SWOV Fact sheet

Vulnerable road users

Summary
The group of vulnerable road users can be subdivided in a number of ways such as the amount of protection in traffic (e.g. pedestrians and cyclists) and 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 mass difference between the colliding opponents is often very important. Vulnerable road users can be spared by limiting the driving speed of motorized vehicles and separating as much as possible unequal road user types. Adapting motor vehicles (e.g. by side-underrun-protection of lorries and collision-friendly car fronts) can lessen the injury severity of vulnerable road users.

Background
Road users who have a high casualty rate and therefore should receive special attention in road safety policy, are often referred to as 'vulnerable road users'. This group can be defined in a number of ways. What is always important is the lack of external protection and in many cases also the task capacity. 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 mentions a number of general measures that can increase their safety.

Who are vulnerable road users?
In *Advancing Sustainable Safety* (Wegman & Aarts (2006) pedestrians and cyclists are refered to as vulnerable road users because of their unprotected state. Because 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 associated with age, Wegman & Aarts (2006) emphasize children and the elderly when they are pedestrians or cyclists. What they refer to are task capability aspects, viz. inexperience of children and a declining task capability (and physical resistance) 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 thoughts regarded as vulnerable: they ride much faster than pedestrians or cyclists.

The Transport Research Centre (AVV) uses three criteria to distinguish vulnerable road users from others: the amount of external protection, the task capability and the resilience (AVV, 2003). For example, a subdivision based on task capability distinguishes road user groups who have various task *limitations*. Besides novice road users, the following groups are therefore counted as vulnerable: invalids and the less skilful because of social or cultural circumstances. Because applying the above mentioned criteria strictly would also mean that novice motorists (limited task capability) or elderly motorists (little resilience) could also be referred to as vulnerable, there is another criterion: the vulnerable may not themselves be threatening to others. That is why neither young nor elderly motorists are not considered to be vulnerable, because 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 distinguishes vulnerable groups and risk groups (the latter includes young motorists). The AVV subdivision of vulnerable road users is a slightly broader definition than that of Wegman & Aarts (2006).

This SWOV Fact sheet uses the subdivision of Wegman & Aarts (2006) which is, as that of AVV, based on the following starting points: in the first place vulnerable road users are *unprotected*, leading to a modal split subdivision (i.e. pedestrians and cyclists). Secondly there is a certain amount of *task incapability*, leading to an age subdivision (i.e. the young and the elderly; what is more, the elderly have an increasing degree of *injury sensitivity*).

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 influences. In the case of protection by a vehicle, occupants of motorized vehicles (such as cars, vans, lorries and busses) have the advantage: they are the least sensitive to injury. Most vulnerable are those who are road users without a vehicle, and thus without a shell (pedestrians) and those on a vehicle without a shell (cyclists and light moped riders). Moped riders and motorcyclists are only protected from head injuries if they wear an obligatory crash helmet. When we only take the body as protection into account, and not the vehicle, the elderly road users have a disadvantage. Once someone is 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.

Crash seriousness

A measurement of crash seriousness is the mortality rate that divides the number of deaths by the number of in-patients within a group of road users. *Table 1*. uses the severity index: the number of deaths per 100 in-patients. This table shows the indexes for the combination of age group and mode of transport.

Age	Pedestrian	Bicycle	(Light-)moped	Motorcycle	All transport modes
0-14	6	5	-	-	6
15-24	9	6	3	11	7
25-64	15	6	4	11	8
65-74	15	11	9	-	11
75+	30	19	24	-	19
All ages	14	8	4	11	9

Table 1. *Severity index of vulnerable road user groups by age, 2001-2005. (Source: Registered Crashes in the Netherlands BRON).*

As shown in *Table 1*, the average severity index of all modes of transport and age groups is 9. For 'All transport modes' the 65 years old and older are above average, and the 75 years old and older have an index that is more than twice the average. For 'All ages' only pedestrians (14) and motorcyclists (11) are above average of 9. (Light-) moped riders are very low (4) and cyclists (8) are about average.

The severity index is especially capable of illustrating the *age effect* of vulnerability, but is not able to characterize all modes of transport as such. This only works for pedestrians and motorcyclists. The index of (light-) moped riders (4) is so low in comparison with the average (9) that the opposite of vulnerability appears to be true.

Inequality

The lack of a protecting shell can also be approached in another way. After all, the difference in crash seriousness is often also determined by mass difference between the colliding parties (Van Kampen, 2000). The modes of transport are then unequal. A good way of expressing this difference in crash seriousness is to use the ratio of the numbers of casualties in the weaker party and those in the strong party, viz. the *inequality factor* (i.e. the number of severely injured drivers in one vehicle divided by the number in the other vehicle. By definition, this factor is equal to or more than 1 because the weaker party is always in the numerator: there are always more casualties there than at 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 have no 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	Van & Car	Lorry
Pedestrian	1,5	4,2	5,4	283,0	175,0
Bicycle	1	2,1	2,3	184,2	126,0
(Light-) moped		1	6,8	107,3	266,0
Motorcycle			1	48,7	125,0
Van & Car				1	31,6
Lorry					1

Table 2*. Inequality factor in serious two-vehicle crashes, 2001-2005 (Source: AVV).*

Table 2 shows that the inequality factor of collisions between two of the unprotected road user group (pedestrians, cyclists, and (light-)moped riders) is far below 10. That also applies to collisions with motorcycles. As soon as one of the parties is a car, van or lorry the inequality factor increases to hundreds.
With regard to the motorcyclists themselves, you can see that they really do have difficulties with vans and lorries as collision opponent; that also applies to drivers of vans and cars in collision with lorries. However, the inequality factors are less dramatically high than those of the real vulnerable road users when hit by these vehicles. The relatively low factor of cyclists against lorries (126) seems to be an exception to this rule.

