SWOV Fact sheet

The relation between speed and crashes

Summary
The exact relation between speed and crashes depends on many factors. However, in a general sense the relation is very clear: if on a road the driven speeds become higher, the crash rate will also increase. The crash rate is also higher for an individual vehicle that drives at higher speed than the other traffic on that road. As speeds get higher, crashes also result in more serious injury, for the driver who caused the crash as well as for the crash opponent. The injury severity of the vehicle occupants in a crash, for example, is not only determined by the collision speed, but also by the mass difference between the vehicles and by the vulnerability of the vehicles/road users who are involved. In a crash between a light vehicle and a heavier one, the occupants of the lighter vehicle generally are considerably worse off than the occupants of the heavier vehicle. Even more so this is the case for pedestrians, cyclists and moped riders in crashes with (much) heavier motor vehicles.

Background and content
Speed is one of the basic risk factors in traffic (Wegman & Aarts, 2006). Higher driving speeds lead to higher collision speeds and thus to severer injury. Higher driving speeds also provide less time to process information and to act on it, and the braking distance is longer. Therefore the possibility of avoiding a collision is smaller. In short: high driving speeds lead to a higher crash rate, also with a greater likelihood of a severer outcome (Aarts, 2004; Aarts & Van Schagen, 2006). However, not everything is known yet about the exact relation between speed and road safety, and the conditions that influence this relation. This makes it difficult, for example, to calculate the exact effects of specific speeding measures. This fact sheet summarizes the most recent insights in the relation between speed and road safety. Other SWOV Fact sheets that discuss aspects of the topics speed and speeding are *Speed choice, the effect of man, vehicle, and road*; *Towards credible speed limits*; *Measures for speed management*; *Police enforcement and driving speed*; *Speed cameras: how they work and what effect they have* and *Intelligent Speed Assistance (ISA)*.

How important is the role of speed in crashes?
In theory, speed plays a role in every road crash: if everybody were to stand still, there would be no traffic. However, it is very difficult to determine the number of crashes in which too fast a speed was the main cause. In addition to speed, there often are various other factors involved that play a role in a crash occurring. In any case: the risk of a crash occurring is greater as speeds get higher; this is one of the reasons that speed limits are set. However, this does not mean that 'keeping to the limit' is always safe. Speed is also dangerous if it is higher than the circumstances at that moment allow (e.g. because of rain, fog or large traffic volume). In general, this inappropriate speed in particular is difficult to determine objectively. Therefore the police rarely register speed as the crash cause. It is generally assumed that about one third of fatal crashes are (partly) caused by speeding or by inappropriate speed (OECD/ECMT, 2006).

What is the relation between speed and crash severity?
The relation between speed and safety rests on two pillars. The first pillar is the relation between collision speed and the *severity* of a crash; the second pillar is the relation between speed and the *risk* of a crash. The higher the collision speed, the more serious the consequences in terms of injury and material damage. This is a law of physics that involves the quantity of kinetic energy that is converted in an instant into e.g. heat and matter distortion. In addition, the human body is physically very vulnerable in comparison with the enormous forces released in a collision. During the past decades, vehicles have become ever better equipped (with crush areas, airbags and seatbelts) to absorb the energy released in a crash, thus protecting the occupants. However, the collision speed still is very important for the crash outcome.

Which road users have the most risk of injury?
Besides speed, the mass of the vehicles involved is important for the outcome of a crash. In collisions between two vehicles of different mass, the occupants of the lighter vehicle are generally considerably worse off than those in the heavier vehicles. The difference in mass determines which vehicle absorbs which part of the released energy. Generally speaking, the energy absorption is inversely proportional to the masses of the vehicles.

Vehicle masses can differ enormously. This is particularly true for lorries and cars, between which the mass difference can amount to a factor of 10 or more. But there are also considerable mass differences between passenger cars, and these are becoming greater (a factor of 3 is by no means an exception). This 'incompatibility' of vehicles still is a large road safety problem (see also SWOV Fact sheet *Euro NCAP, a safety tool*). SWOV has calculated that in crashes between two passenger cars the number of fatalities among drivers would be reduced by a quarter if all passenger cars were to be of the same mass (Berends, 2009).

