SUSTAINABLE
SAFETY
3RD EDITION

Sustainable Safety 3rd edition – The advanced vision for 2018-2030

Principles for design and organization of a casualty-free road traffic system

In a sustainably safe road traffic system ...

... the road and the vehicle protect you and those around you against major traffic hazards ... traffic professionals work together and check one another to achieve a maximally safe result ... the road is intended to facilitate traffic flow or exchange across traffic, but not both ... every child can safely walk or cycle to school, thanks to proper neighbourhood planning, a safe road lay-out, safe speeds, and being sufficiently physically protected ... the older road user understands how the traffic system is intended to work and can thus safely operate in traffic situations ... the government accepts ultimate responsibility for a casualty-free traffic system ... unsafety and each party's responsibility in connection with it are acknowledged and acted on using a risk-based approach ... all fatal crashes are investigated to establish why things still go wrong.

Contents

Summary

The vision of Sustainable Safety is an optimal approach to improve road safety, originating from the Netherlands. It is a vision that is shared by many road safety professionals. A sustainably safe road traffic system prevents road deaths, serious road injuries and permanent injury by systematically reducing the underlying risks of the entire traffic system. Human factors are the primary focus: by starting from the demands, competencies, limitations and vulnerabilities of people, the traffic system can be realistically adapted to achieve maximum safety.

This report briefly describes the recalibration of the vision that was first developed in the 1990s, subsequently implemented in the Netherlands on a large scale in 1998-2002, and updated a first time in 2005/2006. This third edition of the Sustainable Safety vision, is characterized by the following new aspects:

- The five **road safety principles** are adapted from the previous principles and strengthened with new insights, thereby providing a basis for specialized solutions.
- Three of the five principles are **design principles**:
  - (1) FUNCTIONALITY of roads
  - (2) (BIO)MECHANICS: limiting differences in speed, direction, mass and size, and giving road users appropriate protection
  - (3) PSYCHOLOGICS: aligning the design of the road traffic environment with road user competencies
- The other two principles are **organization principles** now:
  - (4) Effectively allocating RESPONSIBILITY
  - (5) LEARNING and INNOVATING in the traffic system
- Concerning the design principles, **vulnerable** modes of transport (pedestrians and cyclists in particular) and the competence of **older** road users are the more explicit standard now.
- The third edition of the Sustainable Safety vision pays greater attention to **cyclist crashes** not involving motorized vehicles.
- **Responsibility** is emphasized with respect to the role and potential actions of stakeholders in realizing an inherently safe road traffic system.
- Sustainable Safety's third edition advocates **in-depth analysis** of all fatal road crashes to learn from the things that still go wrong.
- Furthermore, this third edition of the vision calls for a **pro-active and risk-based** approach, using both crash statistics and road safety performance indicators (or surrogate safety measures) as safety indicators and as a basis for action.

The aim is to work systematically towards maximum road safety for everybody by means of this third edition of Sustainable Safety, the ultimate ambition being a casualty-free traffic system. In other words, in the end, every road user – be it schoolchild, commuter, commercial driver or active senior – will come home safely!

Introduction

Mobility is an important human need. Through participation in traffic we are able to get to work, go shopping or go to see our friends and family. We can choose to drive, take public transport or to cycle or go for a walk to keep healthy. In order to meet these mobility needs, both now and in the future, road traffic ought to be safe and also remain safe.

For a number of years, road safety in the Netherlands has been in decline: whilst road deaths are no longer decreasing, serious road injuries continue to increase (*Figure 1*). The safety of cyclists is a specific problem, not only in terms of road deaths, but also in terms of serious road injuries. These developments demand a renewed focus on road safety.

Society is also changing (see also *Table 1*). The traffic system and other factors are no longer similar to those of a decade ago, and will keep changing in the coming decades. For example, we have witnessed changes in the traffic composition, in the demographics of road users (especially ageing), urbanization and technological developments (increasing automation of traffic tasks, etc.). Moreover, the political-societal context is moving further towards decentralization, there is greater emphasis on integral solutions and extra focus on shared responsibilities. In short, the time is ripe for a new impetus to the strategic approach towards road safety, particularly from a societal perspective.

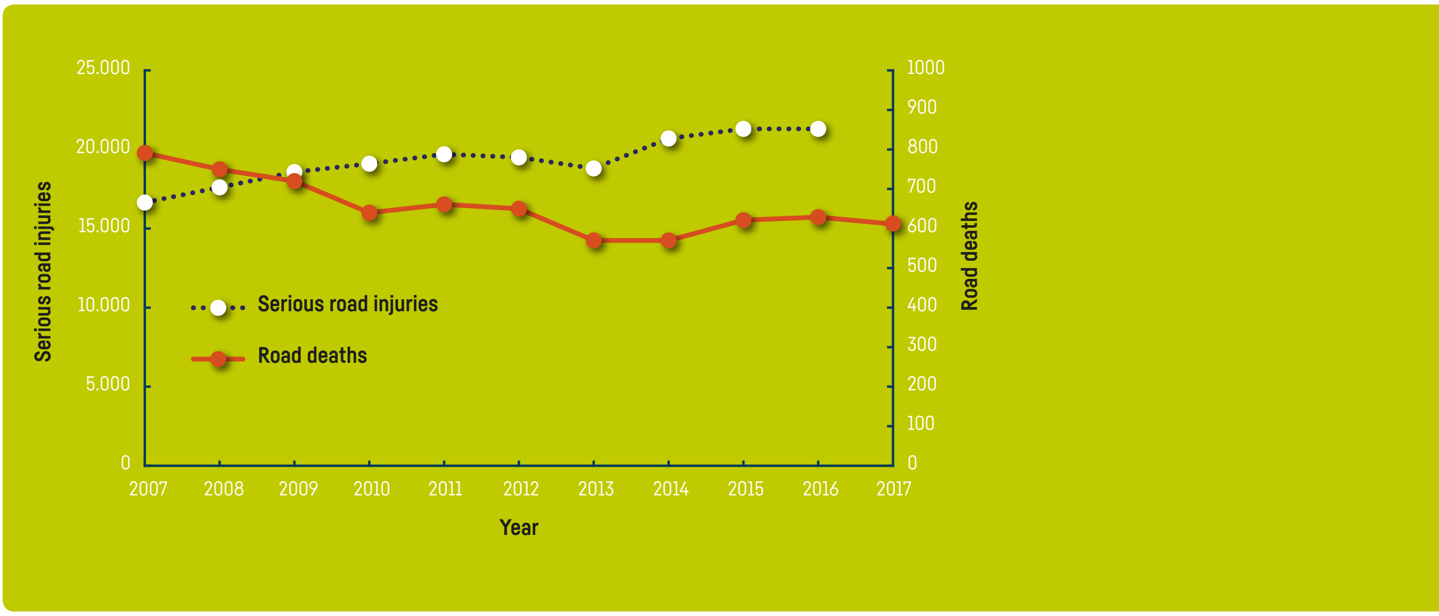


Figure 1 Historical trend of the number of road deaths (right axis) and estimated number of serious road injuries (left axis).

Table 1 A number of societal developments to be expected, and possible effects on road safety.

Area	Development expected until 2030	Possible effect on road safety
Population	• General population increase • More single people • More seniors, especially 75+ • Possibly more immigrants	• A larger population and more single people result in increased mobility. • The increasing number of seniors will result in a greater risk of casualty and injury. • More immigrants with less experience of the local traffic system may initially constitute a higher risk.
Urbanization	• More people in/around cities, fewer in rural areas • Inner cities for recreation (social, economic and cultural meeting-place) • Outer cities for work, bulk-shopping and transport of goods	• Greater mobility in large cities; fewer cars in inner cities, but more pedestrians and two-wheeled vehicles; this latter mode of transport comes with a higher injury risk. • Due to larger distances to amenities in rural areas, there is relatively less mobility of two-wheeled vehicles (with a high risk) and more car traffic (with a lower risk).
Technology	• Smarter cities, smarter traffic system, smarter roads, smarter vehicles • More use of technology during traffic participation • More teleworking • More online shopping	• In theory, smarter traffic leads to more safety, but the effect is still unclear in practice. During the transition phase, the (fallible) road user will still play a role. • Technology in cars (mobile office) and on bicycles also results in distraction from the traffic task. • Mobility is differently distributed across time due to teleworking. Online shopping hardly has an effect on the mobility of individuals, but increases mobility by delivery vans, also in residential areas.

The third edition of Sustainable Safety sets out a path for realizing a maximally safe traffic system in the future. This will also contribute to the reduction of congestion on the road network. This third edition of the vision builds upon the earlier Sustainable Safety philosophy,[1,2] but aligns itself to the developments presented in *Table 1*. Sustainable Safety's third edition makes use of new opportunities and recommends completion of several effective, yet unfinished measures (see box ↓). This has the ultimate aim of reversing the negative trend in the casualty rate to such an extent that we may move towards a casualty-free traffic system.

Research results

Various effective measures underway that have not yet been completed

A few examples:

- In the past, minimum design standards were applied in many of the 30 km/h areas, which turned out to be not physically self-enforcing. As a result, systematic speeding is possible and is a reality in many of these areas. Annually, between 25 and 45 road deaths occur in the 30 km/h areas. Designs that physically enforce a safer 30 km/h speed design help prevent at least some of these crashes.[3,4]
- On 50 km/h roads, motorized traffic and cyclists should be physically separated because of the large differences in speed. However, only about 60% of the 50 km/h roads in the Netherlands actually have a separate cycle track.[5]
- The situation on 80 km/h roads could also be improved, for instance by increasing the obstacle-free zone or providing crash barriers, and by providing directional dividers and reducing the number of access points.[6,7]

The third edition of Sustainable Safety ties in with various national and international developments, such as the appeal of the Organisation for Economic Cooperation and Development (OECD) to arrive at a systematic approach to road safety[8,9] (see box →). This edition of Sustainable Safety aims at providing a substantiated framework for further development of the national road safety policy of the Netherlands that will be laid down in the new *Strategic Road Safety Plan* in 2018.

1 Koornstra, M.J., et al. (1992). Naar een duurzaam veilig wegverkeer: Nationale Verkeersveiligheidsverkenning voor de jaren 1990/2010. SWOV, Leidschendam, The Netherlands (Towards a sustainably safe road traffic: National road safety outlook for 1990/2010; in Dutch only).
2 Wegman, F. & Aarts, L. (red.) (2006). Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020. SWOV, Leidschendam, The Netherlands.
3 SWOV (2018). 30 km/h zones. SWOV Fact sheet, May 2018. SWOV, The Hague, The Netherlands.
4 Schagen, I. van, et al. (2016). Monitoring speed before and during a speed publicity campaign. In: Accident Analysis & Prevention, vol. 97, p. 326-334.
5 Weijermars, W. & Wegman, F. (2011). Ten years of Sustainable Safety in the Netherlands. An assessment. In: Transportation Research Record, vol. 2213, p. 1-8.
6 Hout, R. van den (2013). Road safety provincial roads. ANWB study. ANWB, The Hague, The Netherlands.
7 Schermers, G. & Petegem, J. H. van (2015). Safety considerations for cross-sectional design of 80km/h rural roads in the Netherlands. In: Proceedings of the 5th International Symposium on Highway Geometric Design, 22-24 June 2015, Vancouver, Canada.
8 ITF/OECD (2008). Towards zero; ambitious road safety targets and the Safe System Approach. International Transport Forum/OECD Publishing, Paris.
9 ITF/OECD (2016). Zero road deaths and serious injuries; Leading a paradigm shift to a safe system. International Transport Forum/OECD Publishing, Paris.

