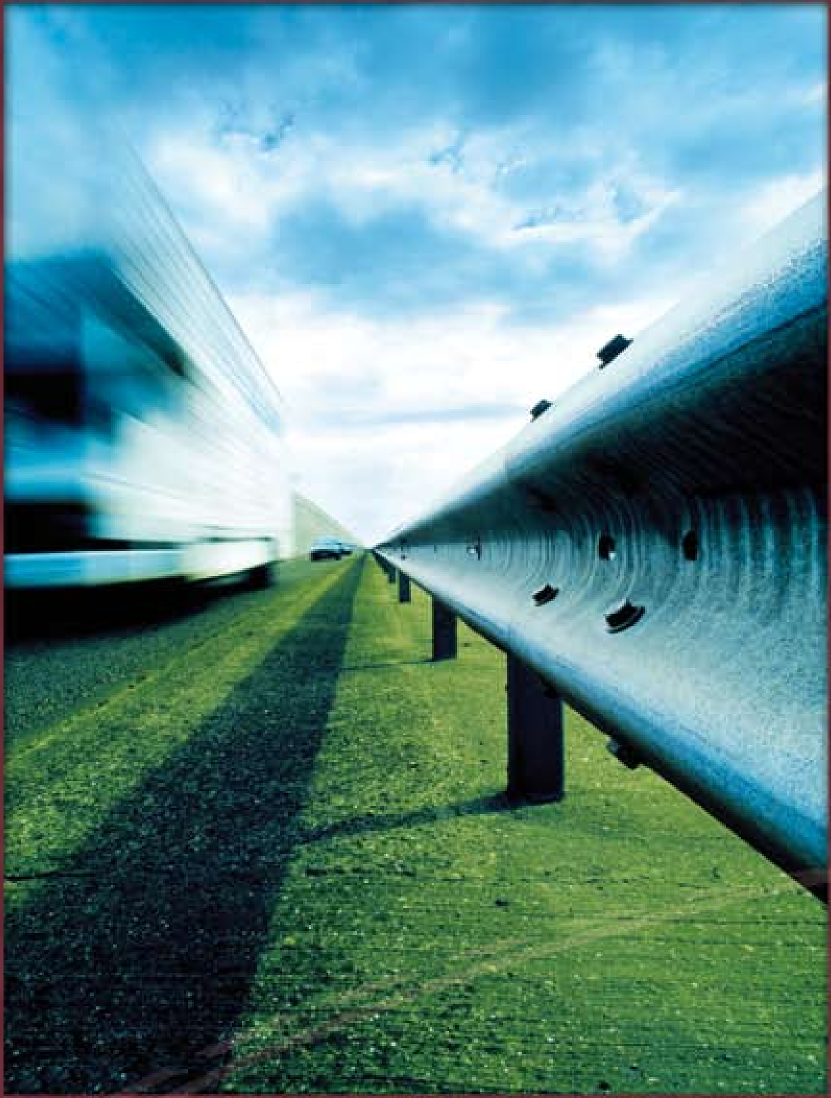
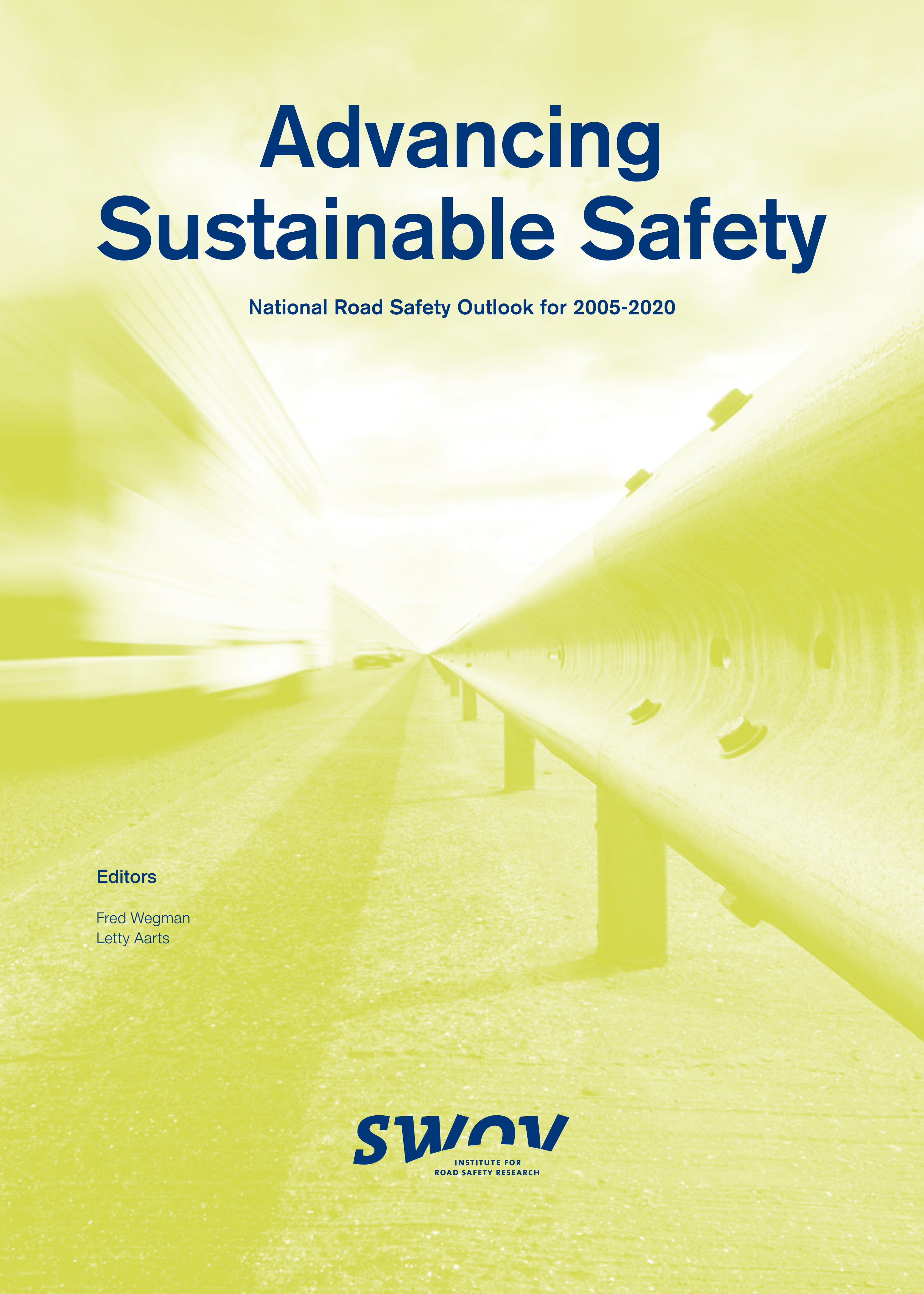
Advancing Sustainable Safety



National Road Safety Outlook for 2005-2020

SWOV Institute for Road Safety Research



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National Road Safety Outlook for 2005-2020

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Preface and acknowledgement

Advancing Sustainable Safety: National Road Safety Outlook for 2005-2020 is the follow-up to *Naar een duurzaam veilig wegverkeer* [Towards sustainably safe road traffic] (Koornstra et al., 1992). *Advancing Sustainable Safety* is a critique of Sustainable Safety. In this advanced version, adaptations have been made, where necessary, based on what we have learned from our first steps towards sustainably safe road traffic. The vision has also been updated in line with new insights and developments.

This book is not a policy document. However, elements of the advanced concept could be further developed in the future, and could provide inspiration for the policy agenda of all levels of government, the private sector and civic society, etc. Every chapter provides many recommendations and possible leads for future road safety policy.

We chose a broader perspective for this book than in 1992. This broader perspective is justified, because we have been able to evaluate the results of our efforts to date. Moreover, there was high demand from practitioners to develop Sustainable Safety for specific problem areas or problem groups. Finally, this perspective offers the opportunity to 'position' the vision again, and to get rid of any misunderstandings. By this means, we want to provide a new stimulus for the further implementation of Sustainable Safety. We hope that this advanced vision will inspire road safety promotion in the Netherlands and abroad in the coming fifteen to twenty years.

Advancing Sustainable Safety is a SWOV initiative and has been published under the auspices of SWOV. Many people, within SWOV and outside, have contributed to this book. Without doing any injustice to other colleagues, I wish to mention two SWOV colleagues in particular, who have made a tremendous contribution: my co-editor Letty Aarts and scientific editor Marijke Tros. Letty's effort since this book was first conceived has been formidable. She was the spider in the web of contacts with other authors, and also with internal and external reviewers. In addition, she contributed to much of the text. In its final stages, Marijke further improved the quality of the book with her perceptive criticism and incisive mind.

The authors of this book are, without exception, true professionals. They are on top of the latest developments and have been able to update the Sustainable Safety vision using their respective expertise. In addition, the collection of essays *Denkend over Duurzaam Veilig* [Thinking about Sustainable Safety] (Wegman & Aarts, 2005) served as an important source of inspiration.

Authors

Many people have contributed to writing this book. Sometimes, the authors of a chapter are easily identifiable. However, there are also chapters which have been based on the contributions of many within and outside SWOV and where authorship is less clear.

The following people from SWOV have contributed to one or more chapters: Letty Aarts, Charlotte Bax, Ragnhild Davidse, Charles Goldenbeld, Theo Janssen, Boudewijn van Kampen, René Mathijssen, Peter Morsink, Ingrid van Schagen, Chris Schoon, Divera Twisk, Willem Vlakveld, Fred Wegman and Paul Wesemann.

At the same time, people outside SWOV have also contributed to the chapters: Maria Kuiken (DHV Consultancy and Engineering), Erik Verhoef and Henk van Gent of Vrije Universiteit Amsterdam, Joop Koppenjan and Martin de Jong of Delft University of Technology, Richard van der Horst, Boudewijn Hoogvelt, Bart van Arem, Leo Kusters and Lieke Berghout of various TNO institutes, and Mars Kerkhof.

Further contributions

Several SWOV people can be mentioned who have helped to bring together information for this book: Maarten Amelink, Niels Bos, Nina Dragutinovic, Atze Dijkstra, Rob Eenink, Marjan Hagenzieker, Jolieke Mesken, Henk Stipdonk and Wim Wijnen. People outside SWOV should also be mentioned, including Rob Methorst (AVV Transport Research Centre), Jeanne Breen (Jeanne Breen Consulting), and Martha Brouwer (Directorate-General for Public Works and Water Management).

In addition, Jane van Aerde, Ineke Fijan, Jolanda Maas and Patrick Rugebregt of SWOV have all contributed to the production of this book.

Internal reviewers

The initial concept chapters of this book were critically read and reviewed internally by one or more people of a so-called 'reading club', consisting of Marjan Hagenzieker, Theo Janssen, Chris Schoon, Divera Twisk and Paul Wesemann.

External reviewers

After the chapters had matured to a stage where they could be considered fit for review, they were sent to various target groups of policy makers and other people 'outside' whose opinions were appreciated. I would like to thank those who made efforts to comment on the material.

From the Dutch Ministry of Transport, Public Works and Water Management, comments were received from:

– Directorate-General for Passenger Transport, Policy Group Road Safety (coordinated by Jonneke van Keep), Christian Zuidema and Cees van Sprundel;
– Directorate-General for Civil Aviation and Freight Transport (coordinated by Janine van Oost);
– Transport Research Centre of the Directorate-General for Public Works and Water Management, with comments from Rob Methorst, Pieter van Vliet (coordination) and Govert Schermers;
– Regional Services of the Directorate-General for Public Works and Water Management, Periodical Road Safety Coordination (with Herman Moning taking care of coordination), Jo Heidendal, Henk Visbeek and Fred Delpeut.

We also received valuable contributions, insights, and comments from the Association of the Provinces of the Netherlands (Jan Ploeger and Gerard Milort); the various Regional Road Safety Bodies: Gerard Kern and Paul Willemsen (Province of Gelderland), Flip Ottjes (Province of Groningen), Hildemarie Schippers and Ewoud Wesslingh (Province of Flevoland), Ada Aalbrecht (Province of Zuid-Holland), Martin Huysse (Province of Zeeland), coordinated by Hans Vergeer and Ben Bouwmeister; the Association of Water Boards (Jac-Paul Spaas and Marcel de Ruijter), and SKVV, the cooperation of metropolitan regions, by Peter Stehouwer.

All these people gave a personal view, rather than presenting their respective organization's viewpoint. We are grateful for their contributions.

Furthermore, we received responses from: Hans Ammerlaan (RDW, Vehicle Technology and Information Centre), Harry Beugelink (Royal Dutch Motorcyclists Organization KNMV), Karel Brookhuis (Groningen University), Carl Koopmans (University of Amsterdam), Dirk Cramer (personal view), Wim van Dalen (National Foundation for Alcohol Prevention), Henri Dijkman (Ministry of Finance), Hans Eckhardt (Police Province of Zeeland), Meine van Essen (Bureau Traffic Enforcement of the Public Prosecution Service BVOM), Tom Heijer (Delft University of Technology), Ad Hellemons (European Traffic Police Network TISPOL), Dries Hop (Police Academy), Ellen Jagtman (Delft University of Technology), Vincent Marchau (Delft University of Technology), Edwin Mienis (Bureau Traffic Enforcement of the Public Prosecution Service BVOM), Paul Poppink (Dutch Employers Organisation on Transport and Logistics TLN), Cok Sas (Municipality of Dordrecht), Paule Schaap (Educational Services Organization CEDIN), Jan van Selm (Province of Flevoland), Wilma Slinger (KpVV Traffic and Transport Platform), Huub Smeets (The Dutch Driving Test Organisation CBR), Frank Steijn (Dutch Employers Organisation on Transport and Logistics TLN), Ron Visser (WODC Research and Documentation Centre), Bert van Wee (Delft University of Technology), Frank van West ('Fédération Internationale d'Automobile' FIA Foundation), Cees Wildervanck ('de Pauwen PenProducten'), Lauk Woltring ('Working with Boys') and Janneke Zomervrucht (Dutch Traffic Safety Association 3VO).

About the translation of the book

Since its inception, Sustainable Safety has attracted a great deal of interest throughout the world. In fact, Sustainable Safety has become one of the authoritative road safety visions. This international interest has inspired us to publish an English translation of the book. The four parts of chapters are called *Analyses*, *Detailing the Vision*, *Special Issues*, and *Implementation*. The first three of these have been translated. The fourth part, entitled *Implementation,* contains many specific features of the Netherlands. To appreciate and understand this sufficiently requires a great deal of knowledge about managerial and financial relations in the Netherlands, as well as knowledge of the decision making process. In light of this, we decided to summarize the original four chapters in this part.

This book was translated by René Bastiaans and Jeanne Breen. They achieved this in a relatively short time and their efforts were impressive. I would like to thank them both for these great efforts!

I want to take this opportunity to thank everybody for their inspiring insights, their creativeness, their critical minds, and the willingness to continue after the umpteenth round of comments and editing. The original version of Sustainable Safety was only available in Dutch. I hope, however, that this book will find its way not only to Dutch readers, but to readers all over the world.

Advancing Sustainable Safety!

Fred Wegman
Managing Director

Contents

Introduction

Road traffic crashes cost too much

In the Netherlands, every year, there are around one thousand deaths and many tens of thousands road users are injured. Compared to other countries, the Netherlands performs very well, and it is one of the safest countries in the world. Currently, the Netherlands tops the world in having the lowest number of fatalities per inhabitant. Dutch road safety policy is often identified as good practice, and the Sustainable Safety vision as leading practice (Peden et al., 2004). Dutch performance commands respect.

At the same time, every year, we have to regret the fact that so many road traffic casualties occur. This represents enormous societal loss. It was calculated that this cost Dutch society nine billion Euros in 2004, including the costs of injuries and material damage caused by road crashes. These costs also comprise intangible costs that are calculated for loss of quality of life for victims and their surviving relatives (SWOV, 2005a).

> "We all come in contact with it. Almost daily. Through newspapers, television and our environment. And still, as long as you haven't experienced it yourself, you will never know what really happens if your life is changed dramatically by a traffic crash from one moment to the other."
>
> *From: Veel verloren maar toch gewonnen; Leven na een verkeersongeluk.* [Much lost, but gained anyway; Life after a road traffic crash]. *Teuny Slotboom, 1992.*

Every year, there is a disaster that is not perceived as a disaster, and which does not get the response that is commensurate with a disaster. One crash with one thousand people killed is a disaster; one thousand deaths in one thousand crashes are as many individual tragedies. The average citizen seems to shrug it off as if all these anonymous deaths are just part of life. The risk of being killed in a road crash seems too abstract a concept to be worried about. However, it is a different story when a fatally injured person is a neighbour, a colleague, a good friend, or your own child. Then there is great dismay about how this could possibly happen, and questions arise as to how this could have been prevented. It is not surprising that Dutch people consider road safety to be of great personal, societal and political importance (Information Council, 2005). But what are the next steps?

The current size of the road safety problem in the Netherlands is characterized as unacceptable, and we strive for further reduction in the number of casualties. 'Permanent road safety improvement' does not say very much, and is more a signal that the subject is not forgotten. Formulating a task is one further step forward, and shows more ambition. Working with quantified targets has been commonplace in the Netherlands for decades. The level of ambition (a reduction in the number of road fatalities by 25% in ten years time) is not out of the ordinary when compared with other countries. The ambition formulated by the European Commission (halving the number of road fatalities in ten years time) is highly ambitious (European Commission, 2001), but has resulted, without any doubt, in the subject being on the agenda in Europe in several Member States. It has led to renewed attention and continuing efforts.

The Dutch *Mobility Paper* (Ministry of Transport, 2004a) states that, while absolute safety and total risk exclusion does not exist, the number of casualties can, without any doubt, be further reduced. There is no lack of ideas, but the question is: at what cost? To this end, SWOV has proposed using the criterion of 'avoidable crashes' (Wegman, 2000). 'Avoidable' in this context means that we know what to do in order to prevent crashes and that it is cost-beneficial in societal terms to do this. In other words: the benefits exceed the costs. Seen from considerations of effectiveness and efficiency, we later added 'and fitting within the Sustainable Safety vision'.

Sustainable Safety: an answer to the lack of road safety

A crash can happen to anyone. Everyone makes errors sometimes in an unguarded moment. In most cases, it turns out all right, because such errors only lead to a crash if the conditions at that moment are such that these errors are not sufficiently absorbed. Examples of this include the presence of other road users who react a fraction too late to oncoming danger, or the presence of a tree in the exact spot where you run off the road in a moment of inattention. There are more than enough examples. Since humans make errors and since there is an even higher risk of fatal error being made if traffic rules set for road safety reasons are intentionally violated, it is of great importance that safety nets absorb these errors. Behold the Sustainable Safety approach in a nutshell! A type of approach that, incidentally, has been commonplace in other transport modes for a much longer time under the name of 'inherently safe'.

Since the launch of the Sustainable Safety vision in the early 1990s (Koornstra et al., 1992), the road safety approach in the Netherlands has shifted from a reactive approach to a general proactive and integral approach to the elements of the traffic system. The idea behind Sustainable Safety was that we have to make our traffic system – with its large speed and mass differences and with its (physically) vulnerable and fallible users – inherently safe. We came to realize that, if we did not want to burden our children with such a dangerous traffic system, something structural had to happen, and a system quantum leap had to be made. At that time, the term 'sustainable' was chosen in order to make a link with ideas concerning a sustainable society and sustainable development.

And it worked. The vision as laid down in the book *Naar een duurzaam veilig wegverkeer* [Towards sustainably safe road traffic] received much support from politicians, from policy makers, from road traffic practitioners, and from interest groups. Subsequently, people started working to implement the theoretical vision in practice. This started in 1995 with several demonstration projects, and eventually resulted in the *Start-up Programme Sustainable Safety* road traffic agreement in 1997 (VNG et al., 1997).
The most salient feats of the *Start-up Programme* include the considerable extension of the number of 30 km/h zones in urban areas, and the establishment of 60 km/h zones outside urban areas. In particular, many infrastructural measures were taken, but there was also preparation in the field of education, such as for permanent traffic education. In the area of enforcement, regional projects were set up. The *Start-up Programme* was meant to finish at the end of 2001, but in order to complete some unfinished matters, it was extended by a year. This laid the way for the start of the next phase of Sustainable Safety.

No waiting around for what the future has in store

We think that a new stimulus is needed. Meanwhile, much experience has been gained with the implementation of Sustainable Safety and infrastructural measures, in particular. Now is a good moment to look back, to reflect on our path to sustainably safe road traffic, and to see if we are still on the right track, or need to alter the course by a few degrees. Apart from the lessons that we can learn from the past, there were other developments – and technological developments in particular; developments that we need, of course, to make use of where they offer new possibilities to improve road safety. In short, enough reasons and a good moment to evaluate the Sustainable Safety vision and to adapt it, where necessary, to new knowledge and recent developments.

This book focuses on the advancing of Sustainable Safety. We hope that the book's contents will stimulate ideas not only in the Netherlands, but also in an international audience, and stimulate new content of work during the next fifteen to twenty years on the way to sustainably safe road traffic.

In the process of thinking about the next steps, we first consulted with a number of professionals in the world of traffic and transport. We asked them to provide their vision about the future of Sustainable Safety. These various ideas have been brought together in a book of essays (Wegman & Aarts, 2005), and these essays have inspired further thinking about the future of Sustainable Safety.

Dutch national road safety outlook 2005-2020

SWOV published the first Dutch National Road Safety Outlook in 1992. This outlook introduced Sustainable Safety as a basis for our thoughts and actions to promote road safety further.

This is the second outlook, and this book also contains a vision. This vision has been developed on the basis of the SWOV mission ("SWOV has a vision to promote road safety and engages in public debate and the preparation of policy development"). Of course, this vision could not be written without making use of the scientific knowledge and creativeness of the many researchers inside and outside SWOV. Just as in the first outlook, SWOV also cooperated with many scientists from various universities and research institutes. This second outlook fits very well with the safety assessment activities that SWOV has carried out since 2003. These activities aim to understand road safety developments, to explain these if possible, and to say something about the future based on this consideration. SWOV aims to produce a quantitatively orientated outlook in which the advanced Sustainable Safety vision as set out in this book is central.

Reading guide

We refer those readers who wish to learn concisely about the update of the Sustainable Safety vision in this book to the next chapter – *Advancing Sustainable Safety in brief*.

The comprehensive exposition of *Sustainable Safety* starts with a section comprising theoretical backgrounds and analyses. The reader will, firstly, find a chapter with general theoretical backgrounds to the Sustainable Safety vision *(Chapter 1)*, followed by analyses of road safety problems in the Netherlands *(Chapter 2)*. The final chapter of Part I *(Chapter 3)* discusses an evaluation of what has been learned during a decade of Sustainable Safety - about implementation and the effects of measures based on that vision.

Part II and III discuss the elaboration in the content of the advanced Sustainable Safety vision. Part II focuses on various types of measures in the field of infrastructure *(Chapter 4)*, vehicles *(Chapter 5)*, Intelligent Transport Systems *(Chapter 6)*, education *(Chapter 7)* and regulation and enforcement directed at road user behaviour *(Chapter 8)*.
Part III focuses on specific problem areas or groups within road safety. We identify these as speed *(Chapter 9)*, drink and drug driving *(Chapter 10)*, young and novice drivers *(Chapter 11)*, cyclists and pedestrians *(Chapter 12)*, motorized two-wheelers *(Chapter 13)* and heavy goods vehicles *(Chapter 14)*.

We conclude this book with a fourth part that sets out in one chapter *(Chapter 15)* implementation aspects and opportunities to advance Sustainable Safety. We discuss the organization of centralized and decentralized policy implementation, we make a proposal for quality assurance of the road traffic system, we review various possibilities for funding road safety measures, and we discuss various aspects that can be characterized as accompanying policy.

We wish readers much inspiration from this book, and we hope to inspire many people in making road transport in the world safer.

Advancing Sustainable Safety in brief

"In a sustainably safe road traffic system, infrastructure design inherently and drastically reduces crash risk. Should a crash occur, the process that determines crash severity is conditioned in such a way that severe injury is almost excluded."

From: Naar een duurzaam veilig wegverkeer [Towards sustainably safe road traffic], *Koornstra et al., 1992.*

The concept of Sustainable Safety was launched in 1992 with the ambition stated above. Since then, SWOV has stated that road traffic should be looked at in the same way as other transport systems. And why not? Just as with other transport modes, death and severe injury due to lack of safety is not inevitable or unavoidable like a natural disaster or a mystery disease. The Sustainable Safety vision specifies that safety should be a design requirement in road traffic in the same way as in the design of (nuclear) energy plants, refineries, or waste incinerators, and also air and rail transport.

If we want to integrate safety as a design requirement in road traffic, we have first to recognize that society appears to be prepared to accept many road crash casualties. Paradoxically, in a country like the Netherlands, we would never accept three wide-bodied aircraft crashes in a year. Even a single plane crash evokes a dramatic societal response.

Despite the downward trend of the annual number of road casualties over the past decades, the current number is still considered too high, given the fact that there is wide political support in the Dutch Parliament to reduce these numbers further. This downward trend is, by the way, the result of many efforts, small and large, to improve road safety. Such efforts were made over a period of many years, and proved to be effective (Koornstra et al., 2002). However, as traffic volumes increase, we have to maintain our efforts in order to prevent the number of road casualties from spiralling upwards.

Sustainable Safety is a vision that was translated into specific action plans in the 1990s; plans that have, in the main, been implemented. This does not mean that our current road system is entirely sustainably safe now, but important steps have been made. And now the time is right to take the next steps.

In updating the vision and its implementation, we concluded that the Sustainable Safety concept, formulated some 15 years ago now, is still a good starting point. However, particularly with respect to implementation, we need to define new emphases. This shift of emphasis is based on our experiences in the implementation of Sustainable Safety measures in recent years, the fact that other and new intervention possibilities have become available, and – last but not least – that the initiation, carrying out and monitoring of traffic and transport policy in the Netherlands all operate under a different system now (Ministry of Transport, 2004a).

Is it possible to improve road safety still further, or are we bound to be the victim of the law of diminishing returns? If this means that the next steps are increasingly more difficult to take than the previous ones, then we believe that this is true. If we understand this law of diminishing returns in such a way that we cannot realize further improvements, then the comparison is at fault, as this book illustrates.

The *Mobility Paper* (Ministry of Transport, 2004a) states that absolute safety and an exclusion of all risk is impossible. Nevertheless, there is no doubt that the number of road casualties can be reduced. There is no lack of ideas, but the question is: at what cost? SWOV proposed the use of the criterion of 'avoidable crashes' (Wegman, 2000). By 'avoidable' we mean that we know what to do in order to prevent a crash as well as knowing that it is cost-effective in societal terms. In other words: the benefits outweigh the costs. From a viewpoint of effectiveness and efficiency, we later added that measures have to fit within the Sustainable Safety vision.

The principles of Sustainable Safety

The opening quotation asserts that the objective of Sustainable Safety was and still is to prevent road crashes from happening, and where this is not feasible to reduce the incidence of (severe) injuries whenever possible. This can be achieved by a proactive approach in which human characteristics are used as the starting point: a user-oriented system approach. These characteristics refer on the one hand to human physical vulnerability, and on the other hand to human (cognitive) *capacities and limitations*. People regularly make errors unintentionally and are not always able to perform their tasks as they should. Furthermore, people are also not always willing to comply with rules and violate them intentionally. By tailoring the environment (e.g. the road or the vehicle) to human characteristics, and by preparing the road user for traffic tasks (by training and education), we can achieve an inherently safe road traffic system.

The most important features of inherently or sustainably safe traffic are that *latent errors* in the traffic system (gaps in the system that result in human errors or traffic violations causing crashes) are, as far as possible, prevented and that *road safety depends as little as possible on individual road user decisions*. The responsibility for safe road use should not be placed solely on the shoulders of road users but also on those who are responsible for the design and operation of the various elements of the traffic system (such as infrastructure, vehicles and education).

A set of guiding principles has been developed to achieve sustainably safe road traffic. The old principles from the original Sustainable Safety vision have been reformulated where appropriate, and some new principles have been added. This results in the five Sustainable Safety principles of *Table 1*. These principles have all been based on scientific theories and research methods arising from disciplines such as psychology, biomechanics and traffic engineering.

Traffic planning

Flow of traffic manifests itself in many ways and with various and different objectives. As long ago as the 1970s, a functional road categorization system had been introduced which formed the basis for the Sustainable Safety *functionality principle*. This principle starts from the premise that roads can only have a single function *(monofunctionality)* and that they must be used in keeping with that function. The road function can, on the one hand, be 'to facilitate traffic flow' (associated with 'through roads'), and, on the other hand, 'to provide access to destinations' (associated with 'access roads'). In order to provide a proper transition between 'giving access' and 'facilitating traffic flow', a third category was defined: the 'distributor road'. The advanced version of Sustainable Safety maintains these three main categories as the basis for a functional categorization of the road network.

Preventing dangerous actions

People can perform tasks at different levels of control: skill-based, rule-based or knowledge-based (Rasmussen, 1983). Generally speaking, the longer people are trained in performing a task, the more automatic their behaviour. The benefit is that task performance requires less time and attention, and that fewer (serious) errors are made (Reason, 1990). To

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 in speed, direction, and mass at medium 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 in 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 task capability to handle the driving task

Table 1

prevent dangerous actions, Sustainable Safety strives to avoid knowledge-based task performance in particular. People have to be sufficiently capable and experienced to take part in traffic, but they also need to perceive what is expected from them and what they can expect from other road users. This is manifest in the *predictability principle*, the benefits of which can be delivered, according to the advanced Sustainable Safety vision, by *consistency and continuity* in road design. This means that the design needs to support the user's expectations of the road, and that all components of the design needs to be in line with these expectations.

People not only act dangerously because they make errors unintentionally; they can also exhibit dangerous behaviour by intentionally violating traffic rules. The original Sustainable Safety vision did not yet take these 'unwilling' people into account, but the advanced vision includes them. In situations where the road environment does not stimulate proper behaviour, a sustainably safe road traffic system benefits from road users who spontaneously obey traffic rules from a normative point of view. To achieve this, traffic regulations have to fit with the environment, and people have to be educated about the logic and usefulness of rules. Where people still fail to comply with the rules, police enforcement to a level where a reasonable chance of being caught is perceived is the usual measure to enforce compliance.

Another element in the advanced vision is that traffic has to be sustainably safe for *everybody*, and not just for 'the average road user'. Fuller's task capability interface model (Fuller, 2005) supplies a theoretical framework here. Fuller's model states that road users' task capability is the sum of their capacities less the sum of their impairments caused by their present state (e.g. because of fatigue or use of alcohol). For safe road use, the task capability has to be large enough to meet the task requirements. These task requirements are primarily dictated by the environment, but they can also be altered by the road user, for instance by increasing or decreasing driving speed.

A new element in Sustainable Safety is the principle of *state awareness*. This principle requires that road users should be able to assess their own task capability for participating in traffic. Task capability can be insufficient due to a lack of competence (e.g. because of a lack of driving experience), or because of – or aggravated by – a state of mind that temporarily reduces the task capability (e.g. because of fatigue, or the use of alcohol or drugs).

Since task capability differs between individuals (e.g. inexperienced and elderly road users with underdeveloped or diminishing competences respectively, and also fatigued 'average' road users, or road users under the influence of alcohol or drugs), generic road safety measures are a necessary basis for safe traffic. However, for the group of road users with a lower task capability in particular, these measures are not sufficient for safe participation in traffic. Therefore, *generic measures* have to be supplemented with *specific measures* aimed at these groups or situations involving them. Specific measures can be found in the areas such as regulation, education, enforcement (e.g. banning drivers under the influence of alcohol or drugs), and Intelligent Transport Systems (ITS).

Dangerous actions can also be affected by explaining and gaining support for the principle of social *forgivingness*. More experienced road users can, by means of forgiving driving behaviour (in terms of being anticipative or defensive), increase the room for manoeuvre of less experienced road users. Errors should still be regarded as errors by the less experienced, in order that they can learn, but a forgiving approach should lead to fewer or less serious crashes.

Dealing with physical vulnerability

If road users perform dangerous actions that lead to crashes, the human body's integrity is jeopardized. This vulnerability results from the release of kinetic energy and the body's biomechanical properties.

Road types combined with allowed 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

To deal with the issue of vulnerability in a proactive fashion, Sustainable Safety requires that controls are placed on factors that may intensify the severity of a crash: differences in speed, direction and mass. This forms the foundation of the *homogeneity principle*. This principle states that, where vehicles or road users with great differences in mass have to use the same road space, speeds will have to be so low that, should a crash occur, the most vulnerable road users involved should not sustain fatal injuries. In addition, where traffic is moving at high speeds, road users should be separated physically. Based both on crash tests between pedestrians and cars, and on ideas developed in the Swedish Zero Vision (Tingvall & Haworth, 1999), the advanced Sustainable Safety vision proposes safe speeds for different situations (see *Table 2*).

Unfortunately, we do not yet have sufficient scientific knowledge to define safe speeds for motorized two-wheelers and heavy vehicles. This issue has also not yet been resolved in practical terms. Separation from other traffic would be the best solution, but it is unclear how this can be realized in practice.

The principle of physical *forgivingness* (a forgiving roadside) can also contribute to reducing injury severity in crashes.

Improved road safety in the Netherlands

Road safety developments

The first road crash victim died in the Netherlands more than one hundred years ago, and since then, mobility and the number of road casualties has grown quickly. In the early 1970s though, a trend evolved of increasing mobility combined with improved road safety. This trend still exists, albeit with some discontinuities over the years. This downward trend in the number of road casualties is also visible if viewed as a cross section by a) road transport means, b) road type and c) age group.

Two types of road traffic participation stand out in this type of analysis: motorized two-wheeled vehicles (due to the relatively high risks), and the passenger car (due to its dominant role in road crashes: the number of car occupant casualties is comparatively high, but risks are relatively low and are decreasing steadily). The car performs a double role in road crashes. In conflict with vulnerable road users (i.e. pedestrians and cyclists), the car is a disproportionately strong crash opponent; in conflict with heavy goods vehicles and in single-vehicle crashes against fixed roadside objects, they are the weaker party. These single-vehicle crashes occur quite frequently on rural roads. Rural roads allowing all kinds of traffic participants yield the highest risks, probably because of the relatively high speeds in combination with the mix of different types of road user.

Looking at the number of road casualties and the risks of different age groups combined with gender, it is striking that both young people (particularly young males) and the elderly (aged over 75 years) have a higher risk of being involved in a crash. The reasons are, in particular, age-specific characteristics, and for young people the added lack of experience in road use.

Looking at road safety in the Netherlands in an international context, it is apparent that we are amongst the safest countries in the European Union and the world. Compared with other well-known top performers – Sweden and the United Kingdom most notably – road safety statistics reveal that the Netherlands has achieved the highest reduction in the number of road casualties and, currently, the Dutch road safety performance level is on a par with these two other countries. Nevertheless, the current number of road casualties is still considered unacceptably high in all three countries.

Causes of road crashes

What makes road traffic so dangerous? This is due to several basic risk factors: high speeds, large differences in speeds and masses between road users, and people's physical vulnerability. In addition, there are a number of road user factors that further increase crash risk, such as lack of experience (a particular problem for young road users), use of psychoactive substances (including alcohol and prescribed or illicit drugs), fatigue, emotional state and distraction (e.g. due to use of mobile phones while driving).

What causes crashes? In the original version of Sustainable Safety, the starting point was that crashes were in the end caused by predominantly unintentional errors by road users. Since it is quite often stated that hard-core or repeat offenders cause crashes, we have tried to investigate the distribution of crash causes. This has led to the view that it is quite often difficult to attribute crash causes to actions that are either 'unintentional errors' or 'deliberate violations'. Material such as police crash registration forms, often fall short in their examination of the road user actions that precede crashes. Moreover, a combination of factors is usually involved, making it even more difficult to separate out the specific cause. Nevertheless, the view emerges that deliberate violations cannot be neglected as a factor that increases the probability of a crash.

Relevant future developments

We can discern several societal developments that may have an impact on (tackling) road safety in the future. Firstly, increasing mobility is coupled with increasing economic growth, both for passenger and freight traffic. It is not yet clear what this means for traffic distribution over the available road network with regard to travel times, speeds and modal distribution. We do not yet know what the impact of a different way of road use pricing will be, but the impact will be small in the short term. We may expect that economic growth will also bring further quality improvement in the vehicle fleet. The 24-hour economy will undoubtedly bring about increasing fatigue in road users.

Taking demographic trends into consideration, we can discern an overall ageing of the population. Ageing combined with increasing individual choice will probably mean a wider urban sprawl, requiring longer travel distances. In addition, the lifestyle of double-income families gives rise to more vehicle use because commuter traffic tends to be combined with the dropping-off and picking-up of schoolchildren.

Countries, such as the Netherlands, will continue to be a home to many cultures. Against this background, certain groups of young people exhibit behaviour that causes a sense of discomfort and insecurity in society. An increased societal aggression and intolerance is perceived that can affect road traffic. The increased call for 'norms and values' coincides with an increased demand for a clean and healthy environment. We can expect that this will have an impact on the organization of spatial planning. Road safety considerations deserve a prominent place in these processes.

Finally, implementation of policies clearly shows a tendency towards decentralization on the one hand, and more EU influence on the other. Moreover, citizens will get more responsibilities in general terms with decreasing governmental responsibilities. This increase in personal (and road user) responsibilities and the corresponding decrease in governmental responsibilities suggest that the improvement of safety in an already busy road traffic system can only be safeguarded by centrally structured measures based on the Sustainable Safety vision.

Sustainable Safety in the past years: together on the right track?

Sustainable Safety has caught on in the Netherlands and it has become a leading vision to further improve road safety. It is apparent that Sustainable Safety appeals to, and is valued by road safety professionals, and is internationally regarded as an authoritative vision. However, outside the inner circle of road safety professionals, relatively few people know about Sustainable Safety.

After the launch of Sustainable Safety in 1992, several steps were taken to implement road safety measures in line with the vision. Perhaps the most important step was the *Start-up Programme Sustainable Safety*: a covenant with 24 agreements between the national government and regional and local authorities (VNG et al., 1997).

