Accident Investigation Board Norway

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THEMATIC REPORT CONCERNING SAFETY IN CARS

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SUMMARY

The thematic investigation concerning safety in cars includes 26 fatalities from the eight head-on collisions with three or more fatalities in 2008 and 2009. During these two years a total of 470 people were killed in road traffic in Norway. The material thus covers 5.5% of the total number of fatalities in 2008 and 2009. The AIBN assumes that there will be similar injury mechanisms in other fatal accidents, i.e. with fewer than three fatalities.

The investigation shows that proper seat belt use, the securing of cargo/items in the car, speed variation and point of impact in the collision, the car's protection against intrusion and available safety equipment are very important for survival. Overall, the investigation confirms that the use of three-point seat belts is the most important and most effective safety measure. However, the investigation also points to other factors that are not as well-known among general road users.

In total, AIBN's analyses show that 16 of the 36 persons that were killed or seriously injured had sufficient survival space, and could have survived or suffered less serious injuries in the accident given the correct use of three-point seat belts and the securing of other people and cargo/items in the car. In addition, one person could probably have survived if the seat belt had permitted less forward motion of the upper body in the collision. Additional survival potential is found if the cars in this material had been replaced with newer cars with better crash safety and safety equipment.

The AIBN would like to point out that every driver can affect the probability of being involved in an accident through safe driving, especially through speed selection. However, one cannot control the behaviour of other road-users. The car's survival space – the room the driver and the car occupants need to survive – is therefore crucial if an accident occurs. As a driver and passenger, it is important to consider how to best ensure this survival space. Regardless of the car's collision protection and safety equipment, properly tightened three-point seat belts for everyone in the car and the correct positioning and securing of cargo/items, are essential to ensure survival space.

The AIBN gives four safety recommendations based on this thematic investigation.

1. INTRODUCTION

1.1 Background for the thematic investigation

In 2008 and 2009, the AIBN investigated all road traffic accidents with three or more fatalities, eight accidents in total. A common denominator identified by the AIBN in the investigation of the eight accidents was the potential for improvement in relation to the chance of survival. The investigations have demonstrated clear connections between use of seat belts and securing of objects in cars, in relation to the personal injuries that occurred in the accidents. The AIBN believes that the findings from these eight accidents provide valuable knowledge to increase traffic safety, and therefore considers it important to present this, so that more people can gain explicit knowledge of the decisive importance of correct seat belt use and securing of cargo should an accident happen. The AIBN has therefore chosen to publish the findings from the investigations in this thematic report concerning safety in cars.

1.2 The Vision Zero and use of seat belts

Good and targeted traffic safety work has in recent years resulted in a declining number of traffic fatalities. The Storting has, through the 2002-2011 National Transport Plan (NTP), declared that the Vision Zero should form the basis for traffic safety work in Norway. The Vision Zero is a vision for a road traffic system that does not result in loss of life or permanent injury. Traffic fatality numbers in Norway have declined markedly since 1971, but in 2010 there were still 208 fatalities in connection with road traffic.

Figure 1 shows the total number of killed and seriously injured car drivers and passengers by age for the years 2001 – 2010. The figure shows that the age group between 17-25 years is most affected by traffic accidents.

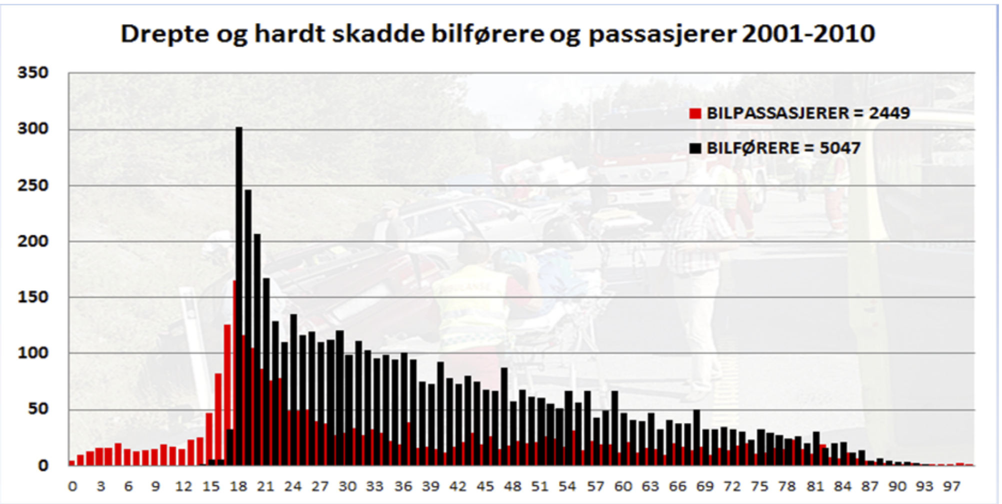

Figure 1: The total number of killed and severely injured drivers (marked in black) and passengers (marked in red) by age for the years 2001-2010.

A common denominator for accidents in recent years is that a large percentage of those killed in traffic did not wear a seat belt, and many of them would probably have survived if a seat belt had been worn. The AIBN therefore believes that there is a potential for further reduction of severe traffic injuries and fatalities by raising seat belt use further. In order to approach the Vision Zero further, designing transport systems and transport vehicles in a manner which promotes correct behaviour and protects against fatal consequences is not sufficient. Road-users must also be aware of their share of the responsibility through safe behaviour, including the use of seat belts.

The Norwegian Public Roads Administration's (NPRA) baseline survey in 2010 shows that more than 94.8% of drivers/front-seat passengers outside densely populated areas use seat belts, and that somewhat fewer (92.7%) use seat belts in built-up areas. The statutory requirement to use seat belts introduced in 1975 and the introduction of the fine in 1979 have resulted in increased use of seat belts, but accordingly there are still those who do not wear seat belts.

A seat belt is the simplest and most efficient way to reduce traffic injuries and fatalities. According to the NPRA, the use of seat belts reduces the chance of fatal injuries by 40-50% for the driver and front-seat passenger. The number of traffic fatalities would probably be reduced by 40 per year if everyone wore seat belts - always[1].

Studies show that a large number of those killed and severely injured in traffic accidents did not wear seat belts. The NPRA's accident analysis groups (UAG) found that for 2010, of the total 149 that were killed in car accidents,[2] 68 (46%) did not wear a seat belt. The corresponding figures for 2009 and 2008 were 44% and 41%. For the period 2005 – 2010 as a whole, 44% of the persons killed in cars did not wear a seat belt. Of the 48 youths aged 16-24 who were killed in car accidents in 2008, about half did not wear seat belts.

Due to lack of medical expertise in the accident analysis groups up until 2010, the NPRA states that it has been difficult to determine whether the casualties had any chance of survival if they had used seat belts.[3]. This aspect makes a significant difference in the AIBN's thematic investigation concerning safety in cars (see Chapter 1.5 relating to the AIBN's investigation method).

1.3 Limitation of the thematic investigation

The purpose of the thematic investigation was to study the survival potential for persons who were killed or severely injured in the eight accidents. The AIBN has therefore chosen to limit the accident investigations to mainly concern survival aspects. The investigations focused on the crash and injury phases, i.e. factors which influence the amount of mechanical energy and factors that influence the severity of the injuries following an accident. This includes assessing the damage to vehicles and injuries to persons, as well as factors in relation to the securing of cargo and persons in cars (seat belts) which could have contributed to reducing the injuries caused by the accident.

An assessment of road conditions which may have influenced the extent of the damages has not been included in the investigations, nor has the AIBN assessed the rescue work after the accidents happened.

Contributing factors to why the accidents happened in the first place (the pre-crash phase, i.e. factors which affect the probability of an accident) have been given less attention in this thematic investigation. The investigations do not look into why the involved persons

[1] Facts concerning use of seat belts
http://www.vegvesen.no/Fag/Trafikk/Trafikksikkerhetskampanjer/Bilbelte/Fakta+om+bilbelte)
[2] 208 persons in total were killed in traffic accidents (including pedestrian, bicycle and motorcycle accidents) in 2010.
[3] From 2010, however, UAG was strengthened with a physician with emergency medicine expertise to assist in the assessment of medical facts and interpretations.

acted as they did, neither in relation to the development of the chain of events itself nor in relation to securing persons and cargo in the cars (why the seat belt was not in use or was not used correctly).

In total, 46 persons were involved in the eight investigated accidents. To limit the investigations, the AIBN has therefore chosen to focus the description of injuries, survival aspects and use of seat belts on the persons who were killed or severely injured in the accidents. For persons who suffered only minor injuries, the AIBN will only comment on whether the seat belt was used or not. Any incorrect use of the seat belt and/or slack in the belt is not described for these persons, as the extent of the injuries was relatively limited.

1.4 Separate reports concerning individual accidents in connection with special findings

If findings in the investigation of an accident have shown a major safety potential regarding the course of events in the accident and why the accident happened, the AIBN has opened for issuing a separate report on the accident in addition to this thematic investigation. This applies to the accident in Alta on County Road (Fv) 13 on 1 January 2009 (accident No. 2 in this general report). It was uncovered that the condition of the county road (deep longitudinal ruts) contributed to the accident. See AIBN Report Vei 2010/03.

1.5 Investigation method

All vehicles involved were subject to a thorough technical investigation by the AIBN. The technical investigations focused on internal and external damage to the vehicle, seat belts, airbags and compartment deformations. During this work, emergency medicine expertise was applied with assistance from the pre-hospital division at Ullevål University Hospital.

The term ***survival space*** is a key concept in this connection, i.e. the available space left for the driver and passengers to survive in after deformation or intrusion of chassis parts in a collision.

The engineering firm Rekon DA has also performed analyses and simulations in the Scan-crash computer program for each of the eight accidents. This was done to estimate collision speeds, speed changes and force direction of the vehicles involved.

The AIBN has also had access to all medical information, patient journals and autopsy reports for everyone involved in the accidents. This has made it possible to combine technical and medical findings in a manner which can contribute to explain the connection between external impact and personal injuries.

In this context, the AIBN has been assisted by Rettsmedisinsk institutt (Norwegian Institute of Forensic Pathology) to describe the injuries of the persons involved in the accidents. This work is based on medical information (patient journals and autopsy reports) and other available documentation concerning the accidents, including findings from the technical review of the internal environment in the vehicles.

For each investigated accident, the following issues were given particular emphasis:

- Was the seat belt used? How did the seat belt function, cf. load patterns?

- If the seat belts were not used/used incorrectly/did not function satisfactory; could any injuries have been avoided if the seat belts had been used/used correctly, and had functioned in a satisfactory?

- Are there injuries that can be in connected to impact with the vehicle’s interior that even correct use of the seat belt could not have prevented?

- Are there injuries in connection with cargo or other persons in motion? If so, could these injuries have been avoided if the cargo and other persons in the car had been securely fastened?

In addition, the AIBN engaged the Institute of Transport Economics (TØI) to assist in general with the report's form, structure, content, analysis and proposal for potential safety recommendations. SINTEF Technology and Society has also been involved in the report, and has, on assignment from the AIBN, reviewed seat belt campaigns and assessed how traffic users can be encouraged to use seat belts. The chapter on seat belt campaigns was updated by TØI on the basis of the experiences from the CAST EU project which was concluded in 2009.

Based on the technical findings on the seat belts in two of the accidents (Accidents 7 and 8 in this thematic report), the AIBN found reason to carry out extended technical investigations of the vehicles. In this connection, the AIBN has carried out full-scale crash tests and extension tests of seat belts with SP Technical Research Institute of Sweden in Borås.

1.6 Report structure

Chapter 2 relates to factual information concerning general safety in cars. This chapter forms the basis for the AIBN's review of the accidents included in the thematic investigation and provides the reader with a general introduction into issues relating to safety in cars (laws and regulations, passive safety in cars, collision forces, crash tests and seat belt campaigns).

Chapter 3 reviews the factual information and findings related to the eight accidents in the thematic investigation. For every accident, the course of events, speeds and loads in the collision, internal investigation of the vehicles, as well as personal injuries and injury mechanisms, are described.

Chapter 4 relates to the tests (crash tests and pull tests) which the AIBN has carried out at SP. The chapter describes how the tests were performed, their results and the AIBN's assessment of the final results.

In Chapter 5, the AIBN analyses the possibility of survival or different injury situations in each of the eight accidents. The chapter collates information from the technical investigations of the car with medical findings and assessments, as well as the simulations of the collisions in Scan-crash.

Chapter 6 describes the conclusions and main findings of the thematic investigation.

In Chapter 7, the AIBN makes safety recommendations to improve traffic safety on the basis of the safety issues uncovered in the thematic investigation.

2. FACTUAL INFORMATION CONCERNING SAFETY IN CARS IN GENERAL

2.1 Laws and regulations

2.1.1 Requirements related to installation and use of seat belts in cars

From 1971, installation of seat belts in the front seats of passenger cars and vans became mandatory in Norway. In 1975, an unsanctioned requirement for the use of seat belts in the front seat was introduced. A fine of NOK 200 for failure to use seat belts was introduced in 1979. In 1984, installation of seat belts in the back seats of new passenger cars became mandatory. From 1985, the use of seat belts in the back seat of these cars became legally required. The requirement only applied to passengers age 15 and above. In 1988, securing children in cars became a legal requirement, regardless of position in the car.

From 1 July 2009, the fine for driving without a safety belt was doubled from NOK 750 (introduced in 2000) to NOK 1500. According to the Regulations of 21 September 1979 No. 07 relating to use of personal protective equipment during operation of motorised vehicles (Regulations relating to use of seat belt, etc.) seat belts and other equipment for securing persons must be worn where installed, regardless of the type of vehicle it has been installed in. The driver is responsible for ensuring that passengers under the age of 15 use seat belts, and the driver must pay the fine if not.

New passenger cars (in force from 1 April 2002 for type approval and 1 October 2004 for new registrations) must be equipped with three-point seat belts of an approved type in all seats in the car. For older cars, two-point belts (hip belts) are permitted in the central back seat and elsewhere where three-point belts cannot be installed. The seat belt must be an automatic inertia-reel belt, i.e. a belt that automatically adapts to the user.

2.1.2 Requirements relating to securing children in cars

The regulations relating to use of seat belts, on securing children in particular:

1. *Where seat belts are installed, children lower than 150 cm must use approved safety equipment adapted to the child or such equipment in combination with regular seat belts.*
2. *Where no approved child securing equipment exists, children shorter than 150 cm and taller than 135 cm can use regular seat belts.*
3. *Where seat belts are not installed, children younger than three must not be transported, and children of three years or older, but lower than 150 cm, must not be transported in the front row of seats.*
4. *Children must not be transported in securing equipment that faces away from the direction of travel with an airbag in front unless the airbag has been deactivated, manually or automatically.*

2.1.3 Exemptions from the use of seat belts

There are exemptions from the requirement to use seat belts, including in cases where the person in question has a medical certificate granting an exemption. The opportunity to grant exemptions for medical reasons is pursuant to EU Directive 91/671/EEC, Article 5. The directive does not specify when such exemptions can be granted. There is no overview of how many people in Norway have been granted a medical certificate for exemption from the use of seat belts.

Exemption from the use of seat belts is covered both in the Norwegian Directorate of Health's IS-1348 "Guidelines for county governors in processing of driving licence cases" (issued Sep. 2011) and in IS-1437 "Rules and guidelines for completion of health certificates for driving licences, etc." (issued Nov. 2011). The guidelines emphasise that there are generally no medical conditions that entail that a seat belt should not be used, and that physicians should be very restrictive in granting exemptions for mental health reasons, and that "*the Norwegian Directorate of Health wants an as restrictive practice as possible in this area.*"

2.1.4 Requirements relating to securing of cargo

The following is quoted from the Regulation of 25 Jan. 1990 No. 92 relating to use of motor vehicles concerning placing and securing cargo:

> *3. Cargo must be secured so that it does not cause injury or risk, is dragged along the road, falls off the vehicle or creates unnecessary noise. The same applies to chains, ropes, tarpaulins or other fastening devices.*

As regards transport of cargo inside passenger cars, no detailed provisions or guidelines have been established.

2.1.5 Requirements relating to seat belts

The following is quoted from the Commission Directive 2000/3/EC of 22 February 2000 adapting to technical progress Council Directive 77/541/EEC relating to safety belts and restraint systems of motor vehicles:

> *2.6.1.3.2 the forward displacement of the manikin shall be between 80 and 200 mm at pelvic level in the case of lap belts. In case of a harness belt the minimum displacement specified for the pelvis may be reduced by half. In the case of other types of belt, the forward displacement shall be between 80 and 200 mm at pelvic level and between 100 and 300 mm at torso level. These displacements are the displacements in relation to the measurement points shown in Annex VIII, Figure 6.*
>
> *2.6.1.3.3 In the case of a safety belt intended to be used in an outboard front seating position protected by an airbag in front of it, the displacement of the chest reference point may exceed that specified in paragraph 2.6.1.3.2 above if its speed at this value does not exceed 24 km/h.2.6.1.4 In the case of a restraint system:*
>
> *2.6.1.4.1 the movement of the chest reference point may exceed that specified in*
>
> *2.6.1.3.2 if it can be shown, either by calculation or by a further test, that no part of the torso or the head of the manikin used in the dynamic test would have come into contact with any forward rigid part of the vehicle, apart from contact of the chest with the steering assembly, if the latter meets the requirements of Council Directive 74/297/EEC (1) and provided that contact does not occur at a speed higher than 24 km/h. For this assessment, the seat shall be considered to be in the position specified in 2.7.8.1.5.*

The Directive's Appendix 8 describes the specifications of the manikin for use in crash tests, which states that the total mass including correction weights shall be 75.5 ± 1.0 kg.

2.2 Passive safety in cars

The car's passive safety is made up of the equipment and structures which are aimed at protecting and minimising injuries from accidents: e.g. safety chassis, impact-absorbing materials, airbags and seat belts. The car's active safety is made up of equipment and structures which are aimed at preventing accidents: e.g. anti-lock braking systems (ABS), emergency braking assist and anti-skid systems.

In the preparation of this chapter, the AIBN has used various sources, see for example the Sikker bil (safe car) section of the website of [4]the Norwegian Public Roads Administration, the Institute of Transport Economics' Traffic Safety Manual (Elvik et al, 1997) and the Norwegian Council for Road Safety.

2.2.1 The car chassis and collision safety

A modern car chassis uses materials with different properties to achieve optimal balance between energy absorption and rigidity. The aim is to absorb as much energy as possible while retaining compartment integrity (survival space). The deformation zones absorb the forces that are created by the collision, thereby extending the retardation period, while stiff protection beams around and in the compartment will prevent passengers from being crushed against the car interior and objects from entering the compartment.

The car chassis generally protects the persons in the car better in frontal collisions than in side collisions. The potential deformation zone in a side collision is only approx. 20-30 cm, while the zone is considerably longer in a frontal collision. In a collision between two vehicles, the protection offered by the vehicle is higher with increased mass, as the retardation forces are generally weaker.

2.2.2 Seat belts

When an accident happens, persons without seat belts will continue to move at the same speed as the car before the impact. Seat belts have the following protective functions:

- Prevent or reduce impact with the car's interior.
- Prevent the person from being thrown out of the car.
- Keeps the person in the seat to reduce the speed in time with the car, thus reducing G forces against the body over a longer time and distance.
- The total belt area in contact with the body distributes the G forces over a larger part of the body.

According to the Traffic Safety Manual, the use of seat belts reduces the risk of being killed by 40-50% for the driver and front-seat passengers, and for the back seat passengers by approx. 25%. The effect on serious injuries is about the same, while the

[4] http://www.vegvesen.no/Kjoretoy/Fakta+og+statistikk/Sikker+bil.
http://tsh.toi.no/
http://www.tryggtrafikk.no/w/Trafikksikkerhet/Bil/Sikkerhetsutstyr/

effect on lighter injuries is somewhat less, about 20-30%. These figures are averages for all types of accidents. More detailed investigations indicate that seat belts are more effective in frontal collisions, and that the risk of being thrown out of the car in accidents where the car drives off the road is greater if not using a seat belt.

The use of seat belts reduces traffic accident injuries, but cannot protect against all types of injuries. In most cars, for instance, the seat belt will not prevent the knees from hitting the steering column or the lower part of the dashboard. In addition, seat belts do not keep the head in place in an accident, and, in a worst-case scenario, cannot prevent the head from being thrown against the steering wheel, the instrument panel or the windshield (Elvik et al, 1997).

The seat belts in newer cars work together with airbags, seat belt pretensioners and force-limiters:

- Airbags are designed to function with the seat belt, see Chapter 2.2.4.

- Seat belt pretensioners are tensioned instantaneously in a collision to hold the passenger in place until the airbag is triggered. When the passengers move forward towards the airbag, the seat belt tension is gradually released.

- Force limiters are activated when the seat belt is exposed to a given collision force and causes the belt to be pulled off the reel (slackens) to increase the retardation distance. The force limiter reduces the force that the seat belt can transfer to the passenger in a collision, and therefore reduces the risk of injuries to the upper body. Systems which detect the weight of the person and use this as a control parameter for the force limiter are available from some car manufacturers.

2.2.3 Seat belt reminders

More and more cars are equipped with seat belt reminder systems, issuing a disturbing light and/or sound signal if the seat belt is not worn while driving. To achieve five stars in the Euro NCAP crash tests (see Chapter 2.5), the car must be equipped with a seat belt reminder.

A European study performed by Lie et al (2008) shows that seat belt reminders have resulted in a significant increase in the use of seat belts. Information about seat belt use was obtained through observations in major cities in six European countries and five cities in Sweden. A selection of car models with seat belt reminders was compared with a selection of similar car models without such reminders. About 80% of drivers who did not use a seat belt in cars without seat belt reminders, use seat belts in cars equipped with a reminder with a light signal combined with an associated loud and clear sound signal.

2.2.4 Airbags

An airbag is a collapsible bag of air that is inflated during a collision. During a collision, sensors in the car's chassis will calculate the forces that are generated in the impact. If the speed and retardation force are sufficiently strong (i.e. when forces become large enough to constitute a risk of serious injury in spite of use of seat belts), the igniter is triggered so that the airbag is inflated. The inflation takes, according to the Traffic Safety Manual, 0.05 seconds at most. After approximately 0.5 seconds, the airbag is emptied of gas. The bags are triggered in collisions that equal an instantaneous speed reduction of at least 20 km/h.

Airbags function by distributing the G forces over a larger part of the body. The airbags are often marked SRS airbag (Supplemental Restraint System). This means that the airbags are a supplement to the seat belt and are intended to be an extra protection for the head and chest in the most critical phase of an accident. The airbags can cause injury if seat belts are not worn, as the system is designed to work together with the seat belt.

Airbags have an initial velocity exceeding 300 kilometres per hour. The Norwegian Council for Road Safety therefore recommends never placing objects on the dashboard, sitting with the feet on the floor and not too close to the airbags, and never to place children shorter than 140 cm in the front seat if the car has an airbag on the passenger side.

There are two main airbag groups: front and side airbags. On the driver's side, the airbag is usually located in the steering wheel, and in the dashboard on the passenger side. In addition, knee bags are available. Side airbags are intended to protect against side impact. They can be installed in the seat side, in the door panel or in the curtain above the side doors. Today a new standard car often has six to eight airbags activated by the weight of the person, seat position, use of seat belts and collision forces. The collision angle decides which airbags are triggered. The front airbags are triggered by a frontal collision within an angle of approx. 30-35 degrees.

According to the Traffic Safety Manual, airbags reduce the risk of the driver being killed in frontal collisions by approx. 20-25%. The effect is somewhat larger for drivers without seat belts than for drivers with seat belts. The effect of airbags on the driver's likelihood of suffering serious injury if accidentally driving off the road is about equal to the effect on the likelihood of being killed in a frontal collision. For adult passengers, airbags seem to have less effect than for drivers. No studies have been found on the effect of side airbags in doors on injuries in accidents.

2.2.5 Securing loose items in cars

Newton's second law (force F = mass $m \cdot$ acceleration a) means that an object of 20 kg during a sudden stop at 50 km/h will constitute a force/weight of approx. 200 kg (2000 N, assuming a retardation of 10 G). When an object has not been secured, it will continue forward at 50 km/h in an instantaneous stop, with a force that can be lethal if it strikes a head. An unsecured passenger or dog will therefore constitute a major risk for other persons in the car in a collision.

2.3 Effect of safer cars

A review by SINTEF (Sakshaug and Moe, 2006) shows that with the 2005 replacement rate for passenger cars in Norway, most pre-2000 models will not be replaced until 2017. If this process is advanced by five years through various measures, the number of persons killed in traffic can be reduced by 250 up to 2020, only due to the improvement in passive car safety up to 2004. In addition, there is the effect of future improvements in the cars' passive and, not least, active safety. There has been a major improvement in the cars' passive and, not least, active safety after 2004, for instance anti-skid systems have become increasingly common.

The Institute for Transportation Economics (Høye, 2011) has studied to which extent safer cars have contributed to the decline in serious traffic injuries and fatalities (from more than 800 in 1999 to less than 600 in 2009). To compare the effects of different car-related measures, Figure 2 shows the effect of all the measures on the risk of being killed or seriously injured, while Figure 3 shows the percentage of effect of each measure.

Seat belts have the greatest effect on the risk of being killed or seriously injured (K/SI). The use of seat belts reduces the risk of being killed or seriously injured by approximately 30% for drivers and front-seat passengers. However, seat belt reminders have only contributed to 13% of the overall reduction in the number of K/SI as a result of car-related measures, partly due to the fact that so many drive with seat belts in any case. Another important issue is that the seat belt use among K/SI is much lower than in traffic in general, explained partly by the risk of being killed or seriously injured increasing without seat belts and partly by many of those driving without a seat belt having an increasing risk of accidents due to other forms of risk behaviour.

After seat belts, improved passive car safety (four or five stars in EuroNCAP) and anti-skid systems, an active car safety measure, have the greatest effect on the risk of K/SI (-10% for each of the measures). Improved passive safety and anti-skid systems have also contributed the most to the reduction in the number of K/SI due to car-related measures from 2000 to 2009 (-33% and -28%). Frontal and side collision airbags have contributed approximately the same to the reduction in the number of K/SI (-14 and -12%). Side collision bags have been less common, but have a slightly greater effect on the risk of being killed or seriously injured (-5% vs. -4%). If looking only at front and back seat passengers, both measures have a greater effect on the risk of being killed or seriously injured.

