SWOV Fact sheet

Vulnerable road users

Summary
A group of road users can be defined as 'vulnerable' in a number of ways, such as by the amount of protection in traffic (e.g. pedestrians and cyclists) or by the amount of task capability (e.g. the young and the elderly). Vulnerable road users do not usually have a protective 'shell', and also the difference in mass between the colliding opponents is often an important factor. Vulnerable road users can be spared by limiting the driving speed of motorized vehicles and separating unequal road user types as much as possible. Adapting motor vehicles (e.g. by side-underrun-protection for trucks and collision-friendly car fronts) can lessen the injury severity of vulnerable road users. In crashes involving only vulnerable road users and no other road users, it is mainly the infrastructure that is important for the prevention and limitation of injury.

Background and content
Road users, who have a high casualty rate and should therefore be given special attention in road safety policy, are often referred to as 'vulnerable road users'. This group can be defined in a number of ways. In all cases, the lack of external protection is important and often the task capability also plays an important role. Vulnerable road users can be subdivided by mode of transport or by age.

This SWOV Fact sheet makes a distinction between various groups of vulnerable road users and discusses a number of general measures that can increase their safety. More detailed information about problems and measures in relation with specific road user groups can be found in the SWOV Fact sheets *Pedestrians*, *Cyclists*, *Moped and light moped riders*, *Motorcyclists*, *Road safety of children in the Netherlands*, *The elderly in traffic*, and in SWOV publication *Advancing Sustainable Safety* (Wegman & Aarts, 2006).

What are vulnerable road users?
In *Advancing Sustainable Safety* (Wegman & Aarts, 2006) pedestrians and cyclists are referred to as vulnerable road users because of their unprotected state. Because riders of motorized two-wheelers (motorcycles, mopeds and light mopeds) are also to a large extent unprotected, they are also referred to as vulnerable. Where vulnerability is used for specific age groups, Wegman & Aarts mainly refer to children and the elderly when they are pedestrians or cyclists. More specifically, they refer to aspects of task capability, viz. inexperience of children and a declining task capability (and physical vulnerability) of the elderly. Besides the fact that vulnerable road users are often unprotected because they have no 'shell', there is also often a difference in speed with other road users. That partly explains why (light-)moped riders and motorcyclists are only on second thought regarded as vulnerable: they travel at much higher speeds than pedestrians or cyclists.

In 2003, the former Transport Research Centre (AVV) used three criteria to distinguish vulnerable road users from other road users: the amount of external protection, the task capability, and the resilience (AVV, 2003). A subdivision based on task capability distinguishes, for example, road user groups who have *limitations* in performing one or more task aspects. In addition to novice road users, disabled road users and road users who are less skilful because of social or cultural circumstances are therefore also considered to be vulnerable road users. Because strict application of these criteria would also label novice drivers (limited task capability) or elderly car drivers (low resilience) as vulnerable, there is a supplementary criterion: the vulnerable should not themselves be a threat to others. For this reason neither young nor elderly motorists are considered to be vulnerable: their vehicles are a threat to others. This additional criterion, of course, also excludes drivers and passengers of other types of motorized vehicles. That is why AVV (2003) distinguishes vulnerable groups and risk groups; the latter group includes young novice drivers. The AVV subdivision of vulnerable road users results in a slightly broader definition of 'vulnerable road users' than that of Wegman & Aarts (2006).

This SWOV Fact sheet uses the subdivision of Wegman & Aarts (2006) which, as that of AVV, uses the following starting points: in the first place vulnerable road users are *unprotected*, which leads to subdivision by mode of transport (i.e. pedestrians and cyclists). Secondly, vulnerable road users display a certain amount of *task incapability*, which leads to a subdivision by age (i.e. children and the elderly; the elderly have an increasing *physical vulnerability*).

Who are most vulnerable in traffic?
The vehicle in or on which the driver sits, together with his own body (e.g. its skeleton) can provide protection against external forces. In the case of protection by the vehicle, occupants of motorized vehicles (such as cars, vans, trucks and busses) have the advantage: they are the least sensitive to injury. Most vulnerable are the road users without a vehicle, and thus without a shell (pedestrians) and those using a vehicle without a shell (cyclists and light moped riders). Moped riders and motorcyclists are only protected from head injuries if they wear the obligatory crash helmet.

When we take the body and not the vehicle as a starting point, the elderly road users are at a disadvantage. From the age of fifty years old the bones get more brittle, the elasticity of the soft tissues declines and so does the muscle strength. In a crash with equal collision energy, these age related changes result in the elderly being more severely injured than the young (see also the SWOV Fact sheet *The elderly in traffic*).

Crash severity
A measurement of the average crash severity for a specific group of road users is the lethality rate which is the ratio of the number of deaths and the number of in-patients within this group of road users. In *Table 1* the groups are based on the combination of age group and mode of transport and the lethality rate is the number of fatalities per 100 serious road injuries[1].

