# SWOV Fact sheet

## The influence of weather on road safety


**Summary**
The weather has an influence on road safety. Weather conditions partly determine the road conditions and the driver's behaviour. Most research into the relation between weather and road safety are about the situation during rainfall. However, many other weather conditions are serious influences: fog, snow and black ice, low sun, hard wind, and high temperatures. Studies, mainly abroad, have produced data about the influence of these weather conditions on the crash rate. Various measures have been taken to increase road safety, such as compulsory rear fog lamps, porous asphalt, and the introduction of slipperiness warning systems. However, the studies which were carried out do not make it possible to infer the effectiveness of these measures. Nor is it certain whether the results of these studies can also be applied to the Netherlands.


**Background**
The term weather describes the state of the atmosphere in terms of air pressure, temperature, humidity, clouds, wind, and precipitation. As yet, not much research has been done into the relation between weather and road safety in the Netherlands.

**In which ways does weather affect road safety?**
Weather conditions affect both crash rate and the exposure to traffic hazards. This influence is strongest for the conditions of precipitation (including snow and hail), fog, low sun, wind, ice forming, and hot temperatures.

*Precipitation*
Research has shown that motorists adjust their road behaviour during showers. They overtake less, driver slower, and increase their following distance (Hogema, 1996; Agarwal et al., 2005). However, the risk of a crash during rain is still greater than in dry weather. The changes in driving behaviour are, apparently, insufficient to compensate for the greater risk during bad weather (Thoma, 1993).
Road users can have problems with reduced visibility during periods of precipitation. This can be reduced to approximately 50 meters during heavy rain or snow, and in thick fog. Splashing water, particularly from lorries, can interfere considerably with the visibility of other motor vehicle drivers (Terpstra, 1995). Clouded windows and windscreens as a result of high humidity during rain can also reduce visibility (Fokkema, 1987). Furthermore, blinding can occur at night because the headlights of oncoming vehicles reflect in the water on the road surface (Ellinghaus, 1983).
The more rain, snow, or hail falls, the less the friction of the road surface. Rain can lead to dynamic aquaplaning. A layer of water on the road surface can cause the vehicle to lose contact with the road surface and to skid. The chance of aquaplaning depends on the skidding resistance of the road, but of course also on the vehicle's speed and tyre tread depths (Ellinghaus, 1983; Terpstra, 1995; Van Ganse, 1981). When it has been dry for a long time, a drizzle can lead to viscous aquaplaning if drops of oil and dust, together with water, produce a thin liquid film on the road surface. When the rain gets heavier, the chance of viscous aquaplaning lessens because the road surface is swept clean (Terpstra, 1995; Eisenberg, 2003).

*Fog*
In a fog the droplets of water are so small and light that they remain floating in the air. This leads to a reduction in visibility because the light is diffused by the fog droplets. In general, fog occurs when the humidity is 100%. When this happens people generally drive somewhat slower, but simultaneously keep a shorter following distance to the vehicle in front of them. In combination with the decreased field of vision, this increases the risk of crashes (Fokkema, 1987; Oppe, 1988). Fog can also cause viscous aquaplaning when water droplets provide a thin film on the road surface (Terpstra, 1995).

*Low sun*
Sunrise and sunset can greatly hinder the view that road users have of other traffic. The sun blinds the most when it is low on the horizon. This is the case until about an hour after sunrise and from about an hour before sunset. Motorists can still look through their windscreen, but cannot see clearly anymore. Also indirect sunlight which is reflected by, for example, a glass building, noise barriers, or other cars can be problematic. When lighted by the sun, dirt on the windscreen is more visible, thus hindering driving. Visibility is affected even more when the road surface is wet and reflects the sunlight (Fokkema, 1987).

*Wind*
Gusts of wind can push relatively high vehicles such as busses, delivery vans, camper vans, caravans, and lorries off course and, under extreme conditions, can even cause them to roll over. This happens mainly on bridges and viaducts. Objects carried by the wind, fallen trees, and broken-off branches can also cause traffic disturbance (Ellinghaus, 1983). Pedestrians and two-wheelers can be troubled by strong gusts of wind and therefore disturb other traffic.