The inequality factor as such differentiates well between the real vulnerable road users (pedestrians and light two-wheelers) and the rest. The fact that even car and van occupants come off worst in collisions with heavier vehicles is of course also the result of inequality (mass difference), but not of vulnerability. Motorcyclists are in-between: they are both vulnerable by lack of a shell as well as dangerous because of their relatively large mass and fast speed.
Single vehicle and obstacle collisions have been omitted from the above overview because, by definition, they would have had an infinite factor. But what is still true is that these crashes can have severe consequences for vulnerable road users and that measures are needed to also avoid this type of collision.

Casualty rate
A third measurement unit is what is usually presented as the *casualty rate* (in this case it is the ratio of the number of casualties per kilometre travelled). Although we would prefer separate units for *crash rate* (irrespective of the seriousness) and *injury rate* (given a crash) the *casualty rate* is a good combination of both.
Casualty rate by age has high rates for various sorts of young road users (Wegman & Aarts, 2006) and for the elderly (Davidse, 2000). What is striking in the first case is the high rate for the young as pedestrians, cyclists, (light-)moped riders and motorists as a result of a low task capability; in the case of the elderly it is mainly a matter of increasing injury sensitivity combined with a decreasing task capability. As already stated, in spite of their high casualty rate young novice motorists are not regarded as vulnerable road users.

With the three measurements severity index, the inequality factor and casualty rate, the various aspects of the vulnerability problem of road users has become reasonably clear: the inequality factor expresses well the large difference between protected and unprotected modes of transport; the casualty rate expresses well the task (in)capability of the young and the elderly which, when combined with the injury resistance of the elderly, shows very clearly the severity index.

Which measures are possible?
There is no place for large mass and/or speed differences in a sustainably safe traffic system because these emphasize the vulnerability differences between the various types of road user. The idea is that at crashes the driving speed should be so limited that what remains is a safe speed (*homogeneity principle)*. Complete separation of unequal road user types is of course the best solution. If this is not possible, the crashes should end up in such a way that pedestrians and cyclists cannot be severely injured (*forgivingness principle)*. This solution requires both facilities for motorized vehicle (see below) as well as speed reduction of these vehicles.

What is a safe speed?
International research has shown that at a driving speed of about 30 km/hour, the low probability of pedestrians being killed in a collision with a car starts to increase rapidly (*Figure 1*). Cyclists also benefit from such a speed reduction.

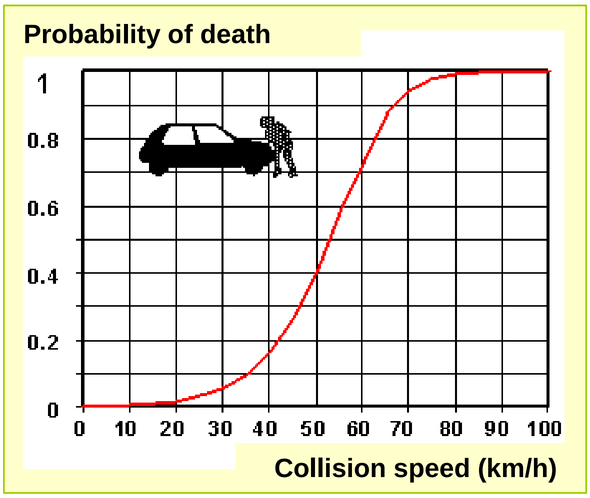

Figure 1. The relation between the probability of death and collision speed in pedestrian-car front contacts (after Ashton & Mackay, 1979).

That is why the road authority uses 30 km/hour zones or intersections at locations with mixed traffic. With regard to facilities for motor vehicles, lorries (that are relatively often involved in crashes that have serious consequences for vulnerable road users) should be equipped with side-underrun-protection, and good side and rear view to as much as possible limit the blind area when turning right. The rules for this are now being improved. The idea at the moment is a collision friendly front for cars that are by far the commonest collision partner of pedestrians and cyclists. The EU guideline for this came into being in 2005 but has, for the time being, a relatively modest set of requirements and is only applicable to new cars.

For problem definitions and measures that are more specific to vulnerable road user groups (i.e. pedestrians, cyclists, and (light-)moped riders) as well as the extra vulnerable age groups (i.e. children and the elderly) please consult the existing SWOV Fact sheets: *Young novice drivers* (SWOV, 2006b), *Young moped riders* (SWOV, 2006c), *Road safety of children in the Netherlands* (*SWOV, 2004)*, *The elderly in traffic* (SWOV, 2005b), *The elderly and infrastructure* (SWOV, 2005a), *Crossing facilities for cyclists and pedestrians* (*SWOV,* 2005c), *Pedestrians* (SWOV, 2006d) en *Cyclists* (SWOV, 2006a) and *Advancing Sustainable Safety* (Wegman & Aarts, 2006).

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