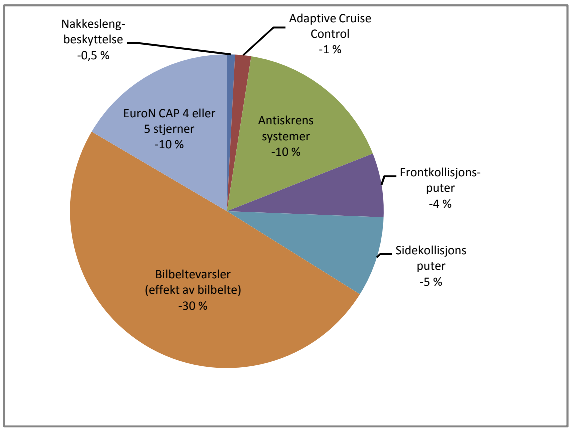

Figure 2: Effect of the car-related measures on the total number of K/SI. (Source: Høye, 2011)

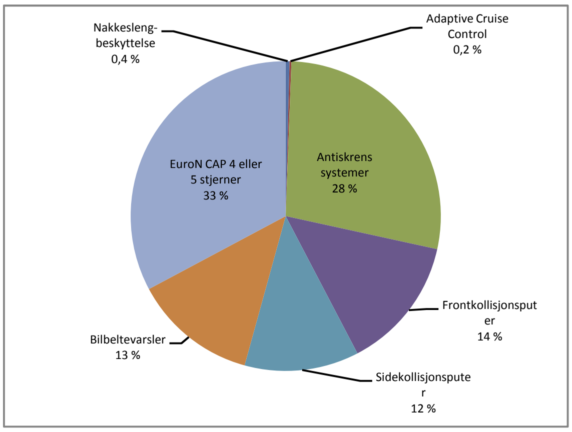

Figure 3: Relative contribution from the measures to the reductions of the number K/SI in 2000-2009. (Source: Høye, 2011)

2.4 Collision forces and human tolerance

If the speed in a collision is sufficiently high, it will not help with a new car with strong deformation zones, the use of seat belts and there being sufficient survival space in the car. This is due to the human endurance and the acceleration forces the body is subjected to in a collision. A powerful frontal collision in reality consists of three collisions:

1. The car stops instantaneously against another car/object.

2. The person continues forward and is exposed to forces when the body hits the interior or is restrained by the seat belt and airbag.

3. Inner collision in the body as internal organs continue forward at the same speed and are thereby displaced or torn off.

G force is an inertial force used to indicate the acceleration force that a body is subjected to. The human ability to tolerate the force depends on the size, direction and duration of the acceleration of gravity[5]. The extent of the injuries in a car accident is very much dependent on the retardation time and the impact surface which the body hits (for example seat belt, airbag, car interior).

At 5*G* the human body is exposed to five times its own weight. A normal person can normally tolerate about 5*G* (50 ms^2) without losing consciousness. A healthy, well young person can survive 50*G* over a short period of time. 100*G* or more is most likely always fatal.

In a car accident, the G forces that occur are related to the car's speed change during the collision time:

Acceleration = $a = \Delta v / t$

It is common to use an average value of $t = 0.12\ s$ for the collision time.

Average G force in the collision: $G = a / g$ where $g = 9.81\ m/s^2$.

The maximum G force in a collision is approximately twice the average G force.

The following consideration can serve as a relevant comparison[6]:

- A collision at 50 km/h without seat belt corresponds to a fall of 10 metres.
- A collision at 70 km/h without seat belt corresponds to a fall of 19 metres.
- A collision at 90 km/h without seat belt corresponds to a fall of 32 metres.

2.5 Crash tests and ranking of car collision safety

Car manufacturers perform both frontal and side crash tests. Some car manufacturers also test properties during overturning and rear collisions. Euro NCAP is the leading and best-known crash test programme in Europe. The insurance company Folksam in Sweden prepares lists of car model safety, based on statistic material from real accidents.

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[5] G force. (2011-10-04) I *Store norske leksikon*. Obtained from http://snl.no/g-kraft.
[6] Based on the formula $m*g*h = ½*m*v^2$ the height of fall is $h = v^2/2g$.

2.5.1 EuroNCAP

2.5.1.1 *History:*

In the 1970s, the authorities of several European countries had tried to set standards for passive safety in cars. This was done through the European Experimental Vehicles Committee (EECV), a EuroNCAP predecessor. In the early 1990s, the research performed by EECV resulted in the development of full-scale test procedures for protection of drivers and passengers in frontal and side collisions, as well as a procedure for testing how injuries to pedestrians was a function of the design of the front section of cars. The programme and test procedure were ambitious right from the start, and the initiators were determined to ensure that testing was scientific.

For comparative testing of multiple car models, it became clear that the test requirements would have to be stricter than those for type approval of cars. Detailed test protocols - the Assessment Protocol - were therefore developed through access to new research results and experts worldwide. Procedures were prepared for expert inspection of cars that could also be expanded to cover a greater range of collision types and the spaces and positions in which drivers and passengers sat.

In 1994, a proposal for EU Directive 70/156/EEC was made from EECV to the effect that the test procedures should be included in European legislation. The car industry vehemently opposed the proposal. The UK Department of Transport designed the first NCAP organisation with a view to expanding this to cover other European countries, and in November 1996 the Swedish Vägverket, Federation Internationale d l'Automobile (FIA) and International Testing joined forces to establish EuroNCAP. EuroNCAP was first seated in England, but later moved to Brussels (1999). In 2011, there were 12 members in EuroNCAP and eight countries are represented in the consortium.

In February 1997, the first tests of Adult Occupant Protection and Pedestrian Protection were presented at a press conference. The results attracted major attention, but were also negatively received by the car industry, which criticised EuroNCAP's test results and classifications. One of the counterarguments was that the requirements were so strict that no car could achieve four stars. In July 1997, new test results were published, with the Volvo S40 the first car to be awarded four stars in EuroNCAP.

In 2001, a new milestone was reached when the Renault Laguna became the first car to achieve five improved stars. After this, car standards have improved steadily, and achieving five stars has become more common. Car manufacturers have now set achieving five stars in EuroNCAP as a goal when developing new models.

In November 2007, EuroNCAP announced a testing procedure and rating for child safety: New Child Protection Rating. The rating is based on an evaluation of the car manufacturers' recommendations for securing an 18 months' old child and a three-year-old. The intention of introducing the child protection rating is to provide consumers with information about what kind of protection car manufacturers can offer for securing children in cars.

In February 2008, the first pick-up truck tests were performed. The background was a tendency for these cars not to be marketed for transporting various forms of cargo, but for marketing them as family cars through designing them with larger compartments. None of the pick-up trucks have achieved more than four stars.

In November 2008, EuroNCAP announced the results of whiplash tests from collisions from the rear for the first time. The results showed that car manufacturers had a fair way to go to design car seats that provide better protection against whiplash injuries. This new whiplash test became part of EuroNCAP's new rating programme, launched in February 2009.

In 2007, and in spite of good results as regards protection of adults in cars, 67% still only received two stars when testing the cars' protection of pedestrians. EuroNCAP observed that many car manufacturers were concerned with achieving high results for adults in cars to attract buyers, but investments in other forms of safety were given lower priority. EuroNCAP has faith in consumers being concerned with all types of safety offered when buying a new car, not just for those inside the car, but also for other road users, including pedestrians.

Based on this, EuroNCAP developed and introduced a new rating system in 2009, aiming to reward the general safety of car models, i.e. in all test areas. The achievable maximum is still five stars, but the new, overall rating system aims to reflect the protection the car offers to adults and children in the car, as well as pedestrians. For the first time, the safety potential in so-called Advanced Driver Assistance Systems (ADAS[7]), particularly Electronic Stability Control (ESC), is also included.

2.5.1.2 *The crash tests*

In EuroNCAP's test programme, cars are tested in frontal collisions at a speed of 64 km/h. The car hits a deformable barrier which is placed to one side of the car (see Figure 4). This represents the most common type of accident resulting in serious or fatal injuries. The speed has been selected to equal half of all accidents with injuries. Half of all accidents with injuries take place at lower speeds, and half at higher speeds. The test simulates a car in a frontal collision with an equally heavy car both at a speed of 55 km/h. The difference in speed is a result of energy being absorbed by the deformable barrier. The barrier is placed to one side of the car as most frontal collisions only involve some of the frontal section of the car.

A frontal collision between two identical cars at 55 km/h corresponds to the cars being exposed to an average force of 13 *G* (based on Chapter 2.4). The AIBN has received information that EuroNCAP is considering the introduction of a full-width frontal test for higher speeds as well. Full-width frontal tests at 55 km/h are the standard US test method.

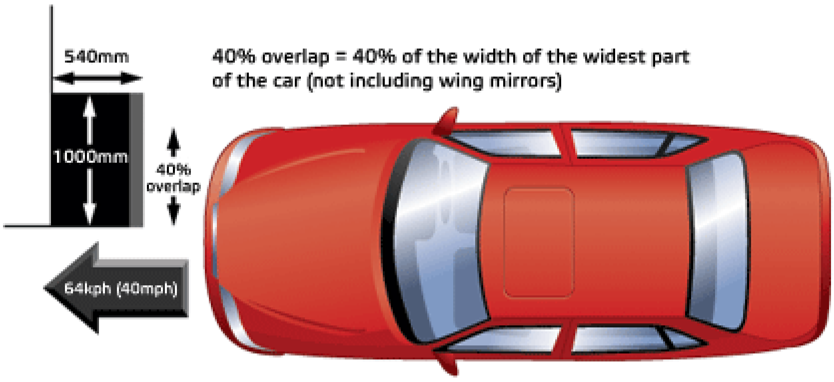


Figure 4: EuroNCAP frontal collision.

[7]ADAS examples: night vision, lane departure warning, adaptive cruise control, intelligent speed adaption (ISA), collision avoidance system, adaptive breaking assistant etc.

EuroNCAP simulates a side collision car against car by a mobile, deformable barrier hitting the driver's door at a speed of 50 km/h (see Figure 5).

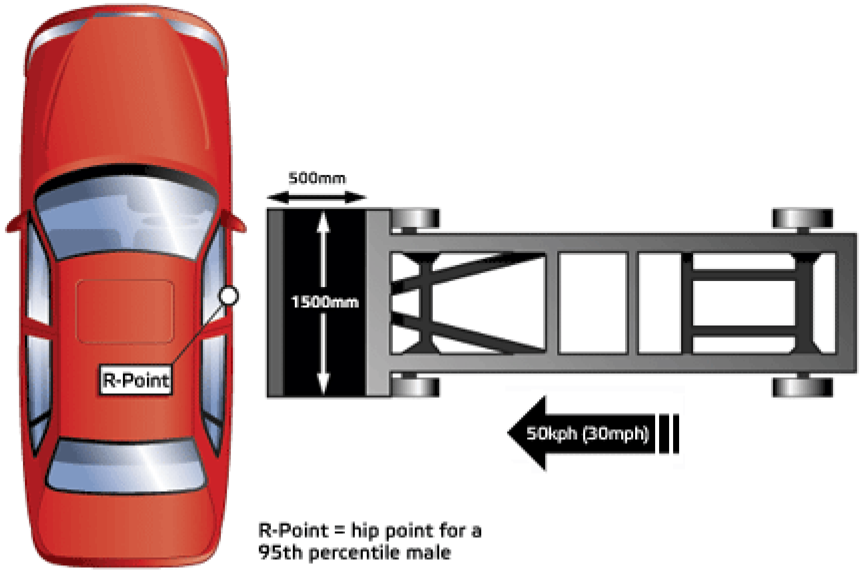


Figure 5: EuroNCAP side collision.

EuroNCAP tests are mainly a test of how well the cars protect against intrusion. By preventing intrusion, the risk of persons being hit by the car's interior is minimised, providing space for the car's protection system to work in an efficient manner.

The AIBN has learned that estimates of 35 *G* are typical peak values for the G forces the car's centre of gravity is exposed to at the test speeds. Up to the chosen test speeds, the persons in the car will suffer light injuries - depending on the car's collision protection. EuroNCAP has not observed that cars have scored less at low speeds as a result of scoring better at high speeds.

The difference of the forces the driver/front-seat passenger is exposed to, compared with the back-seat passengers in a frontal collision, depends on the intrusion. Everyone in the car will experience the same forces from the speed reduction, but the driver suffers a greater risk of the car collapsing and thereby suffering intrusion injuries. In older cars, which were softer and weaker, this was common. People in the front of the car were killed, while the back-seat passengers experienced a slower and softer speed reduction. This is different from modern cars, as they rarely experience intrusion in the front, but also somewhat higher acceleration for the back-seat passengers. For this reason, protecting children by using child car seats designed for installation with the back to the direction of travel is even more important.

2.5.2 The Folksam list

Folksam, along with the Swedish road authority Vägverket, conducts its own studies…in addition to EuroNCAP crash tests. Folksam conducts these tests to make it easier for consumers to choose a safe car. Of the car models from 2011, 14% (46 car models) were approved in Folksam's list of safe and environmentally friendly cars. Folksam has also selected 13 cars from different vehicle classes and prepared a best-in-class list.

2.6 Who does not use seat belts, and why?

SINTEF Technology and Society has prepared a study for the Norwegian Public Roads Administration concerning why drivers and passengers involved in traffic accidents with fatalities and serious injuries did not use seat belts (Moe et al, 2009).

For the period 2000-2004, the STRAKS accident register shows that almost 90 per cent of the killed or seriously injured without seat belts were drivers or passengers in passenger cars or vans[8]. The age group from 15-35 years has the lowest seat belt use percentages, and men generally use seat belts less than women. Of everyone killed or seriously injured in cars without seat belts, the following target groups amount to 60%:

- Girls ages 15-17
- Women and men ages 18-21
- Men ages 22-35

There are many explanation factors as regards why people do not use of seat belts, both psychosocial and situational factors apply and are connected to age and maturity, gender and travel purpose. In its study, SINTEF has arrived at three main groups as regards use of seat belts:

- People who (practically) always use seat belts: This group can contribute as role models and seat belt reminders. By continuing the good habit of wearing seat belts, they not only protect themselves, they also encourage others to do the same.
- People who use seat belts occasionally: In this group, failure to use of seat belts is a result of bad habits. The comprehension platform is important here to develop good habits, while good habits must be incorporated/practiced.
- People who are conscious non-users: Some people are convinced that seat belts can result in situations where they cannot get out of the car, while others want to decide for themselves whether they should use seat belts. Some have a medical certificate to the effect that they do not have to use seat belts.

2.7 Seat belt campaigns

Traffic safety campaigns are used in all countries with the main aim of reducing the number of traffic accidents and fatalities and injuries.

2.7.1 The CAST EU project

2.7.1.1 *Results*

The EU project Campaigns and Awareness Raising Strategies in Traffic Safety (CAST) was implemented from 2006-2009 (see Vaa and Philips, 2009). CAST is a follow-up of

[8]The STRAKS accident register lacks information on whether seat belts were used or not for about half the killed or seriously injured persons in cars. The STRAKS accident register can therefore not provide the correct number of killed or seriously injured without seat belts. However, the data can provide the relative distribution of such injuries, for example as regards age and gender, and when and where such accidents happen.

the GADGET project[9] is also far more comprehensive and was exclusively about campaigns, the effect of campaigns, influence theories and evaluation of campaigns.[10] The methods used to calculate effects were also better and more sophisticated than those used in GADGET. This applied in particular to factors that can explain why campaigns can have an effect on use of seat belts and accidents, which were the two groups analysed in the CAST project.

The CAST project is the most comprehensive study of campaigns and their effect ever conducted including evaluation studies from the last 40 years – i.e. from 1970 to 2009. A total of 228 studies were identified and 182 of them could be used in the database developed for the analyses. All studies included in GADGET were also included in CAST, but the database was significantly larger in CAST. One study can contain more than one result, and the 182 studies covered 437 results in total. Of these, 133 concerned seat belts or securing children. None of 228 campaigns had cargo securing as its topic.

The average effect on use of seat belts from seat belt campaigns was 25%, (+18; +31). When evaluating this high figure, the Institute for Transportation Economics explains that it must be kept in mind that most of the campaigns were conducted in the 1980s, and in situations where the usage percentage was low to begin with (almost 80% of the studies were conducted in the US). It is also a fact that the effectiveness of a seat belt campaign is lower the higher the usage percentage prior to the campaign, which may be relevant to Norway as the usage percentage is already high.

The CAST project developed models to explain what produces effect from seat belt campaigns. The factors included in the final explanation model were:

- Usage percentage (when the campaign starts)
- Limitation: Was the campaign aimed at a limited/delineated population?
- Was the message communicated in the road environment?
- Was use of police controls part of the campaign?
- Was humour used in the communication of the message?
- Were non-shocking consequences of non-use shown?
- Duration of the campaign
- Was the campaign message communicated/combined with use of mass media (TV, radio, newspapers)?
- Were role models used?

[9] The EU project Guarding Automobile Drivers through Guidance Education and Technology (GADGET) concluded in 1999 (se Vaa et al, 1999).

[10] The Institute for Transportation Economics participated in both the GADGET and the CAST projects. The Institute for Transportation Economics also developed the methods used to calculate the effects of campaigns.

The analyses showed the following results:

+	• Low usage percentage at the beginning of the campaign • Limited area/population • Presentation of the message in the road environment • Use of police controls
–	• Use of humour in the communication of the message • Showing non-shocking consequences of failure to use seat belts
Neutral	• Short duration of the campaign • Communication of the message combined with use of mass media • Role models

There is an increase in usage percentage when this is low to begin with, when the campaign targets a limited area or population, when the message is presented in the road environment and with use of police controls.

Furthermore, there is a reduction in usage percentage when using humour to present the message and when the consequences of failure to use seat belts are presented in a non-shocking manner.

Short duration of the campaign, combined use of mass media, and role models do not affect the usage percentage either way.

2.7.1.2 *Comments from the Institute for Transportation Economics*

The Institute for Transportation Economics has some comments to these discoveries. Primarily, this concerns primarily campaigns held in the US where the usage percentage has been significantly lower than in Norway. Secondly, it is recommended showing the campaign message to car drivers while driving along the roads. This is something done in Norway through the large ”Remember seat belts” posters that allude to caring about and showing concern and consideration for others (see Chapter 2.7.5). The third item is about role models, which in this case seems to have no special effect. This is a bit surprising as it has been observed that role models have an effect in campaigns aiming to reduce the number of accidents. This can be in connection with the positive effect of holding seat belt campaigns aimed at limited areas or populations. If envisioning that such campaigns use roadside rest stops, parking lots, petrol stations or local communities, schools and such, this may already have a major role model element, to make this avoid registration as an independent impact channel.

2.7.2 US study

In 2005, a study was published in the US concerning the effect of strategies to influence the use of seat belts among young people, based on a comprehensive literature study. The study was financed by the National Highway Traffic Safety Administration (NHTSA) and carried out by the Pacific Institute for Research and Evaluation. They reviewed 270 reports or publications regarding strategies to influence the use of seat belts.

The main conclusion was that it is most efficient to combine strategies using knowledge dissemination, use of public spaces, high-profile regulatory enforcement and ensure involvement of people locally. They pointed out the following aspects:

- Emphasis on the use of seat belts in driver education. With a graduated driving licence, drivers can be denied further training if they are caught not using the seat belt.
- Using UPU (ungdom påvirker ungdom - young people influencing young people) as a communication method.
- Strengthen parents as monitors to act as role models for young people.

Furthermore, they mentioned that technological solutions such as seat belt reminders and opportunities for preventing the car from starting or young people from using the radio or playing CDs could be alternative solutions.

2.7.3 Seat belt campaign tool box

Transport Research Laboratory developed a tool box for how to conduct campaigns to promote use of seat belts on assignment from the FiA Foundation for the Automobile and Society. The document (FiA, 2004) refers to several campaigns held all over the world, and presents a lot of good advice for how to proceed. They set up the following items for planning a campaign:

1. Define the problem.
2. Determine goals.
3. Who are the most important partners?
4. Who will be responsible for and conduct the campaign?
5. Use expertise on the target group and message design.
6. Have specific goals directed at easily recognisable and measurable behaviours.
7. Design messages that are short, catchy and to the point.
8. Hold the campaign in nation-wide prime time, followed by plenty of advertising.
9. Evaluate the campaign.

The CAST project developed a manual (Delhomme et al, 2009) for how to develop, apply and evaluate traffic safety campaigns. This is a book of 300 pages which shows how much can be said and considered as regards conducting campaigns.

Figure 6: Here are some examples of posters used in campaigns in some countries (FiA 2009).

2.7.4 Campaign evaluation

Evaluation of campaigns has not always been given priority, e.g. for cost-related reasons. The evaluations have therefore been omitted or been given a limited scope, reducing the opportunity to ascertain whether the campaign has had any effect, while learning from the execution of the campaign.

Although it is not possible to refer to isolated results/effects of a campaign, one should not characterise the measures as meaningless. As in everything else, there are good and poor information measures. The information will often be an aid to focusing on problems where other measures can be more directly suitable for altering behaviours/accidents. Moreover, this is a way of maintaining a dialogue between the responsible institutions and the population. In this manner the traffic-related information process is part of the information people are exposed and relate to every day.

What can happen and what can be considered to be results or effects of information campaigns are the following aspects:

- Raising awareness of an issue or behaviour.
- Increasing the information available concerning an issue or subject.
- Contribute to create perceptions, especially where no established perceptions exist.
- Make a problem more prominent, and therefore make the target group more sensitive and susceptible to other influence.
- Stimulate discussion and debate regarding a topic/issue.
- Create interest and stimulate searching for more information.
- Reinforce already existing ideas, perceptions and behaviours.

In its recommendations for future campaign work, the GADGET report raises the topic of evaluation of campaigns, and concludes with the following aspects:

- Governments and local authorities should no longer be willing to spend taxation on campaigns that do not include a detailed report of the rationale and detailed results of the campaign.
- Governments and local authorities should no longer spend taxation if a campaign presents no or weak methodology of evaluation.
- Co-operation between policy makers, safety researchers and communication practitioners must be encouraged leading to better evaluation of future campaigns.
- Process-oriented and effectiveness-oriented research on road safety campaigns must be supported.

It is not always easy, or even possible, to measure accurate and isolated effects of campaigns, but the general development as regards whether the campaign is meaningful and headed in the right direction can be determined. To learn from a campaign, measures or an action with a view to future campaigns, it is important to emphasise the planning work and evaluate all or parts of the campaign. Equally important as regards evaluation is to assess how the work has been performed, and not just the experiences and opinions of the target group.

Many campaigns and actions have been implemented without questioning the idea underpinning the campaign itself. In 2001, SINTEF concluded a study of several nationwide traffic safety campaigns which the Norwegian Public Roads Administration had conducted together with partners. The following critical questions were raised (SINTEF, 2001):

- Is the idea underpinning the campaign based on impulse or reflection?
- Are the issues the right ones?
- Which agencies, institutions and persons have been involved?
- How was the work organised and coordinated?
- Are the financial and personnel-related resources commensurate with the goals of the campaign?
- Have the campaigns been evaluated, and if so, how and with what result?

2.7.5 The Norwegian Public Roads Administration's seat belt campaign

The seat belt campaign "Husk bilbelte" (remember seat belts) was launched by the Norwegian Public Roads Administration at the end of May 2003 and the activities under the auspices of the campaign has been held every year since. The campaign mainly consists of three pictures illustrating concern/caring in association with the text "Remember seat belts”. The campaign is a combination of controls, information and posters along the road network.

Reference is made to Norwegian Public Roads Administration's website for the campaign:

www.vegvesen.no/Fag/Trafikk/Trafikksikkerhetskampanjer/Bilbelte

Figure 7: Pictures from the Norwegian Public Roads Administration's seat belt campaign.

To establish knowledge of the campaign and the chosen expressions, newspapers, magazines/periodicals and partly the internet were used as the main channels early in the campaign period. Signs along the roads were seen as one of the main pillars of the campaign throughout the entire campaign period, from the end of May and until the end of August. Over the course of the summer, the campaign could also be seen on the national TV channels NRK and TV2. The signs can still be seen on some Norwegian roads.

The following is quoted from the Norwegian Public Roads Administration's summary of the evaluation results:

> *- The campaign has received plenty of attention, much more than similar campaigns in the areas of travel/transport*
>
> *- People have primarily noticed the signs along the road*
>
> *- People remember well both the pictures and the message "Remember seat belts".*
>
> *- The audience has a very positive impression of the campaign. This has primarily been created by the pictures and especially the picture "adult – child".*
>
> *- There are indications that the campaign has led to a more positive opinion on the use of seat belts.*
>
> *- After the campaign, there are indications that seat belt use is higher for drivers driving long distances.*

2.8 The 2010-2013 National action plan for road traffic safety

The 2010-2013 National action plan for road traffic safety has been prepared by the Norwegian Directorate of Public Roads, the Norwegian Police Directorate, the Norwegian Directorate of Health, the Norwegian Directorate for Education and Training and the Norwegian Council for Road Safety. The plan is based on the 2010-2019 National transport plan (NTP). The purpose of the plan is to show the challenges traffic safety work in Norway is facing and which measures will be implemented in the plan period to achieve the goal of reducing the number of killed and seriously injured persons in road traffic by a third by 2020.

It is stated that all the measures from the traffic safety players combined will contribute to a reduction of 165 killed and seriously injured persons overall by 2014. In addition, trend extrapolation of the vehicles on the roads will contribute to a reduction of 90 persons, and the expected traffic growth will result in an increase of 55 persons.

From the list of road user measures, the following items of relevance for the thematic investigation are listed below (responsible main player in parenthesis):

> *43. Focus more on information about correct use of seat belts* (Norwegian Public Roads Administration).
>
> *44. Execute the campaign "Remember seat belts" with goal-oriented controls and mass communication directed at young drivers and passengers* (Norwegian Public Roads Administration).
>
> *45. Spread more information about securing children in cars to achieve correct installation of child seats and to emphasise hazards in connection with airbags* (Norwegian Public Roads Administration, Police, Norwegian Council for Road Safety).
>
> *46. Perform counting campaigns to monitor the development as regards backward-facing securing of children in cars* (Norwegian Council for Road Safety).
>
> *58. Increase the number of visible seat belt controls to achieve a higher perceived risk of being discovered among road users* (Norwegian Public Roads Administration, Police).
>
> *59. Hold targeted controls where seat belt use figures are low, for example in locations and at times where the most risk-exposed youth groups are often on the road*(Norwegian Public Roads Administration, Police).
>
> *59. Combine seat belt controls with other controls to a greater extent* (Norwegian Public Roads Administration, Police).

