SWOV Fact sheet

Measuring (un)safety of roads

Summary
Measuring a road's safety is difficult. First of all you have to know how many crashes occurred on a road. Various measurement units are used for this: the absolute number of crashes per road, the number per kilometre of road, and the number per motor vehicle kilometre travelled. These ratios can be used to compare roads with each other. However, to give these ratios any meaning, reference values need to be determined. This SWOV fact sheet also discusses the various ways of visualizing road ratios.

Background
Measuring a temperature is quite simple; it's done very quickly with a good thermometer. Interpreting the temperature, however, is more complicated. First the units of the thermometer used must be known, because 30°C is completely different from 30°F. It is also important to know where the temperature was measured, and what the normal temperature is for that location. 30°C in the Netherlands is considered to be very hot, but in the Sahara it is normal or even rather cool.

The safety of a road or a collection of roads can be measured just like the temperature; it's only a lot more difficult. Safety cannot simply be read directly from a measuring instrument, but can be determined using what are known as safety ratios. These ratios can be calculated. The higher the calculated ratio the lower the safety level. Although measuring the safety of a road is more labour-intensive than measuring the temperature, there also are similarities.
First of all there are various possibilities to express a road's safety, just as temperature can be expressed either in degrees Celsius or Fahrenheit. A number of these road safety ratios will be discussed in this fact sheet.
A second similarity is that, just as it is for temperature, it is important to know where the safety is being measured, for instance on a motorway or on an urban road. A ratio for a motorway, expressed in any possible way, can lead to the conclusion that the road is very unsafe, whereas the same ratio for an urban road can mean that the road concerned is reasonably safe.
A third point of agreement is that the calculated ratios are not meaningful if it is not known which ratio is 'normal' for a particular road and a particular road safety measurement unit. Reference values are necessary for various different road types to compare the calculated ratio to. This fact sheet discusses how such reference values can be determined.

Which safety ratios are there for roads?
The three most obvious types of road safety measurement units are discussed in this fact sheet:
- the number of road crashes in a particular period;
- the number of road crashes in a particular period divided by the road length in kilometres;
- the number of road crashes divided by the number of motor vehicle kilometres, both in the same period.

These three measures can, if necessary, also be subdivided by injury severity: fatal, severe, or slight injury, or material damage only; and they can be calculated for an individual road or a collection of roads.

The first type of unit is perhaps the easiest one, but its use is only limited. After all, a larger ratio should correspond with greater unsafety, but there are examples in which this is not the case. If, for example, there are five crashes per year on one road and ten per year on another, the first road could be concluded to be a lot safer than the second road. But if the second road is twice as long, this conclusion is not justifiable.

This problem can be solved by dividing the number of crashes by the road length in kilometres. Both roads now have the same ratio, also called *crash density*. Using this measuring unit the two roads are equally safe.

There are problems with this ratio if many more cars use the one road than the other. The numbers of crashes per kilometre are the same, but if there are many more cars on the first road, this road is safer. This difference in safety is expressed in the third ratio, the number of crashes per motor vehicle kilometre. This is also the ratio that is used most commonly to measure a road's safety; it is often referred to as the *crash rate* of a road.

The number of motor vehicle kilometres during a particular period is the number of kilometres travelled by motor vehicles on a particular road (or collection of roads) during this period. This is calculated by multiplying the road length by the (estimated) number of motor vehicles that passed during this period. This last number is called the *traffic volume*.

The number of crashes also includes those crashes involving other than motorized vehicles, like bicycles. Thus, the third ratio above should really be replaced by the number of crashes divided by the number of vehicle kilometres. However, vehicle kilometres are not registered reliably enough, so that the number of motor vehicle kilometres is often used instead. In any case, research has shown that the number of motor vehicle kilometres can very well be used to explain the numbers of crashes, including those in which unmotorized vehicles were involved.

In the three ratios dealt with here, the number of casualties could have been used instead of the number of crashes. However, in general a road's design only influences the number of crashes and not the number of casualties which are the result. Seeing as this fact sheet deals with roads' safety ratios, it is more obvious to use the number of crashes.

To illustrate the ratios discussed until now, a number of examples are shown in *Table 1*. 'Serious crashes' is defined as crashes with at least one in-patient or fatality. Often only the most serious crashes are used to calculate a safety ratio, because the registration rate of crashes with less severe injury, or with only material damage, is a lot less complete than that of crashes with severe injury or death. All three ratios show an increase in road safety on urban roads. The second ratio, the number of serious crashes per 1,000 kilometres road length, shows the greatest improvement. This is because the road length increased more than the number of motor vehicle kilometres.

