SWOV Fact sheet

Safe road shoulders

Summary
In the Netherlands, almost one fifth of all serious crashes that are registered are run-off-road crashes; on rural roads the proportion even is one third. In more than 70% of those crashes a passenger car is involved. By far most of the serious run-off-road crashes occur on 80 km/h roads. The causes of run-off-road crashes may be driver-related (e.g. fatigue or alcohol and/or drug use) or road-related (e.g. an unexpected sharp bend). Often a combination of causes will be involved. Measures to prevent run-off-road crashes are: a correct, predictable road layout, the application of rumble strips, hard strips and (semi-)hardened road shoulders. In relation with vehicles, Electronic Stability Control (ESC) seems to be quite effective. Measures to prevent collisions with obstacles are the creation of obstacle-free zones and screening off the so-called danger zones like rows of trees or banks.

Background and content
During the 1960s and 1970s, research into safer roadsides focused on motorways in particular. Later, in the 1980s, guidelines for the design of non-motorways were drawn up in the Netherlands, the so-called RONA guidelines. These guidelines contributed to *new* roads being fitted with safer road shoulders. The road shoulders of older non-motorways, however, have a layout that is considerably less safe. In the recent past, in the Sustainable Safety framework, there has been more attention for specific measures to make these shoulders safer also (Schoon, 2000; CROW, 2004).
The present fact sheet will discuss the size of the problem of run-off-road crashes, their characteristics, and possible solutions. Run-off-road crashes can be obstacle crashes (among which many tree collisions) as well as single vehicle crashes (like turning over and landing in the ditch). See also SWOV Fact sheet *Cars submerged in water*). The present fact sheet will focus on the road sides of 80 km/h roads. By far the most serious run-off-road crashes happen on these roads. Serious run-off-road crashes also happen on 50 km/h roads, but lack of space is an impediment for the construction of safer roadsides. The best way to reduce the risk of serious crashes here is to ensure that drivers keep to the speed limit and wear their seat belts.

What is the size of the problem?
Table 1 shows that in the Netherlands, during the past five years, an annual average of 1,500 serious run-off-road crashes were registered on roads with a speed limit of 50 km/h or higher. This is almost one fifth of all serious crashes that happen on these roads. In 2008, more than 1,400 serious run-off-road crashes happened, nearly 200 of which were fatal and more than 1,200 resulted in inpatients[1]. Absolutely speaking, most of the serious run-off-road crashes occur on 50 km/h en 80 km/h roads. Looking at all crashes on these roads, the proportion of run-off-road crashes is 29% on 80 km/h roads and 11% on 50 km/h roads. With 36% the proportion of run-off-road crashes is highest on 120 km/h roads; in an absolute sense the problem is considerably smaller on these roads.

[1] *Note:* the number of *inpatients* is not a reliable indication of the number of *severely injured casualties* in the Netherlands. The casualties that are admitted into hospital are not necessarily severely injured. Therefore, the numbers of inpatients that are given in this report are only indicative.

Building density	Road type by speed limit	2004	2005	2006	2007	2008	Proportion of total number of crashes (2004-2008)
Urban	50 km/h	408	482	461	447	434	11%
	70 km/h	46	46	28	50	34	18%
Rural	60 km/h	94	140	142	195	207	29%
	80 km/h	722	678	598	547	508	29%
	100 km/h	83	88	72	69	68	29%
	120 km/h	178	189	182	169	172	36%
Total urban and rural		1.531	1.623	1.483	1.477	1.423	19%

Table 1. *Registered number of serious run-off-road crashes (with fatalities and/or inpatients) in the Netherlands in the period 2004-2008, itemized by speed limit. The proportion is that of all types of crashes at that specific road type. The figures include the bicycle crashes (BRON – Ministry of Transport).*

Who are involved in run-off-road crashes most frequently?
More than 70% of the Dutch run-off-road crashes involve a passenger car (*Table 2*). Delivery vans and motorized two-wheelers have a relatively high percentage of about 7% and 9% respectively. One should realize that certain measures to improve road shoulder safety are favourable for car occupants, but unfavourable for motorcyclists and (light) moped riders. Examples are crash barriers and aluminium lampposts. Lorries are rarely involved in run-off-road crashes and in 2008 not a single run-off-road crash involving a bus was registered. The registration rate for run-off-road crashes involving bicycles is very low.