In addition, it is stated that the Norwegian Directorate of Health will look into the exemption practice of physicians as regards use of seat belts.

3. FACTUAL ACCIDENT INFORMATION

In total, 46 persons were involved in the eight investigated accidents. Of them, 26 were killed, 10 were severely injured and 10 suffered only minor injuries. The further review of the survival aspects in the individual accidents will only refer to the killed and seriously injured.

In consideration of the many people involved and next of kin, the AIBN has chosen not to state the exact time and date of the accidents.

3.1 Accident 1: Head-on accident on the E134

3.1.1 Summary of the course of events

In a right curve, a passenger car (Mitsubishi Lancer) lost traction and crossed over into the oncoming lane. The passenger car collided with a Scania lorry with trailer coming the other way () in the middle of the front. At the moment of the collision, the lorry with trailer was about 1.6 metres to the left of the right edge line in its own lane. The passenger car was moved approx. 15 metres back and to the side after the impact.

The speed limit at the location was 80 km/h. Information from the Police and the Norwegian Public Roads Administration indicates that the speed of the passenger car was about 65-70 km/h when it lost traction, while the lorry held a speed of approx. 24 km/h (from the speed recorder). It was snowing lightly with snow and slush on the road when the accident happened.

There were five persons in the passenger car, and the driver and two passengers were killed, while two passengers were severely injured. The driver of the lorry suffered no physical injuries.

3.1.2 Speeds and loads in the collision

A Mitsubishi Lancer passenger car with 5 people has a total weight of 1525 kg[11]. The lorry with trailer had a total weight of 51 700 kg.

Calculations of the collision speeds and loads performed by the engineering firm Rekon DA in the Scan-crash computer program gave the following results:

	Kollisjonshastigheter (km/h)		Belastninger i kollisjonen			
	Personbil	Vogntog	Personbil		Vogntog	
			H.endr.*	Kraftretn.**	H.endr.*	Kraftretn.**
Minimum	42	24	71	-180	2	-180
Maksimum	69	36	93	-180	3	-90
* Hastighetsendring på bilens tyngdepunkt i km/h						
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning. Vinkel mot urviseren om vertikalaksen positiv						

[11] The calculations assume that each person weighed 75 kg.

The simulation shows a collision speed between 24 and 36 km/h for the lorry and between 42 and 69 km/h for the passenger car. The passenger car was exposed to a speed change of between 71 and 93 km/h with the force direction approximately directly backwards in relation to the car. The lorry's speed change in the collision was minimal.

Figure 8: Collision position - Accident 1.

3.1.3 Investigation of the vehicle internally

3.1.3.1 *Mitsubishi Lancer*

The Mitsubishi Lancer 1996 model is classified with medium safety in the Folksam list and with two (not full) stars in EuroNCAP (4 points in the frontal crash test and 11 points in the side crash test). As regards safety gear, the Mitsubishi had airbags in front, in the steering wheel and in the dashboard on the right side, and both were triggered in the accident. There were no seat belt pretensioners[12] or force limiters[13] on the seat belts in the car.

The passenger car sustained major damage to the front, with the compartment being displaced by approx. 70 cm.

It has been uncovered that only the driver and the front-seat passenger were wearing seat belts. None of the three back-seat passengers were using seat belts. They were therefore thrown into the seats in front in the collision.

Survival space has been found for all seats in the car, but with some limitation for the driver's seat, where the compartment had been pushed in in the lower part of the dashboard. The driver's seat belt had been twisted in the upper seat belt anchor, and the belt had therefore not moved in the slide. This, combined with findings in the

[12] Seat belt pretensioners are tensioned instantaneously in a collision to hold the passenger in place until the airbag is triggered.
[13] The force limiter reduces the force that the seat belt can transfer to the passenger in a collision, and therefore reduces the risk of injuries to the upper body.

reconstruction, may indicate that the belt was slack across the chest. The back of the driver's seat had been pushed forward with great force by the unsecured backseat passenger(s) and the steel framework had a likely cranial impression. The steering wheel and the lower part of the dashboard were deformed.

The compartment had also been pushed in towards the right-hand passenger seat. The seat back had been pushed forward 12 cm by the unsecured back seat passenger. The upper seat belt anchor seems to have yielded somewhat, but did not snap, and the seat belt probably functioned. The lower part of the dashboard was deformed.

Seen together, the internal damage to the back of the driver's seat (cranial impression and pushed forcefully forward) and the final positions and injuries of the backseat passengers (passenger with head injury found on the floor behind the driver's seat), indicate that one of the passengers sat unsecured in the boot.

Figure 9: Damage to the front of the Mitsubishi Lancer. Survival space for all seats in the car except the driver's seat.

Figure 10: Restricted survival space for the driver's seat.

3.1.4 Injuries and injury mechanisms

Table 1: Injuries and injury mechanisms Accident 1

Mitsubishi Lancer 1996 model							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**[14]	**Injury mechanisms**
Driver	M 54	162 cm, 90 kg	Dead	+/- Slack across the chest due to twist in upper seat belt anchor	+/-	Complex trauma. Cause of death: Extensive crushing injuries.	Dashboard and steering wheel pushed in. Seat back pushed forward by unsecured back-seat passenger. Injuries are partly due to rapid deceleration (inner chest injuries), impact on the car's interior (head injuries, chest injuries, femoral fracture) and crushing (abdominal injuries).
Front-seat passenger	F 32	175 cm, 75 kg	Dead	+	+	Cause of death: Chest crushing injuries.	Legs and knees slammed into the dashboard. Seat back pushed 12 cm forward by unsecured back-seat passenger. Powerful impact to the upper body from behind.
Left back-seat passenger	M 25	-	Severely injured	-	+	Fractures in left thigh and foot, as well as lower back.	Thrown forward against driver's seat.
Right back-seat passenger	M 24	-	Severely injured	-	+	Serious brain damage as a result of powerful deceleration trauma to the head. Fractures in legs, pelvis and back.	Thrown forward against the front passenger seat.
Passenger possibly in the boot	M 36	170 cm, 74 kg	Dead	-	+	Cause of death: extensive head injury as a result of powerful impact to the side of the head.	Thrown forward from the boot over the back seat against the driver's seat.
Lorry with trailer							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M		Unharmed	?	+		

[14] Conclusion regarding cause of death from coronary investigation/autopsy report.

3.2 Accident 2: Head-on accident on the Fv 13

3.2.1 Summary of the course of events

On a mostly straight stretch of road, a passenger car (Nissan Almera) skidded to the left. The car crossed over into the oncoming lane after rotating somewhat more than 90 degrees and hitting an oncoming Dodge pick-up truck (registered as a small truck). The passenger car was pushed for a few metres in front of the truck, before both vehicles ended in the ditch on the truck's side of the road.

It was dark with snow and ice-covered roads when the accident occurred. In addition, it was uncovered that the asphalt cover had tracks with a depth of up to 4.8 cm (covered in AIBN Report Vei 2010/03). Information from witnesses and findings at the scene of the accident indicate that both vehicles were within the permitted speed of 50 km/h prior to the accident.

All three persons in the passenger car died instantaneously in the accident. The driver and the passenger in the pick-up only received minor injuries.

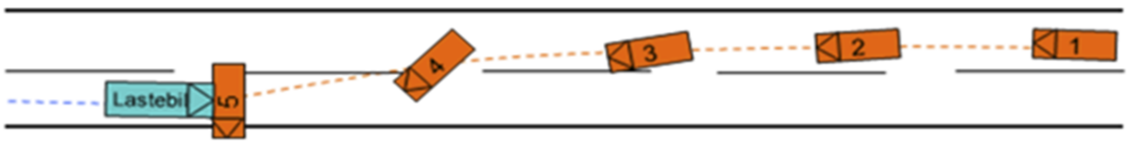


Figure 11: The passenger car skidded to the left before hitting the truck after rotating approx. 90°. (The illustration is not to scale).

3.2.2 Speeds and loads in the collision

A Nissan Almera with three people on board has a total weight of 1330 kg, while a Dodge RAM of this model and with two persons on board has a total weight of 3290 kg[15].

Calculations of the collision speeds and loads performed by the engineering firm Rekon DA in the Scan-crash computer program gave the following results:

	Kollisjonshastigheter (km/h)		Belastninger i kollisjonen			
	Dodge	Nissan	Dodge		Nissan	
			H.endr.*	Kraftretn.**	H.endr.*	Kraftretn.**
Minimum	40	24	17	-180	41	-90
Maksimum	52	26	22	-180	53	-90
* Hastighetsendring på bilens tyngdepunkt i km/h						
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning. Vinkel mot urviseren om vertikalaksen positiv						

The simulation shows a collision speed between 40 and 52 km/h for the Dodge (the truck) and between 24 and 26 km/h for the Nissan (the passenger car). The Dodge was exposed to a speed change of 17-22 km/h with the force direction approximately directly backwards, and the Nissan to a speed change of 41-53 km/h with the force direction approximately directly to the left in relation to the car in the collision. The engineering

[15] The calculations assume that each person weighed 75 kg.

firm Rekon DA has assessed the front of the pick-up truck to be 2.5-3.5 times more rigid than the side of the passenger car.

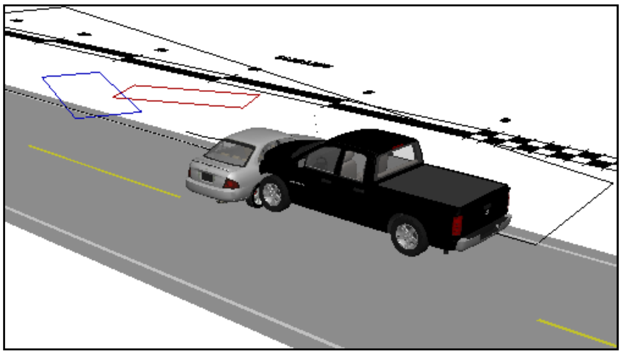


Figure 12: Collision position - Accident 2.

3.2.3 Investigation of the vehicle internally

3.2.3.1 *Nissan Almera*

The Nissan Almera 2001 model is classified with good safety in the Folksam list and with four stars in EuroNCAP (9 points in frontal crash tests and 16 points in side crash tests). Both side collision airbags in the front of the passenger car were triggered. The car did not have side collision airbags in the back. The collision airbags in the front were not triggered as a result of the side collision. There were no seat belt pretensioners or force limiters on the seat belts in the car.

The front of the truck was pushed in over the floor and into the compartment, and the passenger car suffered an intrusion of up to 70 cm on the right side. There was survival space for the driver's seat, without deformations. According to ambulance medics, the Police and personnel from the Norwegian Public Roads Administration who arrived at the site, the driver of the passenger car used a seat belt, but this cannot be confirmed by findings internally in the vehicle or by medical findings.

It has been uncovered that none of the passengers (front and rear right side) in the passenger car were secured by seat belts. There was no survival space for the passengers as a result of the intrusion from the right.

Figure 13: Reconstruction showing the vehicles' positions in relation to each other at the moment of impact.

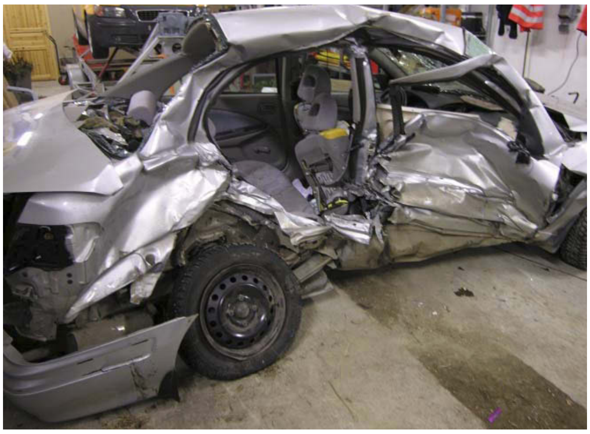


Figure 14: Major damage on the right side of the Nissan Almera. Survival space for the driver's seat, no survival space in the front and back passenger seats on the right.

3.2.3.2 *Dodge RAM*

Both front airbags of the pick-up were triggered. The driver and the passenger did not use seat belts.

3.2.4 Injuries and injury mechanisms

All the fatalities in the passenger car had transverse fractures at the base of the skull. This is a very common finding in deceleration trauma with blows to the head from one side.

Table 2: Injuries and injury mechanisms Accident 2

Nissan Almera 2001							
Person	**Gender**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**[16]	**Injury mechanisms**
Driver	F 44	158 cm, 78 kg	Dead	?	+	Cause of death: Transverse fracture through the base of the skull.	No clear impact points in the car. The direction of movement and the head injuries indicate that the driver and front-seat passenger may have had their heads knocked together.
Front-seat passenger	M 24	175 cm, 87 kg	Dead	-	-	Cause of death: Transverse fracture through the base of the skull and a fracture in the cervical vertebral column. In addition, serious injuries to internal organs have been found that would probably have been fatal on their own.	Substantial intrusion on the right side and following impact with the car's interior, windshield and driver.
Right back-seat passenger	F 18	165 cm, 53 kg	Dead	-	-	Cause of death: Transverse fracture through the base of the skull and severing of the main artery. In addition, serious injuries to internal organs have been found that would probably have been fatal on their own.	Most severe impact and intrusion here. Thrown towards the left side.

[16] Conclusion regarding cause of death from coronary investigation/autopsy report.

Dodge Ram 2003							
Person	**Gender**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M 30		Minor injuries	-	+		
Front-seat passenger	F 24		Minor injuries	-	+		

3.3 Accident 3: Head-on accident on Rv 3

3.3.1 Summary of the course of events

A Polish-registered passenger car (Nissan Terrano) with two people on board heading north lost traction on an open, straight stretch of road and crossed over into the oncoming lane. It collided with the right front side of an on-coming Mercedes Sprinter van and was then thrown back and into the roadside guardrail. The cars left no tracks headed towards the accident site.

The speed limit at the location was 80 km/h. It was dark, no road lighting and snowing lightly when the accident happened. The road was covered in ice and snow. Information from the Police and the Norwegian Public Roads Administration indicates that both vehicles held about 70 km/h when the passenger car lost traction.

The driver and the passenger in the passenger car were killed. The driver of the Mercedes Sprinter was also killed . He was alone in the car.

3.3.2 Speeds and loads in the collision

A Nissan Terrano with two people on board has a total weight of 2300 kg, while a Mercedes Sprinter with driver and cargo has a total weight of 3000 kg[17].

Calculations of the collision speeds and loads performed by the engineering firm Rekon DA in the Scan-crash computer program gave the following results:

	Kollisjonshastigheter (km/h)		Belastninger i kollisjonen			
	Mercedes	Nissan	Mercedes		Nissan	
			H.endr.*	Kraftretn.**	H.endr.*	Kraftretn.**
Minimum	65	46	50	-180	65	-90
Maksimum	75	56	59	-180	76	-90
* Hastighetsendring på bilens tyngdepunkt i km/h						
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning. Vinkel mot urviseren om vertikalaksen positiv						

The simulation shows a collision speed between 65 and 75 km/h for the Mercedes (van) and between 46 and 56 km/h for the Nissan (the passenger car). The Mercedes was exposed to a speed change of 50-59 km/h with the direction of the impact almost straight

[17] The calculations assume that each person weighed 75 kg.

backwards in relation to the car. The Nissan was exposed to a speed change of 65-76 km/h with an angle of approximately 90 degrees to the left in relation to the car.

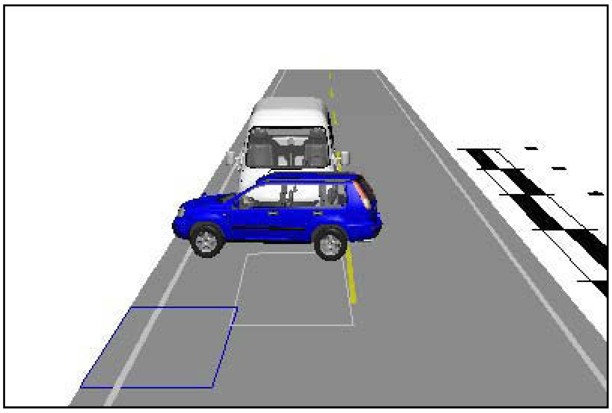


Figure 15: Collision position - Accident 3.

3.3.3 Investigation of the vehicle internally

3.3.3.1 *Mercedes Sprinter*

The Mercedes Sprinter 1996 model has not been tested by EuroNCAP and is not on the Folksam list. The van was not equipped with airbags, force limiters or seat belt pretensioners.

The car was deformed across the front, most on the right, and the compartment was displaced by 16 cm.

It was concluded that there was survival space for the driver's seat. The driver of the van had a medical certificate exempting him from use of seat belt due to claustrophobia. The belt was in its unused position and had no marks. The steering wheel was somewhat deformed. There were possible knee imprints on the dashboard below the steering wheel. The broken windshield had a possible impact mark from a head, a so-called skull imprint.

There was unsecured cargo in the boot which had been displaced forward in the collision. The separating wall behind the driver's seat had been pushed forward approx. 10 cm.

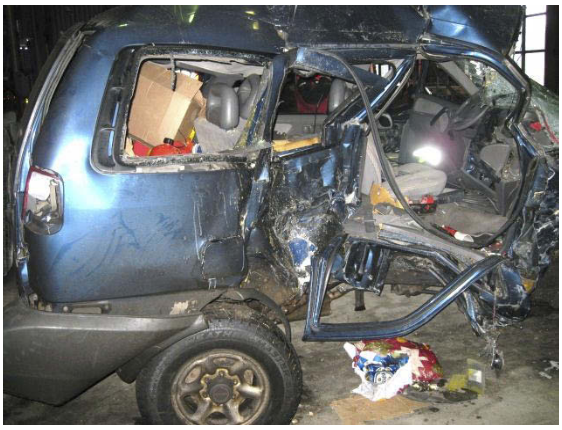


Figure 16: Damage on the right side of the Nissan Terrano. No survival space for the front passenger seat, limited survival space for the driver's seat.

Figure 17: Damage to the front of the Mercedes Sprinter van. Survival space for the driver's seat.

3.3.3.2 *Nissan Terrano*

The Nissan Terrano 1993 model was not equipped with airbags, force limiters or seat belt pretensioners. In the Folksam list, the car model is classified with poorer than average safety. The car has not been tested by EuroNCAP. The car was hit on the side and the intrusion was approx. 95 cm on the right side of the B pillar and the compartment was displaced by about 30 cm.

Both the driver and the front-seat passenger were using seat belts and both seat belts had been secured. It was not possible to see whether the seat belts had been used correctly or incorrectly. There was no survival space for the front passenger seat in the car. There was limited survival space for the driver's seat.

3.3.4 Injuries and injury mechanisms

Table 3: Injuries and injury mechanisms Accident 3

Nissan Terrano 1993							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death[18]**	**Injury mechanisms**
Driver	M 43	-	Dead	+	+/-	Autopsy not performed.	Thrown over towards the front-seat passenger.
Front-seat passenger	M 25	-	Dead	+	-	Autopsy not performed.	Full side intrusion over the passenger.
Mercedes Sprinter 1996							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M 50		Dead	- Medical certificate exemption due to claustrophobia	+	Cause of death: injuries to abdominal blood vessels with damage propagated to the abdominal cavity.	Severe deceleration trauma where the upper body has impacted with the steering wheel and deformed it. The head hit the windshield.

3.4 Accident 4: Head-on accident on the Fv 40

3.4.1 Summary of the course of events

A BMW 325i passenger car lost traction in the entrance to a left curve. The car's rear right tyre then ended up outside the road, the car started rotating and skidded over into the oncoming lane. The car collided sideways with the front into an oncoming passenger car (VW Caravelle) with five persons on board. The VW Caravelle moved to the right before the collision and left 7-metre brake marks.

The road was dry and free of snow when the accident occurred. The speed limit at the location was 80 km/h. The Norwegian Public Roads Administration has estimated that the speed of the BMW was 90-100 km/h and that the VW Caravelle held 70-80 km/h when the car started to skid.

[18] Conclusion regarding cause of death from coronary investigation/autopsy report.

In the BMW, two adults were killed instantaneously in the accident, and attempts were made to resuscitate an eight-month-old child, but the child was declared dead upon arrival at the hospital. In the VW Caravelle, a child of nine years was severely injured, while the driver and the three other passengers suffered only minor injuries.

3.4.2 Speeds and loads in the collision

A BMW with two adults, a child and some baggage on board has a total weight of 1520 kg, while a Caravelle of this model with two adults, three children and baggage on board has a total weight of 2150 kg[19].

Calculations of the collision speeds and loads performed by Rekon DA in the Scan-crash computer program gave the following results:

	Caravelle		BMW			
			mot rekkverk		mot Caravelle	
	min	max	min	maks	min	maks
Kollisjonshastighet*	42	47	69	77	59	66
Hastighetsendring*	41	46	13	16	58	65
Vinkel på kraftstøtet**	-179	-178	-190	-186	-115	-115
			Begge kollisjoner sett under ett			
			min		maks	
Hastighetsendring			66		75	
Vinkel på kraftstøtet**			-48		-49	
*: Alle hastigheter oppgitt i km/h						
**: Vinkel i grader i forhold til forover i bilen, positive verdier mot urviseren						

The calculations show that the Caravelle's collision speed was in the 42-47 km/h range and that the speed change was in the 41-46 km/h range with the direction of the force impact approximately backwards in relation to the car. The collision speed for the BMW was in the 69-77 km/h range when hitting the roadside guardrail and 59-66 km/h when hitting the Caravelle. The speed change for both collisions together was in the 66-75 km/h range with the direction of the force impact at 48-49 degrees in relation to the front of the car.

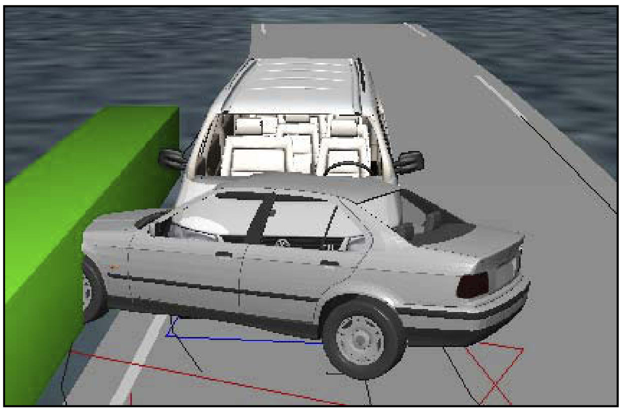


Figure 18: Collision position - Accident 4.

[19] The calculations assume that each person weighed 75 kg.

3.4.3 Investigation of the vehicle internally

3.4.3.1 *BMW 325i*

The BMW 325i was of an older model (1991) and has been classified as having medium safety in the Folksam list and with two (not full) stars in EuroNCAP (2 points in frontal collision and 8 points in the side crash test). The car had no airbags, seat belt pretensioners or force limiters. In this car, the back seat belts are installed with the upper anchor in the middle of the car and not on the door pillar, i.e. the passenger on the right side has the diagonal belt from the left shoulder to the seat belt anchor by the right hip. The energy impact hitting the vehicle was very powerful, the car was hit sideways by the Caravelle and the right side intrusion was up to 90 cm.

The windshield was broken, the steering wheel deformed and pushed towards the driver's seat along with the entire dashboard. There was survival space for the driver's seat in the car. The driver's door had been twisted and opened. After the collision, the driver was found lying with his upper body partly outside the car door and with his head on the asphalt. The chest section of the seat belt was behind his back, while the hip section was over the thighs and the belt buckle was not in the lock. It is therefore unclear whether the belt was correctly fastened when the collision happened.

In front on the right-hand side, the eight-month- old child was sitting in a baby car seat facing backwards. The child car seat was of the BeSafe brand and was fastened by the car's original seat belt, and the child was fastened in the seat with the seat's five-point belt. The child car seat had come apart in multiple sections and had been pushed over towards the driver's seat with the passenger seat itself. There was no survival space in the front passenger seat. The reconstruction as regards the final position of the child, injuries suffered by the child and wear marks on the seat belt indicate that the child's shoulder belt had not been sufficiently tightened. The passenger in the back seat used a seat belt, but there was no survival space for this seat. The seat had been pushed backwards and to the left. The person was lying with the head on the left headrest and the upper body against a ski sled in the left back seat.

Figure 19: The BMW 325i collided sideways into the front of a VW Caravelle. (Photo: the Police)

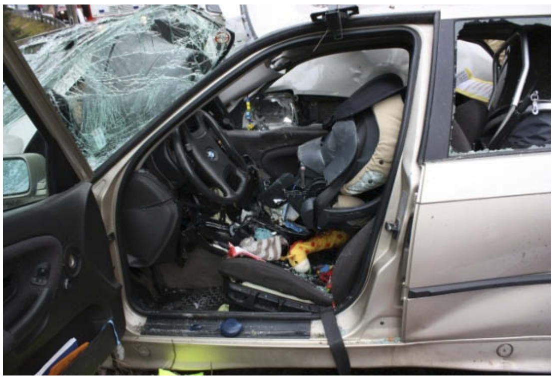


Figure 20: Damage to the front and right side of the BMW 325i (photograph: the Police). No survival space on the car's right side, survival space for the driver's seat.

3.4.3.2 *VW Caravelle*

The VW Caravelle 1994 model is listed as safer than average in the Folksam list.

The car had a broken windshield and some intrusion in the front. The compartment was almost intact. There were two adults in front and three children in the back. Everyone wore seat belts. The child in the middle back seat suffered serious back injuries. The child was fastened with a slack hip belt with a 5 cm clearance between hip and belt.