The incompatibility in collisions between vulnerable road users and practically any type of motor vehicle is of a completely different order. There are mass differences from a factor of 10 (light cars) to nearly 700 (lorries of 50 tons). In addition, pedestrians, cyclists, (light-)moped riders and motorcyclists do not have an 'iron cage' around them that can absorb some of the energy released in a collision. For example, in a collision between a car and a cyclist or pedestrian, the survival rate of the latter two decreases enormously as the car's collision speed increases. According to an overview of recent studies (Rósen et al., 2011): at a collision speed of 20 km/h nearly all pedestrians survive a crash with a passenger car; about 90% survive at a collision speed of 40 km/h, at a collision speed of 80 km/h the number of survivors is less than 50%, and at a collision speed of 100 km/h only 10% of the pedestrians survive. See *Figure 1*)).

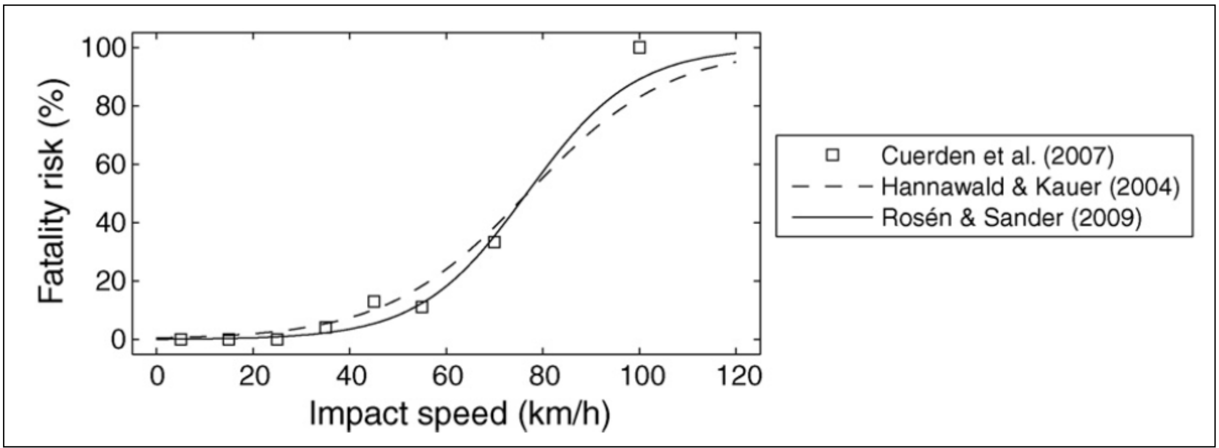


Figure 1. *The fatality rate of pedestrians in crashes with passenger cars as function of the collision speed (from Rosén et al., 2011).*

What is the relation between absolute speed and risk of a crash?
The second pillar of the relation between speed and safety concerns the *risk* of a crash. The faster a car is driven, the higher the risk of being involved in a crash. This is partly due to the longer braking distance and partly to the fact that the human being is limited in its capacity to process information and act on it. It must be noted, however, that the relation between speed and crash rate is much less direct and much more complicated than the relation between speed and crash severity.

Relatively many studies have examined the relation between absolute speed and crash rate. Irrespective of the research method used, practically all the studies concluded that the relation between speed and crash rate can best be described as a power function: the crash rate increases *more rapidly* when the speed increases and vice versa (*Figure 2*).

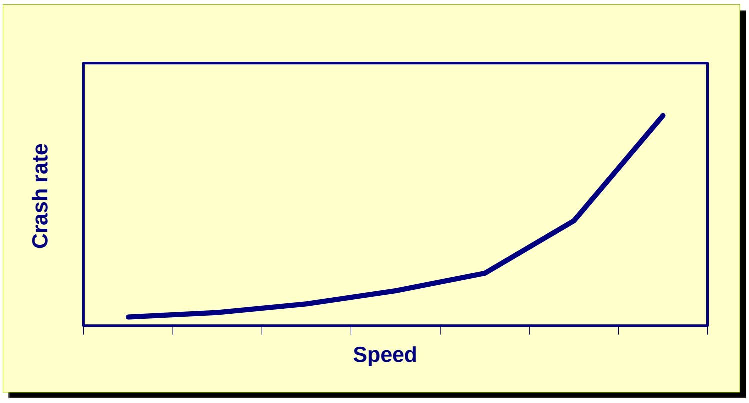


Figure 2. *Diagram showing the relation between speed and crash rate.*

Very well-known Scandinavian studies that are still often quoted in this context are those carried out by Nilsson (1982; 2004), Elvik, Christensen & Amundsen (2004) and Elvik (2009). These studies examined the effects on the number of crashes of the increases and decreases of average speeds on a road section mostly due to changes in speed limit. Furthermore, the effect of the speed driven by individual vehicles with respect to that of the other traffic was also investigated. This will be discussed later, in the section about speed differences.

