SWOV Fact sheet

Measuring (un)safety of roads

Summary
Measuring the safety level of a road is difficult. First of all you have to know how many crashes have occurred on a road. Various units of measurement are used for this: the absolute number of crashes per road, the number of crashes per road length, and the number of crashes per distance travelled. Each of 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 and content
Measuring a temperature is quite simple; it's done very quickly with a good thermometer. Interpreting the measured 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 group of roads can be measured just like the temperature; it's only much more difficult. Safety cannot simply be read directly from a measuring instrument, but can be determined using so-called 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, various safety ratios can be used to express a road's safety level, 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 for temperature, it is important to know where the safety has been measured, for instance on a motorway or on an urban road. A ratio for a motorway, expressed in whatever 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 is reasonably safe.

A third common feature 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 with. This fact sheet also discusses how such reference values can be determined.

Which safety ratios for roads are there?
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 distance travelled, both measured during the same period.

If necessary, these three units of measurement can 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 for a group of roads.

The first unit of measurement is perhaps the easiest one, but its use is only limited. After all, a higher ratio should correspond with less safety, but this is not always 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 correct.

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*. Measured this way, the two roads are equally safe.

However, there are problems using this ratio if one road is more heavily used than the other. The numbers of crashes per kilometre may be the same, but many more cars have travelled on the first road, this road is safer. This difference in safety is expressed in the third ratio, the number of crashes per distance travelled. This is therefore also the ratio that is most commonly used to measure a road's safety; it is often referred to as the *crash rate* of a road.

The distance travelled is often expressed in the number of motor vehicle kilometres: the number of kilometres travelled by motor vehicles on a particular road (or group 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 non-motorized vehicles, for instance 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 non-motorized vehicles are involved.

In the three ratios discussed above, 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. As this fact sheet deals with the safety ratios of roads, 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 serious road injury or fatality. Often only the serious crashes are used to calculate a safety ratio, because the registration rate of crashes with less severe injury, or with damage only, is less complete than that of crashes with severe or fatal injury. All three ratios show an increase in road safety on urban roads over time. The second ratio, the number of serious crashes per 1,000 kilometres road length, shows the greatest improvement. This is because the road length has increased more than the number of motor vehicle kilometres.

	1997	2002	2007
Number of serious crashes	5,461	4,183	3,363
Road length in 1,000 kilometres	56,8	63,9	71,8
Number of serious crashes per 1,000 kilometres road length	96	65	47
Motor vehicle kilometres (billions)	28	30	32
Number of serious crashes per billion motor vehicle kilometres	195	139	105

Table 1. *Three road safety ratios for urban roads in the Netherlands in 1997, 2002, and 2007 (Sources: Ministry of Infrastructure and the Environment (IenM) – Datafile of Registered Crashes in the Netherlands (BRON); Dutch Hospital Data (DHD) - National Medical Registration (LMR); Statistics Netherlands (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 group 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 1997, 2002, and 2007 was compared. This comparison results in the conclusion that the safety on these roads has improved during that 10-year period.

It is also possible to compare the safety of two or more different road types. An example is given in *Table 2*, which shows three ratios for six road types in 2003. Unfortunately more recent data about the distances travelled per speed limit is not available. Therefore the values in *Table 2* do not necessarily apply for the present situation. The smallest number of crashes occurred on 70 km/h urban roads. But

because this road type also has the smallest number of kilometres road length, the second ratio, the number of serious crashes per 1,000 km road length, is not the lowest for this road category. The difference between the second and third ratio for 100/120 km/h roads is remarkable. The number of serious crashes per 1,000 kilometre road length is relatively high, but this road category has the lowest crash rate. This is because by far the largest distance is driven on roads of this category. 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 programme (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 difference between crash rates is statistically significant.

	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/h	615	22	159
50 km/h	3,630	120	299
70 km/h	168	138	33
Rural roads			
60 km/h	261	2823	68
80 km/h	2,094	47	58
100/120 km/h	554	108	8

Table 2. *Three road safety ratios for six road types in the Netherlands in 2003 (Sources: IenM – BRON; DHD – LMR; CBS).*

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

What are reference values and how are they calculated?