Making road infrastructure safer was a visible prime consideration in the execution of Sustainable Safety. This thinking was both understandable and correct ("*crash occurrence is a priori dramatically reduced by infrastructure design*", Koornstra et al., 1992). Nevertheless, this narrow interpretation does not do full justice to the vision; the vision was actually broader in orientation. Page 20 of Koornstra et al. reads: "*The sustainably safe traffic system has an infrastructure that is adapted in design to human capabilities, vehicles having means to support and simplify human tasks and that are constructed to protect the vulnerable road user, and a road user who is trained, educated and informed adequately, and controlled where necessary*." The vision certainly has been translated into road infrastructure design adapted to human capabilities, both in terms of road design handbooks and guidelines and in actual road construction. However, we have to point out that, along the way, concessions have been made in respect of the use of low-cost solutions, in particular concerning a general 30 km/h speed limit in urban areas and a 60 km/h speed limit on rural access roads instead of lower, safer limits. These low-cost solutions were understandable in order that support for Sustainable Safety could be gathered and also to start off quickly, but we now have to see if the implementation has been too low-cost to be effective.

Improvements in secondary vehicle safety (injury prevention) have been advancing, e.g. through EuroNCAP (European New Car Assessment Programme). However, this does not appear to have been stimulated by Sustainable Safety. In-car and out-of-car provisions to simplify and assist driver tasks have been advancing, particularly in the area of ITS (Intelligent Transport Systems) but actual system and product developments in this field have only become visible in the past few years. The role of road safety in this process is still unclear.

Finally, with reference to the "*road user who is trained, educated and informed adequately, and controlled where necessary*", we have to conclude that the Sustainable Safety perspective has not been very inspiring in realizing this ambition. The three areas of driver/rider training, traffic education and police enforcement have advanced, but relatively independently of Sustainable Safety. This, in turn, means that we do not yet have a sustainably, safe development plan for these three areas.

The *Start-up Programme Sustainable Safety* can be hailed as a success, both as a process of cooperation and in the area of implementation. Cooperation between the various levels of administrative authorities was evident both in the preparation of the *Start-up Programme* and during its subsequent execution. Regional and local authorities participated enthusiastically in the execution of (parts of) the *Start-up Programme*. The extent of their enthusiasm becomes clearer when taking into account that they put more of their own budgets into the *Programme* than was agreed in the subsidy scheme.

Does the *Start-up Programme Sustainable Safety* give a good synthesis of the Sustainable Safety vision? In broad terms it does, provided we accept that the objective was to implement measures relatively quickly. For instance, the basic agreement concerning the categorization of roads has been of great importance. Putting access roads to the fore has been a conscious choice within the *Start-up Programme.* This was an attractive idea because there was much support within the population in general to do something about the problems on this type of road. It also created the opportunity to categorize the whole road network, which has now been completed. However, the emphasis on access roads has drawn attention away from distributor roads, which have a comparatively high crash risk. Despite the fact that this was understandable and reasonable (the problems are great and the possibilities for solutions limited) this meant that a large part of the problem has not yet been tackled, apart from the construction of roundabouts.

An important concern of practitioners was to implement certain measures in a low-cost way because of the limited financial means. With hindsight, we have to conclude that this was overdone. If we take as a starting point that there should be no severe road injuries in 30 or 60 km/h zones, we can deduce that this problem has not yet been solved, as we still have fatalities and casualties admitted to hospital in these areas every year. There are indications that the intended speed reduction of motorized traffic has not taken place. There is also an impression that the national road authority did not feel challenged by the Sustainable Safety vision, as there is no highly visible sign of action that we can speak of in this area.

With respect to accompanying policy, the *Start-up Programme* has greatly facilitated the dissemination and sharing of acquired knowledge, particularly between local authorities. Websites, brochures, newsletters, platforms and working groups provided ample evidence of this. The Infopoint Sustainable Safety has played a central role here. However, one of the points that was missing was a structural evaluation of measures on which the continuation of Sustainable Safety could build. The lack of knowledge of education is also worth noting. Much knowledge can still be gained concerning infrastructural measures. This knowledge is necessary to be able to make cost-effective advances in the battle for road safety. Based on the existing knowledge, it has been estimated that the aggregate effect of all implemented infrastructural measures within the framework of Sustainable Safety has resulted in a reduction of 6% in the number of road fatalities and hospital admissions (Wegman et al., 2006).

So, our road system is not yet sustainably safe but we are on the right track. Further progress can be made with the content of the *Start-up Programme*, particularly improvements in the integration of different road safety measures. It is advisable to involve all the stakeholders, such as the police, judicial authorities, interest groups, and the private sector in this implementation process. To achieve this end and taking into consideration the decentralization of policy implementation, a different executive organization than the *Start-up Programme Sustainable Safety* initiated by the Ministry of Transport, Public Works and Water Management will have to be found. This is the aim of a Road Safety Agreement proposed by SWOV and the Dutch Tourist Club ANWB (Wegman, 2004), which in the meantime has taken shape as a National Road Safety Initiative.

It can justifiably be concluded that following the chosen path is advisable but with adaptations and adjustments to the vision, resulting in the advanced Sustainable Safety vision described in this book. The *Start-up Programme Sustainable Safety* was a start. We hope that this advanced vision will lead to new partnerships that can deliver the next steps to sustainably safe road traffic.

Infrastructure

Infrastructure planning and design is an important subject in Sustainable Safety. The principles of *functionality, homogeneity* and *predictability* have always been central. We want to maintain these three principles in the future, with *forgivingness* (a forgiving road environment) added as a fourth principle concerning infrastructure.

Large progress has been made in the translation of the original three principles into guidelines for road design and into practical implementation, showing positive safety results. At the same time, we have to conclude that some problems are still waiting for a solution. With respect to functionality, we need to set requirements for categorization plans at network level. Furthermore, we will have to keep defining essential characteristics of the three Sustainable Safety road categories, and not to restrict ourselves to the agreed and so-called 'essential recognizability characteristics'. We also need to develop essential characteristics for intersections.

The principle of *homogeneity* has been developed further in Sustainable Safety with the idea that, prior to a collision, speeds are limited to a level such that only 'safe crash speeds' pertain. This idea is not found in existing design guidelines. On distributor roads and access roads outside urban areas, discrepancies exist between these accentuated speed requirements and current practice. Many road authorities struggle to decide how to design and construct these roads in a truly sustainably safe way. Our understanding of recognizability and predictability of road course and other road users' behaviour has grown, but not yet to the extent that this principle is put into practice based on our knowledge. The new principle (*forgivingness*) was in fact already embedded in Sustainable Safety, but it is appropriate to position it explicitly. Meanwhile, sufficient knowledge has been gathered to apply this principle in full.

Taking an overview of infrastructure, we have to conclude that we do not know exactly what sustainably safe road infrastructure really means, nor do we know the true effect of low-cost solutions. We propose some improvements for sustainably safe infrastructure in this book. We think it advisable to set up a platform for the discussion of these proposals, and perhaps to do this by means of a road safety agreement. Various infrastructure problems that we refer to could be analysed using this platform, and possible solutions developed. This should form the basis for a multi-annual research programme directed at these problems and linked with information dissemination.

Vehicles

In the past, improvements in vehicle safety have contributed considerably to the reduction in the number of road crash casualties, particularly by preventing severe injury. This raises the question as to what further improvements are possible and how these can be realized. We need to be aware that an insular Dutch policy can only make a modest contribution in this area because other processes are dominant: international regulations (the European Union in Brussels and the United Nations Economic Commission for Europe in Geneva), activities of vehicle manufacturers themselves, and developments such as the EuroNCAP programme (a combination of national authorities, research institutes and consumer organizations that rate vehicle safety performance by means of a 'star system').

We need to be aware that there are developments in areas other than road safety, which have had, or will have in the future, an impact on vehicle safety. Examples are cleaner and quieter vehicles, increased vehicle mass, application of new technologies (ITS, hybrid vehicles), alongside consumer demands (e.g. wanting to drive an SUV). We need to investigate in a more structural way whether or not these developments yield opportunities for road safety or are a threat to it.

In the Sustainable Safety vision, vehicle safety occupies an important position because the outcome of certain crash types is determined by crash speed and direction, and the protection that the vehicle provides (to the occupants and to crash opponents). From this perspective (the perspective of the *homogeneity* principle), stricter requirements need to be put on road infrastructure design and heavy vehicles on the one hand, and on cars relative to vulnerable road users (pedestrians, cyclists, and also motorized two-wheeled vehicles) on the other hand. Travel speeds need to be adapted appropriately. This will have to be the norm for the design of our road traffic.

In the area of primary safety (crash prevention), the development of intelligent vehicle systems comes to mind. In secondary safety (injury prevention), it is to be expected that the process initiated with EuroNCAP will continue to bear fruit in the future. It is advisable to expand crash test types (rear-end collisions – to prevent whiplash) and to promote crash compatibility, and also testing of primary safety. Technological developments will increase the effectiveness of seat belts and airbags. The traditional role of European regulation is still desirable. One point of concern is the increasing incompatibility between passenger cars (particularly because of the SUV).

Intelligent Transport Systems

The application of Intelligent Transport Systems (ITS) deserves a prominent place in the advanced Sustainable Safety vision. ITS are an important means of making road safety less dependent on the individual choices of road users. It is estimated that safety-directed ITS may lead to 40% fewer fatalities and injuries. However, in reality, a large part of the possibilities to reach this estimate have not fully matured yet, and it is possible that large-scale implementation may run into a variety of problems. We recommend adhering to strong, promising ITS developments, for areas such as congestion reduction and comfort improvement. Road safety should be better integrated in the development process.

In the area of road safety, we recommend directing attention to information providing and warning system variants aimed at speed adaptation and dynamic speed limits (Intelligent Speed Assistant as a support system for road *recognizability*) for the time being. A second area is to guide road users along the shortest and safest routes, using navigation systems. In a next phase, we can think of more advanced systems, such as ITS applications that control traffic access (valid driving licences key, alcolocks). Seatbelt locks are another possibility. In the still longer term, we will have to think more of automated traffic flow management in order to realize a truly sustainably safe traffic system. Nevertheless, it is worth remarking that it would be unwise to stop applying traditional measures and to wait for the introduction of ITS applications; the future is too uncertain for that.

More than ever before, a joint effort of all the relevant stakeholders in ITS implementation (public authorities, industry, academic and research institutions, interest groups, consumer representatives, etc.) is required to direct this potentially effective innovation towards casualty reduction. Perhaps, it is worthwhile to consider whether or not a road safety agreement on the subject of 'Sustainable Safety and ITS' can play a facilitating role here.

Education

Traffic education in various forms plays an important, albeit perhaps underexposed role in Sustainable Safety up to now. By the term 'education', we mean teaching, instruction (aimed at specific roles in traffic, such as driver training) and campaigns. Within sustainably safe road traffic, it is important also to use people's capacity to teach themselves. In our view, education should aim at five behavioural themes: 1) creating an adequate understanding of the road safety problem and an acceptance of Sustainable Safety measures as a means to improve road safety; 2) encouraging the making of conscious strategic choices (modal or vehicle choice, route choice); 3) counteracting intentional violations; 4) preventing the development of undesirable or incorrect behaviour; 5) preparing 'novices' as much as possible. Education is not a panacea, it cannot be a substitute for other interventions (a sustainably safe road user environment), but it does provide an essential complement to them.

For 'learning', we have to take human characteristics as a starting point. By taking into consideration, more than in the past, that road users learn continuously from their experiences, it is possible to assemble a coherent package of measures to direct the learning process in the direction desired. Formal education is required to teach correct behavioural routines; however, practicing these routines needs to take place in informal education. Education's key task is to focus on those subjects that are difficult to be learned directly from traffic because the relationships cannot be clearly deduced. Examples are: the relation of road safety to driving speed, the organization of the transport system, the road design and the allowed manoeuvres (e.g. understanding the 'essential recognizability characteristics'), overestimation of ones capacities, and so on. This may also help to make the principles of *state awareness* and *forgiving* road user behaviour more tangible. More attention needs to be devoted to education aimed at minimizing exposure to dangerous situations.

Current traffic education is overly directed towards training in operational skills, and too little towards acquiring an understanding of traffic that supports safe participation in it. Above all, traffic education has become a matter of the government (including schools) to a greater extent than necessary, and this has caused the education to be less effective. It is necessary to broaden educational care, particularly where operational training of novices is put back into the hands of parents and carers. To create such a 'broader learning environment, consisting of both formal and informal education, coordination between organizations and guidance on content are needed in order to help these organizations carry out their tasks with competently and with sufficient resource. Central government has an important directorial role to play here.

Regulations and their enforcement

In sustainably safe road traffic, regulation forms a foundation for the safety management of traffic processes, minimizing latent system errors, and restraining risk factors. Ideally, in sustainably safe road traffic people comply with the rules (spontaneously) without having to make an effort and without feeling negative about it. On the one hand, this can be accomplished by adapting the traffic environment (such as infrastructure and vehicles) in such a way that it supports the (prevailing) rules as much as possible. This would be the basis to prevent latent errors in the traffic system, because it tackles the cause of traffic violations at the earliest possible stage. On the other hand, intrinsic motivation could prompt people to comply with rules spontaneously.

Unfortunately, spontaneous traffic rule compliance is far from being a reality and it is highly doubtful that it could be relied on in the future. Not everyone is always motivated to comply with the rules, not even when the environment has been adapted optimally. The threat of penalties is needed to deter these road users not to comply with the rules, for instance by making the cost for non-compliance outweigh the perceived benefits of it. Current enforcement practice can be optimized by using more effective and efficient methods. More research can show us the way. Specific enforcement, focused on target groups and inspection prior to taking part in traffic, fits within sustainably safe road traffic (an aid in the principle of *state awareness*). In order to lower the number of violations substantially, intelligent transport systems provide some solutions for the future. To prevent people violating rules unintentionally, intelligent systems can be employed as advisory systems. For dedicated target groups, this type of system can also be used as a radical, coercive variant (such as for recidivists or serious offenders). These systems may become commonplace in the more distant future.

Speed management

Speed and speed management are key elements in Sustainable Safety, because speed plays an important role both in crash risk and in crash severity. That is why speed is addressed in all (original) Sustainable Safety principles, more particularly in homogeneous road use. With respect to speed, the essential matter is to manage crash speed in such a way that severe injury is almost completely ruled out, starting with certain types of crash (e.g. frontal and side impacts) and the level of protection for car occupants. Where there is less protection (e.g. for pedestrians), crash speeds should be lower.

We recommend making safe speed limits as a point of departure for the whole of the Dutch road network. However, we are not blind to the fact that many current speed limits are being very widely flouted, and some individual road users experience 'going fast' as fun, exciting and challenging. SWOV estimated that if everyone were to comply with existing speed limits, this would lead to a reduction of 25% to 30% in the number of casualties (Oei, 2001). If safe speed limits were to be introduced and if road users complied with them, the benefits could be even greater. Speed limits have to be credible for the road user; that is: they have to be seen as logical in the given circumstances. In the short term, apart from setting safe and credible limits, good information needs to be given to road users (principle of *predictability*). Next, we have two instruments that have proved effective in the past and that, if put into practice appropriately, will also be usable in the future: physical speed reducing measures and police enforcement. In the longer term and making use of ITS, we recommend that speed limits are made dynamic. This will result in speed limits that are not coupled inflexibly with a given road, but are adapted to prevailing conditions.

In order to attain sustainably safe speeds in the Netherlands, the phased plan that follows can be used:
– to identify criteria for safe and credible speed limits and minimum requirements for road user information;
– to survey the Dutch road network in order to assess if the road environment and the existing speed limits are in conformity with each other, and to implement adaptations (to the road environment or the speed limit) where necessary;
– to re-orientate regarding enforcement of speeds of intentional violators;
– to prepare for and to introduce dynamic speed limits.

We recommend to look for appropriate harmonization of speeds that serves safety, the environment and accessibility.

Drink and drug driving

Driving under the influence of alcohol continues to be a persistent problem. In recent years, drugged driving has created an additional problem. Simultaneous use of different drugs and combined use of alcohol and drugs brings about a considerable increase in crash and injury risk. Although driving under the influence of alcohol may have decreased dramatically over the past decades, the decrease in the number of casualties has fallen short of expectations. Apart from an increase in the combined use of alcohol and drugs, the number of serious offences has decreased less than the number of less serious violations. Heavy drinkers may constitute only a fraction of all offenders, but they are responsible for three-quarters of all alcohol-related casualties. Furthermore, current problems are concentrated during the night, as they were in the past, with customers of the catering industry (e.g. pubs, bars and restaurants) and with young males. Combined use of alcohol and drugs is most prevalent in this latter group.

The approach to combating drink driving takes place at several levels: through legislation, police enforcement, education, punishment, rehabilitation and exclusion. In some of these areas, considerable further gains can be achieved. The chosen policies can be maintained for the fight against driving under the influence of alcohol. The number of offenders reached an all-time low in 2004. Police enforcement on alcohol use has doubled since 2000, particularly since the setting up of dedicated traffic police enforcement teams. In the Netherlands, more than two million road users are tested for alcohol annually. We recommend the dedication of part of the total enforcement capacity to serious offenders. Much can also be improved in the area of rehabilitation of alcohol offenders, particularly by fitting the cars of more serious offenders with alcolocks (principle of *state awareness*).

Of all new measures mentioned against drink driving, the alcolock fits best with the Sustainable Safety vision. The alcolock has proved effective with convicted drivers and the system should be introduced in the Netherlands as quickly as possible. Perhaps in the longer term, all cars can be fitted with alcolocks. However, before that decision is taken, the question of whether or not compulsory use of alcolocks for all road users yields a safety benefit that outweighs the costs and other possible disadvantages must be answered. If the answer is a resounding “yes”, it will probably not be difficult to get sufficient support from the population in general and politically for the introduction of this measure. Social acceptance of driving under the influence of alcohol is very low in the Netherlands.

Lowest possible limits (so-called zero limits) need to be established for all drugs used in combination with other drugs or with alcohol. Efficient policing of drug use is made almost impossible due to the lack of legal limits and associated detection devices. However, easily usable saliva and sweat tests have been much improved in recent years. Within a few years, EU research results can be expected in this field.

Young and novice drivers

Sustainable Safety originally started out from the ‘human measure’ of the ‘average’ (relatively experienced) road user. However, young people taking part in traffic for the first time on their own (as cyclist, moped rider, motorcyclist or car driver) do not have the skills that older, more experienced road users possess. Young road users behave more dangerously than other age groups. Generally speaking, the start of a driving or riding career corresponds with a relatively high risk of crash. The comparatively high risks are caused by a combination of lack of experience and age-specific (biological, social and psychological) characteristics. A sustainably safe environment will lead to lower risks because the lack of experience is compensated for by a safer environment (generic measures). This risk can be reduced further by ensuring that young people take part in traffic in less dangerous circumstances (specific measures, e.g. driving without passengers at night).

Education and traffic enforcement can be made more effective more easily if the environment has been designed to be sustainably safe. Less emphasis should be put on education and driver or rider training in basic skills, and more on acquiring an understanding of the traffic system and of their own capacities. Formal and informal learning should reinforce each other. The graduated driving licence for novice drivers is an effective approach.

Rowdy behaviour is not appropriate in road traffic. Police enforcement needs to be intensified, accompanied by suitable penalties for novice road users (often young people). In addition to punishing inappropriate behaviour, rewarding appropriate behaviour can improve safety. An example is a special no-claim insurance bonus to reward careful novice drivers or riders.

Cyclists and pedestrians

Walking and cycling are healthy and environmentally friendly activities, and should also be safe. Walking and cycling (safely) are most important modes for young (school-) children, and the elderly. These vulnerable groups are particular beneficiaries of a sustainably safe road traffic system design, specifically based on the principle of homogeneous use. Pedestrians and cyclists are vulnerable in crashes with other types of road users, because they are unprotected and also because other types of road users move at higher (sometimes too high) speeds. Crash speeds of motorized vehicles need to remain below 30 km/h in order for pedestrians or cyclists to survive the crash. This means that pedestrians and cyclists have to be separated from high-speed traffic. If this is not possible, the result of conflicts should be such that pedestrians or cyclists are not severely injured (*forgivingness*). This requires both provisions for motorized vehicles ('friendly' car fronts, and under-run protection for heavy goods vehicles and buses) and for speed reduction for these vehicles. Speed reduction needs to be applied on access roads but these need to be investigated further because there are signs that the low-cost design of both 30 km/h and 60 km/h roads do not fit these speed limits well enough. Speeds also need to be less than 30 km/h at those locations where pedestrians and cyclists and motorized traffic meet (on distributor roads with a 50 km/h or 80 km/h speed limit). These locations should follow logically from route plans for cyclists and pedestrians. The construction of roundabouts and raised crossings can be effective here.

The downward trend in crash statistics for pedestrians and cyclists show that we are on the right track. So, the slogan could be: proceed on the chosen path. This path comprises: mix traffic where speeds are low, separate traffic where speeds are too high, and introduce targeted speed reduction where pedestrians and cyclists meet motorized traffic flows. Here, SWOV introduces two new ideas: the *Toucan crossing* (joint pedestrian and cyclist crossing), and the *two-path* (joint use of pavement with a separate lane for both pedestrians and cyclists). Incidentally, it is only logical to address pedestrians and cyclists about their own responsibilities for safe road use; that they behave predictably, for instance using their bicycle lights at night, and do not cross streets while the lights are red. This will also remove a cause of crashes.

Motorized two-wheelers

Motorized two-wheeled vehicles do not fit well into sustainably safe traffic, because they have a high vulnerability/injury risk in crashes with other motorized vehicles, because motorized two-wheeled vehicles are quite often not noticed by others, and also because they often move at high speeds. The combination of juvenile recklessness, tuned-up engines, and sometimes excessive speeds results in relatively high risks for this road user category.

Only a few Sustainable Safety measures provide a truly substantial casualty reduction in crashes involving motorized two-wheeled vehicles. This leads us to a fundamental discussion concerning risk acceptance in a risky society, and to the questions of what is a reasonable and responsible expectation of risk reduction, the distribution of individual and collective responsibility with respect to risk-associated behaviour, and so on. We advocate a fundamental discussion on this topic.

We need to facilitate the safest possible way of using motorized two-wheeled vehicles, given their inherently dangerous characteristics. There are definitely some, although limited, possibilities: obstacle-free zones, advanced braking systems, ITS to influence speeds, conspicuity at crossings, and registration plates for mopeds and light mopeds. The last of these require extra enforcement to achieve their potential. In rider training, much more emphasis needs to be given to recognizing and anticipating dangers. In the same way as for young and inexperienced drivers, a positive effect may be expected from graduated driving licences (both for motorcyclists, and light moped and moped riders). Research (from the UK) has shown that motorcyclists often have incorrect risk perception and risk awareness; this may also be true for light moped riders and moped riders. When the graduated driving licence for novice drivers is introduced, we recommend that the period of the training phase for novice riders of motorized two-wheeled vehicles be extended. When riders have mastered more higher-order skills, they can participate in traffic under more dangerous conditions.

Heavy goods vehicles

The freight transport industry represents a large economic interest in the Netherlands and, therefore, it is important to manage freight transport flows safely. This is also important for the sector's efficiency and image. Dangerous heavy goods traffic almost always means a lack of safety for the other crash party. Fatal crashes already occur at very low speeds (particularly for the lighter collision opponent). We need to acknowledge that there is a high level of incompatibility between the heavy goods vehicles and all other road users.

There is very little else that can be done about this structural problem other than separating heavy goods vehicles from other traffic. From the Sustainable Safety vision, everything possible has to be done to prevent unnecessary movement, and then to manage the mileage travelled as safely as possible. Learning from other transport modes and based on an analysis of heavy goods vehicles safety problems, SWOV advocates:

- two designated road networks for heavy goods transport and light goods transport;
- two vehicle types adapted to the road and traffic situation;
- two types of drivers with different skills requirements.

The leading idea is to separate heavy goods vehicles and other traffic as much as possible in place or time. To this end, a logistics system will have to be developed where heavy goods vehicles use the major road network, and are in contact with other, mostly more vulnerable, road users as little as possible. 'Light goods vehicles' made compatible with other traffic then use the remaining road network. The Quality Net Heavy Goods Vehicles (*Kwaliteitsnet Goederenvervoer*) may offer a good starting place. Furthermore, the logistics system should be designed such that safety is a design requirement, as is common practice in other transport modes. This also means that the sector develops additional professional skills further. It is also important that companies improve their own safety cultures.

Implementation

Organization of policy implementation

In general, the context of road safety policy implementation, and that of Sustainable Safety specifically, has become increasingly complex in the Netherlands in recent years. From a relatively hierarchical setting, the implementation context has developed an increasing number of networking characteristics. The network is characterized by both horizontal and vertical fragmentation. The relationships and roles between those responsible have changed drastically, and the new relationships have not yet been clarified. It is necessary to look for a new balance. It is also better to aim for improving the use of these new structures than to propose new institutional arrangements. A reduction of unclear commitments is desirable in the new structures with business-like products and results-orientated co-operation. We will limit ourselves here to those with a principal role: the national government, provincial and local authorities, interest groups, and research institutes. The role of the police and the judiciary is also highly important but will only be touched upon here.

We recommend that the national government's role be characterized as 'policy innovator', now that the role of 'central policy decision maker' is one of the past. Further definition of the role at the national level with respect to Sustainable Safety is desirable as well as that of the competences (Europe, national legislation, national road authority) and legal tasks ('framework agreements'). We recommend facilitating and encouraging further policy innovation, giving particular attention to facet policy and integration with other policy areas. The role of 'director' can be effectively combined with the functions of facilitator of research and dissemination of knowledge. These functions are well matched to the role at the national level.

The role of provinces and regions can be seen as a spider's web. In the Netherlands, they are responsible for directing the implementation of Sustainable Safety and for the distribution of financial resources provided by the national government. Decisions have to be made that reconcile different interests, and it goes without saying that 'road safety' will only be part of these integral considerations. The provinces and metropolitan areas will have to see to it that 'road safety' is explicitly taken on board in a transparent decision making process, making it clear how (regional) safety targets can be met.

The role of local authorities is one of providing feedback, both to citizens and other authorities. Local politics can play a role in stimulating and manifesting the citizens' (latent) demands for improved safety and in the actual implementation of Sustainable Safety.

Interest groups act as critics, and are sometimes ideologically motivated. They can keep those responsible on their toes. They have an essential role to play, albeit that this role is more complex and uncoordinated because of policy fragmentation. Interest groups can also link Sustainable Safety with other societal developments (sustainable society, environment, quality of life, etc.). Interest groups may feel challenged to make road safety manifest, based upon issues of concern to citizens, and to channel it towards decision making about Sustainable Safety.

Quality assurance

In order to attain a sustainably safe traffic system, it is important to counteract latent errors. This can be achieved with the aid of quality assurance. Various considerations and developments lead to the conclusion that this link is necessary for the high-quality delivery of Sustainable Safety, but which is at present lacking. A good example of a situation where such quality assurance is needed is in offering road users a recognizable and understandable road design that facilitates the predictability of the road course and other road users' behaviour. To this end, road authorities should agree on a certain level of uniformity of road design. This possibility does not exist currently but is fully accepted in other branches of the traffic system. For example, transport companies are required by law to incorporate safety into their business (safety assurance systems). However, this is not yet reality within road transport operations, apart from the transport of dangerous goods. The system of (overarching) quality assurance should be an addition to the quality control that each organization concerned provides itself. Quality assurance will have to be directed at all road traffic components. We recommend conducting an exploration into this subject.

It is interesting to see how politicians judge the observed 'quality deficit' and the desirability of inspection as part of quality assurance for the further implementation of Sustainable Safety. More research is needed to prepare this political choice, weighting the benefits and disadvantages. If the choice were to install a (central) supervisor, then their involvement would have to be such that the autonomous competences of authorities are not affected, assuming that those responsible keep and fulfil their own responsibilities. That is: one knows the rules, norms, requirements and so on, and one acts accordingly, or requires third parties (e.g. contractors) to act accordingly. This should satisfy the requirement for the first step of quality assurance (competences and capabilities are sufficiently covered).

The quality assurance system needs to have a legal basis. We recommend developing this system initially for road authorities. Legislation could take the form of a framework law or principle law as a basis for (delegating) arrangements concerning road safety priorities. A phased structure can be chosen in such framework or principle law aimed at road authorities. This could look as follows:
- restricting unclear commitments by supervision of road authorities at arm's length; a basis is constituted for requirements concerning dissemination of information and knowledge, safety assurance systems, training, audits and reviews, terms of reference for contracting, etc.;
- the assurance that safety is taken on board and weighted in spatial planning and transport and traffic plans, e.g. by means of impact assessment reports;
- conformity and uniformity in infrastructure design, operation and maintenance;
- compulsory analysis and remedial action in case of crashes and latent errors;
- compulsory safety monitoring, both in terms of crash statistics and process indicators.

We advocate starting with four headings:
- the obligation of the Minister to report to Parliament progress on road safety indicators and on progress made by other authorities (also process indicators);
- implementation of road safety audits;

- indication of road safety impact assessment of sizeable investments, for instance within the framework of infrastructure plans or environmental impact assessments of these plans;
- revision of existing guidelines and recommendations for road design in the Netherlands, such that they are usable in the quality assurance system as discussed.

To avoid misunderstanding: the intention is not to accelerate the implementation of Sustainable Safety by means of the appointment of a supervisor. The intention is to implement Sustainable Safety better. To this end, agreements will have to be made within the regular political and administrative arrangements. Quality assurance should not only be embedded within the organizations, but embedded more completely through a supervisor.

Funding

Funding road safety measures, including Sustainable Safety, is a matter that continuously needs attention because the available funding does not cover all needs. Structural funds are also insufficient. Often, the road safety budget is not earmarked for the purpose but forms part of another budget line which makes it unclear how much is available to meet road safety needs. We will restrict ourselves here to a category of expenditure that is highly relevant for the implementation of a sustainably safe traffic system, that is, infrastructure investment, and more particularly, regional infrastructure. Funding needs are known to be high here, and existing available budgets are insufficient. Our judgement is that this is also the case for other road authorities in the Netherlands. The proposals developed are therefore also relevant for those roads.

Before discussing the issue of funding, we need to flag up that economic justification can be given since government is, itself, active in road safety investment, and should not expect 'the market' to be responsible for road safety improvement. In economists' terms: because the market fails, government intervention is justified. A second relevant point is that investments in Sustainable Safety (CPB et al., 2002) can be characterized as robust investments (societal cost-effective investments and a proper governmental task).

Three possibilities have been investigated to cater for identified funding need: 1) increasing liability for road crash damages, 2) pricing policy for road use, and 3) more money from regular and existing budgets. The first two options are not thought to lead to more resources for the government for various reasons. If we stick to the idea that the introduction of road use charging would have to be 'budget neutral', this option does not bring in anything extra by definition. The third option therefore remains, which is a realistic option, but is dependent on the political will to free up the money. We recommend that a multi-track approach is followed and that a committee is formed (Paying for a Sustainably Safe Infrastructure) to oversee the development of this issue.

Accompanying policy

We expect the implementation of Sustainable Safety to be better and easier if attention is devoted to four related topics. These are brought together under the term of 'accompanying policy': *integration, innovation, research and development, and knowledge dissemination*.

Using a variety of criteria, it is plausible that the implementation of Sustainable Safety will not so much take place within sectoral policy, but rather as an element of other policy areas (facet policy). Here we see two lines of development: enlargement of the area of work, and possibly organizational *integration* with other topics. Integral considerations are desirable regarding traffic and transport (quick, clean and safe) and road infrastructure investment decisions. Integral considerations and cooperation in implementation are complicated in terms of content and organization. We recommend conducting an exploration first, and based on this exploration, carrying out the practical implementation of this enlargement and integration, and using the results as a starting point for targeted and practical implementations.

Both the advanced Sustainable Safety vision, the wish to enlarge the area of work (more facet, less sector), and the new institutional setting in the Netherlands ('decentralized where possible, centralized where needed') ensure that in the further implementation of Sustainable Safety new and unknown paths will have to be followed. This requires much 'policy energy', especially if the wheel is reinvented in many places. Therefore, stimulating policy *innovation* is important. We propose to invite the Dutch Ministry of Transport, Public Works and Water Management to create a 'facility' to help bring about these policy innovations.

Based on experiences in the implementation of

Sustainable Safety up till now, we can draw the conclusion that the learning capacity of road safety professionals has been modest. This makes it difficult for us to take next steps. Reinforcing *research and development* is therefore required. Given the broad character of Sustainable Safety, research and development on all facets and aspects of Sustainable Safety can best be delivered in a structured way. We need to give attention to the availability and quality of basic data, and to cluster research activities. Here, we recommend fostering international cooperation.

Existing forms of *knowledge dissemination* should be better harmonized in order to provide road safety professionals efficiently with high-quality knowledge. Special attention should be devoted to professional education. We recommend using Sustainable Safety as a road safety communication carrier to citizens and road users. In this way we can obtain more societal acknowledgements for road safety, the Sustainable Safety principles will become better known, and support can be built up for tangible measures.

A Dutch National Road Safety Initiative can facilitate combining of resources, and this way it can aid the realization of its mission: the exchange, dissemination, and development of knowledge about road safety, and about established road safety results of all those involved. To this end, the objectives and targets from the *Mobility Paper* for the year 2010 need to be achieved (faster if possible). Later on, we can check if this mission should continue beyond 2010.

Closing reflection

In *Advancing Sustainable Safety,* the original Sustainable Safety vision has been updated. It is not a completely new vision, but it provides a broader elaboration of Sustainable Safety, and in this sense it can be called innovative. This book makes many recommendations for the further development of these ideas. The elaboration and definition of complex issues in a complex environment places great demands on the creativity and effort of the many organizations bearing responsibility in this area, or organizations that should bear responsibility. Political will is an indispensable support in this process. We encourage all those involved to proceed along the chosen path, and not to shun new opportunities and challenges. We hope that this advanced vision inspires the further promotion of road safety in the next fifteen to twenty years.

Part I: **Analyses**

1. The principles of Sustainable Safety

A vision can be considered as 'an image of' or 'a view on' reality, often a future and ideal reality, and preferably setting out an approach to its achievement. Theories are also images of reality. They constitute the building blocks and elucidate the contents of a vision. In a book like this, in which the Sustainable Safety vision is again examined, it is important to pay explicit attention to the theories at the foundation of the Sustainable Safety vision, and to clarify the choices made in that vision.

We start by listing the points of departure (Koornstra et al., 1992; *1.1*). These points are the guidelines for the psychological and traffic planning theories and biomechanical laws that follow (*1.2*), and that culminate in the principles of the current, advanced Sustainable Safety vision (*1.3*). Following an examination of the theories and research results which underpin the first version of Sustainable Safety, the original principles remain valid. Some principles have been added that, in our view, update the vision for a next phase of Sustainable Safety.

Policies and funding theories that are fundamental to the implementation of the vision are dealt with in *Chapter 15,* because these theories are different in character to the theories that underpin the basic content of Sustainable Safety.

1.1. The points of departure restated

1.1.1. Two objectives: preventing crashes and severe injuries

The Sustainable Safety vision, as described in Koornstra et al. (1992), aims to prevent crashes and, if this is not possible, to reduce crash severity in such a way that (severe) injury risk is almost excluded. These objectives are aimed for by means of a proactive approach informed by prior study of the traffic situations in which serious, injury-producing crashes can occur. The next stage involves two options: either the circumstances are changed in such a way that the crash risk is almost totally removed, or, if this is inevitable, serious crash injury risk is eliminated. 'Severe injury' is defined here as fatal injury, life threatening injury, injury causing permanent bodily damage or injury requiring hospital admission.

1.1.2. Man is the measure of all things in an integrated approach

In the analysis of and approach to preventing crashes or reducing the severity of consequences of dangerous situations, human capacities and limitations are the guiding factors: "man is the measure of all things". The central issue is that people, even if they are highly motivated to behave safely while using the road, make errors that may result in crashes. In addition, man is physically vulnerable and this has consequences for injury severity when a crash occurs.

Taking into account these human characteristics as the starting point, sustainably safe road traffic can be attained by an integral approach to the components 'man', 'vehicle' and 'road'. This means that the infrastructure has to be designed such that it meets human capacities and limitations, that the vehicle supports the performance of traffic tasks and provides protection in the event of a crash, and that the road user is well informed and trained, and is controlled wherever necessary in the correct performance of the traffic task.

1.2. From theory to vision

1.2.1. Reducing latent errors in the traffic system

Crashes are virtually never caused by one single dangerous road user action; in most cases a crash is preceded by a whole chain of events that are not

[1] In literature, these are also referred to as 'active errors', but as we will see later that dangerous actions are comprised by both unintentional errors and intentional violations, it is better to use the term 'dangerous actions' here.
[2] See also the more recent TRIPOD model (e.g. Van der Schrier et al., 1998) that distinguishes no fewer than 111 types of latent errors. However, this model is particularly applicable for safety organisation in industry (such as Shell, for which it was developed). For a system such as road traffic, the general idea suffices that, prior to a crash, already elements are present that contribute to the fact that dangerous actions by road users actually lead to a crash.

well adapted to each other. For example, one or more dangerous road user actions[1] may cause a crash; or deficiencies in the traffic system may contribute to dangerous actions by road users, leading to crashes. These system gaps are called *latent errors* (see Rasmussen & Pedersen, 1984, in Reason, 1990).

Latent errors occur in the following elements of the traffic system[2]:

– The traffic system, defined as the organized whole of elements that create the conditions for traffic, such as:
  - Design of the system, where the potential for road crashes and injuries have been insufficiently taken into account.
  - Quality assurance in the establishment of components of the traffic system. Inadequate or lack of quality assurance of traffic system components can lead to errors that have implications for road safety (see also *Chapter 15*).
  - Defence mechanisms limited to the traffic system itself. These do not comprise the defence mechanisms employed by road users while taking actively part in traffic, but, for instance, error-tolerant or forgiving infrastructure or Intelligent Transport Systems that may help prevent a crash. These defence mechanisms are the last component in the chain leading up to a crash that can prevent latent errors and dangerous actions from actually causing a crash.

– Psychological precursors of (dangerous) actions. These are the circumstances in which the human actually operates, or the state in which he/she is that increase the risk for dangerous actions during active traffic participation.

> "If road traffic were invented today, and if it were to be assessed according to labour legislation, it would be immediately prohibited."
>
> *Cees Wildervanck, traffic psychologist, 2005*

Road traffic is characterized by a great many latent errors, particularly compared with other transport modes. Therefore, current road traffic has to be considered to be *inherently dangerous*. In the end, crashes occur if latent errors in the traffic system and dangerous actions coincide in (a sequence of) time and place during traffic participation (*Figure 1.1*).