What is the quantitative effect of absolute speed?
As described above, absolute speed has an effect on the crash rate and on injury severity. In the early 1980s, Nilsson (1982) quantified this relationship on the basis of kinetic laws. According to his calculations, the effect of a change in the average speed on a road on the number of injury crashes could be expressed by the formula:

$$LO_2 = LO_1 \left(\frac{v_2}{v_1} \right)^2$$

with LO_2 being the number of injury crashes after the change in speed, LO_1 being the initial number of injury crashes, v_1 being the average speed before the change, and v_2 being the average speed afterwards. The same formula could be used to describe the effect on the number of crashes with severe injury, but not to the power 2, but to the power 3, and for fatal crashes its effect was to the power 4. The power functions have largely been validated using newer data (Nillson, 2004; Elvik, Christensen & Amundsen 2004).

A recent study (Elvik, 2009) made it possible to refine this quantitative relationship, by, among other things, making a distinction between urban and rural roads. This showed that the effect of an increase or decrease of speed on rural roads is relatively greater than the effect on urban roads. 'Relatively' in the sense of 'regarding the percentage of speed increase or decrease'. If we regard an absolute increase or decrease of for example 1 km/h, this has a greater effect on rural than on urban roads. *Table 1* shows the exponents of the power functions for these two road categories and for different crash severities.

Based on Nillsson's formula and the 'substitute' exponents from *Table 1*, the effects of speed changes can be estimated for different speed limits and for different crash severities. For example: if on a road the average speed goes down from 120 to 119 km/h, the number of road fatalities is estimated to be reduced by 3,8% and the serious road injuries by 2,9%. And if on a road the average speed goes down from 50 to 49 km/h, this is expected to result in 5,9% fewer fatalities and 4% fewer serious road injuries.

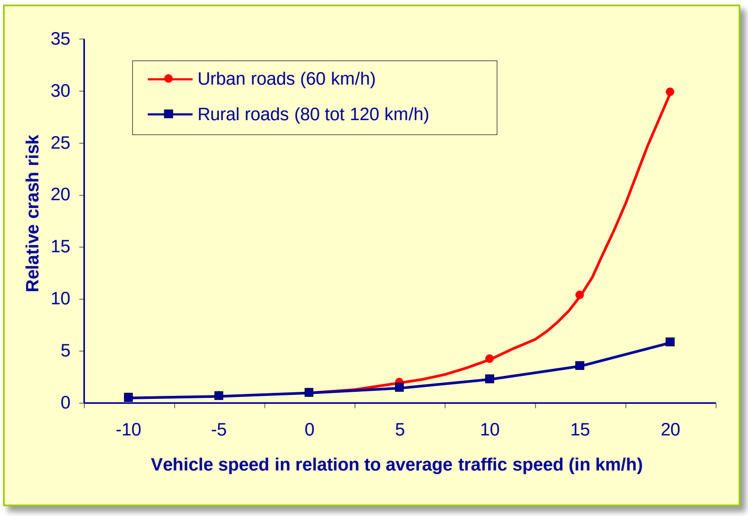
Crash severity	Rural roads (incl. Motorways)		Urban roads	
	Best estimate exponent	95% reliability interval	Best estimate exponent	95% reliability interval
Fatal crashes	4,1	(2,9-5,3)	2,6	(0,3-4,9)
Casualties with fatal injury	4,6	(4,0-5,2)	3,0	(-0,5-6,5)
Crashes with serious injury	2,6	(-2,7-7,9)	1,5	(0,9-2,1)
Casualties with serious injury	3,5	(0,5-5,5)	2,0	(0,8-3,2)
Crashes with slight injury	1,1	(0,0-2,2)	1,0	(0,6-1,4)
Casualties with slight injury	1,4	(0,5-2,3)	1,1	(0,9-1,3)

Table 1. *The exponents of the power functions for the relationship between speed and crashes/casualties with different injury severity (Elvik, 2009).*

What is the effect of speed differences?

In addition to absolute speeds, the speed differences between vehicles also have an effect on the crash rate. This effect is studied in two ways. The first type of studies are those that compare the crash rates between roads that have a large speed variance (large differences in vehicle speeds during a 24 hour period) and roads that have a small speed variance. These studies mostly conclude that roads with a large speed variance are less safe (Aarts & Van Schagen, 2006).