A reference value is a set value that is used to allow for a better interpretation of other values. 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 over 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 make a measured road safety ratio meaningful, a reference value 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 purpose for which it is used.

In the example in which the safety of urban roads in the Netherlands during a number of years was compared, the ratios in 1997 were used as reference ratios. The ratios of 2007 were compared with these reference ratios, and this led to the conclusion that the roads involved had become safer during these ten years. This does not mean, however, that they were unsafe in 1997 and safe in 2007. Another reference ratio is needed to draw such a conclusion. This could possibly be a value indicating the maximum acceptable ratio. However, such a value is difficult to calculate and rather subjective.

The safety of an individual road can be assessed by comparing this road's safety ratio with that of a group 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 2007 can be compared with the value 169 in *Table 1*. The right hand column of *Table 2* contains the reference values for 2003 for six road types.

However, the reference ratios in *Tables 1* and *2* are too rough to determine the safety level of individual roads. They were calculated from a very large group 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 are being determined. 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 set containing the road length, the number of crashes during a certain period, and the average daily traffic, for every road in the group. The literature calls such a reference function an *accident prediction model*. In the past, such models have been developed for various urban and rural road types (Dijkstra & Wegman, 1992; Commandeur et al., 2002). An overview of accident prediction models that have been used in other countries can be found in Reurings et al. (2006).

As was mentioned earlier, reference ratios are used to allow better interpretation of 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 to visualize 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.

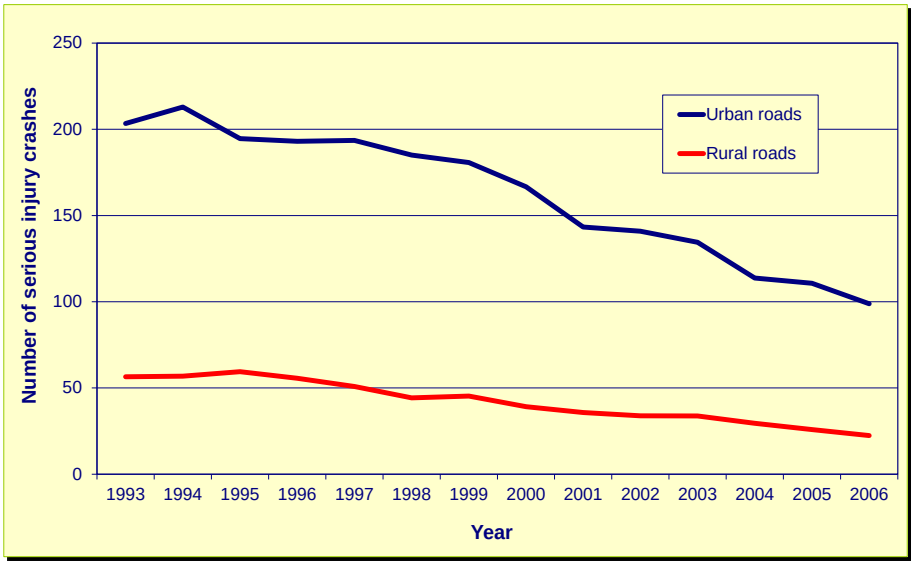

Figure 1a. *The number of serious crashes per billion motor vehicle kilometres for urban and rural roads 1993-2006. Sources: IenM - BRON; DHD – LMR; CBS.*

Figure 1a shows 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 a different way.