Since dangerous actions can never be completely

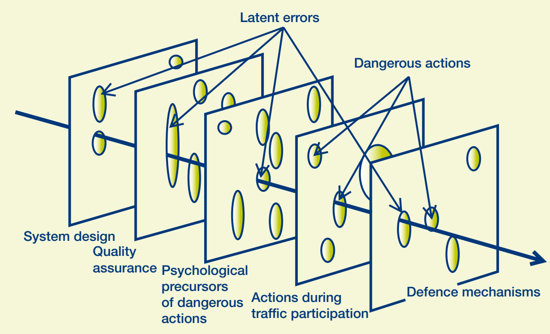


Figure 1.1. ***Schematic representation of the development of a crash (large arrow) caused by latent errors and dangerous actions in different elements in road traffic (free after Reason, 1990). If the arrow encounters 'resistance' somewhere, a crash will not occur.***

avoided, the Sustainable Safety vision strives to remove latent errors from traffic: the traffic system has to be *forgiving* to dangerous actions by road users, so that these cannot lead to crashes. The sustainable nature of measures is characterized by the fact that actions, while taking part in traffic, are less dependent on momentary and individual choices that can be less than optimal, and, consequently, increase risk.

Adapting the environment to human capacities and limitations comes from cognitive ergonomics (also referred to as 'cognitive engineering'), originating in the early 1980s from the aviation and process industries. In fact, this way of thinking has led to an advanced safety culture in all modes of transport, except road transport. Further incorporation of the Sustainable Safety vision should ultimately lead to a situation where road transport can also be considered as 'inherently safe' because of such as approach.

1.2.2. Task performance levels and preventing dangerous actions

People are and always will be fallible, but the extent to which they make errors can certainly be reduced by educating and training them in the tasks they have to perform while in traffic.

From attention-demanding to automatic task performance

In order to explain and also to link up with the founding principles of Sustainable Safety, we will first discuss the taxonomy of task performance levels as defined by Jens Rasmussen in the 1980's (e.g. Rasmussen, 1983). The levels in this taxonomy are dependent upon the extent to which people are familiar with their environment and with the tasks they perform within that environment. The following task performance levels can be distinguished:

- *Knowledge-based behaviour:* actions at this level are performed in situations where either conditions or how to cope with them are unknown (for instance: driving a car for the first time, but also taking part in an unfamiliar or unclear environment). People then use their reasoning capacity to define the situation and to assess the likely effect of certain actions. Whether or not these conjectures are correct will only be apparent afterwards. Actions at this level are slow, require much attention, and, moreover, are very error prone.
- *Rule-based behaviour:* actions at this level are based on acquired general rules, for instance in the form: if X is the case, then do Y. These rules are built up of experiences with similar situations in the past, or they are explicitly learned. The decision to apply a certain rule occurs consciously (strategic level), but the actual application of the rule occurs automatically and requires no attention (operational level). One example is: giving priority to traffic coming from the right. Here, a conscious assessment is made if 'giving priority' is applicable, but the actual yielding is an automatic process.
- *Skill-based behaviour:* actions at this level are performed completely without attention and they reach this level when they are 'ground down' by much repetition (practice). Automatic behaviour is fast, rigid, often without error, and most of the times does not take account of feedback on progress in the action process already achieved. Nevertheless, control moments can be applied during automatic processes (Brouwer, 2002; Groeger, 2000). Automatic processes are, for example, actions at operational level, like walking and steering. However, there is evidence that single actions during a driving task are not completely automatic but take place at a higher level (Groeger, 2000).

Sustainably safe traffic benefits from task performance that demands as little mental capacity (or knowledge-based behaviour) from road users as possible. To understand this, we will first look at the different types of error that can be made at different levels of performance.

From slips to dangerous mistakes

Errors differ from each other, depending on the level of task performance in which they are made. Based on Rasmussen's task performance taxonomy, *Table 1.1* lists the different error types according to Reason (1990).

Slips are manifest as an action that is incorrectly executed in the context of that action. Lapses are omissions (or not executing an action that should have been executed). Errors during automatic behaviour generally do not often result in crashes because they produce an immediate, noticeable, negative result and are therefore quickly detected (see e.g. Woods, 1984). Because of this, a series of sequential errors that may lead to a crash can be broken.

Mistakes are characterized by performing actions based on a wrong decision or diagnosis. Mistakes produce results that seem to be desirable, but because they are made in an incorrect context or situation, without the knowledge of the actor, they are not quickly detected and they often lead to crashes (Woods, 1984). Mistakes can have many causes, such as the incorrect classification of situations in which certain rules are applicable (rule-based behaviour), or a lack of knowledge based upon a correct plan (knowledge-based behaviour), or a lack of mental capacity given the amount of information needed to process for taking a correct decision.

As much routine task performance as possible

From the above, it is clear that particularly mistakes have to be avoided in order to avoid crashes. Mistakes lead to the most serious situations that can

Level of task performance	Error type
Skill-based (automatic) behaviour	Slips Lapses
Rule-based behaviour	Rule-based mistakes
Knowledge-based behaviour	Knowledge-based mistakes

Table 1.1. ***General classification of error types (Reason, 1990) that can occur at the different levels of task performance (Rasmussen, 1983).***

easily culminate in a crash in the absence of preventative measures. This serious error type predominantly occurs in task performance at higher levels (rule-based and knowledge-based behaviour; see Reason, 1990). Especially in view of the fact that knowledge-based behaviour demands much time and attention, Sustainable Safety aims to avoid the necessity to have to operate based on knowledge-based behaviour.

Nevertheless, since routine actions are rigid and do not offer the flexibility that is required to stay alert and respond adequately, sustainably safe road traffic needs to strive for optimal performance at the action level. Actions at operational level (like steering, braking and gear shifting) can best be executed at automatic level, leaving more mental capacity for processes requiring conscious regulation. At this higher (tactical) level, the aim is for rule-based behaviour: the choice to apply or not to apply certain rules or behaviour remains a conscious process that does not take too much time and energy.

On the one hand, this entails informing road users well by training them, and especially by letting them practice the tasks they have to perform in traffic (see *Chapter 7*). In addition, the environment has to provide support, a) by offering a self-explaining environment that meets the expectations of road users and where they can revert to their skills, learned rules and routines (see *Chapter 4*) and b) by optimizing traffic task demands, e.g. by providing in-vehicle information (see *Chapter 6*).

Two issues play a role in making the road environment recognizable to encourage the correct expectations in road users in order to prevent crashes. Firstly, the road design and layout corresponding to a certain type of road has to evoke the right expectation with respect to the road course, the road user's own behaviour and the behaviour of other road users. Ideally, the picture of the road environment is so clear for road users that it can be considered to be 'self-explaining' (Theeuwes & Godthelp, 1993). In such a case, the road user needs no additional information to use the road safely. Conversely, if the road environment meets user expectations insufficiently, road users may miss relevant objects and delay the action needed to prevent a crash (see e.g. Theeuwes, 1991; Theeuwes & Hagenzieker, 1993).

Also relevant to this framework are the popular theories stemming from the 1990s on *situation awareness* (Endsley, 1995). Situation awareness distinguishes three levels: 1) the perceptual level, 2) the level at which perceived information from the environment is understood and its value assessed, and 3) the level at which the current state is extrapolated into the near future and predictions are made. If a problem occurs at one of these levels, this has consequences for correct situation awareness and appropriate reaction to that situation. In making the environment recognizable, these levels can be taken into account to see if there are barriers to right situation awareness and expectations of road users, and an adequate response to traffic situations. Intelligent transport system applications, in particular, can play a support role here.

Secondly, and of equal importance, particularly for user expectations concerning speed behaviour, is that the road course permanently supports road user expectations by *continuity and consistency in design*. These concepts have been worked out both by Lamm (under the terms 'design consistency' and 'operating speed consistency'; e.g. Lamm et al., 1999) and by Krammes (totally covered by the term 'design consistency'; e.g. Krammes et al., 1995). By *continuity in design*, we mean that the required speed adaptation when negotiating a road has to be limited (particularly in transitions from straight road stretches to curves, but also at intersections). If the differences in the road course are too great, this increases crash risk, since it requires too high a mental workload to have to change speeds regularly. A curve after a long road stretch is more dangerous since larger speed adaptations are required and road users' expectations are not met. Speed adaptation should either be unnecessary, or should be made clear to the road user (on site or by means of in-vehicle information provision). By *consistency in design* we mean an environment that keeps speed differentials between close-moving vehicles as small as possible, by bringing all road design elements into conformity. This principle fits well into Sustainable Safety because it results in the homogeneity of traffic flows, which has the benefit of making the behaviour of other road users more predictable. Complying with built-in requirements is very useful, particularly for inexperienced road users, because they can more quickly adapt to normal traffic, thereby making fewer errors.

With these principles, Sustainable Safety explicitly rules out a chaos approach, particularly when traffic flows are managed at high speed. In the chaos approach, the line of thinking is more that if people do not know what to expect, they act more cautiously because they cannot revert to (rigid) routines. However, people operating at the knowledge-based level, make more serious errors and need more time and attention to perform their tasks than when they can operate at rule-based or skill-based level (see above). This is a particular problem if they participate in traffic at high speeds. According to the Sustainable Safety vision, unpredictable and barely recognizable road traffic is the most undesirable situation. If we look at the risks associated with various road types, it becomes clear that these are lowest on motorways (see *Chapter 2*). One important reason for this is that on motorways the situation is standardized and predictable.

Intentional offences and the role of motivation

In addition to different types of unintentional errors, we can also distinguish *violations* as 'dangerous actions' (see also Reason, 1990; *Figure 1.2*). From a psychological perspective, we can only speak of violations if people *intentionally* break a rule. After all, breaking a rule can also occur unintentionally, without the offender being aware of it. In order to differentiate between deliberate violations and a legal violation, which is independent of intentions, we will therefore speak of *intentional violations*.

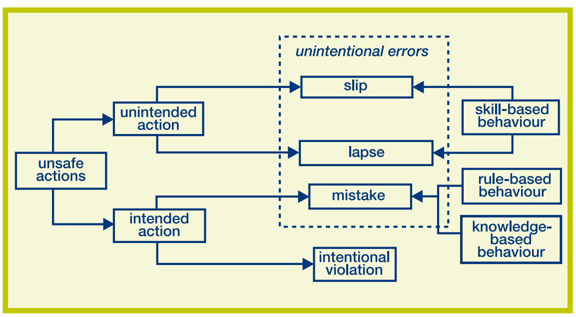


Figure 1.2. ***Taxonomy of dangerous actions (after Reason, 1990).***

Motivation (or the lack of motivation) plays an important role in intentional violations of rules. Relevant theories can generally be distinguished by starting from a *normative* or an *instrumental* perspective to obey the rules or not (see e.g. Tyler, 1990; Yagil, 2005). According to normative theories, people respect rules from an inner conviction about what one ought and ought not to do, irrespective of the circumstances. Respecting the rules voluntarily as an aim in itself is also called 'intrinsic motivation'. Within the normative perspective, the legitimacy of rules, in particular, determines whether or not people will obey them (Kelman, 2001). An individual weighting is given to how justified one finds a rule or a rule maker in general, rather than whether a rule should be respected in any given situation. Of course, a rule is considered more readily as 'justified' if the relationship between the rule and the rule's objective is clear. In the instrumental perspective, the assumption is that, in violating rules, people weigh up the personal 'profit' and 'loss' that the violation will bring. If the subjective profit exceeds the calculated cost, people opt for a certain behaviour, and if it does not, they will not. In these assessments, a violation as a result of, for example, being in a hurry, the need for excitement and so on, may result in such 'benefits' that exceed the calculated potential costs of a crash or a fine. This instrumental theory fits within Reason's categorization, particularly concerning exceptional violations.

In practice, many violations do not fit such rational models. People have a strong inclination to be led by habit, or by imitating others (see Yagil, 2005). Even if conscious assessments play a role in breaking rules, these are moreover often based on incomplete information or intuition. The conclusion gives an indication of the grey area which exists between unintentional errors and intentional violations (see also Rothengatter, 1997; *Chapter 8*).

Tackling undesirable behaviour

In the original Sustainable Safety vision, the starting point was fallible man: the otherwise well-intentioned person who can make errors, thereby causing crashes. This is particularly centred on the word 'can'. But we have to add the intentional, 'willing' person. To what extent unintentional offences and intentional violations are at the basis of crashes, will be discussed in *Chapter 2*, but the issue deserves more research.

A sustainably safe traffic system would be most served, as far as the 'willing' person is concerned, by the intrinsic motivation of road users to respect the imposed rules or – even better – to act safely under given circumstances. Intrinsic motivation makes behaviour consistent (that is: sustainable) in situations and over time. This consistency would not exist if people always behaved according to their own assessment of potential costs and benefits of different behaviour in specific situations. Therefore, we should not depend on the calculating road user.

Since it is unrealistic to rely exclusively on the intrinsic motivation of all road users, the road user's immediate environment has to incite the desired spontaneous behaviour in sustainably safe road traffic (particularly in relation to speed behaviour; see *Chapters 4, 8 and 9*). Since this causes other road users to comply with the norm, the (unconscious) social influence of imitating others works in the right direction. We should also look into the extent that we can improve the explicit communication of rules. By applying rules, for instance, in such a fashion that people can easily understand why they are in force at that particular moment and/or that location, compliance can be increased. Rules have to be logical, correspond to the (road) situation, and in that sense incite (see *Chapter 8*) and confirm spontaneous compliance. Education also has an important role to play. It can help to reinforce intrinsic motivation and combat dangerous habits by providing (more) insight into the relationships between rules and road safety (see *Chapter 7*).

In so far as intentional offences cannot be prevented by the direct (road) environment, logical regulations that are clearly understood and/or (vehicle) technological measures offer the means of preventative enforcement. Preventative, unannounced police checks should ensure that traffic offences cannot occur, for instance by making it impossible to drink and drive, or to start the engine without belting up (see *Chapters 6, 8 and 10*).

Given this optimized environment and trying to prevent unintentional errors and intentional violations as far as possible, it is nevertheless necessary to check if people actually exhibit proper behaviour. This is necessary as long as active participation in traffic is determined by humans. Enforcement is the appropriate means of checking this and an essential element of the Sustainable Safety vision (see *Chapter 8*).

1.2.3. Man with his capacities and limitations in interaction with his environment

Another model that helps to understand the choices that are made within the Sustainable Safety vision – with man as the measure of all things – is the task capability model created by Ray Fuller (see 2005, for the most recent version). This model is a response, among others, to the risk homeostasis model by Wilde (1982), which starts with the hypothesis that road users keep the perceived crash risk constant. This means that if road users think they run a lower risk in traffic, then they adopt riskier behaviour.

According to Fuller, however, observations that are explained by risk homeostasis or risk compensation can also be explained in a different way. He hypothesizes that road users keep the *difficulty of the task* as a constant rather than subjective risk. In this theory, this subjective measure depends upon the ratio between the objective task demands and the driver's capability to accomplish this task. This task capability consists of a person's competences, minus his situation dependent state (*Figure 1.3*). People lose control over a situation if the task demands exceed the capability to perform the task. This is, of course, a breeding ground for creating crashes. Only an optimally designed, forgiving environment (see *Chapter 4*) in combination with adequate responses of other road users can then prevent an injury crash. The task demands are, in the first place, influenced by road design, traffic volume, and the behaviour of other road users, but the road user can influence the task demands in part, for example by increasing speed, or engaging in secondary, distracting activities such as using a mobile phone.

As is also known from the old arousal theory (Yerkes & Dodson, 1908), people have a tendency to keep the difficulty of tasks (and consequently the corresponding activation level) at a reasonably constant and optimal level. In Fuller's model, this means an optimal ratio between task capability on the one hand, and task demands on the other. If the task demands become too small relative to the task capability (e.g. being hale and hearty and well trained, and driving at low speeds on a boring straight stretch of road with no other traffic), then people have a tendency to make the task more difficult to lift the feeling of boredom. Conversely, if the task demands are about to exceed safe task capability (e.g. making a phone call while driving in busy traffic at high speeds), the driver will try to make the task easier.

Speed is the most distinctive factor in relation to decreasing and increasing task difficulty, because speed has a direct influence (at operational level). At strategic level, route and vehicle choice can also have an influence on task demands, but these choices have to be made beforehand, and cannot always be changed en-route. ITS applications and education can be supportive here (see *Chapters 6 and 7*).

The optimal balance experienced between task capabilities and task demands differs, however, between individuals. This does not mean that this balance is also ideal for safe task performance. Some people have more need for excitement (see Zuckerman, 1979)

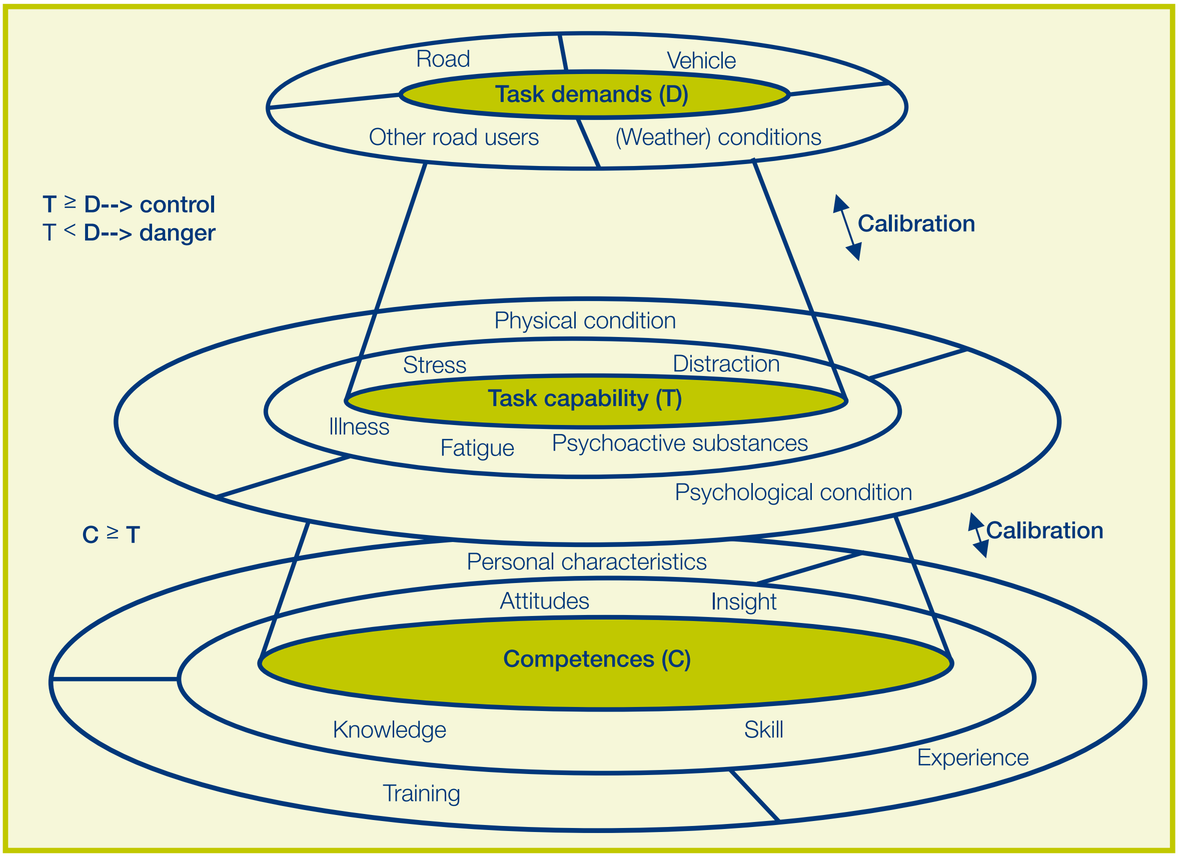


Figure 1.3. ***Schematic representation of Fuller's model: task demands (D) can only be met if task capability (T) is great enough. Task capability is the result of competences (C), minus the situation dependent state.***

and therefore accept higher task demands relative to their task capability. This is, for instance, typical for young drivers, especially males. By having less reservation about their task capabilities, they run a higher risk of crash involvement (in Fuller, 2005; see *Chapter 11*). Apart from that, they also lack the skills to recognize dangerous situations in time and to anticipate their behaviour (tactical level; *Chapter 7*). In view of this, they have to resort to reactive strategies, and can be thrown from a controlled into an uncontrolled situation (see Fuller, 2005). The next section will discuss the implications of this for Sustainable Safety.

A sustainably safe traffic system for everyone

In sustainably safe road traffic, task difficulty should always be kept at an optimum level for safety. By always keeping task capability higher than the task demands, serious errors can, largely, be prevented. Ideally, task difficulty can be adapted in two directions: firstly by reducing task demands, secondly by improving task capability. The problem is that road users are not a homogeneous group, with individuals differing in task capability. Therefore, a given traffic situation is more difficult for one individual than for another. The question is then how to make a traffic system safe for *everyone*. Sustainably safe road traffic is attained firstly by implementing *generic* measures that provide an adequate level of safety in the system for the 'average' road user under normal circumstances. Here, one can think of infrastructural measures, general vehicle measures and an adequate educational base (see *Chapters 4, 5, 6 and 7*). In normal circumstances, average road users have to be easily capable of anticipating dangerous situations by having a good view of the traffic situation, possibly supported by ITS. Who this 'average' road user may be, and within which margins a road user can be considered 'average', is a subject for further research.

Road users 'at the extremes', and particularly those at the lower end of the task capability distribution (the borderline between average and not average is, by the way, not clear), profit from generic measures. But for these groups *specific* measures are also necessary to bring task difficulty to a personal optimum level or to make the behaviour of more capable road users acceptable to them.

At the 'lower end' of the distribution, we find, amongst others, inexperienced drivers and the elderly. These have a lower task capability because of underdeveloped competences in the first case and the deterioration of certain functions in the second. To improve competences, education has a fundamental and important role. It is particularly important that the road user learns to assess if he or she is capable of taking part in traffic, given the capacity of the individual and situation dependent state (also called 'calibration'; see *Chapter 7*). One can also think of gradually increasing task difficulty (e.g. through graduated driving licensing, see *Chapter 11*) in order to pace the task demands with growing task capability, until the level of the average road user has been reached. Improving task capability for the elderly should, to the extent they are driving cars, be sought in ITS-like driving task support systems in order to compensate for the degradation in their functions (Davidse, 2006).

A third group of road users at the lower end of the distribution comprises the average or sub-average road users whose task capability is temporarily decreased due to factors such as fatigue or alcohol consumption. In order to prevent this group from causing crashes in traffic, ITS and enforcement (see *Chapters 6 and 8*) can be of service. Measures have to prevent such people from engaging in traffic (alcolock; specific enforcement) or driving after being warned about reduced task capability (driver monitoring systems). The levels of situation awareness discussed by Endsley (1995) are also relevant here. If such road users cannot be excluded from traffic, ITS and education may help them to recognize and prevent one's own poor condition (*state awareness*), so that an assessment can be made about safe traffic participation (see *Chapter 6 and 7*).

At the other end of the distribution, there is the group of highly experienced road users for whom the task demands of the general system are regarded as too low, given their task capability. By being engaged consciously in a safe, anticipating driving style, the task demands for such experienced drivers/riders can be increased without detriment to road safety. Taking on these higher task demands would reduce boredom. In addition, other road users could benefit, because their potential errors can be absorbed by the more experienced road user should a conflict arise. Evaluation studies of training courses on defensive driving indicate that there is no negative effect on road safety (see e.g. Lund & Williams, 1984). Further research should reveal if such a measure is functional.

It remains the case that many road users think that they are safer drivers than they actually are, and start to increase task demands to dangerously high levels. In order to prevent this leading to serious crashes, we should on the one hand invest more in obtaining insight into actual versus experienced task difficulty. On the other hand, a solution has to be found by providing a forgiving environment, both in the physical and social respect. In this way, not only can the design of the traffic system prevent errors, which cause serious crashes, but also crash risk can be decreased by giving people more room to make errors without consequences. Concerning the latter, road users should not only be engaged with their own tasks, but also be anticipating other road users' behaviour as much as possible. Such a forgiving attitude could be asked of experienced road users, in particular.

1.2.4. Physical vulnerability and requirements for conflict situations

In addition to human psychological characteristics, physical characteristics also play an important role in creating sustainably safe road traffic. The central issue is that human beings are physically vulnerable in impacts with comparatively large masses, hard materials and large decelerations acting on the human body. The combination of these factors can cause severe injury, sometimes with irreversible effects, and even death. Some of the forces released in a crash are absorbed by the vehicle (if present). This means that people involved in a crash sustain less (severe) injury as vehicles absorb more released energy. This also means that higher crash speeds and travel speeds are acceptable if the vehicles are more crash protective in their design, if vehicle occupants are wearing seat belts, and if airbags are present, etc.

Pedestrians and two-wheelers (motorized or non-motorized) have little or no crash protection. To prevent severe injury in this group of road users, two kinds of measures are taken: reduction of (impact) speeds and increased energy absorption by cars to benefit literally 'vulnerable' road users. In addition, roadside obstacles should either be removed, or designed in such a way that they cannot cause severe injury. As we shall see in *Chapter 2*, collisions between road users and obstacles are very often fatal. This is because obstacles almost do not yield, and the road user (and pos-

Road types combined with allowed 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 1.2. ***Proposal for safe speeds in particular conflict situations between traffic participants (Tingvall & Haworth, 1999).***

sibly the vehicle) has to absorb all the kinetic energy released in the crash within a fraction of a second.

Motorized two-wheelers can take part in traffic at comparatively high speeds, so they have additional risk of being injured or killed in a crash. In view of this dangerous combination of high speeds and virtually no protection, motorized two-wheelers are a category that does not fit well into a sustainably safe traffic system (see *Chapter 3*).

Given that people make errors, it is important in creating a sustainably safe road traffic system, to design the environment such that these errors cannot lead to crashes or, if this is impossible, do not cause severe injury. The homogeneity principle in the Sustainable Safety vision is a method of meeting these requirements (see *Chapter 4*). Until now, this principle has been worked out in two ways: firstly to separate moving vehicles with large speed and/or mass differences and, consequently, to avoid collisions; and secondly to lower travel speeds and, consequently, impact speeds in those instances where a crash cannot be avoided. The 30 km/h speed limit zones are a good example of adapted speed limits to prevent fatal crashes. This is based on the fact that the fatality risk for pedestrians is low when involved in a car crash at 30 km/h. With crash speeds higher than 30 km/h, fatality risk increases dramatically. A crash at 70 km/h or higher is almost always fatal for the pedestrian (Ashton & Mackay, 1979; *Figure 1.4*).

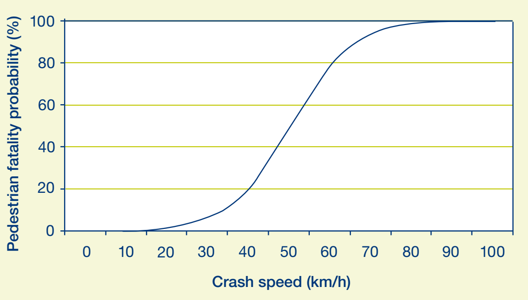


Figure 1.4. ***Probability that a pedestrian will die as result of a car crash as a function of the impact speed of the car.***

The human body's vulnerability (the biomechanical tolerance) and the important influence of speed (determining the degree of local force and deceleration acting on the body) on crash severity is the starting point for a proposal for safe travel speed by Claes Tingvall, one of the founding fathers of the Zero Vision in Sweden (Tingvall & Haworth, 1999; *Table 1.2*). The starting point for this proposal are modern, well-equipped cars, and 100% use of seat belts and child restraint systems. However, safer speeds ought to be used in crash tests (such as in EuroNCAP), but also in tests for protective design (see *Chapter 5*). In addition, as the car fleet does not yet consist of the best designed cars, and seat belt use is not yet 100%, the proposed speeds are too high for the current conditions. A higher degree of penetration of 'the best designed cars' is necessary before the proposed speeds can be viewed as 'the maximum allowable speeds'. Taking the current fleet conditions and seat belt use into account, it is, however, hard to say what are safe speeds at this moment, other than that they are lower than the speeds listed in *Table 1.2.* These speeds are neither valid for motorcyclists for instance, who are much more vulnerable, nor for crashes with relatively heavy vehicles such as lorries.

As with Tingvall & Haworth's proposal, Sustainable Safety proposes safe and, consequently, moderate travel speeds. This means: low speeds where vulnerable road users mix with car traffic. Higher speeds are allowable only where high-speed traffic cannot get into conflict. Where higher speeds are allowed, only vehicle types that are equipped for these speeds, and which provide sufficient protection in case of a crash are permitted.

Strategic travel choices by road users

A road user can also improve road safety at a strategic level. He could choose to travel as short a distance as possible on dangerous roads and he could, prior to traffic participation, more often consider safety in his vehicle choice. In both route and modal choice, cooperation with other sectors is obvious, such as spatial planning and environmental protection. Above all, road users have to be made aware of the available options and the consequences of these choices, and they have at least to be given the opportunity to make such choices. Sustainably safe road traffic does not only mean that every effort is made to guarantee safety at operational and tactical level, but also takes account of the contribution of measures at the strategic level. Furthermore, considerations and measures at strategic level fit even better into the spirit of Sustainable Safety than measures at other levels, because at strategic level, choices are made that have consequences for road safety in the early stages of the decision making process of traffic participation (*Chapter 6 and 7*). A similar line of thinking forms the basis of tackling latent errors, but here the approach is to make the traffic system safer, given the fact that people do make use of it.

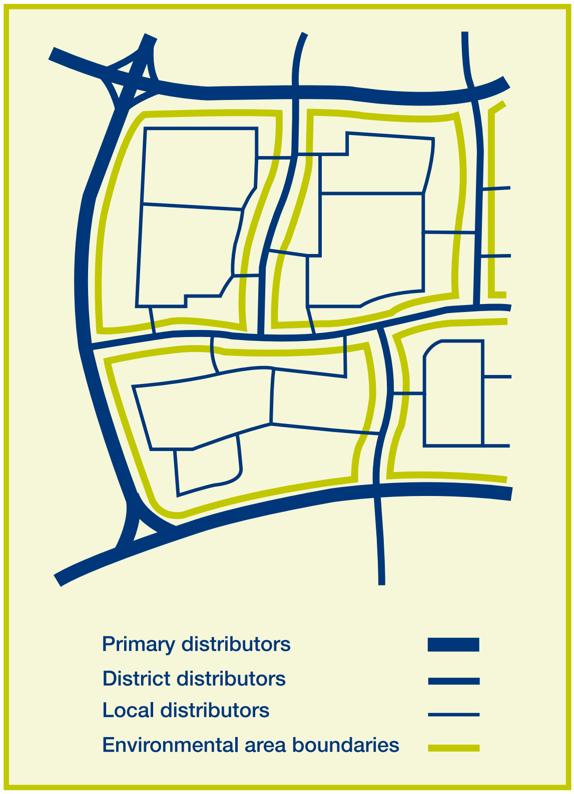


Figure 1.5. ***Functional categorization of roads according to Buchanan (1963).***

1.2.5. Functional road categorization

Alongside psychological and physical road user characteristics as the starting point for Sustainable Safety, we also have functional road categorization and further traffic flow management. From this ensues the Sustainable Safety principle of *functionality*.

The term ‘functionality’ dates back to 1963, when the report *Traffic in Towns* was published (Buchanan, 1963). This report contained a comprehensive vision for the design of our towns and villages in a highly motorized society. A distinction was presented between roads having a traffic flow function (‘distributor designed for movement’), and roads that give access to destinations (‘access roads to serve the buildings’). Elaboration of these ideas resulted in a proposal for a route hierarchy, built up from primary, district and local distributors and access roads to destinations (*Figure 1.5*). Buchanan argued that, within access roads, traffic should be of minor importance to the environment, and in every area at least the maximum acceptable traffic capacity had to be determined.

Buchanan’s report put the idea behind of the traditional Dutch main road that had a mixture of different functions. In the course of time, different interpretations have been given to this new traffic planning categorization. A completely new idea for the Netherlands was the elaboration of *woonerf* and later 30 km/h zones.

The Swedish SCAFT-guidelines, in which similar principles have been developed for traffic planning in towns and villages, are also based on the same ideas (Swedish National Board of Urban Planning, 1968).

In the same period, a contribution by Theo Janssen was presented as a report for the annual conference of the Society of Dutch Road Congresses 1974. The above was chosen as starting point and four functional requirements were formulated for categorizing roads:

- *consistency* of characteristics within a road category;
- *continuity* of characteristics within a road category;
- *little variety* in characteristics within a road category;
- *recognizable* road categories for road users.

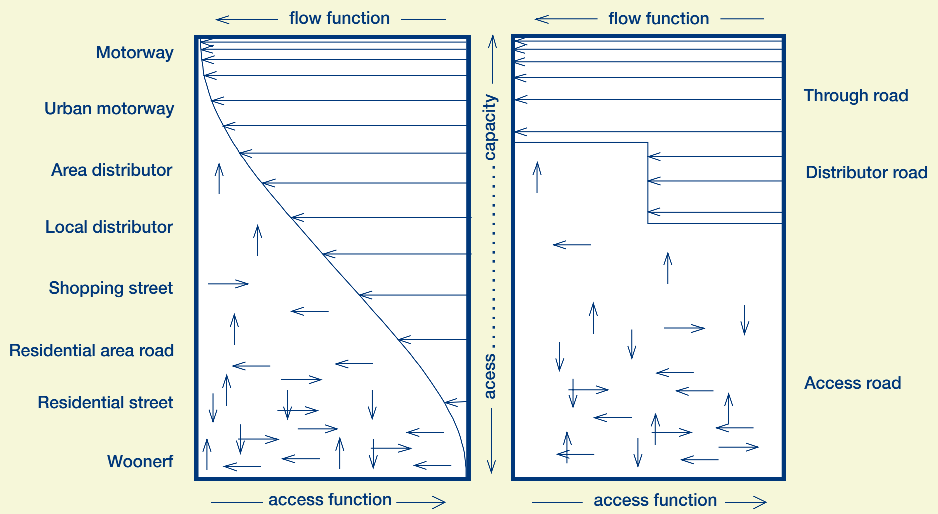


Figure 1.6. ***Left: categorization of roads and streets in flow and access function according to Goudappel & Perlot (1965). Right: categorization of roads according to the tri-partition used in Sustainable Safety.***

The Sustainable Safety vision builds upon the hierarchy of roads as proposed in the Buchanan report, and further elaborated by Janssen (1974), by making a distinction between 'residential function' and 'traffic function'. Within the traffic function, two subfunctions are distinguished: 'flow function' and 'access function' (making destinations along roads and street accessible; see *Figure 1.6*). The flow and access functions are strictly divided in the Sustainable Safety vision. For each function, there is a separate road category (the access function and the residential or 'liveability' function are combined). The roads that connect both categories are distributors. A distributor may not only provide a flow function: it also is the link between both other categories. This combination will have to be manifest in a safe way in the design of a distributor (and an appropriate speed limit).

1.3. How to take Sustainable Safety forward?

Given the fact that people make errors, do not always comply with rules and, moreover, that they are vulnerable, it is essential that latent errors (or gaps) in the traffic system are prevented in order to avoid a breeding ground for crashes. According to the Sustainable Safety vision, in order to prevent serious unintentional errors, the environment and the task demands that this environment entails have to be adapted to a level that the majority of road users can cope with. This produces, as it were, desirable behaviour almost automatically: the road user knows what to expect, and possible errors can be absorbed by a forgiving environment. This also makes the breeding ground for intentional or unintentional violations less fertile. In so far as violation behaviour prior to traffic participation can be detected (such as alcohol consumption or not having a driving licence), denying traffic access fits within sustainably safe road traffic.

Road users have to be well informed and experienced to participate in traffic. Where their skills and capabilities do not meet the task demands, their safe behaviour needs to be encouraged by means of specific measures. It is essential that road users are aware of their situation-dependent state, and, consequently, their task capability, to take adequate decisions that may prevent a potential crash. Since there are differences in road user capabilities, we should ask more experienced road users to engage consciously in safe behaviour, directed at less experienced road users. In traffic as a social system, a forgiving driving style can absorb the emergence of crashes caused by other road users.

The vulnerable human has to be protected in traffic by the environment by means of structures that absorb the kinetic energy released in a crash. To this end, the mass of vehicles sharing the same space needs to be compatible. If this is not possible, then speeds need to be lowered. This system is embedded in a traffic planning taxonomy of fast traffic flows on the one hand and access to residences on the other. Between these two extremes, traffic has to be guided in good, sustainably safe ways.

With this slightly adapted vision on sustainably safe road traffic, we finally arrive at the *five central principles:* functionality, homogeneity, predictability, forgivingness and state awareness. A short description of these principles is given in *Table 1.3*.

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 in speed, direction, and mass at medium 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 in 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 task capability to handle the driving task

Table 1.3. ***The three original and two new Sustainable Safety principles: forgivingness and state awareness.***

2. Road safety developments

For a clear route to sustainably safe road traffic, it is important to start with an overview of road safety present and past, as well as of expectations for the future. This chapter will show, in general, how road safety has developed in the course of time, what it looks like now, and what future developments are likely to have an influence on road safety.

The first section of this chapter (*2.1*) gives an introduction to road safety. This starts with examination of trends over time, both in past decades as well as the most recent trends in various cross sections of the traffic and transport system. Following this, we will look at road safety in the Netherlands in an international context. We base the analyses predominantly on data about fatalities and severely injured victims since these data are the most reliable, and suffer least from problems of under-reporting. The introductory section closes with a brief overview of factors that have an influence on crash risk, either positively or negatively.
The second section (*2.2*) addresses the behavioural causes of crashes. The question that we will attempt to answer is how road user errors and violations contribute to crash causation.
The third and last section (*2.3*) gives an outline of national and international developments that are expected to influence road safety in future.

All these analyses and descriptions aim for a better understanding of road safety in general, and of the specific factors that play a dominant role. These key factors are so important that they deserve explicit attention in any vision of future road safety.

2.1. Road traffic in the Netherlands – how (un)safe was it then and how (un)safe is it now?

2.1.1. Road fatalities then and now

After the first road fatality in the Netherlands, shortly after 1900, the number of road deaths grew rapidly (see *Figure 2.1*). The main reasons for this are the enormous growth in mobility, the development of ever-faster vehicles in a traffic system that was not designed for such use in safety, and road users who make errors and break the rules.