Sustainably safe road traffic: a systematic approach of road safety

Research results

Worldwide, Sustainable Safety is one of the best-known exponents of a systematic approach to road safety, today more commonly known as a 'safe system approach'. This encompasses the system in its entirety. Until the 1960s, the lack of road safety was mainly accepted as 'bad luck' and the result of errors made by individual road users (the 'accident prone'). Later it was realized that not only people, but also the road or the vehicle can cause crashes; first mainly as separate factors (mono-causality), later as inter-related factors (multi-causality). Since the 1990s, road safety has been approached more systematically, with the organization and the system increasingly being considered together as the cause of human failures and as a point of engagement for prevention. This development is in line with the safety philosophy in the aviation and petro-chemical sectors. In the third edition of Sustainable Safety this is presented by studying how responsibilities can be assigned most effectively and efficiently.

Short history of the vision

The Netherlands, along with Sweden, was one of the first countries that implemented a safe system approach in practice. In 1992 the vision on a sustainably safe road traffic was conceptualized, in 1995 a small number of demonstration projects were launched and in 1997 this culminated in the adoption of the *Start-up Programme Sustainable Safety*. The *Start-up Programme* was a milestone involving the adoption of a formal covenant, signed by all the public road authorities. Even before the formal adoption of the Sustainable Safety vision, and parallel to the *Start-up Programme* covenant, measures had been taken in the spirit of this vision, including: building motorways with full median separation, providing footpaths for pedestrians and separate bicycle tracks for cyclists, and large-scale construction of roundabouts and home zones.[10,11] The *Start-up Programme* not only created a financial incentive for the further roll-out of Sustainable Safety measures, it also facilitated a coordinated approach to redress the growing road safety problems. Since implementation, these measures have proved to be extremely cost-effective and reduced the number of road deaths (see box ↓).[12] This systematic approach set an international example[13,14] and made the Netherlands a top-ranking player in the field of road safety.

Results of the Start-up Programme Sustainable Safety

Research results

The Start-up Programme Sustainable Safety included 24 agreements between the central government, regional and local public authorities. This resulted in the adoption of uniform guidelines, large-scale implementation of infrastructure measures such as 30 and 60 km/h areas (resp. urban and rural access roads), stricter enforcement and the setting up of permanent road user education. These measures resulted in a reduction of between 1600-1700 road deaths in the period 1998-2007 and yielded a benefit-cost ratio of 4 to 1.[12]

In 2005, the first revision of the Sustainable Safety approach was presented with *Advancing Sustainable Safety*. This generated renewed interest in the philosophy, partially attributable to two new principles: forgivingness and state awareness. Road authorities and policymakers continued with the implementation of measures in accordance with the outlines of the *Start-up Programme*. However, a lack of coordination and resources prevented the programme from being completed, and due to various barriers[15] (see box →) we have seen in recent years that, unfortunately, the number of road deaths has held constant and the number of serious road injuries has been increasing.

10 Schagen, I.N.L.G. van & Aarts, L.T. (2018). DV3 – Huidige situatie, maatschappelijke trends en wensbeelden. R-2018-6A. SWOV, Den Haag, The Netherlands [Sustainable Safety 3rd edition background report I – Current situation, societal trends and ideals; In Dutch, with a summary in English].
11 Aarts, L.T. & Dijkstra, A. (2018). DV3 – Achtergronden en uitwerking van de verkeersveiligheidsvisie. R-2018-6B. SWOV, Den Haag, The Netherlands [Sustainable Safety 3rd edition background report II – Backgrounds and elaboration of the updated road safety vision; In Dutch, with a summary in English].
12 Weijermars, W. & Wegman, F. (2011). Ten years of Sustainable Safety in the Netherlands. An assessment. In: Transportation Research Record, vol. 2213, p. 1-8.
13 ITF/OECD (2008). Towards zero; ambitious road safety targets and the Safe System Approach. International Transport Forum/OECD Publishing, Paris.
14 ITF/OECD (2016). Zero road deaths and serious injuries; Leading a paradigm shift to a safe system. International Transport Forum/OECD Publishing, Paris.
15 Weijermars, W.A.M. & Aarts, L.T. (2010). Duurzaam Veilig van theorie naar praktijk. R-2010-23. SWOV, Leidschendam, The Netherlands [Sustainable Safety from theory into practice; In Dutch, with a summary in English].

Research results

Important barriers for sustainably safe road traffic

The most important barriers for the complete implementation of Sustainable Safety[16] appeared to be:

- Lack of stakeholder knowledge about the effectiveness of various measures
- Lack of turning vision into practice
- Decentralization of policy
- Opportunities to choose sub-optimal solutions
- Pressure of other interests
- Lack of physical space
- Lack of financial resources

Prerequisites and approach

With a sustainably safe road traffic system we aim at a maximally safe traffic system, that is: as safe a system as possible. This third edition of the vision is tuned to the developments in the traffic system that are expected to come by 2030.

The vision acknowledges the mobility demands of various groups in our society, the importance of proper accessibility by road and the need for a personal freedom of choice. It is a fact that certain modes of transport are inherently less safe (i.e. two-wheeled vehicles) and certain road users are more vulnerable to traffic injury than others (e.g. children, teenagers, seniors). With these facts as a starting point, Sustainable Safety's third edition aims at maximum safety for all.

In a sustainably safe road traffic system, everything possible is done to realize maximally safe road traffic, keeping in mind the above-mentioned prerequisites. The approach is implemented in stages, in line with the societal context:

- **Eliminating:** ideally, dangerous situations are made physically impossible so that people do not find themselves in such situations.
- **Minimizing:** the number of dangerous situations are limited and certain modes of road transport are made unattractive to limit people's exposure to risks.
- **Mitigating:** where people are exposed to risks, their consequences should as far as possible be mitigated by taking appropriate mitigating measures.

Commentary

Why (still) call the vision 'Sustainable Safety'?

When the vision originated, the name 'Sustainably Safe Road Traffic' was derived from the Brundtland report of the United Nations (1987) on sustainable development, which was extremely relevant at the time. It was defined as 'a development that meets the current demands without impeding the possibilities of future generations to fulfil their needs'. Sustainable Safety builds on this definition, towards a land use development and traffic system design that promotes a level of safety that can be sustained, using what is also referred to as 'inherently safe' design in areas other than road traffic. In the past, 'inherently safe' was not included in the name of the vision, even though it actually better expresses a system approach.

Since that time, Sustainable Safety has become a familiar 'brand' for traffic professionals in the Netherlands and the safe system approach abroad. A brand that, similar to the Swedish Vision Zero, is taken as an effective and professional way of improving road safety systematically. Thus, the essence of the vision has not changed but the vision has been expanded and adjusted in a number of ways to be better aligned with the remaining problems and future possibilities.

16 Weijermars, W.A.M. & Aarts, L.T. (2010). Duurzaam Veilig van theorie naar praktijk. R-2010-23. SWOV, Leidschendam, The Netherlands (Sustainable Safety from theory into practice; In Dutch, with a summary in English).

Commentary

How did this third edition of Sustainable Safety originate?
This edition of the vision originated thanks to the assistances of many organizations. Through discussions, individual talks and written reactions with representatives from these organizations, current problems in the traffic system were validated, future developments defined, the ideal future traffic system was conceptualized and finally, the tools for further improvements by 2030 were determined. This was also based on incorporating the needs and possibilities of the most important mobility groups in the Netherlands.[17]

These stakeholders will also play an important part in the next stage, the further implementation of the vision in concrete, feasible measures.

What's new?

New highlights in this edition are:

- **Current road safety problems:** This third edition of Sustainable Safety focuses more directly on new and still frequently occurring serious crashes (in the Netherlands). For instance, more attention is paid to bicycle crashes with specific focus on those not involving motorized traffic.
- **Points of departure:** the vision is more explicit in what to accept in road traffic, what needs to be mitigated and what needs to be eliminated.
- **Types of solution:** in this edition of the vision, the road safety principles are more often linked to more than one type of measure. They provide the opportunity to achieve similar results through a combination of complementary measures. For instance, reducing the speed in residential areas can be realized through infrastructural measures, but the effect can be strengthened by technological solutions. The road safety principles are also expanded and divided into three design principles and two organization principles.
- **Organization:** this third edition more explicitly emphasizes the specific responsibilities of different road safety stakeholders in realizing a sustainably safe road traffic system. Traffic professionals (see box ↓) are crucial in this respect, even if the problem is the behaviour of road users. Responsibilities are made more explicit in one of the organization principles, 'effectively allocating responsibility'. In this respect, the vision agrees more clearly with the international vision of an inherently safe traffic approach.
- **Implementation tools:** in order to better assist traffic professionals in making the traffic system structurally safer, not only are data on common crash types and casualties used as the basis of policy, but this third edition also explicitly focusses on developing and using surrogate safety measures in traffic (risk factors or road safety performance indicators, SPIs in short). The most important risk factors can serve as significant intermediate goals and offer deeper understanding of the underlying problems. These risk factors are necessary for assigning roles and responsibilities to the various road safety stakeholders.

In the revised sustainably safe road traffic vision, the ideal for the future is to make road use as inherently safe as possible by taking into account the demands and possibilities of people now and in the future. We call this **maximum safety**.

Commentary

Who are 'traffic professionals'?
Traffic professionals have crucial responsibility in realizing and maintaining a sustainably safe road traffic system. They are the people who play a part in the design, implementation, control, execution and the enabling activities. Specifically, they are system designers, traffic managers, vehicle manufacturers, regulators, enforcers, technology innovators, communication specialists, trainers, educators and policymakers who directly contribute to safe movement of road traffic. The central government is ultimately responsible for the system.

In addition, other professionals and the social context of road users play a role, such as employers, hospitality industry, sport organizations, schools and educators.

17 Schagen, I.N.L.G. van & Aarts, L.T. (2018). DV3 – Huidige situatie, maatschappelijke trends en wensbeelden. R-2018-6A. SWOV, Den Haag, The Netherlands (Sustainable Safety 3rd edition background report I – Current situation, societal trends and ideals; In Dutch, with a summary in English).

Sustainable Safety 3rd edition: towards a sustainably safe road traffic system in 2030

In practice, traffic professionals use different definitions of Sustainable Safety. Some define it as the essence of the vision, others as the guidelines derived from the philosophy, whilst another group mainly focuses on the specific measures taken on the roads.

This third edition of the vision will be discussed on the basis of the various levels at which the vision can be perceived:

1. **Human factors** as the starting point
2. The **traffic system** that should take the human factors into account
3. **Road safety principles** that are essential to realize a sustainably safe traffic system
4. The **operationalization** of these safety principles into criteria
5. **Measures** that are supportive of a sustainably safe traffic system

This report mainly deals with the first three levels of the vision as a step forward to new and future implementation programmes based on elaboration of the last two levels.

