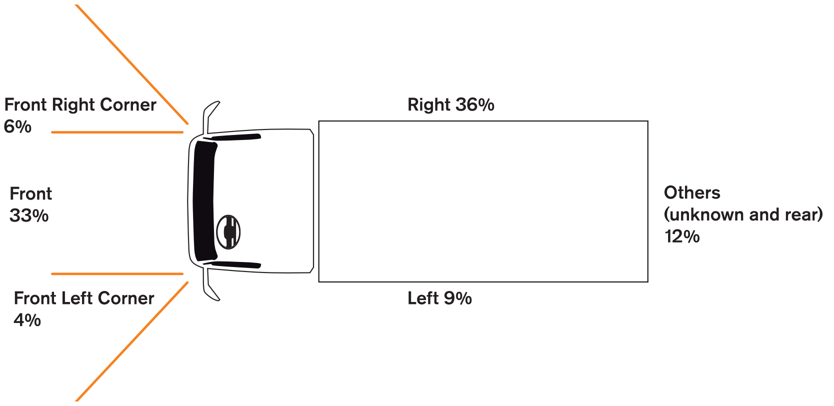


Figure 16: Frequency of impact zone between HGVs and cyclists in right-hand traffic (4)

Indirect vision aided by mirrors is regulated within the EU.

Direct view from the cab is not regulated by any law. This question is raised in the EU.

Most Common VRU-accidents

The focus for future development in the industry should be on the accident types that result in most severe injuries and fatalities – crossing accidents (C3) and accidents with turning HGVs (C4). They are most common in urban areas, and a combination of active and passive safety systems could reduce the risk significantly.

Crossing Accidents (C3)

The accident type causing most injuries to pedestrians is when a person crosses the street and gets hit by an HGV. This is also the most common type C accident (30%) and it causes the highest share of severe injuries and fatalities.

There may be several reasons for these accidents, from HGV drivers or pedestrians not paying attention, to limited visibility due to obstacles or infrastructure.

Crossing accidents typically occur in urban areas, at speeds that are high but within the speed limit. However, some take place in rural areas at higher speeds. In most accident cases the pedestrian is crossing the street from the same side that the HGV drives on; right in right-hand traffic and left in left-hand traffic. The available reaction time is much shorter if a pedestrian walks out into the street on the same side of the road. When approaching from the opposite side the chance is greater that the HGV driver sees the pedestrian and reacts accordingly. Additionally, since the driver is seated on the traffic side of the vehicle, visibility toward the same side of the road is not as good as good as to the opposite side. Of course, the same goes for the pedestrian in both cases. Avoiding accidents is a shared responsiblitiy – everyone in traffic needs to be careful and pay attention.

One unfortunate cause of crossing injuries and fatalities, for which it is difficult to get the full picture, is suicide attempts. It is challenging to develop active safety systems that would make a difference at such high speeds. Working with suicide prevention in society is also necessary.

- **Pedestrians**
- **Urban areas**
- **HGV at higher speed (within the limit)**

Turning HGV (C4)

This is the most dangerous and frequently occurring accident between cyclists and HGVs. C4 accidents make up 20% of accidents between HGVs and VRUs, and it is most common in urban areas. Typically, it occurs when an HGV is turning and a cyclist in the lane or cycle path next to it is going straight ahead or turning. The decreased turning radius for the HGV as it negotiates the corner is one of the major concerns. The initial impact is in both cases between the front or side of the cyclist and the side of the HGV.

The vast majority of turning accidents take place in cities, but there are also some in rural areas. In older cities, for example London and Rome, the streets are narrow and people cycle among other road users. If an HGV turns and a cyclist is riding alongside, the lateral distance between the two might get too small and cause a collision. In countries where the bicycle infrastructure is well-established, for example in Denmark and the Netherlands, there are often bicycle lanes parallel to the road lanes. Accidents occur when an HGV turns in front of a cyclist, who drives straight into the side of the HGV.

A short lateral distance between the HGV and the cyclist makes it harder for the driver to detect the cyclist, and gives the cyclist a shorter time to react to the situation. The most common causes are wrongly adjusted mirrors and obscuring objects, and that either the HGV driver or the cyclist fails to follow the right of way rule (26).

The collision speed in this kind of accident is usually not very high. In a vast majority of such cases, the HGV's speed is below 30 km/h and the cyclist's below 20 km/h (31). Still, the consequences can be severe since the cyclist is often run over by one or more of the HGV's wheels.

This type of accident also happens to PTWs and pedestrians. However, cyclists are more exposed. Most PTWs follow the traffic flow and should not be exposed to this kind of situation, with the exception of some moped categories that are allowed to use bicycle lanes.

Pedestrians move more slowly than cyclists do and have more time to see the intentions of the HGV driver, and move accordingly.

- **Cyclists**
- **Urban areas**
- **HGV and VRU at lower speeds**

6. Summary

Volvo Trucks Accident Research Team has thorough knowledge about accidents involving heavy goods vehicles through investigative work and analyses of research and traffic data throughout the years. Based on that knowledge, which is compiled in this publication, the most important focus areas for the future has been identified.

PRIORITISED AREAS FOR IMPROVED TRAFFIC SAFETY

- Increase HGV occupant seat belt usage.
- Secure driver awareness as well as direct and indirect visibility from the cab. Improving both direct and indirect visibility is important from a safety perspective, and the market demands it – for example cities like London pushes this question.
- Enable Driver Coaching Services that provide direct feedback to the driver, both when it comes to safer driving and more economical driving.
- Development of Active Safety Systems has great potential when it comes to HGV occupants as well as fellow road users, such as VRUs and car occupants. Active Safety Systems aim by design not merely to mitigate an accident but also avoid it. Listed below are a few examples of active safety systems and technologies that could improve safety in the future:

Advanced Emergency Braking System (AEBS)
The currently legislated AEBS is designed to mitigate or avoid rear-end accidents. In the future, it would be beneficial to include scenarios involving VRUs, for example crossing accidents.
For pedestrians: forward detection, intervention and side detection.
For cyclists: detection for HGV turning scenarios.

Detection systems that identify VRUs in close proximity to the HGV
Could be either information on monitor or visual/acoustic warnings.
Examples of technologies: Camera, radar, lidar and ultrasonic – either stand-alone or integrated systems.

Cooperative Intelligent Traffic Systems (C-ITS)
Enable communication between vehicles and infrastructure. C-ITS extend the horizon for active safety systems, which is currently limited by sensors on the own vehicle. With C-ITS information is sent by other vehicles or objects close by.

Safety is a core value for Volvo Trucks, and the goal is zero accidents.

Volvo Trucks has a long and proud history of working with and developing safety systems. Leading the development of passive safety systems over the years, Volvo Trucks has a safety message to convey. Safety is a core value for Volvo Trucks, and the goal is zero accidents. To reach this target, sharing knowledge is important – everybody in the traffic environment needs to be aware of their part and we all need to work together, which is why you have this report in your hand.

7. References

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