Mode of transport	Fatal	Inpatient	Total	Percentages
Passenger car	133	883	1.016	71%
Delivery van	17	82	99	7%
Lorry	6	28	34	2%
Motorcycle/motor scooter	22	100	122	9%
(Light) moped	8	103	111	8%
Bicycle	5	15	20	1%
Other	2	19	21	2%
Total	193	1.230	1.423	100%

Table 2. *Numbers of registered serious run-off-road crashes in 2008 on Dutch urban and rural roads with a limit of 50 km/h and higher, subdivided by mode of transport and crash severity (BRON – Ministry of Transport).*

What are the causes and which manoeuvres can be distinguished?
Road users can go off the road unintentionally because they try to avoid an animal, object, or oncoming traffic or because of fatigue, speeding, alcohol and/or drug use, bad weather conditions, a bad road surface, et cetera. The road layout can also contribute to a run-off-road crash occurring. An extensive literature study, for example, indicated that certain road side characteristics (e.g. lines of trees) can act as a 'visual guidance' resulting in (too) high unadjusted speeds. This is important in run-off-road crashes developing (Janssen et al., 2004). The road's recognizability and predictability are also important (see SWOV fact sheet *Recognizable road design*). Unpredictability, e.g. an unexpected and unannounced sharp bend can be the reason for a driver maintaining too high a speed which can result in running off the road. A run-off-road crash will often occur due to a combination of factors.

Broadly speaking two types of run-off-road crashes can be distinguished: the 'controlled' run-off-road crashes and the 'uncontrolled' run-off-road crashes. 'Controlled' run-off-road crashes (incidents) develop, for example, when a driver is distracted or fatigued and therefore loses direction. In these cases the vehicle crosses the edge marking and partly lands in the road shoulder. If the roadside has

a safe layout, it offers the driver the opportunity to steer the vehicle out of the road shoulder and back on to the road in a controlled manner. This requires a hard road shoulder directly alongside the road and the transition between shoulder and carriageway being level.
'Uncontrolled' run-off-road crashes mainly occur in bends, at high speeds or when the driver is under the influence of alcohol and/or drugs. These are mostly real crashes, in which a vehicle crosses the edge marking and goes into the road shoulder entirely. Measures warning a driver of crossing the edge marking are generally not effective in these cases. Once a vehicle is in the road shoulder, the risk is high that the vehicle turns over (especially when the shoulder is soft), hits an obstacle, or lands in a ditch.

What is the effect of rumble strips (acoustic edge markings)?
If a vehicle should go off the carriageway in a more or less controlled manner, rumble strips (acoustic edge markings in longitudinal direction) and hard strips (narrow asphalted strip alongside the edge marking) may prevent a vehicle hitting the road shoulder. Driving over acoustic edge markings causes a sound that alerts the driver. A hard strip alongside the carriageway is intended to make it possible for drivers to steer back on to the road way. A hard strip can be fitted with ridges that also produce a sound.
No study of rumble strips has been made in the Netherlands, but studies in the United States and Canada have indicated the application to be an effective measure. The number of run-off-road crashes on single carriageway roads decreased by 20-60% (FHWA, 2001).

What are the advantages of good road shoulder surfaces?
If a vehicle still runs off the road, two measures are necessary to enable the driver steering the vehicle back on to the road. The first measure is an as-small-as-possible difference in height between the carriageway and the shoulder. This prevents the wheels of the vehicle being subjected to unexpected forces when the vehicle is steered back on to the carriageway.
The other measure is hardening the road shoulder by applying concrete bricks, plastic slabs, or gravel. This keeps the vehicle more controllable when it lands in the shoulder. The colour and/or texture of the (semi-)hardened shoulder need to be different from the carriageway surface to prevent the road looking wider than it actually is. In the Netherlands, various types of (semi-)hardening have been tested in a number of projects (Schoon, 2003). In the Province of Overijssel, for example, concrete bricks with hollow spaces were tested best (Overkamp, 2004). The types of shoulder hardening were tested for, among other things, bearing capacity, management and maintenance, design, and the possibilities of carrying out steering corrections.
International studies have investigated the road safety effects of shoulder surfacing. In Australia, Ogden (1997) found that a hardened shoulder strip of 0.6-0.8 metres alongside 'highways', the national single carriageway roads, resulted in a more than 40% decrease in the number of run-off-road crashes with injury. Some other studies have found smaller reductions. No research into the road safety effect of semi-hardened shoulders has been carried out in the Netherlands. In calculations SWOV uses a 20% effect for rural single carriageway through-roads and distributor roads (Schoon, 2003).

