SWOV Fact sheet

Background of the five Sustainable Safety principles

Summary
The Sustainable Safety vision of road safety is based on five principles. These principles are 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 and content
Five principles of Sustainable Safety are leading for sustainably safe traffic (Wegman & Aarts, 2006; see *Table 1*). In this fact sheet we will discuss the background and scientific foundation of these principles. The fact sheet discusses, in this order, the functional categorization of roads (functionality), physical vulnerability of people (predictability and physical forgivingness), and the prevention of unsafe actions (recognition, state awareness and social forgivingness).

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
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
Forgivingness of the environment and of road users	Injury limitation through a forgiving road environment and anticipation of road user behaviour
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*

These five principles should lead to a sustainably safe traffic system in which:
- (serious) crashes are prevented, and, where this is not possible, severe injury is almost totally prevented;
- the premise is that man is the measure of all things: his physical vulnerability and cognitive capabilities and limitations (such as fallibility and the desire to explore boundaries);
- the elements man, vehicle, and road are not only tuned to the human measure but are approached and dealt with in an integrated manner;
- safety gaps in the traffic system are bridged through a proactive approach.

For more information, see SWOV fact sheet *Sustainable Safety: principles, misconceptions, and relations with other visions*.

What do we mean by a functional categorization 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; see also SWOV fact sheet *Functionality and homogeneity*).

Three types of road are distinguished.

1. *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. Preferably, traffic would drive the largest part of a journey along through roads.
2. *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.
3. 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, human's physical 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* entails the following (see also SWOV fact sheet *Functionality and homogeneity*):

- There 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. In an ideal situation this is achieved by evoking low speeds through the road infrastructure, not by appealing to the road users' individual choices.
- At locations where traffic uses *high speeds*, different types of road user and road users driving in different directions should be *physically separated* from each other as much as possible and road users should be *protected* by their vehicle. That way, conflicts leading to severe injury are prevented.

Based on studies of collisions between pedestrians and cars (see for example www.euroncap.com or more recent evidence such as that of Rosèn et al., 2011) and the Swedish road safety vision called Vision Zero (Tingvall & Haworth, 1999), SWOV has proposed safe speeds for each road type (*Table 2*). These are specified in Aarts & Van Nes (2007) and Aarts et al. (2012).

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 possible frontal or transverse conflicts between road users	≥100

Table 2. *Proposal for safe speeds, given the possible conflicts between different road users (based on Tingvall& Haworth, 1999).*

Physical forgivingness
In addition to functionality and homogeneity, *physical forgivingness* is also an important factor in preventing injury, even if the infrastructure did not give rise to the crash. Forgiving surroundings ensure that the physical 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 (see also SWOV fact sheet *Safe road shoulders*). 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 make errors, however well-trained or motivated they are. Also, people commit offences, either deliberately or unintentionally. 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. Yet, the layout of the traffic environment and the behaviour of other road users also substantially affect the extent to which people safely carry out their traffic task and are inclined to ignore traffic rules. The available knowledge on this provides the basis for the elaboration of the three Sustainable Safety principles below.

Predictability
A *predictable layout* of a road prevents unsafe actions in traffic as much as possible because it allows road users to better know what to expect (types of road users, manoeuvres, road course) and what will be expected of them (speed, manoeuvres). Studies have shown that people make fewer mistakes when they have to react to (traffic) situations they expect than when they react to unexpected situations (for example, see Theeuwes & Hagenzieker, 1993). Their actions are then routine, which 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, especially 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 entire road and the road design elements correspond to these expectations. For more information on the principle of predictability see SWOV fact sheet *Recognizable road design*
The principle of predictability is also related to the *credibility* of the road layout, with regard to the rules as well as the road use. A credible speed limit is attuned to the road design in such a way that it elicits the desired speed more or less automatically. This way, a credible speed limit provides a predictable road environment. . For more information on the credibility of speed limits, see SWOV fact sheet *Towards credible speed limits*. .

State awareness
The principle of *state awareness* involves a road user being capable of assessing his own task capability well. In other words, the assessment of task capability has to correspond to the actual task capability of a person (see Davidse et al., 2010; *SWOV fact sheet State awareness, risk awareness and calibration*). This principle therefore also involves a person's insight into how capable he is to perform the traffic task well. The task requirements (road condition, weather condition, vehicle condition and the condition of other road users) determine what is needed to perform the traffic task well. The task competence of the traffic participant is determined by his competences (more or less

static skills), and physical and psychological situations (stress, fatigue, alcohol and such; see *Figure 2*).