3.4.4 Injuries and injury mechanisms

Table 4: Personal injuries and survival aspects Accident 4

BMW 325i 1991							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death[20]**	**Injury mechanisms**
Driver	M 24	-	Dead	? The belt buckle was not found in the lock	+	Autopsy not performed.	Thrown to the right and forward against the steering wheel and dashboard, then hit by the baby seat and passenger seat and thrown to the left out of the driver seat door.
Front-seat passenger	M 8 months	-	Dead	+/- Shoulder belt not optimally tightened?	-	Autopsy not performed. CT examination of the entire body showed internal bleeding in the bran, air in the right cavity of the chest and fractures in the right lower leg, right lower arm, pelvis and several ribs.	Energy and intrusion from the right side. The child was thrown to the sides and forward in the child car seat. The child car seat was destroyed in the collision.
Right back -seat passenger	F 24	-	Dead	+	-	Autopsy not performed.	Side intrusion in its entirety over this passenger.
VW Caravelle 1994							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M39	-	Minor injuries	+			
Front-seat passenger	F 40	-	Minor injuries	+			
Right back-seat passenger	M 13	-	Minor injuries	+			
Passenger middle back seat	F 8	-	Severely injured	+/- Hip belt not optimally tightened.	+	Fracture in the lower back, level L3-L4.	Extended forward movement of the upper body and powerful jerk against the abdomen/hip section.
Left back-seat passenger	M 11		Minor injuries	+			

[20] Conclusion regarding cause of death from coronary investigation/autopsy report.

3.5 Accident 5: Head-on accident on the Fv 653

3.5.1 Summary of the course of events

The passenger car (Mercedes W124 E220) with four people on board lost hold on the road in a left curve approx. one km into the tunnel on the Fv 653. The passenger car skidded across all three lanes and hit the concrete railing in the tunnel on the left side before hitting a van (VW Caravelle) driving in the opposite direction. The van left brake marks for the last 8.4 metres before the collision site. The passenger car hit the oncoming van in the front in a sideways position and somewhat above the road surface. The passenger car caught fire immediately following the collision, and the car burned completely out.

The speed limit in the tunnel was 80 km/h. Based on registered skid marks, potential friction coefficients and the extent of the damage, the Norwegian Public Roads Administration has estimated the speed to the 150 – 200 km/range when control of the passenger car was lost.

All four persons in the car were killed instantaneously in the accident. The driver of the VW Caravelle, who was alone in the car, was also killed.

3.5.2 Speeds and loads in the collision

A Mercedes of this type with four persons on board has a total weight of 1710 kg, while a VW Caravelle with driver has a total weight of 1845 kg[21].

Calculations of the collision speeds and loads performed by Rekon DA in the Scan-crash computer program gave the following results:

	Kollisjonshastigheter (km/h)		Belastninger i kollisjonen			
	Mercedes	Transporter	Mercedes		Transporter	
			H.endr.*	Kraftretn.**	H.endr.*	Kraftretn.**
Minimum	125	11	72	90	67	-173
Maksimum	149	24	92	90	86	-173
	Hast. Før skr/br. (km/h)		Endring i rotasjon om vertikalaksen (rad/s)			
Minimum	152	48	-5		-0,7	
Maksimum	180	56	-7		-0,8	
* Hastighetsendring på bilens tyngdepunkt i km/h						
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning.						
Vinkel mot urviseren om vertikalaksen positiv						

The simulation shows a collision speed of 125-149 km/h for the Mercedes and 11-24 km/h for the Caravelle. The Mercedes' centre of gravity was exposed to a speed change of 72-92 km/h with the force direction to the left and slightly backwards in relation to the car. The car was also given a clockwise rotation speed around the vertical axis of 5-7 rad/s, which kept almost constant until it hit the tunnel wall. The Caravelle's centre of gravity was exposed to a speed change of 67-86 km/h with the force direction backwards and somewhat to the right in relation to the car. The car also experienced a minor

[21] The calculations assume that each person weighed 75 kg.

clockwise rotation speed around the vertical axis. The speeds prior to the collision have been calculated to 152-180 km/h for the Mercedes and 48-56 km/h for the Caravelle.

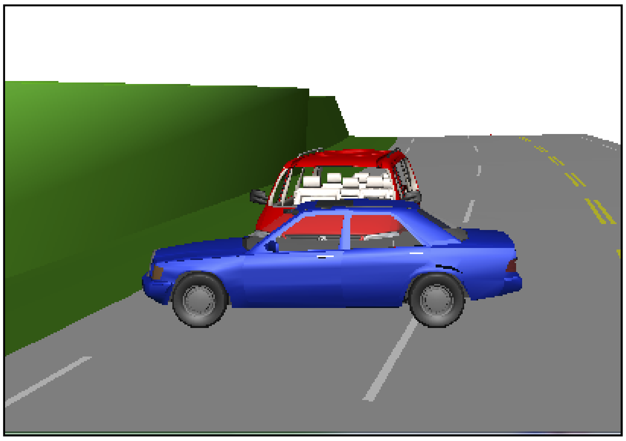


Figure 21: Collision position - Accident 5.

3.5.3 Investigation of the vehicle internally

3.5.3.1 *Mercedes W124 E220*

The Mercedes E220 1994 model is listed with lower-than average safety in the Folksam list. The car has not been tested by EuroNCAP. The car was equipped with airbags, seat belt pretensioners and force limiters in front.

The passenger car held a high speed and had multiple impact points in the tunnel. The intrusion on the right side of 80 cm at the car's strongest point (the side member) shows that powerful forces were involved. The roof was pushed down about 15 cm. There was therefore no survival space in the car before the fire started.

The passenger car was burnt out, making it impossible to describe movement or impact points in the car. Both persons in the back seat probably used seat belts as the belt buckle was in the lock. In front, everything was deformed/burned out making it impossible to ascertain whether seat belts were used.

Figure 22: Mercedes E220 completely burned out, no survival space in the car.

Figure 23: Damage to the front of the VW Caravelle. Survival space for the driver's seat.

3.5.3.2 *VW Caravelle*

The VW Caravelle 1997 model is listed as safer than average in the Folksam list. The car has not been tested by EuroNCAP. Airbag for the driver's seat and the front passenger side had been triggered. The car was not equipped with seat belt pretensioners or force limiters. The car was deformed along the entire front and the largest compartment deformation/intrusion was 50 cm (somewhat less on the left side).

The compartment around the driver's seat was mostly intact and physical survival space was found to exist. The seat belt hung in its regular position, proving that the driver did not wear a seat belt. The dashboard had displaced 35 cm in towards the drivers' seat and had impact damage from knee imprints in the lower part. The steering wheel was deformed. The windshield was broken with findings of a skull imprint.

3.5.4 Injuries and injury mechanisms

All autopsy reports state that there is no soot in the respiratory passages, meaning that they all died of other causes than the fire, even if this started relatively soon after the collision. All four persons in the passenger car died as a result of head and chest injuries in the collision.

Table 5: Injuries and injury mechanisms Accident 5

Mercedes E220 1994							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**[22]	**Injury mechanisms**
Driver	M 23		Dead	?	-	Cause of death: extensive crushing injuries to the brain and chest organs.	Not possible to describe due to severely deformed/burned-out car and body.
Front-seat passenger	M 23	188 cm, 77 kg	Dead	?	-	Cause of death: crushing injuries to the head and brain.	As above.
Back-seat passenger	M 28	-	Dead	+	-	Cause of death: various crushing injuries.	As above.
Back-seat passenger	M 30	-	Dead	+	-	Cause of death: crushing injuries to the chest, head and abdomen.	As above.
VW Caravelle 1997							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M 53		Dead	-	+	Autopsy not performed.	Steering wheel deformation consistent with impact from chest/stomach. Knee imprints under the dashboard. Head against windshield.

[22] Conclusion regarding cause of death from coronary investigation/autopsy report.

3.6 Accident 6: Head-on accident on the E18

3.6.1 Summary of the course of events

A Ford Transit minibus transported a hunting party of seven, with three dogs, a lot of baggage and a boat on a trailer. The accident occurred when a Volvo 240 passenger car crossed over into the oncoming lane and collided with the left-hand side of its front against the left-hand side of the minibus' front. In the powerful collision, the Volvo was pushed sideways and slightly forward in its own direction of travel, while the minibus continued forward in its own direction of travel and then rotated and overturned.

It was dark with no road lighting and the road was dry and free of snow when the accident occurred. The speed limit at the location was 80 km/h.

The driver of passenger car was killed. He was alone in car. The driver and a passenger in the minibus were killed, three passengers were severely injured and two suffered minor injuries.

3.6.2 Speeds and loads in the collision

The minibus had a total weight of 2975 kg and the boat trailer weighed approx. 700 kg. The Volvo had a total weight of 1355 kg[23].

Calculations of the collision speeds and loads performed by Rekon DA in the Scan-crash computer program gave the following results:

	Kollisjonshastigheter (km/h)		Belastninger i kollisjonen			
	Volvo	Ford	Volvo		Ford	
			H.endr.*	Kraftretn.**	H.endr.*	Kraftretn.**
Minimum	90	69	82	-15	30	-18
Maksimum	115	83	104	-18	38	-21
			Endring i rotasjon om vertikalaksen (rad/s)			
Minimum			5		0,9	
Maksimum			5,3		1,7	
* Hastighetsendring på bilens tyngdepunkt i km/h						
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning. Vinkel mot urviseren om vertikalaksen positiv						

The simulation shows a collision speed between 90 and 115 km/h for the Volvo and between 69 and 83 km/h for the Ford In the collision, the Volvo was exposed to a speed change of between 82 and 104 km/h, with the force direction backwards at an angle of approx. 16 degrees to the right in relation to the car. The car rotated about 5.1 rad/s counter-clockwise around the vertical axis. The Ford was exposed to a speed change of between 30 and 38 km/h with the force direction backwards at an angle of approx. 20 degrees to the right in relation to the car and a rotation of between 0.9 and 1.7 rad/s counter-clockwise around the vertical axis.

[23] The calculations assume that each person weighed 75 kg.

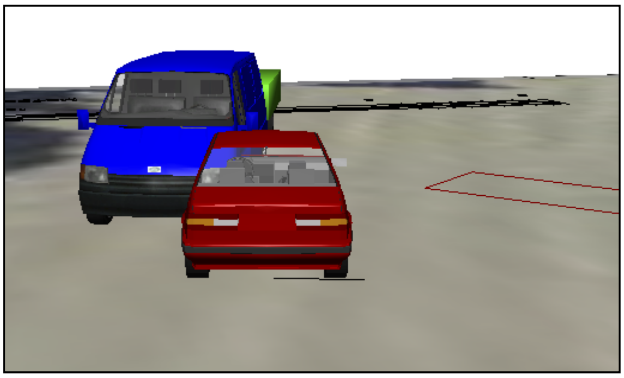


Figure 24: Collision position - Accident 6.

3.6.3 Investigation of the vehicle internally

3.6.3.1 *Volvo 240*

The Volvo 240 passenger car 1984 model is listed with medium safety in the Folksam list. The car has not been tested by EuroNCAP. The car was not equipped with air bags, seat belt pretensioners or force limiters. The passenger car hit the minibus at high speed and was totally destroyed. The driver of the Volvo used the seat belt, but there was no survival space in the car.

Figure 25: Damage to the front of the Ford Transit (photograph: Norwegian Public Roads Administration). Survival space for all seats in the car, limited space for the driver's seat.

Figure 26: Totally destroyed Volvo 240 (photograph: Norwegian Public Roads Administration). No survival space for the driver's seat.

3.6.3.2 *Ford Transit*

The minibus is a 1996 model not tested by EuroNCAP, nor is it listed by Folksam.

The Ford had an intrusion of 55 cm at the left front. This car was equipped with airbags in front and both had been triggered. The car had also had seat belt pretensioners in the front, but no force limiters. There were seven people in the car, three in front, three on the second row and a person on the right in the third row. Figure 25 shows the passengers' location in the car, degree of injury and use of seat belts.

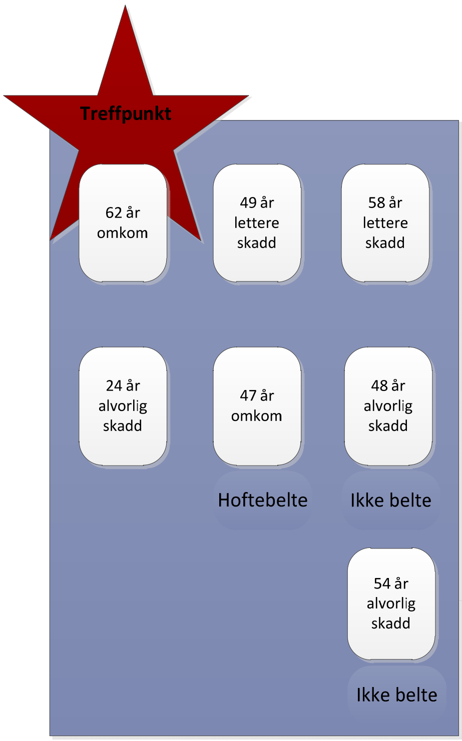


Figure 27: The passengers' location in the Ford Transit, use of seat belts and degree of injury.

Behind and to the left of the passenger in the third row, there was loose cargo in the form of a 200 kg freezer, hiking backpacks, other equipment, as well as three loose dogs not secured in dog cages. After the accident, two of the dogs were taken care of by a veterinarian, while one dog ran away and had to be searched for by the local game board. The AIBN has not investigated more about the dogs.

There was survival space for all seats in the minibus, except for the driver's seat. The three passengers in the front of the car and the passenger on the left side all used three-point belts. At the time of the accident, the seat back for the passenger in the second row on the left had been lowered to a reclined position. The passenger in the middle of the second row was secured with a hip belt. The passengers on the right side in the second and third row were both unsecured. The rear passenger was hit in the back by the 200 kg freezer and was thrown forward against the passenger in front.

3.6.4 Injuries and injury mechanisms

Table 6: Injuries and injury mechanisms Accident 6

Ford Transit 1996							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death[24]**	**Injury mechanisms**
Driver	M 63	179 cm 94 kg	Dead	+	-	Cause of death: extensive acute injuries to the head, chest and legs.	Intrusion in the left front. Severe decaleration, impact against upper body, crushing/cutting injuries to the legs. Serious chest injuries as a result of impact against the diagonal seat belt, head injury as a result of impact against interior.
Middle passenger in front	M 49		Minor injuries	+			
Right front passenger	M 58		Minor injuries	+			
Left back-seat passenger	M 24		Severely injured	+	+	Multiple compression fractures in the back.	Seat back lowered to the reclined position.
Passenger middle back seat	M 47	178 cm 78 kg	Dead	+ Hip-belt	+	Cause of death: internal bleeding from injury to the aorta.	Upper body thrown forward against front seats. All injuries stem from powerful blunt force hitting the body from the front/left.
Right back-seat passenger	M 48		Severely injured	-	+	Bleeding in side artery to the aorta, minor crushing injuries in the lungs and spleen and a fracture in the lower arm.	Unsecured cargo/ passenger behind in the seat back (displaced 45-50 cm), thrown towards the seat back and ceiling in front.
Rear passenger	M 54		Severely injured	-	+	Cuts to the face/legs, facial fractures, pelvic fracture, dislocated left hip, crushing injuries in the abdomen.	Freezer (approximately 200 kg) in seatback (displaced 55 cm), thrown against the back of the seat and ceiling in front.
Volvo 240 1984							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M 19	179 cm 70 kg	Dead	+	-	Cause of death: head injuries.	Head and upperbody hit by the ceiling/ windshield/steering wheel/ dashboard

[24] Conclusion regarding cause of death from coronary investigation/autopsy report.

3.7 Accident 7: Head-on accident on the E39

3.7.1 Summary of the course of events

A Toyota Avensis with three people on board was in the overtaking lane to the left, eastbound on the E39, overtaking multiple cars in the right lane. At the end of the interweaving lane, the Toyota tried to re-enter the right lane. However, it hit the car on the right that it was overtaking and then lost control. The Toyota skidded over into the oncoming lane and collided with an oncoming Chevrolet Astro (1990 model) with four people on board.

The speed limit at the location was 80 km/h. It was raining when the accident occurred, and the road was wet and free of snow.

The driver and passenger in the front of the Toyota Avensis were killed and the passenger in the back seat (child 12 years) was severely injured. In the Chevrolet Astro, one passenger (child 5 years) was killed, while the driver and one passenger were severely injured, and one passenger suffered minor injuries.

3.7.2 Speeds and loads in the collision

A Toyota of this type with two adults and one child has a total weight of 1495 kg, while the Chevrolet has a total weight of 2220 kg with four people and cargo[25].

Calculations of the collision speeds and loads performed by Rekon DA in the Scan-crash computer program gave the following results:

	Kollisjonshastigheter (km/h)		Belastninger i kollisjonen			
	Toyota	Chevrolet	Toyota		Chevrolet	
			H.endr.*	Kraftretn.**	H.endr.*	Kraftretn.**
Minimum	60	41	64	124	43	2
Mest sanns	**70**	**48**	**75**	**146**	**50**	**3**
Maksimum	81	55	86	168	58	4
Endring i rotasjon om vertikalaksen ***						
Minimum			3,7		-2	
Mest sanns			**4,3**		**-2,4**	
Maksimum			5		-2,8	
* Hastighetsendring på bilens tyngdepunkt i km/h						
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning. Vinkel mot urviseren om vertikalaksen positiv						
*** Rotasjonshastighet i rad/sek. Positiv verdi mot urviseren om vertikalaksen						

The simulations show that the most probable collision speeds were 70 km/h for the Toyota and 48 km/h for the Chevrolet. The corresponding speed changes are then 74 km/h for the Toyota and 50 km/h for the Chevrolet. This results in up to maximum considered total deformation energy, approximately correct rotation for both cars, but a somewhat too short distance between the cars.

The simulations have not been able to establish correct final positions, and the best final positions have been established applying deformation energy up the upper limit. The

[25] The calculations assume that each person weighed 75 kg.

most probable reasons for this are uncertainties in the assessments of the applied parameters, the collision model and the ability of the movement models to represent the case correctly and the considered areas for the final positions, as well as whether the simulations performed have given a set where the collision position is approximately correct.

Minimum and maximum assumed values for the cars have been assumed on the basis of the most probable simulated values in adding and deducting 15% from these values, respectively.

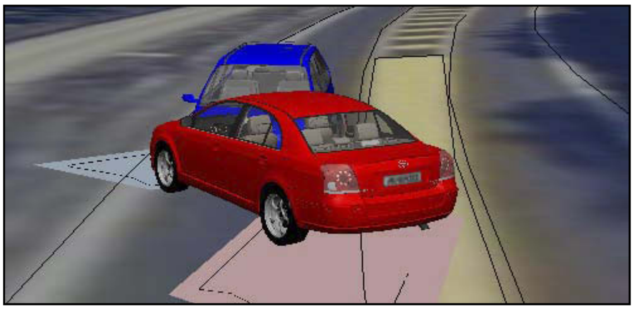


Figure 28: Collision position - Accident 7.

3.7.3 Investigation of the vehicle internally

3.7.3.1 *Toyota Avensis*

The Toyota Avensis 2005 model has 5 stars in EuroNCAP (14 points in frontal collision and 16 points in the side crash test) and is registered as one of the safest cars on the Folksam list. The car was equipped with airbags, seat belt pretensioners and force limiters.

The Toyota Avensis was deformed across the entire front with the largest intrusion of 35 cm on the right side of the front. The airbag had been triggered in both seats in front, from the steering wheel and under the dashboard. All three in the car used seat belts.

The compartment around the driver's seat was almost intact and there was survival space for the seat in the car. There were deep knee imprints in the dashboard under the steering wheel. The steering wheel was slightly twisted upwards. The driver was secured with a seat belt. A 36 cm wear mark was measured on the seat belt at the B pillar feed-through.

For the passenger in front who was killed, there was limited survival space. An intrusion of approx. 35 cm was measured on the front right side, and the A pillar and upper door pillar were pushed back and into the compartment. The seat back in front on the right side had been pushed 8-10 cm forward, probably as a result of baggage lying on the seat and floor behind. The dashboard was pushed slightly downwards and the passenger was stuck after the collision. A 12-cm wear mark was measured on the seat belt.

The seat belt for the left back-seat passenger had ordinary short wear marks both in the lock and in the feed-through in the seat back. The seat back in this car was in two parts and the seat back division between the parts had been pushed forward 25 cm, probably as a result of a loose 50.8 kg suitcase in the boot.

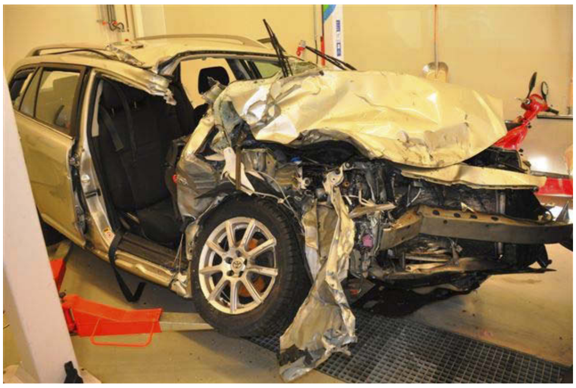


Figure 29: Damage to the front of the Toyota Avensis. Survival space for the driver's seat and the back seats, limited survival space for the front passenger seat.

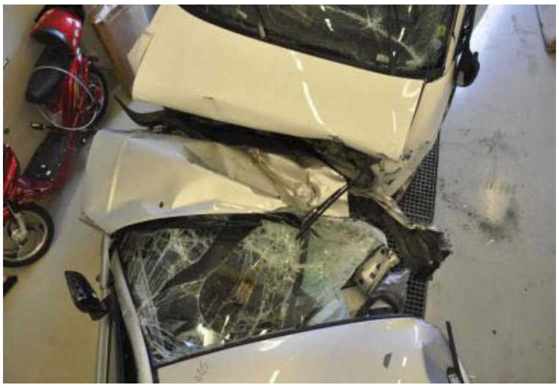


Figure 30: Reconstruction showing the vehicles' positions in relation to each other at the moment of impact.

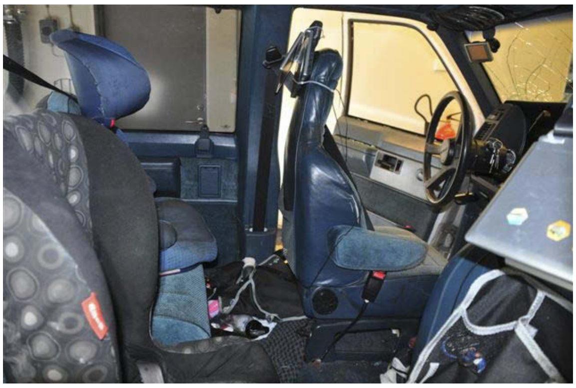


Figure 31: Chevrolet Astro with survival space for all seats in the car.

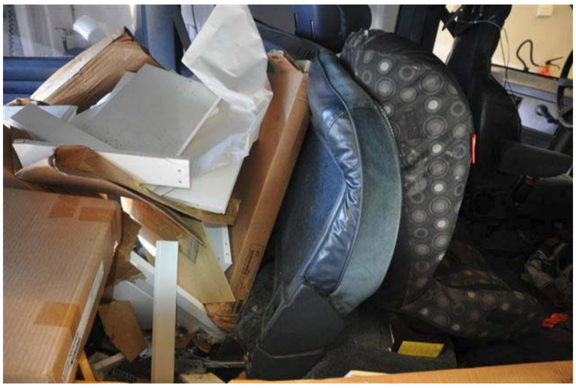


Figure 32: Cargo displacement into the seat back for the child in the middle of the Chevrolet Astro.

3.7.3.2 *Chevrolet Astro*

The Chevrolet Astro 1990 model has not been tested by EuroNCAP and is not on the Folksam list. The car had no airbags, seat belt pretensioners or force limiters.

The Chevrolet Astro was deformed across the entire front with the greatest intrusion of 20 cm on the left side. The car's compartment was more or less intact and there was survival space for all seats in the car. The car was loaded with approx. 160 kg of flat-packed furniture. The heaviest packs were at the bottom against a speaker box built into the floor, but the load was not secured with straps. In the collision, the displacement of the cargo caused extra energy impact on the seat back of the child in the middle and the passenger on the right side.

On the driver's side, there were marks on the dashboard (assumed to be knee imprints) and the steering wheel had been bent upwards. The wear mark on the belt at the hip lock may indicate that the hip section of the belt was pulled out a little (slack).

The right front seat was pushed forward a little and there was a rectangular pack on the floor behind (25 kg), which may have hit the seat. There were imprints from what was assumed to be the passenger's knees in the dashboard. The seat belt was used correctly.

A five year-old boy who was killed in the accident sat in an Asis child car seat in the middle of the back seat with a four-point belt. This child car seat was fastened to the seat with the car's original two-point belt. A reconstruction with a 5-year-old as a model indicates that the belt was tight, but somewhat loose over the shoulders. The back of the back seat had been pushed forward, especially on the right (25 cm down on the floor and 35 cm for the upper part of the seat back) as a result of the loose flat furniture packs.

A seven-year-old girl was on the left side in a child car seat of the make Cosi Corgi. The wear marks on the three-point belt indicate that it was tensioned tight.

3.7.4 Injuries and injury mechanisms

Table 7: Injuries and injury mechanisms Accident 7

Toyota Avensis 2005							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**[26]	**Injury mechanisms**
Driver	M 57	186 cm, 106 kg	Dead	+ Approx. 36 cm wear marks on the belt.	+	Cause of death: serious chest injury with several ribs fractured and crushing injuries in the lungs, brain damage with minor bleeding.	The chest injuries are due to the severe deceleration trauma where the chest impacted the diagonal belt, steering wheel (and airbag). Brain damage partly caused by the actual impact (severe deceleration with impact against the forehead) and in part lower circulation of blood/ oxygen supply.
Front-seat passen ger	F 52	176 cm, 97 kg	Dead	+ Approx. 12 cm wear mark on the belt.	+/-	Cause of death: multiple injuries to the neck, chest and pelvis.	Approx. 35 cm intrusion on the right side of the front. Impacted against the right side of the car. The injuries to the head, neck, chest, right arm and thigh caused by impact with the car's interior (car door/A pillar/ceiling). Pushed forward and to the right as a result of cargo in the back seat pushing the seat back 8-10 cm forward.
Left back-seat passen ger	F 12		Severely injured	+	+	Skin injuries to the upper body, severe chest and abdominal injuries.	Pushed forward and slightly to the right. Exposed to powerful pressure to the right side of the abdomen and chest. Heavy unsecured cargo pushed the seat back forward.

[26] Conclusion regarding cause of death from coronary investigation/autopsy report.