	1993	1998	2003
Number of serious crashes	6,400	6,275	5,533
Road length in 1,000 kilometres	50,4	58,6	66
Number of serious crashes per 1,000 kilometres road length	127	107	83
Motor vehicle kilometres (billions)	28	30	33
Number of serious crashes per billion motor vehicle kilometres	229	209	168

Table 1. *Three road safety ratios for urban roads in the Netherlands in 1993, 1998, and 2003 (Sources: AVV Crashes & Network; CBS)*

How can road safety ratios be used?

Road safety ratios can be used for various purposes, for example, to compare the safety of a collection of roads during a period of years. This has already been illustrated in the previous paragraph, in which the safety of urban roads in the Netherlands for the years 1993, 1998, and 2003 was compared. This led us to conclude that the safety on these roads has improved during that period of 10 years.

It's also possible to compare the safety of two or three different road types. An example is in *Table 2*, which shows three ratios for six road types in 2003. The smallest absolute number of crashes occurred on 70 km/hour urban roads. But because this road type has the smallest number of kilometres road length, the ratio per 1,000 km. road length is not the lowest for this road type. This ratio is highest for 100/120 km/hour roads, although they have the lowest crash rate (per motor vehicle kilometres). This is because by far the most kilometres are driven on 100/120 km/hour roads; these are motorways and trunk roads. In any case, the crash rates of different road types can only really be called different if this difference is statistically significant. In the past SWOV developed the KenPro program (Braimaister, 1996) which makes it relatively simple to calculate the crash rates of various groups of roads. It can also test whether or not the crash rates are significantly different from each other.

	Number of serious crashes	Number of serious crashes per 1,000 kilometre road length	Number of serious crashes per billion motor vehicle kilometres
Urban roads			
30 km/hour	494	18	137
50 km/hour	4,891	162	199
70 km/hour	148	122	31
Rural roads			
60 km/hour	320	28	238
80 km/hour	2,928	66	52
100/120 km/hour	912	178	22

Table 2. *Three road safety ratios for six road types in the Netherlands in 2003 (Sources: AVV Crashes & Network; CBS).*

So far it has only been possible to calculate if one road was safer than another road, or if a particular road type had become safer over a period of years. Reference values are necessary to label a road as 'safe' or 'unsafe'. They will be dealt with in the following paragraph.

What are reference values and how are they calculated?

A reference value is one that has been calculated to make a better interpretation of other values possible. The temperature of 0°C is a good example of a reference value. If the temperature is below 0°C , it freezes, otherwise it does not. Another example is the average summer temperature during the last 30 years. The current summer can then be compared with the average to determine whether it is normal, too cold, or too warm.

In order to give to a measured road safety ratio any meaning, a reference ratio is needed. Unlike for temperature, the value of zero is not suitable because all road safety ratios described can only be zero or higher. The correct reference ratio depends on the question for which it is used.

In the example in which the safety of urban roads in the Netherlands was compared for a number of years, the ratios in 1993 functioned as reference ratios. The ratios of 2003 were compared with them, and this led to the conclusion that these roads had become safer in 10 years. This does not mean, though, that they were unsafe in 1993 and safe in 2003. Another reference ratio is needed to draw such a conclusion. This could possibly be a value indicating the maximum acceptable ratio. Such a value is, however, difficult to calculate and somewhat subjective.

The safety of an individual road can be judged by comparing this road's safety ratio with that of a collection of roads very similar to it. This total ratio can then be regarded as the 'normal' value: all roads with a higher ratio are relatively unsafe and all roads with a lower ratio are relatively safe. For example, the number of serious crashes per billion motor vehicle kilometres in a particular municipality in 2003 can be compared with the value 168 in *Table 1*. In the right hand column of *Table 2* the reference values for the same year for six road types are given.

However, the reference ratios in *Tables 1* and *2* are too rough to calculate the safety level of individual roads. They were calculated from a very large collection of roads that, although they have the same speed limit, can be very different with regard to design and traffic volume. That is why in the Roads and Traffic programme that SWOV is currently conducting, more detailed reference values will be calculated. These reference ratios are calculated by using a sort of reference function that, based on the length and average daily intensity of a particular road, calculates how many crashes can be expected on that road during a certain period. The reference function is modelled using mathematical techniques and a data collection that contains the number of crashes during a certain period, the average daily traffic, and the road length of every road in the group. In literature, such a reference function is called an *accident prediction model*. Such models have been developed in the past for various urban and rural road types (Dijkstra & Wegman, 1992; Commandeur et al., 2002). An overview of accident prediction models used in other countries can be found in Reurings et al. (2006).