The human dimension

The view that human factors are essential when it concerns road safety has been accepted for decades:[18] people are vulnerable and can be seriously or fatally injured in crashes in which the body is subjected to large acceleration or deceleration forces. For instance, twenty per cent of the serious road injuries in the Netherlands are permanent.[19]

People are not only physically vulnerable but also fallible: they make errors and are not always motivated to act safely or to leave other people room to get by safely. Human characteristics are therefore a very important factor in crash occurrence.[20] It was long thought that the solution could be found in addressing

18 Hagenzieker, M., et al. (2014). The history of road safety research: a quantitative approach. In: Transportation Research Part F, vol. 25, p. 150-162.
19 Weijermars, W., et al. (2016). Health burden of serious road injuries in the Netherlands. In: Traffic Injury Prevention, vol.17. nr. 8, p. 863-869.
20 Treat, J.R., et al. (1977). Tri-level study of the causes of traffic accidents: Final report. Institute for Research in Public Safety, Bloomington, Indiana, USA.

road user behaviour. It was hoped that road risks could be countered through education, training, setting rules and issuing fines for violations. However, the effects of such measures on safety have been limited. Gradually it was discovered that the design of the system was more important in permitting or preventing errors and hazardous behaviour – behaviour which is not always conscious. These insights have been an important basis for safety in industrial systems such as the process industry, aviation and railways: rather than adapting people to the system, the system should be adapted to people's abilities and desires ('safety by design').

In a sustainably safe road traffic system ...

... the road and the vehicle protect you and those around you against major traffic hazards

People use their own desires and 'personal wisdom' as an important basis for their choices prior to and during their participation in traffic. However, people do not always make these choices consciously; they often behave routinely so as to be efficient. A sustainably safe road traffic system therefore accounts as much as possible for people's mobility demands and their human characteristics so as to limit their freedom and 'personal wisdom' as little as possible, whilst at the same time providing the best possible protection against serious injuries. A sustainably safe road traffic system is organized in such a way that the human characteristics that undermine safety (see *Table 2*, left column) lead as little as possible to serious crashes and injuries. Where hazardous situations remain, the traffic system appeals to people's self-preservation instincts and other human characteristics that improve safety (see *Table 2*, right column).

People are not only to road users, but also the professionals who design, implement and manage elements of the traffic system (roads, vehicles, information, control systems, etc.) The same human characteristics that apply when they are road users (see *Table 2*) are also valid when acting in this professional capacity. This implies that in the development and maintenance of a sustainably safe traffic system, there is a need for the organization of all the processes involved to take maximum account of the human dimension of the professionals.

Table 2 Human characteristics and how they relate to (a lack of) road safety.

Human characteristics that can contribute to the **occurrence** of crashes and injuries	Human characteristics that can contribute to the **prevention** of crashes and injuries
• People are physically vulnerable: their tolerance to rapid acceleration and deceleration forces are limited, and impact with solid objects is a source of injuries for road users. • People occasionally make errors, even if they are well trained, informed or educated. • People's concentration span is limited and they are not always conscious of their behaviour and choices and of their consequences, in particular when they are inexperienced or impaired. • People can only process certain amounts of information simultaneously and will get tired after a while. • People easily create connections between their daily experiences, so that they may develop a different perception of reality and risks than what objective information reveals. • People regularly behave based on motives that are not necessarily ideal for the safety of themselves or those around them.	• People have the ability to learn and to adapt. They relatively easily adjust to new circumstances. • People are creative and inventive, including when they encounter unfamiliar problems. • People easily recognize new patterns, which helps them to develop expectations and more efficient methods (faster ones and with fewer errors). • The natural behaviour of people is directed at self-preservation. • People are (mostly) empathetic, which gives them a reason to look out not only for their own well-being, but also for that of others.

Adapting the traffic system

A sustainably safe traffic system is organized in such a way that it pro-actively adapts to human factors (see previous section) and integrates the various elements of the road traffic and transport system optimally. The following requirements apply for these elements:

- **Roads, the roadside environment, vehicles and technological solutions** are compatible with and supportive of human capabilities. In addition, they offer maximal protection – sometimes with the help of additional body protection devices – to all road users in or on a vehicle and in the immediate surroundings. Responsible organizations and the government as the ultimately responsible party take care that these conditions are always met and that deficiencies are addressed.
- People are prepared as much as possible for the traffic task through **education, information and training** and are enabled to become aware of the safety consequences of their own choices and what they can do about them. People in organizations that influence the development, implementation, management, and maintenance of a sustainably safe traffic system are optimally trained and equipped for these tasks.
- Inspectors and law enforcement authorities exercise sufficient control to ensure that the system functions at maximum safety (both at the level of road and vehicle design as well as road user behaviour). There is likely sufficient control to ensure that traffic professionals exert themselves appropriately in their contribution to sustainably safe road traffic. Enforcement occurs on the basis of the most effective combination of **regulation, inspection and fines**; unsafe behaviour by road users and by traffic professionals will, where possible, be eliminated or at least be made unattractive by effectively applying the knowledge about the 'human dimension' in the design of the traffic system. This kind of enforcement is one of the roles of the government which is responsible for the system.
- **Trauma care** and – where possible – technology in the vehicle ensure a fast response, optimum care and maximum recuperation of road users in case they are involved in a serious traffic crash. A short travel time to the hospital and sufficient space for trauma care are also important.

In a sustainably safe road traffic system ...

... traffic professionals work together and check one another to achieve a maximally safe result

The elements of sustainably safe road traffic complement and reinforce each other, making it as fail-safe as possible. If one element in the system fails, it should be substituted or compensated for by other elements. This applies for unsafe situations – such as if a part breaks or temporarily malfunctions – as well as for human behaviour. It applies during the process of traffic participation as well as in the work processes of traffic professionals.

Road safety principles

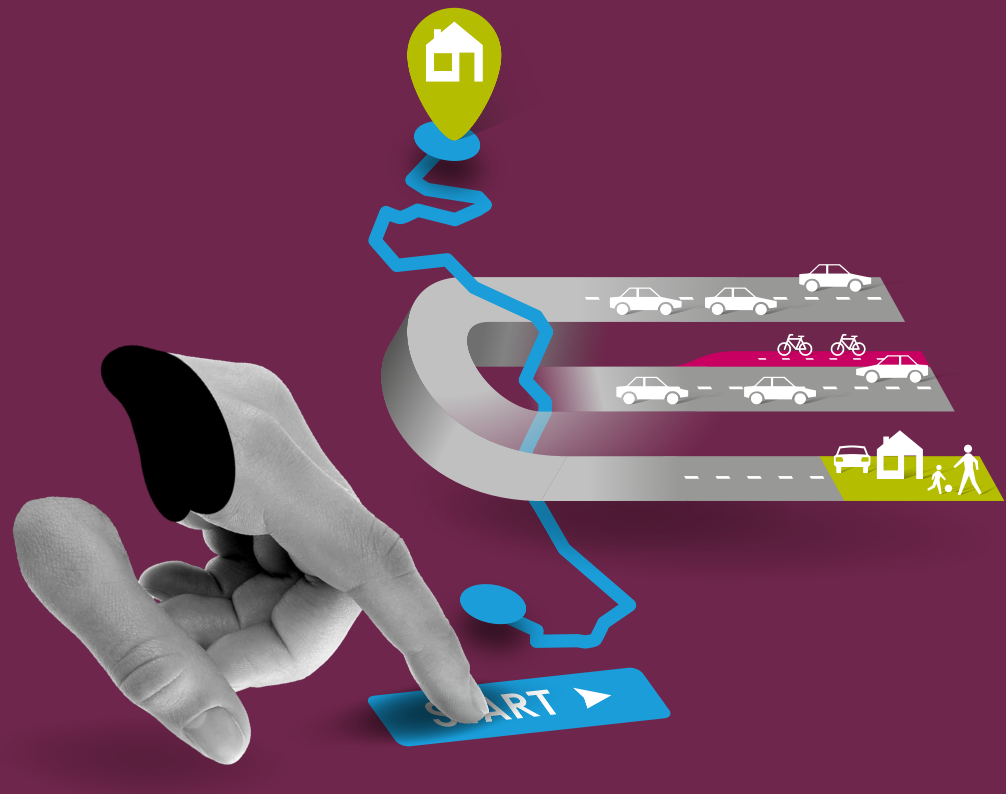
three design principles and two organization principles

In a sustainably safe road traffic system, five road safety principles are essential: three design principles and two organization principles. *Table 3* shows the evolution of the Sustainable Safety principles through time.

Table 3 The traffic safety principles in the various editions of Sustainable Safety.

Towards a sustainably safe road traffic (1992-2010)	Advancing Sustainable Safety (2005/2006-2020)	Sustainable Safety 3rd edition (2018-2030)
Functionality of roads	Functionality of roads	**Functionality** of roads
Homogeneity in mass, speed and direction	Homogeneity in mass, speed and direction Physical forgivingness Social forgivingness	**(Bio)mechanics**: minimizing differences in speed, direction, mass and size whilst maximizing protection of the road user
Predictability of traffic behaviour by a recognizable road design	Predictable traffic behaviour and road alignment by a recognizable road design State awareness	**Psychologics**: aligning the design of the road traffic environment and road user competencies
		Effectively allocating **responsibility**
		Learning and innovating in the traffic system

The next pages will briefly describe the advanced Sustainable Safety principles, taking into account problems and criticism with respect to the previous principles. Each safety principle is followed by a section *Customization and phased solutions* which serves to address previous shortcomings and proposes remedial measures. Finally, a number of special challenges for the future have been formulated for each principle.



Functionality

of roads

Ideally, road sections and intersections have only one function for all modes of transport (mono-functionality): a traffic flow function or an exchange function. The road network ideally shows a hierarchical and functional structure of these functions.

In any city or rural area, land consists of dwelling areas and traffic areas. The dwelling areas are spaces where people live, work, and recreate; the traffic area consists of road sections and intersections. "Flow" means that traffic participation does not involve interaction with the environment; with "exchange," there is interaction with the environment and there are abrupt manoeuvres (e.g., to access to private properties). The functions of flow and exchange do not combine safely and are best kept separate. Road function is therefore the basis for a safe design and use of roads.

According to the design principle of functionality, the road network is ideally a hierarchical and functional structure of traffic functions, consisting of three categories of roads (see *Figure 2*):

- **through-roads** (flow function on road sections and across intersections),
- **distributor roads** (flow function on road sections and exchange function at intersections) and
- **access roads** (exchange function on road sections and at intersections).[21]

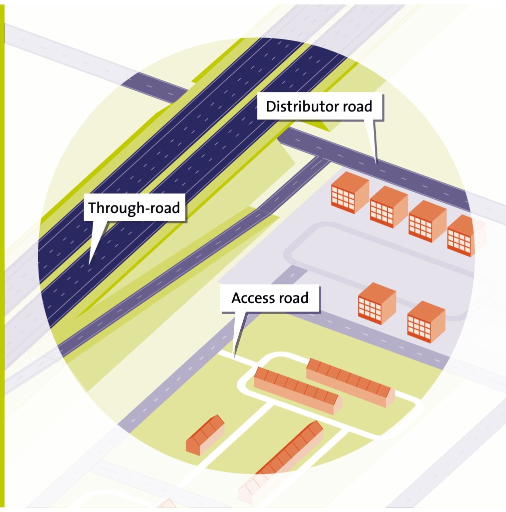


Figure 2 Functional classification of roads.

This functional classification of roads relates to the 'traffic space'. 'Dwelling' functions such as playing, visiting and shopping do not combine safely with traffic, least of all with through-traffic. Access roads, and in particular home zones, are the only type of traffic space that, where necessary, combines with an area's dwelling function.

Problems and criticism

Problems and criticism with respect to the functionality of roads
- Roads are not always mono-functional.
- The functional classification as described is especially applicable to roads outside the urban area.
- The functional classification of roads is mainly a classification from the perspective of motorized traffic.

21 In Sustainable Safety, an access road is a road for local access. It is not the type of 'access road' that is used in some countries to provide access to a major destination such as a port or an airport, most often a through-road, functionally.