Chevrolet Astro 1990							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M 35		Severely injured	+/- Slack	+	Head injuries, sternum fracture, fracture in right ankle and heel.	The head injury was due to severe deceleration. The head and upper body hit the car's interior/steering wheel.
Front-seat passenger	F 36		Severely injured	+		Torn muscle fibres, severe whiplash, two broken ribs.	Flat packs into the seat back. Knees into the dashboard.
Passenger middle back seat	M 5		Dead	+/- Slack belt at the shoulder	+	Autopsy not performed. From CT: neck injury and upper spinal cord injury. No sign of head injury.	Flat packs into the seat back, powerful push against the upper part of the child car seat. Shoulder straps had slid off, and the child was thrown forward as a result.
Left back-seat passenger	F 7		Severely injured	+		Upper jaw teeth broken, cranial fracture, eye fracture.	The injuries to the face are consistent with being hit by the car's interior (back of seat in front or left window/B pillar).

3.8 Accident 8: Head-on accident on the E16

3.8.1 Summary of the course of events

A Toyota Avensis passenger car with three people on board crossed over into the oncoming lane in a slight right curve and collided with an oncoming Volvo lorry with trailer. The Toyota hit the lorry with the left of the front, rotated 180° and was pushed back approx. 15 metres.

The road was dry and free of snow when the accident occurred. The speed limit at the location was 70 km/h.

The driver of the Toyota Avensis was declared dead at the scene of the accident after 15 minutes. The front-seat passenger died at the scene of the accident after approx. 20 minutes while waiting for a helicopter. The back-seat passenger died in hospital four days later from the injuries he suffered. The driver of the lorry was unharmed.

3.8.2 Speeds and loads in the collision

A Toyota of this type with three people on board has a total weight of 1515 kg, while the lorry with trailer has a total weight of 48 000 g (27 000 kg + 21 000 kg)[27].

Calculations of the collision speeds and loads performed by Rekon DA in the Scan-crash computer program gave the following results:

[27] The calculations assume that each person weighed 75 kg.

	Kollisjons-hastigheter (km/h)		Belastninger i kollisjonen					
			Toyota			Vogntog		
	Personbil	Vogntog	H. endr.*	Kr. retn**	Rot. hast***	H. endr*	Kr. retn**	Rot. hast***
Min	54	68	87	-168	2,6	3	-156	-0,6
Maks	68	77	104	-168	3,1	4	-156	-0,7
* Hastighetsendring på bilens tyngdepunkt i km/h								
** Retning på kraftstøtet i kollisjonen i forhold til bilens lengderetning.								
Vinkel mot urviseren om vertikalaksen positiv								
*** Rotasjonshastighet i rad/sek, positiv verdi mot urviseren								

The simulation shows the following ranges for the collision speeds: between 54 and 68 km/h for the Toyota and between 68 and 77 km/h for the lorry. The calculated collision speeds give a speed change in the collision of between 87 and 104 km/h and a rotation speed immediately following the collision of between 2.6 and 3.1 rad/sec (positive value counter-clockwise around the vertical axis) for the Toyota.

For the lorry, the speed change was between 3.3 and 4.0 km/h and the rotation speed between -0.6 and -0.7 rad/sec. The rotation speed was maintained at the same level for about 1 second for the Toyota due to the simulation of secondary collisions with the lorry, but is reduced to 0 after only approx. 0.2 seconds for the lorry.

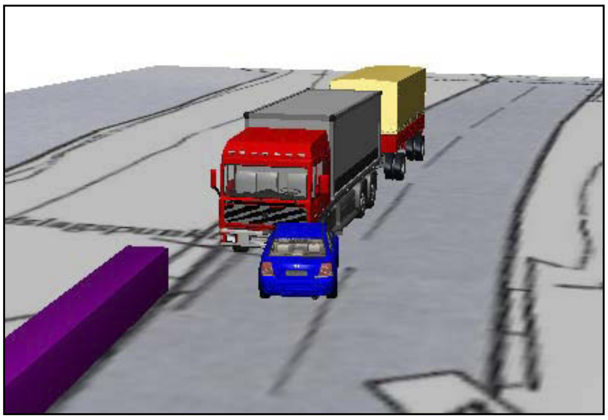


Figure 33: Collision position - Accident 8.

3.8.3 Injuries and injury mechanisms

Table 8: Injuries and injury mechanisms Accident 8

Toyota Avensis 2004							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**[28]	**Injury mechanisms**
Driver	M 74	175 cm, 90 kg	Dead	+ Approx. 12 cm wear marks on the belt.	-	Cause of death: crushing injuries to the neck and chest.	Approx. 45 cm intrusion on the left side of the front. Severe deceleration trauma and blunt force where the head, chest, left arm and thigh impacted with the car's interior, probably the steering wheel and intruding parts of the dashboard and door. The blow to the head and chest gave the fatal injuries.
Front-seat passenger	F 67	165 cm, 79 kg	Dead	+ Approx. 37 cm wear marks on the belt.	+	Cause of death: chest and abdominal injuries.	Severe deceleration trauma with powerful jerk and intrusion towards the abdomen from the hip belt and upper part of the chest from the diagonal belt/airbag.
Left back-seat passenger	M 55	182 cm, 73 kg	Dead	+	+	Cause of death: Extensive injuries to the head, chest and abdomen.	Pushed forward in the crash and possibly slightly to the right in relation to the car's interior, possibly thrown out of the diagonal belt. Severe deceleration trauma where the head and right side of the chest struck something in the car, probably the back of the seat in front, the left knee has probably hit the back of the seat in front.
Lorry with trailer							
Person	**Sex Age**	**Height Weight**	**Degree of injury**	**Seat belt**	**Surv. space**	**Injuries or cause of death**	**Injury mechanisms**
Driver	M 34		Unharmed	?	+		

[28] Conclusion regarding cause of death from coronary investigation/autopsy report.

3.8.4 Investigation of the vehicle internally

3.8.4.1 *Toyota Avensis*

The Toyota Avensis 2004 model has 5 stars in EuroNCAP (14 points in frontal collision and 16 points in the side crash test) and is registered as one of the safest cars in the Folksam list. The car was equipped with airbags, seat belt pretensioners and force limiters.

The car was deformed in the front and had an intrusion of approx. 45 cm on the left side of the front. The airbag had been triggered in both seats in front, from the steering wheel and under the dashboard. The side curtain airbag above the front side door had not been triggered.

There was little survival space for the driver, but it seems to have been sufficient to maintain respiratory function. The driver used a seat belt, and a 12 cm wear mark was measured on the belt, in a location which indicates that it was used correctly when the accident happened.

There was survival space for the front passenger on the right side, but there was an intrusion in front under the dashboard, probably indentations from the passenger's knees. The front passenger used seat belts, and a 37 cm wear mark was measured at the feed-through in the B pillar.

The left back-seat passenger's seat belt had been pulled out and the belt feed-through in the seat back, a plastic pulley, had been torn off. There was an impression down on the seat back, possibly from the impact of one of the passenger's legs.

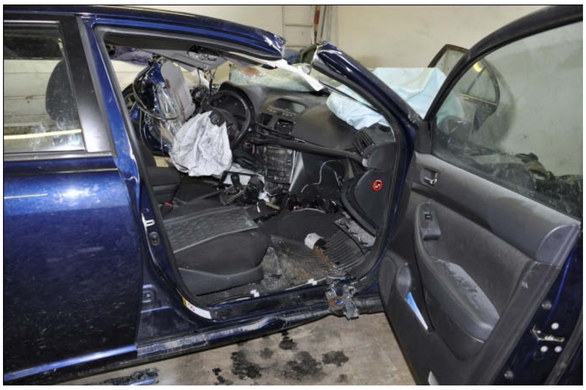


Figure 34: Toyota Avensis with limited survival space for the driver's seat, survival space for the front passenger seat and in the back of the car.

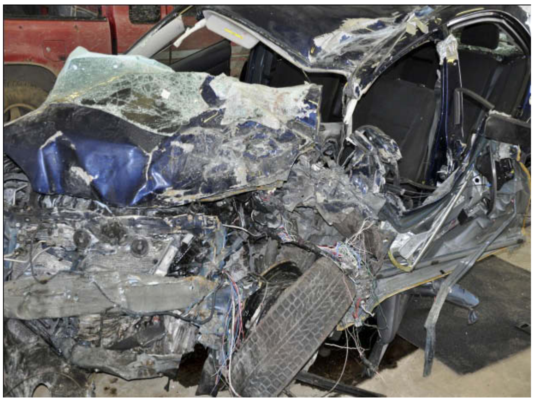


Figure 35: Damage to the front of the Toyota Avensis.

4. TEST OF SEAT BELTS

4.1 Introduction

Based on the technical findings (wear marks) on the seat belts in Accident 7 and Accident 8, the AIBN found reason to conduct further technical investigations of the vehicles. In this connection, the AIBN has carried out tests at SP Technical Research Institute of Sweden (SP) in Borås. Full-scale crash tests were carried out to register how much of the seat belts were pulled out and pull tests were conducted to determine the forces that had to be applied to the belt to trigger the seat belts' force limiter.

The purpose of the tests was to investigate whether the seat belts from Toyota in Accident 7 and Accident 8 complied with the EU's seat belt requirements, as well as making a comparison of the seat belts from Toyota with seat belts from other car makes.

The crash tests (crash tests) were carried out using a Toyota Avensis chassis with two front seats installed. This chassis was identical with the vehicle (station wagon) involved in Accident 7. The vehicle involved in Accident 8 was also of a corresponding model, but a saloon car. Both the test chassis and the vehicles involved in the two accidents were equipped with the same type of seat belts, anchoring points for seat belts in the driver and passenger seats.

New, original seat belts were used for all tests.

4.2 Conducting tests

4.2.1 Conducting crash tests (dynamic tests)

The tests were carried out on SP's test track, which is also used to test seat belts in accordance with EU Directive 77/541/EEC with later amendments (under which EU Directive 2000/3/EC is included) and tests in accordance with ECE R16[29]. Three crash tests were conducted with two crash test dummies placed in the test object in each test. One dummy weighed 79 kg and the other 102 kg. During the tests, the 102-kg dummy sat in the left front seat, and the 79-kg dummy sat in the right front seat.

The three tests were conducted as follows:

Test 1: 50±1 km/h, 26-32 G in accordance with the cycle described in Figure 36

Test 2: 50±1 km/h, 20 G in accordance with the time cycle described in Figure 36

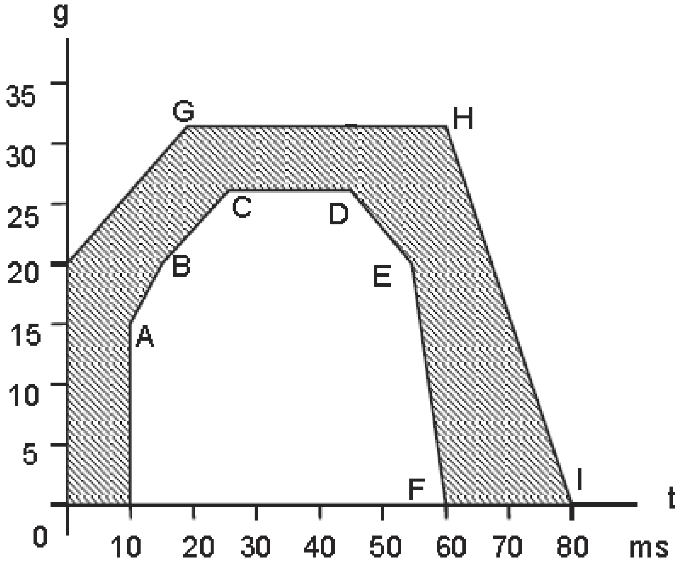
Test 3: 61 km/h, 26-32 G in accordance with the cycle described in Figure 36

[29]Technical guidelines and test requirements for seat belts prepared by the United Nation's Economic Commission for Europe (UNECE). UNECE has 55 member states and reports to FNs økonomiske og sosiale råd. .The Commission concentrates on economic analysis, statistics, environment, bærekraftig energy, trade, industry and business development and transport.

Test 1 was conducted so that retardation, speed and time were in line with the descriptions in ECE 16. This corresponds to the cycle as described in EU Directive 2000/3/EC.

Test 2 was carried out in accordance with the same criteria as described in Test 1, but with lower retardation.

Test 3 was also carried out in accordance with the same criteria as in Test 1, but the velocity was increased to 61 km/h instead of 50±1 km/h.



	t	g
A	10	15
B	15	20
C	25	26
D	45	26
E	55	20
F	60	0
G	18	32
H	60	32
I	80	0

Figure 36: The graph shows the car's retardation as a function of time, as indicated in Appendix 9 to EU Directive 2000/3/EC and ECE 16 Annex 8.

Figure 38 show the test chassis with the two crash test dummies before the dynamic tests were carried out.

Figure 37: Chassis with dummies before the tests were conducted.

4.2.2 Conducting pull tests of seat belts (static tests)

Pull tests were conducted for four seat belts. The belts were identical with the belts used in the crash tests. When the tests started, there was 600 millimetres of belt left on the belt spool.

The tests were carried out to register how much the belt had to be pretensioned to trigger the force limiter, and to test how much force had to be applied to the belt throughout the pull period for the force limiter to remain in continuous function. The power was applied until the entire belt had been pulled from the spool.

To compare the results with seat belts from other car brands, corresponding tests were conducted for the seat belts on other car brands. These were:

- The BMW 3 series
- Ford Mondeo
- The Mercedes C series
- Nissan Qashqai
- Opel Insignia
- Volkswagen Passat
- Peugeot 407
- Skoda Octavia
- Volvo V70

Two tests of each car brand were conducted.

4.3 Test results

4.3.1 Crash test results (dynamic tests)

4.3.1.1 *Test 1: 50±1 km/h, 26-32G in accordance with the cycle described in Figure 36*

The results from this test show that the 79-kg dummy had a forward movement of 250 mm at chest height, while the corresponding movement for the 102-kg dummy was 270 mm.

This movement resulted in a pull-out/extension of the belt through the upper anchor on the B pillar of 350 mm for the 79-kg dummy and 420 mm for the 102-kg dummy.

4.3.1.2 *Test 2: 50±1 km/h, 20G in accordance with the time cycle described in Figure 36*

The results from this test show that the 79-kg dummy had a forward movement of 140 mm at chest height, while the corresponding movement for the 102-kg dummy was 180 mm.

This movement resulted in a pull-out/extension of the belt through the upper anchor on the B pillar of 190 mm for the 79-kg dummy and 230 mm for the 102-kg dummy.

4.3.1.3 *Test 3: 61 km/h, 26-32 G in accordance with the cycle described in Figure 36*

The results from this test show that the 79-kg dummy had a forward movement of 290 mm at chest height. When the 102 kg dummy had moved 320 mm at chest height, the belt snapped. The belt snapped where it went over the left side edge of the sitting cushion as a result of large strain. The dummy fell out of the seat and was pushed against the front wall of the chassis. This movement resulted in a pull-out/extension of the belt through the upper fastener on the B pillar of 350 mm for the 79-kg dummy and 420 mm for the 102-kg dummy when the belt snapped.

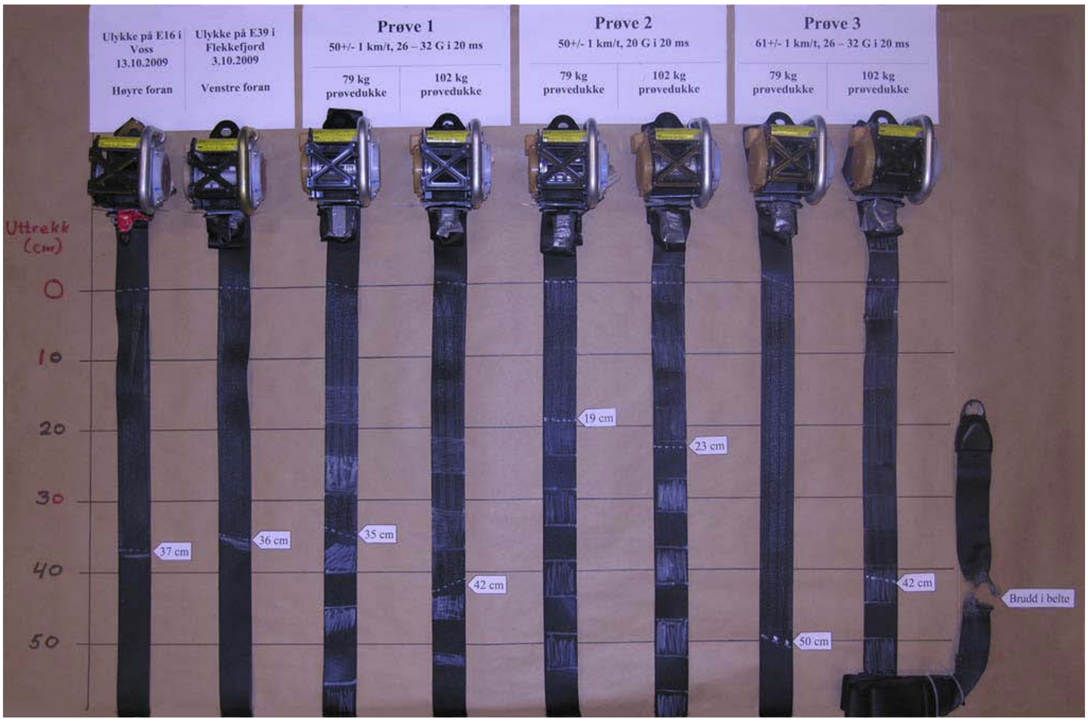


Figure 38: Shows a picture of the seat belts involved in Accident 7 and Accident 8, as well as belts used in connection with crash tests at SP in Borås.

In Figure 38 the pull-out is marked on the individual belts. The right side of the picture shows where the belt snapped. To the left, you can see the pull-out on the seat belts installed in the Toyotas involved in Accident 7 and Accident 8.

4.3.2 <u>The result of the pull tests (static tests)</u>

Figure 39 shows a combined overview of pull cycles for each car brand.

The static pull tests for the seat belts from Toyota showed that the force limiter was activated when a force of approx. 3 kN was applied to the belt. This power increased as the belt was pulled off the spool. When the entire belt was off the spool, the power necessary to activate the force limiter was approx. 5.5 kN.

Pull tests for the other car brands varied somewhat, but the pull-out range was approximately the same for all vehicles in the test. No seat belts stood out to any significant degree. The tests also showed that none of the belts had any limitations on the length that could be pulled out, as all belts could be pulled out until the spool was empty.

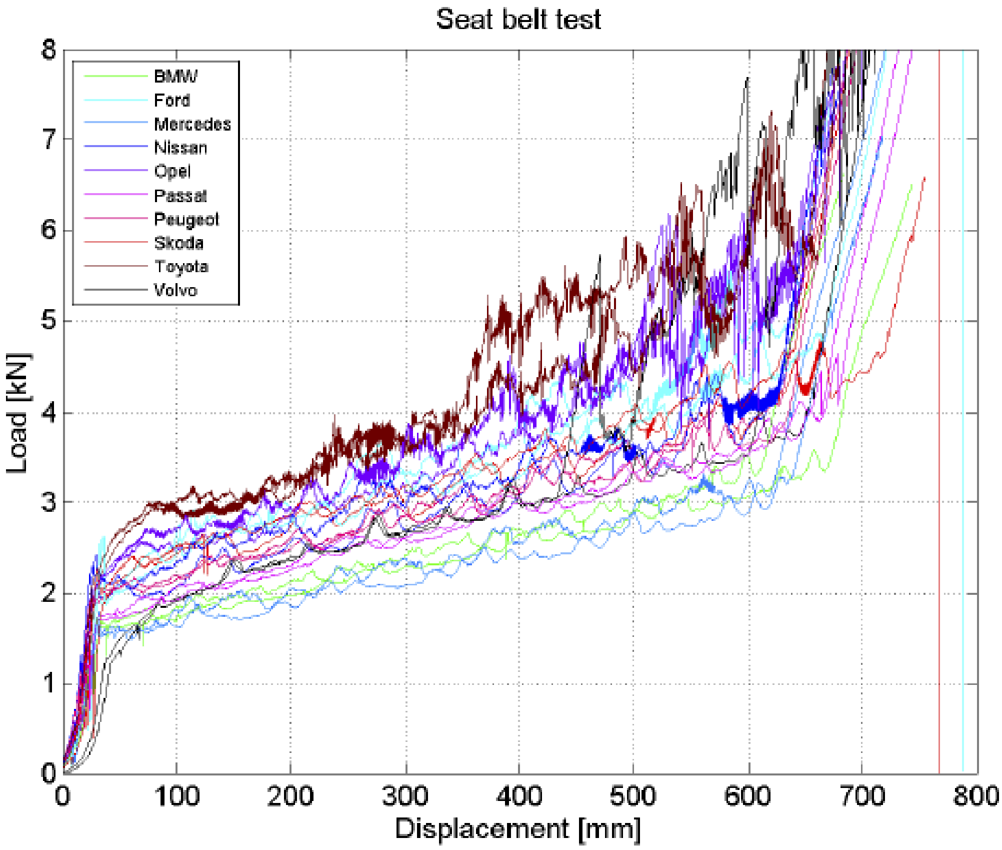


Figure 39: Overview of the load and pull development for the tested seat belts. (Source: SP)

4.4 Assessment of the test results and their relation to Accidents 7 and 8

For Accidents 7 and 8, the term "wear mark on belt" was used. The wear mark is made due to friction and increased temperature in the upper belt anchor on the B pillar when the belt is pulled out of the spool as a result of the force limiter being activated due to the high collision forces. The belt is pulled out to increase the retardation distance and reduce the load on the person from the seat belt.

The wear marks created in Accidents 7 and 8 cannot be compared against the regulatory requirements relating to a person's forward movement of up to 30 cm. 30 cm is the requirement when conducting lab tests where speeds, G forces and the gravity of persons are specified. In addition, the belt has a different angle across the chest than the movement direction for the crash test dummy.

The dynamic tests conducted by the AIBN show that the Toyota Avensis seat belts comply with the applicable regulatory requirements.

Both crash test dummies used in Test 1 (conducted so that retardation, speed and time were as described in ECE 16) were heavier than stipulated in the test criteria, but were still within the limit values(between 100 to 300 mm) for forward movement at chest height. This was also the case for the 79-kg dummy in Test 3, where the speed was 10 km/h higher than stipulated in the test criteria.

The result from all the tests also showed that the crash test dummy of 102 kg exposed the seat belts, and that part of the dummy lying against the seat belt, to a load greater than the 79-kg dummy did. It shows both the forward movement of the crash test dummies and the pull-out of the safety belts.

Figure 38 shows that the seat belt from Accident 8 has a pull-out of 37 cm. This corresponds to the pull-out registered in Test 1 for the 79-kg doll. The person (female) who wore this belt weighed 79 kg. This indicates that she, when the collision happened, was exposed to a load corresponding to the load for the 79-kg dummy in Test 1. The assumption is that the airbag which was triggered in connection with the accident did not cushion (reduce) the person's forward movement.

The seat belt from Accident 7 has a pull-out of 36 cm (see Figure 38). The person (male) who wore this belt was slightly heavier (106 kg) than the crash test dummy of 102 kg used in Test 1 (with a pull-out of 42 cm). This indicates that he was exposed to a lower load than the 102-kg dummy was exposed to in Test 1. The triggered airbag may have influenced the person's forward movement and the pull-out of the seat belt.

The static pull-out tests (Figure 39) show that there was some variation between the different car brands, but that the development was more or less identical throughout the pull-out period. The pull-out force for the seat belts from Toyota was not significantly different from the seat belts from other car brands.

Based on the static pull-out tests, we cannot say anything about the pull-out development for the relevant seat belts in a dynamic test (crash test). The seat belt's anchors in the upper and lower part of the B pillar and the centre console are of import for how the seat belt will absorb the load from the person in the seat. Seat belts with almost identical pull-out characteristics in static tests can therefore have major variations in dynamic tests (crash tests). It must also be noted that the recorded pull-out power cannot be evaluated in isolation and must be seen in the context of other safety equipment (e.g. airbag function).

5. ANALYSIS OF SURVIVAL ASPECTS IN THE ACCIDENTS

5.1 Introduction

The purpose of the thematic investigation has been to investigate survival potential in each of the eight accidents. For every accident, the AIBN has assessed the potential for survival or changes in the injury situation for the severely injured and killed, given that the securing of people and cargo had been correct. The AIBN has also assessed the potential for survival in a more modern car with better collision protection and safety equipment. In the analysis of the accidents, information from the technical investigation of the car has been collated with medical findings and assessments, as well as simulations of the collisions in the Scan-crash computer program.

5.1.1 The AIBN's basis for evaluation of G forces and survival potential

An overview of the analysis with survival potential and G forces for each accident has been presented in tables in Appendix B.

The Scan-crash simulations have given an estimate of the speed changes for the car's centre of gravity in the collisions. Based on the speed change, the AIBN has calculated the average G force in the collision, given a collision time of 0.12 seconds (cf. Chapter 2.4). A collision time of 0.12 seconds is a value based on experience from real collisions and full-scale crash tests.

It is important here to note that the calculated G forces are only estimates and that a minor increase or reduction in collision time has substantial impact on the calculation of the G forces. The cycle described in connection with the crash tests performed by the AIBN (see Figure 36) has a duration of 0.08 seconds. This follows from criteria set for laboratory tests. In real accidents, the cycle will vary, as no collisions are identical and as a result of different factors such as variations in the impact, the design of the chassis and deformation zones.

In Appendix A, the timeline and G forces in full-scale tests have been compared with the cycle for the laboratory tests. The figures show that the full-scale tests have longer brake engagement time and longer completion phase (time) in relation to maximum G forces, compared with the defined corridor in the laboratory tests. The maximum G forces for the full-scale test at 83 km/h have corresponding average values to the laboratory test (see Figure 3 in Appendix A).

The most important aspect to emerge from the calculated G forces is the difference between the accidents and not the absolute G force values themselves.

The AIBN has assumed that the EuroNCAP frontal crash test equals an average calculated G force for the car's centre of gravity of 13 G (given a collision time of 0.12 seconds) and that such an accident can be survived with light injuries - given sufficient survival space and securing. With calculated average G forces in a frontal collision in the area 15-20 G, the AIBN considers that it is possible to survive with serious injuries. In a frontal collision with a calculated average G force of up to 25 G, the AIBN considers that the forces exceed what the human body can survive (the maximum G force in a collision is about twice as high as the average G force) and therefore there is little chance of survival regardless of the car and the safety equipment.