How wide should obstacle-free zones be?
If it is no longer possible to steer a vehicle back on to the carriageway, the driver benefits from an obstacle-free zone that is as wide as possible. Such zones contain no objects that can cause serious damage to the vehicle and severe injury to the occupants, but they can be fitted with 'forgiving' roadside objects such as thin-walled aluminium lampposts and emergency telephones which give way in a collision with a passenger car. The road shoulder may have a side slope, provided it is not too steep. Experimental research and mathematical simulations carried out by SWOV indicated that for downhill side slopes, the slope must be no steeper than 1:6 and for uphill side slopes no steeper than 1:2 (Schoon, 1999).

For all road types there are guidelines for the width of the obstacle-free zone *(Table 3).* These zones consist of a supportive shoulder which should enable the road user to steer the vehicle back on to the carriageway or to safely bring it to a halt. The widths of the obstacle free zones for different road types were determined on the basis of SWOV research (Schoon, 1999) and international studies. With an estimated 20% effectiveness of the semi-hardened shoulder, the effectiveness of an obstacle-free zone is estimated to be 69% (Wijnen et al., 2010).

	Standard	Minimum
Rural access roads – 60 km/h	2.5 m	1.5 m
Rural distributor roads – 80 km/h	6 m	4.5 m
Single carriageway through roads – 100 km/h	10 m	8 m
Dual carriageway motorways – 100 km/h	10 m	-
Dual carriageway motorways – 120 km/h	13 m	-

Table 3. *The required widths of obstacle-free zones for various road types in the Netherlands (CROW, 2004; Dubbeldam, 2006).*

The obstacle-free zone preferably has the standard width; for the different road type this varies between 2.5-13 m. If, for example, the obstacle-free zone alongside a distributor road is insufficiently wide and the road's function is not in accordance with its use, downgrading the road into an access road may be considered. *Table 3* shows that the difference is 3.5 m in required width. A cost-benefit analysis, for instance using VVR-GIS, can be used as a basis for such a decision. VVR-GIS is an instrument for the calculation of effects, costs and benefits of local and regional road safety measures (see also SWOV fact sheet *VVR-GIS 3.0: support for investment decisions*).

What to do with 'danger zones' alongside the carriageway?
Many roads have a so-called danger zone alongside the carriageway, for example a line of trees, a steep slope or a ditch. Preferably the danger zone is removed. If this cannot be done, safety barriers of steel or concrete are constructed alongside motorways (Heijer et al., 1994). Freestanding obstacles on motorways are screened off with an obstacle guard; in the Netherlands that is the RIMOB impact attenuator. A RIMOB is capable of 'catching' passenger cars with speeds of up to 100 km/h in a relatively safe way (Schoon, 1990; Van der Drift, 1992).
At single lane carriageways, safety barriers are only placed near objects like fly-overs and rarely alongside regular road stretches. One reason is the danger of the vehicle bouncing back with the risk of a head-on collision; another reason is that the standard safety barrier is too high and therefore does not fit into the single carriageway road image. The WICON, a construction that 'catches' the wheels which is 45 cm high, does not have this disadvantage and also catches the vehicle during the collision and thus prevents bouncing back. Due to the high purchasing costs the WICON is placed at only four locations in the Netherlands. Presently, alternative barrier constructions are being investigated in the Netherlands, in particular those for screening off lines of trees alongside the older 80 km/h roads.
Motorcyclists benefit most from an obstacle-free zone. If safety barriers are required, for instance in a bend, barriers with underrun protection are to be desired (CROW, 2003).
The standard barrier construction on motorways is capable of guiding lorries and buses of up to approximately 13 tons. Heavier lorries (up to 50 tons) require extremely heavy constructions. These are only used for engineering works, for instance for a fly-over across an underlying road or railway when running off the road causes extra dangers. The lower safety barriers of up to 50 cm high which are required for single carriageways offer little guideway for lorries. Taking the low proportion of lorry run-off-road crashes on these road types into consideration, this is not a problem.