As mentioned earlier, reference ratios are used to better interpret the road safety ratio calculated for a road or group of roads. If they are smaller or larger than the reference ratio, and the difference is statistically significant, the road or group of roads is considered to be safe or unsafe respectively.

What is a good way of visualizing safety ratios?
The crash rate of a road is the number of crashes per billion motor vehicle kilometres per year, if necessary, subdivided by injury severity. This crash rate can be visualized in a number of ways. In *Figure 1* two examples are shown. *Figure 1a* is the number of serious crashes per billion motor vehicle kilometres per year for all roads in the Netherlands, subdivided by urban and rural roads. It is clear that the crash rates for both road types have declined. However, this figure cannot show the development of the number of crashes or the traffic volume. This can only be done if the crash rates are shown in another way.

This other way is illustrated in *Figure 1b*, which compares the number of serious crashes per 1,000 kilometres road length with the average daily intensity for urban and rural roads. The tangent of the angle of the straight line with the x-axis is, except for a constant, equal to the crash rate of urban roads in 2003. The wider the angle, the larger the crash rate. This graph also shows that the crash rates for both urban and rural roads have declined in the course of time. It also shows that there is a sharp increase in the traffic volume on rural roads, whereas the traffic volume on urban roads has decreased.

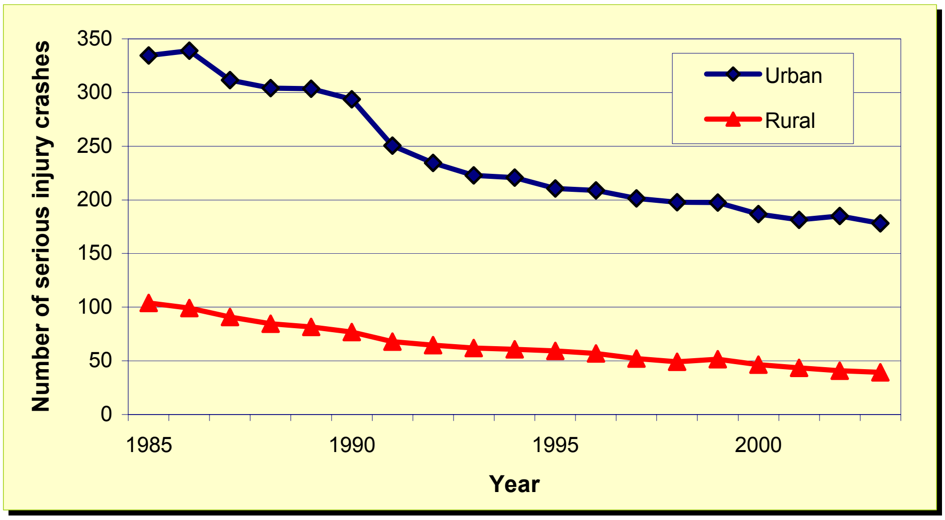

Figure 1a. *The number of serious crashes per billion motor vehicle kilometres for urban and rural roads 1985-2003.*

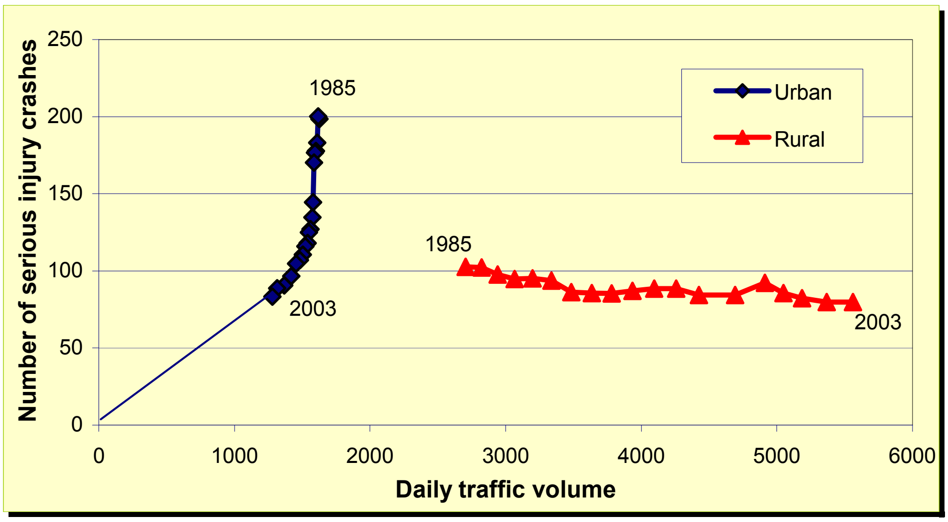

Figure 1b. *The number of serious crashes per 1,000 km. road length compared with the average daily traffic volume for urban and rural roads 1985-2003.*