An average value of 15-20 G with a collision time of 0.12 seconds has been calculated for the Toyota in Accident 7 and 21-25 G for the Toyota in Accident 8. The peak forces for both collisions are higher, but over a shorter period of time. The tests performed by the AIBN (see Chapter 4) indicate that the peak forces may have been up to 30 G.

The evaluations are somewhat different for side collisions. This follows from the fact that intrusions in the car, a result of generally poorer protection against side collisions, will occur before the forces exceed what the human body can survive.

Furthermore, the AIBN assumes that if one of the persons survived in a specific car, it would have been possible for the others in the same car to survive given sufficient survival space and safety equipment.

5.1.2 Explanation of the figures

The survival potential for each accident is illustrated in a radar diagram. The diagram shows the survival potential/potential for lighter injuries for the persons severely injured or killed in the accident, as well as the various injury factors of importance for the extent of the injuries in the accident.

For accidents where people had been seriously injured/killed in both involved vehicles, two lines with different colours appear in the diagram. For one person, 0.5 point is given for medium survival potential, 1 point for high survival potential and zero points for low survival potential. This means that for a vehicle involving five seriously injured and killed persons, the survival potential is maximum five points. Correspondingly, points are given for the various injury factors that the AIBN considers to be of importance for the survival potential: use of seat belts, damage or injury caused by unsecured cargo or passengers, incorrectly used/slack seat belts, use of hip belts, high energy/side collision.

5.2 Accident 1 – survival aspect assessment

5.2.1 Mitsubishi passenger car

The simulation in Scan-crash shows that the passenger car was exposed to a speed change of between 71 and 93 km/h, corresponding to an average G-force of 17-22 G, in this frontal collision with a lorry with trailer. The fact that two people, who did not use seat belts, survived the accident with serious injuries indicates that the collision forces in this accident were high, but within what can be survived.

An important observation in this accident is that the three unsecured passengers in the rear of the passenger car (of whom the person who was killed probably sat unsecured in the boot) were thrown against the seats in front of them in the collision, thereby contributing significantly to the injuries suffered by the driver and front-seat passenger. There is reason to believe that the extent of the injuries to the front-seat passenger, who was killed in the accident, would have been significantly reduced and the chance of surviving the accident high, had the back-seat passengers used seat belts.

The chance of survival for the three passengers in the rear of the car is also considered to be high had seat belts been used. In a newer car with seat belt pretensioners and force-limiters in the back seat, as well as correctly adjusted head rests, the outcome could have been insignificant/minor injuries for the passengers.

As regards the driver who was killed, it was found that the belt was twisted in the upper belt anchor, preventing the belt from sliding in the slide. A belt that is slack across the chest and hips will not prevent forward movement of the upper body. In a collision, this will result in a powerful jerk/impact as the upper body is kept back by the belt. In this case, the impact was exacerbated by the seatback being pushed forward by the unsecured back-seat passenger. The survival space was somewhat limited for the driver, but it cannot be ruled out that the driver could have survived if the seat belt had been correctly used and the back-seat passengers had been secured. The extent of the injuries would probably have been considerably reduced if the seat belt had been used correctly. This applies in particular to chest and abdominal injuries. The survival potential is considered to be medium in the car in question. The AIBN considers that the survival potential in a newer car with 5 EuroNCAP stars would be higher.

5.2.2 Total survival potential

Figure 40 illustrates that all five persons in the passenger car had survival potential given correct seat belt use for everyone in the car, but somewhat limited survival potential for the driver. Three persons did not use seat belts, two persons used seat belts, two persons were injured by other unsecured passengers and one person (the driver) had a slack seat belt.

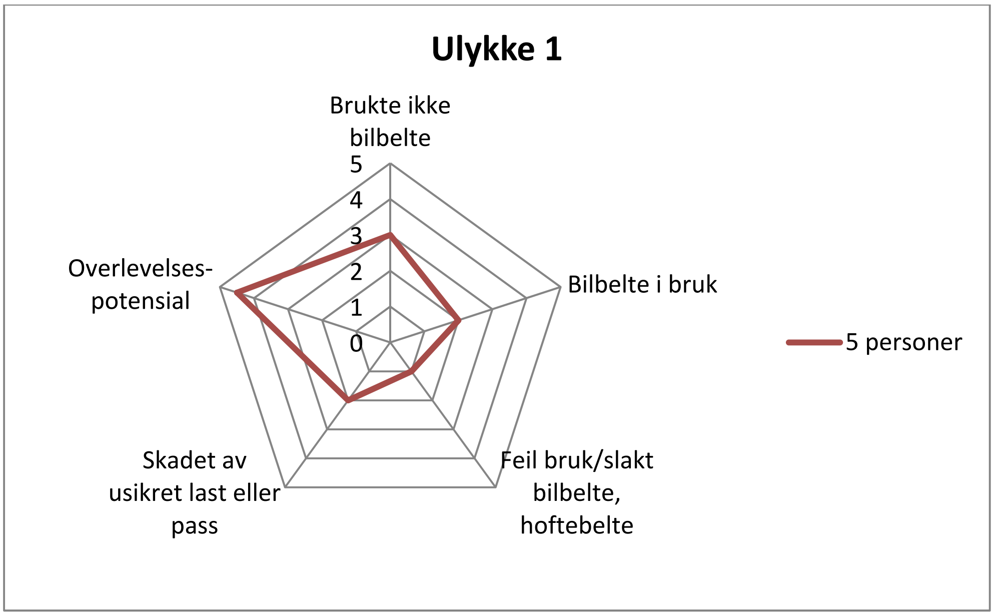


Figure 40: Survival potential – Accident 1 passenger car.

5.3 Accident 2 – survival aspect assessment

5.3.1 Nissan passenger car

In this accident, the impact on the side of the passenger car with high energy from a much larger car must be considered critical. The investigation shows that head-on accidents at speeds that are generally not considered to be critical have dramatically reduced survival potential when the vehicles are of different sizes and the smallest vehicle in addition is hit on the side.

The lorry had a high front, resulting in the passenger car being hit above the floor and side member and into the compartment, where the chassis is relatively weak and easily deformed in a crash. In addition, the lorry had a greater mass than the passenger car, and a structure with a stiff frame which absorbed a limited part of the total collision energy. Although the speeds of both cars in the collision were relatively low, the simulations in Scan-crash indicate a speed change of 41-53 km/h for the passenger car. This corresponds to an average G force of 10-13 G. The forces on the passenger car and the persons in the car were far higher than for the lorry. These factors resulted in the passenger car's original compartment width being reduced to half in the collision.

The persons in the lorry, which had an intact compartment, suffered far lower forces in the collision. This was essential for the modest injuries, in spite of seat belts also not being used in this vehicle.

For the driver of the passenger car, where it cannot be determined with certainty whether he was wearing the seat belt, the eventual use of seat belt was of no significance for the fatal head injury. In a side collision from the right, a standard three-point belt (pulled across the chest from the left) is unsuited to prevent the driver from being thrown to the right. In the collision, the driver was probably hit by the front-seat passenger. It is possible that their heads collided, as they both had a transverse fracture through the skull base. This is a "classic" finding in deceleration traumas with impact to the head from one side. It is unlikely that the injuries suffered by the driver could have been avoided even if the front-seat passenger had used the seat belt. The survival potential is considered to be low.

For the front-seat passenger on the right and the back-seat passenger on the right, using seat belts would not have prevented the fatal injuries due to the major intrusion in the side and the following impact with the car's interior, as well as for the front-seat passenger's impact with the driver. For the back-seat passenger, a newer car with better collision safety as well as side airbags and side curtain airbags would probably have limited the extent of the injuries, but it is uncertain whether it could have prevented a fatal outcome. The survival potential is considered to be low for both passengers.

5.3.2 Total survival potential

Figure 41 illustrates that there was probably no survival potential for the three persons in the car due to high energy/side collision even if they had used seat belts. The two passengers did not use seat belts and it is uncertain whether the driver used the seat belt.

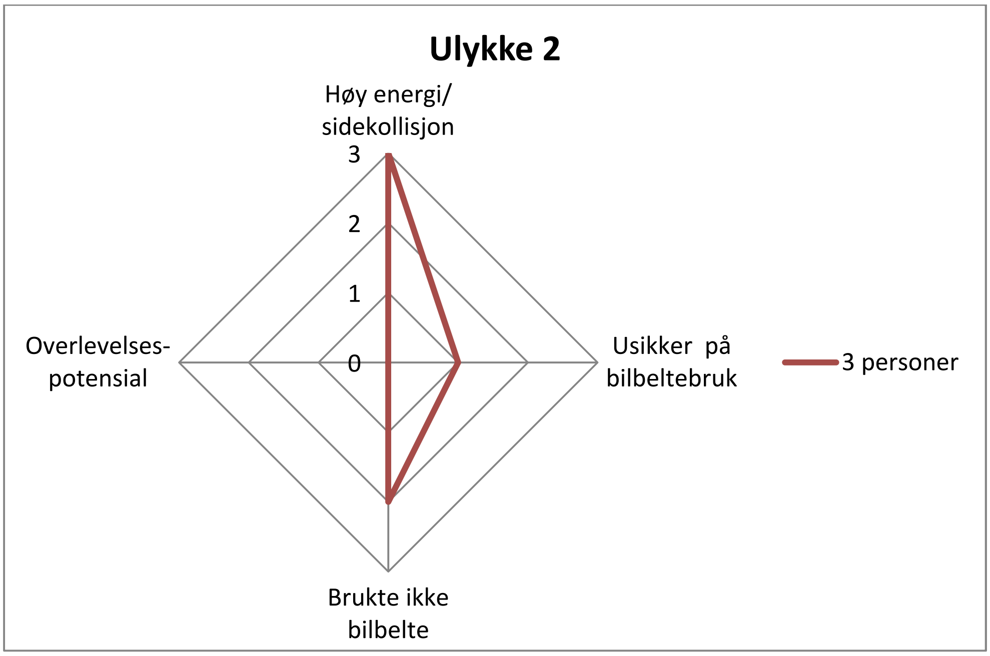


Figure 41: Survival potential – Accident 2 passenger car.

5.4 Accident 3 – survival aspect assessment

5.4.1 Mercedes van

The simulation in Scan-crash shows a speed change of 50-59 km/h for the van, corresponding to an average G force of 12-14 G. The energy level in the van was very likely within a survivable range, given that the seat belts were used correctly.

The special factor in this accident is that the driver had been given an exemption from use of seat belt due to claustrophobia. In the AIBN's opinion, all serious/fatal injuries suffered by the driver could have been avoided had the seat belt been used correctly. The van had significantly higher unladen weight than the involved passenger car. In this side collision on a slippery roads, the force impact for the driver of the van was less than for the passengers of the other car. The survival potential is considered to have been high for the driver of the van. As regards the loose cargo in the boot which pushed the separating wall forward, this was probably not a factor in the injuries suffered by the driver. It is uncertain whether the loose cargo could have been of importance if the driver had used the seat belt.

5.4.2 Nissan passenger car

For the passenger car hit in the side, the Scan-crash simulation gives a speed change of 65-76 km/h, corresponding to an average G force of 15-18 g.

As no autopsy was performed of the driver and the passenger in the front seat of the passenger car, and consequently no description of the injuries is available, it is hard to assess the injury mechanisms. Both used seat belts. However, there was no survival space for the front passenger seat as a result of the considerable intrusion. There was more survival space for the driver, but ordinary three-point belts have limited protection potential in side collisions of this type (corresponding comment as for Accident 2, see Chapter 5.3). The belt will slip off the left shoulder as the driver is thrown towards the right side. The survival potential is considered to be small for the driver and passenger in the passenger car. The Nissan Terrano 1993 model is ranked to be less safe than average, and it can in general be said that a newer car with installed side airbags and side curtain airbags could have limited the extent of the injuries in this side collision.

5.4.3 Total survival potential

Figure 42 shows the survival potential for the driver of the van, but that he did not use a seat belt and was hit by unsecured cargo in the seat back. For the driver and passenger in the passenger car, there was no survival potential as a result of high energy/side collision, although both of them used seat belts.

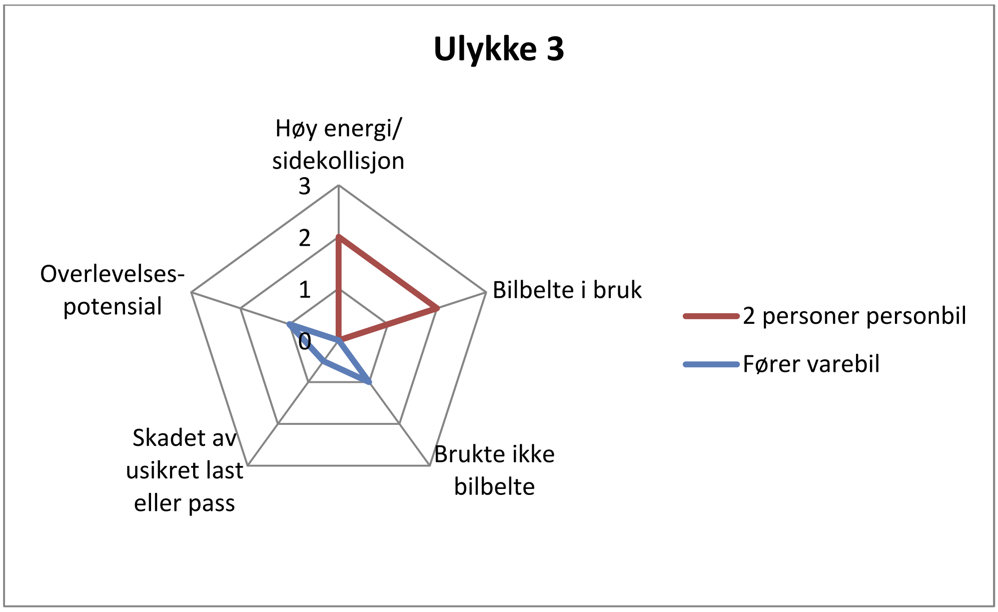


Figure 42: Survival potential - Accident 3.

5.5 Accident 4 – survival aspects assessment

5.5.1 BMW passenger car

The Scan-crash simulation shows a speed change in the range 66-75 km/h, corresponding to 16-18 G, for the BMW which first collided with the roadside guardrail and was then hit in the side by the Caravelle. As no autopsy was performed, it is not possible in this case either to describe the injury situation for the driver and the back-seat passenger on the right side of the BMW.

Whether the driver used the seat belt is somewhat uncertain. The fact that he was not thrown out of the car and was found with the belt around the upper body indicates that the belt was used. At the same time, it is peculiar that he was found with his upper body outside the car door, with the belt buckle out of the lock, if the seat belt was used. There is a possibility that the belt came loose just before the collision occurred. Use of seat belt or not, there was probably no chance of the driver surviving the accident in this case. It is also doubtful whether modern safety equipment could have prevented the fatal outcome. The survival potential is considered to be low.

Although the seat belt was correctly used by the back-seat passenger on the right, an intrusion of 90 cm on this passenger's side was not compatible with survival. A newer car with side airbags and side curtain airbags would have contributed to reduce the injuries, but it is highly doubtful if such an accident could have been survived. The passenger may have been hit by the ski sled on the left side in the boot, but this was probably not of decisive significance. The survival potential is considered to be low.

There is nothing certain to indicate that five-point belt was not optimally tightened around the child in the car seat. The AIBN considers that this in any case would not have had any impact on the fatal outcome for the child. The child was thrown to the sides and forward in the car seat. The child car seat was destroyed in the collision and did therefore not prevent the serious injuries to the child. It is also possible that the child was hit by the ski sled in the back seat. The survival potential is considered to be low.

5.5.2 Caravelle

As regards the Caravelle involved in this accident, it is clear that a hip belt does not secure a passenger sufficiently in a collision. In a collision, a hip belt causes an extended forward movement of the upper body and a powerful jerk against the abdomen/hips. A poorly tightened belt makes the jerk even more severe. The girl who sat in the middle in the back, only secured by a hip belt, therefore suffered serious back injuries, while the four others in the car only suffered minor injuries. The Scan-crash simulation shows a speed change of 41-46 km/h, corresponding to 10-11 G for the Caravelle which was hit in the front. The potential for less serious injuries is considered to be high, given a three-point belt.

5.5.3 Total survival potential

Figure 43 illustrates small survival potential for the three persons in the BMW passenger car due to a high energy collision with massive intrusion. The two passengers used seat belts, but the child in front probably had a slack seat belt, and it is uncertain whether the driver used his seat belt. The figure illustrates the potential for reduced injuries for the passenger in the middle of the back seat of the Caravelle given use of a three-point belt.

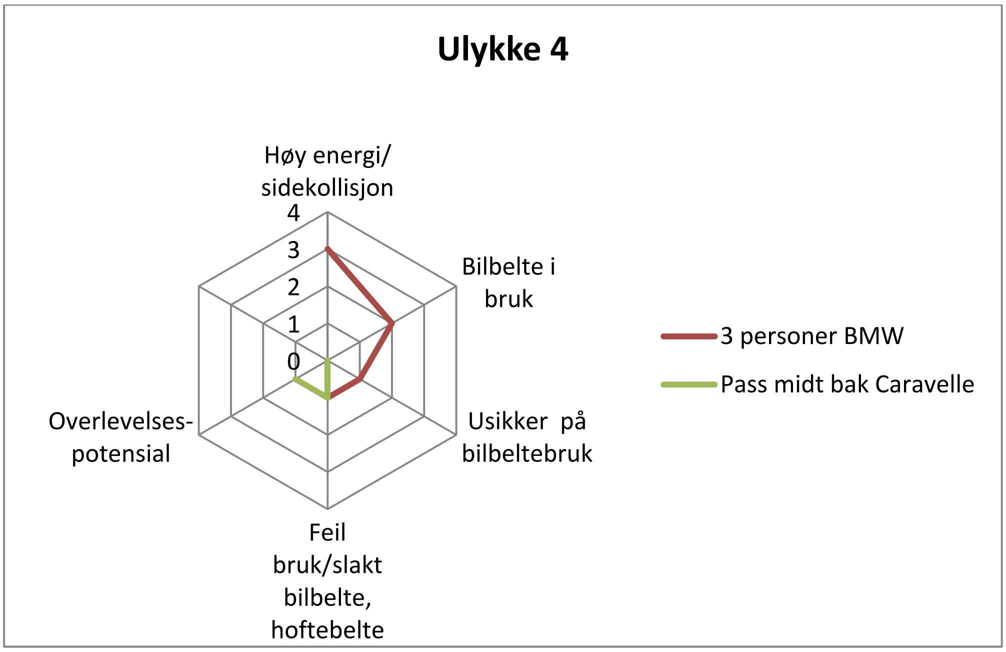


Figure 43: Survival potential - Accident 4.

5.6 Accident 5 – survival aspects assessment

The special factor in this accident is the high speed of the involved Mercedes, making it impossible to survive the accident in this car, regardless of safety equipment, in combination with the involved VW Caravelle where there clearly was survival space for the driver, but where the seat belt was not in use.

5.6.1 Mercedes passenger car

The Scan-crash simulation shows that the Mercedes, which was hit in the side, was exposed to a speed change of 72-92 km/h, corresponding to an average G force of 17-22 G. The Mercedes was completely deformed/burned-out, with the appearance of the deceased being marked by this. Whether seat belts were used could not be established. The fact that none of the four in the Mercedes were thrown out of the car, as well as belt buckles in the back seat being inserted in the lock, indicates that the deceased were using seat belts, at least the two passengers in the back seat. The fire which broke out in the passenger car does not seem to have influenced the outcome of the accident. The accident could probably not have been survived, even in a newer car with all available safety equipment and no subsequent fire. The survival potential is considered to be low.

5.6.2 Caravelle

It is impossible to assess specifically how the injuries to the driver of the VW Caravelle were sustained, as no autopsy was held. The seat belt was not used. It is uncertain whether there was a survival potential in this case, due to the very high speed (and momentum) of the oncoming Mercedes in the impact. The Caravelle, which was hit in the front, was exposed to a speed change of 67-86 km/h according to the Scan-crash simulation. This corresponds to an average G force of 15-20 G, which indicates that there was a survival potential. It was concluded that there was survival space for the driver's seat. With reservations regarding lack of information about the injuries suffered by the driver, the AIBN considers that the accident could have been survived given correct seat belt use. The survival potential is considered to be medium.

5.6.3 Total survival potential

Figure 44 illustrates no survival potential for the four persons in the passenger car, regardless of seat belt use, as a result of the high-energy collision. The figure illustrates medium survival potential as a result of the high-energy collision for the driver of the van, who did not wear a seat belt.

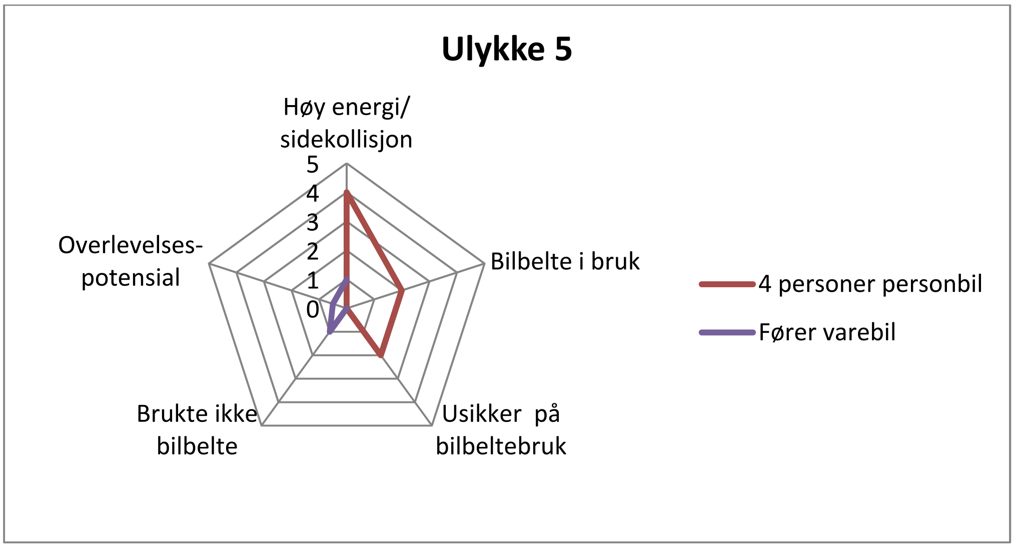


Figure 44: Survival potential - Accident 5.

5.7 Accident 6 – survival aspect assessment

5.7.1 Volvo passenger car

There was no survival potential for the driver of the Volvo 240 in this high energy collision, in spite of using seat belt. The speed change in this frontal collision has been calculated to 82-104 km/h for the Volvo, corresponding to 19-25 G. The survival potential is considered to be low.

5.7.2 Ford minibus

For the minibus, the speed change has been calculated to 30-38 km/h corresponding to an average G force of 7-9 G. This is a collision that can be survived given correct securing.

The driver of the minibus had extensive injuries and there was no survival space for the driver's seat. The survival potential was therefore low in the involved car. However, it should be possible to survive such an accident in a newer car with better collision safety.

The deceased passenger in the middle of the second row of seats wore a hip belt. In a collision, a hip belt causes an extended forward movement of the upper body and a powerful jerk against the abdomen/hips. The passenger died as a result of inner bleeding from an injury to the aorta. A three-point belt would have reduced the extent of the injuries substantially by preventing impacting the seats in front with great force, and survival would in such a case be possible. The cargo in movement is assumed to be less relevant in this case. The survival potential is considered to be high, given a three-point belt.

For the passenger on the left back seat, it was probably significant that the seat had been lowered to a reclining position. A reclining position for the seat gives a poorer effect for the three-point belt and he suffered several compression fractures in the back as a result. The potential for less serious injuries is considered to be medium if the seatback had been in the correct position.

For the passengers on the right side of the second and third row of seats, it can be concluded that the combination of cargo and persons in movement and not using seat belts contributed to the serious injuries. However, if they had been correctly secured in three-point belts and the cargo (freezer)/passenger behind were not sufficiently secured, this alone could have been fatal. The potential for less serious injuries is considered to be high given correct securing of cargo and persons.

5.7.3 Total survival potential

Figure 45 illustrates no survival potential for the driver of the Volvo in this high-energy collision even though the seat belt was used. In the van there was survival potential/potential for reduced injuries for four of the five seriously injured/killed. One person used a hip belt. Two people did not use seat belts and were injured by unsecured cargo or passengers. The driver probably had a low survival potential in the car in question, even if he used the seat belt. One person used the seat belt and had lowered his seat to the reclining position.

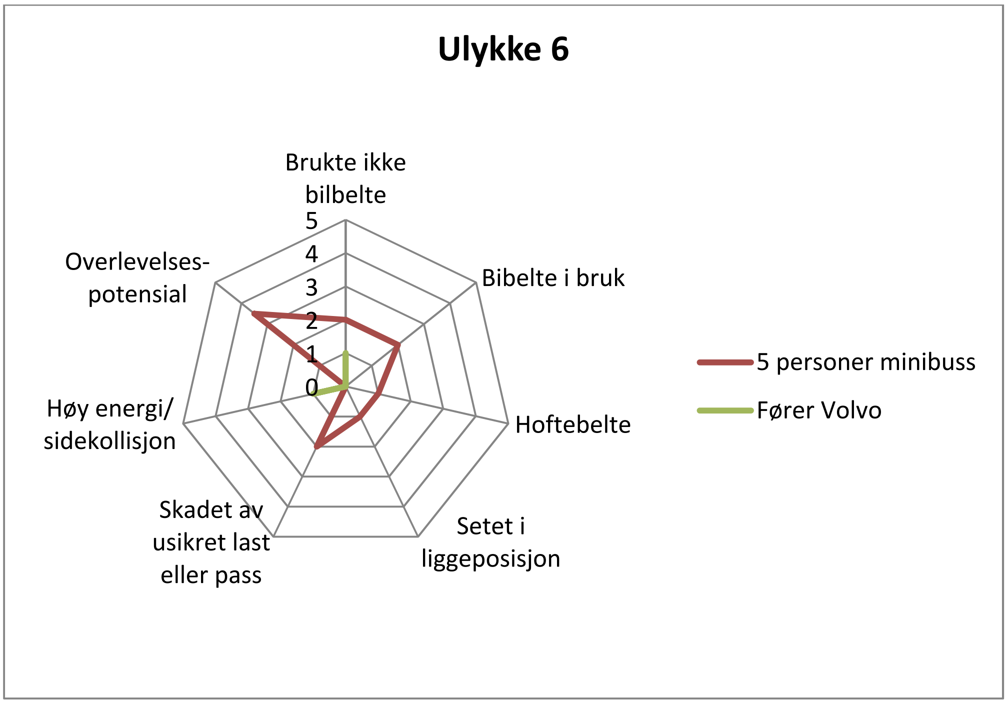


Figure 45: Survival potential - Accident 6.