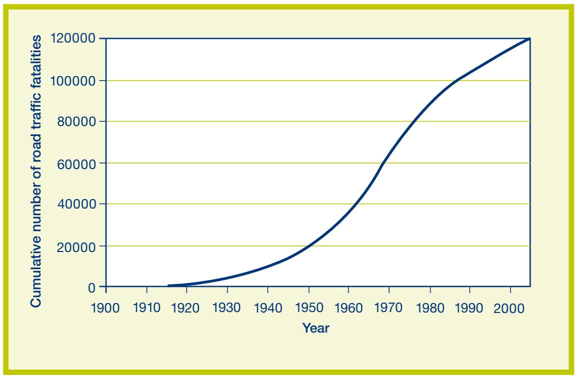


Figure 2.1. ***Cumulative number of road fatalities in the Netherlands from 1900 up until 2004 (after Koornstra et al., 1992).***

The number of fatalities in road traffic peaked with a record of 3264 in 1972 (*Figure 2.2*). This amounts to about 9 deaths everyday. After that, the increase in deaths reversed, despite ever increasing mobility, and a downward trend has been maintained. The number of deaths first decreased sharply (except during the period 1975-1977), but from the mid-1980s onwards, this trend became somewhat less pronounced (see *Figure 2.3*)

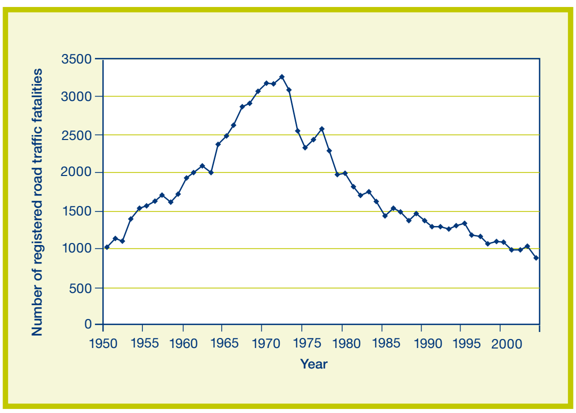
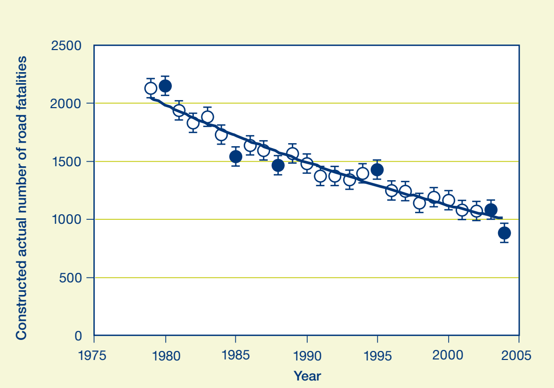


Figure 2.2. ***The number of registered road fatalities per year in the Netherlands in the period 1950-2004. Source: AVV Transport Research Centre.***

The number of road deaths in 2004 is clearly outside the margins calculated for the annual downward trend. For the time being, this lower figure cannot be attributed to specific underlying developments or to



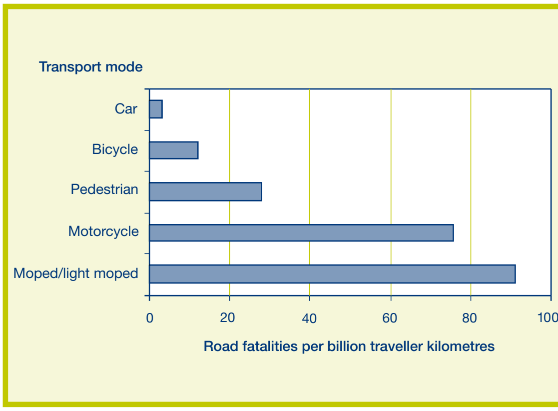


Figure 2.3. *Actual number of road fatalities per year in the period 1979-2004 with negative exponential trend line and 95%-reliability intervals. The actual numbers of road fatalities before 1995 have been constructed based on the average percentage of under-reporting of road fatalities.*

Figure 2.4. *Fatality risk (number of road fatalities per billion kilometres travelled) by road transport mode, averaged over the years 2001-2004. Source: AVV Transport Research Centre, Statistics Netherlands.*

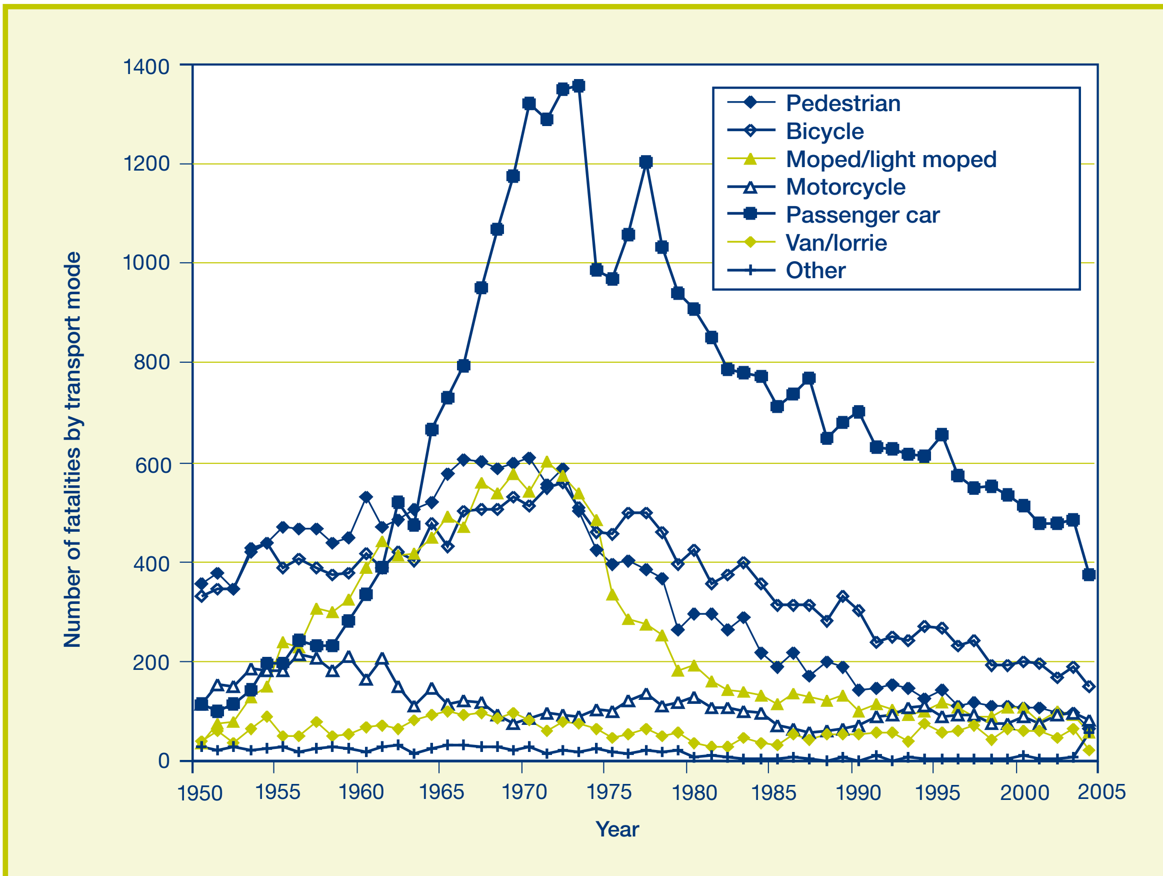


Figure 2.5. *Annual number of road fatalities by road transport mode in the period 1950-2004. Source: AVV Transport Research Centre.*

particular policy interventions. The number of road fatalities in 2003 was high, which emphasizes the low 2004 total. It is also the case that, quite often, the actual number of road traffic fatalities falls outside the statistical margin of the trend line (see *Figure 2.3*; black dots).

2.1.1.1. Large differences between transport modalities

The risk of being killed in a traffic crash per kilometre travelled is highest for moped/light moped riders, followed by motorcyclists (*Figure 2.4*). In itself, this is not surprising for this mode of transport, given that high speed combines with little physical protection (see also *Chapter 13*). If we look at the development of road deaths amongst motorized two-wheelers (*Figure 2.5*), it becomes clear that the number of fatally injured moped/light moped riders rose sharply between the 1950s and 1970s. By the mid-seventies, the number of fatalities under moped/light moped riders had decreased rapidly, partly because of the introduction of compulsory crash helmet use which had a positive effect on injury risk and a side effect of decreased moped use. During the past few decades, the number of moped/light moped riders killed in traffic has been stable, both in absolute numbers and in relative share. The trend in fatally injured motorcyclists has had a less pronounced course. Within this group, the fluctuation in deaths coincides predominantly with the motorcycle's popularity.

Two other groups of road users with a high risk of being killed in traffic per kilometre travelled are pedestrians and cyclists (*Figure 2.4*). The absolute number of total fatalities for these groups is also high, and the highest of all road transport modes before 1960 (*Figure 2.5*). Nevertheless, the number of pedestrian and cyclist deaths has sharply decreased in the past decades, which is remarkable in light of increased cycle traffic and steady pedestrian flows in the Netherlands.

Car occupants have the lowest fatality risk per kilometre travelled (*Figure 2.4*). The fact that, in absolute terms, most lives are lost in passenger cars is due to the rise of increased car mobility (*Figure 2.5*).

2.1.1.2. Large differences in conflicts between road transport modes

In *Table 2.1,* the most important conflict types[3] are assessed using three criteria: 1) the severity of the outcome, 2) the incompatibility between the different parties, and 3) the frequency of the conflict type.

Car or moped impacts with obstacles (such as trees and posts) account for the greatest proportion of severely injured traffic victims and (logically) collide in a most incompatible or unequal way.

Out of two-party crashes, pedestrians in conflicts with cars are the most incompatible (vulnerable) crash opponent. To a somewhat lesser extent, this is also the case for two-wheelers in conflict with cars and lorries (although conflicts between moped riders and lorries do not occur very often and are not included in *Table 2.1*). In the Netherlands, conflicts between cyclists and cars occur most often.

In five out of the six most serious conflict types between two road users (printed bold in *Table 2.1*), the weakest party is a pedestrian or a two-wheeler user (see also *Chapter 12*).

Cars are, indeed, disproportionally strong crash opponents in conflicts with pedestrians and cyclists. However, in conflicts with lorries (and fixed obstacles), cars come out worse as the weaker party. Cars, therefore, play a double role in the compatibility picture in road safety. Cars are involved in five out of the six most serious conflicts between road users (printed bold in *Table 2.1*). The sixth serious conflict is between bicycle and lorry (see also *Chapter 5)*.

2.1.1.3. Large differences between road types

Most road deaths and severe injuries occur on rural roads with an 80 km/h speed limit (*Figure 2.6, Table 2.2*) and on urban roads with a 50 km/h speed limit (*Figure 2.6, Table 2.3*). However, on these roads, the number of fatalities decreases most rapidly over time. On rural roads with a 60 km/h limit and urban roads with a 30 km/h limit, the number of fatalities is low, but has increased over the past few years (*Figure 2.6*).

[3] In this consideration, all two-party crash injuries (period 1999-2003) between pedestrians, moped riders, motorcyclists, car drivers, van drivers, and lorry or bus drivers have been taken into account. Also obstacles have been included as a crash opponent. Of all combinations, only those conflict types that account for more than 1% of the total number of two-party crashes have been included. Together, these account for 90% of the two-party crashes in the afore-mentioned period in the Netherlands.

Conflict parties	Severity (% severely injured victims)	Incompatibility (weakest party / strongest party)	Size (number of injury crashes)
Car-obstacle	40.8	∞	12,188
Moped-obsacle	41.7	∞	2,378
Pedestrian-car	**36.7**	**284**	6,979
Bicycle-car	25.0	**150**	**28,115**
Moped-car	22.5	**120**	**24,124**
Bicycle-lorry	**40.7**	95	1,643
Motorcycle-car	**35.6**	50	5,377
Car-lorry	30.2	30	3,828
Pedestrian-moped	23.0	4	1,775
Bicycle-moped	16.1	2	6,519
2 cars	21.6	1	**29,692**
2 mopeds	33.2	1	1,963
2 bicycles	28.2	1	3,206

Table 2.1. ***Severity of main conflict types, assessed using three criteria. 1) Relative share of deaths and severely injured under weaker of two conflict parties as percentage of total number of conflicts of that type. 2) Quotient of number of fatalities and severely injured of weaker party, divided by number of fatalities and severely injured of stronger party. 3) Annual number of injury crashes per conflict type. All figures are averages over the period 1999-2003. Source: AVV Transport Research Centre.***

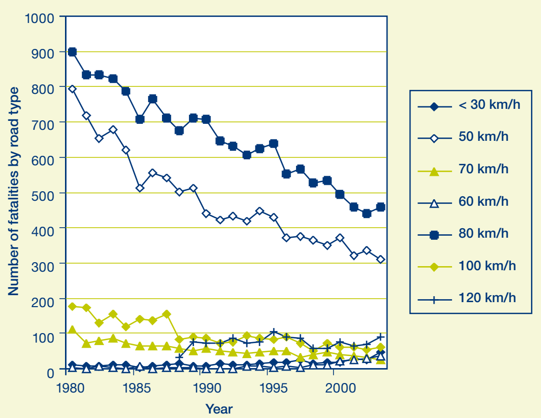


Figure 2.6. ***The number of road traffic fatalities by road type, based on posted speed limits over the period 1980-2003. Source: AVV Transport Research Centre.***

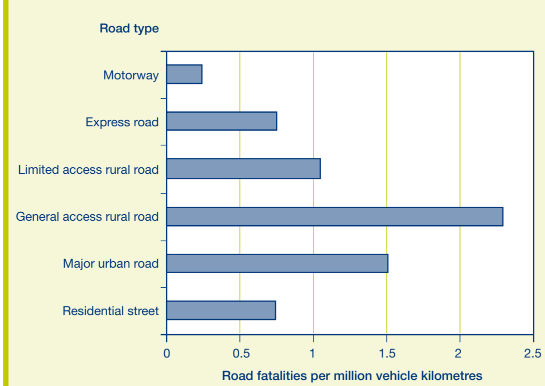


Figure 2.7. ***Fatality risk (number of road fatalities per million vehicle kilometres) by road type (situation 1998; Janssen, 2005).***

When we look into more detail at the type of conflicts occurring on different road types, it is clear that single-vehicle conflicts on road sections predominate in serious crashes outside built-up areas (*Table 2.2*). On urban roads, transverse conflicts at intersections are predominant (*Table 2.3*). The exceptions are urban roads with a 30 km/h speed limit, where, as with rural roads, single-vehicle conflicts on road sections predominate.

When we look at fatality risk by road type (*Figure 2.7*), it is clear that the motorway has the lowest crash fatality risk per vehicle kilometre travelled. Rural roads which are open to all traffic have the highest risk, but major urban roads also have a high score. These are roads where relatively high speeds, large speed differences, and interaction between different types of road users co-exist.

Rural roads and motorways	120 km/h		100 km/h		80 km/h		60 km/h		Rest	Total
	Road section	Inter-section	Road section	Inter-section	Road section	Inter-section	Road section	Inter-section		
Number of serious crashes	521	21	307	57	2,059	1,165	101	30	603	4,864
Number of fatal crashes	57	1	44	7	314	129	14	3	59	629
Conflict type										
Longitudional conflicts	157	3	87	4	195	91	8	1	104	650
Converging & diverging	54	1	34	2	137	88	8	3	57	384
Transverse conflicts	0	7	1	37	112	718	7	17	107	1,005
Frontal conflicts	3	1	41	4	421	151	23	4	99	747
Single-vehicle conflicts	289	9	130	10	1,091	106	48	4	193	1,879
Pedestrian conflicts	8	-	6	0	77	10	5	1	30	138
Parking conflicts	10	0	8	0	27	1	3	-	13	62

Table 2.2. ***Total numbers of serious and fatal crashes, and number of serious crashes of different conflict types on different locations by road type (by speed limit) outside urban areas (average over period 1998-2002).***

Urban roads	70 km/h		50 km/h		30 km/h		Rest	Total
	Road section	Inter-section	Road section	Inter-section	Road section	Inter-section		
Number of serious crashes	62	102	2,277	2,838	322	152	261	6,013
Number of fatal crashes	8	9	139	158	13	4	14	344
Conflict type								
Longitudional conflicts	15	13	231	116	18	5	16	414
Converging & diverging	7	7	292	354	28	19	32	737
Transverse conflicts	3	66	238	1,582	19	61	42	2,011
Frontal conflicts	8	5	347	358	58	17	44	838
Single-vehicle conflicts	27	8	571	228	120	36	81	1,070
Pedestrian conflicts	2	4	437	184	58	12	39	736
Parking conflicts	0	0	162	14	21	2	7	207

Table 2.3. ***Total numbers of serious and fatal crashes, and number of serious crashes of different conflict types on different locations by road type (by speed limit) in urban areas (average over period 1998-2002).***

2.1.1.4. Large differences between gender and age groups

Since the 1960s, the largest number of road deaths has been amongst young road users aged between 15 and 24, alternating during the last decade with the 25 to 39 aged (*Figure 2.8*). The proportion of deaths amongst the 15-24 group has risen since the 1950s from around 12% to 24%, during the last decade. This is, without any doubt, due to increased mobility of young moped riders on the one hand, and young car drivers on the other.

Younger road users not only stand out when looking at absolute numbers of road victims, but also when taking account of person kilometres travelled. Young people – particularly males – between the age of 15 and 17 run a considerably higher risk of being fatally or severely injured per kilometre travelled than other age groups (see *Figure 2.9*). The reasons for this are moral, emotional and cognitive age-specific factors on the one hand, and insufficient skill in assessing situations and risks on the other (Vlakveld, 2005; see also *Chapters 7 and 11*). In addition, this age group often uses high-risk transport modes, such as the moped.

A second group of road users with high risk of severe injury in a road crash per kilometre travelled, are older road users aged 75 years or more (*Figure 2.9*). The elevated fatality risk of older road users is explained by their increased physical vulnerability (particularly

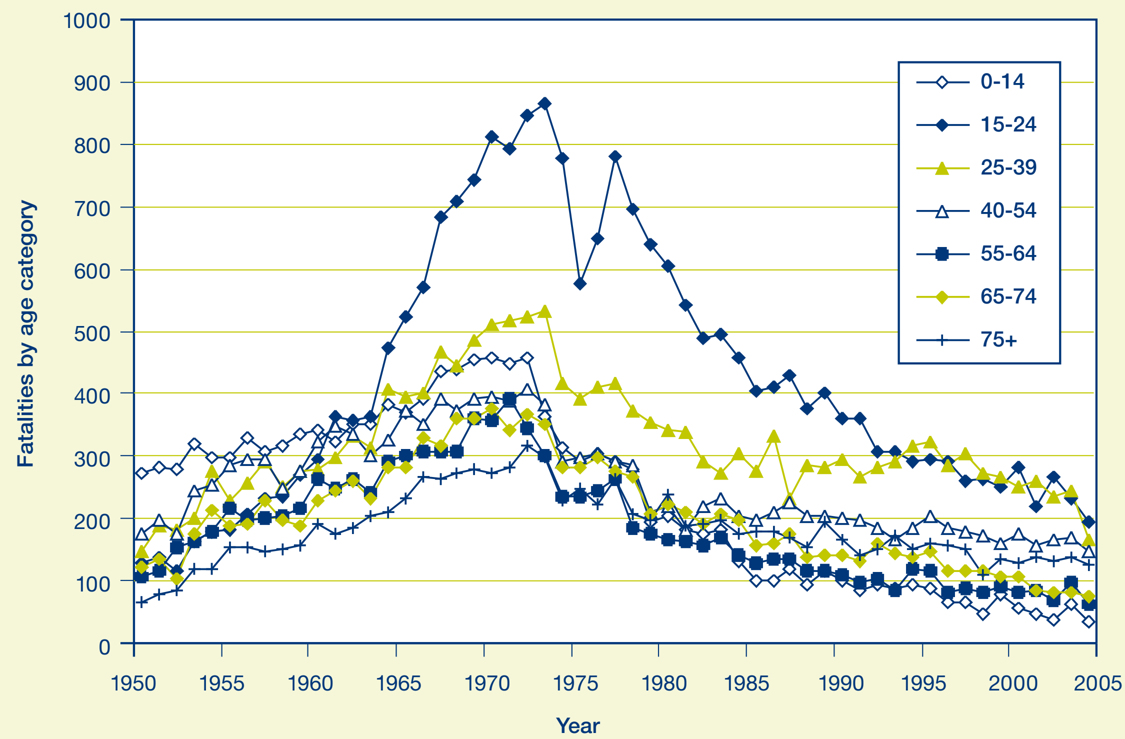


Figure 2.8. ***Annual number of road fatalities by age group between 1950 and 2004. Source: AVV Transport Research Centre.***

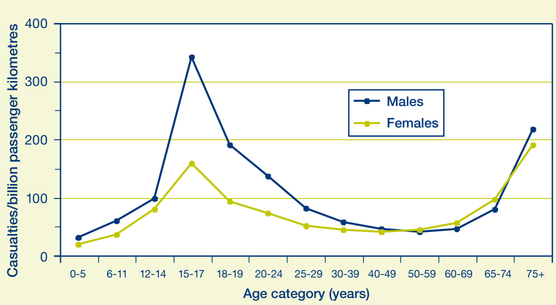


Figure 2.9. ***Average number of fatalities and hospitalized (2000-2003) per billion passenger kilometres by age category for males and females separately. Source: AVV Transport Research Centre; Statistics Netherlands.***

as pedestrians and cyclists (see also *Chapter 2*), and by the deterioration in various skills needed to participate in traffic (e.g. Davidse, 2006). The number of road deaths amongst people aged 75 years and above was at its lowest in the 1950s until the mid-1970s (*Figure 2.8*). One explanation for this is that the relative share of older people in the total population has risen steadily (source: Statistics Netherlands) and people are mobile for longer than in the past.

2.1.1.5. Large differences between countries

The European Union, with its 25 Member States, has between 40,000 to 45,000 reported road fatalities per year. Comparisons of deaths per 100,000 inhabitants amongst Member States indicate that the Netherlands has the lowest number of road fatalities in the EU, together with the United Kingdom and Sweden (*Figure 2.10*).[4] These three countries have, in common with each other, approached road safety in a systematic way for several decades (Koornstra et al., 2002).

The total number of road fatalities has decreased considerably in the past decades. In the 1970s, there were some 80,000 to 87,000 road fatalities within the Member States at the time, whereas this figure has

[4] Malta has become an EU member recently, and holds the position of having the lowest annual number of road fatalities per 100,000 inhabitants.

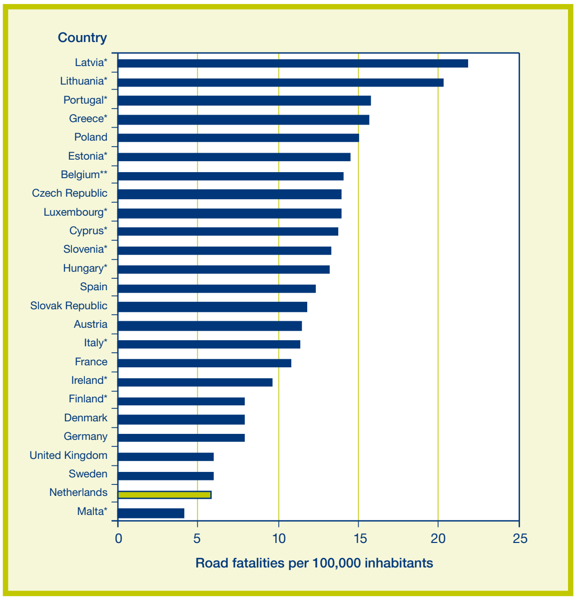


Figure 2.10. ***Number of road fatalities per 100,000 inhabitants for the current 25 EU Member States averaged over 2002-2004 (* = 2001-2003, **= 2000-2002). Sources: IRTAD; CARE; Eurostat.***

been halved now. Compared with the decrease in road fatalities per number of inhabitants in the United Kingdom and Sweden, the decrease between 1970 and 1985 is largest in the Netherlands (*Figure 2.11*), while the rate of improvement in these three countries has been comparable in recent years.

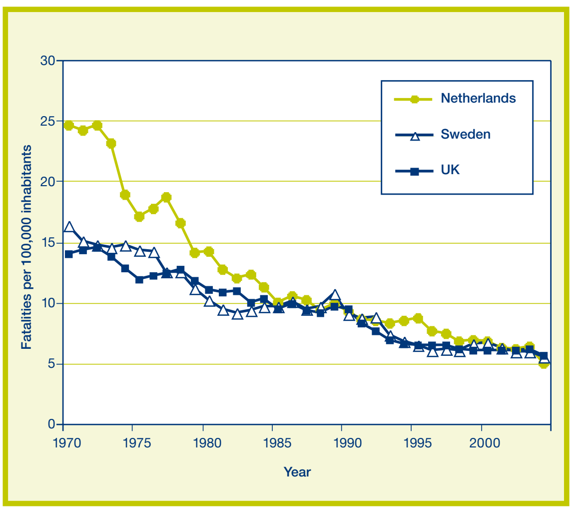


Figure 2.11. ***Development of the number of road fatalities per 100,000 inhabitants for Sweden, United Kingdom and the Netherlands, period 1970-2004.***

2.1.2. What makes road traffic so dangerous?

Taking part in traffic is a dangerous affair in itself. This is due to the basic risk factors in traffic: the road user's vulnerability combined with speed, as well as the presence of objects with large masses and/or stiffness with which one can collide (see also *Chapter 1*). In addition, there are also road user factors that increase crash risk, such as alcohol use, fatigue, or distraction.

2.1.2.1. Fundamental risk factors in road traffic

Fundamental risks are inherent to road traffic, and the basis of the lack of safety in current road traffic. These are factors such as speed, mass and vulnerability. With fundamental factors we do not mean those factors that form the foundation of the process towards a safer system (see TRIPOD-model; e.g. Van der Schrier et al., 1998).

Speed

Speed is not only a given in traffic, it is also a fundamental *risk* factor. Firstly, speed is related to crash risk (for an overview, see Aarts & Van Schagen, 2006). From several studies of the relationship between speed and crash risk, we can conclude that higher absolute speeds of individual vehicles are related to an exponential increase in risk (Kloeden et al., 1997; 2001). If the average speed on a road increases, then the increase in crash risk can be best described as a power function: a 1% increase in average speed corresponds with a 2% increase in injury crashes, a 3% increase in serious injury crashes and a 4% increase in fatal crashes (Nilsson, 2004). With the same absolute increase in speed, for both individual speed and average road section speed, an increase in risk is higher on urban roads than on rural roads and motorways.

Speed *differences* are also linked with increases in crash risk (e.g. Solomon, 1964). Recent research however, has not proven that vehicles travelling at lower speeds than the traffic flow have a higher risk than vehicles that go with the flow (e.g. Kloeden et al., 1997; 2001). At the same time, it was confirmed that vehicles going faster than the traffic flow have an increased risk. Speed variance at the level of road section is also linked to increased crash risk (e.g. Taylor et al., 2000).

Secondly, speed is related to crash *severity*. This is based on the kinetic energy (of which speed is an important indicator), which is converted into other energy forms during a crash, causing damage. Injury risk is also determined by speed level, the relative directions of crash parties, their mass differences and protection level, and biomechanical laws.

Mass and protection

While in motion, the total mass of a vehicle[5] combined with its speed produces kinetic energy, which is converted into other energy forms during a crash and can cause material and/or bodily damage. In a crash between two incompatible parties, the lighter party is at a disadvantage because this party absorbs a lot more kinetic energy and the vehicle generally offers less protection to its occupants than a heavier vehicle (see also *Chapter 5*). Mass differences between colliding vehicles can amount to more than a factor of 300 (pedestrian weighing 60 kg versus a heavy goods vehicle weighing 20,000 kg). Furthermore, in view of their stiffness and structure, heavier vehicle types generally offer better protection to their occupants in the event of a crash. For occupants of vehicles with a high mass, injury risk is much lower than that of the lighter crash party. Let us assume that the injury risk of an occupant of an 850 kg car is 1 in collision with another 850 kg car. The injury factor increases to 1.4 if the crash opponent weighs 1000 kg, and increases to a factor 1.8 if the crash opponent weighs 1500 kg (Elvik & Vaa, 2004).

2.1.2.2. Risk-increasing factors from the road users' side

Lack of driving experience

The effect of driving experience on crash risk is strongly linked with age effects. Since driving experience is strongly correlated with age, and since both factors are associated with specific characteristics which increase risk (see also *Chapter 11*), it is difficult to separate age and experience. Research into the influence of driving experience on crash risk, indicates that about 60% of crash risk of novice drivers can be explained by lack of driving experience (e.g. Sagberg, 1998). From this research, it can also be concluded that the increased crash risk of novice drivers (a factor of 2.5 relative to drivers with more than five years of experience) decreases rapidly within the first year after passing a driving test.

Psychoactive substances: alcohol and drugs

Alcohol is one of the most important factors which increase risk in traffic, and is recognized as such by road users (see also *Chapter 10*). Crash risk increases exponentially with increased blood alcohol content (BAC). Compared to sober drivers, the crash risk is a factor of 1.3 with a BAC between 0.5 and 0.8 g/ℓ, a factor of 6 with a BAC between 0.8 and 1.5 g/ℓ, and even a factor of 18 above 1.5 g/ℓ (Borkenstein et al., 1974). Apart from that, alcohol use also increases severe injury risk (Simpson & Mayhew, 1991; BESEDIM et al., 1997).

Recent research into the crash risk of road users under the influence of psychoactive substances, revealed that the risk is about a factor of 25 with the combined use of drugs. This risk can even increase from 13 to 180 with the combined use of alcohol and drugs relative to sober road users, depending on the quantity of consumed alcohol (Mathijssen & Houwing, 2005). Also, there is cumulative road crash fatality risk when combined with the use of alcohol and drugs (BESEDIM et al., 1997).

Illnesses and ailments

Visual limitations or ailments are generally associated with a very small increase in crash risk (on average a factor of 1.1 relative to healthy people; Vaa, 2003). Further examination indicates that, crash risk is higher for two conditions (Vlakveld et al., 2005):
– Reduced useful field of view (UFOV) by more than 40% increases risk by a factor of 5 relative to normal UFOV. The occurrence is higher in people of 65 years and above (Rubin et al., 1999).
– Glare sensitivity increases crash risk by a factor of 1.6 (only a few studies).

Decreased hearing only results in a slightly increased risk of 1.2 (Vaa, 2003). The same is the case for neurological disorders, that are associated with increased risk by a factor of 1.8. People with Alzheimer's disease run a risk of crash involvement which is twice as high as healthy people (Vlakveld et al., 2005). Other psychiatric disorders, such as cognitive disorders and depression, result in a slightly increased risk of a factor 1.6 on average (Vlakveld et al., 2005).

[5] If a road user travels without a vehicle, this is only the person's body mass.

Emotion and aggression

During the past few years in particular, many road users have held the view that aggression in traffic is a major contributor to road crashes. Several questionnaire studies show the relationship between self-reported aggressive behaviour (offending behaviour) and self-reported road crash involvement (e.g. Deffenbacher et al., 2003; Mesken et al., 2002; Stradling et al., 1998). However, this does not imply a causal relationship between the two elements. It is also the case that aggressive behaviour coincides with risk-seeking behaviour. This makes it difficult to draw conclusions about the relationship between aggression and road safety. The literature leaves the impression that there is a coherent behavioural pattern of a combination of various aggressive and/or risky behaviour types that result in a dangerous driving style. However, for the time being it is not possible to quantify the risk associated with this risk factor.

Fatigue

Fatigue is most probably a much more frequently occurring factor in increasing risk than data from police reports shows. Participating in traffic whilst fatigued is dangerous because, in addition to the risk of actually falling asleep behind the steering wheel, fatigue reduces general ability to drive (keeping course), reaction time, and motivation to comply with traffic rules. Research shows that people suffering from a sleep disorder or an acute lack of sleep, have a 3 to 8 times higher risk of injury crash involvement (Connor et al., 2002).

Distraction

Like fatigue, distraction is probably a much more frequent crash cause than reported police data shows. Currently, one of the more common sources of distraction is use of the mobile phone while driving. The permitted hands-free option does not reduce the effect of distraction either (e.g. Patten et al., 2004). The most well-known and best research into the risk of using a mobile phone while driving indicates an increase in risk by a factor of 4 relative to non-users (Redelmeier & Tibshirani, 1997; McEvoy et al., 2005). Other studies show a similar risk increase (for an overview, see Dragutinovic & Twisk, 2005). Other activities such as operating route-navigation systems, tuning CD-players and radios etc. can also be a source of distraction, as can activity such as eating, drinking, smoking and talking with passengers (see Young et al., 2003).

2.1.3. Increased understanding of road traffic safety

Much can be understood about road safety from the fundamental risk factors: speed, mass and vulnerability. Research results from the past teach us this. They also identify where the opportunities are for improvement. Users of motorized two-wheelers have the highest fatality and injury risk in road traffic, which can largely be explained by a combination of high speed with the relatively low mass of the vehicle in conflict with other motorized traffic, as well as poor crash protection. On top of that, mopeds are popular with young people who have yet to obtain a driving licence. This group already has a relatively high risk in traffic because of age-specific characteristics and needs, and lack of experience.

Currently, car occupants have the major share of the total number of road fatalities because of the relatively high kilometrage travelled in cars. On the one hand, the car is a fast and weighty opponent in conflicts with two-wheelers and pedestrians who also comprise especially vulnerable road users, such as children and the elderly. On the other hand, the car is the vulnerable party in terms of weight in conflicts with heavy goods vehicles and not very ‘forgiving’ roadside obstacles. Young people are an especially high risk group of those involved in serious crashes because of their lack of driving/riding experience and age-specific characteristics. Elderly road users (of 75 years old or more) are as a car occupant the next most important risk group because of their physical frailty.

Safety on roads can also to a large extent be explained by a combination of fundamental risk factors. For example, serious crashes outside urban areas, and particularly on rural 80 km/h roads, are dominated by single-vehicle conflicts along sections of road. These are usually the result of inappropriate speeds, possibly in combination with other factors which increase risk, such as alcohol consumption, distraction and/or fatigue, and the fact that many roads are not ‘forgiving’; this results in errors being punished with (severe) outcomes. Intelligent Transport Systems that keep speeds within limits or which monitor the driver’s state, could reduce risk here, but the road and roadside could be designed in such a way that errors are not punished with severe outcomes. On urban roads, transverse conflicts, in particular, predominate. On 50 km/h roads, in particular, where most people are killed in urban areas, mass differentials and the vulnerability of road users are important factors, combined with comparatively high speed, and the vulnerability of vehicles in transverse conflicts. In the Netherlands, the risk of being involved in a crash is highest on urban 50 km/h and rural 80 km/h roads. Motorways are the safest roads when it comes to crash risk. This is due to a combination of road design (and vehicles allowed on this type of road) which is appropriate for high driving speed, both physically (separation of driving directions) and psychologically (predictable design), so that high speeds can be managed in relative safety.

In general, road safety has improved enormously over time, and the Netherlands is one of the safest countries in the world. The rate of improvement in the Netherlands has also been high in the past decades. This is partly due to a learning society, which has grown used to modern, fast traffic. In addition, infrastructural adaptation has taken place (such as the construction of relatively safe motorways), secondary safety in vehicles has been improved, and there is more safety legislation and enforcement which takes account of factors which increase risk and reduce injury (such as alcohol consumption in traffic, and mandatory crash helmet and seat belt use respectively). These measures have also contributed to reductions in the number of traffic fatalities and injuries, despite increased mobility. The SUNflower research has made these possible explanations plausible (Koornstra et al., 2002) and is supported by other scientific literature (Elvik & Vaa, 2004). But, as yet, we do not have a totally conclusive explanation for these improvements.

2.2. Cause: 'unintentional errors' or 'intentional violations'?

Taking into account the analyses and risk factors which have been discussed previously, the next question is how road traffic crashes originate and how the factors mentioned play a role in this. In identifying the cause of crashes in whatever system, *man* is always quoted as the most important cause of crashes. People make errors, no matter how hard they try not to. At the same time, people do not always (intentionally or otherwise) obey rules designed to reduce risks.

The original version of Sustainable Safety (Koornstra et al., 1992) took as its starting point the well-intentioned road user who is, unintentionally, fallible. The contribution of (intentional) violations to dangerous traffic was considered to be extremely small, and violations were consequently not specifically taken on board in the vision. We can, nevertheless, question if this supposition was correct then, or if it can continue to be neglected these days.

An opinion which is often expressed is that crashes are caused by antisocial road users who grossly disrespect all rules. This feeling is perhaps nurtured by television programmes, watched from a comfortable chair in the living room, in which characters who grossly offend and behave in traffic like kamikaze pilots are pursued. People imagine their own driving behaviour to be safe, because what one can see on television or on the road bears no comparison with how they drive themselves. A driver's own offending behaviour (for instance: speeding just a little or running a red light because there is no other traffic) is thought to be safe, because he thinks he knows exactly what he is doing, and thinks that everything is under control. When asked, most road users think that they are better and safer drivers than others, but statistically this is, of course, impossible. The question arises how serious offences actually are for road safety, and with what frequency they do cause traffic crashes.

In order to get a picture of the extent to which (unintentional) errors and (intentional) violations (see also *Chapter 1*) play a role in crash causation, we look to empirical research for a possible answer to this question. Studies into crash causes can be classified into two groups. The first group of studies takes the crash as the starting point and identifies contributory factors. The second group of studies takes road user behaviour as the starting point, and investigates to what extent they are related to crashes.

2.2.1. Crash research

Research that take crashes as the starting point produces very diverse findings on the contribution of errors and offences to crash causes. We need to note here that most investigations did not look explicitly to distinguish between (unintentional) errors and (intentional) violations.

From Australian research based on police registration forms (Cairney & Catchpole, 1991), visual perception errors emerge as particularly important causes of crashes. Fifty percent of crashes involving road users reported not to have seen each other. However, since this research does not provide any information about factors that can be labelled as offences, no inferences can be made from this research as to whether violations are an important factor in crash causation.

A Swedish in-depth study of Sagberg & Assum (2000) found that 30% of fatally injured drivers in road crashes had used alcohol or drugs, had not worn their seat belts, or combinations of these offences.

Recently, Van der Zwart (2004) found in an investigation based on police registration forms on fatal crashes on national roads in the Dutch province of Zuid-Holland that 30% of drivers had probably been under the influence of alcohol. There was also suspicion that in 50% of the crashes, inappropriately high speeds had played a role in the causation of the crash. In 20% of the cases, it was suspected that the people involved had not worn their seat belts.

