SWOV Fact sheet

The relation between speed and crashes

Summary
The faster one drives, the more likely a crash and the chance of severe injury. The exact relation between speed and crashes depends on many factors. The injury severity of the vehicle occupants in a crash is not only determined by the collision speed but also for example by the mass difference between the vehicles. With regard to the crash rate, speed plays a larger role in more complex situations (e.g. on urban roads) than on less complex roads (e.g. motorways). What is anyway true is that the effect of speeding measures depends on absolute driving speeds, road types and speed differences between vehicles.

Background
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 injuries. Higher driving speeds also provide less time to process information and to act on it, and the braking distance is longer. Thus the possibility of avoiding a collision is smaller. In short: high driving speeds lead to a higher crash rate, also with a severer outcome. However, not everything is yet known 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 effects of concrete speeding measures. This fact sheet summarizes the most recent insights in the relation between speed and road safety (Aarts; 2004; Aarts & Van Schagen, 2006).

How large is the role of speed in crashes?
In theory, speed plays a role in every road crash: if everybody was 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. Besides speed, there are often various factors involved that result in a crash. Speed can contribute to there being a crash if this speed was higher than the local speed limit or than the circumstances at that moment allowed (e.g. because of rain, fog or large traffic volume). Inappropriate speed is especially difficult to determine objectively. Therefore the police rarely register speed as the crash cause. It is generally assumed that about a third of fatal crashes is (partly) caused by excessive or inappropriate speed (OECD/ECMT, 2006).

What is the relation between speed and the 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 crash *rate*. The higher the collision speed, the severer 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 by a collision. During the past decades, vehicles have become ever better equipped (with crush areas, airbags and seatbelts) in order to absorb the energy released, thus protecting the occupants. However, the collision speed is still of great importance for the crash outcome. With a collision speed of 80 km/hour, the chance that car occupants are killed is about 20 times greater than with a speed of 30 km/hour (IHHS, 1987).

Which road users have the highest injury rate?
Besides speed, the mass of the vehicles involved is important. In collisions of two vehicles of different masses, the occupants of the lighter vehicles are in general 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 in the case of lorries and cars, between which the mass difference can easily be a factor 10. But there are also considerable mass differences between cars, and these are becoming ever greater (a factor 3 is by no means an exception). This 'incompatibility' of vehicles is a large and increasing road safety problem.

The incompatibility in collisions between vulnerable road users and practically any motor vehicle type is of a completely different order. There are mass differences from a factor 10 (light cars) to nearly 700 (lorries of 50 tons). In addition, pedestrians, cyclists, (light-)mopedists and motorcyclists do not have an 'iron cage' around them that can absorb some of the released energy of a collision. Laboratory tests therefore show that in a collision between a car and a pedestrian, the survival rate of the pedestrian decreases dramatically as the car speed increases: at a speed of 30 km/hour, 'only' 5% of the pedestrians is killed; at 50 km/hour this is 45% and at 65 km/hour the number is even 85% (ETSC, 1995).

What is the relation between speed and crash rate?
The second pillar of the relation between speed and safety concerns the crash *rate*. The faster drivers drive, the greater the chance of being involved in a crash. On the one hand this has to do with the longer braking distance and, on the other hand, with the fact that the human being is limited in its capacity to process information and act on it. However, the relation between speed and crash rate is much less direct and much more complicated than the relation between speed and crash severity.

What effect does the absolute speed have?
Relatively many studies have examined the relation between absolute speed and the 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 having a power function: the crash rate increases *faster* when the speed increases and vice versa (*Figure 1*).

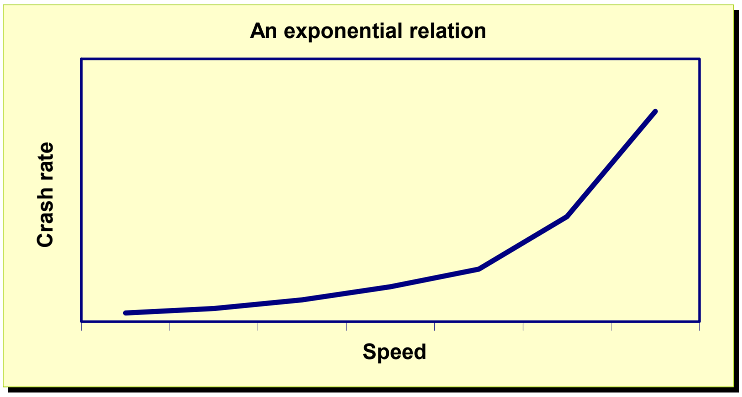

Figure 1. *Diagrammatic reproduction of the power function in the speed-crash probability relation.*

Very well known Swedish studies that are still often quoted in this context are those of Nilsson (1982; 2004). These studies examined the effects on the number of crashes of the increases and decreases of average speeds on a road section with changes in speed limit.

In Australia a lot of research has been conducted on the effect of the speed of individual vehicles on the crash rate (Kloeden et al., 1997, 2001, 2002). These studies even show an exponential relation between speed and crash rate. Furthermore, Kloeden et al. (1997) compared the crash rates of speed with those of alcohol. The study concentrated on urban through roads with a speed limit of 60 km/hour. The results showed that a motorist driving 5 km/hour faster than this speed limit has a twice as large probability of being involved in an injury crash than a motorist who keeps exactly to the speed limit. Exceeding the speed limit by 10 km/hour has a four times as large rate and by 15 km/hour a more than ten times as large rate. On the roads studied, this probability increase by exceeding the speed limit was about the same as that of a blood alcohol content (BAC) of 0.5, 0.8, and 1.2 respectively (*Figure 2*).