Customization and phased solutions

In cases where mono-functionality cannot be realized in the short term, so-called 'grey roads', efforts should be made to achieve temporary results that provide adequate safety by means of safe speeds. The determinant for what can be considered as 'safe' is the most vulnerable or least protected road user reasonably expected in the traffic interaction (see also the next principle of (bio)mechanics). This safe travel speed should be accounted for in the design of the road, the road environment, and/or the vehicle (the principle of psychologics). In this way, the other two design principles compensate for any sub-optimal implementation of the functionality principle.

In some special circumstances, flow and exchange functions can be combined: when through-going cyclists travel at a safe speed, there is limited local access traffic, and the speed differences are small. An example would be a well-designed bicycle street, or a 'car-lite' shopping or school zone. However, this situation is not ideal and should be carefully considered in terms of the consequences for other vulnerable road users.

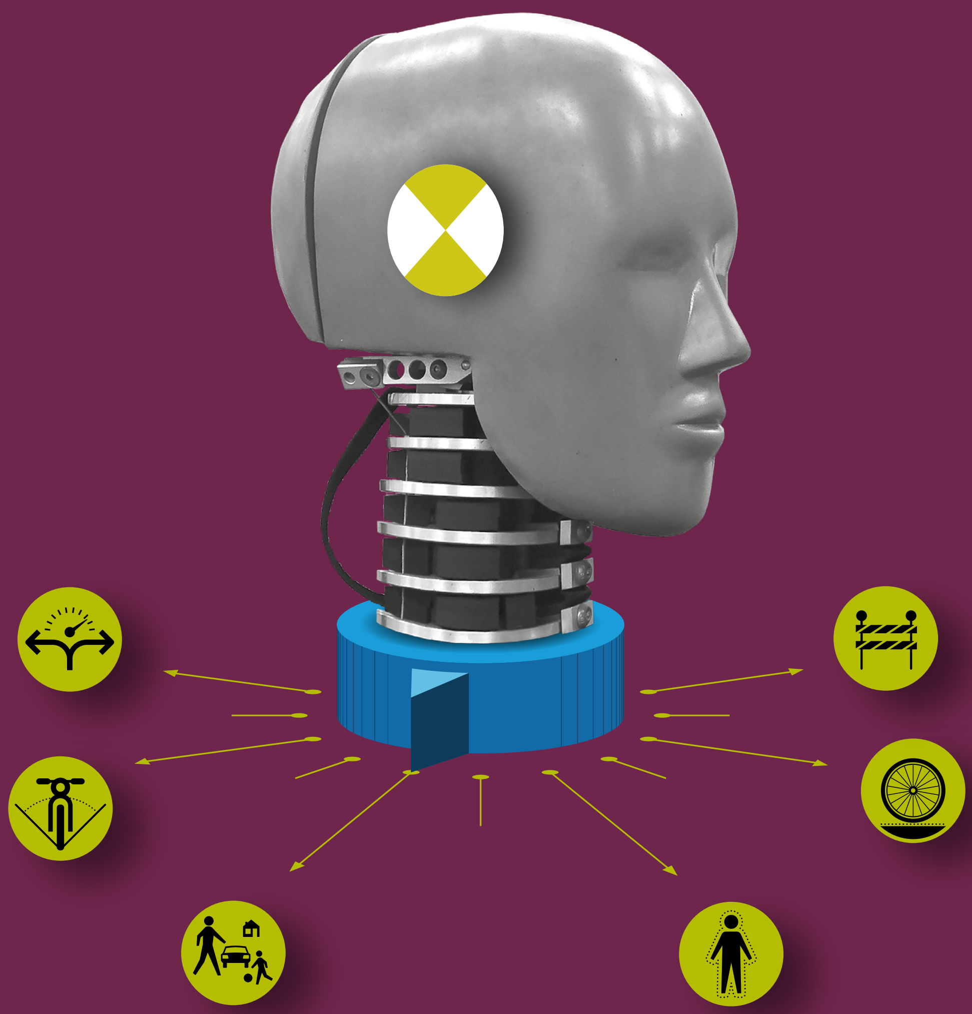
Where the dominant traffic function differs by time (e.g., times of the day, or by season), dynamic mono-functionality may offer a solution: at particular times a road has a predominant flow function, and at other times a predominant exchange function. This is only expected to be safe if traffic speeds are restricted. It should be further examined how this can be carried out practically and safely, perhaps in some combination of technology and physical measures.

In a sustainably safe road traffic system ...

... the road is intended to facilitate traffic flow or exchange across traffic, but not both

Challenges for the future

- Traffic growth may call for increased regulation of public space and traffic space (functional categorization). This presently focuses mainly on urban areas and vulnerable road users (cyclists, pedestrians, schoolchildren, active seniors etc.).
- Senior road users will increasingly participate in traffic and be found on the roads. Where mono-functionality is no option, it would be sensible to design road facilities using the physical and psychological characteristics of the older road user as the point of departure in order to offer conditions that are safe for all.
- It may be desirable to explore whether technology can offer solutions for road functionality problems, for example, time-of-day controls for school zones, in shopping streets, etc. The least desirable option is doing nothing in the conviction that technology will (soon) solve the problem, when we do not know for sure whether technology is actually capable of doing so.



(Bio)mechanics

Limiting differences in speed, direction, mass and size, and giving road users appropriate protection

Ideally, traffic flows and transport modes are compatible with respect to speed, direction, mass, size and degree of protection. This is supported by the design of the road, the road environment, the vehicle, and, where necessary, additional protective devices. For two-wheeled vehicles, it is important that the road and the road environment contribute to the stability of the rider.

The design principle of (bio)mechanics implies that fast-flowing traffic is separated, either physically or in time, from slow moving traffic, from traffic travelling in opposite direction, from traffic with a substantially different mass or width, from hazardous obstacles, and from vulnerable road users. The road and the direct road environment are forgiving, meaning that they are designed and built in such a way that the free flow speed is safe in the event of an incident (see *Table 4*). Furthermore, road users will be sufficiently physically protected by the vehicle, by roadside barriers, or by protection devices on their body. If a mode of transport cannot meet the speed, mass, size and road user protection criteria that are necessary for a safe outcome, then this mode will not be allowed on roads intended for a flow function (through-roads or distributor roads). For such transport modes, special infrastructure is provided that is adapted to traffic with low speed and small size and mass.

Table 4 Further implementation of 'safe speed limits'.[22,23,24] Difference with the row above are **indicated in bold**.

Potential conflicts and requirements associated with	Safe speed
· Possible conflicts with vulnerable road users in home zones (woonerfs) (no footpaths and pedestrians using the carriageway)	15 km/h
· Possible conflicts with vulnerable road users **on roads, at intersections**, including situations with **bike lanes or advisory bike lanes**	30 km/h
· No conflicts with vulnerable road users, except with helmet-protected riders of motorized two-wheelers (mopeds in the carriageway) · Possible right-angle conflicts between motorized vehicles, possible frontal conflicts between motorized vehicles **· Stopping sight distance ≥ 47 m**	50 km/h
· No conflicts with vulnerable road users **No right-angle conflicts between motorized vehicles,** possible frontal conflicts between motorized vehicles **Obstacles shielded or obstacle-free zone ≥ 2.5 m, (semi-)hard shoulder** **Stopping sight distance ≥ 64 m**	60 km/h
· No conflicts with vulnerable road users No right-angle conflicts between motorized vehicles, possible frontal conflicts between motorized vehicles Obstacles shielded or **obstacle-free zone ≥ 4.5 m**, (semi-)hard shoulder **Stopping sight distance ≥ 82 m**	70 km/h
· No conflicts with vulnerable road users **No right-angle or frontal conflicts between motorized vehicles** Obstacles shielded or **obstacle-free zone ≥ 6 m**, (semi-)hard shoulder **Stopping sight distance ≥ 105 m**	80 km/h
· No conflicts with vulnerable road users No interactive and frontal conflict between motorized vehicles Obstacles shielded or **obstacle-free zone ≥ 10 m, hard shoulder** **Stopping sight distance ≥ 170 m**	100 km/h
· No conflicts with vulnerable road users No right-angle or frontal conflict between motorized vehicles Obstacles shielded or **obstacle-free zone ≥ 13 m**, hard shoulder **Stopping sight distance ≥ 260 m**	120 km/h
· No conflicts with vulnerable road users No right-angle or frontal conflict between motorized vehicles Obstacles shielded or **obstacle-free zone ≥ 14.5 m**, hard shoulder **Stopping sight distance ≥ 315 m**	130 km/h

22 Potential conflict situations demanding a maximum speed of 15 km/h are based on Directie Verkeersveiligheid (Road Safety Management) (1985). Van woonerf naar erf. Ministerie van Verkeer en Waterstaat, Den Haag, The Netherlands (From woonerf to courtyard; In Dutch, with a summary in English).

23 Potential conflict situations and design requirements linked to safe speed limits between 30 and 120 km/h are based on Tingvall, C. & Haworth, N. (1999). Vision Zero - An ethical approach to safety. Paper presented to the 6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, 6-7 September 1999, Melbourne, Australia, and Aarts, L.T., et al. (2009). Safe speeds and credible speed limits (Sacredspeed): a new vision for decision making on speed management. In: Compendium of papers of the 88th Annual Meeting of the Transportation Research Board TRB, 11-15 January 2009, Washington, D.C. USA.

24 Design requirements for safe travel on roads at 130 km/h involve a preliminary assumption that needs further study.

Where traffic has an exchange function, different transport modes mix. In these situations, motorized traffic will drive at a low, safe speed in order to minimize crash risk and potential for injury, particularly to vulnerable road users. The road lay-out and the vehicle help achieve these lower speeds. Moreover, the road should offer sufficient room for passing and overtaking other road users.

To prevent bicycle crashes that don't involve motorized vehicles, cyclists should have sufficient room for manoeuvring at low speed, a clean and skid-resistant road surface and a forgiving road environment without stability-undermining elements (e.g., sharp-edged elevation differences, obstacles). In addition, they have made themselves adequately protected against injury if they fall in cases where the road and road environment are not yet forgiving enough.

In a sustainably safe road traffic system ...

... every child can safely walk or cycle to school, thanks to proper neighbourhood planning, a safe road lay-out, safe speeds, and being sufficiently physically protected

Problems and criticism

Problems and criticism with respect to (bio)mechanical principles

- Design dilemmas occur with respect to roads that are not mono-functional and tree-lined roads, especially in rural areas.
- Traffic is getting increasingly more heterogenic because of new transport modes and a greater variety in mass and size of existing transport modes. How can these transport modes be safely combined and what is their position on the road network (for example, agricultural vehicles, light-mopeds, speed-pedelecs, racing bikes)? The dilemma is whether compatibility should be searched for in terms of speed, mass, or size.
- Who is responsible for achieving greater compatibility in terms of the (bio)mechanic characteristics of road traffic? Should it be the road authority by providing a safe road lay-out? Or bicycle and vehicle manufacturers, providing technology to prevent crashes or offer sufficient protection? And what can be expected of the road users themselves?

