SWOV Fact sheet

Seat belts, airbags and child protection devices

Summary
In the Netherlands, the use of seat belts results in a yearly reduction of hundreds of fatalities. Seat belts reduce the risk of fatal injury by 37 to 48%, depending on the position in the car. At 50%, the effect of child protection devices is even slightly higher. When last measured (in 2010), 97% of the front seat occupants in cars used a seat belt, and so did approximately 82% of backseat occupants. In delivery vans, lorries and buses equipped with seat belts, the use of seat belts is lower. Circa 68% of children are transported with sufficient protection. Seat belts are continuously being improved. For instance, there are systems to reduce the forces that seat belts exert on the human body (the seat belt tensioner and the force limiter) and to activate the seat belt earlier during the crash process (pre-crash sensors).

Front airbags supplement seat belts. Airbags in the outer sides of the seats and in the rim of the roof have an important independent function in case of side-crashes or when the car hits a tree or other vertical object from the side.

Background and content
Cars are increasingly getting safer, partly as a result of primary or active safety systems and secondary or passive safety systems. Primary safety systems focus on preventing crashes, secondary safety systems diminish the consequences of crashes. Seat belts, airbags and child protection devices diminish injury and therefore fit in the latter category. Seat belts, often in combination with the airbag, and child protection devices are primarily intended for the protection of occupants in the case of a head-on collision. In the case of side-collisions and roll-overs, seat belts and child protection devices mainly prevent occupants from being thrown across or out of the car and this way they considerably increase the chances of surviving a crash. However, in the case of a rear-end collision the effect is limited. In the 1970s the use of seat belts was made compulsory in practically all European countries. This fact sheet discusses the contribution of the use of seat belts, airbags and child protection devices to casualty reductions. Regulations will also be dealt with. Furthermore, the airbag in combination with seat belts and child restraint seats in front seat position will be discussed.

How often are seat belts and child protection devices used in the Netherlands?
In the course of the last few decades, an increasing number of occupants have been using seat belts in the Netherlands. Since 1972, the year with the largest number of fatalities among car drivers, the use of seat belts has resulted in a reduction of, on average, 250 fatalities per year among car occupants. In 1972, the seat belt wearing rate amounted to no more than 20% (solely front seat position); in 2010 the seat belt wearing rate for front seats was 97%. Outside urban areas, the seat belt wearing rate for drivers increased from 78% in 1990 to 97% in 2010; within urban areas this figure increased from 59% to 96% (see *Table 1*). Thus, the traditional difference between within and outside urban areas has practically disappeared. The use of seat belts by front seat passenger is more or less of the same level as that of the use by drivers. The seat belt wearing rate for rear seats increased tremendously in the last few years: from 20% in 1990 to 82% in 2010. The increase can be explained by a combination of factors: enforcement (see also SWOV Fact sheet *Effects of police enforcement of protection devices and moped helmet use and red light running*), education and equipment in cars of a warning system for the use of seat belts (see SWOV Fact sheet *Seat belt reminders*).

The national measuring of the use of seat belts (since 1969) take the occupants of cars into account as well as of delivery vans. Despite a large increase in the seat belt wearing rate since 2000, the level in delivery vans clearly falls short of that of car occupants (not differentiated in *Table 1*). In 2010 almost 87% of the drivers of delivery vans wore seat belts and almost 81% of the front seat passengers. The seat belt wearing rates in lorries and buses have not been quantified, but they appear to be considerably lower than those in delivery vans.

Year	Drivers		Rear seat passengers	
	Rural areas	Urban areas	Rural areas	Urban areas
1990	78%	59%	22%	18%
1995	77%	64%	21%	20%
1998	80%	67%	43%	40%
2000	86%	74%	36%	28%
2002	91%	83%	56%	49%
2004	92%	88%	67%	71%
2006	94%	93%	73%	73%
2008	96%	95%	80%	82%
2010	97%	96%	85%	79%

Table 1. *Seat belt wearing rates for drivers and rear seat passengers in cars and delivery vans in rural and urban areas in the period 1990-2010, Front seat passengers are comparable to drivers (Mulder, 1998; Transport Research Centre, 2000-2006; Centre for Transport and Navigation (DVS), 2007; 2008; 2010).*