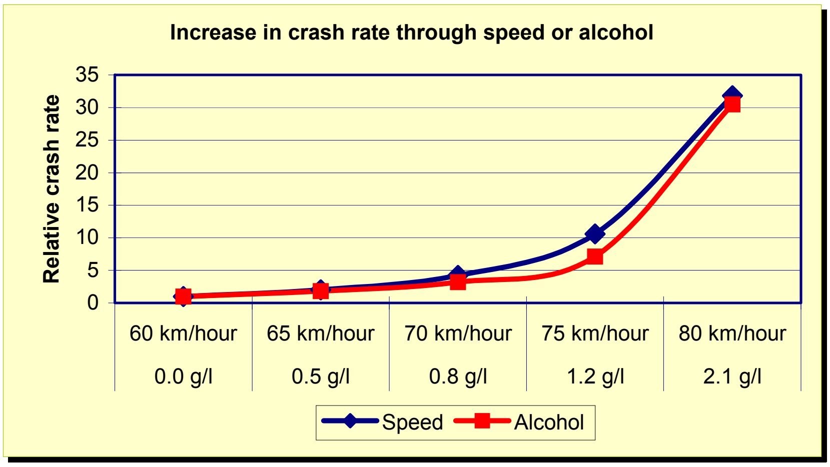

Figure 2. *Crash rates of various speeds and various BAC levels (Kloeden et al., 1997).*

Is the relation between speed and crash rate the same for all roads?
The fact that the crash rate increases more as the speed gets faster, suggests that speeding measures have more effect on, for example, motorways than on urban roads. However, this is not the case, because both the size of the crash rate as well as the extent of the crash rate increase at faster speeds are strongly dependant on the road type. Roughly speaking, motorways have the lowest crash rate and, as the speed increases, the crash rate increases less rapidly than is the case on lower order roads. The reverse is also true: the same drop in speed (in km/hour) has a larger safety effect on lower order roads than on higher order roads.

Very probably, these differences have to do with the complexity of the road and traffic environment in combination with the human being's limitations to cope with large quantities of information, especially if little time is available. In comparison with motorways, rural roads and, to even greater extent urban roads, have much more complex traffic environments: there are meetings with more different types of road users coming from different directions and therefore with a less predicable behaviour. In addition, and partly connected with it, the road speed design also has an influence. On a road with a design speed of 80 km/hour, a speed increase from 80 to 90 km/hour leads to a larger increase in crash rate than the same increase on a road with a design speed of 100 km/hour. After all, the 80 km/hour roads were not designed for these faster speeds.

Is the speed-crash rate relation the same for serious and less serious crashes?
An increase or decrease in speed has a greater effect on serious crashes than on light crashes. Based on kinetic laws Nilsson (1982) had already calculated this in the early 1980s. The effect on the number of injury crashes can be expressed in the following 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 number of injury crashes before, v_1 being the average speed before the change, and v_2 being the average speed afterwards. The same formula could describe the effect on the number of crashes with severe injury, but not to the power 2, but to the power 3, and its effect on fatal crashes was to the power 4. The power functions have been validated by more recent data (Nillson, 2004; Elvik, Christensen & Amundsen 2004). They apply to different road types.

Based on these formulas, the effect of speed changes has been calculated for different speed limits and for different crash severities (*Table 1*). These percentages give an indication of the expected effects of a change in average speed of 1 km/hour for different initial speeds. Of course, the real effect on a particular road can deviate from this, e.g. because of specific road or traffic features.

Crashes	Initial speed					
	50 km/hour	70 km/hour	80 km/hour	90 km/hour	100 km/hour	120 km/hour
Injury crashes	4.0%	2.9%	2.5%	2.2%	2.0%	1.7%
Severe injury crashes	6.1%	4.3%	3.8%	3.4%	3.0%	2.5%
Fatal crashes	8.2%	5.9%	5.1%	4.5%	4.1%	3.3%

Table 1. *The expected effect of a speed change of 1 km/hour on the number of crashes of different severities at different initial speeds (Aarts & Van Schagen, 2006).*

What effect do speed differences have?
Besides the absolute speeds, the speed differences between vehicles also influence 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 between 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 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 the car drives compared with most of the vehicles on that road, the more the crash involvement rate increased. However, more recent studies that used more modern measuring instruments and used a more accurate research design, came to an other conclusion (Kloeden et al., 2002). They found that vehicles that drove a lot faster than average on that road had a higher crash rate; vehicles that drove slower did not have a higher rate.

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 faster the speed, the greater the probability of a crash. The crash rates are also larger on roads where the speed differences are greater than on roads where they are smaller. The faster people drive, the greater the probability of severer crashes, for both the one that caused the crash as the collision opponent. If a road and its corresponding traffic situations are more complex and the driver thus has to process more information and has to make a decision more often, the crash rate increases with the same increase in speed, more than on roads that are less complex. This means in practice that the effects of speed changes are larger on lower order roads than on higher order roads.

In order to make an estimation of the effects of speeding measures on the crash rate, the following must in any case be taken into account:
– absolute *speed*: the relation between (absolute) speed and crash rate is not linear, but follows a power function (the average speed along a road section) or an exponential relation (individual vehicle speed);
– *road type*: the absolute crash rate and its increase at faster speeds is higher in complex traffic situations than in less complex situations;
– *speed differences*: greater speed differences result in a higher crash rate; if a measure results in a slower average speed, but simultaneously in greater speed differences, then the ultimate safety effect can be smaller or even the opposite of the effect of the average speed reduction alone.

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

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

ETSC (1995). *Reducing traffic injuries resulting from excessive and inappropriate speed.* European Transport Safety Council ETSC, Brussels.

IIHS (1987). *55 speed limit.* IIHS Facts (1987-02). Insurance Institute for Highway Safety IIHS, Arlington.

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. Organisation for Economic Co-operation and Development 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.

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.

