SWOV Fact sheet

Background of the five Sustainable Safety principles

Summary
The Sustainable Safety vision of road safety is based on five principles. These five principles refer to the functionality of roads, the homogeneity of mass and/or speed and direction, physical and social forgivingness, recognition and predictability of roads and behaviour, and state awareness. This fact sheet describes the theories and scientific background on which these principles are founded.

Background
The five principles of Sustainable Safety are the essence of a sustainably safe traffic (Wegman & Aarts, 2006; see *Table 1*). In this fact sheet we will discuss the background and scientific foundation of the principles. The following points are the essence of the Sustainable Safety vision:
– the prevention of (serious) crashes, and where this is not possible, the almost total elimination of the risk of severe injury;
– the premise that man is the measure of all things due to his physical vulnerability and cognitive capabilities and limitations (such as fallibility and offence behaviour);
– an integrated approach to the elements human-vehicle-road which is tuned to the human measure;
– a proactive approach to bridging gaps in the traffic system.

Sustainable Safety Principle	Description
Functionality of roads	Monofunctionality of roads as either through roads, distributor roads, or access roads in a hierarchically structured road network
Homogeneity of mass and/or speed and direction	Equality of speed, direction, and mass at moderate and high speeds
Forgivingness of the environment and of road users	Injury limitation through a forgiving road environment and anticipation of road user behaviour
Predictability of road course and road user behaviour by a recognizable road design	Road environment and road user behaviour that support road user expectations through consistency and continuity of road design
State awareness by the road user	Ability to assess one's capacity to handle the driving task

Table 1. *Description of the five Sustainable Safety principles*

What do we mean by a functional division of roads?

Functionality
Traffic has two functions: to flow and to exchange. These are very different functions, and they each require a specific infrastructure and specific use requirements to make safe traffic distribution possible. Based on this traffic engineering distinction and inspired by the functional categorization of roads (Buchanan, 1963), the Sustainable Safety principle of *functionality* emerged (Janssen, 1974). According to this principle, roads ideally fulfil just one single function (monofunctionality)
Three types of road are distinguished. *Through roads* are meant to enable traffic to flow as much as possible and are designed in such a way that traffic can move safely from A to B at high speed. This road type is specifically suited for through traffic. It would be preferable if traffic could drive the largest part of a journey along through roads. *Access roads* are meant to provide access to destinations. On these roads, fast traffic mixes with vulnerable road users such as pedestrians and cyclists. Residence is the main function here and motorized vehicles are guests. This traffic function also requires its own infrastructure. Finally, connecting roads have been defined and are called *distributor roads*. This road type has a flow function on road segments and an exchange function at intersections, and connects through roads with access roads, as well as through roads and access roads among each other.

Figure 1 shows how the different road types make up a road network.

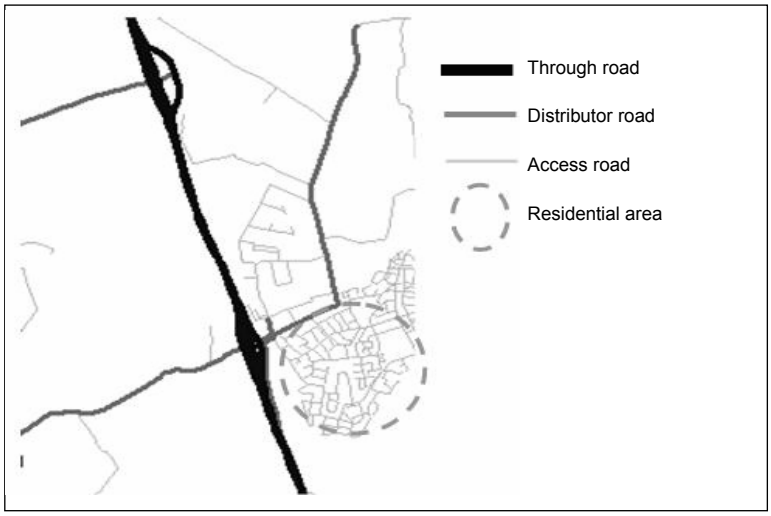

Figure 1. *Three functional road types as the basis of a sustainably safe road traffic*

How does Sustainable Safety deal with the physical vulnerability of the human being?