In 2006, a series of new traffic laws resulted in a considerable improvement of the safe transport of children up to 1.35 m tall (see 'What are the rules in the Netherlands' under *Child protection devices*). *Table 2* shows that in 2004, 62% of the children observed were transported without any or with insufficient protection; in 2010 this had decreased to 32%. *Unprotected* transport should be read as, for instance, travelling in a seat without a seat belt, in an unattached carrycot, or being seated on a passenger's lap. *Insufficiently protected* transport is transport with a protection device that does not meet the legal requirements, as, for instance, a mere seat belt where a child protection device should be used. The criteria for 'insufficiently protected' were adjusted in 2006; consequently the corresponding percentages do not always refer to the same situation. Until March 2006, children up to 1.35 m tall and aged 3 years and older were allowed to use a seat belt in the rear of a car instead of a child protection device. Also, it was allowed to travel without a child protection device in the front of the car for children with a minimum height of 1.50 m instead of 1.35 m (and a minimum age of 12).

Year	Children observed	
	Not or insufficiently protected	Sufficiently protected
2002	55%	45%
2004	62%	38%
2006	28%	72%
2008	12%	88%
2010	32%	68%

Table 2. *Percentages '(in)sufficiently protected' transport of children in the period 2002-2010, permitted exceptions not included. (Transport Research Centre, 2000-2006; Centre for Transport and Navigation (DVS), 2007; 2008; 2010).*

Table 2 shows a decrease in 2010 of the percentage of 'sufficiently protected' in comparison with 2008 (from 88 to 68). A considerably larger number of children among those observed in 2010 were found to be transported with the use of a seat belt without a child restraint seat or booster seat. As the study in 2010 included older (4 years on average) and therefore taller children than in 2008 (2.5 years on average), the share of children using no more than a seat belt was more substantial. Therefore, 2010 may not necessarily indicate a decline, but 2008 may, on the other hand, present a flattering picture. Nevertheless, the percentages before and since 2006 shows a noticeable effect of the tightening of the rules in 2006.

What is the effect of child protection devices on road safety?
Table 3 shows that seat belts reduce the risk of serious or fatal injury considerably.

Type of injury	Seat belts in front	Seat belts in rear	Child protection devices
Serious injury	25%	20%	30%
Fatal injury	40%	30%	50%

Table 3. *Estimated reduction of the injury rate when using seat belts and child protection devices in cars in the Netherlands (seat belt figures based on Evans, 1986 and 1991; child protection devices on Schoon & Van Kampen, 1992).*

Research by Glassbrenner & Starnes (2009) indicated a 48% lower risk of fatal injury for car drivers using a three-point seat belt in comparison with drivers not using a seat belt. For front seat passengers of 5 years and older, this risk is 37% lower. In combination with an airbag, the risk reduction amounts to 54% for drivers and 44% for passengers of 12 years and older; up to this age, an airbag shows no positive effect. According to Glassbrenner & Starnes, three-point seat belts in the back of the car account for a 44% lower risk of fatal injury. Mizuno et al. (2007) arrived at an almost equal percentage of 45. It is plausible that the higher figures in these more recent studies provide a better view of the current situation than those in earlier studies, because the seat belt configurations have been improved over the years. *Table 3* shows that the net effect of the seat belt on serious injury is less substantial than the effect on fatal injury. The explanation being that the number of severely injured increases with the reduction of fatalities due to seat belt use. They may constitute injury of internal organs and the spine, as a result of the impact of the seat belt. A number of the severely injured casualties will sustain less serious injury when using a seat belt, but will nevertheless still be severely injured.

With 50%, the effect of child protection devices is slightly greater than the effect of seat belts (Schoon & Van Dampen, 1992; Brown et al., 2002). These studies did not distinguish between age of the children, type of protection device, or position in the car.

The use of seat belts in the back of the car also has a positive effect on the safety of the front seat passengers. In fact, research by Ichikawa et al. (2002) shows that the fatality rate of front seat passengers using a seat belt increases by a factor of five, when rear seat passengers do not use a seat belt, as they can hit the front seat during a head-on collision. Of course front seat occupants can also injure each other when at least one of them does not use a seat belt, in particular in the case of a side impact.

Front airbags are mainly important as an addition to seat belts: they increase the effectiveness of the seat belts by 11% (Glass Brenner & Starnes, 2009). With no seat belts used, they have an independent effectiveness of 14%. Side-airbags distribute the impact of the parts of the car interior which are pressed inwards across a larger surface of the human body and thus lead to, among other things, a reduction of rib fractures. Curtain airbags protect the head against impact of the rim of the roof and the pillars. Both reduce the severity of the injury and are potentially life-saving. Studies quantifying this reduction are not yet available.