The *Figure 1b* type of graph can also be used to determine the safety of individual road sections by using reference values. An example of this is shown in *Figure 2*. The reference function in this figure has been modelled on the number of injury crashes per kilometre and the average daily traffic on provincial roads in the provinces of Noord Holland, Zuid Holland, and Gelderland. Road sections 1 and 2 are fictitious provincial roads. The angle of road section 2 is smaller than that of road section 1, which implies that the crash rate of road section 2 is also smaller. But if the crash rates of both road sections are compared with the reference values, road section 1 has a lower crash rate than the reference ratio and road section 2 has a higher crash rate. Therefore road section 1 can be considered to be safe, and road section 2 to be unsafe, even though road section 2 has a lower crash rate than road section 1.

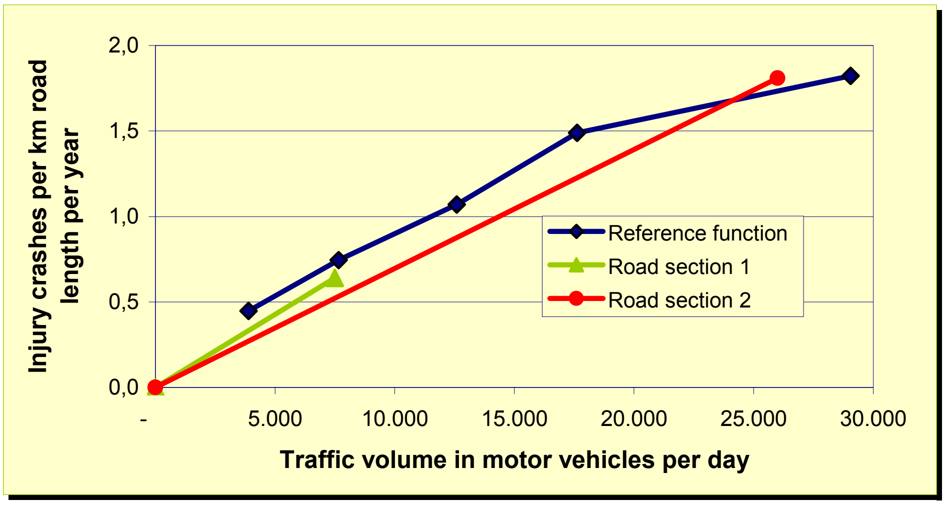

Figure 2. *The number of injury crashes per kilometre per year compared with the traffic volume in motor vehicles per day for rural distributor roads in the provinces of Noord Holland, Zuid Holland, and Gelderland.*

Conclusions

There are several ways of expressing the road safety level of a road or a collection of roads. A number of examples show that the crash rate, defined as the number of crashes per motor vehicle kilometre, possibly subdivided by injury severity, is the most usable. This is because this ratio does not only take the number of crashes into account, but also the road length and the number of passing motor vehicles. Reference ratios are necessary to interpret the ratio found by making a comparison. The correct reference ratio is determined by the problem. In general, however, the reference ratio is calculated for a particular road type in a particular year. Using reference functions is also possible; they calculate how many crashes are to be expected on that road considering its length and average daily traffic volume.

Publications and sources
(SWOV reports in Dutch have an English summary)]

Braimaister, L.G. (1996). *Risks by road type : methodology for calculation and preparation* (in Dutch). R-96-66A. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, Leidschendam.

Commandeur, J.J.F., Bijleveld, F.D., Braimaister, L.G. & Janssen, S.T.M.C. (2002). *The analysis of accident, road, and traffic features of the state* (In Dutch). R-2002-19. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, Leidschendam.

Dijkstra, A. & Wegman, F.C.M. (1992). *Verkeersveiligheid in de vervoerregio: inbreng van het aspect verkeersveiligheid in de vervoerregio's Utrecht en Arnhem-Nijmegen* (In Dutch). R-92-54. Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, Leidschendam.

Reurings, M., Janssen, T., Eenink, R., Elvik, R., Cardoso, J. & Stefan, C. (2006). *Accident prediction models and road safety impact assessment; a state-of-the-art*. First deliverable of WP2 of the Ripcord-Iserest project.