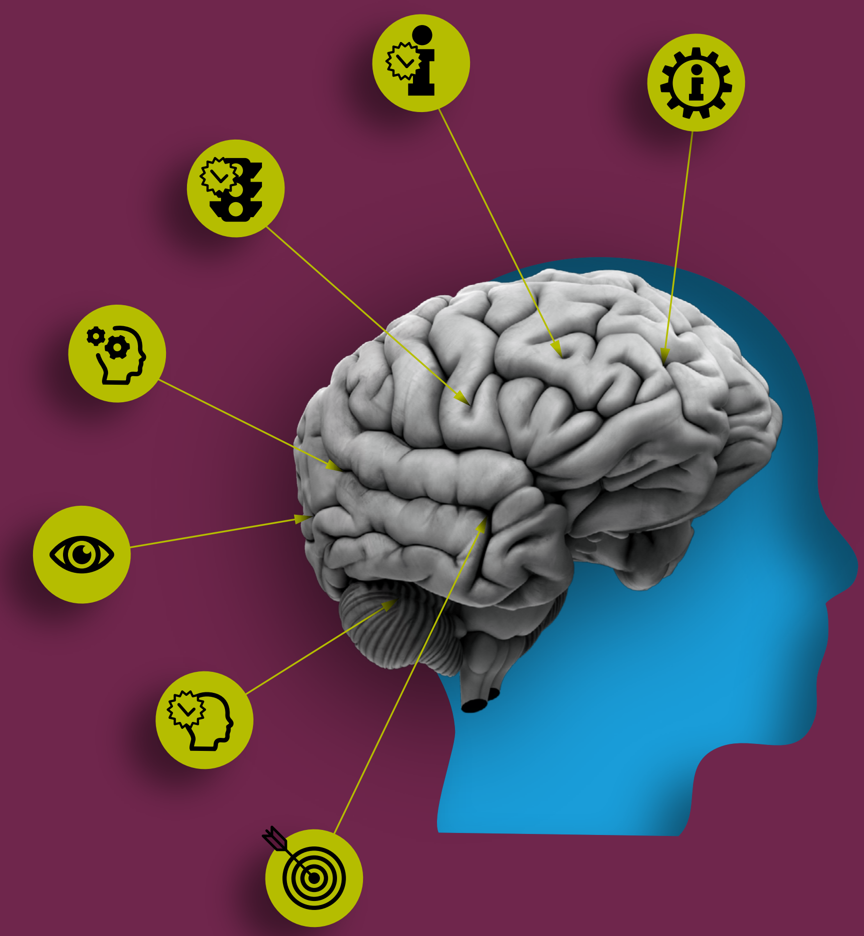
Customization and phased solutions

In cases where (bio)mechanic compatibility between different road users groups and the road lay-out cannot yet be sufficiently guaranteed, the speed of all traffic should be adapted (see Table 4) to the most vulnerable transport modes (in particular, pedestrians and cyclists) and road users (in particular, children and seniors).

In situations lacking sufficient compatibility between (bio)mechanic characteristics, additional integrated safety solutions and measures should be implemented to prevent crashes (e.g., physical separation of directions, low speeds, safe shoulders, automatic braking systems) and to limit the injury impact (e.g., low speeds, removing or shielding obstacles, protection by means of the vehicle, protection by means of protective devices on the body).

Challenges for the future

- Compatibility of speed, direction, mass and size is a challenge in an increasingly heterogeneous traffic composition with a greater share of seniors. This challenge may be met by restricting more roads to certain types of traffic and by making more roads safe for relatively vulnerable road users.
- In addition to a static form of (bio)mechanic compatibility of speed, direction, mass and size, technology may also offer dynamic solutions. This implies that situations that are now solved statically, such as separating motorized traffic from vulnerable road users on roads with high speed limits and enforcing low speeds where traffic is mixed, could be solved in a more situation-dependent manner. Given the design of the road, technical systems might apply speed limits are dependent on the presence of certain types of road users. However, this demands proper coordination between road authorities and the private sector, as well as an appropriate study of the prerequisites under which technology can offer a safe solution. Also important is the understanding of how these different measures will provide mutual back-up if one of them fails (failsafe design).



Psychologics

Aligning the design of the road traffic environment with road user competencies

The design of the traffic system is well-aligned with the general competencies and expectations of road users, particularly senior road users. This means that for them as well as others the information from the traffic system is perceivable, understandable ("self-explaining"), credible, relevant and feasible. Road users are capable to carry out their traffic task and to adjust their behaviour according to the task demands for safely participating in traffic under the prevailing circumstances. This applies for drivers (skilled and fit for the driving task) as well as non-motorized road users (skilled in dealing with traffic and fit to participate in traffic).

Information about the prevailing conditions of the traffic system is transferred to the road users by the road lay-out, the road environment, traffic signs and regulation, via the vehicle and via technology. Information in this context may be explicit as well as implicit. *Figure 3* indicates how information is selected and processed. According to the psychologics design principle, road users should be able to process this traffic information correctly – in particular senior road users, who are generally faced with diminishing physical and mental abilities, often aggravated by illness and disabilities. Designing the traffic system according to their needs will make the system in principle safer for (almost) all road user groups.

Adapting road behaviour to the task demands of safe traffic participation (see *Figure 4*) especially applies to road behaviour at a strategic level (selection of destination, travel mode and route) and at a tactical level (manoeuvres on the road). Road users are adequately educated, informed and trained. Road users who are still developing their task capability (e.g. children and teenagers) or people who (temporarily) lack sufficient task capability, participate in traffic under supervision of sufficiently capable adults or under conditions that are less demanding (as with graduated licencing, for example). Drivers of motorized vehicles need to have a minimum task capability (skilled in driving and fit-to-drive); so too with non-motorized road users, such as cyclists and pedestrians (skilled in dealing with traffic and fit for participation in traffic). The task demands are higher when the vehicle constitutes a greater danger to others (e.g. due to its greater mass or speed).

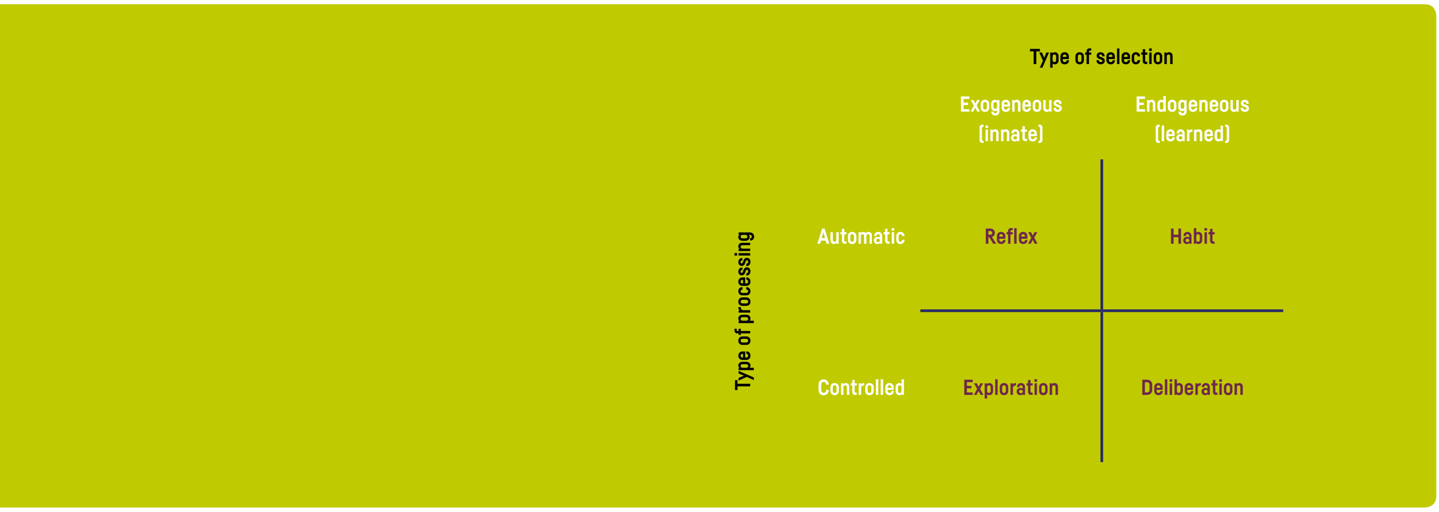


Figure 3 Schematic representation of various types of information selection and processing, and additional opportunities for behavioural guidance.[25]

Ideally, safe road behaviour is a little dependent as possible on individual road users' choices or on the roadway environment. For this reason, road users are supported in making safe choices in road behaviour (e.g. by means of intelligent speed assistance – ISA) or by preventing them (temporarily) from participating in traffic when they appear to be incapable (e.g., by means of an alcolock or other smart tools).

25 Trick, L.M. & Enns, J.T. (2009). A two-dimensional framework for understanding the role of attentional selection in driving. In: Castro, C. (eds), Human factors of visual and cognitive performance in driving. CRC Press, Boca Raton, Florida, p. 63-73.

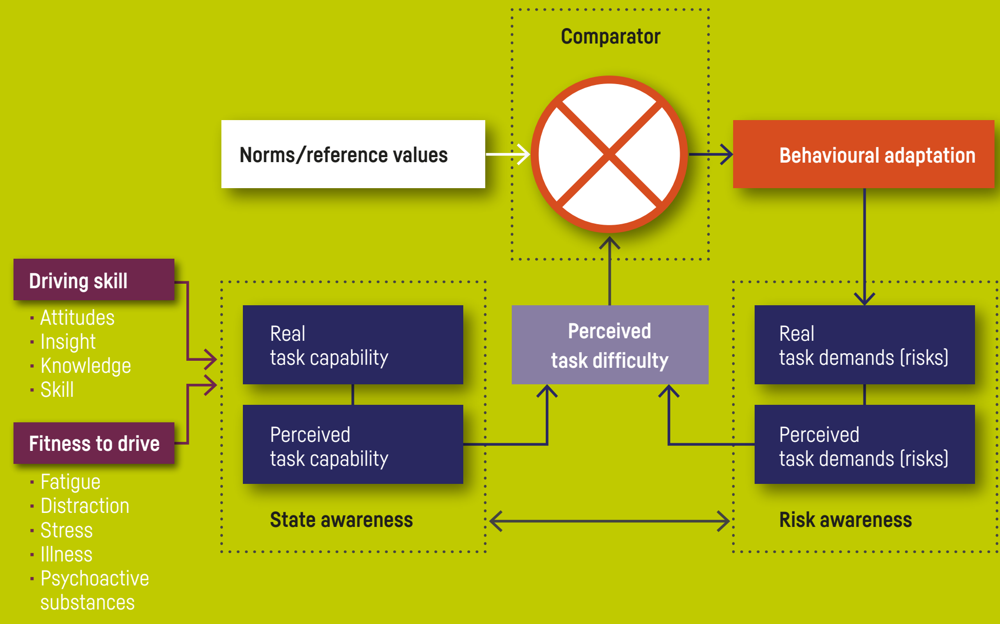


Figure 4 Schematic representation of the processes and factors that play a role in proper calibration of the road user.[26]

Problems and criticism with respect to psychological principles

Problems and criticism

- A point of criticism on the previous psychological principle of predictability is that acting on routine (i.e. learned habits and routines) might be dangerous. However, scientific research has shown that this is less dangerous than people not acting on their routine and experience.[27]
- In general, crash statistics show that in countries where traffic is chaotic and seemingly few crashes occur, road traffic is often substantially less safe than in 'well-regulated' countries. A well-regulated and safe environment offers more tools for preventing crashes.
- According to some critics, uniformity in traffic implies that everything should look the same. However, the essence of uniformity in a sustainably safe road traffic system is that people recognize the right context for their behaviour, which is not enhanced if people are continually faced with a different design. Yet, this does not imply that small variations are problematic. Variations **within** a certain type of traffic environment are no major problem, as long as the differences **between** various situations are substantial enough.[28]
- The earlier psychological principles of predictability, state awareness and social forgivingness apparently do not cover all the essential psychological elements of a safely designed traffic system. At the same time, it appears that the concept of a 'design user' (a norm for physical and psychological attributes) is an inadequate basis for guidelines and for traffic system design. The psychological principles in this latest version of the Sustainable Safety vision have therefore been expanded and made more explicit when dealing with the competencies of the 'design user'.