The percentages for the effectiveness of the crash protection devices mentioned in this section are average figures. The effectiveness is, among other things, dependent on the collision speed (Evans, 1996) and factors such as the construction of the car (for instance, height, weight, the effect of the crumple zones, the strength of the passenger compartment and the installation of seat belt tensioners and seat belt force limiters), the correct use of the seat belts, the age and physical condition of the occupants, and the degree in which the object collided with yields. In the case of very high collision speeds, the effect of protection devices will ultimately decrease to 0. There are definitely limits to the degree of deceleration that a human body can withstand, not to mention whether the passenger compartment still leaves room for survival after the crash. In the case of lower speeds, the effect is actually substantial, because the degree of deceleration remains limited and the seat belt, possibly in combination with the airbag, prevents contact with the interior of the vehicle. It is therefore important to use seat belts in urban areas as well. Those who have ever run into a glass door can imagine how much difference a seat belt can make at low speeds.

What are the rules in the Netherlands?

Seat belts and seats
On 1 January 1971, anchorage points and seat belts in the front of new cars were made compulsory. From June 1975, it was made compulsory to use front seat belts. Initially, the regulations for the presence and use of seat belts only applied for passenger cars and was later made compulsory for all cars and for specific types of buses. Since 1 April 2008, passengers are only allowed to be transported on actual seats, made for use by adults during transport. During transport, passengers are therefore not allowed to be seated on an improvised seat or a seat for stationary purposes, such as a seat in a camper van. There are a few exceptions to this rule, for instance, the transport of children up to 1.35 m tall on a standard seat or a seat later installed in a station wagon and the transport of wheelchair passengers. It is not permitted to transport passengers in the luggage compartment or the loading space or in (or on top of) a trailer or caravan behind a motor vehicle, if no exemption has been given (for instance in the context of a parade). Since 1 May 2008 it is no longer allowed to transport more occupants than there are seatbelts in cars with seat belts in all seating positions. For instance, if there are only two rear seat belts, no three passengers can be seated in the back of the car.

Seat belts should be installed in conformity with the European directives for seat belts and seat belt anchorage points (directives *77/541/EEG* and *76/115/EEG*). In the Netherlands, compulsory use of seat belts is laid down in articles *59*, *59a* and *59b* of Traffic Code 1990 (RVV 1990). Further measures with respect to the use of seat belts can be found under *Measures* at the SWOV website. See also the section about the use of seat belts and child safety systems in the publication of Ministry of Infrastructure and the Environment entitled *Road Traffic Signs and Regulations in the Netherlands*.

Child protection devices[1]
Seat belts have been developed for adults. For this reason, special protection devices have been developed for children. These may be carrycots, baby or child restraint seats with their own seat belts or booster seats, used in combination with seat belts for protection of the child. In 2003 it was organized on European level[2] that children shorter than 1.35 m or 1.50 m must use a child protection device, in the front, as well as in the back of the car. It is left to the member states to decide between 1.35 m or 1.50 m. For instance, the Netherlands adheres to 1.35 m, Germany to 1.50 m. This has to be taken into account when travelling abroad. In addition to certain child protection devices developed by car manufacturers for their own brand, universal and semi-universal child protection devices have been developed (for all cars and for a number of cars included in a list, respectively).

No child protection devices are permitted to be used other than those that meet the requirements of *ECE-regulation 44*, version 3 or following. They are divided into weight categories[3]. An age indication is used for each weight category (see *brochure*). The type certification and the weight category are found on the label of the child protection device. The safety of the various certified child protection devices fluctuates. For this reason, consumer organizations regularly carry out tests and publish them (*Royal Dutch Touring Club ANWB*, *Consumentenbond*). Even a well-tested device may not meet the requirements in practice, for instance, because of the gradient of the car seat, a seat belt of insufficient length, the positioning of the seat belt lock or inconvenient fastening of the device in the car or the child in the device. It is therefore important to test the device in the car prior to purchase.

Babies have a relatively heavy and vulnerable head. The head can best be protected by transporting babies in a rear-facing child seat, so that body and head are caught in the seat in case of a head-on collision or when braking hard. A rear-facing seat should only be fastened on a seat with a de-activated airbag. If the airbag is activated, the outcome of a (head-on) collision may be fatal for the child, because seat and child will be forcefully thrown backwards by the airbag. For this reason, cars with one or more airbags at the passenger front seat should legally be fitted out with a warning sticker.