While traffic rules indicate the formal boundary between 'acceptable' and 'unacceptable' behaviour, the principle of state awareness is concerned with individual assessment of one's own limitations – within these formal boundaries – and with adequate adjustment of one's own behaviour based on it.

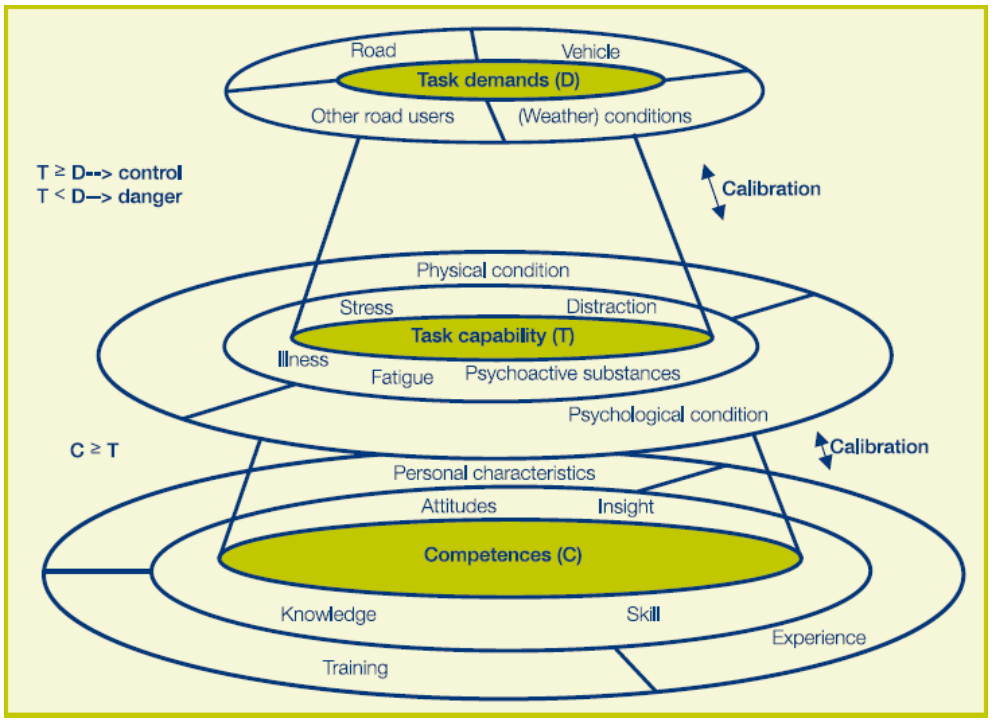

Figure 2. *Schematic representation of the relation between competence, task capability, and task requirements or demands (Fuller, 2005; Vlakveld, 2002).*

Social forgivingness

Social forgivingness refers to the role of traffic participants in preventing crashes. The principle is defined as follows: "The willingness to anticipate a potentially unsafe action of another road user, and to act in such a manner that negative consequences of this potentially unsafe action are prevented or in any case limited" (Houtenbos, 2009). After all, even in a well-developed traffic system road users make errors and perform unsafe acts. Other road users can neutralize these unsafe acts by responding in a *socially forgiving* manner: by anticipating on behaviour of the other person, leaving each other space and holding reckoning with each other, so that unsafe situations are prevented, or so that the consequences are in any case limited. See also SWOV fact sheet *Social forgivingness*.

How are the five principles put into practice?

Especially the infrastructural principles of functionality and homogeneity have been put into practice on a large scale for the first time during the implementation of the *Sustainable Safety Start-up Programme* as from 1997. Later, the principle of predictability has also been elaborated in practice. Physical forgivingness is also being worked out, mainly by constructing safe road shoulders. SWOV has recently carried out a large-scale national evaluation study of the implementation of the Sustainable Safety principles (Weijermars & Van Schagen, 2009): see also SWOV fact sheet *Sustainable Safety: principles, misconceptions, and relations with other visions*. Into the elaborations of every Sustainable Safety principle, further research is being carried out.

Conclusion

The Sustainably Safe vision is based on five principles which each in their own way contribute to achieving sustainably safe road traffic. The five principles are based on scientific 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. Especially the original

three principles of functionality, homogeneity, and predictability have been worked out and put into practice for the first time in the Netherlands. Together with the two newer principles, forgivingness and state awareness, they are still being elaborated further.

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(SWOV reports in Dutch have an English summary)

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