26 See SWOV (2010). State awareness, risk awareness and calibration. SWOV Fact sheet, March 2010. SWOV, Leidschendam, The Netherlands.
27 See for instance Martens, M.H. (2007). The failure to act upon important information: where do things go wrong? PhD Thesis. VU University, Amsterdam, The Netherlands.
28 See Theeuwes, J. & Diks, G. (1995). Subjective road categorization and speed choice. TNO Human Factors, Soesterberg, The Netherlands, and Aarts, L.T. & Davidse, R.J. (2007). Distinctiveness, self-explainingness, and behavioural effects of recognizable rural roads in the Netherlands. In: ETC 2007 Congress. Volume 38, 17-19 October 2007, Noordwijk, The Netherlands, p. 215-224.

Customization and phased solutions

As long as the traffic system does not yet sufficiently support safe behaviour choices – in particular, safe speeds – adequate regulation, surveillance, detection, fines and information must be used for discouragement of (deliberate) dangerous traffic behaviours. Deliberate unsafe behaviours are a sign of incompetence: road users who deliberately behave dangerously do not sufficiently realize the risks they subject themselves and other road users to. These road users must be better detected and, if necessary (temporarily) removed from traffic by means of an enforcement system that is well adapted to human tendencies; afterwards, measures will be taken that aim to bring these road users' task capability and risk awareness to an adequate level.

New, theoretically opportune solutions that make use of the psychological aspect of the human dimensions should first be evaluated before they are (broadly) implemented. Evaluations should not only provide understanding of the (behavioural) results in the prevailing conditions, but should also reveal the consequences for and correspondence with the other two design principles, namely, functionality of roads and (bio)mechanic characteristics. An example of such a coordinated approach might be a speed adaptation system that induces road users to drive at a speed that is safe for the road's function and that accounts for features of the road design or the road environment that, at a higher speed, might be unsafe from a (bio)mechanic perspective (such as by detecting dangerous obstacles close by the road, or slippery road conditions).

In a sustainably safe road traffic system ...

... the older road user understands how the traffic system is intended to work and can thus safely operate in traffic situations

Challenges for the future

- More systematic effort is needed to acquire knowledge about psychological characteristics of humans, about how to be safe in traffic, and about how to motivate people to safer behaviour.
- Seniors are becoming more important for the definition of the 'design individual' to which traffic should adjust to in order to achieve maximum safety. Complexity and low-cost treatments for traffic situations threaten road safety from the point of view of the psychologics principle. We will have to keep studying whether safe solutions for seniors are still safe for other groups of road users.
- Technology offers a threat in terms of distraction. As much as new technology offers opportunities to meet transport needs, it may also introduce elements that compromise road safety. The major challenge is the combination of what is technically feasible, what people can safely deal with, including when the system breaks down, and what people want and will accept. Technology developments in the road transport environment affect all road users in a way that is not always well understood.

Effectively allocating

Responsibility

Responsibilities are allocated and institutionally embedded in such a way that they guarantee a maximum road safety result for each road user and optimally integrate with the inherent roles and motives of the parties involved. In principle, road users follow the rules and set a good example for children and teenagers. Thanks to a forgiving traffic system, road users will not be punished for their errors and weaknesses by crashing and sustaining serious injuries.

As regards assigning responsibilities effectively, the national government is responsible for the system in the first place, and as such carries the ultimate responsibility. The national government has the inherent task to protect its citizens and to provide them with the opportunity to live in freedom and safety. It ensures that short-term profit (economically speaking) does not hinder the realization of the long-term benefits associated with societal goals such as road safety.[29] The national government sets targets in terms of the maximum number of road deaths and serious road injuries, in combination with intermediate goals (road safety performance indicators or SPIs) for road safety. These intermediate goals provide the framework for agreements with directly involved stakeholders. SPIs can also be used for integrated policy formation. A 'chain approach'[30] can be helpful to make optimum use of the relations between the parties that are involved in the chain from conceptualization of a measure through to its production and implementation. The central government establishes the appropriate conditions for implementation, for instance, via agreements and information about desired behaviour, results and consequences of policy and consumer choices. It implements laws and regulations with respect to the intended social result and is responsible for (financial) incentives to stimulate the desired behaviour of actors. In all of this, the 'human dimension' is taken into account, while also accounting for utility (public interest) and proportionality (weighing costs and benefits). Finally, the central government monitors the results and adjusts the aims and conditions accordingly.

In a sustainably safe road traffic system ...

... the government accepts ultimate responsibility for a casualty-free traffic system

Spatial planners, road authorities, enforcement officers, lawmakers, safety education officers and other traffic professionals carry operational responsibility to realize what is in fact a sustainably safe traffic system. For instance, spatial planners plan community and neighbourhood development patterns that lead to a safe hierarchical road network structure, thus influencing travel distances, routes, road transport modes, and traffic volumes. Road authorities see to it that roads are designed and maintained in such a way that road users are physically protected and that the road supports their competencies and safe behaviour. Lawmakers implement fair, safe and credible laws and enforcement officers work toward honest and effective respect for the rules. Preferably, undesirable behaviour is prevented primarily through appropriate road design, information and/or technology. Safety education officers have the operational responsibility to make sure that road users are optimally equipped and have been able to practise participating safely in traffic in a safe learning environment, and that they are able to assess hazards correctly and to adjust their behaviour safely. Policymakers stimulate safe choices and check that no products are sold or used that contribute to the increase of hazardous situations.

The private sector – including vehicle manufacturers – strives to develop products that offer road users maximum physical protection for themselves and those around them, and support them in making safe behavioural choices. They do so from a desire to promote a good corporate image by making investments focused on road safety and that show corporate social responsibility. Industry develops strategies to make the safest products most attractive to consumers and employees. The fact that the greater part of the road safety expenses are paid for by the consumers may help in this respect. Providers of leisure activities (societies, clubs, bars etc.) show socially responsible behaviour, seeing to it that their members or customers have safe conditions in which to participate in traffic. For example, they encourage road users not to drink too much alcohol and offer an attractive range of non-alcoholic alternatives. They point customers to traffic rules and encourage them to pay attention to safe road behaviour.

29 The sustainability principle from the Brundtland report: Brundtland Commission (1987). Our common future. World Commission on Environment and Development, United Nations, Oslo.

30 This approach concerns the use of the links in the chain between various parties, i.e. the relations they directly or indirectly maintain among each other or in terms of a traffic-related aspect.

Employers and product manufacturers provide safe road traffic conditions by ensuring that productivity is not at the expense of road safety and by ensuring sufficiently safe working conditions, promoting a general safety culture.

Social organizations examine whether the road safety interests of their clients are sufficiently served and develop improvement initiatives when necessary.

In a sustainably safe road traffic system ...

... unsafety and each party's responsibility in connection with it are acknowledged and acted on using a risk-based approach

Customization and phased solutions

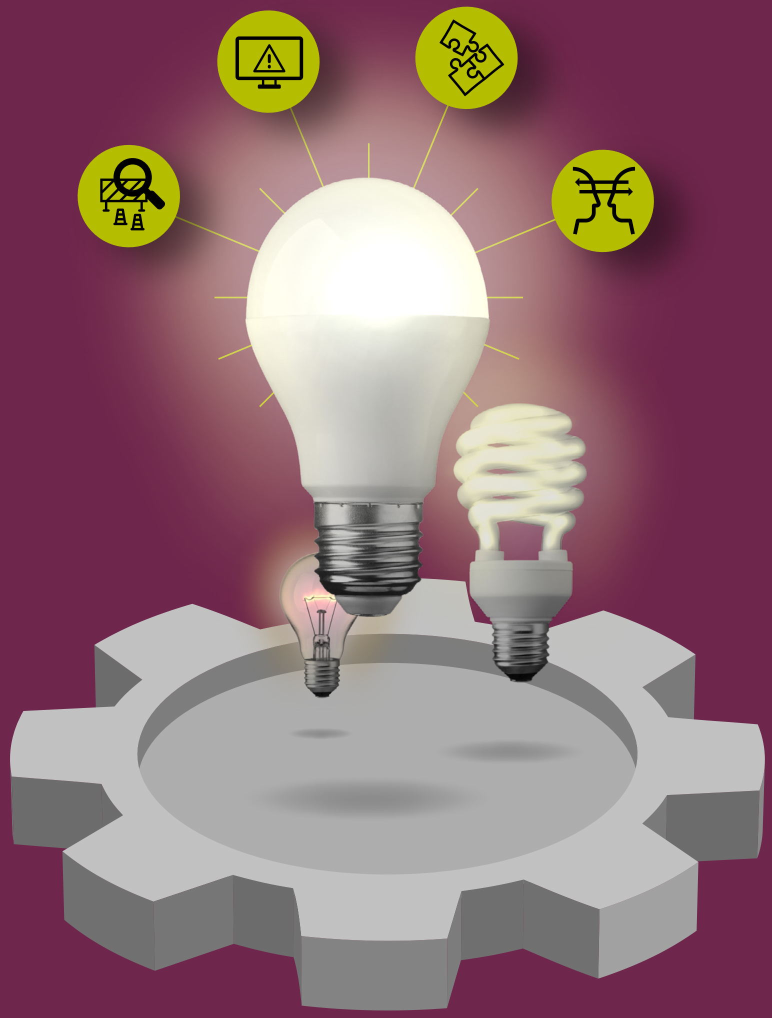
In cases where operational responsibilities are not optimally assigned or where there are conflicts with other interests, the protection of vulnerable road users has priority: children, seniors and other road users making use of vulnerable modes of transport, such as walking and the use of two-wheeled vehicles.

Road users that cannot adequately participate in traffic but nevertheless make use of the road network have to be protected by a traffic system that is forgiving and can compensate for errors by protecting the road users. It is the responsibility of the government to protect its citizens against factors beyond their own capabilities and awareness and against injuries as a result of other road users' behaviour.

As far as possible, unsafe behaviour is prevented in advance (elimination, for example, by means of smart access systems, ISA or – in time – self-driving vehicles). There should be sufficient legitimization for measures such as smart access and speed adaptation. If this is not possible, effective information, financial incentives and other enticing elements (e.g., credible speed limits and adjusting traffic lights) can be used to try and evoke the required behaviour.

Challenges for the future

- It is a future challenge to find a proper balance between avoiding being a 'nanny state', providing sufficient 'freedom for the individual', and realizing the possibilities of 'empowering' citizens, ultimately leading to a reduced number of traffic casualties. In this context it is relevant what citizens (seniors in particular) are capable of, and it is important that the freedom and safety of one road user will not be at the expense of another's.
- Market-oriented thinking and consumerism may result in an adequate level of provision in urban areas, with rural areas falling behind. This clashes with the requirement of safeguarding the societal principle of 'equal treatment' that presumes that citizens, wherever they live, can expect that the government provides them with the same basic facilities.
- Technology can offer an opportunity to facilitate the need for freedom as well as the need for safety, but in this respect, some boundary conditions must be applied.



Learning and innovating

in the traffic system

Traffic professionals continually learn how they can improve their policy. The Deming cycle is relevant here: it starts with the development of effective and preventive system innovations based on knowledge of causes of crashes and hazards (Plan). By implementing these innovations (Do), by monitoring their effectiveness (Check) and by making the necessary adjustments (Act), system innovation ultimately results in fewer crashes and casualties.