Age	Pedestrian	Bicycle	(Light-)moped	Motorcycle	All vulnerable transport modes
0-14	8	11	4	0	9
15-24	26	13	6	20	9
25-64	25	9	6	17	12
65-74	22	20	15	21	20
75+	36	31	39	22	33
All ages	22	14	7	18	14

Table 1. *Lethality rate of vulnerable road user groups based on data over the period 2005-2009 (Sources: Ministry of Infrastructure and the Environment (IenM) and Dutch Hospital Data (DHD)).*

As shown in the bottom right cell in *Table 1*, the average lethality rate for vulnerable road users is 14. For 'All vulnerable transport modes' the over-65s are above average, particularly the over-75s whose lethality rate is more than two times higher than average. For 'All ages' only pedestrians (22) and motorcyclists (18) are above the average of 14. The lethality rate of (light-) moped riders is very low (7) and the lethality rate of cyclists (14) equals the average of all vulnerable road users.

Inequality
The lack of a protecting shell can also be approached in another way. After all, the difference in crash severity is often also determined by the difference in mass between the colliding parties (Van Kampen, 2000): the modes of transport are then unequal. A good way of expressing this difference in crash severity is to use the ratio of the numbers of casualties in the weaker party and those in the stronger party: the *inequality factor* (i.e. the number of fatally and severely injured drivers in one vehicle divided by the number in the other vehicle. By definition, this factor is equal to or larger than 1 because the weaker party is always in the numerator: the weaker party always has more casualties than the collision opponent. In collisions between two parties of the same vehicle type the index is 1; in collisions against obstacles the ratio is indefinite because objects as the other party have no

[1] A serious road injury is defined as a traffic casualty who has been admitted to hospital with a minimum injury severity of 2, expressed in MAIS, and who has not died of the consequences within 30 days after the crash. MAIS is an international measure to indicate the injury severity.

casualties. *Table 2* shows the inequality factor for various road user groups; obstacle collisions have been excluded here.

Transport mode of casualty	Crash opponent transport mode				
	Bicycle	(Light-) moped	Motorcycle	Car or van	Lorry
Pedestrian	1.7	4.1	2.0	43.3	-
Bicycle	1	1.8	2.0	32.1	45.4
(Light-) moped		1	0.7	24.0	33.8
Motorcycle			1	26.2	88.0
Van & Car				1	15.5
Lorry					1

Table 2*. Inequality factor in serious two-vehicle crashes, 2005-2009 (Sources: IenM and DHD).*

Table 2 shows that the inequality factor of collisions between two parties of the unprotected road user group (pedestrians, cyclists, and (light-)moped riders) is far below 10. This is also the case for collisions with motorcycles. As soon as one of the parties is a car, van or lorry the inequality factor increases to multiples of ten.

With regard to the motorcyclists themselves, it is clear that they have difficulties with vans and trucks as collision opponents; this also applies to drivers of vans and cars in collisions with lorries. However, their inequality factors are less dramatically high than those of the real vulnerable road users when they collide with these vehicles.

The inequality factor appears to differentiate well between the real vulnerable road users (pedestrians and light two-wheelers) and the rest. The fact that car and van occupants can come off the worse in collisions with heavier vehicles is of course also due to inequality (mass difference), but not to vulnerability. Motorcyclists take an ambiguous position: they are vulnerable by lack of a shell as well as dangerous because of their relatively large mass and high speed.

Single vehicle and obstacle collisions have been omitted from the above overview because, by definition, they would have had an infinite factor. These crashes, however, can also have serious consequences for vulnerable road users and measures are needed to also avoid this type of collision (Davidse, 2011; Davidse et al., 2011; Boggelen et al., 2011).

Casualty rate
A third measurement unit is risk, usually expressed as the *casualty rate*, which is defined here as the ratio of the number of casualties per distance travelled. Although we would prefer separate units for *crash rate* (irrespective of the severity) and *injury rate* (given a crash) the *casualty rate* is a good combination of both.

The casualty rate by age is high for various types of young road users (Wegman & Aarts, 2006) and for the elderly (Davidse, 2007). For the young the high casualty rate as pedestrians, cyclists, (light-)moped riders, and drivers as a result of a low task capability is notable; in the case of the elderly the high casualty rate is mainly a matter of increasing physical vulnerability combined with a decreasing task capability. As already stated, in spite of their high casualty rate young novice drivers are not regarded as vulnerable road users.

With the three measurement units severity index, inequality factor and casualty rate, the various aspects of the vulnerability problem of road users can be made reasonably clear: the inequality factor expresses the large difference between protected and unprotected modes of transport; the casualty rate expresses the task (in)capability of the young and the elderly which, when combined with the injury resistance of the elderly, is very clearly shown by the lethality.

Which measures are possible?
In a sustainably safe traffic system there is no place for large mass and/or speed differences because these strengthen the vulnerability differences between the various types of road user. The idea is that in case of a crash the driving speed should be limited in such a way that a safe collision speed

remains (*homogeneity principle)*. Complete separation of unequal types of road user is of course the best solution. If this is not possible, the crash consequences should be such that pedestrians and cyclists cannot be severely injured (*forgivingness principle)*. This solution requires both special facilities for motorized vehicles as well as speed reduction of these vehicles. At locations where conflicts with motorized traffic are not possible, the layout and maintenance of the infrastructure remain of importance.