In similar research – a pilot study – into the causes of fatal crashes in the Netherlands in 2003 (Aarts et al., in preparation), specific study was made into unintentional errors and intentional violations as causes of crashes. From the available material, however, it proved to be extremely difficult, and in 60% of the cases even impossible, to extract information about unintentional errors and intentional violations. In those cases where a judgement could be made about errors and/or violations, it was found that in about half of the cases one or more violations were involved.

In an overview study into the relationship between offences and crashes (Zaidel, 2001) based on offence registrations in Israel, Sweden and the United Kingdom, it was concluded that, while violations increase crash risk, the (causal) relationship between (judicial) violations and crashes is difficult to establish. This is partly caused by the fact that the data is too imperfect for research purposes.

From the abovementioned studies, no clear picture emerges of the relative contribution of intentional violations and unintentional errors to crashes. It is clear, however, that error is not the only factor in the causation of crashes. We have to bear in mind that violations, in principle, increase crash risks, but that they can lead to crashes perhaps mainly in combination with errors made by the driver or by other road users. We also need to realize that one violation is different from the next (see *Chapter 1*).

2.2.2. Research into the behavioural patterns of road users

One of the most important sources for research where driving behaviour or the behavioural tendencies of a driver is related to the driver's crash history, is research using the Driver Behaviour Questionnaire (DBQ). Dutch research carried out with car drivers, using the DBQ (Verschuur, 2003), shows a strong relationship between violation behaviour[6] and crashes, as did the results of DBQ studies in other countries (e.g. Stradling et al., 1998). To a lesser extent, a strong relationship was also found with the frequency of mistakes (see *Chapter 1*). From the research it became clear that tendencies to making task performance errors (slips and lapses) have little or no relationship with crashes, but the question arises whether this relationship is underestimated due to the nature of these errors or not. Although this research demonstrates a relationship with certain types of dangerous behaviour and crashes, it says nothing about the role of errors or violations in crash *causation*.

A Canadian study looked into the relationship between violations and crashes as evidenced by driver behaviour (Redelmeier et al., 2003). The research team tracked car drivers who were convicted of causing a fatal crash, and recorded the crash involvement of these offenders in the period following the conviction. The research revealed that, in the first month following the penalty, the chance of being involved in a fatal crash was 35% lower than could be expected on the basis of coincidence. The research attributed this effect to the fact that there were less traffic violations immediately after the period that the drivers were fined. However, this benefit decreased substantially over time and disappeared after three to four months.

Out of the above research emerges a strong relationship, particularly between violations and crash involvement. It must be emphasized, however, that this type of research cannot say anything conclusive about causality between the two phenomena.

2.2.3. The importance of intentional violations

On the basis of empirical research into crash causation, we can conclude that both errors and (intentional) violations play a role in the causation of crashes and,

[6] The questionnaire is particularly geared towards speed violations.

therefore, deserve a place in the Sustainable Safety vision. The role of (unintentional) error seems, however, to be the most important. How large the share of (unintentional) error and (intentional) violation is exactly cannot be stated based on current knowledge. The picture is too vague. The information that can be extracted from police registration forms about crash causes cannot be used to identify the underlying causes of crashes. This is not surprising, given that this data is gathered primarily with the objective of being able to identify the guilty party, rather than the underlying causes of a crash. It should also be remembered that crashes are always the result of a combination of factors.

That unintentional errors still form the lion's share of crash causes is logical on the one hand, given that intentional offending in itself never leads directly to a crash. Violations certainly can increase the risk of error and the serious consequences of these errors. However, there is no evidence to support the widely held opinion that antisocial road hogs are the major perpetrators of crashes. Without doubt, they cause part of the road safety problem, if only because other road users cannot always react appropriately to them. Still, many crashes are the result of unintentional errors that everybody can make in an unguarded moment.

2.3. What will the future bring?

So much for the past and present. But what will the future have in store for us? In order to determine the appropriate strategy in a road safety vision and to propose the right measures, we need to take account of future societal changes. After all, Sustainable Safety has the ambition to be proactive to anticipate possible dangerous developments, tendencies and situations, instead of taking action after serious crashes have taken place. In the next section, a number of current developments relevant to traffic and road safety in the Netherlands are outlined.

2.3.1. Developments in the Netherlands

Mobility

The first development that is expected to have an effect on future road safety, is further growth in mobility. This growth can be mainly attributed to economic and population growth (Statistics Netherlands, 2004). It is expected that this will set two developments in motion.

Firstly, further growth in car mobility, especially car use for social activities (Social and Cultural Planning Office of the Netherlands, 2004, in Schoon, 2005), with which extension of the road network will not keep pace. This means that traffic will become increasingly busy, and traffic will also be distributed more evenly over time ('the off-peak hours between peak hours will fill up') and place ('more cut-through traffic'). The exact consequences for road traffic are difficult to assess, but they will depend upon the way in which people react to ever heavier traffic. More conflict possibilities will occur, for example because the relatively dangerous secondary road network will be used to relieve the main road network (see also *Figure 1.6*). At the same time, when so much traffic has to be accommodated, the increased intensity will also result in lower speeds, with less likelihood of serious crashes. Modal shift may also occur.

Concurrent with mobility growth, a second development is an increase in mileage by heavy goods vehicles and vans (AVV, 2004, in Schoon, 2005). This is also related to expected economic growth. The need to deliver goods just-in-time, the rise of internet shopping, and the spread of goods distribution centres across the country also play a role in this (Schoon & Schreuders, 2006). A future new mobility policy may have an influence on the distribution of traffic over time and place, and also on the choice of individual or public transport. We recommend that the various options for different mobility policies in a scenario approach are outlined, and the safety effects *ex ante* assessed. If the safety effects are regarded as unacceptable, compensatory measures will need to be taken.

Demography

A second development concerns demography within the Netherlands. Of particular note are the large and increasing numbers of older people, and the large numbers of young people born in the 1980s (Statistics Netherlands, 2004). Combined with the trend of increasing individualism, this is expected to result in more single households. It is expected that the effect of this will result in facilities being spread over larger areas with increasing dependence on cars (Methorst & Van Raamsdonk, 2003). Contributing to this also is the life pattern of double-income families who, in combining (part-time) work, care tasks and often considerable commuting distances, will use the car more often, having previously gone on foot or taken the bicycle (the school trip, for example, is now combined with commuting to and from work; Schoon, 2005). This trend is another source of increased car mobility, but also of increased driving experience and driving licence ownership in traffic. Since children will begin to participate in traffic at a later age, they will also need to learn to cope with traffic at a later stage (Schoon, 2005). This has a possible negative effect on the risk of (young) cyclists and moped riders.

Social culture

Developments in various cultural, societal and/or age-specific subcultures can also have their effect on road safety (Schoon, 2005). There is a trend that certain groups of young people in the lower socio-economic groups in particular (linked with certain car types and motorized two-wheelers), regard traffic as a playing field where one can let oneself go in risky behaviour in striving for sensation. This is also related to increased (perceived) aggression and intolerance in traffic ("We sometimes have a very short fuse in our small country", see *Frame 2.1*). This is possibly also related to increasingly congested traffic and resulting delays when travelling. Leaving aside some, fortunately incidental, cases of excessive aggression in traffic, the question remains as to the extent that aggression actually leads to more crashes (see *2.1.2.2*). Nevertheless, it seems to be appropriate here to keep a finger on the pulse.

Consumption

The growth in prosperity, linked to the growth in disposable income, is expected not only to result in mobility increases, but also a more rapid renewal of the car fleet. This has benefits for severe injury risk, because new cars usually have better primary and secondary safety (see also *Chapter 5*). This will also have an influence on the increase in technological applications in motorized traffic (see also *Chapter 6*). However, an increase in consumption possibilities is much less positive for road safety when it comes to the number of motorcyclists, increased alcohol consumption and increasing fatigue – thinking for instance of the advance of the 24-hour economy (Schoon, 2005).

Quality of life

Increasing prosperity also results in increased importance being attached by society to the quality of life. Health, healthy lifestyles and a clean environment become important issues. These can be beneficial for road safety, not only because of decreasing acceptance of risks, but also recognition of high-quality trauma organization as a secondary effect (Amelink, 2006; Racioppi et al., 2004). City centres that are not accessible to car traffic, and which shift mobility to the periphery of urban areas, provide one example. This trend is also related to the increased densities of urban areas, where congested traffic flows offer opportunities for expanding the public transport network and reducing car mobility in residential areas (Schoon & Schreuders, 2006). In Sustainable Safety, there is a

'Short fuses' in the Netherlands

'Short fuses' occur most often in road traffic (61%), and predominantly in men reacting agitatedly to other road users (48%). These 'other road users' are most probably mainly women, because they indicate that they always behave in a civilized manner in traffic, but they are confronted almost twice as often with uncivilized reactions of others in traffic compared to on the street. These results follow from research carried out by TNS NIPO in August 2005, commissioned by SIRE (Dutch organization of Idealistic Advertisement). This research also revealed that almost everybody (90%) considers this type of behaviour as annoying, and even that 84% of people finds that others are more quickly annoyed than 10 years ago.

All this was a reason for SIRE to start a publicity campaign entitled: 'Short fuse'. With this campaign, SIRE aims to hold a mirror up tot people, and to confront them with their own behaviour in a humorous fashion.
Adri de Vries, SIRE managing director: "We live on top of each other, we have little space, we are extremely assertive, and we claim our rights immediately. To assert one's right has become the norm, otherwise you are a loser."

Source: SIRE/Metro

Frame 2.1.

clear interest in taking advantage of developments in urban planning and development. However, it has to be said that this has not yet found a firm footing. But the interest is there, and it certainly is an issue that deserves more attention.

Public governance

Finally, we mention trends in the governance of the public sector in relation to developments in society, and the relationship between individual and governmental responsibility. Firstly, this concerns the effects of governmental organization on road safety. In the Netherlands, this is organized in a decentralized way, but there is also the increasing influence of Europe. The decreased room for manoeuvre in government funding, the reduced staff capacity and expertise, the decreasing tendency to regulate centrally for executive organizations, together with decreased frequency of inspection of the implementation of measures, have to be compensated by the increased responsibility of citizens who, well-educated, do not like to be told what to do. In view of this, the central organization of a number of traffic and transport matters is no longer an issue, and the question arises as to what this means for road safety. *Chapter 15* will address this in more detail. In view of these developments in public governance, the high economic importance of traffic and transport, the ever increasing traffic congestion which takes up all available physical space, and the fact that new consideration has to be given to accessibility, quality of life, environment, and road safety, decision making processes become ever more complex. Extra effort and dedicated knowledge is required to allow full consideration of road safety in decision making (see also *Chapter 15*). Add to all this the fact of life of more emancipated citizens (see *Frame 2.2*) and the fact that they view road crashes as a large problem, this means a growing 'market' for the societal centre ground.

If we combine this conclusion with the notion that citizens' support becomes increasingly important, then it is clear that the 'road safety lobby' has to play an important role in the future. Improving road safety and realizing Sustainable Safety will benefit from a strong road safety advocacy.

2.3.2. International developments that are relevant to the Netherlands

Most European road safety developments are of particular interest for countries where road safety is at a lower level than in a country such as the Netherlands. In a number of cases, especially concerning the development of a vision and infrastructural measures, the Dutch approach to road safety has been exemplary (Peden et al., 2004). However, in the future, the Netherlands can expect to profit from European attention to better monitoring of road safety policy and measures, and exchanging best practice knowledge. This fits with initiatives at national and regional level,

Perception of road safety in the Netherlands

As far as Dutch citizens are concerned, road safety is the highest priority within the theme 'traffic and transport', and above congestion. Road safety is also considered to be of both societal and personal importance. It is remarkable that people do see this subject less as something that should be given more priority by government. People obviously think that road safety also is partly a matter of changing attitudes, something that we as citizens need to solve together (or is this only something for 'the others'?).

Subject	Of (large) societal importance	Of (large) personal importance	Should get government priority
Road safety	96%	95%	79%
Ignoring traffic rules	92%	87%	80%
Infrastructure maintenance	92%	68%	69%
Punctuality of trains	88%	29%	79%
Travel time	78%	47%	64%

Percentage of respondents who (strongly) agree with the statement mentioned (Information Council, 2005).

Frame 2.2.

and hopefully can count on the interest from road safety professionals, road authorities, road designers, the police and judicial authorities.

With respect to infrastructure, the European Commission is considering drafting recommendations or directives, inviting Member States to consider road safety and to assess the expected road safety effects in their infrastructure plans in a transparent way. The expectations for European road safety developments are that the emphasis of vehicle-related measures will be on intelligent technological systems. However, improvements are also expected in the field of secondary safety measures (see *Chapter 5*). In this field, the Netherlands, in particular, depends upon international developments, the vehicle industry's own initiatives, developments from Geneva and Brussels, and developments via EuroNCAP. This programme will be supported by the European Commission in the future, and will lead to safer cars coming onto the market. In addition to car front and side (impact) improvements, it is probable that more attention will also be given to compatibility standards between vehicles (see *Chapter 14*).

With respect to driving skill measures, the Netherlands might benefit particularly from licensing arrangements for motorized two-wheelers. Increasing minimum moped rider age in combination with more and prolonged education could considerably improve road safety for a vulnerable but also dangerous group of road users. Unfortunately, the political support for such measures, to date, is lacking in the Netherlands.

With the aim of reducing injury severity after a crash, the EU is developing an e-Call system. In the event of a crash, the system can automatically notify the emergency services of the vehicle location. The objective for the longer term is to fit all motor vehicles with such a system. Dutch road safety can also benefit from these measures in terms of a reduction in severely injured road victims.

2.3.3. Increasing mobility, technology and consumption

Town and country planning, increasing prosperity, and the composition of the population have quantitative and qualitative consequences for road safety in the future. Further increases in car mobility dominate this picture. The quality of motorized traffic, in particular, is likely to increase with increasing prosperity (secondary safety measures, safety-orientated ITS, more attention to health and environment). While this may lead to improved occupant safety, special attention needs to be given to vulnerable road users, particularly cyclists and pedestrians. The desire for more economic growth and the need for the Netherlands to increase its competitiveness also puts pressure on road safety, as freight flow volumes increase, as well as citizens' fatigue. The increasingly congested road traffic will most certainly have an impact on road safety, but it is not possible to say in advance if the outcome will be positive or negative.

The most important influence from Europe for the Netherlands is expected in the area of vehicle safety. In the longer term, technological applications, such as e-Call and Intelligent Speed Assistance (ISA) systems, can make a contribution. Furthermore, road safety in the Netherlands could benefit from tighter European requirements in various fields (vehicles, driver training, professional freight transport, road infrastructure).

2.4. Mapping traffic system gaps

The previous road safety analyses show that car mobility, in particular, has increased in the course of time, with an enormous and simultaneous improvement in safety. Much of the latter is due to large and small efforts to improve the safety of all the components of the traffic system. While mobility is expected to grow even more in future, the growth rate is likely to be lower than in the past. We need to keep a close eye on road safety trends as a consequence of this. The growth in mobility has specific consequences for combined traffic management as the numbers of vulnerable road users, such as cyclists and pedestrians, increase. A large proportion of these, in the Netherlands, will be elderly road users.

As noted previously, motorized two-wheelers are a comparatively dangerous transport mode. This is related to the combination of relatively high speeds and a lack of physical protection. Moreover, motorized two-wheelers are popular with young people, who run a higher risk of serious crash involvement due to a lack of experience and age-specific characteristics.

With respect to safety on roads, rural 80 km/h roads and urban 50 km/h roads deserve the greatest attention. These roads will be considered more and more as part of a road network and the optimum use of this network. Particularly single-vehicle crashes result in severely injured victims on these roads. Injury-producing side impacts are the main problem at intersections.

Large differences in mass exacerbate the injury severity of the weaker party. This can partly be alleviated by secondary safety design and equipment, such as crash helmets, airbags and seat belts, and by pedestrian-friendly and cyclist-friendly car fronts. It is preferable, however, to avoid large differences in mass and in speed. This not only has consequences for the separation of slow and fast moving traffic, but also for light and heavy traffic. Into the future, road safety should also be able to benefit from Intelligent Transport Systems aimed at the detection of obstacles and driver state monitoring and warning.

The important factors which increase risk are speed, in particular, and the use of psychoactive substances (mainly alcohol and drugs). Other factors that probably cause crashes far more frequently than can be ascertained from (police) records, are issues such as fatigue and distraction. Fatigue is expected to be an increasing problem in future, as will distraction in an era where more and more tasks will be automated.

The general crash causation picture is that anyone can make unintentional errors and, while these probably comprise the lion share, violations should not to be neglected. At least, violations can substantially increase crash risk, whether a combination of individual error, or other road user error. Preventing human error from resulting in a serious crash remains a very important issue for improving road safety. This can be reinforced by preventing violations of the limits which society has set to address known factors which increase risk.

3. Sustainable Safety to date: effects and lessons

Following the initiation of the Sustainable Safety concept (Koornstra et al., 1992), preparations were made for its implementation, culminating in the setting up of four Sustainable Safety demonstration projects in 1995. Experiences gained in these projects then informed the development of the covenant underlying the *Start-up Programme Sustainable Safety*, negotiated and subscribed to by the Ministry of Transport and regional and local authorities in 1997 (VNG et al., 1997). The covenant comprised a package of 24 road safety measures that could be implemented comparatively quickly, coupled with a declaration of intent to make a policy agreement for a second phase of Sustainable Safety after the *Start-up Programme* was completed (foreseen in 2001). In order to complete a number of measures, the *Start-up Programme* was extended to 2003.

The second phase of Sustainable Safety was taken up in the Dutch *National Traffic and Transport Plan (NVVP)* which defined specific actions by and between key public bodies. However, the Dutch Parliament rejected the *NVVP*. Nevertheless, relevant contents of the Plan found their way, in general terms, into the *Mobility Paper* (Ministry of Transport, 2004a).

In parallel with the measures in the *Start-up Programme*, other measures have been taken during the period 1990-2005 (and some even earlier) that fit very well with Sustainable Safety. These measures and the 24 defined actions from the *Start-up Programme* are reviewed in this chapter (*3.1*). We consider what implementation has taken place to date and assess future needs. We also want to ascertain whether or not the road safety measures that are labelled as 'sustainably safe' have had any effect (*3.2*). Knowledge about the effectiveness of measures is, of course, important for recommendations on future implementation.

The chapter closes with conclusions about the results of the first phase of Sustainable Safety, the experiences acquired, and the effects of implementation so far (*3.3*). The conclusions are intended to inform the next phase of Sustainable Safety which this publication is keen to promote.

3.1. From vision to implementation

Two aspects of the implementation of Sustainable Safety measures in the period 1990-2005 can be evaluated. Firstly, the actual result of the preparation for, and/or implementation of these measures, either with reference to the *Start-up Programme*, or without it (*3.3.1*). Secondly, what is known about the implementation process (*3.3.2*) the experiences of executive parties, the problems encountered and ways of dealing with them.

3.1.1. Successfully implementing Sustainable Safety measures

According to the original Sustainable Safety vision, an inherently safe traffic system is attained by a) designing the infrastructure in such a way that it is in compliance with human characteristics, b) introducing vehicle measures that protect the vulnerable human and that support the driving task, and c) ensuring that road users are well informed, well trained, and, where necessary, supervised. By adopting an approach that integrates the elements 'human', 'vehicle', and 'road', sustainable traffic safety can be achieved.

The next sections look at the Sustainable Safety measures that have been taken in these three areas. These are mainly, but not exclusively, measures from the *Start-up Programme,* and those that have made a good contribution to sustainably safe road traffic are highlighted. Much of the analysis comes from an evaluation of the *Start-up Programme* conducted in 2004 (Goudappel Coffeng & AVV, 2005). Most of the numbers in this evaluation are based on a survey under road authorities at the end of the *Start-up Programme* (SGBO, 2001).

3.1.1.1. Measures on infrastructure

Road categorization

Before road authorities could start to implement infrastructural measures in line with Sustainable Safety, the first requirement was to categorize roads based on traffic planning functionality (flow and access). To this end, CROW, the Dutch information and technology platform for infrastructure, traffic, transport and public space, laid down functional and operational requirements for categorization (CROW, 1997). Meanwhile, the road authorities have categorized the greater majority of roads. The method recommended by CROW has not been used in all cases (Van Minnen, 2000).

Audits

Since 1998, protocols have been set up for road safety audits (Feijen & Van Schagen, 2001; Van Schagen, 1998a; b) in order that new road design and revision of existing roads always fit uniformly within Sustainable Safety. Additionally, a number of auditors have been trained and trial audits have been held. It is apparent that, in comparison with many other countries in the world (see e.g. Lynam, 2003), road safety audits are not well advanced in the Netherlands.

30 km/h zones

During the *Start-up Programme*, 19,000 kilometres of 30 km/h zones were built, far more than the Programme's target of 12,000 kilometres. The strong interest of the municipalities in this part of the *Start-up Programme* can undoubtedly be attributed to the subsidy arrangement which foresaw 50% of building costs being covered. However, as the amount of implementation considerably exceeded expectations, only 36% of costs were covered by central government subsidies. The road authorities themselves paid for the remainder. Now, there are about 30,000 kilometres of 30 km/h streets, representing just over a half of the convertible potential.
As regards the quality of 30 km/h zones, the road authorities themselves indicate that about two-thirds have been implemented at low-cost, and one-third at an optimum sustainably safe[7] level. Low-cost solutions were not originally part of the Sustainable Safety vision, but they have been permitted at an early stage to allow for large scale construction of 30 km/h zones within the available budget. Priority was also given to the most important bottlenecks and dangerous locations. It was assumed, however, that low-cost construction would be followed by sustainably safe construction at an optimum level. It is intended that the next phase of Sustainable Safety should continue with the construction and adaptation of 30 km/h zones.

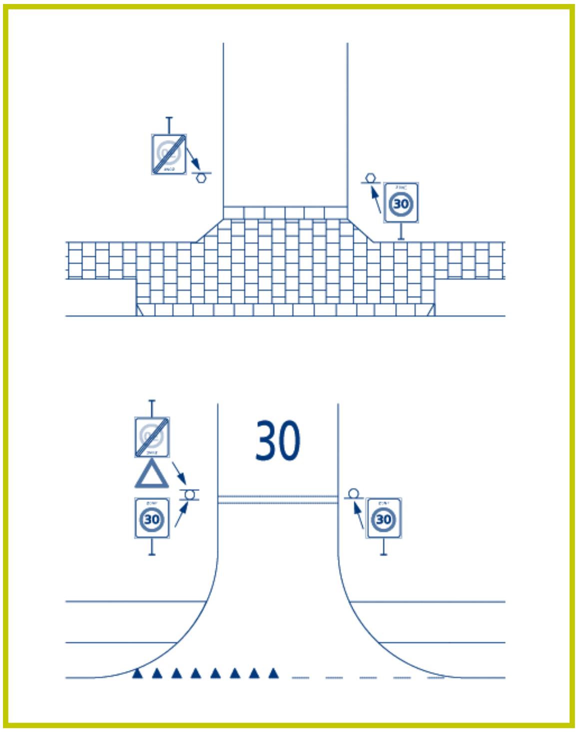


Figure 3.1. ***Two examples of a gate construction of a 30 km/h zone entrance. Source: CROW.***

60 km/h zones

According to the original Sustainable Safety vision, rural access roads should have a 40 km/h speed limit in order to manage the mixture of slow and fast traffic without severe crash risk. This speed limit however, was not considered realistic by the signatories of the *Start-up Programme* covenant. A speed limit of 60 km/h was chosen.
More 60 km/h zones have been constructed (more than 10,000 kilometres) than targeted (3,000 kilometres); a sign of great interest from road authorities. To date, the completed construction covers about half of the zones that qualify for 60 km/h conversion. The costs per constructed kilometre of 60 km/h road proved to be higher than originally assumed. This is partly due to the fact that the construction at a number of locations was less low-cost than was originally planned. In the road authorities' opinion, one-fifth of the zones have actually been

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[7] This follows from an inquiry that AVV Transport Research Centre held with respect to the final evaluation of the *Start-up Programme*. The road authorities involved mean the following by a 'low-cost' and 'optimum' construction of 30 km/h zones:
– *Low-cost:* gate construction (see e.g. *Figure 3.1*) at the transition boundary of speed limit zones, combined with speed reducing measures such as speed humps at intersections.
– *Optimum:* such a road design, and physical speed reducing measures that are placed so close to each other, that driving too fast becomes less self-evident.

Figure 3.2. ***Example of a gate construction entrance to a rural access road.***

Figure 3.3. ***Roundabout with separate cycle path in an urban area.***

built to optimum sustainably safe standards, the other zones have used a low-cost alternative[8]. Whilst the targeted number of 60 km/h zones to be constructed was exceeded, 18% of the building costs were covered by central government subsidies with the road authorities paying the remainder. This can be interpreted as a sign of the road authorities' great interest in Sustainable Safety. Just as for 30 km/h zones, the construction and adaptation of 60 km/h zones will be followed up at regional level.

Roundabouts

As early as the 1980s, road authorities in the Netherlands had started to reconstruct three-branched and four-branched intersections into roundabouts. The implementation of this measure, which fully fits in the Sustainable Safety vision, was nevertheless not part of the *Start-up Programme*. To date, more than 3,000 roundabouts have been built in the Netherlands (AVV, 2004).

In order to bring uniformity to rules about priority at roundabouts, one of the agreements within the *Start-up Programme* was that motorized traffic on the roundabout has right-of-way over approaching traffic. Later, outside of the *Start-up Programme*, the recommendation that cyclists on separate cycle facilities next to rural roundabouts should not get right-of-way over motorized traffic was added to the new priority rules. On urban roundabouts, cyclists do have right-of-way in these situations (*Figure 3.3*).

Nowadays, on nearly all rural roundabouts, priority rules have been implemented in conformity with the CROW recommendations (CROW, 1998). In urban areas this is the case in about 60% of the roundabouts (SGBO, 2001; Goudappel Coffeng & AVV, 2005). Uniformity of priority rules at urban roundabouts is unlikely to be achieved because a number of (northern) road authorities are against it. A supplement to the CROW guideline has been set up for such cases (CROW, 2002a), so that road authorities can explain the priority rules to road users as clearly as possible. According to Sustainable Safety, uniformity in the implementation of measures is highly important to improve the predictability of traffic situations, and to avoid confusing road users.

Priority on major roads

In preparing the measure in which slow traffic coming from the right would get priority (a wish that was not part of the Sustainable Safety vision), road authorities regulated priorities by adapting road signing and redesigning dangerous intersections. Since May 1st, 2001, both motorized and non-motorized traffic coming from the right at intersections of equivalent roads have right-of-way. This measure has also been taken with a view to uniformity of priority rules in Europe.

Both priority uniformity and visual clarity about priority rules for every type of road user fit the Sustainable Safety vision. Combined with this, priority rules should also fit with road categories meeting at intersections.

[8] According to road authorities, 'low-cost' and 'optimum' construction of 60 km/h zones are the following:
– *Low-cost*: gate construction at the transition boundary of speed limit zones, combined with edge marking.
– *Optimum*: gate constructions (see *Figure 3.2*), edge marking and a controlled number of speed reducing measures at intersections and road sections where appropriate. There is, nevertheless, some difference between road authorities what is considered to be optimum sustainably safe.

These specific measures are, nevertheless, not part of the original Sustainable Safety vision as formulated in Koornstra et al. (1992).

Moped riders on the carriageway

After several successful trials with moped riders on (urban) carriageways instead of on cycle paths, this measure has been in force in the Netherlands since December 15th, 1999. Where exceptions to this rule apply (e.g. on 70 km/h roads, short connecting roads and solitary cycle paths), special road signs have been installed (see *Figure 3.4*). Although this measure has been introduced on more than half of all urban roads (some 2,000 kilometres), it has not been implemented uniformly throughout the Netherlands.
In the same way as 'right-of-way for slow traffic coming from the right' was not originally part of the Sustainable Safety vision, 'moped riders on the carriageway' was also not included. Nevertheless, the measure fits the vision because it results in homogeneity of speed rather than homogeneity of vulnerability, which was the case beforehand.

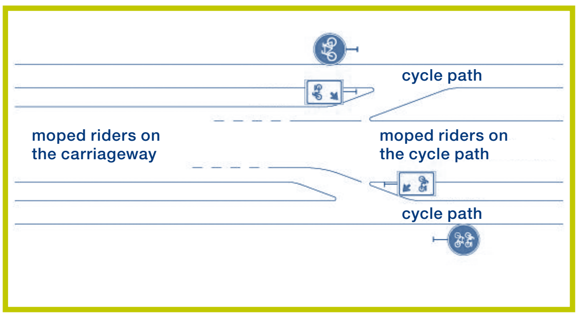


Figure 3.4. ***Schematic representation of 'moped riders on the carriageway'. Source: CROW.***

Other infrastructural measures

In addition to the construction of 30 km/h and 60 km/h zones and roundabouts, there has been continuous development of sustainably safe infrastructural measures, in the period 1990-2005, outside of the *Start-up Programme*. Examples are construction of cycle paths and parallel facilities, introduction of (physical) separation of driving directions, application of road markings in line with the 'essential recognizability characteristics' set up later (which will result ultimately in uniform road markings on Dutch roads), removal of crossings and intersections, the introduction of roadside safety constructions and obstacle-free zones. The exact number of these measures that have been implemented in the Netherlands is not known.

The influence of the Sustainable Safety vision on the design of motorways in the Netherlands (and on motorway design guidelines) is barely noticeable. Other developments around the new Dutch motorway design guidelines (accessibility, congestion, environment, costs, rigidity of guidelines, etc.) set the agenda here (De Vries, 2005).

Revision of infrastructural handbooks

In the meantime, the design guideline for rural roads (RONA) has had a supplement with Sustainable Safety principles added to it in the new handbook for rural road design (CROW, 2002b). Sustainable Safety supplements have also been added to the design recommendations for urban roads and streets (CROW, 2004a). CROW has also published a handbook for safe shoulder implementation (CROW, 2004b). Safe implementation of shoulders was not part of the *Start-up Programme*, but it fits well within Sustainable Safety, and calculations show that this measure would save many traffic casualties (Schoon, 2003a). In the next phase of Sustainable Safety, the safe implementation of shoulders has been included in the *Mobility Paper*. At the same time, CROW has drawn up 'essential recognizability characteristics' (CROW, 2004c) to improve predictability of roads by means of centre line markings and edge markings. The 'essential recognizability characteristics' have been approved in the national mobility round table (*Nationaal Mobiliteitsberaad*) and are also part of the *Mobility Paper*. They are also part of the guideline signing and marking (CROW, 2005). This is a supplement to the handbook for rural road design (CROW, 2002b), which CROW revised earlier. The authors of the guidelines consider the 'essential recognizability characteristics' to be an affordable compromise. These recognizability characteristics are part of wider essential characteristics for road design that were proposed earlier. The considerations with respect to the content that led to the proposal for essential characteristics are still valid.

Adapting recommendations and guidelines for road design need large-scale and far-reaching efforts, and it is clear that the most recent revisions in the Netherlands are inspired by Sustainable Safety. This increased the opportunities for road designers to arrive at sustainably safe designs. In relation to recommendations and guidelines, large advances have been made in the last decade. Motorways, as stated earlier, are an exception to this.

Detailed examination of the handbook for rural road design (CROW, 2002b) and the recommendations for urban traffic facilities (CROW, 2004a) makes it clear that further improvements are desirable and possible. Here, we will deal with three subjects that require further elaboration. Firstly, the idea of categorization is a central issue in Sustainable Safety. However, in the absence of a 'network approach' no concrete requirements are defined yet for a good categorization plan to meet. A second area that requires further attention is so-called 'design consistency'. This concerns continuity in design elements, and more particularly in road marking. Finally, many choices made in the handbooks are not yet based on scientific research. How much safety is lost if a designer deviates from a recommended 'optimum value' is too often not known.

3.1.1.2. Vehicle measures

The *Start-up Programme* did not contain any agreements with respect to vehicles. Nevertheless, vehicle measures have been implemented in the period 1990-2005 that can be characterized as a step in the direction of a sustainably safe traffic system. These have largely arisen as a result of market initiatives (at European level).

Primary vehicle safety

Measures for primary safety that fit with Sustainable Safety in that they enhance the anticipation of dangerous situations are aimed principally at improving the field of view and warning systems (see further in *Chapters 5 and 6*).

Secondary vehicle safety

Secondary vehicle measures fit particularly well with Sustainable Safety's second aim of reducing injury severity if a crash occurs. Relevant measures include the greater presence of air bags in the vehicle fleet and greater crash protection in vehicle design. These types of measure are often market driven and are typically dealt with at an international level (for example the EuroNCAP programme has made a very positive contribution in Europe since 1997). These measures are also connected with economic prosperity, in that this can influence the purchase of newer and safer cars.

Decreasing moped risks

Moped riders in Dutch traffic represent a relatively high risk and, therefore, the original Sustainable Safety vision proposed to increase both the minimum age and access requirements for riding a moped. This proposal was later underpinned by research (Wegman et al., 2004). A concerted attempt to increase the minimum age for riding a moped from 16 to 17 years was made in 2004 with a ministerial proposal but this did not lead to a revision of the law.

3.1.1.3. Educational measures and enforcement

Education

The Sustainable Safety vision foresees educative measures that prepare road users so that they have an optimum level of relevant skill and information. The concept of permanent traffic education fits this requirement. Some preparatory activities have been undertaken in this field, particularly by the regional bodies for road safety. The national round table for traffic education (*Landelijk Overleg Verkeerseducatie LOVE*), representing regional and provincial road safety bodies, has set up starting points for various age groups laid down in a framework memorandum Permanent Traffic Education (see Van Betuw & Vissers, 2002). This also contains the recommendation to set up a Permanent Traffic Education project office.

Campaigns

Campaigns have focused on the introduction of new rules, for instance 'mopeds on the carriageway' and 'right-of-way for slow traffic coming from the right'. This fits with Sustainable Safety, because it enhances road users' familiarity with rules. Campaigns to prevent the non-wearing of crash helmets and seat belts, red light running, drink driving, and speeding contribute to sustainably safe road traffic if they reduce violation behaviour by road users by making them aware of risk. All these campaigns have been run nationally (following the so-called 'campaign calendar' of the Ministry of Transport) and were supported by regional bodies at their own initiative. For the period 2003-2007, similar agreements on road safety publicity campaigns have been made between regional and national authorities, the police and the judiciary.

Enforcement

In the original Sustainable Safety vision, enforcement was seen as the final component and was given relatively little attention. Representatives of the enforcement community asserted that they did not wish to intensify enforcement on roads that were not designed as sustainably safe.

However, the *Start-up Programme* did contain plans to intensify enforcement. On a regional basis, efforts were to be aimed at the most pressing violations, irrespective of the link with other Sustainable Safety measures. Since 1999, intensified surveillance projects have been initiated in all police districts. Advances have been made in this area (see *Chapter 8*), but coordination with other elements of road safety, for instance infrastructure, has not been very strong.

To achieve more intensified enforcement without further burdening the limited capacity of police and judiciary, road authorities proposed to deal with minor offences by means of administrative fines. However, in 2001, based on research by the University of Groningen (Haan-Kamminga et al.,1999) into the possibilities and problems of various alternatives of administrative enforcement, the national government decided to reject the road authorities' proposal. There has been widespread and intensive discussion on the subject of administrative enforcement in the past few years, but this has not contributed to the further integration of policy on infrastructure and enforcement. Perhaps, even the contrary has happened. However, from a road safety perspective, it is highly desirable that this integration takes place in the future.

To investigate the extent to which cooperation between administrative and judicial parties can be improved to achieve more effective and efficient enforcement, a steering group on interdepartmental policy research for traffic surveillance (*Interdepartementaal Beleidsonderzoek Verkeerstoezicht*) has been set up. This steering group has initiated two test trials in the provinces of Zeeland and Utrecht, to see how collaboration between relevant parties can best be achieved.

Our conclusion is that, despite being a part of the *Start-up Programme*, education and enforcement have not developed to their full potential and, most importantly, are not seen as an integrated part of other activities, principally infrastructure.

3.1.1.4. Accompanying measures

From the road user's point of view, predictable road course and predictable traffic situations are important in order to avoid confusion and the concomitant increase in risk of errors. To fine-tune measures that create a predictable environment and to bring about nation-wide uniformity, it is of the utmost importance that an exchange of knowledge takes place between the parties responsible. For this reason, agreements about the exchange of knowledge have been included in the *Start-up Programme*.

From 1997, exchange of knowledge between central and decentralized (road) authorities on Sustainable Safety has been routed through the knowledge platform VERDI. However, decentralization policy has caused this platform to be dismantled and it has been replaced by KpVV Traffic and Transport Platform (*Kennisplatform Verkeer en Vervoer KpVV*), which also has a budget for research. This platform will have an important role to play in future exchange of knowledge on Sustainable Safety between decentralized authorities.

In 1998, an Infopoint Sustainable Safety was set up by CROW and SWOV to which road safety professionals can refer questions about Sustainable Safety. This Infopoint has an internet page where, in addition to general background material about Sustainable Safety, information on Sustainable Safety publications is provided. A newsletter (*Signalen*) is also issued four times a year, and a telephone helpdesk was in operation until 2004. Since April 2005 the Infopoint internet page has been sited within CROW's knowledge net. The Infopoint also organizes annual thematic programmes, where executive agencies can obtain information on current, published Sustainable Safety measures.

3.1.2. The implementation process

At the end of the 1980s, the Dutch government commenced decentralizing the implementation policies. In the mid-1990s, this decentralization was incorporated in three *Traffic and Transport Covenants (Convenanten Verkeer en Vervoer COVER*). These were the *Decentralization Covenant Road Safety* in the governance field, supplemented later by the *VERDI Covenant*. The third covenant was the *Start-up Programme Sustainable Safety*, which, unlike the first two covenants, was mainly concerned with content.

The expectation of decentralization of policy is that it can be more sensitive to local and regional needs, connect more readily with public support, and facilitate greater integration of measures within a defined area.

Central government provided subsidies for the execution of this policy and for the implementation of road safety measures. In tangible terms, this meant that road authorities could use subsidy and their own budgets for the construction of some of the infrastructural measures within the framework of the *Start-up Programme*. Central government also funded Regional Road Safety Bodies, comprised of all stakeholders in the road safety field. They have been and are especially active in the fields of education, campaigns and enforcement at regional and local level.