[1] The choice is made here to use the collective term 'child protection devices', subdivided into carrycots, baby restraint seas, child restraint seats and booster seats. In other publications, for instance, by the government or by manufacturers, different collective terms are used, such as child protection systems, child restraint seats, car child seats or car child restraint seats, and other terms are also used for the sub-groups. However, in practice, it is generally clear what is meant, especially when it is mentioned for which group the child protection device is intended.
[2] Directive 2003/20/EG for the amendment of directive 91/671/EEG, enforced in the Netherlands on 1 March 2006.
[3] Group 0 (0-10 kg), group 0+ (0-13 kg), group 1 (9-18 kg), group 2 (15-25 kg), group 3 (22-36 kg). Some child protection devices are suitable for more than one group, sometimes after some modifications.

Neither children nor adults are allowed to have the diagonal part of the normal three-point seat belt run behind the body or underneath the arm, because the effectiveness of the seat belt will then be conciderably reduced. The use of seat belt adjusters is also prohibited for children for whom it is compulsory to use a child protection device, as children who have outgrown a child restraint seat can make use of booster seats. They ensure that the shoulder part of the three-point seat belt is strapped across the shoulder of the child correctly and, more importantly, that the hip part is strapped across the pelvis, rather than the stomach, where it can injure the soft tissue and tender parts in the abdomen (Nance et al. 2004).

Booster seats come in both high-back models and backless models. High-back models are safer, because the child sits more to the front, so that it can bend its legs without sliding back and they also provide protection in case of a side-collision.

How can seat belts be most effective in the case of head-on collisions?
Three-point seat belts are particularly developed to protect occupants during a head-on collision and to prevent the occupants from being ejected from the car during a crash. The occupant not using a seat belt increases the risk of serious injury in case of a crash, not only personally, but also for the other occupant(s) in the car.

It is important that the seat belt fits snugly across the body. If a seat belt has too much slack, the pressure on the body will increase in case of a crash, possibly resulting in a fractured breastbone and ribs. The body may also partly escape from under the seat belt, resulting in internal injury of the abdomen, because of the lap belt and leg injury, because of hitting hard parts of the car. The diagonal or shoulder belt should preferably not be strapped too close to the neck, but diagonally across the middle of the shoulder and the middle of the chest. To make sure that the shoulder belt is strapped on as correctly as possible, cars are often equipped with an adjustable top anchorage point that the user can adjust dependent on the size of the upper body and the position of the seat.

The lap belt should be strapped on as low as possible, across the thighs, and not across the abdomen to avoid injury of the inner organs. Pregnant women in particular should be aware of this risk. The position of the lap belt may depend on the position of the seat. Correct adjustments of the seat (distance from the pedals) and seating position (height and angle) help prevent the lap belt from being pushed up during a crash. The tension in the shoulder belt is regulated by the roller mechanism in the automatic seat belt device. This tension and rolling force is in fact a compromise between required safety (tighter) and desired comfort (less tight) when driving. To release the tension on the upper body, seat belt clips may introduce extra slack. Their use is advised against because the extra slack they produce increases the risk of more serious injury .

The majority of modern cars are nowadays equipped with seat belt tensioners (reversible or pyrotechnic pretensioners). A seat belt tensioner is an extra device for the three-point seat belt system that, in case of a crash, increasingly tightens the seat belt in order to counterbalance slack. Furthermore, force limiters make sure that the seat belt will also yield during a crash, in order to reduce the impact on the upper body.

Similar to use in the front of the car, seat belt tensioners and seat belt force limiters may also reduce fatal and serious injury in the back of the car. Out of financial considerations, car manufacturers have equipped only a limited number of car models with these devices. This is not directly noticeable, partly because the comparative rear seat crash tests by Euro NCAP (www.euroncap.com) do not test the protection of adults, but that of children in child restraint seats. When regularly transporting older children and adults on rear seats, it may be worthwhile paying attention to this aspect when choosing a car.

Airbags provide additional protection to seat belts in the case of head-on collisions, provided the occupants do not sit too far forward and the seat belt is strapped on tight. The airbag is especially effective in case of severe crashes, when occupants may hit parts of the interior, despite the use of seat belts. In those cases, the combination of an airbag and seat belt results in an estimated 11% lower fatality rate than the seat belt alone (Glassbrenner & Starnes, 2009).