Safe collision speed
In a crash between for instance a passenger car and a cyclist or pedestrian, the survival rate of the latter two decreases dramatically when the car's collision speed increases. According to an overview of recent studies (Rosén et al., 2011) nearly all pedestrians survive a collision with the front of a car at a collision speed of 20 km/h. When the collision speed is 40 km/h, the survival rate is approximately 90%, at 80 km/h much less than half the pedestrians survive, and at 100 km/h the rate goes down to only 10% (*Figure 1*). For this reason, a road authority constructs raised junctions or zones 30 at locations with mixed traffic. SWOV Fact sheets *Zones 30: urban residential areas* and *Bicycle facilities on distributor roads* give more information about this subject.

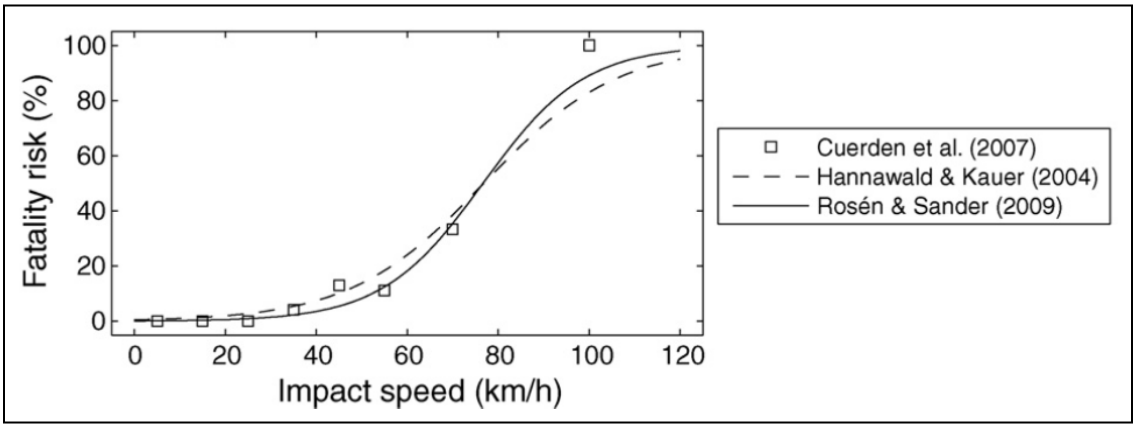

Figure 1. *Fatality rate for pedestrians in crashes with passenger cars as a function of the collision speed (Rosén et al., 2011).*

Vehicle facilities
With regard to facilities for motor vehicles, trucks (which are relatively often involved in crashes that have serious consequences for vulnerable road users) must be equipped with side-underrun-protection, and good side and rear view facilities to as much as possible limit the blind spot when turning right (see SWOV Fact sheets *Lorries and delivery vans* and *Blind spot crashes*). Presently, a collision friendly front for passenger cars is being considered, as cars are by far the commonest collision opponent of pedestrians and cyclists. The EU Directive to this effect was published in 2005 but at this moment has a relatively modest set of requirements and only applies to new cars (see SWOV Fact sheet *Cyclists*. Since early 2009, the SaveCAP consortium (see also www.savecap.org) has, under the supervision of the Netherlands Organization for Applied Scientific Research TNO, been working on the development of an airbag which is to be attached to the car front, This type of airbag is expected to increase the chances of survival in crashes for pedestrians and cyclists.

Infrastructure
By constructing bicycle paths and pavements vulnerable road users on road sections can be separated from the other traffic. But crashes can also happen on pavements and bicycle paths. A study by Schepers (2008) found that in about half of the single bicycle crashes the road design, layout and maintenance play a role in the origin of the crash. Common causes for the crashes that occurred on bicycle paths were steering off the road (against the kerb or in the verge), cycling into a bollard, and a slippery road surface. It is therefore not only important to provide facilities for a specific group of road users, but to also pay attention to safe design and layout, and good maintenance. Also among pedestrians there are fatalities and injuries in accidents not involving a vehicle. The statistics register these accidents as fall-accidents in the public road, and according to the general definition they are not included in the category of traffic crashes. Methorst et al. (2010) have used National Medical Register data to indicate there are 9 fatalities and 800 severely injured per year in such pedestrian crashes.

Conclusion

Within the group of vulnerable road users the lethality (defined as the ratio of the number of road fatalities and the number of serious road injuries) of over-65s, pedestrians and motorcyclists is higher than average. In collisions between vulnerable road users, the inequality factor is low (<10), which means that the number of casualties among the weakest road users is no more than ten times higher than among the other vulnerable road users. In collisions between a vulnerable road user and a car, (delivery) van, or truck, the inequality factor is much higher. Vulnerable road users can be provided for by completely separating unequal types of road users, or, alternatively, to ensure speed reduction when traffic types mix. Facilities for motor vehicles can make sure that crashes are prevented or injury severity reduced. In single-vehicle crashes, infrastructure in particular is important for prevention and injury limitation.

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