Homogeneity
In a crash, the human being's vulnerability comes into play. Injury is the result of a combination of released kinetic energy (mass x speed), biomechanical properties of the human body, and the physical protection that the vehicle offers its occupants. The *homogeneity principle* states that, where road users/vehicles with large mass differences use the same traffic space, the speeds should be so low that the most vulnerable road users and transport modes come out of a crash without any severe injuries. There where the traffic uses high speeds, road users should be physically separated from each other as much as possible and be protected by their vehicle. Based on studies of collisions between pedestrians and cars (Ashton & Mackay, 1979; www.euroncap.com) and the Swedish road safety vision called Vision Zero (Tingvall & Haworth, 1999), SWOV has updated its Sustainable Safety vision and proposes safe speeds for each road type (*Table 2*).

Road types in combination with permitted road users	Safe speed (km/h)
Roads with possible conflicts between cars and unprotected road users	30
Intersections with possible transverse conflicts between cars	50
Roads with possible frontal conflicts between cars	70
Roads with no possbile frontal or transverse conflicts between road users	≥100

Table 2. *Proposal for safe speeds, given the possible conflicts between different road users.*

Physical forgivingness
Next to functionality and homogeneity, *forgivingness* is also an important factor in preventing injury. Forgiving surroundings ensure that the consequences of errors remain limited. This is particularly important in traffic situations where people drive fast. In the elaboration of this principle, one could, for example, think of safe (i.e. matted) shoulders, obstacle-free zones, or collision-friendly obstacle protection. The principle of forgivingness also has a social meaning which will be discussed in the following paragraph.

How does Sustainable Safety prevent unsafe actions?
Road users will always continue to make errors, however well -trained or motivated they are. People also, deliberately or unintentionally, commit offences. These are two major causes of crashes. In order to achieve a traffic condition which is as safe as possible, it is important to continue to train and inform road users, and to continue to control their behaviour. The layout of the traffic environment and the behaviour of other road users also affect the extent to which people safely carry out their traffic task

and are inclined to ignore traffic rules. The elaboration of the Sustainable Safety principles below is based on this knowledge.

Predictability
A *predictable layout* of a road prevents unsafe actions in traffic as much as possible because road users then know what to expect. Expectations refer to both the behaviour of other road users as well as one's own (safe) behaviour. Studies have shown that people make fewer mistakes if they have to react to (traffic) situations that they expect than to unexpected situations (for example, see Theeuwes & Hagenzieker, 1993). Their actions are then routine, and this results in fewer (dangerous) errors (Rasmussen, 1983; Reason, 1991). A predictable layout of roads helps to predict the traffic situation; this is of vital importance when high speeds are involved.
A predictable road layout can be achieved by *consistency* in road design and *continuity* in road course. Ideally, the road layout supports the road user expectations along the whole length and the road design elements correspond to these expectations. The principle of predictability is also related to the *credibility* of the (behavioural) rules in force on a road.

State awareness
Road users differ from each other and from one moment to another; and this is also a source of unsafe behaviour. People's 'normal' competence can be temporarily influenced by factors such as alcohol, stress, or fatigue (for example see Fuller, 2005). The combination of competence and the actual situation determines how capable a road user is to cope with the task requirements (see *Figure 2*). The principle of *state awareness* involves a road user being capable of assessing his/her own task capability well and adjusting it to his/her competence and the task requirements. For safe traffic participation, the task capability must be sufficiently large to cope with the task requirements. The task requirements are determined by environmental factors, but the road user can self adapt them by, for example, driving faster or slower.