What are the developments in seat belts?
Presently, intelligent force limiters are being developed that determine the degree of slack, dependent on the progress of the crash and the available space between the occupant and steering wheel or dashboard. There are indications that a considerable reduction of chest injuries can be achieved by these new types of force limiters, in comparison with the current systems (Van der Laan, 2009).

Seat belts with airbags using cold-compressed gas are among the most recent developments in safer transport of rear seat passengers. These so-called *inflatable seat belt airbags* cover a body surface that is at least five times larger than that of a standard seat belt, so that the impact on the body of the passenger can be better counteracted and injury caused by the seat belt is reduced or prevented. Furthermore, an inflated seat belt airbag keeps the passenger better in position.

Seat belt reminders are increasingly installed for all seating positions, not only for the front of the car. Cars are equipped with more and more sensors that can continually detect all kinds of movements and (possible collision) situations while driving, in the car (occupant monitoring), as well as in the environment of the car (pedestrians, cyclists). These kind of intelligent systems are capable of sending out a signal a few seconds prior to a crash (pre-crash sensing), in order to activate a seat belt tensioner, for instance.

What are the developments in airbags?
Airbags are getting 'smarter', in the sense that level and speed of deployment is attuned to the collision speed and the position of the occupant involved. When seated forwards or bending over, an occupant can be severely injured because he may be hit in his face by the airbag that is inflated with great speed. This can be avoided when using a smart airbag. If a child restraint seat is installed on the seat behind the airbag (or if the seat is unoccupied) the airbag can be de-activated automatically.

Side-airbags and curtain airbags are now becoming more customary under the influence of adjustments of tests for side-collisions with a car or a post, in the context of the European type certification and the Euro NCAP evaluation.

What are the developments in child protection devices?
In addition to child restraints fastened with seat belts, so-called ISOFIX baby- and child restraints are available. In order to use them, the car needs to be equipped with special anchorage points. Tests have shown that ISOFIX child safety devices reduce the risk of improper use, increasing the protective effect of the baby or child restraint seat. Rear-facing child seats in which children up to circa 4 years of age (up to 18 kg) can be transported[4] are gradually being introduced into the market. This is also safer for these children than travelling in a forward-facing direction. It may be difficult or impossible to install such child restraint seats in smaller cars, because of the extra space they require.

In the context of ECE (see SWOV Fact sheet *Vehicle regulations*) a new regulation is being developed that no longer uses categories based on the weight of the child, but rather its height.

Which child protection devices can be used with lap belts?
Lap belts (two-point seat belts) are no longer installed in new cars, but many cars are still used with at least one lap belt (in the centre of the back-seat). Hardly any certified child protection devices are available for fastening with a two-point seat belt. As far as we know, there are no baby car seats for instalment with a two-point seat belt. A few restraint seats for group 1 (9-18 kg) do come with this option[5]. The booster seat is used for children from 18 kg upwards, but it comes without its own seat belt attached, so that the use of a two-point seat belt offers far from ideal protection in case of a crash.

Conclusion
Seat belts, airbags and child protection devices are an indispensable link in the so-called safety chain: crumple zone - bodywork cage - protection device. The use of seat belts and child protection devices has increased during the last few decades. Presently, 97% front seat occupants of a car use seat belts; 82% of the rear seat occupants use seat belts. Approximately 68% of the children are transported with sufficient protection. The percentage of seat belt use in delivery vans is considerably

[4] One example is the *Ellermeyer G0-1 ISOFIX* for groups 0 and 1 (0-18 kg). It can be used as a baby and child restraint seat up to 18 kg in combination with an Isofix platform for counter-direction instalment.
[5] The Ellermeyer (or Fair) G0-1 Isofix among others, used in forward direction and the Römer (or Britax) Eclipse.

lower: 87% of the drivers and 81% of the front seat passengers use a seat belt. Percentages of use in lorries and buses are not known, but they are lower than in delivery vans. The effectiveness of the seat belt in preventing fatal injury is estimated at no less than 40% and in preventing serious injury at no less than 25%. With 50%, the effectiveness of child protection devices is even higher than that of seat belts. Seat belts are still being improved. For instance, there are systems for diminishing the impact that the seat belt exerts on the human body (the seat belt tensioner and force limiter) and for activating the seat belt in the collision process earlier (pre-crash sensors). Front seat airbags supplement seat belts; side-airbags and curtain airbags have an important independent function.

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