The second type of studies are those that concentrate on the speed differences between the individual vehicles that were involved in a crash and all the other vehicles. The first studies of this type were conducted in the United States in the 1950s and 1960s, e.g. Solomon (1964). These studies always found a U-curve: the slower or faster a car drives compared with most of the vehicles on that road, the more the risk of being involved in a crash increased. However, more recent studies, especially those carried out in Australia (e.g. Kloeden et al., 1997; 2001; 2002) that used more modern measuring instruments and used a more accurate research design, reached a different conclusion. They still indicate that vehicles that drive faster than average on that road have a higher crash rate; vehicles that drive slower, however, were found not to have an increased risk *(Figure 3).*



Afbeelding 3. *The relative risk on urban roads (Kloeden et al, 2002) and rural roads (Kloeden et al., 1997; 2001) for vehicles driving faster or slower than the average speed on that road (=0 km/h deviation)*.

Conclusion

The exact relation between crashes and speed depends on a large number of factors. In general however, the relation is very clear and has been shown in a large number of studies: the higher the speed, the greater the probability of a crash. At the same percentage increase in speed, the crash rate on rural roads increases more than the crash rate on urban roads. The crash rate is also higher for an individual vehicle that drives faster than the other traffic on that road.

As the speed increases, the injury severity in crashes also increases, for the driver who is responsible for the crash occurring as well as for the collision opponent. The mass and vulnerability of the vehicles/road users who are involved also plays a role. In crashes between a lighter and a heavier vehicle the occupants of the lighter vehicle are generally worse off than the occupants of the heavier vehicle. More so this is the case for pedestrians, cyclists and moped riders in crashes with (much) heavier motor vehicles.

Publications and sources [SWOV reports in Dutch have a summary in English]

Aarts L.T. (2004). *Snelheid, spreiding in snelheid en de kans op verkeersongevallen; Literatuurstudie en inventarisatie van onderzoeksmethoden.* R-2004-9. SWOV, Leidschendam.

Aarts, L. & Schagen, I.N.L.G. van (2006). *Driving speed and the risk of road crashes; A review.* In: Accident Analysis and Prevention, vol. 38, nr. 2, p. 215-224.

Berends, E.M. (2009). *De invloed van automassa op het letselrisico bij botsingen tussen twee personenauto's: een kwantitatieve analyse*. R-2009-5. SWOV Leidschendam,

Elvik, R. (2009). *The Power Model of the relationship between speed and road safety: update and new analyses.* TØI Report 1034/2009. Institute of Transport Economics TØI, Oslo.

Elvik, R., Christensen, P. & Amundsen, A. (2004). *Speed and road accidents; An evaluation of the Power Model.* Institute of Transport Economics TØI, Oslo.

Kloeden, C.N., McLean, A.J. & Glonek, G. (2002). *Reanalysis of travelling speed and the risk of crash involvement in Adelaide South Australia.* Report CR 207. Australian Transport Safety Bureau ATSB, Civic Square, ACT.

Kloeden, C. N., McLean, A. J., Moore, V. M. & Ponte, G. (1997). *Travelling speed and the risk of crash involvement. Volume 1: findings.* Report CR 172. Federal Office of Road Safety FORS, Canberra.

Kloeden, C. N., Ponte, G. & McLean, A. J. (2001). *Travelling speed and the risk of crash involvement on rural roads.* Report CR 204. Australian Transport Safety Bureau ATSB, Civic Square, ACT.

Nilsson, G. (1982). *The effects of speed limits on traffic accidents in Sweden*. In: Proceedings of the international symposium on the effects of speed limits on traffic accidents and transport energy use, 6-8 October 1981, Dublin. OECD, Paris, p. 1-8.

Nilsson, G. (2004). *Traffic safety dimensions and the power model to describe the effect of speed on safety*. Lund Bulletin 221. Lund Institute of Technology, Lund.

OECD/ECMT (2006). *Speed management.* Organisation for Economic Co-operation and Development OECD/European Conference of Ministers of Transport ECMT, Paris.

Rosén, E., Stigson, H. & Sander, U. (2011). *Literature review of pedestrian fatality risk as a function of car impact speed*. In: Accident Analysis and Prevention, vol. 43, nr. 1, p. 25-33.

Solomon, D. (1964). *Accidents on main rural highways related to speed, driver and vehicle.* Bureau of Public Roads, U.S. Department of Commerce, Washington, D.C.

Wegman, F. & Aarts, L. (eds.) (2006). *Advancing sustainable safety; National Road Safety Outlook for 2005-2020.* SWOV, Leidschendam.