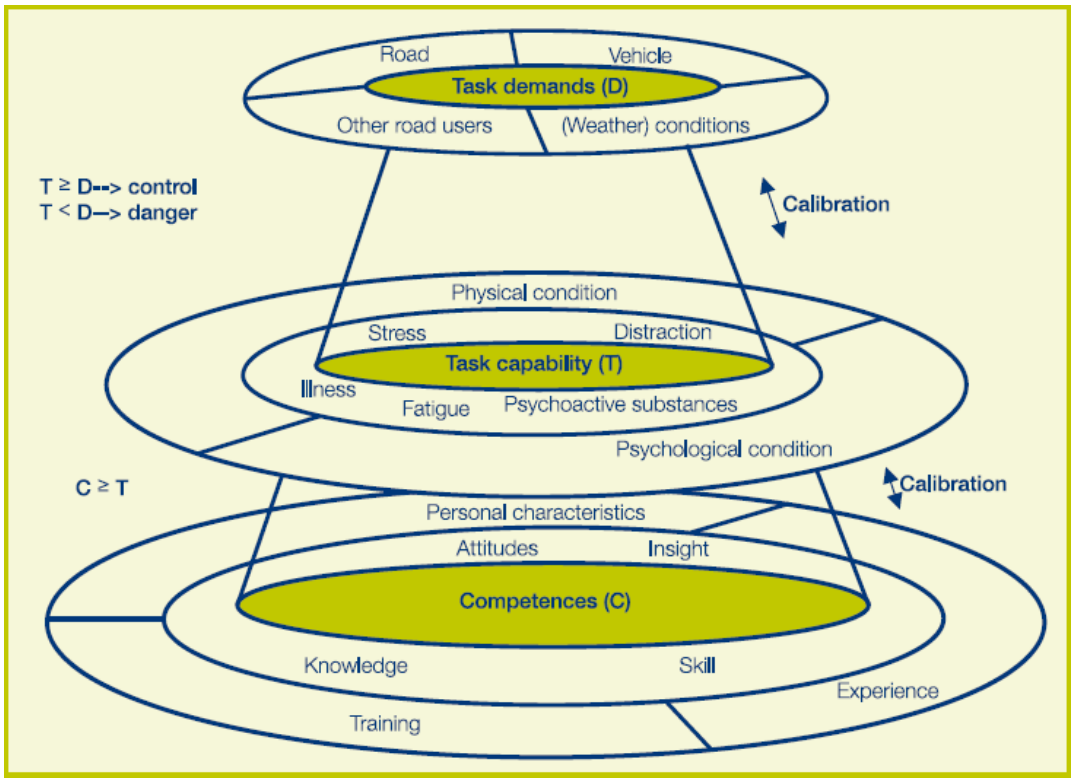

Figure 2. *Schematic representation of the relation between competence, task capability, and task demands (Fuller, 2005).*

Social forgivingness
Traffic is a social system in which crash causes can partially be traced to the interaction between road users. Therefore it is important that road users allow for each other's shortcomings. This is the social

elaboration of the principle of *forgivingness*. Forgiving road behaviour, particularly of the more competent road users, could increase the possibility for the less competent road users to commit errors without any serious consequences. However, errors must still be recognized as 'wrong' so as not to lose the corrective working. Social forgivingness can contribute to errors less often having serious consequences in terms of deaths and hospital admissions.

Will follow-up studies be carried out?
The infrastructural principles of functionality, homogeneity, and physical forgivingness have already been elaborated in practice during the implementation of the *Sustainable Safety Start-up Programme*. Practically the entire road network has now been categorized, although there is the problem of what are known as 'grey roads': these are roads where a monofunctional layout is not yet possible. The principle of homogeneity has been used in the construction of 30 km/hour and 60 km/hour zones, roundabouts, and in the construction of parallel facilities, cycle paths and footpaths. The predictability of certain road types, such as motorways, is already good; for other road types attempts have been made to improve the predictability by introducing what are known as 'essential predictability characteristics'. The physical forgivingness is mainly being carried out by constructing safe road shoulders.
For these infrastructural principles follow-up studies are being carried out of, for instance, the effects of practical application of the principles, of the definition of minimum safety requirements as part of quality assurance, and of using other than the usual traffic engineering applications within the Sustainable Safety starting points.
Furthermore, the two new principles of state awareness and (social) forgivingness need to be elaborated with respect to content. This requires further research in which we will link to existing initiatives which may contribute to the realization of the two principles as much as possible.

Conclusion
The Sustainably Safe vision is based on five principles that each in its own way contributes to achieving a sustainably safe road traffic. Its purpose is to prevent (serious) crashes and, when this is not possible, to reduce the risk of severe injury. The five principles are based on theories from traffic engineering, biomechanics and psychology; they take the human being as the physical and psychological starting point, and relate to the functioning of traffic in general. In *Advancing Sustainable Safety* (Wegman & Aarts, 2006), SWOV has come to the conclusion that the original three principles of functionality, homogeneity, and predictability are still of undiminished importance; and has now added another two principles: forgivingness and state awareness. The five principles provide a robust foundation to continue working towards safer traffic in the Netherlands. What is more, they can be a source of inspiration for other countries.

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

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