This organization principle calls for a process of learning and innovating that goes through all phases of the Deming cycle and is embedded in the organization (see *Figure 5*).

In order to learn and to innovate (improve the system), researchers map crash mechanisms through in-depth study of all fatal crashes in the country. When possible, this will be supplemented with a study of other serious crashes and by means of knowledge derived from linking of databases.

Policymakers and scientists define suitable additional surrogate safety measures[31] such as risk factors (SPIs) and conflicts. These are monitored by structurally measuring them at strategic locations and times, and with relevant groups. The implementation of applicable measures is also structurally monitored (*Figure 6*). Complaints from citizens can be reasons to measure and determine whether risk factors are present, such as hazardous system design or unsafe behaviour.

Stakeholders, such as policymakers, the road transport industry, scientists and lobbyists contribute to innovations by linking knowledge about problems with (possibly) effective measures and methods. The applicability and efficacy of these measures or methods are assessed and, if necessary, are adjusted and evaluated again.

Organizations arrange sufficient knowledge transfer within their own networks, recognizing this as vital for continual and systematic improvement. This can be achieved by means of training materials for new colleagues, but also by exchanging knowledge with other disciplines and other organizations such as policymakers, industry, and scientific research. Organizations are responsible for stimulating an active exchange of knowledge and continuous professionalization of their employees (professional education). Not only do they supply know-how, but they also provide the networks that can offer expertise. In this respect, knowledge institutes can play an active role.

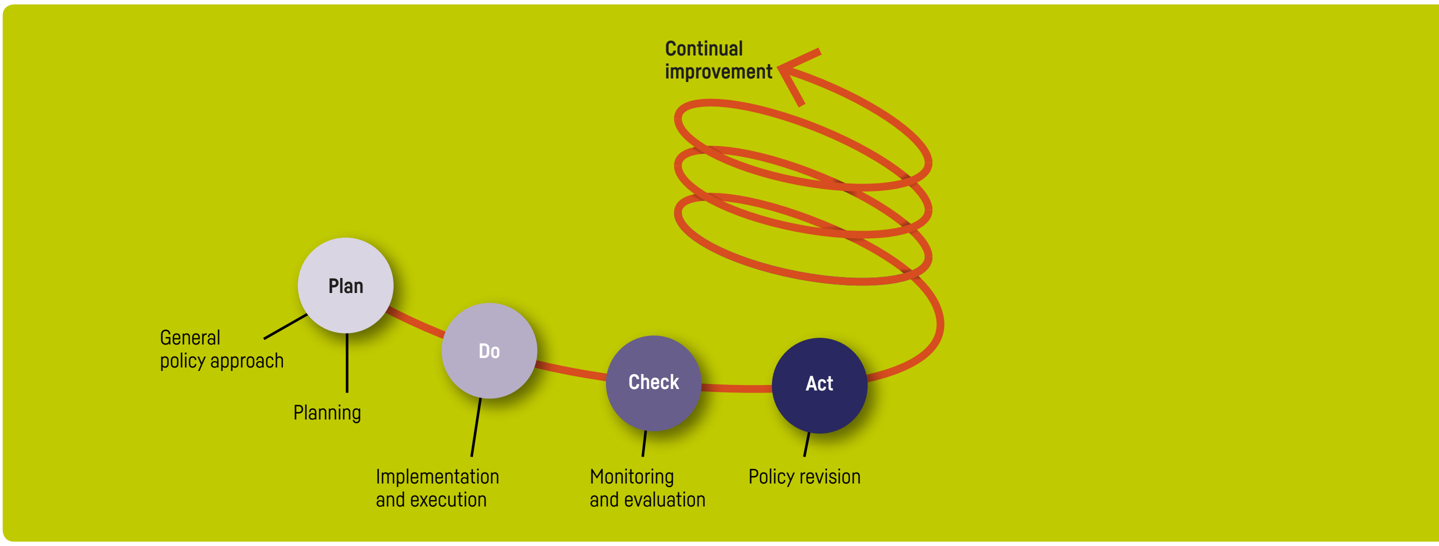


Figure 5: Deming cycle[32] as used in ISO standards for quality management.

31 See, for instance, Tarko, A., et al. (2009). Surrogate measures of safety. White paper. Subcommittee on Surrogate Measures of Safety, Transportation Research Board of the National Academies, Washington D.C., USA..
32 See Deming, W.E. (1986). Out of the crisis. MIT Center for Advanced Engineering Study, Cambridge, Massachusetts, USA.

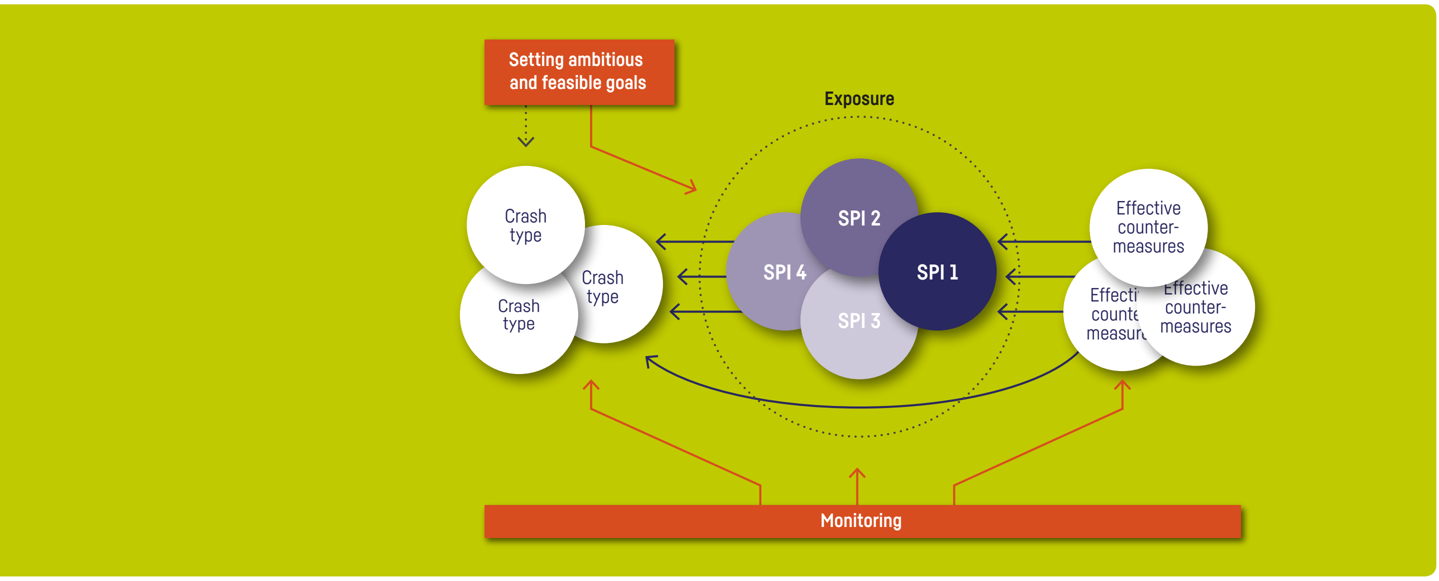


Figure 6 Correlation between crashes, risk factors (SPIs) and countermeasures and the connecting activities necessary to contribute to a sustainably safe traffic system: setting aims, applying counter-measures and monitoring.

Customization and phased solutions

In case a national approach is not yet feasible, learning and innovating can be introduced on a small scale. Examples are:

- In-depth research into all fatal crashes: initial focus on representative areas in the country or specific crash types.
- Monitoring of road safety indicators: initial focus on one or a few SPI's (for example, speed, drunk-driving and safety quality of the road and bicycle infrastructure). Simultaneously, possibilities can be explored for indicators that are more difficult to monitor (for instance, distraction and fatigue) before expanding the monitoring programme.
- Evaluation of innovations: innovations are first applied in a pilot field-study or studied by means of simulations.
- Learning processes within organizations: to begin with, they are organized among early adopters or specific function groups to establish whether experiences can be shared more widely and embedded in other groups or organizations. Road safety managers from national government and regional authorities and early adopters can play a pioneering role, exploring how the learning process can be further organized and embedded among traffic professionals. Knowledge institutes and road safety consultants can also play a supportive role.

In a sustainably safe road traffic system ...

... all fatal crashes are investigated to establish why things still go wrong

Challenges for the future

- Learning and effectively innovating are necessary for re-establishing and sustaining a declining trend in casualties. Inspiration can be derived from experiences with a safe systems approach in other sectors (process industry, aviation, rail transport).
- Innovation encompasses the functional and effective use of new and existing technology, as well as the improvement of the traffic system by means of other effective measures and process improvements. Where innovation results in system transitions, it is particularly important to consider to what extent new system elements or solutions for existing problems may introduce new problems. One example is the self-driving, automated car, which the masses believe to be the solution to all safety problems, but whose negative effects and interaction with existing traffic is poorly understood.
- With the presumed increase in differences between urban and rural areas and the demographic shift to a larger proportion of senior citizens, it will become increasingly important to consider these changes and the potential problems they introduce for the traffic system. How do these developments affect the operation of the system? Are there risks for system failures, and are there solutions available to address them? And how does the operating of the traffic system accommodate the different circumstances and road users involved? Incorporating these issues in research on crashes and risk factors is expected to deliver a better basis for understanding the system in its entirety and improving it.[33]

33 See also Hughes, B.P., et al. (2015). System theory and safety models in Swedish, UK, Dutch and Australian road safety strategies. In: Accident Analysis & Prevention, vol. 74, p. 271–278.

From principles to action

In order to derive countermeasures that are implementable and practical, it is important to further operationalize the road safety principles into *Requirements for a Sustainably Safe Road Traffic System*. This entails developing concrete descriptions of requirements that the traffic system should meet. They can subsequently be used for regulations and clear guidelines in what could become a *Sustainable Safety Follow-up Programme*.[34] In addition to the follow-up programme, which is directed at operationalization and implementation of safety measures, it is also important to draw up a *Sustainable Safety Knowledge and Research Agenda* that will strengthen further development of a sustainably safe road traffic system (see also the learning and innovating principle).

A number of measures that fit in a sustainably safe road traffic system are illustrated below.

Illustration 1: Exposure of vulnerable road users to motorized traffic

Where vulnerable road users share road space with motorized traffic, the road clearly has an exchange function (functionality principle). From the principle of (bio)mechanics, major differences in speed should be avoided. In order to prevent crashes with serious injuries, it is important that motorized traffic be limited to a maximum speed of 30 km/h. This can be realized by adapting road design, vehicle, information provision and enforcement to these traffic conditions and to the needs of the prevailing road users groups (the principle of psychologics).

Aim: Maximum speed of 30 km/h where there is interaction between vulnerable road users and motorized traffic. Types of solution ranging from restricting choice (1) to full freedom of choice (3) in speeding behaviour (and thus a decreased level of Sustainable Safety):

1. Mandatory closed intelligent speed adaption (ISA)[35]: eliminate high speeds by limiting the speed of all motorized traffic to 30 km/h.
2. Credible road design: nudge motorized road users physically to maintain a maximum speed of 30 km/h by providing a road lay-out that is appropriate for no more than this speed. This can be achieved by limiting the length of tangents (straight road sections), by providing physical speed reduction measures (e.g. speed humps or raised junctions), a narrow cross-sectional profile, an uneven road surface, or by placing buildings or vegetation close to the road.[36]
3. Mandatory open ISA and fines: continuously inform motorized road users about the legal speed limit and fine them when they drive too fast.