*Ice forming*
If a road surface has an open structure, such asporous asphalt, wet parts of the road surface will freeze quicker than surfaces with a closed structure. When there is black ice, a thin layer of ice forms so quickly on porous asphalt that it looses its friction (CROW, 2000). Roads that have just been laid also have a greater risk of slipperiness: the layer of black bitumen has a lower temperature and is thus more sensitive to wet parts freezing. In due time the risk of slipperiness will lessen because of the wear and tear of the upper layer (CROW, 2006).

*Temperature*
High temperatures have especially a psychological and/or physiological effect on a driver. However, a lot less is found in the literature about the physical effects of weather conditions. According to a German study, emotions rise with the temperature, people are more irritable to others, they get tired, lose their concentration, and their reaction time gets slower (DVR, 2000). French researchers found an increase in the number of crashes during heat waves. Their explanation was that people possibly drive at other times of the day and that they sleep shorter or less deeply because of the high night-time temperatures. This results in them being more tired when they take to the road (Laaidi & Laaidi, 2002).

**What is the extent of the weather's influence on road safety?**
During the last decades, various studies have been made of the road safety effects of weather conditions (Keay & Simmonds, 2005; Stiers, 2005; Bos, 2001). Besides data from meteorological offices, the police road crash registration is a useful data source because weather conditions is one of its variables. To be able to make a good estimation of weather's influence on road crashes, the average weather should be used as point of departure. People more or less prepare themselves for expected weather, and it is usually extreme weather conditions or sudden changes in the weather that produce fluctuations in the numbers of crashes (Bos, 2001; Eisenberg, 2003).

*Crash data*
AVV crash data shows that in the 2002-2004 period there was an average of 84 fatal crashes when it rained, 5 during snow, and 12 during fog. To find out if these numbers are relatively large, we have to relate them to the numbers of hours that it had been raining, snowing, or was foggy. This was also looked for in the literature study. Bos (2001) concluded that, during the 1997-2000 period, there were more road casualties than usual in a relatively warm and dry summer. A cold and dry winter resulted in fewer casualties, but there were more in a cold and wet winter. No unambiguous conclusions could be made about spring and autumn.
A recent study of the relation between weather and road crashes on Dutch national state roads showed that there was an increase in the number of accidents of between 25% and 182% when it rained. Ice forming on the road surface even led to an increase of between 77% and 245%. However, ice forming is far less frequent than rain, and thus has a smaller impact on the total number of crashes (Stiers, 2005).
A Scottish study of the effects of weather on road crashes in Glasgow reported a 20% increase in crashes during on days. The largest effect of rain was found during the summer and autumn months (Smith, 1982). In a Scandinavian study, during a period of snow the number of crashes decreased by 1.2% per additional snowy day (Fridstrøm et al., 1995). Traffic counts show that there was not less

traffic. According to the authors, the reduction in crashes was due to adapted driving behaviour and, in addition, possibly by an improved night-time visibility when there is snow on the road, fewer novice drivers, and finally the limiting effect of vehicles that had skidded off the road to the roadside.

*Crash rate*
Based on literature, we can assume that the crash rate approximately doubles during rain. The size of the crash rate depends on, among others, the speed limit, the day of the week, and the time of day. Less research has been done on crash rates during other weather conditions. Snow seems to lower the crash rate because it makes people drive more carefully and there probably are fewer vulnerable road users on the road (Fridstrøm et al., 1995). Here are some examples:

– Australian research into the effects of rain on the traffic volume in Melbourne and surroundings found that, after correction for traffic volume, there was an average crash rate increase of 2.4%. During the night when it was raining, the crash rate even increased by 5.2% (Keay & Simmonds, 2005).
– Canadian research in the 1979-1983 period found a 75% higher crash rate during rainfall. This increase was particularly sharp during the first hours of rainfall (Andrey & Yagar, 1991).
– Swiss research of driving speed and crash rate during rainfall, after correction for exposure, found that during rainy daylight hours, in spite of slower driving, the crash rate was 2.5 times larger on non-motorways and 5 times larger on motorways (Thoma, 1993). At night-time these crash rates again more than doubled, to 6 times and 11 times larger respectively.
– German research during the 1970s also showed that the wet, night-time crash rate was nearly twice as large as that during wet, daylight hours (Brühning et al., 1978).