> "Improving road safety requires strong political will on the part of governments."
>
> *Kofi Annan,*
> *United Nations Secretary-General, 2003*

The information above describes the policy background for the implementation of the Sustainable Safety measures of the *Start-up Programme*. Two evaluations that were published in 2001, respectively the evaluations of four Sustainable Safety demonstration projects (Heijkamp, 2001) and the evaluation of the COVER *Traffic and Transport Covenants* (Terlouw et al., 2001), give us an insight into the experiences gained during this first phase. The evaluation of demonstration projects provides an analysis of detailed implementation issues at local policy level, whereas the COVER evaluation gives a more general picture, both of policy experiences and experiences concerned with content. A summary of these experiences will be discussed in the next sections.

3.1.2.1. Cooperation between stakeholders

The evaluation of the four Sustainable Safety demonstration projects found that cooperation between road authorities and police/judiciary was often below the optimum level. The COVER evaluation came to the same conclusion at national level. This evaluation concluded that problems connected with the deployment of traffic enforcement have even more to do with poor cooperation between the police and road authorities than with the problem of police capacity (the so-called 'enforcement deficit').

It was also found that cooperation and communication with or commitment to other stakeholders, such as road safety interest groups, was not all it should be (Terlouw et al., 2001). These groups were of the opinion that the Regional Road Safety Bodies were insufficiently able to act as critics of central government because their funding came from central government. The experience of the demonstration projects was that good prior agreements between relevant parties about the distribution of tasks and funding, stimulates cooperation and avoids problems at a later stage. Good mutual communication is clearly of the greatest importance here. At a higher level, cooperation and, consequently, road safety can be improved by making agreements or by coordinating arrangements between relevant agencies and stakeholders, such as road authorities, police and judiciary, and pressure organizations (Heijkamp, 2001; see also Wegman, 2004).

3.1.2.2. Issues arising from the types of measure

Measure types

With respect to the types of measures, particularly from the *Start-up Programme*, the COVER evaluation noticed that there was too heavy an emphasis on the infrastructural approach of road safety. The evaluation committee judged that education and enforcement should be integrated to achieve a better balance with infrastructural and technological measures.

Low-cost alternatives of measures

In addition, the evaluation committee found that, by using low-cost implementation, infrastructural measures were in fact spread too thinly across too large areas. This brought about less safe behaviour by road users and aggravated problems of enforcement, according to the committee.

3.1.2.3. Experiences with the actual implementation

From the evaluation of the demonstration projects, it is clear that public support is seen as the most important prerequisite for the successful implementation of measures. Public support often guides the more intricate actions of executive authorities. It was reported that alternating between attractive and less attractive measures was a good way to obtain and maintain support. Furthermore, commencing the implementation of measures where they were clearly most required or were perceived to be so, engendered good public support. Good communication with the citizen was regarded as crucial for gaining public support.

In 2001, the COVER evaluation committee reported that too little had been done about the evaluation of measures. In particular, it was found that little was known about the effectiveness of education. There is a need to gain a better insight into both costs and benefits of measures. This insight is essential to determine where the most effective and efficient solutions lie for a next generation of Sustainable Safety. The evaluation committee also found from the Regional Road Safety Bodies that too little had been done to innovate educational programmes, for example, and to deal with available budgets creatively.

Finally, the evaluation committee concluded that the Sustainable Safety projects that had been initiated were too loosely embedded in overall policy development, and that, consequently, they were vulnerable to being cut short if other priorities arose. The committee also reported that decentralized authorities were disappointed about the level of support from central government in relation to funding, responsibility for non-infrastructural measures and sensitivity to the views of regional stakeholders.

Sustainable Safety is seen internationally as a good road safety practice

"Vision Zero in Sweden and the Sustainable Safety programme in the Netherlands are examples of good practice in road safety. Such good practice can also have other benefits. It can encourage healthier lifestyles, involving more walking and cycling, and can reduce the noise and air pollution that result from motor vehicle traffic."

World Health Organization WHO,
in: World Report on Road Traffic Injury,
Peden et al., 2004

3.2. Effects of Sustainable Safety

Research carried out into the effects of Sustainable Safety measures, falls into two areas. Firstly, the effects on road user behaviour (*3.2.1*) and (subsequently) the effects on the number of crashes and secondly, the number of victims involved (*3.2.2*).

3.2.1. Effects on behaviour

3.2.1.1. Behavioural effects of infrastructural measures

30 km/h zones

In general, no evaluation of the effects of road user behaviour (particularly speed behaviour) in 30 km/h zones has been carried out in the Netherlands. This is to be regretted because the view was expressed (Terlouw et al., 2001) that the measures taken were too low-cost to reduce speeds to the target level. This picture is confirmed by (incidental) speed checks carried out by the Dutch Traffic Safety Association 3VO in 2004 at 40 different 30 km/h locations. This showed that 85% of all car drivers exceeded the speed limit, although by no more than 15 km/h. Sixty-five percent exceeded the limit by more than 10 km/h. This picture was consistent in all selected locations (3VO, 2004).

Low-cost solutions: road marking measures

On rural access roads with non-compulsory cycle lanes, cyclists tend to ride slightly further away from the road edge. This became evident from 'before and after' studies into the behavioural effects of cycle lanes (Van der Kooi & Dijkstra, 2003). Possible negative effects of this are that the distance between cars and cyclists is slightly reduced and also cars keep slightly further away from the road edge. However, in most cases, the average speed of faster traffic is slightly reduced.

From a national and international meta-analysis of the effects of road markings (Davidse et al., 2004), it was found that edge markings or centre line markings actually cause speed to increase and that traffic shifts a little towards the edge of the road.

The effect of low-cost design of rural distributor roads has been evaluated in various ways since 2000 (*Table 3.1*), low-cost design components being broken line edge markings and double centre line markings. From these studies, no clear positive or negative effects of low-cost design were found. On the one hand, this may be because these investigations were often carried out on a limited number of road sections. On the other hand, it may be that low-cost implementation does not result in (sufficient) changes in behaviour.

In addition to these objective behavioural studies of the effects of low-cost measures, the Royal Dutch

Study	Subject	Behavioural effects	Remarks
Van Beek (2002; not published research)	Double centre line marking; research based on detection loop data and video.	Small reduction in speed and decrease of overtaking manoeuvres.	Probably also influence of environmental characteristics and presence of speed cameras.
Steyvers & Streefkerk (2002)	Low-cost implementation of rural distributor roads (80 km/h limit); research with instrumented car.	No difference in travel speed. Driving closer to road edge. Larger variance in steering angle. According to heart beat measurement more strenuous, but according to subjective assessment not.	Larger differences in before period between experimental and control road section than in after period. Makes interpretation of data difficult.
Commandeur et al. (2003a)	Low-cost implementation of rural distributor roads (80 km/h limit); research based on detection loops and instrumented car.	Less speed decrease on experimental road section than on control road section. Less overtaking manoeuvres. No effects on speed distribution and headway times. Driving closer to road axis.	Freight traffic increased in after period and this may explain the overall reduction in speed.

Table 3.1. ***Summary of studies into the behavioural effects of low-cost designed rural distributor roads.***

Figure 3.5. ***Example of low-cost implementation of rural distributor road (80 km/h limit).***

Touring Club ANWB (Hendriks, 2004) has recently undertaken user research into predictability of current road markings. This investigation was carried out by driving with pairs of subjects on a predetermined road section, and by noting user remarks. The results revealed that more than half of the subjects said that they did not understand the meaning of different kinds of road markings, and that the lack of uniformity was unsettling. Some participants tried to establish a connection between road markings and speed limits, but none identified this correctly. Subjects also said that they tend to miss cues when edge or centre line markings are missing. This research also revealed more specific problems with edge marking on rural access roads where markings were too far away from the road edge. Road users are confused by this, and some will not cross the marking because it is not clear where the pavement edge ends in adverse light conditions.

Physical separation of driving directions

A number of studies into the behavioural effects of different types of physical separation of driving directions on rural distributor roads have been undertaken.

In 1995, a study was performed into the effect of physical elevation (ledge; see *Figure 3.6*) between carriageways on part of a rural distributor road (80 km/h speed limit); (Goudappel Coffeng, 1996). This was compared with a classic direction separation (single centre line marking), and with direction separation by means of a double centre line marking (with the possibility of adding a ridge in the future). The results did not show any changes in average speed[9]. To

[9] Because different methods were used in the before period and after period to acquire speed data, the speed data cannot be compared in detail.

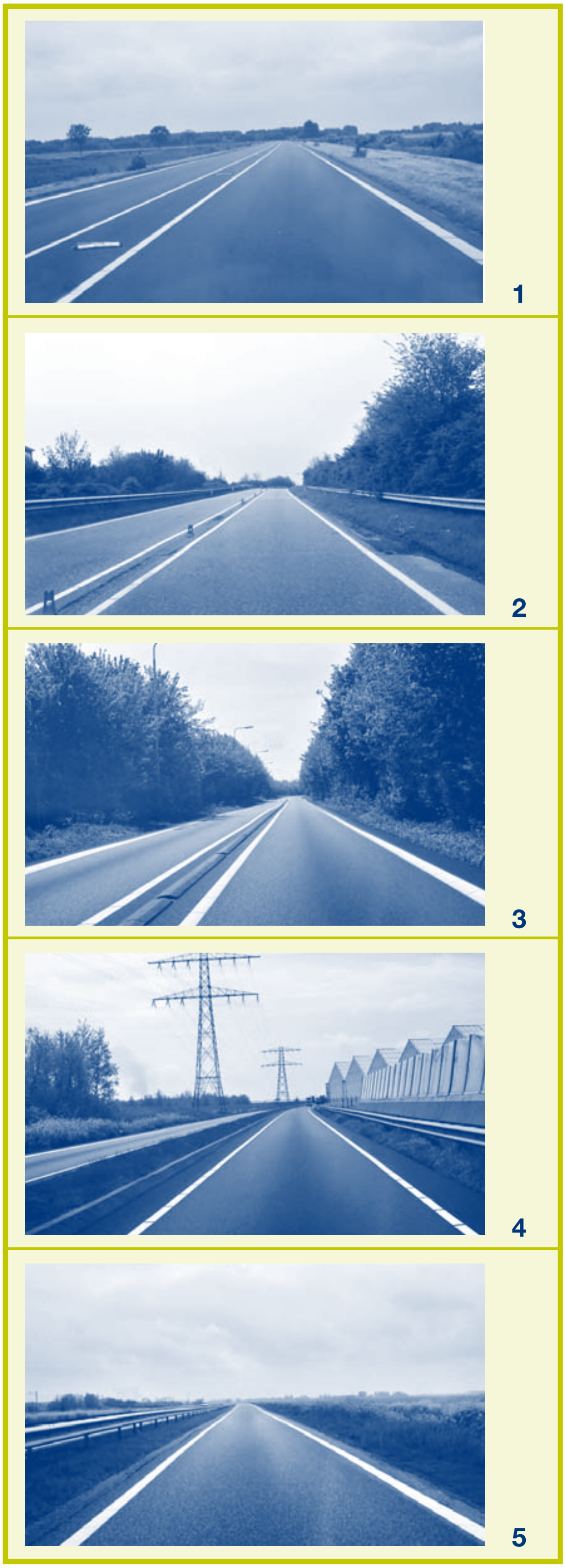


Figure 3.6. *The five most important methods to seperate driving directions physically: 1) ridges 2) flaps, 3) ledge, 4) elevated median, and 5) crash barrier.*

be more specific, no differences were found in speed and the percentage of offenders between the three options of direction separation during daytime. During the evening, the physical separation did result in halving the number of speed offenders compared to the other methods of direction separation. With physical separation, 65% of the vehicles moved toward the right-hand side road edge, as opposed to 59% of vehicles on roads with double centre line marking, and 39% on roads with classic centre line marking.

Another study examined the behavioural effects of strips as a form of direction separation on a rural distributor road (Van de Pol & Janssen, 1998). This measure resulted in the complete stoppage of overtaking movements (at least, none were observed), the average speed dropped from 84 to 80 km/h (5% reduction), and the percentage of speed limit offenders dropped from 57% to 40% (30% reduction). These behavioural differences were found predominantly in car drivers and motorcyclists.

In the same study, the behavioural effects of flexible poles (flaps; see *Figure 3.6*) as direction separation on rural distributor roads were also evaluated. This measure also resulted in a complete stoppage of overtaking manoeuvres (during the trial period). No quantitative data was available for speed behaviour, but based on the video images, the conclusion was drawn that there were hardly any differences in speed behaviour compared to the situation where strips were applied.

The safest and most cost-effective solution for direction separation for rural distributor roads is not very clear from currently available information. We recommend that further research is carried out.

3.2.1.2. Behavioural effects of vehicle and technological measures

Tests with Intelligent Speed Assistance

Separate from the *Start-up Programme*, but fitting the Sustainable Safety vision, research has been done in the Netherlands into the behavioural effects of Intelligent Speed Assistance (ISA), in anticipation of its possible introduction in the future. Two studies have been undertaken, based on local field trials.

In the first study, which was part of the European MASTER programme (Managing Speeds of Traffic on European Roads), the behavioural effects of a half-open ISA version[10] were assessed in a quasi-experimental field study, where subjects had to drive a defined road section in a car equipped with special instrumentation (Várhelyi & Mäkinen, 1998). The same test was performed in Sweden and Spain, but only the results of the Dutch trial are referred to here. This study showed that people drove more slowly on roads with a speed limit lower than 70 km/h, particularly when approaching intersections and roundabouts. There was also less variance in driving speeds and drivers allowed more headway. The reason that less effect was found on roads with higher speed limits may be due to the fact that these roads were very busy and traffic already circulated at limited speeds.

The second study concerned a field trial with a closed ISA[11] version in an area in the city of Tilburg in the period 1999-2000 (Van Loon & Duynstee, 2001)[12]. Subjects were local drivers who were given an ISA-equipped car. This trial showed that speed was reduced on roads with a 30 km/h and 50 km/h speed limit, but not on roads with an 80 km/h speed limit. This last finding can also be attributed to the presence of speed cameras on these 80 km/h roads, so that drivers obeyed the speed limit both in the before period with non-ISA-equipped cars and during the trial period. At present, ISA seems a promising means of reducing speed.

3.2.1.3. Behavioural effects of education and enforcement

Police enforcement of speed limits, seat belt wearing, and non-drink driving.

An evaluation study into the effects of regional enforcement plans (Mathijssen & De Craen, 2004) has shown that in regions that enforce according to such a plan (particularly speed offences and seat belt wearing), speed offences are significantly reduced and seat belt use increases compared with regions where there is not such a plan.

An evaluation of intensified speed surveillance on rural distributor roads (80 km/h speed limit) and regional through roads (100 km/h speed limit); Goldenbeld & Van Schagen (2005) have clearly shown a positive effect on speed behaviour. Intensified surveillance combined with campaigns resulted in a decrease of the percentage of offenders on rural distributor roads from 30% to 15% over a five-year period; and on regional through roads, the percentage of offenders decreased from 15% to 8%.

An evaluation of the effects of intensified police surveillance within the framework of regional plans revealed that surveillance of drink driving increased by 5% to 10% in the period until 2001 (Mathijssen & De Craen, 2004). However, the intensified surveillance during this period was not translated into a reduction in the percentage of alcohol violators. From more recent data, it may be concluded that the number of detected alcohol violators has decreased in the period 2002-2004 (AVV Transport Research Centre, 2005), but the causes for this are not clear.

Road safety campaigns

Dutch national road safety campaigns are mainly evaluated on the basis of levels of awareness of targeted road user groups. In addition, levels of the development of dangerous behaviour targeted by campaigns are also evaluated. In 2004, such evaluations were carried out, assessing the reasons for changed behaviour regarding seat belt use (in the front and back seats in cars), drink driving, distance keeping, and cycle lighting. This was in response to the Multi-annual Campaigns Road Safety, started in 2003 under the banner ‘Returning home’ (Feijen et al., 2005). Compared to 2002, seat belt use proved to have increased both in front and back seats, as did the use of bicycle lighting. In addition, a decrease in alcohol violations during weekend nights was observed. Only car headway distances, determined by detection loop data, did not increase. These results may be partly attributed to campaigns, but partly also to other factors, independent of campaigns. No control groups were used and therefore, it is not possible to determine exactly the effect of campaigns on behaviour or the effort required to provide information that will bring about behavioural changes.

3.2.2. Effects of Sustainable Safety measures on crashes

Since the *Start-up Programme* concentrated on the implementation of infrastructural measures, the effects of this type of measure have been studied most.

[10] In a half-open ISA version, the driver receives haptic feedback (counterpoise) from the accelerator when the maximum speed is approached.
[11] In a closed ISA version it is not possible to exceed the speed limit.
[12] Several issues were evaluated in the field trial, but we will restrict ourselves to behavioural effects.

Research has been done into the effects of other measures (particularly police surveillance) however, these measures neither fitted in with the intentions of Sustainable Safety, nor have they been elaborated upon as a part of the *Start-up Programme*.

30 km/h zones

In a recent evaluation of twenty low-cost implemented 30 km/h zones, it was found that the number of hospital admission crashes decreased by 27% (Steenaert et al., 2004). This evaluation also found that safety in 30 km/h zones depends very much on the spatial planning of the area. Areas with a grid structure, mainly from the 1950s and 1960s, are relatively dangerous per hectare, per kilometre of street, or number of inhabitants.

It follows from calculations, that both by kilometre of road and by vehicle kilometre, 30 km/h zones are generally about three times as safe as streets with a 50 km/h speed limit (SWOV, 2004a; based on figures from 2002). With respect to the total safety contribution of 30 km/h zone construction at the time of the *Start-up Programme,* a reduction of about 10% in fatalities and almost 60% in the number of hospital casualties followed when measured by the number of kilometres of road (Wegman et al., 2006).

Though these results are in line with earlier Dutch studies (Vis & Kaal, 1993) and international studies (Elvik, 2001a), the results cannot be characterized as very satisfactory. After all, severe injury risk is low if crash speeds are below 30 km/h (see *Chapter 1*). In fact, there should have been hardly any severely injured traffic casualties in these areas. The fact that there were some, requires further investigation and subsequent action.

60 km/h zones

A recent evaluation of safety effects in twenty 60 km/h zones (Beenker et al., 2004) shows an 18% reduction in injury crashes per kilometre of road compared to roads with an unchanged 80 km/h speed limit. Intersections where the 80 km/h regime was changed to 60 km/h have shown a 50% reduction in injury crashes (Beenker et al., 2004). The overall road safety effect on 60 km/h zones relies mainly on the effect at intersections.

The evaluated areas accounted for a 25% casualty reduction (Beenker et al., 2004). In the period 1998-

Figure 3.7. ***Example of a 30 km/h zone.***

2003, the construction of 60 km/h zones have resulted, approximately, in a 67% reduction in road fatalities in these areas, and a 32% reduction in severe injuries (Wegman et al., 2006).

This result deserves some further research. It was not expected that casualties could be completely avoided (the speed of motorized traffic is still relatively high in situations where fast and slow traffic mix, particularly when the 60 km/h speed limit is exceeded), but the percentage casualty reduction could be called modest. We recommend that means of increasing this percentage should be investigated.

Roundabouts

After road authorities started to construct roundabouts to replace three-branched and four-branched intersections in the 1980s, various evaluations into the safety effects of roundabouts have been conducted in the Netherlands (Dijkstra, 2004; Van Minnen, 1990; 1995; 1998). The conclusion from the first evaluation by Van Minnen (1990) was a casualty reduction of 73% from roundabout construction. For two-wheeled vehicles, this reduction was 62%, which means that roundabouts are particularly effective for reducing car occupant casualties. This picture was later confirmed in a study by the province of Zuid-Holland (2004). Internationally, lower reduction percentages are reported (between 10 and 40%), depending, partly, on the situation before reconstruction (Elvik & Vaa, 2004).

From an evaluation study by Dijkstra (2004), it can be concluded that urban roundabouts with separate cycle paths on which cyclists give way, are safer than roundabouts where cyclists have right-of-way.

The overall conclusion is that roundabouts have, indeed, brought about the improvement that was expected, and that there are compelling reasons to advocate their construction. However, the operation of urban roundabouts in the Netherlands has not yet been fully resolved, particularly with regard to the priority position of cyclists.

Priority regulations

One year after road authorities introduced the regulation of priority on their roads, and since mid-2001 at unregulated intersections, a rule came into force that allows slow traffic coming from the right to have right-of-way. An evaluation study has been conducted into the safety effects of this measure (Van Loon, 2003). No change in the total number of road crashes followed from this study, but both measures were not meant to improve road safety directly, rather they aimed to create more uniformity. Nevertheless, the evaluation reported a slight increase of 5% in crashes between motorized and non-motorized traffic. This increase could possibly be explained by the fact that everyone was not yet used to the new situation only one year after its introduction.

Moped riders on the carriageway

An evaluation study, conducted one year after the introduction of the measure 'moped riders on the carriageway' (Van Loon, 2001), concluded that 60% of moped trips had shifted from the cycle path to the carriageway. This caused the number of injury crashes on these routes to drop by 31%. At national level, this means a 15% reduction in the number of injury crashes involving mopeds.

Total road safety effect

It is estimated that the infrastructural Sustainable Safety measures (including roundabout construction) undertaken in the period 1997-2002, led to a 9.7% reduction in road crash fatalities and a 4.1% reduction in severe road injuries nationally (Wegman et al., 2006). This boils down to an average reduction of about 6% of severe road casualties. In absolute numbers, this means between 1,200 and 1,300 fatalities and severely injured during this period.

3.3. Lessons for the future

3.3.1. The Start-up Programme as a stimulus for action

In the period 1990-2005, much was achieved towards creating a sustainably safe traffic system. Sustainable Safety has proved to be an important stimulus to the promotion of road safety in the Netherlands, and it has led to more focused orientation and implementation. The results achieved are substantial, as can be read in this chapter. However, only the first outlines of a sustainably safe traffic system are rendered visible by the measures taken, and these are barely recognized as such by road users. There is still much more to do and the opportunities are clear.

The greatest stimulus for action in the recent past has undoubtedly been provided by the demonstration projects and, subsequently, the covenant for the *Start-up Programme*. The latter was initiated by the Ministry of Transport, and it was taken up by the various levels of authorities in the Netherlands. The covenant deserves recognition because it embodies concrete agreements between four important stakeholders in the field of road safety. The ambitions of the *Start-up Programme* have been surpassed in several areas. Whether this is because the formulated ambitions were overly cautious ('playing it safe'), or that the covenant partners did more in the course of the process than was originally foreseen is unclear. However, we have to conclude that the national road authority has lagged behind (particularly where motorways are concerned), and only a few initiatives in the area of Sustainable Safety have been developed.

For the next phase, cooperation between the aforementioned authorities should be continued and added to by including not only other authorities, such as the police and judiciary, but also private organizations and the private sector to achieve an even more integrated approach. To this end, Wegman (2004) has proposed a Road Safety Agreement between all parties to create a comprehensive approach to improving road safety. The second point that deserves praise is the fact that the *Start-up Programme* provided a particularly important stimulus to the construction of 30 and 60 km/h zones. The attractive subsidy arrangement was certainly an important factor, partly because it encouraged the road authorities themselves to fund and build many more zones than were originally agreed!

From the foregoing, we may conclude that there is a very broad consensus to achieve a sustainably safe or inherently safe traffic system, and that much support was demonstrated for the measures in the *Start-up Programme*. Parties responsible for the implementation of relevant measures agree with the binding nature of the vision and have proved to be sensitive to the subsidy arrangement. Now that the initial stimulus function of the *Start-up Programme* has passed, the task is to find a way within the new administrative relationships that can lead to a similarly successful implementation of Sustainable Safety. The regions and provinces have a key task here.

This publication aims to update the Sustainable Safety vision of road safety in the Netherlands for the coming 15 to 20 years and to lay a foundation in terms of content for the further execution of Sustainable Safety. The means and methods of implementing this vision within current administrative arrangements is also a key aim (see the section on *Implementation*).

3.3.2. A shift in emphasis is desirable

The translation of the original Sustainable Safety philosophy into measures that can be implemented has, particularly in the *Start-up Programme*, laid a strong emphasis on infrastructural measures. Non-infrastructural measures were somewhat underexposed. This has caused a lack of balance in the interrelationship between measures in the fields of 'human', 'vehicle' and 'road'. The emphasis on infrastructural measures was justifiable, and fitted well within the Sustainable Safety vision. Road design has a dominant influence on both behaviour and errors by road users on the one hand, and (serious) crash prevention on the other. The more vocational measures, however, such as education and enforcement, were not well addressed in the *Start-up Programme*. Vehicle measures are completely missing. Fortunately, improvements in the vehicle field have been made, mainly through the influence of EuroNCAP. Nevertheless, a strong national programme is lacking.

Within the issue of infrastructure, the emphasis was mainly on 30 km/h and 60 km/h access roads. This was an understandable and a responsible choice. Measures on these roads were welcomed with overwhelming support from the population and from politicians. Measures fitting within the Sustainable Safety vision were well-known, and could be implemented comparatively swiftly. In the future, there is a clear need to strive for a broader approach. Coordination can be achieved by thinking in terms of road networks, as proposed in the *Mobility Paper*. Road safety considerations should be integrated with those of flow/access and the environment to arrive at rational and transparent choices. Specific knowledge of these subjects is essential to underpinning these choices.

A broader approach is also required to further integration of technology and vehicles and elements such as education and enforcement. We recommend developing much fuller integration of measures in the field of infrastructure, vehicle technology, education, and enforcement.

3.3.3. Diluting the effect

We have concluded that, in various instances, too many compromises were made during the transfer from vision to implementation. For instance, low-cost solutions were introduced and original proposals for a general urban 30 km/h speed limit and a 40 km/h speed limit on rural access roads were not chosen as the general policy. There was, unfortunately, not enough knowledge at that time to be able to assess the possibly diluting effects of such low-cost solutions.

From the evaluations of the *Start-up Programme*, and from the more qualitative analyses of the three Traffic and Transport Agreements in the Netherlands (COVER evaluation), we can conclude that low-cost implementation indeed meant too much dilution. Reductions of 25%-30% in severe road traffic casualties, brought about principally by infrastructural measures in the *Start-up Programme*, are quite modest. Although no specific research has been done into the effects of low-cost solutions, it seems reasonable to assume that this frugality has had a less positive effect on safety than would otherwise have been the case. This means that we can speak of 'avoidable crashes' (Wegman, 2001), and assume that there have been unnecessary fatalities and casualties. The tendency to implement measures on a low-cost basis should be re-evaluated. There are also other measures than those listed in the *Mobility Paper* that are relevant here (see Wegman, 2001; Wegman et al., 2006).

3.3.4. Knowledge and knowledge management

This chapter shows that knowledge about the effects of Sustainable Safety measures have been gathered haphazardly, rather than in a structured way. In order to know which measures really improve road safety and which merit (substantial) investment, more evaluation of measures is required. For instance, not much is known about the effects of education on behaviour, although some work, which should be continued, is taking place to address this. Much is already known about infrastructural measures (notwithstanding that this knowledge needs to be actively disseminated to road designers), but also much is still unknown. For instance, we still do not know what the 'optimum values' are in a given road design, and how many extra road casualties result from low-cost solutions.

A new organization is required for knowledge gathering and dissemination in the Netherlands, as well as for establishing long-term agreements between existing organizations. These include the Ministry of Transport, the Dutch information and technology platform for infrastructure, traffic, transport and public space CROW, KpVV Traffic and Transport Platform, SWOV, police and judiciary, the regional authorities, and education institutes. Knowledge gathering and dissemination will have to go hand-in-hand in such a new structure and the issue of knowledge management should include 'how' as well as 'what'. In the 'how' field, there is a need to stimulate policy innovation and to disseminate acquired knowledge and experience given the current decentralized structures. This could be done, for instance, by renewing the Infopoint Sustainable Safety and by converting it to include all current Sustainable Safety knowledge not just that concerned with infrastructure. The Infopoint should also deal with programming, organization, research funding and, last but not least, policy innovation (see *Chapter 15*).

Policy measures taken without proper evaluation and subsequent knowledge of their effectiveness will most likely lead to a loss of direction. In order to stay on course in the future, we will have to pay more attention to evaluation studies and manage the knowledge gained in a systematic way. For effective policy and for efficient use of resources, more knowledge is needed and existing knowledge needs to be better disseminated!

Part II:
Detailing the Vision

4. Infrastructure

In this chapter, road infrastructure planning and design are discussed. These are central issues in the Sustainable Safety vision. Many steps forward have been taken in the past decade to allow infrastructure to comply with this vision (see *Chapter 3*). The *Start-up Programme Sustainable Safety* contained many 'agreements' directed at infrastructure, so many in fact that the misperception formed that Sustainable Safety was only about making road infrastructure safer. At the same time, the view that the road user's environment, of which the infrastructure of course is an essential component, plays a central role in managing traffic safely, remains intact (see also *Chapter 1*).

In general, the experience gained and the results achieved in the area of infrastructure can be characterized as very positive, even if there are (of course) still some wishes.

The design principles (*functional, homogeneous, and predictable* use) as listed in *Towards sustainably safe road traffic* (Koornstra et al., 1992) are still completely usable and there is no good reason to abandon them. Nevertheless, we feel it is wise to add a fourth principle to these three: *forgiving usage*. By this, we mean that roads, and particularly shoulders, are forgiving to human errors. We can even add that human errors should be absorbed by other road users, but this aspect of forgivingness has little connection with road design.

Translating the vision into actual road design requires a number of steps (see among others Dijkstra, 2003c) and, in theory, information can get lost in each of these steps. Firstly, the vision is translated into theoretical recommendations for road design, also named 'functional requirements'. These are subsequently translated into operational requirements that are converted ultimately from design requirements into design principles that, in turn, end up in road design *Guidelines* and *Manuals*. Subsequently, practical interpretations and considerations are made, based upon these guidelines and manuals, leading to tangible design of specific components of those networks (road sections and intersections). Information loss, and perhaps loss in safety quality, is also possible here. The last stage is the implementation of a design.

But the proof of the pudding is in the eating, which in this case means: determining the traffic safety effects (*4.3*), the various choices in road design guidelines (*4.1*), and actual implementation (*4.2*). The fourth section of this chapter revisits the design principles and the new emphases in these principles (*4.4*). This elaborates the theoretical backgrounds outlined in *Chapter 1*.

In fact, not much is known about how information and quality loss happens in practice. The Dutch Safety Board (2005) has recently acknowledged this factor and considers it as one of the causes of the long-term problem of 'high-risk regional main roads'. The Board considers that the choices made in the design of roads: 'preventing as many casualties as possible within the available budgets', are not always transparent. How road safety is weighted explicitly is also unclear. This holds, too, when changes in the design and implementation of roads are made because of objectives other than safety. The question arises how precisely road safety is considered then. With reference to this, section *4.5* discusses which instruments are available to map the potential effects of design choices, to allow balanced judgements to be made.

These observations have informed various recommendations in this book and particularly the plea made for supplemental agreements about *quality assurance* (*Chapter 15*), where suggestions are given about how the situation outlined above can be improved. While this *Infrastructure* chapter does not lead to further specific recommendations for sustainably safe road design (although suggestions can be found in other chapters), it does highlight issues for further research and policy.

The fact that road safety is not usually weighted explicitly and transparently in road design is, among other factors, due to a lack of knowledge and research results to underpin the operationalization of design requirements. This chapter outlines a number of questions that exist around sustainably safe road design; it extends an invitation to the professional world to address these questions seriously and subsequently, to provide research-based answers.

4.1. From vision to road design guidelines

The proactive character of Sustainable Safety (to eliminate latent errors to decrease, if not to prevent, severe crashes) were translated more or less directly into road design in the original Sustainable Safety vision (Koornstra et al., 1992). In the Netherlands, the starting points for road and street design have been laid down in *Guidelines, Handbooks* and *Recommendations*, drafted by CROW and put at the disposal of road authorities. The exceptions are the motorway design guidelines developed by the Directorate-General for Public Works and Water Management (*Rijkswaterstaat*). Although all these documents do not have any legal status, it is safe to assume that they play an important role in actual road design. The publication of the Sustainable Safety vision has provided an important stimulus to the revision of many design guidelines in the Netherlands (see also *Chapter 3*).

The principles of sustainably safe road infrastructure were threefold (Koornstra et al., 1992):

1. *functional usage*: to prevent unintended use of the infrastructure;
2. *homogeneous usage*: to avoid large differences in speeds, directions and masses at moderate and high speeds;
3. *predictable usage*: to prevent uncertain behaviour.

Based on the first principle (*functional usage*), roads have to be unequivocally distinguishable in the function that they perform ('monofunctionality'). To this end, the total number of potential collisions with a possibly severe outcome is minimized. Three road categories are distinguished, based on their function: flow, distribution and access.

The requirement that large differences in speed, direction and mass have to be avoided (*the homogeneous usage principle*) aims to reduce crash severity when crashes cannot be prevented.

The third principle (*predictable usage*) is aimed at preventing human error by offering a road environment to the road user that is recognizable and predictable. This indicates permissible road user behaviour and makes the behaviour of other road users more predictable. Within each road type, everything has to look similar to a particular level, whereas the differences between road types need to be as large as possible.

A start has been made in translating the Sustainable Safety principles into functional requirements for *road networks*, but this start has not been developed further or outlined in handbooks (Dijkstra, 2003a). Moreover, no connection has been established between the traditional road and street design guidelines and (dynamic) (area-wide) traffic management, etc.

The translation of Sustainable Safety principles into operational requirements for categorized roads has received ample attention (CROW, 1997). Sustainable Safety has opted for monofunctionality, that is: one function per road. Mixing functions leads to conflicting road design requirements and, hence, to unclear road design for road users, resulting in higher risks. A road network functions properly if function, design and usage (behaviour) are well tuned. The operational requirements set out in the CROW publication 116 (1997) have also been translated into an assessment tool for Sustainable Safety (see e.g. Houwing, 2003).

In the past few years, little progress has been made with respect to the second principle (*homogeneous usage*) in the Netherlands. This is surprising, since it concerns the core of the Sustainable Safety vision. For instance, no criteria have been formulated yet to indicate when this principle has been met. For this reason, this issue receives explicit attention in this book (in *Chapters 1 and 5*). Internationally (Sweden, Australia), developments can be observed which translate homogeneous usage into clear criteria for 'safe' crash circumstances, and safe travel speeds in particular.

At the same time, a further and new consideration has been added to this second principle: homogenizing flows. The corresponding idea is that it is beneficial for road safety when there is little variation in the speeds of close-moving vehicles travelling in the same direction (see *Chapter 1*). This is a plausible factor and one which is easy to observe on sections of road (see *Chapter 1*). In relation to intersections, this is more difficult, particularly if the speed exceeds the 'safe' side-impact crash speed.

The third principle (*predictable usage*) aims in practice to ensure that the road user can recognize the road type by its road characteristics (*recognizability*), which makes the road course and the behaviour of other road users more predictable (*predictability*). To this end, Sustainable Safety has been translated into 'essential characteristics' (CROW, 1997). This is a collection of road characteristics that, together, ensure that the road type is recognizable to the road user, as well as ensuring that the essential characteristics of road design meet other Sustainable Safety principles.

There has been strong debate in the professional world about this issue, in which doubts have been expressed about complying with and funding these essential characteristics. So much that, currently, we speak of the *essential recognizability characteristics* of road infrastructure (CROW, 2004a). As this publication acknowledges, this is no more than an intermediate step and cannot be regarded as sufficient from a Sustainable Safety perspective. Even then, some content questions remain about the basis of the selected characteristics (Aarts et al., 2006). SWOV pleaded in previous publications for the formulation of a minimum level of Sustainable Safety, which were called essential characteristics. The concern now is that the essential recognizability characteristics may be regarded as the final step and sufficient to achieve sustainably safe roads. Road authorities need to ensure that this does not happen in reality.

Without doubt, Sustainable Safety has played a key role in recent years in the establishment of handbooks and recommendations for road design of the secondary road network (CROW, 2002b; 2004a; see also *Chapter 3*). This is an important positive result. For motorway design, however, the situation is less clear. Although Sustainable Safety principles are already applied widely in motorway design, no evaluation or research results are available to indicate how far current Dutch design guidelines and recommendations meet the 'Sustainable Safety test'. We recommend that research is carried out to evaluate the Sustainable Safety quality of design guidelines in future.

4.2. From road design guidelines to practice

4.2.1. SustainableSafety in functional categorization of roads

Categorizing roads is a core activity for sustainably safe infrastructure and was acknowledged as such in the *Start-up Programme Sustainable Safety.* An agreed procedure for establishing a categorization plan exists (CROW, 1997). According to the final evaluation of the *Start-up Programme*, virtually all road authorities have formally established such a plan, but have not always exactly followed the approach developed by CROW (Goudappel Coffeng & AVV, 2005; see also *Chapter 3*). A SWOV survey (Dijkstra, 2003b), carried out in part of the Dutch province of Limburg, shows that assigning traffic functions to roads (road categorization) at network level complies, in most cases, with the requirements of Sustainable Safety. In addition, the directness of connecting routes (where a detour is not necessary) is generally in place everywhere. However, there are no requirements relating to content for these categorization plans, so it is unknown if they actually comply with the Sustainable Safety vision in the Netherlands. We recommend that further information is provided about how the principle of functionality is addressed in practice so that categorization plans can be tested.

4.2.2. Sustainable Safety in traffic planning design

We do not have research results that allow us to assess systematically the implementation of sustainably safe road design against Sustainable Safety principles. Nevertheless, an assessment tool is currently in development (Houwing, 2003) but not yet in use. We also do not have road safety audit results or independent assessments of road design to shed light on the extent to which designs comply with Sustainable Safety. We also lack a system which is used in the United Kingdom, which attempts to investigate the safety effects of applied infrastructure changes systematically (Molasses: Monitoring of Local Authority Safety Schemes; www.trl.co.uk/molasses). We will have to rely here upon some subjective assessments. One impression, for instance, is that there is a problem in the speed behaviour of motorized traffic at pedestrian crossings (see *Chapter 12*).

Categorization

Sustainable Safety practice has, in the meantime, shown that the theoretical categorization of roads and the linked uniformity of road sections and intersections have given rise to some large problems. The initial three categories were extended to five after a distinction was made between inside and outside urban areas for distributor roads and access roads (urban through roads should not exist in Sustainable Safety). In developing this division into five, road authorities indicated that they needed yet another distinction between road classes by speed regime. This produced two versions for urban distributor roads: the standard with a 50 km/h speed limit and a type of through road with a 70 km/h speed limit. Also a single type of rural through road turned out to be insufficient. Finally, a cheaper alternative was found for motorways: the regional through road with a narrower cross section and a lower speed limit.