Illustration 2: Single-bicycle crashes

In the Netherlands, cyclists form a significant proportion of the seriously injured traffic casualties, many of them being seriously injured in a single-vehicle (bicycle) crash. The bicycle infrastructure plays an important role in these single-bicycle crashes. In particular, obstacles (lack of forgivingness) and balance-disrupting road elements (combined in the principle of (bio)mechanics) are sources of concern.[37] To substantially reduce hazardous situations on the cycling infrastructure, particular attention should be given to these crashes in the future.

34 It is partly dependent on the final choices made how effective such a follow-up programme may be. Insights in ways in which the current number of casualties can be substantially reduced can be estimated based on the knowledge from effect studies.
35 Closed ISA makes it impossible to drive at a higher speed than the speed limit. Open variants of ISA allow to overrule the system when needed. Informative ISA just informs about the speed limits. Best safety results are met with a system that leaves fewer room for the driver to exceed the speed limit.
36 See for example Aarts, L., et al. (2009). Safe speeds and credible speed limits (Sacredspeed): a new vision for decision making on speed management. In: Compendium of papers of the 88th Annual Meeting of the Transportation Research Board TRB, Washington, D.C., 11-15 January 2009, Washington D.C. and Houtenbos, M., et al. (2011). Road user pilots in different European countries. Report No. WP02-02 of ERA-NET Road - ERASER. SWOV, Leidschendam, The Netherlands.
37 Schepers, P. (2013). A safer road environment for cyclists. PhD Thesis TUDelft. SWOV, Leidschendam, The Netherlands.
38 Dingus, T.A., et al. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. In: Proceedings of the National Academy of Sciences of the United States of America PNAS, vol. 113, nr. 10, p. 2636–2641.

Aim: Cyclists do not fall, do not hit obstacles and are physically protected in case something goes wrong. Types of solution within the traffic system and for the road user, again with an increasing amount of freedom for unsafe choices and thus a decreasing level of Sustainable Safety:

1. Obstacle-free, spacious and skid-resistant bicycle infrastructure: create a bicycle infrastructure that is forgiving and therefore free from slippery substances (loose sand/gravel/leaves), obstacles, and vertical edges and ridges that can cause cyclists to lose their balance, fall, and injure themselves. Additionally, create a bicycle infrastructure that is wide enough to provide cyclists the space for natural lateral movement and is sufficiently skid-resistant to prevent cyclists from slipping in bends.
2. Physical protection of the cyclist: as long as the road infrastructure and the road environment do not offer sufficient protection against injuries in the event of a crash, protective cycling gear provides some level of protection to the cyclist.

Illustration 3: Distracted motor vehicle drivers

Distraction among drivers, for instance because of the use of the smartphone, contributes to a 3 to 4.5 times' higher crash risk compared to normal, undistracted driving.[38] Causes and solutions are mainly found in the Sustainable Safety third edition principle of psychologics.

Aim: Distraction of motorized vehicle drivers does not result in serious casualties. Types of solution with an increasing amount of freedom to choose for unsafe behaviour and consequently a decreasing level of Sustainable Safety and a decreasing future orientation:

1. Autonomous (self-driving) vehicles: the vehicle undertakes the driving task without interference from occupants. The vehicle and related technology is programmed to safely deal with all kind of traffic interactions. Vehicle occupants can engage in non-driving tasks, for example, reading a newspaper, operating a laptop, phoning or participating in a meeting. The large scale introduction of autonomous vehicles is only expected after 2030, but preparations for a safe operating system and the transition towards it are ongoing.
2. Restricting use of electronic devices: electronic non-traffic devices are automatically switched to a safe mode which prevents the driver from using them whilst behind the wheel. Other vehicle occupants can still use their devices.
3. Warning system: the car warns the driver against unsafe situations and gives priority to the most important information to prevent the driver from being overloaded with information.

The way forward

This report provides a first detailed outline of the revised vision for a sustainably safe road traffic system in the Netherlands. The vision builds on previously developed and shared principles, requirements and measures. A primary recommendation is therefore also to **finish what has proven to be effective**. Past Sustainable Safety measures have had great success despite not being fully implemented. Examples of measures that should be finalized to have even more effect are the full implementation of credible road lay-outs, sufficient separation of high-speed traffic and evidence-based education.

This third edition of the vision also provides a framework for elaboration, operational requirements and measures that may be developed in the future or that already exist but cannot as yet be applied toward sustainably safe road traffic. For example, we may consider vehicle safety and protective measures, road and vehicle technology, responsibility of professionals and the role of education, regulation and enforcement for road safety professionals, as well as for road users. In other words: **take up new challenges and make effective use of new technologies**.

The updated vision also looks back at the results that have already been achieved – fully or only partially. For instance, effective interventions focussed on the prevention of serious road injuries were insufficiently incorporated in the previous edition of Sustainable Safety. Also, further road safety improvements for vulnerable road users deserves more attention from the perspective of current insights. The problems encountered in the past stemming from the implementation of minimally designed 30 and 60 km/h zones should no longer impede the realization of maximum road safety. Road safety would also benefit from **correcting flaws** that stem from failing to sufficiently account for the human dimension as a basis for design and guidelines.

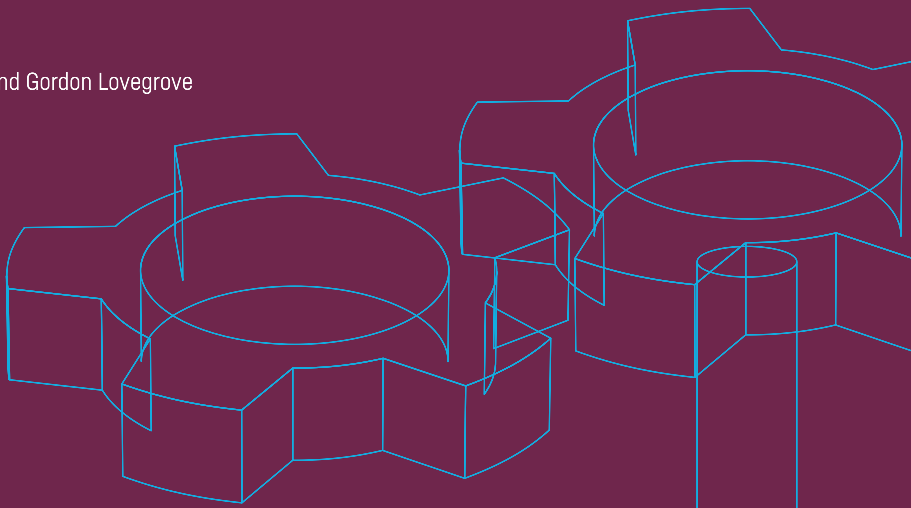
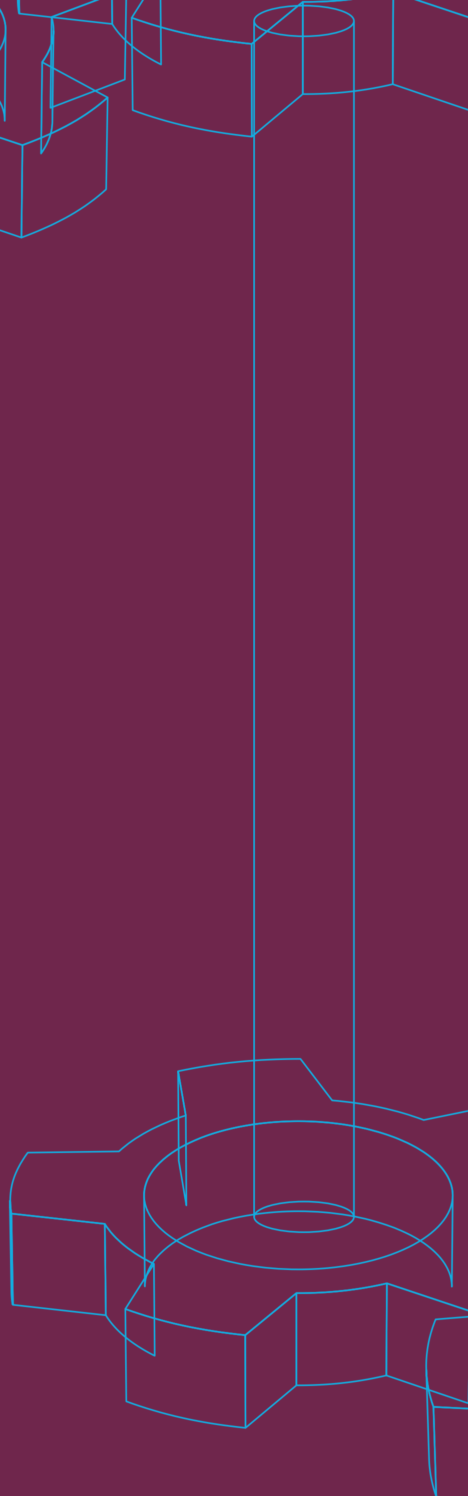
Collaboration

For the further implementation of the updated vision, it is beneficial to collaborate with other organizations and stakeholders. The elaboration of operational requirements clearly calls for collaboration with organizations that are active in the field of regulation, guidelines development, publication and professional education, but also with interest groups representing groups such as motorists, cyclists, and traffic safety advocates. With respect to implementing measures, road authorities and other traffic professionals have the most important role. They will be invited to reflect on how the updated vision may be relevant for their policy and how it may help them in taking new steps.

Opportunities

Current initiatives also offer opportunities to realize a sustainably safe road traffic system. Recently, the Royal Dutch Touring Club together with a number of other organizations launched a *Road Safety Manifest*. The Manifest provides various tools for the short term, including concrete suggestions for taking measures and a request for giving higher priority to road safety. The new *Strategic Road Safety Plan 2030* being prepared by the central government and other road authorities in the Netherlands provides insight into the approach by government authorities as they look towards 2030. Policy directions such as the risk-based approach, the chain-approach to implementation, and the reflection on the 'governance' of road safety policy and ambitions to get to zero (serious and fatal) road casualties, seem to emerge in this strategy. Sustainable Safety's third edition provides the framework to realize these ambitions with maximum safety by adopting the following, most important policy aspects:

- Make clear choices when it concerns the functionality of roads;
- Take vulnerable road users as a basis from the perspective of (bio)mechanics;
- Adjust the traffic system to the competencies of seniors, in accordance with the principle of psychologics;
- Further reflect on the maxim 'decentralize where possible and centralize where needed' for an effective allocation of responsibility;
- Perform in-depth research into all fatal crashes and implement a risk-based approach with SPIs as the basis for learning and innovating.

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Background reports

Schagen, I.N.L.G. van & Aarts, L.T. (2018).
DV3 – Huidige situatie, maatschappelijke trends en wensbeelden;
Kader voor de visie Duurzaam Veilig Wegverkeer 2018-2030.
[Sustainable Safety 3rd edition background report I – Current situation, societal trends and ideals; In Dutch, with a summary in English]
R-2018-6A. SWOV, Den Haag.

Aarts, L.T. & Dijkstra, A. (2018).
DV3 – Achtergronden en uitwerking van de verkeersveiligheidsvisie;
De visie Duurzaam Veilig Wegverkeer voor de periode 2018-2030 onderbouwd.
[Sustainable Safety 3rd edition background report II – Backgrounds and elaboration of the updated road safety vision; In Dutch, with a summary in English]
R-2018-6B. SWOV, Den Haag.

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