What is the importance of vehicle technology for the prevention of run-off-road crashes?
Several developments are taking place where vehicles are concerned. Especially the anti-skidding device Electronic Stability Control (ESC) appears to be effective in the prevention of run-off-road crashes. From 2014, ESC must be fitted into all new passenger cars as a standard system. Also other technological developments are or will be playing an important role in the prevention of run-off-road crashes. Examples are Intelligent Speed Assistance (ISA), Advanced Cruise Control (ACC) and Lane Departure Warning Systems. The eCall system, a system that automatically sends a message to the incident room in case of a crash, is expected to be made compulsory for all new vehicles from 2014 onward. Especially in single-vehicle crashes like run-off-road crashes this system can realize faster assistance. It is important to keep track of these developments and take account of them in designing the road shoulder layout. More information about these types of systems can be found in the SWOV fact sheets *Intelligent Transport Systems (ITS) and road safety*, *Advanced Cruise Control (ACC)*, *Intelligent Speed Assistance (ISA)* and *Electronic Stability Control (ESC)* (to be published).

What are the developments in the field of research and advice?

In the Netherlands as well as in other European countries there are several initiatives aimed at making road shoulders safer.

Looking at the Netherlands, the CROW platform 'Forgiving road and road environment' is presently active. Its task is to collect and disseminate the knowledge in the field of forgiving road infrastructure. The platform can also initiate or give guidance to research. SWOV has recently started an in-depth study into run-off-road crashes to gain more insight into the causes and consequences. The first results are expected late 2010. The Directorate-General for Public Works and Water Management has drawn up an advice for the Ministry of Transport to reduce the number of single-vehicle crashes (Schepers, 2008). In addition to measures concerning road shoulders, it proposes preventive measures in relation with the driver training, alcohol, drugs and fatigue.

Analyses and inspections of the road image are very suitable for finding specific design elements that may prompt unsafe driving behaviour. From 2011, inspections will even be compulsory, also for motorways and 80 km/h roads (Schepers, 2008).

Run-off-road crashes happen scattered all over the Netherlands and it is therefore desirable to have forgiving roadsides everywhere. Hence, the question has arisen of how to assign priority. The most obvious approach is to include safer road shoulders in major maintenance projects. A second approach is to use 'priority assignment methods' for roads or road sections. The KEM method (Cost Effective Measures) used by the Dutch province of Overijssel (Schepers et al., 2009) and SWOV's Accident Prediction Models (Reurings & Janssen, 2007) seem to be suitable.

Also at the European level several authorities are active in projects concerned with safe road shoulders:

– RISER (2006; Roadside Infrastructure for Safer Roads) was a European project that aimed at the identification of danger zones, drawing up guidelines, carrying out inspections and giving trainings.
– EuroRAP (European Road Assessment Programme) is a programme which gives roads (including the road shoulder) a safety score.
– SafetyNet offers Safety Performance Indicators for roads and road shoulders.
– FEMA (Federation of European Motorcyclists' Associations) is dedicated to motorcycle-friendly safety barriers at European level.

Conclusions

Almost 200 fatal run-off-road crashes per year are registered in the Netherlands and more than 1,200 run-off-road crashes with inpatients. This is almost one fifth of all serious crashes. A passenger vehicle is involved in more than 70% of the run-off-road crashes. By far the most serious run-off-road crashes occur on 80 km/h roads. One third of all serious crashes on these roads are run-off-road crashes. Run-off-road crashes also happen on 50 km/h roads. The road shoulder safety on these 50 km/h and 80 km/h roads in particular needs attention. In the past decades, much has already been achieved concerning shoulder safety of motorways. The causes of run-off-road crashes may be found in the driver (e.g. fatigue, speeding, alcohol and/or drug use) or in the road (e.g. bad road surface, a sharp bend). Often a combination of these factors will be involved.

Possible measures to prevent landing in the road shoulder are: a correct and predictable road layout the application of rumble strips, and the construction of hard strips and (semi-)hardened road shoulders. In relation with vehicles, especially Electronic Stability Control (ESC) seems to be effective. This anti-skidding device must be present in all new passenger cars from 2014 onward.

Measures to prevent collisions with obstacles are creating obstacle-free zones and screening off so-called danger zones. A Dutch national platform of experts is looking at the types of screening constructions that can be used, especially those for screening off lines of trees on the older 80 km/h roads.

Recommendation

As run-off-road crashes are responsible for many traffic casualties and the quality of many road shoulders is still insufficient, SWOV is of the opinion that road shoulders deserve more attention. SWOV proposes to set a deadline for all road shoulders to meet a number of yet to be determined minimum quality demands.

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

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