Separation of driving direction

The extent of separation of driving direction has led to much discussion, particularly for rural distributor roads. Road authorities are mindful of the costs of widening road cross sections, the impossibility of overtaking, and provision in case of obstructions and emergency services. The '2+1-roads' solution (roads with an intermittent overtaking lane by direction), which is increasingly popular in other countries, is not popular in the Netherlands. On the basis of theoretical considerations (homogeneity principle) potential frontal impacts with crash speeds exceeding 70 km/h have to be excluded. This means that the direction of travel on roads with speeds higher than 80 km/h (rural distributor roads) will need to be separated in such a way that cars cannot hit each other head on. In practice, the double centre line was devised, on the understanding that the double line would better separate traffic, both visually and physically. Overtaking slow traffic would need different facilities with overtaking lanes, for example, or closing the carriageway to vehicles unable to reach permissible speed limits. Instead of a rigid, behaviour determining infrastructure, the choice is made in favour of more flexible design, where the road marking (particularly the double centre line) should be self-explaining. For a road user, the aim of such design may be clear, but his safe behaviour remains largely dependent on his willingness to behave safely. Moreover, this kind of road marking does not prevent unintentional errors, which might lead to crashes. Such a solution, therefore, does not have a sustainably safe character. Meanwhile, a discussion is going on in the Netherlands concerning what is called a 'cable barrier', a solution that is advocated within the Vision Zero in Sweden. Also, questions are not yet answered about the combined use of parallel roads alongside distributor roads (mixing agricultural traffic and cyclists and moped riders).

Access roads

In the execution of the *Start-up Programme Sustainable Safety,* it was also decided to encourage 'low-cost' options for 30 km/h zones. There are indications that 'low-cost' has become too sparing (see *Chapter 3*) and that road users exceed the speed limit. We recommend that this issue of 'low-cost implementation' is investigated in more detail.

The choice of a 60 km/h speed limit on rural distributor roads is not a sustainably safe solution, because of the fast and slow traffic mix, and the fact that crashes can still occur with severe consequences for vulnerable road users. The evaluation study into the effects of 60 km/h zones (Beenker et al., 2004) revealed that the positive effect is mainly the result of casualty reduction at intersections, rather than on road sections. It is unknown how often and by how much travel speeds exceed the speed limit on these roads.

Intersections

In 2002, an evaluation of Sustainable Safety in practice was carried out in the Dutch province of Limburg (Dijkstra, 2003b). It was noted, among other things, that only a small number of intersections of distributor roads complied with the corresponding Sustainable Safety requirement, that is: a roundabout. In the implementation, for instance, many intersections on distributor roads had been reconstructed into roundabouts, but not all intersections are suitable for such treatment. Heavily trafficked intersections can only be regulated by means of traffic lights, requiring infrastructural adaptation to influence speed behaviour, which can be difficult. This then raises the question of how car drivers can be made to comply with a local lower speed limit when the traffic lights are green – with cameras, raised junctions (see *Figure 4.1*), speed humps. Fortuijn et al. (2005) showed that humps just before a junction will lead to crash reduction.

Consistency

More consistency needs to be brought into road and traffic characteristics within road sections and inter-

Figure 4.1. ***Example of a raised T-junction between two rural access roads.***

sections in any one road category. Moreover, more continuity in these characteristics is desirable from one road section to the next as well as in intersections that form part of a route having the same function.

Miscellaneous problems

Two other problems remain: a) the lack of physical space to construct additional facilities, e.g. parallel roads alongside distributor roads or split-level junctions, and b) the lack of financial resources (Hansen, 2005). Hansen, therefore, suggests a number of changes in the further development of Sustainable Safety principles:
- to eliminate the regional through road (because these resemble a national through road too much) and to downgrade it to a distributor road, or to upgrade it to a motorway, or to detour traffic;
- to introduce the urban through road (70 km/h), which would bring us to six road categories;
- to allow for an incidental junction at grade on regional through roads (split level is "excessively costly, not sustainable, feasible only with difficulty and unnecessary with the introduction of ITS");
- to revise the design of the rural distributor road.

Dijkstra (2003a) advocates, in particular, the revision of traffic engineering design of distributor roads, and the adoption of Sustainable Safety measures which are strongly related to severe crash reduction in Sustainable Safety plans.

Room for compromise solutions?

The problem of the lack of physical and financial room for manoeuvre is a political/administrative problem which, without doubt, needs attention. However, it is thought to be too soon to abandon the principles for those reasons. The question also arises as to whether there are any safe alternatives. We strongly advise here that possible alternatives and their corresponding characteristics are investigated. However, that needs to be preceded by a comprehensive study. Meanwhile, we recommend that solutions are implemented which are 'physically and financially' feasible, but which will not obstruct the real sustainably safe solutions of the future.

Conclusions

Unfortunately, a firm conclusion about the Sustainable Safety quality of road design in the Netherlands cannot yet be drawn, since we lack sufficient comprehensive research results. However, as *Chapter 3* indicates, some results are available. From these, it emerges that we are on the right track as far as design is concerned, but still have to resolve some problems. These are: through roads (regional through roads, split-level junctions), rural distributor roads (separation of driving direction, parallel roads, intersections), speed behaviour at urban distributor road crossings and access roads (60 km/h speed limit on rural distributor roads, and low-cost implementation in urban areas).

4.3. The results and a possible follow-up

4.3.1. First results achieved!

No overall research has been conducted into the road safety effects of the introduction of the *Start-up Programme Sustainable Safety*. However, several small studies have been carried out (see *3.2.2*). We have tried to estimate the number of casualties saved based on these studies and estimates from other studies (Wegman et al., 2006). It is also the case that 'roundabouts' have been taken into account as an infrastructural measure in these evaluations, despite the fact that they were not formally a part of the *Start-up Programme*; however, they fit into the Sustainable Safety vision perfectly. Following the implementation of infrastructural measures including roundabout construction, there were some 1200-1300 fewer fatally and severely injured road casualties. This amounts to up to a 6% reduction.

4.3.2. What have we learned?

The Sustainable Safety principles are, in general, unchallenged and are widely accepted among road safety professionals in the Netherlands. The translation into road design guidelines and their application in practice has taken place widely, even though it has not yet yielded the potential and still has possible safety benefits. The key factors to blame are practical obstacles to making roads monofunctional, (sometimes combined with) a lack of physical space, (sometimes combined with) a lack of financial resource or the overriding consideration of other interests or priorities.

We realize that integrated approaches are called for more and more, which, in the past, have not turned out to be advantageous for road safety. However, when road safety has to be weighted in the same physical space with accessibility, quality of life and costs, road safety needs proper consideration. That assessment, it must be emphasized, needs to take place in an explicit and transparent way. One has to be able to calculate it afterwards! We advocate in several places in this publication to separate transport modes, given the needs of traffic tasks (and flow and road safety). These include, for example, separate networks, for pedestrians and cyclists (see *Chapter 12*), and for motorized light and heavy vehicles (see *Chapter 13*). Much attention needs to be devoted to the interfaces between the different infrastructures!

On the basis of experience to date, we recommend proceeding along a path with some distinct changes in emphasis. These changes result from an improved theoretical basis of Sustainable Safety, the desire to make sustainably safe infrastructure a more integral part of traffic and transport, and the wish to embed a sustainably safe environment in the wider perspective of Sustainable Safety. This embedment aligns well with the four divisions proposed by Immers (2005):
1. spatial planning and infrastructure;
2. network structure;
3. network component design in combination with ITS;
4. road traffic management.

The suggestions made by Hansen (2005) and Dijkstra (2003a; b) can also be included here.

4.3.3. Whichcrashes can still be prevented?

Several conflict types at certain specific locations are eliminated in truly sustainably safe road traffic. *Tables 4.1 and 4.2* give an overview of the severe injury crashes that occurred during the period 1998-2002. Crash patterns, both inside and outside urban areas, are presented: crashes between specific traffic types (fast, slow) and their distribution over road sections and intersections with different speed limits. In addition, the distribution of different conflict types are presented for similar location types (frontal, transverse, longitudinal etc.).

In a sustainably safe traffic system, the crash pattern 'slow x fast' should not produce crashes on through road sections (100 and 120 km/h), since that com-

Outside urban areas	120 km/h		100 km/h		80 km/h		60 km/h		Rest	Total
	Road section	Intersection	Road section	Intersection	Road section	Intersection	Road section	Intersection		
Crash pattern										
Fast x fast	220	11	167	41	543	678	24	12	169	1,865
Fast single	186	6	93	8	785	73	34	3	67	1,256
Fast x slow	12	1	10	6	346	368	23	14	92	871
Rest of fast traffic	102	3	36	1	230	24	8	0	16	421
Slow x slow	1	-	0	-	78	13	7	0	149	248
Slow single	0	-	0	-	32	3	3	0	50	89
Rest of slow traffic	0	-	0	-	44	7	3	0	60	115
Totals severe crashes	521	21	307	57	2,059	1,165	101	30	603	4,864
Conflict types										
Longitudinal conflicts	157	3	87	4	195	91	8	1	104	650
Converging & diverging	54	1	34	2	137	88	8	3	57	384
Transverse conflicts	0	7	1	37	112	718	7	17	107	1,005
Frontal conflicts	3	1	41	4	421	151	23	4	99	747
Single-vehicle conflicts	289	9	130	10	1,091	106	48	4	193	1,879
Pedestrian conflicts	8	-	6	0	77	10	5	1	30	138
Parking conflicts	10	0	8	0	27	1	3	-	13	62
Totals severe crashes	521	21	307	57	2,059	1,165	101	30	603	4,864

Table 4.1. ***Crash pattern and conflict types of the number of severe crashes on different road locations outside urban areas (averaged over 1998-2002).***

In urban areas	70 km/h		50 km/h		30 km/h		Rest	Total
	Road section	Inter-section	Road section	Inter-section	Road section	Inter-section		
Crash pattern								
Fast x fast	25	60	408	698	10	8	11	1,220
Fast single	23	7	338	125	7	1	7	508
Fast x slow	7	33	1,070	1,759	76	56	39	3,041
Rest of fast traffic	3	0	39	20	1	-	1	65
Slow x slow	2	1	228	151	115	51	130	680
Slow single	1	-	101	33	68	18	34	254
Rest of slow traffic	0	0	93	52	44	17	39	245
Totals severe crashes	62	102	2,277	2,838	322	152	261	6,013
Conflict types								
Longitudinal conflicts	15	13	231	116	18	5	16	414
Converging & diverging	7	7	292	354	28	19	32	737
Transverse conflicts	3	66	238	1,582	19	61	42	2,011
Frontal conflicts	8	5	347	358	58	17	44	838
Single-vehicle conflicts	27	8	571	228	120	36	81	1,070
Pedestrian conflicts	2	4	437	184	58	12	39	736
Parking conflicts	0	0	162	14	21	2	7	207
Totals severe crashes	62	102	2,277	2,838	322	152	261	6,013

Table 4.2. ***Crash pattern and conflict types of the number of severe crashes on different road locations in urban areas (averaged over 1998-2002).***

bination is not allowed. Yet, an annual average of 22 severe injury crashes still took place in that period (12+10). Similarly, there were 533 crashes annually (112+421), comprising transverse and frontal conflicts on (80 km/h) distributor road sections. The problem on distributor road sections, measured by the number of crashes, is very large: an annual average of 2,059 outside urban areas and 2,339 (2,277+62) in urban areas. If frontal conflicts are excluded, then 776 (421+347+8) fewer crashes took place annually. In addition, by eliminating head-on crashes on intersections on those roads, an annual reduction of 514 (=151+358+5) would be possible.

The high number of crashes in single-vehicle conflicts is notable: 1,879 (38.6%) on average annually outside urban areas, and 1,070 (17.8%) in urban areas.

For the further development of the vision we recommend that 'forbidden conflicts' should be investigated further in Sustainable Safety, and proposals should be developed to eliminate certain crash patterns and conflict types or, at least, to ensure that the outcome is less severe.

4.4. New (emphases on) Sustainable Safety principles

Making errors is inherent to human functioning in complex situations. Taking part in traffic is a complex task which involves serious risk. The example of *Figure 4.2*, taken from a presentation by Lie about the Zero Vision philosophy from Sweden (Lie, 2003), uses an analogy with driving on a single carriageway road with oncoming traffic. As pointed out in *Chapter 1*, a sustainably safe (or better: an 'inherently safe') traffic system has firstly to prevent road users from making errors. If errors are made, then the environment has to be forgiving (an error should not result directly in an unavoidable crash).

People make use of a limited number of elements in structuring their environment. While a detailed distinction between various road categories is useful for road designers or road authorities, this is not necessarily the case for road users. Research by Kaptein et al. (1998), for example, shows that if people have to learn to distinguish between completely new environments, they use a limited number of elements from a few categories. Their research also shows that peo-

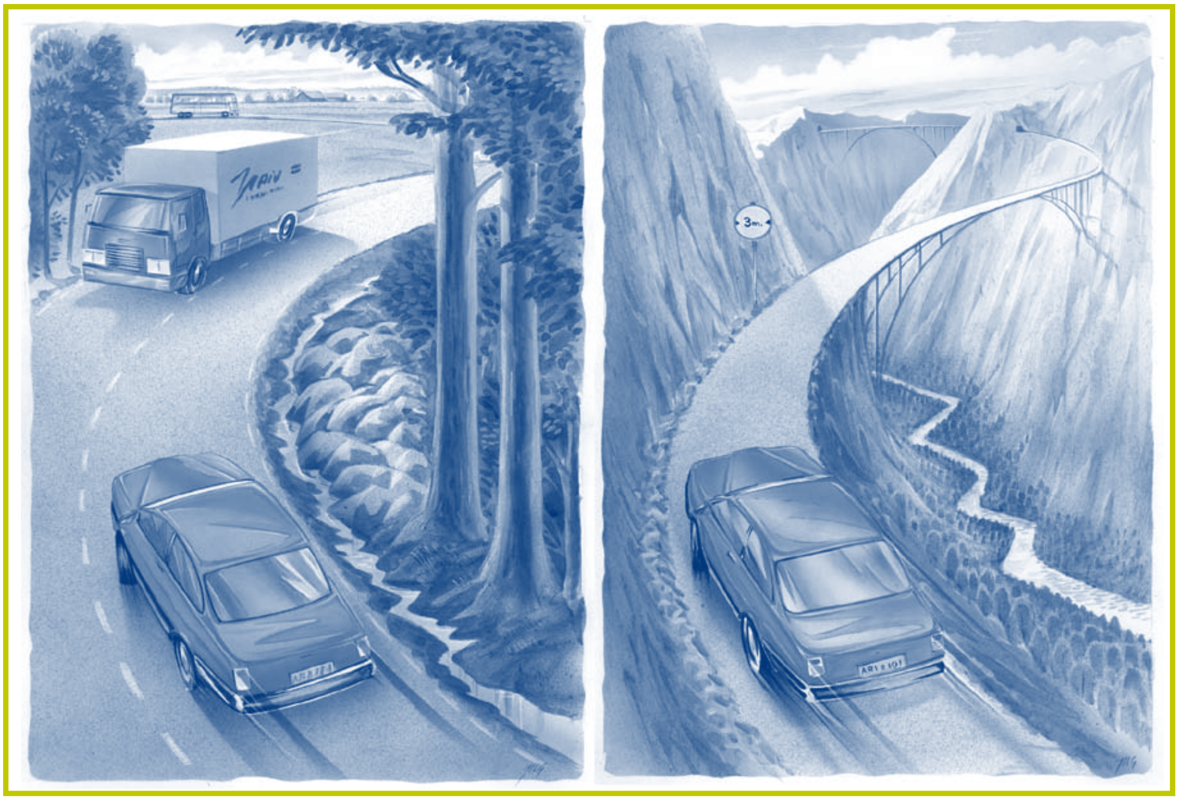


Figure 4.2. ***Left, driving on a single carriageway road with oncoming traffic, and right, a similarly dangerous activity (Lie, 2003).***

ple use only two out of three independent dimensions in classifying different categories. However, which two out of three dimensions are used, differs widely between people. So, redundant information is useful to people in general, but it does not help to improve individual performance.

There is no convincing scientific evidence to date that incorrect expectations play an important role in crash causation. However, a French study by Malaterre (1986) does give indications into this direction. He found that 59% of crashes were probably the result of incorrect expectations and of an inadequate or incorrect interpretation of the environment. Incorrect expectations can transform events that are sufficiently visible and conspicuous into ones which are not observed. Since expectations play an important role in the anticipation of events, it is important that road design, roadway scene and traffic situation automatically elicit safe behaviour, leading to Self-Explaining Roads (SER) at the far end of the scale (Theeuwes & Godthelp, 1993). Motorway and *woonerf* designs are to some extent self-explaining.

We conclude that the original three principles are still usable. The original distinction between infrastructure functionality, homogeneity and predictability remains valid, and a fourth principle is added: forgivingness. These principles are discussed in more detail in the next sections.

4.4.1. Functionality

Motorized traffic should be directed to roads with a flow function, causing roads with an access function to be burdened minimally with motorized traffic. Roads with a distribution function should direct motorized traffic coming from roads with an access function as quickly as possible to roads with a flow function and vice versa. This principle is meant primarily to minimize the number of potential conflicts with severe consequences.

There is no reason to discard the first principle of sustainably safe road traffic: a functional road network categorization is one where each road or street fulfils only one function – either a flow function, or a distribution function, or an access function. This framework is, generally, accepted in the Netherlands and forms part of road design handbooks and categorization plans (see *Chapter 3*). Apart from the assignment of a traffic function, there is also a residential function, and this function can be combined with the access function (reaching destinations along an access road) without too many problems.

The ideal through road is the motorway; it complies with the three principles mentioned. An ideal access road is the 30 km/h street, as this also complies with the three principles. The rural access road has different characteristics to the urban access road. The speed limit outside urban areas is 60 km/h, and this speed limit is too high, given the traffic composition (a combination of motorized traffic and vulnerable road users in the same space). The same is, in fact, also the case for the distributor road. Up until now, no satisfactory solution has been found for this. Functionally, we speak of flows on road sections and interchange at intersections, but this flow and interchange needs to occur at speeds below 50 km/h, if we are to prevent, for instance, severe injuries to pedestrians when crossing the road. In such cases, is it appropriate any longer to talk about 'flow'?

There are certainly wishes for further improvements (see *4.2*), but in fact, there is too little knowledge at the moment to translate these wishes into specific proposals.

4.4.2. Homogeneity

The principle of homogeneous use (see for *Figure 4.3*) has led, for example, to operational requirements for directional separation on through and distributor roads. For intersections, operational requirements have been derived from the starting principle to eliminate collisions with high speed and mass differences. Pedestrians, cycles and mopeds should not be present at the points of access of through roads. Speed differences should be reduced to acceptable levels at distributor roads where mass differences are allowed functionally.

In this vision, discontinuities should be avoided as much as possible, and should be signed very clearly where they are unavoidable. In this way, road users can perceive the discontinuity clearly and have sufficient space and time to adapt speeds to a safe level. On roads where traffic 'flows', an intersection or a sharp curve would count as a discontinuity. Speeds should be adapted to such a level that 'safe travel speeds' or 'safe crash speeds' are not exceeded (see also *Chapters 1 and 5*).

Figure 4.3. ***Example of homogeneity in an urban area: separation of large mass and speed differences.***

Apart from this, Hansen (2005) suggests some changes are made with respect to speed limits (*"It is strange that the historic system with eight different speed classes has never been put up for serious discussion during the operationalization of the Sustainable Safety philosophy"*). To discuss this subject, we present in *Table 4.3* a first draft of a system of 'safe speeds'. The following starting points were used in this attempt:
– Speed limits and travel speeds should *not* be higher than safe crash speeds (see *Chapters 1 and 5*).
– The current road categories are the basis, supplemented with the urban through road (Hansen, 2005).
– The distinction between urban and rural areas is useful (although the difference is less and less clear for road users).
– Deviations are allowable from the strict 'even' speed limits (if divided by 10) in rural areas and 'odd' limits in urban areas.

The three aforementioned regimes of 40, 60 and 80 km/h on rural access roads in *Table 4.3* possibly demand clarification. What is proposed is that 40 km/h is desirable (as mentioned in the original version of Sustainable Safety, although 60 km/h was selected eventually). Sometimes, this speed limit is too high (at specific locations) and sometimes too low. The idea of different regimes within one road category which allows for more customization can be further developed here. In the United States this idea is also known as 'speed zoning'. The ultimately desirable situation, however, does not limit itself to a few fixed speed regimes (see also *Chapter 9*). The idea of standard speed limits for five road categories could actually be abandoned. Instead, credible speed re-

Location	Safe travel speed (km/h)
Rural road sections	
Through road (no mutual road user crashes, fixed roadside objects only)	120
Distributor road (no conflicts possible with pedestrians and cyclists) with physical separation of driving directions without physical separation of driving directions	 80 70
Access road	40/60/80
Rural intersections	
Distributor road and access road without vulnerable road users with vulnerable road users	 50 30
Urban road sections	
Through road Distributor road Access road	70 50 30
Urban intersections	
Distributor road Access road	50 30
Pedestrian and cyclist crossings (urban and rural)	30
Against obstacles (urban and rural)	
Head-on crashes Side impacts	70 30

Table 4.3. ***Example of a safe-speed system.***

gimes could be implemented which are adapted to local conditions and the moment, thus creating dynamic speed limits.

The transition between flowing, flowing/providing access and providing access, and vice versa, also deserve special attention in the future with an unambiguous application of certain types of intersection for interfaces between road categories. The CROW publication 116 (1997) gives an operational requirement for transitions such that these occur, preferably, at an intersection or at the entrance to or exit from an urban area.

The next question that arises concerns the transition from rural to urban area and vice versa. The distinction between these two area types may be clear for the road authority, but certainly not always for the road user, particularly if the environment gives contradictory information (for instance a road in a rural area with an urban speed limit, or a road with many adjacent buildings, but with a rural speed limit (Brouwer et al., 2000). Implicit rules for behaviour or prohibitions (for example the general rule that parking is prohibited on shoulders of main roads in rural areas) are generally very badly understood. The place-name sign as indication for ‘urban area’ without further speed indication falls within the same category of implicit rules. In sustainably safe road traffic, road users should be able to see what the rules for behaviour or prohibitions are, rather than have to remember or deduce these from other road characteristics. A sign with speed limit 50 (or when leaving the urban area, e.g. 80) works more directly.

4.4.3. Recognizability and predictability

A sustainably safe road traffic system starts from a limited number of road categories *within* which roads achieve maximum homogeneity in function and use, and *between* which there is maximum distinctiveness. A high level of recognizability is a necessary, but not as yet a sufficient requirement to elicit safe behaviour, since road users have to be able and willing to behave safely. For each road category: speed limits have to be clear, as should the types of intersections allowed, the available route information, as well as the expected road user types. Traffic situations should always meet road user expectation about the function and use of the type of road being used. Within a given road category, the road and traffic characteristics have to be as uniform as possible and designed homogeneously (see e.g. Aarts et al., 2006). From a road user perspective, a considerable amount of uniformity is desirable. The road authority's wish to produce tailor-made solutions, for whatever reason, is subordinate to that. Further research is needed to address when a 'considerable amount of uniformity' is, in fact, reached.

Road user expectations of a given road category concerns both the infrastructure design and the intended use. Predictable, for instance, also means that no cyclists are expected on a road with separated bicycle facilities. Unexpected traffic situations simply cost more time for road users to detect, to perceive, to interpret, to assess, and to elicit the correct behaviour or response. This also means that transitions from one road category to another require the necessary precision and time from road users to adapt their behaviour (see also *Chapter 1*).

The *Guideline essential recognizability characteristics* (CROW, 2004c) mainly addresses road section characteristics. Priority regulations occur on through and distributor roads, but not on access roads. The question arises as to how to evoke the correct expectation in road users unambiguously at transitions from one road category to another. In the further development of this guideline, more attention will need to be devoted to road user expectations at intersections. The driving task is often most complex of intersections. Expectations have a long-term, but also a short-term component. Recent experiences with a certain type of intersection on a recently completed stretch of road of a given road type, also create expectations for the next intersection. As intersections are often the transitions between road categories, they deserve special attention. Road users will need to be made conscious that another regime is in force, with different expectations. On roads with separated bicycle facilities, cyclists and motorized traffic often meet later at intersections; a shift in conflicts (and consequently in crashes) between motorized traffic and cyclists from road sections to intersections seems to be obvious.

4.4.4. Forgivingness

The starting principle of 'man as measure of all things' is that road users make errors and that the environment should be sufficiently forgiving for road users to avoid the severe consequences of these errors. The same applies, of course within limits, for people who commit offences consciously. We can think in the first instance of road and shoulder design, but obviously, also of ITS and vehicles (see e.g. *Chapters 5 and 6*).

The first step towards making the road user environment forgiving is to make road shoulders sustainably safe. This activity takes place on rural distributor roads and also on through roads, albeit to a lesser extent. The problem with road shoulder crashes is that they are scattered. It is, therefore, necessary that such measures are applied on extended lengths of road (whole road sections; Schoon, 2003a), and this addresses immediate questions of costs and cost-effectiveness. SWOV advocates that a *National Programme Safe Road Shoulders,* aimed at all rural roads, should be introduced (Wegman, 2001). This may link up with current practice where road authorities make safe road shoulders as a part of rehabilitation and maintenance programmes (Schoon, 2003a).

The *Handbook Safe Road Shoulders Implementation* (CROW, 2004b) has made an important contribution. In safe road shoulder implementation, the CROW working group prefers a cross section which is sufficiently wide, has sufficient bearing capacity and obstacle-free shoulders, and is adapted to acceptable risks to third parties or risks to car occupants. If this is not feasible and if the danger zone cannot be removed in another way, then the Handbook recommends the use of a protective feature. A (political) discussion has not taken place yet about what constitutes acceptable risk to third parties or car occupants. The argument could be that severe injury risk should be (almost) excluded where a vehicle leaves the road and ends up in a shoulder. A second argument is based on a cost-benefit balance in which risks should be avoided when the safety benefits outweigh the necessary investments.

Up until now, forgivingness has been mainly translated for shoulders on the basis that if a vehicle leaves the road it should not hit any obstacles causing severe injury. Fixed roadside objects should be designed such that crashes at high speeds cannot result in severe injuries. Here, international criteria ('performance classes') have been established (NEN-EN 1317-1 to 7). The fact that there are still many road crash victims (on motorways and on distributor roads) following impact with protective devices, raises questions as to whether the currently used criteria require revision, or in turn, the decision to implement a protective device in certain circumstances.

Safe shoulders along distributor roads are a difficult subject. Often, the free space is not sufficiently wide, nor has it sufficient bearing capacity, nor is it obstacle-free for protective devices to work in a safe way. In addition, it is not yet general practice in the Netherlands to protect roadside obstacles on rural distributor roads. In Sweden, cable barriers are placed along extensive lengths of road, and in France, examples can be found where traditional safety barriers protect trees. In the Netherlands, work has been done on the WICON (Schoon, 2003a), a wheel clamp construction. A complicating factor with such protection is its performance for lorries and motorcycles. For both issues, important considerations prevail that cannot be settled from the design point of view. How strong should a crash barrier be? Which vehicles should they stop and under which circumstances? Should median barriers be able to stop heavy goods vehicles? If a lorry crashes into a barrier and ends up on the opposite lane, the consequences are often very severe (casualties on the opposite road, and congestion as a result of these crashes). At the same time, existing designs are not safe for motorcyclists and padded constructions are preferable. Such users might even be safer with nothing in place at all. Both research and product development is necessary in this field, as well as risk analyses to form the basis of rational decision making.

Figure 4.4. ***Example of forgivingness translated into safe shoulders.***

In addition to making shoulders safer, it is also possible to design the cross section in such a way that an emergency lane lies next to the edge marking (CROW, 2002b). Double centre lines with some distance between can also be regarded as such.

The question is whether or not the forgivingness principle, translated here into roads and shoulders, can also be applied to road user traffic behaviour. Forgiving road user behaviour would be compensating and correcting when somebody makes errors. This interesting topic deserves further discussion.

4.5. Instruments for road authorities

Road authorities have several instruments at their disposal to assess the safety of their road network, routes, road sections and intersections. It is not sustainably safe to take action only after a crash has occurred. A black-spot approach (adapting those locations where most crashes occur or where risk is highest) therefore does not fit in Sustainable Safety. Based on general Sustainable Safety principles, Sustainable Safety defines which road and traffic conditions (function-form-behaviour) are allowed and which are not.

Within Sustainable Safety, the choice has been made to adapt roads and streets at the pace of road rehabilitation and maintenance, that is, to let roads comply with Sustainable Safety requirements in the framework of 'operation, maintenance and reconstruction'. Of course, there is nothing against giving higher priority to road safety by gathering information about the safety of a road network. As such, information about road safety quality fits very well within Sustainable Safety if the objective is to promote general road safety awareness (as proposed for example in the EuroNCAP star system). If this system were to be used to set priorities for infrastructure measures, then contradictions would arise with the Sustainable Safety vision. If a road authority decided to tackle road infrastructure solely based on road safety considerations, then a system would still be needed to set priorities. It stands to reason that priorities would comprise those measures which are most cost-effective. Of course, these need to fit into Sustainable Safety.

In the Netherlands, we have to look at how the EuroRAP (European Road Assessment Programme) approach (www.eurorap.org) could be embedded into other instruments for road authorities. A devel-

Characteristic	Road safety audit	Sustainable Safety Indicator	Regional Road Safety Explorer
Assessment by expert	Yes	Hardly	Hardly
Data requirements	Design drawing with comments	Design data aimed at Sustainable Safety	Road design variables
Implementation mode	Checklists	Menu driven	Menu driven
Quantitative judgements	Hardly	Many	Exclusively
Relation with crash statistics	Sometimes	By considerations in Sustainable Safety requirements	By formulae
Reporting	Audit report	Sustainable Safety level per Sustainable Safety requirement (in %)	Optimization of design variables

Table 4.4. ***Similarities and differences between three instruments for potential use by road authorities (Dijkstra, 2003b).***

opment of EuroRAP aimed at road authorities stands alongside the idea of providing road users with information to allow them to choose safer roads. It is also interesting to think of linking this latter type of information with information in navigation systems (see *Chapter 6*).

Dutch road authorities have several instruments at their disposal to gather safety information about their network, although the user-friendliness of these instruments need to be improved. These instruments are:

- The regional Road Safety Explorer, that allows for the effects of measures (also in terms of cost-effectiveness) to be calculated for a road network by means of quantitative relationships between crash, road and traffic characteristics. This approach is also named Road safety Impact Analysis (RIA).
- The road safety audit: a formalized, standardized procedure to assess independently the possible effects of a design on road safety in various stages of new road design and construction, and/or (significant) reconstruction of existing roads.
- The Sustainable Safety Indicator: an instrument that summarized the twelve functional requirements of CROW (1997) to measure the 'level of sustainable safety' in a study area (Houwing, 2003).

The first instrument, the Road Safety Explorer (Reurings et al., 2006), embedded in the Road safety Impact Assessment, is still under development, but it is in essence already applied in the impact assessment of the 'bypass concept' (Immers et al., 2001) on road safety (Dijkstra, 2005).

The second instrument that road authorities could use is the road safety audit. Despite the fact that this subject was one of the agreements resulting from the *Start-up Programme Sustainable Safety* (agreement no. 15) and that the necessary preparatory work has been carried out (Van Schagen, 1998b) and auditors have been trained, this instrument has never got off the ground properly, though, it is not clear why. While the Netherlands is in the vanguard in promoting road safety in many fields, this is one area where the country lags behind. Within Sustainable Safety, much can be said in favour of the use of road safety audit not only as an instrument to determine if a new road design complies with Sustainable Safety requirements, but moreover as an instrument to foster infrastructure uniformity. Australian research (Macauley & McInerney, 2002) cites the clear benefits of road safety audit.

The last instrument to be mentioned here, is the Sustainable Safety Indicator, previously also named Sustainable Safety Level Test (Dijkstra, 2003c). This instrument is also promising, but it requires further elaboration before road authorities can use it on their own.

Dijkstra (2003b) has characterized the three different instruments as in *Table 4.4.* We recommend that these instruments are developed further to allow their use by road authorities. Subsequently, it is necessary that the instruments are actually used in practice. This will not come about by itself. Therefore, we recommend the establishment of a road safety agreement on the establishment of such instruments, and to ensure that these instrument will be used properly in practice.

4.6. Discussion

The three original principles for a sustainably safe road infrastructure have been supplemented with a fourth. These four principles are: *functionality* (preventing unintended infrastructure use), *homogeneity* (preventing large differences in speed, direction and masses at medium and high speeds), *predictability* (preventing insecurity in road users), and *forgivingness* (adapting the road environment in such a way that road users do not suffer the serious consequences of errors).

In translating the three original principles into road design guidelines and into practical application, great progress has been made in the past few years, and positive safety results have been recorded. However, at the same time, we have to conclude that some problems still await a solution.

With respect to functionality, we can think, firstly, of setting requirements for categorization plans at network level. Furthermore, the essential characteristics of the three Sustainable Safety road categories need to be defined and not to be limited to essential recognizability characteristics. The latter, incidentally, requires further development for intersections. In Sustainable Safety the homogeneity principle is defined further by the principle that travel speeds should be limited to allow a 'safe travel speed' in the event of a crash. This concept is not present in the various guidelines. Particularly on rural distributor and access roads, there are discrepancies between these 'accentuated' requirements and current practice. Our understanding has grown about the recognizability of roads, the predictability of road course and other road users' behaviour, but is not yet sufficiently elaborated to implement this principle. The new forgivingness principle was in fact already anchored in Sustainable Safety, but it is appropriate to position it explicitly. There is sufficient knowledge to be able to apply this principle in full.

Looking back on this field over the past years, we have to conclude that, unfortunately, we do not know enough about the Sustainable Safety quality of current road infrastructure and where the dilution of requirements is no longer to be held responsible. In this chapter, some proposals have been made to improve sustainably safe infrastructure. We recommend that these proposals are tabled and a platform set up, perhaps through a road safety agreement. The problems identified in this chapter can be analysed in this platform, together with possible solutions. This should then form the basis for a perennial research programme aimed at these problems, and linked to the dissemination of knowledge gained. We truly will have to invest in this research in order to avoid future Polish conventions and a veritable Tower of Babel.

5. Vehicles

5.1. Introduction

This chapter addresses the safety of four-wheeled motor vehicles, passenger cars in particular, but also heavy vehicles (lorries and vans). The safety of freight traffic logistics (*Chapter 14*) and motorized two-wheeled vehicles (*Chapter 13*) will be discussed in separate chapters. Most other road travel modes are addressed in the context of the collision opponents of four-wheeled motor vehicles.

The terms *primary* and *secondary* safety are used for crash prevention and injury prevention respectively, rather than the terms active and passive safety. These terms are the most common terms used internationally, and their use avoids confusion with new, *active* systems in the area of passive safety. In this chapter, the vehicle, and especially the passenger car, is viewed from the Sustainable Safety perspective, identifying any changes since the original version of Sustainable Safety in the process (Koornstra et al., 1992). In particular, attention will be paid to differences in mass, incompatibility, and the protection of car occupants and vulnerable road users (*5.2*). A key element of the chapter is a comparison between passenger car crash requirements and the objective of Sustainable Safety to eradicate (as far as it is possible) severe injuries occurring in road traffic crashes. The assessment is expressed in terms of a 'match' or a 'mismatch' between these requirements (*5.3*). In the final sections, primary (*5.4*) and secondary safety (*5.5*) are addressed, looking at what has been achieved to date as well as current developments. The chapter concludes with a discussion.

5.1.1. Vehicle safety fits within Sustainable Safety

This chapter focuses on the collision types involving different types of vehicle, pedestrians and roadside obstacles. It will become clear that in the most important collision types (the most frequently occurring and the most serious) the passenger car is always one of the parties. In view of this large involvement, improvements in safety characteristics of passenger cars offer a particularly large opportunity to reduce road crash casualties further. This is the case both for primary safety characteristics (concerning driving characteristics) and for secondary safety characteristics (concerning the crash safety of occupants and third parties). The existing and, usually, international setting (regulations, consultation, and research) for the establishment of, or improvements to measures for passenger cars is also well developed. Industry plays an influential role in this.

Apart from crash speed and crash type (frontal, side, rear-end) the safety characteristics of the construction of passenger cars determines whether or not a crash results in severe injuries to the people involved (see also *Chapter 1*). In other words, passenger car construction should guide the establishment of a sustainably safe infrastructure and corresponding speed limits in order to create the conditions for effective crash protection. This bridges the gap between vehicle and infrastructure design. However, there is also a link with ITS facilities and regulation and enforcement in so far as these influence driving and crash speeds.

In summary, the connection can be described as follows. Given the secondary safety vehicle characteristics, safe crash speeds can be defined for different conditions (crash opponents, crash types). Below these speeds, no severe injuries should occur in case of a crash. If these requirements cannot be met in practice, then the crash severity will need to be limited by means of vehicle measures. This, for instance, is possible through changing the design characteristics of the other (heavier) party, or by increasing the stiffness of the lighter-weight party. In this way, the so-called 'incompatibility' in or between vehicle types can be reduced. If the difference is still be too great, the answer lies in appropriate speed reduction or the permanent separation of traffic types.

5.1.2. Since the establishment of Sustainable Safety

Since 1992, when Sustainable Safety was established, there have been many changes and improvements in the area of vehicle safety. Nearly all of the original Sustainable Safety recommendations in the area of secondary safety have been realized, even though most of these were largely due to an international process which is influenced greatly by the car industry (see *Frame 5.1*). In the area of primary vehicle safety, no specific recommendations were taken on board in Sustainable Safety, but here, also, important developments are taking place, which have been influenced, in particular, by the progressive application of electronics.

There are also examples of less successful or unsuccessful developments in the vehicle field. The targeted classification (limitation) of the number of vehicle types has not been achieved. The contrary is the case. Furthermore, the average weight of almost all vehicle categories has increased, having both negative and positive consequences: negative for pedestrians in collision with (heavier) vehicles, and positive for car occupants where the additional mass gives more protection. However, the most remarkable thing is that we have not succeeded in coupling the advances in vehicle safety with Sustainable Safety, despite the attempts which have been made (Ammerlaan et al., 2003).