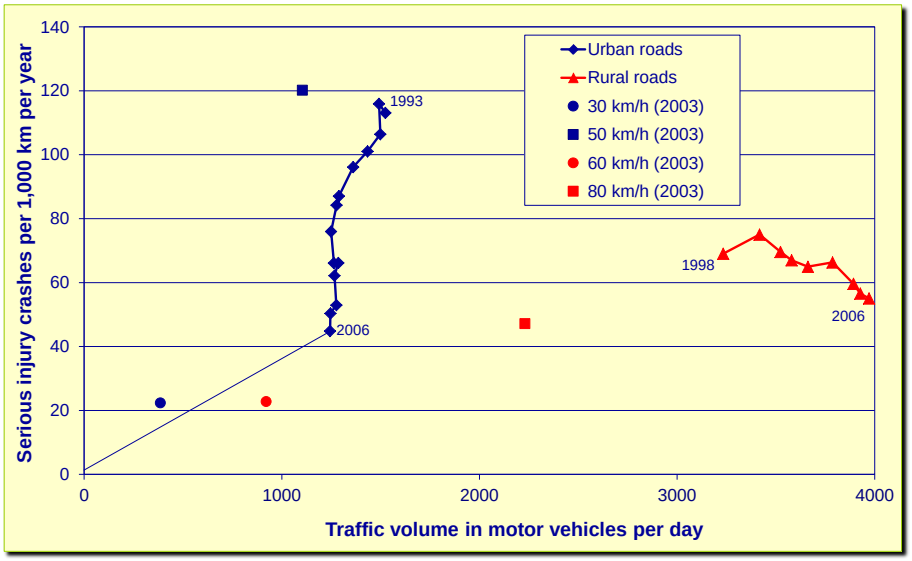

Figure 1b. *The number of serious crashes per 1,000 km road length compared with the average daily traffic volume for urban and rural roads 1993/1998-2006. Sources: IenM – BRON/NWB; DHD – LMR; CBS*

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 traffic volume 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 2006. The wider the angle, the higher the crash rate. This graph also shows that the crash rates for both urban and rural roads have decreased 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.

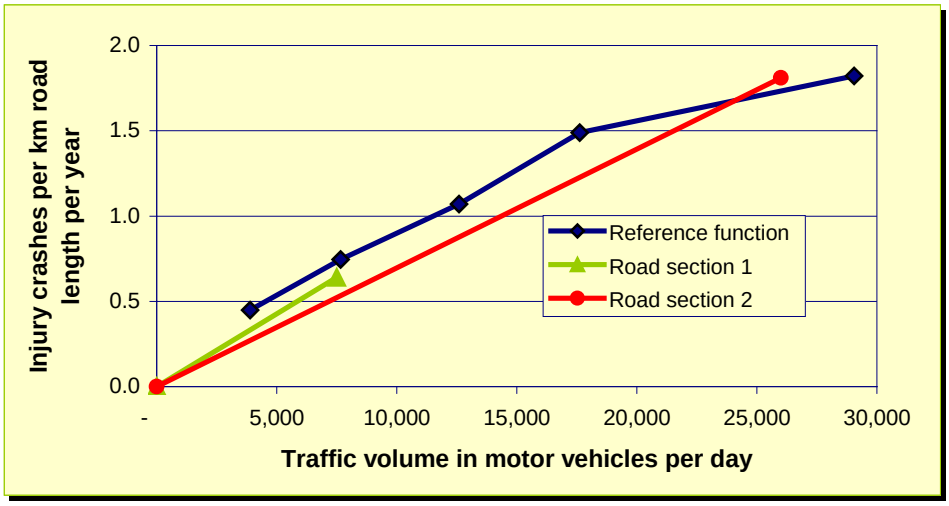

Figure 2. *The number of injury crashes per kilometre per year compared with the traffic volume in motor vehicles per day for rural distributor roads in the provinces of Noord-Holland (NH), Zuid-Holland (ZH), and Gelderland (Gld). Sources: IenM – BRON; Dutch provinces NH, ZH and Gld.*

The type of graph in *Figure 1b* can also be used to determine the safety of individual road sections by using reference values. An example is shown in *Figure 2*. The reference function in this figure has been modelled on the number of injury crashes (according to BRON) per kilometre and the average daily traffic volume on provincial roads in the Dutch 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.

Conclusions

There are several ways of expressing the road safety level of a road or a collection of roads. A number of examples showed that the crash rate, defined as the number of crashes per motor vehicle kilometre, subdivided by injury severity if required, is the most suitable. 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 purpose for which it is used. 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)]

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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.

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