5.8 Accident 7 – survival aspect assessment

5.8.1 Toyota

The speed change in this frontal collision has been calculated to 64-86 km/h for the Toyota, corresponding to an average value of 15-20 G calculated with a collision time of 0.12 seconds. The driver and front-seat passenger, who both used seat belts, were killed. A child, secured in the back seat, survived the accident with serious injuries. This indicates that the collision forces in this accident were high, but within what can be survived.

For the driver, it is conspicuous that he suffered major chest injuries when the compartment is intact and the safety equipment (seat belt and airbag) were correctly used and triggered. The AIBN has registered a 36 cm long wear mark on the seat belt (cf. explanation of wear mark in Chapter 4.4). The tests commissioned by the AIBN (see Chapter 4) show that the seat belt worked as required by the regulations.

However, the AIBN questions the length of belt that was pulled off the reel, as the driver's head and body hit the interior of the car. In this case, the driver weighed 106 kg, while the international test requirement for seat belts is 75 kg. The tests commissioned by the AIBN showed that higher body weight increases the length of belt that is pulled off the reel. In addition, the kinetic energy increases with higher body weight to make the forces to the person higher in a crash.

The chest injuries suffered by the driver were extensive and may have been caused by retardation forces from the belt and then probably an impact with the car's interior (steering wheel). The injuries are not fatal in isolation, but may have caused reduced respiration, contributing to lack of oxygen to the brain. Had the belt given away less, to prevent the driver's body from hitting the interior of the car (steering wheel) with great force, then the chest injuries would probably have been less serious. The primary head injuries were also considerable and may have been fatal in isolation, and were due to a powerful sudden stop with a probable impact to the forehead (e.g. against the steering wheel and airbag). The head injuries would probably have been avoided if the belt had given away less, so that the head had not hit the steering wheel/airbag with great force.

The long stretch of belt that was pulled off the reel did in this case cause the driver's chest and head to hit the car's interior with great force, even if the compartment was intact. The AIBN therefore considers the survival potential for the driver to be medium if the seat belt had permitted less forward movement of the upper body.

For the front-seat passenger, the seat belt was found to have a wear mark of 12 cm. The cargo in the back seat had pushed the seat back slightly forward, but it is uncertain whether this had a decisive effect on the outcome. There was limited survival space for this seat in the car, as a result of the A pillar and upper door beam having been pushed back and into the compartment. The AIBN considers the survival potential for the front-seat passenger to be low in this collision. However, a triggered side airbag and side curtain airbag could probably have limited the extent of the injuries.

The child who sat in the left back seat had conspicuously serious injuries in spite of correct use of the seat belt. The child was exposed to a powerful pressure to the right side of the abdomen and chest as a result of the heavy baggage in the boot pushing the seatback substantially forward. The body was probably squeezed between the retaining force of the belt and the loose baggage pushing the seat back forward. The AIBN considers the potential for less serious injuries to be high, if the cargo in the boot had been secured. Seen against the limited survival potential for the driver, given sufficient survival space, the child in the back seat probably had greater resistance in this high-energy collision.

5.8.2 Chevrolet

For the Chevrolet, the speed change has been calculated to 43-58 km/h corresponding to an average G force of 10-14 G. This is a collision that can be survived given correctly securing. The accident shows that although the cargo is stacked correctly with the heaviest objects at the bottom, the load can be displaced by great collision forces as long as it is not securely fastened.

The driver of the Chevrolet was secured by a seat belt which was probably not correctly tightened and suffered serious injuries in the collision. The potential for less serious injuries is considered to be medium, given a correctly tightened seat belt. Furthermore, the AIBN considers that a newer car with an airbag and belt pretensioner could have prevented the chest injuries resulting from the impact with the steering wheel, as well as the serious deceleration injuries to the head.

The front-seat passenger was correctly secured by the seat belt, but flat packs probably pushed into the seat from behind, pushing her forward and squeezing her between the seat back and the seat belt. The potential for less serious injuries is considered to be medium had the cargo been secured.

The passenger in the central back seat, a five year-old boy, was killed in the accident. The fatal neck/head injury occurred as a result of loose cargo moving (160 kg of flat packs) impacting against the seat back and causing a powerful push against the upper part of the child car seat. The survival potential is considered to be high had the cargo been secured.

The seven-year-old girl sat on the left back seat, correctly secured by a child car seat and a three-point belt. Her face probably hit the car interior.

5.8.3 Total survival potential

Figure 46 illustrates the survival potential/potential for reduced injuries for three of the persons in the Chevrolet. Two people had slack seat belts and two people were injured by unsecured cargo. In the Toyota, there was survival space for the back-seat passenger and partial survival potential for the driver. Both the back-seat passenger and the front-seat passenger were injured by unsecured cargo, while in the driver's case, a long stretch of the belt was pulled off the reel.

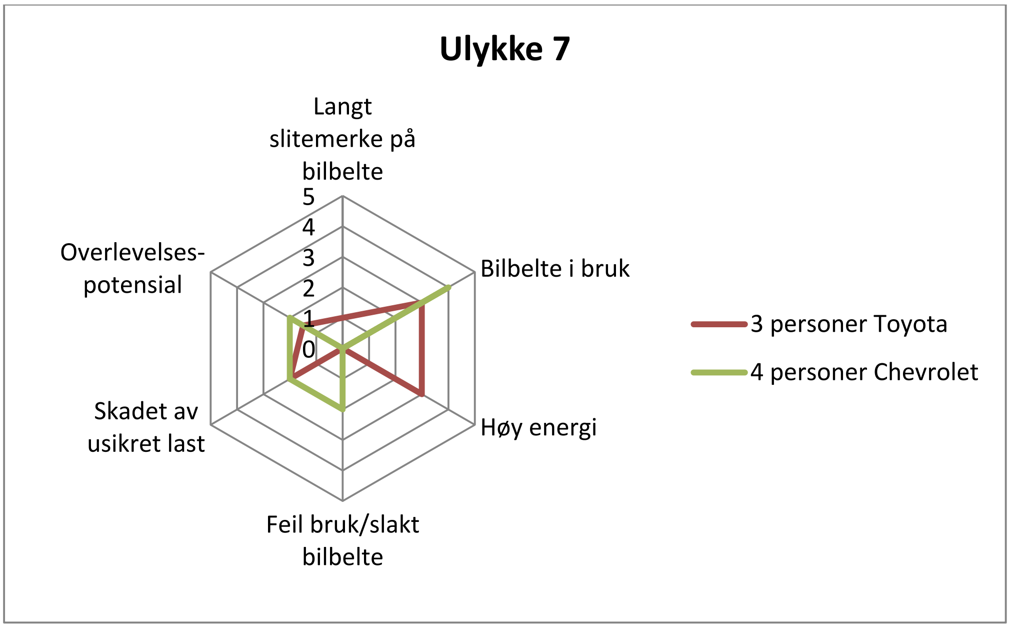


Figure 46: Survival potential - Accident 7.

5.9 Accident 8 – survival aspect assessment

5.9.1 Toyota

The speed change in this frontal collision has been calculated to 87-104 km/h for the Toyota, corresponding to an average value of 21-25 G calculated with a collision time of 0.12 seconds. All three persons in this car were killed. The G forces were high, but the fact that the passengers lived for some time after the accident (the person in the back seat died after four days) indicates that it was possible to survive the accident.

There was limited survival space for the driver, with an intrusion of 45 cm on the left side of the front. The driver's head and chest hit the car interior, suffering fatal injuries. A 12 cm wear mark was registered on the driver's seat belt. Overall, the survival potential for the driver is considered to be low.

For the front-seat passenger, a 37 cm wear mark was registered on the belt (cf. explanation of wear mark in Chapter 4.4). The tests commissioned by the AIBN (see Chapter 4) show that the seat belt worked as intended by the regulations.

Medical findings indicate that the belt pushed powerfully against the abdomen rather than the hips, and the fatal injuries arose primarily as a result of a powerful impact with the seat belt and not as a result of impact with the interior. There was survival space for this seat in the car, and considering the high collision forces, the AIBN considers the survival potential to be medium had the belt been tightened optimally and been placed against the hips.

The AIBN has received information indicating that there would have been extra survival potential for the driver if correct and timely medical first aid. However, in order to limit the investigation, the AIBN has chosen not to pursue the health and rescue aspect in the accident further.

The back-seat passenger used the seat belt, but was pushed forward and possibly slightly to the right in relation to the car in the crash. One possibility is that he was thrown out of the diagonal belt and hit the car interior, and thereby suffered the extensive head, chest and abdominal injuries. There are no certain indications that the belt was used incorrectly in any way.

There is a general weakness in three-point belts that it is possible to "slip" out of the diagonal belt. This may in particular happen if a person in the belt twists the upper body out of the belt, or in side collisions. The survival potential for the back seat passenger in this case is considered to be low. Improvements in the design of seat belts and airbags for back-seat passengers could probably have prevented fatal injuries in this accident.

5.9.2 Total survival potential

Figure 47 shows that there was low survival potential for the deceased in the Toyota. All three used seat belts. There was medium survival potential for the passenger in the front seat, given correct seat belt use and optimal medical first aid.

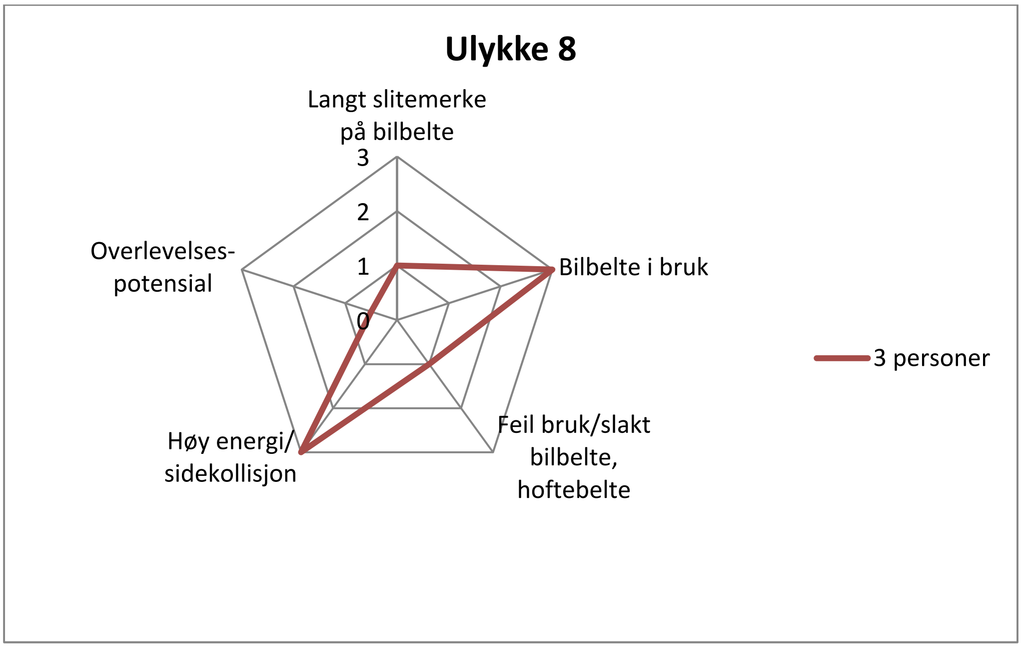


Figure 47: Survival potential - Accident 8.

5.10 Summary of survival aspects

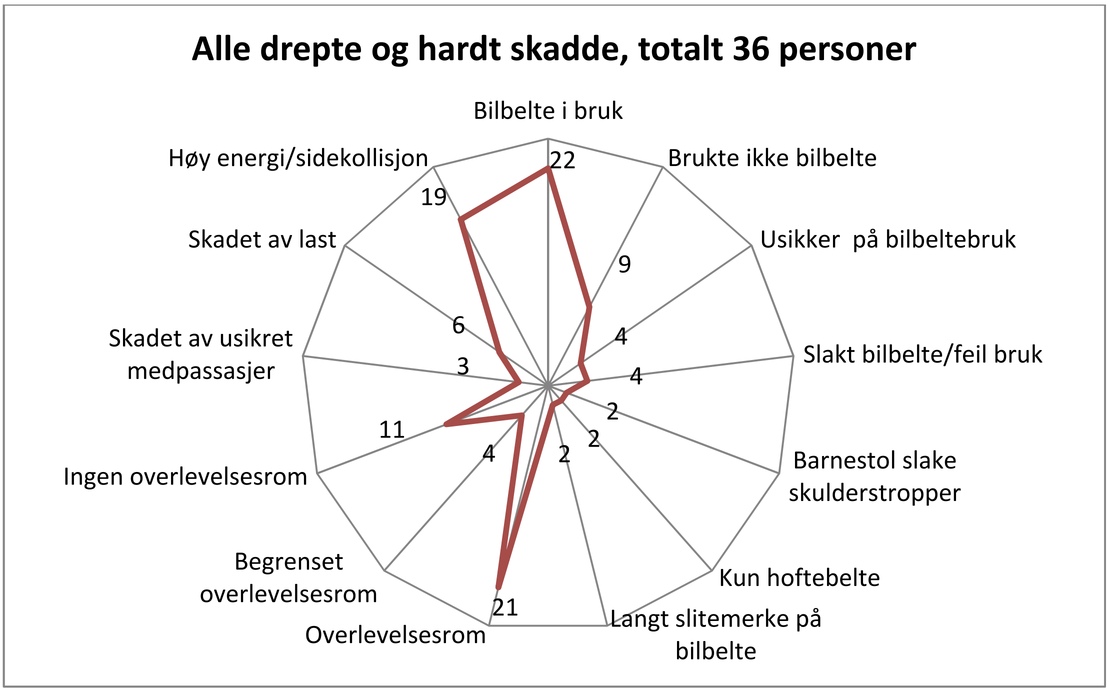


Figure 48: Summary of survival aspects for the 36 seriously injured and killed in the eight investigated accidents.

5.10.1 Use of seat belts

A total of 22 of the 36 seriously injured and killed used seat belts.

5.10.1.1 *Failure to use of seat belts*

Using a seat belt prevents or reduces the impact with the car interior, as well as reducing and distributing the G forces against the body over a longer time and distance.

Nine people did not use seat belts in the accidents. Of them, the AIBN considers that three could have survived if they had used seat belts. This applies to: the unsecured passenger in the boot of the Mitsubishi in Accident 1, the driver of the van in Accident 3 and the driver of the VW Caravelle in Accident 5. Another four persons (the back-seat passenger in Accident 1 and the passengers in the minibus in Accident 6) would have suffered lesser injuries had they used seat belts.

There is uncertainty as regards the seat belt use for four persons: the driver of the Nissan in Accident 2, the driver of the BMW in Accident 4, as well as the driver and passenger in the front seat of the Mercedes in Accident 5. In these cases, the AIBN considers that failure to use seat belts had no significance for the survival potential.

5.10.1.2 *Exemption from the use of seat belts for medical reasons*

The driver of the van in Accident 3 had an exemption from using the seat belt due to claustrophobia. In the AIBN's opinion, all serious/fatal injuries could have been avoided with correctly used seat belt. The AIBN therefore questions the validity of exemptions from the use of seat belts due to claustrophobia. In this connection, reference is made to the Directorate of Health's guidelines for physicians IS-1437, issued in November 2011, which emphasise that physicians must be very restrictive in granting such exemptions (see Chapter 2.1.3). The AIBN's believes that it’s important that the physicians' practice in this area is followed up.

5.10.1.3 *Slack seat belts/incorrect use*

A belt that is slack across the chest and hips will not prevent forward movement of the upper body. In a collision, this will result in a powerful jerk/impact as the upper body is kept back by the belt.

Slack/incorrectly used seat belts were registered for six persons. For the driver of the Mitsubishi in Accident 1, the left back-seat passenger in the minibus in Accident 6, the driver of the Chevrolet in Accident 7 and the front-seat passenger in the Toyota in Accident 8, a slack seat belt was probably of significance for the injuries they suffered. Reconstructions indicate that two children who was killed(baby in the BMW in Accident 4 and child in the middle back seat in the Chevrolet in Accident 7) sat in children’s car seats with slack belts over the shoulders. For the two children, however, the slack seat belt is not considered to have had a decisive effect on the fatal outcome.

The AIBN is uncertain whether road-users in general are aware that seat belts only function in an optimal manner when sufficiently tightened, without twists, lying against the hips and the seat is in the correct position (upright). It is particularly important that children are placed and optimally secured in cars. In this connection, we refer to a study from Norway by Skjerven-Martinsen et al (2011), which showed that 60% of children that are severely injured or die in car collisions wore the seat belt incorrectly. The most common errors are that the belt is insufficiently tightened and that the diagonal belt is placed under the arm or behind the back.

5.10.1.4 *Only hip belt*

A child who sat in a slack hip belt in the middle of the back seat of the Caravelle in Accident 4 was severely injured, while the others in the car suffered only light injuries. The passenger in the middle back seat in the minibus in Accident 6 suffered fatal injuries as a result of the hip belt. The accidents show the importance of three-point belts for all seats in a car, as a hip belt causes an extended forward movement of the upper body and a powerful jerk against the abdomen/hips.

In 2001, a requirement was introduced for three-point belts in all seats in passenger cars, also the middle back seat. Installation of three-point belts is not required for the middle back seat in older cars. It is therefore important that road-users are made aware of the hazards in connection with using hip belts and that the other seats in the car are preferable if the middle back seat lacks a three-point belt.

5.10.2 Side collisions and three-point belts

Side collisions generally entail a greater risk of injury. Cars have poorer side collision protection, and standard three-point belts have limited protection potential in side collisions. On this basis, the AIBN considers that systems in the car that prevent skidding (electronic stability control) are important. Electronic stability control, which is nearly a standard feature on new cars, improves the opportunity to retain control of the vehicle.

In a side collision from the right, a standard three-point belt (pulled across the chest from the left) is unsuited to prevent the driver from being thrown to the right. The belt will slip off the left shoulder as the driver is thrown towards the right side. In addition, a general weakness in three-point belts is that it is possible to slip out of the diagonal belt if the person sitting in the belt twists the upper body out of the belt. Three persons (driver of the Nissan Terrano in Accident 3, driver of the Nissan in Accident 2 and the left back-seat passenger in the Toyota in Accident 8) could probably have survived with a belt preventing being thrown to the right. In four of the side collisions (Accident 2, Accident 3, Accident 4 and Accident 7) the AIBN considers that installed side collision airbags and side curtain airbags could probably have limited the extent of the injuries.

5.10.3 Securing cargo

Six persons have been registered as probably having suffered injuries as a result of cargo moving inside the compartment during the collision. In four cases, the AIBN considers that deficient securing of cargo had direct consequences for the injuries suffered. This applies to the rear passenger in the minibus in Accident 6, who was hit in the seat back by a 200 kg freezer, the child in the left back seat in the Toyota in Accident 7, who was hit by baggage in the seat back, as well as the front passenger and the child in the middle back seat of the Chevrolet in Accident 7, who were hit by flat-packed furniture in the back of their seats.

An unsecured object will continue forward at the same speed as the car when colliding, and will as such represent a significant force, depending on the weight of the object. Accident 7 shows that although the cargo is stacked correctly with the heaviest objects at the bottom, the load can be displaced by great collision forces as long as it is not sufficiently secured. There are requirements stating that cargo must be secured correctly so that it poses no threat and causes no injury, but more detailed provisions or guidelines have not been established as regards securing cargo internally in passenger cars.

5.10.4 Injuries from unsecured passengers

It was registered that unsecured passengers contributed to injuries for three other persons. They were the driver and front-seat passenger in the Mitsubishi in Accident 1, as well as the right back-seat passenger in the minibus in Accident 6. The accidents show the importance of not only securing yourself in the seat belt, but also checking that the others in the car are sufficiently secured. In the worst case, as shown by Accident 1, it is possible to be killed from injuries suffered from other unsecured passengers even if you are correctly secured in a seat belt.

5.10.5 Survival space and collision forces

Overall, survival space in the car was registered for 21 of the seriously injured or killed persons in the accidents, as well as somewhat limited survival space for four persons. 11 of the in total 36 seriously injured or killed persons had no survival space and could accordingly not have survived the accidents in the cars involved. Of the 21 with survival space, the AIBN considers that 17 of them could have survived or suffered reduced injuries with optimal securing of loads and people.

19 of the seriously injured or killed persons were exposed to high-energy and/or side collisions with limited survival potential regardless of safety equipment. This applies to the following accidents/vehicles: Accident 2 passenger car, Accident 3 passenger car, Accident 4 BMW passenger car, Accident 5 passenger car, Toyota in Accident 7 as well as Toyota in Accident 8. However, the survival potential would probably have increased with a newer car in some of these cases (see Chapter 5.10.7). In addition, individual capacity to survive is of importance to the survival potential, as illustrated by Accident 7.

5.10.6 Force-limiter and high-energy collisions

For the two final accidents in this material, seat belts with long wear marks were registered (for the driver in the Toyota in Accident 7 and the passenger in the Toyota in Accident 8) in combination with survival space. The wear marks were deposited on the seat belts when the force-limiter was activated by the high collision forces and the belts were pulled off the reel to increase the retardation distance. The tests commissioned by the AIBN show that the seat belts functioned as intended by the regulations. During forces of the magnitude registered in the two accidents, the AIBN considers that it is advantageous with a long length of seat belt pulled from the reel to increase the retardation distance and thus reduce the force on the persons from the seat belt.

However, this does not apply when the length of belt pulled off the reel is long enough to allow the persons to hit the interior of the car with great force. The tests commissioned by the AIBN showed that higher body weight increases the length of belt that is pulled off the reel. This may have an impact on people who weight significantly more than the test requirement of 75 kg. The length of belt pulled off the reel for the driver of the Toyota in Accident 7 resulted in his chest and head hitting the car interior with great force even if the compartment was intact. The AIBN considers that the driver could probably have survived the accident if the belt had permitted less forward movement of the upper body. For the passenger in the Toyota in Accident 8, medical findings show that the fatal injuries primarily occurred as a result of a powerful impact against the seat belt and not as a result of the impact with the interior.

5.10.7 The cars' collision safety and age

It is worth pointing out that most of the cars in this accident material are conspicuously old (older than the average Norwegian car). Of the 16 involved cars, 13 of them involved fatalities or severe injuries. The average age of these 13 cars is 13.2 years. The newest cars are the two Toyota Avensis (3 and 5 years old) and a Nissan Almera (8 years old). The oldest car was a Volvo 240 (1984 model/25 years old).

Five of the cars had been tested by EuroNCAP. Two had five stars (both Toyota Avensis, 2004 and 2005 models), one had four stars (Nissan Almera 2001) and two had two (not full) stars (Mitsubishi Lancer 1996 and BMW 325i 1991). The rest of the cars (11) had not been tested (all cars with a EuroNCAP ranking are also on the Folksam list).

Nine of the cars were on the Folksam list. Four cars are safer than average/one of the safest (VW Caravelle 1994, VW Caravelle 1997, Toyota Avensis 2004 and 2005). One car has good safety (Nissan Almera 2001). Three cars have medium safety, (Mitsubishi Lancer 1996, BMW 325i 1991, Volvo 240 1984), two are poorer than average (Nissan Terrano 1993, Mercedes E220 1994).

Three cars which were hit sideways by the other vehicle involved, with resulting intrusion into the compartment, were also listed as having medium or poorer than average safety in the Folksam list. For three of them (the BMW in Accident 4 and the Nissan Terrano in Accident 3), the AIBN has noted that a newer car could probably have limited the extent of the injuries. For the Mercedes in Accident 5, the forces involved were too great for survival, regardless of the properties of the car.

In three of the frontal collisions in this material, the AIBN has noted that a newer car with better collision safety and safety equipment could have reduced the injuries. This applies to the driver of the Mitsubishi in Accident 1, the driver of the minibus (Ford Transit) in Accident 6 and the driver of the Chevrolet in Accident 7.

Based on the analysis above, the AIBN expects that as older cars are phased out, they will be replaced by safer models, and the traffic fatality statistics will be further reduced. The 2010-2013 National Plan of Action for Road Traffic Safety (see Chapter 2.8) stipulates that an extrapolated renewal of cars in Norway will reduce the number of fatalities and seriously injured by 90 by 2014. This process can, if so desired, be advanced through measures and priorities giving a greater replacement rate for the Norwegian car fleet. In the AIBN's opinion, this should be emphasised when the National Transport Plan and the National Plan of Action for Road Traffic Safety are renewed in the next period. Renewal of the Norwegian car fleet is of importance for the issues raised in the thematic investigation, through features such as seat belt reminder systems, improved collision safety and driver support systems such as anti-skid and various emergency braking assistance systems.

5.10.8 How to promote increased use of seat belts?

The Norwegian Public Roads Administration's (NPRA) seat belt statistics show that seat belt use has increased significantly since 2004, both in and outside of built-up areas. As mentioned in Chapter 1.2, the usage percentage in 2010 was 94.8% outside of built-up areas and 92.7% in built-up areas. The NPRA has identified the following factors which have contributed to the higher seat belt usage: The NPRA’s seat belt campaign initiated in 2003, raised fines for not using seat belts from 2009 and an increasing percentage of the car fleet being equipped with seat belt reminders. In addition, a general focus on safety in society in general may also have contributed to increased use of seat belts. Both the NPRA’s and the Police's efforts as regards seat belt controls will also influence the usage percentage.

There may be many reasons why drivers and passengers do not use the seat belt. SINTEF's study (see Chapter 2.6) shows that most people are positive to using the seat belt, but that using the seat belt must become an automated habit. In this connection, the AIBN sees that efficient seat belt reminders can play an important role (see Chapter 2.2.3), in addition to seat belt campaigns. There is therefore reason to believe that replacement of the car fleet will also contribute to higher seat belt use through improved seat belt reminder systems.

Probably, there is also a percentage of remaining non-users that can be hard to influence. Some have a medical certificate exempting them from use of seat belts. The AIBN does not know how large this percentage is. Others may have problems complying with laws and rules in general - for various reasons. It is possible that we will be left with an unreformed group of people who are hard to influence through traditional means such as campaigns. One idea that has been launched is a "Seat belt lock” – on the same principle as an ”Alcolock”: The car will not start until everyone in it has inserted the buckle in the lock. It is unknown what the status of such a system is.