*Exposure (mobility)*
Changes in mobility, distances travelled, are an important explanatory factor for changes in road safety (Fridstrøm et al., 1995). This means that weather conditions also have an indirect influence on the number of casualties by changes in mobility. However, the influence of weather on the number of vehicle kilometres is generally limited to rural, recreational traffic. Commuter traffic hardly changes (Edwards, 2000; Hogema, 1996).
Weather conditions also influence the choice of transport mode (Bos, 2001). For example, in bad weather there are fewer cyclists. This can also be seen in the crash statistics: the relative proportion of car-bicycle crashes is a lot lower when it rains, snows, or is foggy than when it is dry (Ellinghaus, 1983).

**Which measures can be taken?**
Obviously, the weather itself cannot be influenced. However, its negative road safety effects can be reduced by measures aimed at man, vehicle, and road.

*Behavioural measures*
In the driver training, the Netherlands already pays attention to the negative effects of bad weather conditions on driving conditions. However, there have been few campaigns to warn road users about certain weather conditions. The Dutch Meteorological Office can give a weather and traffic alarm when the weather conditions are very bad. Then the media warns road users not to travel unless it is absolutely necessary.
Technological developments during the last few years have resulted in more ways to draw road users' attention to bad weather. Fog detectors such as the Fog Prediction System are installed at a number of locations where poor visibility leads to problems. They warn road users with signs above the road if they approach a road section with poor visibility. These signs could possibly be used to give extra information to drivers about the recommended headway distances.
Besides such fog warning systems, there are also those warning for slipperiness. These systems continuously measure the road surface temperature, the relative humidity, the precipitation, and the quantity of anti-icing chemicals on the road. This data is used to determine whether or not there should be preventative scattering to prevent skidding as much as possible (CROW, 2000).
In France, the speed limit on motorways during rainfall is 20 km/hour lower than during dry weather. Such an adaptation also acts as a signal to road users that it is riskier to travel during rain.

*Vehicle measures*
Cars that were sold after 1st January 1998 are obliged to have a third, rear fog light. The light is located at only one place on the vehicle so as to avoid mistaking it for a brake light. Since 1st January 2006, a rear fog light is also obligatory for practically all trailers. Furthermore it is recommended that

motor vehicles have an attention-increasing signal installed which is activated with sudden braking. Rain and winter tyres especially suitable during bad weather conditions are also for sale. Technological developments such as ABS and ESP ensure that cars skid less quickly. Lorries can also have adaptations installed to lessen the amount of splashing water. Finally, testing tyres and windscreen wipers, as is done during vehicle testing, can also prevent crashes during bad weather conditions.

*Infrastructural measures*
During the past ten years it has become almost standard to use porous asphalt on road surfaces in the Netherlands. It allows rainwater to drain away quicker that normal asphalt. This ensures that there is a smaller risk of aquaplaning and the road markings remain better visible during rain. In contrast to normal asphalt, porous asphalt also has hardly any road rutting. Furthermore, when it rains, the effect of splashing water is considerably less than on other road surface types. However, its positive effects can be annulled by the average road user's risk compensation; when raining, road users on a wet road surface are thought to drive faster on porous asphalt than they would do on normal asphalt (Tromp, 1993).
With a Slipperiness Warning System, road authorities are warned in time to scatter salt if slipperiness is predicted. To install these systems, state, provincial, and many municipal roads have had sensors installed in the road surface that keep track of various weather parameters. They can give an estimate of the risk of skidding at a certain location. Finally, quality control and maintenance of the road surface material contribute to keeping the risk of aquaplaning small.

**Conclusions and recommendations**
In the past, the study of weather conditions has particularly focussed on the influence of rain. The risk of a road crash during rainfall is about twice as high as when it is dry. Although the risk during fog, snow, and fierce gusts of wind is probably even larger, there are four times more crashes during rainfall in the Netherlands, simply because it rains far more often.
Besides influencing the crash rate, weather also influences exposure. However, this influence is limited to the mobility of weekend recreation traffic and to the choice of transport mode. In bad weather, the car traffic volume does not change much, but there are considerably fewer cyclists.
During the last few years, roads and vehicles have been improved to such an extent that one would expect that the crash rate during bad weather had become smaller. However, Tromp (1993) reports risk compensating behaviour by motorists on wet porous asphalt in which the motorists compensate for vehicle and infrastructural improvements by less adapting their speed to the bad weather conditions.
Current literature on weather effects on road safety does not make it possible to determine the effectiveness of various measures. Many foreign studies were found in the literature study, but we wonder if the results of these studies apply to the Netherlands. Plans have been made for a number of Dutch studies of the road safety influence of weather in the near future. These will probably provide greater clarity.

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