5.10.9 The basic data

Seven of the 26 killed in the described accidents were not autopsied (three of the seven were car drivers) in the eight accidents. The basis for AIBN's assessments of survival potential could have been even better if all the killed had been autopsied.

The Prosecuting Authority's application for an expert post mortem examination (also including an autopsy) is governed by Section 228 of the Criminal Procedure Act and supplemented by rules given in Section 13-2 of the Prosecution Instructions. The AIBN cannot apply for an autopsy through its legislation, but can request the assistance of the Police (Section 46 of the Road Traffic Act concerning securing of evidence). The AIBN has experienced that requests for assistance are not always successful.

In the AIBN's opinion, valuable knowledge concerning injury mechanisms in accidents and information that could have an effect in the overall traffic safety work is lost as result of autopsies not being generally performed on everyone killed in traffic. The AIBN realises that there will be both financial and resource-related costs in this connection, but would like to remind the Prosecuting Authority and the Police of the need for applying for autopsies in road traffic accident with fatal outcomes, in cases where traffic safety could learn from this.

6. CONCLUSION

The combination of technical findings in cars, medical findings and assessments, simulations in the Scan-crash computer program, as well as crash tests and extension tests of seat belts have given the AIBN the opportunity to consider the potential for survival or changes in the injury situation for the seriously injured and killed in the eight investigated accidents. Combined, this constitutes an extensive material about safety in cars and provides increased knowledge about the factors/conditions which affect survival potential in a car accident.

The available material covers 26 people killed in head-on accidents with three or more fatalities in 2008 and 2009. During these two years a total of 470 people were killed in road traffic. The material thus covers 5.5% of the total number of fatalities in 2008 and 2009. The AIBN assumes that there will be similar injury mechanisms in other fatal accidents, i.e. with fewer than three fatalities.

The investigation shows that proper seat belt use, the securing of items in the car, speed variation and point of impact in the collision, the car's protection against intrusion and available safety equipment is of great importance for survival. Overall, the investigation confirms that the use of seat belts (three-point seat belts) is the most important and most effective safety measure. However, the investigation also points to other issues/factors that are not as well-known among general road users.

The investigation puts focus onto the following aspects:

a) Failure to use seat belts with survival space in the car. In the eight accidents, nine persons did not use seat belts. Three of the people killed and four of the seriously injured could have survived/suffered less serious injuries had they used seat belts. Using a seat belt prevents or reduces the impact with the car interior, as well as reducing and distributing the G forces against the body over a longer time and distance.

b) In one of accidents, the driver had an exemption from using the seat belt due to claustrophobia. In the AIBN's opinion, all fatal injuries suffered by the driver in this accident could have been prevented by a correctly used seat belt, and the AIBN questions the validity of exemptions from the use of seat belts due to claustrophobia.

c) It is important that the seat belt is sufficient tightened, without twists, lying against the hips and that the seat is in the right position (upright). A belt that is slack across the chest and hips will not prevent forward movement of the upper body. In a collision, this will result in a powerful jerk/impact as the upper body is kept back by the belt. For four persons, incorrect use of seat belts contributed to death/injury. In addition, two children covered by the study had not optimally tightened belts over the shoulder, but this did not decisively affect the outcome.

d) An object that is not secured will continue forward at the same speed as the car in a collision, and will as such represent a significant force, depending on the weight of the object. Loose cargo in the car therefore entails a risk, and in four cases the AIBN believes that securely fastened cargo to prevent the displacement of cargo could have changed the injury outcome.

e) Correspondingly, it is important that all persons in the car are secured. Two persons who used seat belts themselves died from injuries inflicted by other persons in the car who were not secured.

f) The AIBN would also like to point out the importance of three-point belts for all seats in the car as hip belts cause an extended forward movement of the upper body and a powerful jerk against the abdomen/hips. One person was killed and a child was severely injured as a result of this.

g) Most frontal collisions can be survived, up to an average G force of 20-25 G, given sufficient survival space and correct securing of people/objects in the car.

h) Side collisions generally entail a greater risk of injury. Cars have poorer side collision protection, and standard three-point belts have limited protection potential in side collisions. On this basis, the AIBN considers that systems in the car that prevent skidding (electronic stability control) are important. In four of the side collisions, the AIBN considers that installed side airbags and side curtain airbags could probably have limited the extent of the injuries for the persons involved.

i) In high-speed collisions involving cars with seat belts installed with force-limiter, the AIBN's investigations show that higher body weight increases the length of belt pulled off the reel. There is therefore a risk that a heavy person[30] can result in the belt being pulled out so far that the person hits the interior of the car with great force even if the car's survival space is intact. In one of the accidents, the car driver could probably have survived if the safety belt had permitted less forward movement of the upper body.

j) Most of the cars in this accident material are conspicuously old (older than the average Norwegian car). The AIBN believes that six persons could have suffered less serious injuries given a newer car with better collision safety.

In total, AIBN’s analyses show that 16 of the 36 persons that were killed or seriously injured had sufficient survival space, and could have survived or suffered less serious injuries in the accident given the correct use of three-point seat belts and the securing of other people and cargo/items in the car. Additional survival potential is found if the cars in this material had been replaced by cars with better crash safety and safety equipment.

The AIBN would like to point out that every driver can affect the probability of being involved in an accident through safe driving, especially through speed selection. However, one cannot control the behaviour of other road-users. The car’s survival space – the room the driver and the car occupants need to survive – is therefore crucial if an accident occurs. As a driver and passenger, it is important to consider how to best ensure this survival space. Regardless of the car’s collision protection and safety equipment, properly tightened three-point seat belts for everyone in the car and the correct positioning and securing of cargo/items, are essential to ensure survival space.

[30] Who weighs significantly more than the test requirement for seat belts of 75 kg (as set in Appendix 9 to EU directive 2000/3EC and ECE 16 Annex 8).

7. SAFETY RECOMMENDATIONS

The thematic investigation that includes eight road traffic safety accidents has identified several areas where the AIBN considers it necessary to make safety recommendations aiming to improve traffic safety.[31] The AIBN considers that the safety recommendations comply with and reinforce several of the measures listed in the 2010-2013 National Plan of Action for Road Traffic Safety.

Safety recommendation ROAD No. 2012/01T

A total of three of the 26 persons killed and four of the ten persons seriously injured in the eight accidents could have survived/suffered less serious injuries had they used seat belts. For another four persons, incorrect use of seat belts contributed to death/injury, two children in child seats did not have optimally tightened belts, and two persons who used belts died as a result of injuries inflicted by other persons in the car who were not secured.

The AIBN recommends that the Norwegian Public Roads Administration and the Police focus on correct use of seat belts and child seats in controls.

Safety recommendation ROAD No. 2012/02T

The high usage percentage in Norway shows that various measures and campaigns to increase seat belt use have had an effect. However the AIBN sees a further safety potential through this study. For four people, incorrect seat belt use contributed to death/injury, two children in child seats did not have optimally tightened belts, two persons who used seat belts were injured by other persons in the car who were not secured, and for two persons use of hip belts caused death/injury.

The AIBN recommends that the Norwegian Public Roads Administration, the Norwegian Council for Road Safety and the Police reinforce their information work in connection with correct use of seat belts and securing of children in cars, as well as the importance of three-point belts.

Safety recommendation ROAD No. 2012/03T

In four cases, the AIBN considers that securely fastened cargo to prevent displacement could have resulted in a different injury outcome. There are requirements stating that cargo must be secured correctly so that it poses no threat and causes no injury, but more detailed provisions or guidelines have not been established as regards securing cargo internally in passenger cars.

The AIBN recommends that the Norwegian Public Roads Administration reinforces its information work, e.g. through preparing own guidelines relating to securing of cargo internally in passenger cars.

Safety recommendation ROAD No. 2012/04T

In high-speed collisions involving cars with seat belts installed with force-limiter, the AIBN's investigations show that higher body weight increases the length of belt pulled off the reel. There is therefore a risk that a heavy person (heavier than the test weight of 75 kg as set in Appendix 9 to EU directive 2000/3EC and ECE 16 Annex 8) can result in

[31] The study report will be submitted to the Ministry of Transport and Communications, which will implement the necessary measures to ensure that the safety recommendations are taken under due consideration, cf. Section 14 of the Regulations of 30 June 2005 relating to public investigations and notification of traffic accidents, etc.

the belt being pulled out so far that the person hits the interior of the car with great force even if the car's survival space is intact. In one of the accidents, the car driver could probably have survived if the safety belt had permitted less forward movement of the upper body.

The AIBN recommends that the Norwegian Public Roads Administration works to influence the European directive so that passive safety in cars is better safeguarded for people weighing more than the test weight of 75 kg.

Accident Investigation Board of Norway

Lillestrøm, 5 March 2012

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LIST OF TERMS

Airbag	A compressed airbag inflated in a collision (see Chapter 2.2.4).
Deceleration trauma	Injuries caused by very fast deceleration (e.g. collision) where the body stops, while the inner organs continue the movement.
EuroNCAP	The leading and best known independent crash test programme in Europe (see Chapter 2.5.1).
Folksam list	The insurance company Folksam in Sweden prepares lists of car model safety, based on statistic material from real accidents (see Chapter 2.5.2).
Force limiter	The force limiter reduces the force that the seat belt can transfer to the passenger in a collision, and therefore reduces the risk of injuries to the upper body (see Chapter 2.2.2).
G force	Inertial force used to indicate the accelerative force that a body is exposed to (see Chapter 2.4).
Risk	Expression of the combination of the probability of and consequence of an undesirable incident.
Seat belt pretensioner	Is tensioned instantaneously in a collision to hold the passenger in place until the airbag is triggered (see Chapter 2.2.2).
Skull base	The bottom of the skull, formed by the occipital bone, the temporal bones, the sphenoid bone and the ethmoid bone.
Survival space	The available space, after deformation or intrusion of chassis sections in a collision, which the driver and passengers have available in the compartment to survive the accident.
Transversal fracture at the skull base	Fractures across the longitudinal direction of a long bone/transversal fracture at the skull base, typically from one auditory canal orifice to the other.

APPENDICES

Appendix A: Full scale tests compared with laboratory tests

The engineering firm Rekon participated at the EES Workshop Graz 2 – 3 Nov. 1996. There, identical cars (Ford Escort, 1980 – 1982 models) were driven against barriers at different speeds, and the acceleration pulse of the car was measured by UDS (UnfallDatenSpeicher) installed on the floor of the boot.

In Figures 1-4 below, the acceleration pulses at four different acceleration speeds (38, 52, 83 and 95 km/h) were drawn into the diagram for the corridor which the curve for the car's retardation must be within when testing seat belts (as set in Appendix 9 to EU directive 2000/3EC and ECE 16 Annex 8) with correct scale in the horizontal and vertical axis in relation to the acceleration pulse. The corridor has been moved along the time axis to make the acceleration corridor fit the corridor as well as possible.

The figures show that full-scale tests have longer duration and longer ending phases (time) in relation to maximum G forces, compared with the defined corridor in the laboratory tests. The maximum G forces for the full-scale test at 83 km/h (Figure 3) have average values corresponding to the laboratory test.

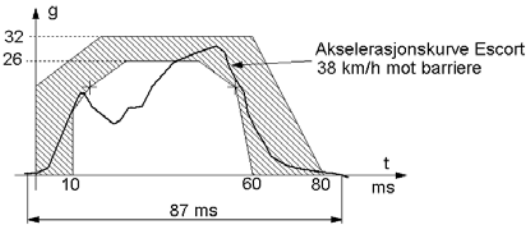

Figure 1: The test corridor for belt tests in relation to the acceleration curve for Ford Escort in barrier tests with a collision speed of 38 km/h.

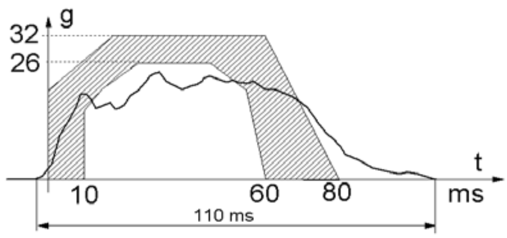

Figure 2: The test corridor for belt tests in relation to the acceleration curve for Ford Escort in barrier tests with a collision speed of 52 km/h.

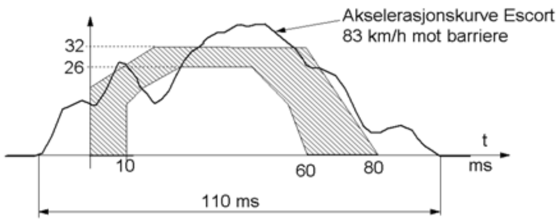

Figure 3: The test corridor for belt tests in relation to the acceleration curve for Ford Escort in barrier tests with a collision speed of 83 km/h.

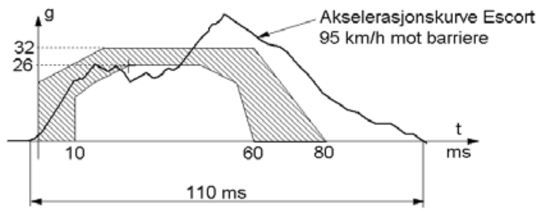

Figure 4: The test corridor for belt tests in relation to the acceleration curve for Ford Escort in barrier tests with a collision speed of 95 km/h.

Appendix B: Summary of survival potential for the eight investigated accidents

<table>
<tr><th colspan="13">Accident 1</th></tr>
<tr><th>Person Location</th><th>Gender Age</th><th>Degree of injury</th><th>Seat belt</th><th>Airbag</th><th>Seat belt pre tensioner/ force limiter</th><th>Surv. space</th><th>Hit by unsecured cargo/ passenger</th><th>Year model EuroNCAP Folksam</th><th>Speed change Point of impact</th><th>Average G force</th><th>Surv. potential</th><th>Comments</th></tr>
<tr><th colspan="13">Mitsubishi Lancer 1996 model. Weight: 1525 kg.</th></tr>
<tr><td>Driver</td><td>M 54</td><td>Dead</td><td>+/-
Slack across the chest due to twist in upper seat belt anchor</td><td>Yes
Steering wheel - triggered</td><td>-</td><td>Somewhat limited</td><td>Seat back pushed forward by unsecured back-seat passenger</td><td rowspan="5">1996
*(*)
Medium</td><td rowspan="5">71-93 km/h impact in front</td><td rowspan="5">17-22 G</td><td>Medium</td><td>Given correct seat belt use and use of seat belt by back seat passengers. Higher survival potential given a newer car with better collision safety (4-5 stars in EuroNCAP).</td></tr>
<tr><td>Front-seat passenger</td><td>F 32</td><td>Dead</td><td>+
Upper belt anchor yielded slightly, but did not break.</td><td>Yes
Dashboard - triggered</td><td>-</td><td>Yes</td><td>Seat back pushed 12 cm forward by unsecured back-seat passenger</td><td>High</td><td>Given that the back seat passengers had used seat belts.</td></tr>
<tr><td>Left back-seat passenger</td><td>M 25</td><td>Severely injured</td><td>-</td><td>-</td><td>-</td><td>Yes</td><td></td><td>High</td><td>Given use of seat belt.</td></tr>
<tr><td>Right back-seat passenger</td><td>M 24</td><td>Severely injured</td><td>-</td><td>-</td><td>-</td><td>Yes</td><td></td><td>High</td><td>Given use of seat belt.</td></tr>
<tr><td>Passenger possibly in the boot</td><td>M 36</td><td>Dead</td><td>-</td><td>-</td><td>-</td><td>Yes</td><td></td><td>High</td><td>Given use of seat belt.</td></tr>
<tr><th colspan="13">Scania lorry. Weight 51 700 kg.</th></tr>
<tr><td>Driver</td><td>M</td><td>Unharmed</td><td>?</td><td></td><td></td><td></td><td></td><td></td><td>2-3 km/h impact in front</td><td>approx. 1 G</td><td></td><td>No further investigation made</td></tr>
</table>

Accident 2												
Person Location	**Gender Age**	**Degree of injury**	**Seat belt**	**Airbag**	**Seat belt pre tensioner/ force limiter**	**Surv. space**	**Hit by unsecured cargo/ passenger**	**Year model EuroNCAP Folksam**	**Speed change Point of impact**	**Average G force**	**Surv. potential**	**Comments**
Nissan Almera 2001. Weight: 1330 kg.												
Driver	F 44	Dead	Uncertain	Yes Front side airbag - triggered Front airbag - not triggered	-	Yes	Heads of driver and front seat passenger collided	2001 **** Good	41-53 km/h side impact	10-13 G	Low	Even though both the driver and front-seat passenger used seat belts. Three-point seat belts have limited protection potential in side collisions
Front-seat passenger	M 24	Dead	-	Yes Front side airbag - triggered Front airbag - not triggered	-	No	Heads of driver and front seat passenger collided				Low	As a result of significant intrusion.
Right back-seat passenger	F 18	Dead	-	-	-	No					Low	Higher survival potential given a newer car with better collision safety, installed side and side curtain airbags.
Dodge Ram 2003. Weight: 3290 kg.												
Driver	M 30	Minor injuries	-	Yes In front - triggered	-	Yes		2003 - -	17-22 km/h impact in front	4-5 G		
Front-seat passenger	F 24	Minor injuries	-	Yes In front - triggered	-	Yes						

<table>
<tr><th colspan="13">Accident 3</th></tr>
<tr><th>Person Location</th><th>Gender Age</th><th>Degree of injury</th><th>Seat belt</th><th>Airbag</th><th>Seat belt pre tensioner/ force limiter</th><th>Surv. space</th><th>Hit by unsecured cargo/ passenger</th><th>Year model EuroNCAP Folksam</th><th>Speed change Point of impact</th><th>Average G force</th><th>Surv. potential</th><th>Comments</th></tr>
<tr><td colspan="13">Nissan Terrano 1993. Weight: 2300 kg.</td></tr>
<tr><td>Driver</td><td>M 43</td><td>Dead</td><td>+</td><td>-</td><td>-</td><td>Limited</td><td></td><td rowspan="2">1993
-
Poorer than average</td><td rowspan="2">65-76 km/h
Side impact</td><td rowspan="2">15-18 G</td><td>Low</td><td>Three-point seat belts have limited protection potential in side collisions</td></tr>
<tr><td>Front-seat passenger</td><td>M 25</td><td>Dead</td><td>+</td><td>-</td><td>-</td><td>No</td><td></td><td>Low</td><td>Higher survival potential given a newer car with better collision safety, installed side and side curtain airbags.</td></tr>
<tr><td colspan="13">Mercedes Sprinter 1996. Weight: 3000 kg.</td></tr>
<tr><td>Driver</td><td>M 50</td><td>Dead</td><td>-
Medical certificate of exemption due to claustrophobia</td><td>-</td><td>-</td><td>Yes</td><td>Unsecured cargo pushed the divider wall against the seat back.</td><td>1996
-
-</td><td>50-59 km/h
Front impact</td><td>12-14 G</td><td>High</td><td>Given seat belt. Unsecured cargo of no significance.</td></tr>
</table>

Accident 4

Person Location	Gender Age	Degree of injury	Seat belt	Airbag	Seat belt pre tensioner/ force limiter	Surv. space	Hit by unsecured cargo/ passenger	Year model EuroNCAP Folksam	Speed change Point of impact	Average G force	Surv. potential	Comments
BMW 325i 1991. Weight: 1520 kg.												
Driver	M 24	Dead	? Belt buckle not found in lock	-	-	Yes		1991 *(*) Medium	66-75 km/h Side impact	16-18 G	Low	Probably not possible to survive with correct seat belt use.
Front-seat passenger	M 8 months	Dead	+/- Shoulder belt not sufficiently tightened?	-	-	No	Child may have been hit by ski sled in the back seat.				Low	As a result of the child car seat being destroyed in the collision.
Right back-seat passenger	F 24	Dead	+	-	-	No	Hit the ski sled in the back seat.				Low	Intrusion on the right side up to 90 cm not compatible with survival. Higher survival potential given a newer car with better collision safety, installed side and side curtain airbags. The ski sled was probably not decisive.
VW Caravelle 1994. Weight: 2150 kg.												
Driver	M 39	Minor injuries	+					1994 - Safer than average	41-46 km/h Front impact	10-11 G		
Front-seat passenger	F 40	Minor injuries	+									
Right back-seat passenger	M 13	Minor injuries	+									
Passenger middle back seat	F 8	Severely injured	+/- Hip belt not sufficiently tightened.			Yes					High	Given a three-point belt. Hip belts cause an extended forward movement of upper body and a powerful jerk against the abdomen/hips.
Left back-seat passenger	M 11	Minor injuries	+									

Accident 5												
Person Location	**Gender Age**	**Degree of injury**	**Seat belt**	**Airbag**	**Seat belt pre tensioner/ force limiter**	**Surv. space**	**Hit by unsecured cargo/ passenger**	**Year model EuroNCAP Folksam**	**Speed change Point of impact**	**Average G force**	**Surv. potential**	**Comments**
Mercedes E220 1994. Weight: 1710 kg.												
Driver	M 23	Dead	?	None	-	No		1994 - Poorer than average	72-92 km/h Side impact	17-22 G	Low	The accident could not have been survived, even in a newer car with all available safety equipment and no subsequent fire.
Front-seat passenger	M 23	Dead	?	None	-	No					Low	As above.
Back-seat passenger	M 28	Dead	+	None	-	No					Low	As above.
Back-seat passenger	M 30	Dead	+	None	-	No					Low	As above.
VW Caravelle 1997. Weight: 1845 kg.												
Driver	M 53	Dead	-	Yes Triggered for driver and passenger seat	-	Yes		1997 - Safer than average	67-86 km/h Front impact	16-20 G	Medium	Given use of seat belt. Reservations due to no autopsy.

Accident 6

Person Location	Gender Age	Degree of injury	Seat belt	Airbag	Seat belt pre tensioner/ force limiter	Surv. space	Hit by unsecured cargo/ passenger	Year model EuroNCAP Folksam	Speed change Point of impact	Average G force	Surv. potential	Comments
Ford Transit 1996. Weight: 2975 kg + 700 kg.												
Driver	M 63	Dead	+	Yes In front – both triggered	Yes/No	Limited					Low	Low in this car. Medium - given a newer car with better collision safety and seat belts with force limiters.
Middle passenger in front	M 49	Minor injuries	+	Yes In front – both triggered	Yes/No							
Right front passenger	M 58	Minor injuries	+	Yes In front – both triggered	Yes/No							
Left back-seat passenger	M 24	Severely injured	+			Yes		1996 - -	30-38 km/h impact in front	7-9 G	No change?	Given seat back in the upright position?
Passenger middle back seat	M 47	Dead	+ Hip belt			Yes					High	Given a three-point belt
Right back-seat passenger	M 48	Severely injured	-			Yes	Unsecured cargo/passenger behind in seat back.				High	Given correct securing of all persons and cargo.
Rear passenger	M 54	Severely injured	-			Yes	Freezer (approximately. 200 kg) in seat back.				High	Given correct securing of all persons and cargo.
Volvo 240 1984. Weight: 1355 kg.												
Driver	M 19	Dead	+	-		No		1984 - Medium	82-104 km/h Front impact	19-25 G	Low	No survival potential

Accident 7

Person Location	Gender Age	Degree of injury	Seat belt	Airbag	Seat belt pre tensioner/ force limiter	Surv. space	Hit by unsecured cargo/ passenger	Year model EuroNCAP Folksam	Speed change Point of impact	Average G force	Surv. potential	Comments
Toyota Avensis 2006. Weight: 1495 kg.												
Driver	M 57	Dead	+ Approx. 36 cm wear mark on the belt.	Yes Steering wheel - triggered	Yes/Yes	Yes					Medium	Given that the seat belt had permitted less forward movement of the upper body.
Front-seat passenger	F 52	Dead	+ Approx. 12 cm wear mark on the belt.	Yes Dashboard - triggered	Yes/Yes	Yes	Oblong flat pack (25 kg, on the floor) pushed seatback 8-10 cm forward	2006 ***** One of the safest	64-86 km/h Front impact	15-20 G	Low	Triggered side and side curtain airbags could probably limited the injuries.
Left back-seat passenger	F 12	Severely injured	+		Yes/Yes	Yes	Heavy unsecured cargo pushed seatback forward				High	Given securing of baggage.
Chevrolet Astro 1990. Weight: 2220 kg.												
Driver	M 35	Severely injured	+/- Possibly slack belt	No	No	Yes					Medium	Given tightened belt. Higher given a newer car with airbag and seat belt pretensioner.
Front-seat passenger	F 36	Severely injured	+				Flat packs in seat back				Medium	Given secured cargo
Passenger middle back seat	M 5	Dead	+/- Slack belt at the shoulder (slid off), wear marks, thrown forward against the driver seatback	No	No	Yes	Flat packs (160 kg) into seatback, which was pushed forward	1990 - -	43-58 km/h Front impact	10-14 G	High	Given secured cargo.
Left back-seat passenger	F 7	Severely injured	+								Low	

Accident 8												
Person Location	**Gender Age**	**Degree of injury**	**Seat belt**	**Airbag**	**Seat belt pre tensioner/ force limiter**	**Surv. space**	**Hit by unsecured cargo/ passenger**	**Year model EuroNCAP Folksam**	**Speed change Point of impact**	**Average G force**	**Surv. potential**	**Comments**
Toyota Avensis 2004. Weight: 1515 kg.												
Driver	M 74	Dead	+ Approx. 12 cm wear mark on the belt.	Yes Steering wheel - triggered	Yes/Yes	No		2004 ***** One of the safest	87-104 km/h Front impact	21-25 G	Low	
Front-seat passenger	F 67	Dead	+ Approx. 37 cm wear mark on the belt. Medical findings indicate that the belt was pushed in towards the abdomen instead of the hips.	Yes Dashboard - triggered	Yes/Yes	Yes					Medium	Probably survival potential given correct use of the seat belt and optimal medical first aid.
Left back-seat passenger	M 55	Dead	+		Yes/Yes	Yes					Low	General weakness in three-point belts that it is possible to slide out of the diagonal belt. Improvements in the design of seat belts and airbags for back-seat passengers could probably have prevented fatal injuries in this accident.
Lorry with trailer 2007. Weight: 48 000.												
Driver	M 34	Unharmed	?			+			3-4 km/h Front impact	approx. 1 G		No further investigation made