International regulations

A characteristic of vehicle regulation is its international character. This is why a country such as the Netherlands can really only influence these regulations, which mainly concern motor vehicles and trailers, through international discussion platforms (such as the EU in Brussels and the UN/ECE in Geneva). In the EU framework regulation 70/156, a limited number of four or more axles motor vehicles have been included historically: passenger cars (M1), buses (M2 and M3), vans (N1) and heavy goods vehicles (N2 and N3). In addition, this regulation includes trailers (O) in four different weight categories. Furthermore, there are regulations for two and three-wheeled motor vehicles, such as mopeds and motorcycles.

Vehicle regulations from Brussels are binding. A Member State may not refuse (type-) approved vehicles. The main objective of these regulations, however, is not to promote road safety, but to remove trade barriers. Industry, therefore, has an important voice in this. The negotiation process for regulation takes place in Brussels, and is lengthy and not particularly easy. It is not unusual that the market place is only regulated when a specific facility is being used or is likely to be widely used.

Apart from having to comply with internationally agreed regulations, car manufacturers also build in safety on a voluntary basis, to a greater level than is required. Examples include airbags and ABS (except for heavy goods vehicles). Manufacturers take such action if they think they can strengthen their market position. These special efforts in the field of secondary safety of passenger cars have been strongly stimulated by an international assessment system called EuroNCAP: European New Car Assessment Programme. EuroNCAP comprises a series of crash tests to which new cars are subjected and where the requirements are stricter than the legal requirements (see www.euroncap.com). Results of EuroNCAP tests are systematically published, and serve as a consumer information function in particular. In practice, car manufacturers take the results very seriously, and adapt their products quickly where necessary. Discussions are taking place about further improvements to the tests included in EuroNCAP.

In addition to 'Brussels', where EU regulations are drafted, we also have 'Geneva' where, under the UN/ECE flag, more technical aspects of vehicle regulations are agreed in an even broader international forum (primarily Europe, but also Japan and the USA). A potentially good development is the establishment of 'worldwide' agreements, called GTR's (Global Technical Regulations), one existing example of which concerns requirements to car locks and car door hinges. Here, US and EU requirements are co-ordinated.

Though limited in number, special vehicle categories such as trikes, quads, one-seat cars with moped engines, etc., pose special road safety problems, despite the fact that they fall within the scope of European regulations. But Member States may add (safety) requirements for roadworthiness, as has been the case in the Netherlands (Schoon & Hendriksen, 2000; www.verkeerenwaterstaat.nl).

Frame 5.1.

5.2. Mass, protection and compatibility

5.2.1. Mass increase

Most motor vehicle types have become heavier over the past decades. The ‘kerb weight’ of passenger cars has increased by more than 10% in the past ten years and by 17% since 1985. Then, passenger cars weighed 910 kg on average, which has increased to 1069 kg (car fleet at 1-1-2004). New passenger cars (model year 2003) already weigh, on average, 1208 kg.
There are various reasons for weight increases: increase in comfort, increase in engine power, and safety improvements. The end of this increase in weight is not yet in sight, despite the increasing use of more lightweight materials, such as plastics and light metal (Van Kampen, 2003).
Weight (mass) plays a very prominent role in the outcome of crashes. Grossly simplified: the heavier the vehicle, the safer it is for its occupants. The other side of this, however, is: the heavier the other party (the larger the mass difference), the worse the outcome for the lighter-weight vehicle’s occupants. In extreme cases, this means a factor of four within the categories of passenger cars; four times as many fatalities in the lighter-weight vehicles compared to the heavier-weight vehicles (Van Kampen, 2000). This comparison does not even include the new vehicle category Sports Utility Vehicles or SUVs.

5.2.2. Better car occupant protection

There is much literature about the improved secondary safety of passenger cars over past decades (Elvik & Vaa, 2004; Evans, 2004). Vehicle facilities, such as seat belts, airbags, collapsible steering columns, safety glass, non-deformable occupant compartments, crumple zones, and reinforced sides all contribute to better car occupant protection. Occupants are protected by a combination of structural characteristics (particularly crumple zones and non-deformable occupant compartment) and safety equipment (seat belts and airbags; see also *5.5*).

5.2.3. The incompatibility problem

The fact that lighter-weight cars comply with existing (crash) regulations and, at the same time, come off so badly in crashes with heavier vehicles is a disadvantage of existing crash safety requirements. These do not take into account the other party (and its weight). Therefore, cars are suited, primarily, for impacts with themselves (i.e. equal weight and construction).

The understanding that cars need to be mutually compatible has been an issue for quite some time. However, both current legal crash tests and the ‘natural’ tendency of car manufacturers to keep occupant safety at the top of their priority list, block important breakthroughs. Added to this, achieving the compatibility of car structures with different masses, dimensions and stiffness is not a particularly simple task. However, positive exceptions have been noted. One paper on the construction and successful testing of a lightweight passenger car (700 kg kerb weight!), indicates that it is possible for manufacturers to construct vehicles in their product line such that impacts between lighter-weight cars and heavier ones produce good results. Renault is mentioned as an example here (Frei et al., 1999).

Unequal traffic parties

The incompatibility problem already plays an important role in crashes between cars of the same type, but it is an even more fundamental problem between unequal traffic parties. Passenger cars are relatively disadvantaged in crashes with heavy goods vehicles, but on the other hand, pedestrians and cyclists are *very seriously disadvantaged* in crashes with passenger cars.

There are known measures which could address both types of inequality (ETSC, 2001). An example in the field of the lorry-against-passenger car is ‘front underrun protection’. This comprises safety equipment on the front of a lorry to prevent a passenger car from running under a lorry in a crash. The ‘crash-friendly car front’ is an example in the area of car-pedestrian/cyclist crash protection. After many years, the implementation of measures is now a possibility. However, the eradication of certain types of incompatibility in crashes will require much time for research, much discussion and also political will. Since such measures benefit third parties more than car occupants, car manufacturers are not very eager to make improvements. The (pedestrian) crash friendly car front is one of the most telling examples. After about thirty years of research, and international debate in which the car industry appeared not to be very cooperative, it was possible, thanks to the European Parliament, to draft a regulation that marks the beginning of a legally required improvement (EC/2003/102). Phase 1 of this requirement came into effect on October 1st 2005 for new car types. New cars of existing types will have to comply gradually with these new requirements, with all new cars having to satisfy the Phase 1 requirements by early 2013. Phase 2, where stricter requirements will apply, does not come into effect until 2010 for new car types, applying to all new cars by 2015. This illustrates the treacle-like and lengthy process mentioned earlier behind improvements in vehicle safety. The current European requirement is adapted mainly to the benefit of pedestrians. However, SWOV has advocated that the regulation should also be applied to cyclists (Schoon, 2003b).

If market forces do not lead to improvements, the ball is in the authorities' court. Here, there are interesting examples where industry has been given the opportunity to meet (long-term) objectives. An example is the *Zero Emission Vehicle Program* in California (www.arb.ca.gov). An example of effective authority pressure on manufacturers is the European emission standard for clean lorry engines. This began with the introduction of Euro 1, leading in time to the much stricter Euro 4 standard with which new lorries will have to comply with from October 2006. The first Euro 5 engines have even been delivered on a voluntary basis, also encouraged by the possibility of receiving a rebate in German road pricing for heavy goods vehicles.

SUV problems are particularly large

As in the United States, where Sports Utility Vehicles (SUVs) represent 50% of the market, it is beginning to be understood in Europe that SUVs (and some vans) cause a disproportionately heavy burden to crash opponents. This is because of their relatively large mass and high and stiff structure. As a result, existing cars are no longer hit at bumper height in a head-on crash, but above, rendering the built-in safety construction inadequate. The same is true for side collisions in which the SUV is the impacting vehicle. Moreover, in the US it has been established that this type of vehicle is relatively often involved in roll-over crashes due to its high centre of gravity (NHTSA, 1998; O'Neill, 2003).

Vans: a growing problem

In the Netherlands, the van fleet is about five times as large as the lorry fleet. During the period 1995-2004, the number of vans increased by 80%. Most vans are in use by service companies; only 5% is used for the transport of goods. Further growth of the van fleet and/or increased exposure to vans will bring negative road safety consequences, unless special measures are taken. This is explained by the fact that vans are, on average, heavier than passenger cars and, consequently, can cause more harm to most of their crash opponents.

5.2.4. Collisions: extent and inequality

The most common two-party collisions and their severity in current traffic have already been discussed in *Chapter 2*. This information can be used in establishing priorities in future policy. The various collision types are assessed by, among other things, crash inequality and crash frequency (see also *Table 2.1*). In this analysis, vans have been classified within the passenger car category.

Crashes between cars or mopeds against fixed roadside obstacles (such as trees and poles) are the more unequal for the vehicle users. In crashes between two different types of road user, pedestrians in impacts with cars are the most unequal (vulnerable) crash opponent. To a lesser extent, this is also the case for two-wheeled vehicles in collisions with cars and lorries. Of these impacts, those between cyclists and cars occur most frequently.
When we look both at the size and the inequality of impacts, we see that vulnerable road users (pedestrians and two-wheelers) are the weaker party in most serious impacts.

Cars may be disproportionately strong crash opponents in impacts with pedestrians and two-wheelers, but in crashes with heavy goods vehicles (and also fixed roadside obstacles), they come off worse. Cars are involved in most serious collisions between road users.

In order to address the most frequently occurring collisions, the most obvious intervention is to reduce the number of collisions, through, for example, traffic management and infrastructure-related measures. The most unequal conflicts though, demand vehicle or speed measures that reduce crash severity.

5.3. Can crash criteria be adapted to a sustainably safe infrastructure or vice versa?

5.3.1. Test impact speeds

Table 5.1 shows the crash speeds used in full-scale crash tests or component tests for the most important crash safety characteristics of passenger cars. These impact speeds are important for the design of

Regulation type	Frontal/ barrier	Side/ mobile barrier	Side/ pole	Rear-end/ mobile barrier	Car front/ pedestrian
EU directives	50	50	–	–	40
EuroNCAP	64	50	28	–	40

Table 5.1. *Summary of test crash speeds (in km/h) as applied in legal criteria (EU directives) and other criteria (EuroNCAP).*

infrastructure and the corresponding speed limits, as discussed previously.

Although the crash test speeds for various criteria may correspond per test type, the tests themselves are sometimes different in important respects. This is the case, for example, in the car frontal test (last column of *Table 5.1*) where the recent EU directive (2003/102) requires a less strict frontal crash test than the one applied in EuroNCAP tests. It should be remembered, however, that these frontal crash tests can only be passed if seat belts are worn and if airbags function properly.

A summary of the legal criteria and a further explanation of the crash tests can be found on the websites of the relevant organizations: European vehicle directives (www.europa.eu.int), Dutch vehicle regulations (www.rdw.nl or www.tdekkers.nl) and EuroNCAP (www.euroncap.com).
With regard to the rear end of the car, a European test does not yet exist in regulation or in EuroNCAP. However, such a test is under development. An ad hoc group in EuroNCAP has recently presented a concept of whiplash protocol with a relatively low impact speed of about 15 km/h. American tests follow a crash test speed for rear-end collisions of 80 km/h. This US test (from FMVSS 207) has been designed as a test for the strength of car seats in rear-end collisions. This test is also applied by non-American manufacturers, as shown by an extensive description of the safety characteristics of the new BMW 3-series (Heilemann et al., 2005).

If we compare this information with the proposals listed in *Table 1.2* in *Chapter 1*, we can see some differences. Firstly, a crash between a passenger car and a pedestrian can develop in relative safety at impact speeds of up to 30 km/h. We maintain this speed in Sustainable Safety and a crash test at 40 km/h therefore gives some room and additional safety for pedestrians. The values for side impacts between passenger cars are similar. For a frontal crash, the proposals from *Table 1.2* and the values in *Table 5.1* differ somewhat, but not much. This leaves two subjects. We will discuss crashes against fixed objects and safety barriers (guardrails) in *5.3.2.3* in more detail. Crashes involving heavy goods vehicles and motorized two-wheeled vehicles are a different subject. For heavy goods vehicles, we can think of separating traffic types due to incompatibility (see *Chapter 14*) and also of protection devices around the lorry. For motorized two-wheeled vehicles, unfortunately, few such opportunities are foreseen (see *Chapter 13*).

5.3.2. Do crash tests match with infrastructure design?

The relevance of these crash tests to Sustainable Safety has been explained in preceding sections. Based on this reasoning, the constructional design possibilities of vehicles are a guiding principle for infrastructure design. This is already partly the case when it comes to 30 km/h zones and roundabouts. We shall determine in what follows if this is also the case in other situations. Or in other words: to what extent is there already a good 'match' between vehicle properties and the infrastructure concerning crash safety? We will limit the detail, for the time being, to passenger cars and even further, to secondary safety. This is because European regulations and EuroNCAP crash tests have moved forward in this area in the main. Furthermore, we will start by considering the regular speed limits on various road types assuming that speeding is reduced (by means other measures). We also recommend similar crash assessment of other vehicle types (lorries, buses, motorcycles).

Firstly, we will distinguish between collisions on road sections and intersections in a sustainably safe infrastructure. Then, we will address roadside obstacle crashes. Every discussion will conclude with a 'MATCH' or 'MISMATCH' statement, as to whether or not the vehicle criteria are in conformity with Sustainable Safety design and infrastructure crash conditions.

5.3.2.1. Conflicts at road sections

Access roads (30 and 60 km/h speed limits)

– The most common collision type on 30 km/h roads is the head-on crash. In terms of construction, this means that the car front has to be safe for pedestrians and cyclists up to speeds of 30 km/h. The crash criteria that are compulsory for new car types as of October 2005 are adapted to 35-40 km/h. So this is a good MATCH, but we have to note that new cars of existing types will only have to comply gradually with these criteria. A second point is that these criteria have been developed for pedestrians and not for cyclists. The windscreen and windscreen pillars are not included in the crash criteria. Therefore, cars with a short bonnet are not safe for cyclists in impacts with cars (and in many cases nor for pedestrians) at speeds of up to 30 km/h.
– The speed limit on Dutch rural access roads is 60 km/h. These roads do not have separated bicycle lanes, so there is a mix of cars and cyclists where crash speeds up to 60 km/h are possible. The travel speed will not always be the crash speed, so we may assume lower crash speeds. With a 20% speed reduction, a safe crash speed would have to be 48 km/h. This 48 km/h is a MISMATCH, given the previously discussed safe crash speed of 30 km/h.

Distributor roads (50 and 80 km/h speed limits)

– Distributor roads are diverse in character, not least because of their location in urban and rural areas. Overtaking is prohibited, so head-on crashes are no likely to occur.
– Rear-end collisions can occur with speed differences of up to 80 km/h. Also here, we argue that travel speeds will not always be the crash speed, and we assign a 20% speed reduction. In this case a safe crash speed would have to be up to 64 km/h. No crash criteria have been established for the rear end of passenger cars. If American standards were applied, the test crash speed would be 80 km/h.
– Strictly speaking, side impacts should not occur on distributor roads ('crossing traffic takes place at roundabouts'). However, in practice, on these roads there are junctions with access roads (T-junctions), in urban areas in particular. This means that side impacts can occur with speeds of up to 80 km/h. If we also assume here a 20% speed reduction, then the side has to offer crash protection for speeds of up to 64 km/h. There is a MISMATCH here, since the current criteria for side impact crashes go up to 50 km/h (both for legal regulations and EuroNCAP). While side airbags may provide additional protection, the increase from 50 to 64 km/h is very large. Speed reduction is the solution here.
– Distributor roads have separate cycle paths for pedal cyclists and light mopeds. In the Netherlands, mopeds ride on the road in urban areas. The most frequently occurring crashes occur during lane changing, left-turning manoeuvres and when merging from a side street. In the last two manoeuvres, moped riders can be hit in the side by passenger car fronts. The maximum speed is 50 km/h. If we again apply 20% speed reduction, then the car front has to offer crash protection for moped riders for speeds of up to 40 km/h. This looks like a good MATCH, because new and future car fronts have to offer crash protection for pedestrians for speeds of up to 40 km/h. However, for cyclists, less safety is provided than for pedestrians, but by wearing a crash helmet, moped riders are better off than pedal cyclists.

Through roads (100 and 120 km/h speed limits)

– On these single and dual carriageway roads there are no head-on crashes and no side impacts. No collisions may occur between fast and slow traffic.
– For cars travelling in the same direction, rear-end collisions occur with other passenger cars. There may be speed differences of up to 120 km/h (e.g. when crashing into the rear of stationary traffic). If we also apply a 20% speed reduction here, this would mean that passenger cars would have to be designed for front-rear end collisions with crash speeds of up to 80 and 96 km/h (for driving speeds of 100 and 120 km/h respectively). We saw that the test crashes go up to 64 km/h, and for rear-end collisions perhaps to 80 km/h in the future. Also here, we have to conclude that there is a MISMATCH. Problems of road side obstacle crashes on through roads are discussed in *5.3.2.3*.

5.3.2.2. Conflicts at intersections and crossings

Intersections

– The intersections where most traffic is managed are intersections between two distributor roads and distributor roads with access roads. We distinguish between two types of intersections: roundabouts and a 'regular' intersection (with or without traffic lights).

– On roundabouts, travel speeds do not exceed 30 km/h. Passenger car fronts have to be adapted to crashes with vulnerable road users up to this speed. On roundabouts, we see a situation similar to urban access roads, so we have a MATCH here.
– At intersections with traffic lights, we only see collisions where there is red-light violation. Side impact collisions at speeds of up to 80 km/h are common (so 64 km/h taking into account a 20% reduction). Newer types of intersections are also constructed as raised plateaux with a 50 km/h speed limit. In these cases, there is a MATCH. In the worst case, vehicles have to offer crash protection at speeds of up to 64 km/h for side impact collisions. We already saw that this 64 km/h is a problem, particularly if no side airbags have been fitted. This means a MISMATCH.

Crossings

– Cyclist and pedestrian crossings on distributor roads are constructed preferably at split level. If this is not the case, then crashes can occur in these locations where cyclists are hit from the side by a passenger car front with crash speeds of up to 50 or 80 km/h (for urban and rural areas respectively). In construction terms, this means that the car front has to be designed for crash speeds of up to 64 km/h. We saw that a crash speed of up to 30 km/h is acceptable for pedestrians, and to a lesser extent for cyclists. So we have a MISMATCH here.

5.3.2.3. Obstacle and guardrail crashes: infrastructure and vehicle requirements

There is also a relationship between speed and vehicle mass in crash tests between vehicles and safety barriers or guardrails. Motorway barriers (and guardrails) are subjected to crash tests with passenger cars at 100 km/h and a mass varying between 900 to 1500 kg. The heaviest barriers are tested with vehicles of 38,000 kg. Barriers that can be used on non-motorway roads are tested with a passenger car of 1500 kg and a speed of 80 km/h. This means that well-designed and well-placed barriers need to offer sufficient crash protection.
– For a road type to be described as 'sustainably safe', the obstacle-free zone must be sufficiently wide. Serious crashes will not occur.
– If space next to the carriageway is lacking, then obstacles have to be protected with safety barriers. We saw that crash tests determine if barriers meet the criteria. In practice, however, there is still a relatively large proportion of casualties involved in impacts with guardrails and barriers. This is partly due to braking and steering manoeuvres by drivers, that cause cars to skid and roll over. American research has shown that after a crash with a barrier, a second crash takes place with more serious consequences in 70% of the cases (McCarthy, 1987). Also, on motorways in the Netherlands, there are many guardrail crashes. There is a MISMATCH, and SWOV recommends further research. Guardrails are implemented as a safety feature, but nevertheless, there are still fatalities with guardrail involvement.
– Obstacles (trees) are still positioned too close to 80 km/h roads in the Netherlands. This causes many fatalities in head-on and side impact crashes. If we assume that the 80 km/h speed limit is not exceeded on these roads, and that the crash speed is 20% lower than the travel speed, then this means that both the car front and side have to withstand crashes of up to 64 km/h. MATCH and MISMATCH. There is a reasonable MATCH for frontal crashes. The tests go up to 64 km/h, but the test surface is not an obstacle, but a flat area. The intrusion of an

Location	Mismatch of crash test and practice
Through road 100 and 120 km/h	Too dangerous in rear-end collisions.
Distributor road 80 km/h	Side impact tests only go up to 50 km/h whereas 64 km/h is essential. Speeds should be max. 70 km/h in case of possible frontal car conflicts.
Access road 60 km/h	Pedestrian-friendly car front is not adequate for cyclists.
Intersection 80 km/h roads	No crashworthiness in side impacts up to 64 km/h (although crash tests do match an intersection speed limit of 50 km/h).
Pedestrian and/or cyclist crossing	Cars are faster than a safe 30 km/h.
Obstacles 80 km/h roads	Car side not adequate in side impacts.

Table 5.2. ***Differences between crash criteria and current speed limits.***

obstacle is deeper. For side impact crashes a pole is used as a test object, but the crash speed is not higher than 28 km/h. So there is a clear MISMATCH that can not be compensated by side airbags.

5.3.2.4. Summary of mismatches

We have observed mismatches on six points (see *Table 5.2*). All these problems occur on the rural road network where the passenger car can offer insufficient crash protection for its occupants and for the other party. This means that, at those locations, infrastructural measures will need to be applied, particularly those which limit driving speeds.

In theory, three possibilities are conceivable for modifying a mismatch into a (sustainably safe) match. Firstly, one can strive to improve further the protection that vehicles offer to their occupants and crash opponents. If this is not possible, or would take too long, then one can decide to simply eliminate these conflicts. And if this is not possible either, or would take too long, then the only remaining solution is to decrease impact speeds, and perhaps also to limit travel speeds.

5.4. Primary safety (crash prevention) developments

5.4.1. What has been achieved to date?

Historically, it has proved to be not easy to determine the effects of primary safety features by means of crash research. Often, adequate crash data is not available or the effects of the specific safety feature cannot be separated from other influences. There is also the effect of behaviour compensation: drivers start to take more risks (e.g. higher speeds, shorter distance headways, etc.) because they feel safer in a car with certain safety features. This proved to be the case in studies into the effects of ABS, a high-quality technological braking facility in cars with a potentially large safety effect. With an ABS-fitted car, the vehicle can still be steered during emergency braking, whereas this is not the case without ABS. American research has shown that ABS on balance has little or no effect on road safety, resulting, at most, in a shift in crash pattern (from multi to single crashes; Kahane, 1994). In the United States, there is a legal obligation to evaluate vehicle measures. In this large

Mineta announces study - Estimates lives saved by safety features

"Nearly 329,000 lives have been saved by vehicle safety technologies since 1960, U.S. Transportation Secretary Norman Y. Mineta announced today. A new study by the U.S. Department of Transportation's National Highway Traffic Safety Administration indicates of all the safety features added since 1960, one – safety belts – account for over half of all lives saved.
The study also says government-mandated safety standards have added about $839 in costs and 125 pounds to the average passenger car when compared to pre-1968 vehicles.

"The Department has worked diligently to reduce highway deaths", Mineta said. "Thousands of our friends, neighbors and family members are alive today because of these safety innovations."

According to the study, the number of lives saved annually increased steadily from 115 per year in 1960 to nearly 25,000 per year in 2002.

"These reports showcase the achievements of NHTSA and the automotive industry," said NHTSA Administrator Jeffrey Runge, MD. "Vehicle safety technology is truly a lifesaver, especially the simple safety belt."

The study examined a myriad of safety features, including braking improvements, safety belts, air bags, energy-absorbing steering columns, child safety seats, improved roof strength and side impact protection, shatter-resistant windshields and instrument panel upgrades. It did not evaluate relatively new technologies like side air bags and electronic stability control systems.

Assessing the costs, NHTSA estimated that safety technologies cost about $544,000 for every life saved. They added about the same cost to a new vehicle as popular options like CD players, sun roofs, leather seats or custom wheels."

www.nhtsa.dot.gov/cars/rules/regrev/evaluate
January 2005

Frame 5.2.

country, which has good road safety data which has been analysed over an extended period of time, a convincing picture emerges of the positive safety effects of vehicle innovations (see *Frame 5.2*).

An example of the large effect of Electronic Stability Control

Two more or less similar studies have been published recently in the US on the effect of Electronic Stability Control (ESC) (NHTSA, 2004; Farmer, 2004). Both studies indicate that in the US, ESC equipped cars are at least 30% less often involved in fatal single-party crashes than non-ESC-fitted cars. According to one of the studies, the effect for SUVs was about twice as high (about 60% less fatal single-party crash risk).

Such large road safety effects were reported several years ago, but they were usually based on estimates and often from suspect sources. The two studies mentioned are based on data from a sufficiently large number of actual crashes, the methodology and design of the studies allow firm conclusions to be made, ESC-equipped and non-equipped cars were properly distinguished, and their crashes were made comparable.

However, some observations need to be made. The studies discuss American ESC-equipped cars from the more expensive market segment, making the result not necessarily valid for all other car types. Furthermore, the American conditions are possibly different from e.g. those in the Netherlands with respect to crash and collision types. Nevertheless, such high effectiveness certainly offers potential for the situation in the Netherlands. As outlined previously, about half of all fatalities are involved in single-party road crashes in the Netherlands, making the potential area of effectiveness of ESC large. On the other hand, the penetration of ESC into the car market still is relatively small, and limited mainly to the more expensive car types. Meanwhile, ESC is fitted in about 28% of new cars (end of 2003). EuroNCAP now recommends purchasing an ESC-fitted car (see www.euroncap.com).

5.4.2. Future prospects: intelligent vehicle systems?

As mentioned previously, important developments are currently taking place in the area of intelligent vehicle systems. While the main discussion can be found in *Chapter 6,* some trends with respect to vehicles are outlined here briefly:

- There is a general increase of electronics in vehicles. In various areas (engine, comfort, safety, warning systems, etc.) electronics are used to improve performance, to support or warn the driver, or even to intervene autonomously.
- There is an increase in system complexity, such as Electronic Control Units, sensors, etc.
- Systems integration, and vehicle stability systems in particular, are important developments. This is firstly due to the fact that various systems can use the same sensors, which reduces costs. Secondly, integration is also necessary in order to overcome negative interactions between systems, and to achieve better systems.

5.4.3. Future prospects: lighting and signalling

In a study commissioned by the European Commission, a number of European institutes, including Dutch TNO and SWOV, investigated Daytime Running Lights (DRL). They concluded that 5 to 15% of the number of road casualties could be saved by DRL (Commandeur et al., 2003b). This measure can be implemented in two ways, and also a combination is possible. One option is to switch dipped lights on and off automatically, as is the case in cars imported from Sweden. The other option is to switch lights on manually. In order to save fuel, and thereby to protect the environment, the research institutes advocate energy-saving lighting instead of the standard low-beam headlights.

In view of the large numbers of rear-end collisions, various European countries advocate extending the current brake light by introducing signalling emergency braking. Several systems are currently being discussed, such as intensifying the third brake light proportionally as the brake force increases. It is expected that an agreement will soon be reached in Brussels. Unambiguous brake indication is essential here.

5.4.4. Future prospects: classification of vehicles

To fit into Sustainable Safety, it is also essential to classify vehicles in a limited number of categories that are clearly and easily to recognize, similar to roads (each with their specific access requirements for vehicle types, speed regime and regulations for behaviour). Vehicle classification is well established in general terms, or at least they have been defined in classes according to usage needs, mass and speed range, as is the case in international regulations. It is also necessary for specific road types to be allocated to different types of road users (e.g. pedestrians on footpaths, cyclists on cycle paths, cars and other motor vehicles on various other road types, with or without limited access). In addition, separate roads or dedicated lanes for very dissimilar vehicle types in terms of danger, such as heavy goods vehicles, can be designated (see *Chapter 14*).

At the same time, two vehicle types stand out that barely fit in the system: mopeds and one-seater cars with a moped engine. The former have to travel on the road in urban areas, and in rural areas on the cycle path. The latter may travel almost anywhere, except on footpaths. At first sight, many mopeds cannot be distinguished from light mopeds or even motorcycles. And one-seater cars with a moped engine have many characteristics of normal passenger cars. This is a problem, although it will always be difficult to calculate *how many* additional casualties it causes.

Future activities in the field of vehicle classification should address further limits to vehicle diversity.

5.4.5. Future prospects: heavy goods vehicles and vans

Apart from some of the developments for passenger cars which have already been mentioned, specific developments can also be expected for heavy goods vehicles. The following are relevant:

- Speed limitation. At the moment, there is in the EU a speed limitation for heavy goods vehicles of 85 km/h. Currently, a proposal is being discussed to fit vans with speed limiting devices (set at 100 km/h).
- Application of tyres with a higher friction coefficient. The picture emerges from published braking tests that braking deceleration at the level of passenger cars (7-10 m/s^2) are possible. The legal requirements are considerably lower.
- Roll-over prevention.
- Field of view: new requirements to reduce the blind spot.

In summary, substantial casualty reduction may be expected from primary safety features. The most important are ESC and sensors that warn and/or intervene before a collision occurs.

5.5. Secondary safety (injury prevention) developments

5.5.1. What has been achieved to date?

It is anything but simple to attribute the casualty reduction of the past decades to individual measures, and it is even more difficult where a feature has been introduced gradually, as is the case with many vehicle characteristics. Improving vehicle safety in the main is a continuous process, fundamentally affected by the way manufacturers compete with each other, and influenced by how market demands work on product improvement. New regulation often takes place only after such developments. It is seldom the case that a substantial change takes place from one day to the other, where the effect can be easily determined.

The Transport Research Laboratory (TRL) has estimated how many fatalities and severe injuries have been reduced in the United Kingdom as a result of improved car crash protection (Broughton et al., 2000). The result of this study, which compared the injury severity of drivers of older cars (1980-81) with that of newer cars (1996) under comparable circumstances, indicates an improvement of 14% in the construction year range mentioned. This means, in gross terms, 1% fewer fatalities and severely injured victims annually by improvements in the crash safety of passenger cars, separated out as far as possible from other road safety effects.

It is more difficult to establish what test programmes such as EuroNCAP have contributed up until now. Lie & Tingvall (2000) looked for a relationship between (high scoring) car types in EuroNCAP and results in actual practice based on crash data of those car types. The study shows that car types with 3 or 4 EuroNCAP stars are about 30% safer in car-to-car crashes than car types with 2 stars or no star. This does not prove that EuroNCAP has brought about this improvement, but nonetheless that a high star rating and a high level of crash safety concur.

Despite the progress achieved, secondary safety remains an area with large potential to reduce road injuries and victims further. We can think of reducing head injury risk, protecting pedestrians and cyclists, preventing whiplash of neck injuries etc. Such potential developments in this field address a broader range of crashes and road users than before, namely:

- Protection of car occupants in the most important crash scenarios. That is, not only in head-on and side impact crashes, but also in rear-end crashes

Seat belt wearing in the Netherlands

Over the decades, more and more car drivers have been wearing their seat belts. In rural areas the compliance percentage rose from 66% in 1982 to 92% in 2004; in urban areas, this rose from 50% to 88%. While the difference between the two has been drastically reduced, it still exists. The wearing percentage levels in the rear seat has risen enormously in the past years, to about 70% at present.

Year	Wearing percentage drivers		Wearing percentage on rear seat	
	Rural areas	Urban areas	Rural areas	Urban areas
1982	66	50	n/a	n/a
1985	66	49	n/a	n/a
1990	78	59	22	18
1995	77	64	21	20
1998	80	67	43	40
2000	86	74	36	28
2002	91	83	56	49
2004	92	88	67	71

Seat belt wearing percentage in passenger cars in the Netherlands. Sources: SWOV until 1998; AVV Traffic Research Centre since 2000.

With this significant increase in wearing percentage levels, the Netherlands has reduced its arrears and caught up with a number of other well-performing Western European countries. The wearing percentage level of car drivers in Germany, Great Britain and Sweden has been relatively stable for a decade at around 90%.

Frame 5.3.

and roll-overs, and crashes with heavy goods vehicles.
- Prevention of a variety of severe injuries in addition to fatal injuries, and injuries that result in long-term disability in particular.
- Addressing all road users, comprising car occupants, children and the elderly, lorry and bus occupants, and also pedestrians, cyclists and motorcyclists.

Current research and technological developments address, among other fields, the biomechanics of injury in order to produce more realistic (biofidelic) crash test dummies and better criteria for determining injuries, for crash testing passenger cars and heavy goods vehicles. Work also addresses the development of light-weight energy-absorbing materials, particularly for the interaction between (heavy goods) vehicles and pedestrians or cyclists. *Leitmotiv* in the development of secondary safety is the advance in virtual design and validation methods using computer simulation. New and strongly developing are intelligent systems linked to pre-crash sensor information, where primary and secondary safety considerations will gradually merge.

5.5.2. Smart restraint systems and pre-crash sensing

The seat belt is one of the best available safety devices, and the assumption that seat belts are used is fundamental to all consideration of safe crash testing speeds. It is pleasing to observe that seat belts are worn more and more in the Netherlands (see *Frame 5.3*). In addition, developments are underway that will encourage more seat belt use in the future (seat belt reminders), or that can prevent injury more effectively. Much research and development is aimed at this latter issue.

Seat belts and airbags can be made adaptive by the introduction of (fast acting) electronic features such as intelligent sensors. Nowadays, there are active safety systems to further optimize the functioning of these adaptive systems. These can be adapted to specific conditions (real-time) during the crash phase. A next step in this development is *anticipating* the crash.

In conjunction with pre-crash sensing, active safety systems may protect car occupants even more effectively. Pre-crash sensing systems make use of sensors such as radar, laser and video, to observe the vehicle's surroundings and to detect a potential collision in an early phase. The system can alert the driver to dangerous situations, or, if necessary, activate safety systems autonomously, such as reversible seat belt tensioners.

Since early 1990, car manufacturers have fitted cars with an Electronic Data Recorder (EDR) to control airbags. Apart from controlling airbags, the EDR also logs data (e.g. speed data) of the last five seconds prior to a crash. Up until now, car manufacturers have been quite reticent about acknowledging the existence of such a function. EDR data are currently not used in road crash analyses, whereas this can be extremely useful in determining the crash facts and crash severity. At the moment, the cooperation of car manufacturers is needed to be able to read the signals registered. Legislation offers possibilities to request this data and to ensure that it is delivered by the manufacturer. In order to make the data more easily accessible, a standard would need to be agreed at European level, which would have to be applied mandatorily.

5.5.3. Heavy goods vehicles and vans

Improving crash compatibility between heavy goods vehicles and passenger cars aims at underrun protection (frontal, side and rear). This aims to prevent the passenger car from running under the heavy goods vehicle. A directive for (rigid) frontal underrun protection already applies to new heavy goods vehicles. For further frontal improvements, an extension to a more dynamic, energy-absorbing feature is under discussion.

As for improving passenger cars to benefit third parties (such as pedestrians), manufacturers and vehicle owners/transport operators are even less interested in investing in improving heavy goods vehicles if these improvements are in the other party's interest. In view of this, a desired safety feature will only be widely used if a legal requirement exists, unless the measure also provides some other benefit for the investor.

5.5.4. Much has been achieved already

In conclusion: secondary safety pays. A reduction in casualty numbers of about 1% annually is likely to be the case in the Netherlands, as in the United Kingdom (Broughton et al., 2000) and Sweden (Koornstra et al., 2002). It is unlikely, however, that this trend will extend into the future, since the higher bumpers and higher masses of SUVs are likely to have a negative influence on road safety. Measures for crash-friendly car fronts will contribute to the safety of vulnerable road users. Long-term disability, such as whiplash, can be reduced by also carrying out crash tests on the rear end of passenger cars.

5.6. Discussion

Vehicle safety measures, and particularly those in the field of secondary safety, have been popular since the 1970s. Seat belts (and the promotion of their use) and improving crash safety through vehicle construction come immediately to mind. Without doubt, this has improved road safety to a large extent. This result has been achieved in two ways: legal requirements have been established, and, as mentioned previously, manufacturers have also been very active in improving their vehicles in these areas.

More recently, particularly due to the rapid advance of electronics, primary safety features have gained much ground, often on a voluntary basis (e.g. ABS, ESC, Adaptive Cruise Control (ACC), etc.).

It is clear that man (as a driver who has to perform complex tasks) benefits from the support and simplification of tasks offered by this type of high-performance operating equipment. This is particularly the case in emergency manoeuvres, where steering and braking will be safer than relying upon human hands and feet. Some experts envisage that the realization of these measures, which are currently in various stages of development, have the potential to completely prevent crashes.

In the United States, meanwhile, this has led to the view that further safety improvement will have to come (mainly) from the area of primary safety; a view that is also held by manufacturers. Like Wismans (2005), we do not subscribe to this point of view. Although it is clear that the rapidly advancing developments in the area of ITS offer important opportunities to promote road safety (thinking e.g. of ESC), we also believe that improving secondary safety will make an important road safety contribution.
This certainty stems firstly from taking account of current practice where the incompatibility between passenger cars (including SUV's) is an important cause of poor crash outcomes. There is clear evidence that such incompatibility problems can be limited considerably by better engineering design. This is also the reason why the EU has taken up this subject explicitly in its pack-

age of measures. In addition, while the outcomes of rear-end crashes, are seldom fatal or even severe, these could be ameliorated if long-term complaints caused by the whiplash syndrome can be eliminated through improved engineering design. A comprehensive European crash test should be developed to this end.
A second important motive for the vigorous implementation of improvements in secondary safety is the existing inequality between vulnerable road users and cars. In a sustainably safe traffic system, in particular, further improvements to the car front, a hard-won subject by the way, is an absolute must to serve vulnerable road users. Tightening up the requirements, also aimed at the interest of cyclists will mean an important step forward.

The European Commission has formulated a highly ambitious road safety target with the objective of improving road safety by 50% by 2010. To this end, a programme of possible measures and research support has also been established (European Commission, 2003). The more important crash safety intentions are:
- further increases in the use of seat belts and child restraint systems;
- improvements to (car-to-car) crash compatibility;
- improvements to underrun protection for heavy goods vehicles;
- improvement of pedestrian safety (car front);
- further extension of EuroNCAP.

The Dutch government has high expectations of the introduction of vehicle technology, according to the *Mobility Paper* (Ministry of Transport, 2004a). Without being specific, the Ministry expects that after 2010 ‘substantial innovation in the field of vehicle technology’ could result in up to 200 saved lives annually. So both the European Commission and the Dutch authorities have high expectations. First of all, it is important to embed this area well in the Sustainable Safety vision, and subsequently to arrive at a specific action plan.

It is striking that modern electronics have brought the areas of primary and secondary safety together. Interesting supporting evidence for this is the application of *pre-crash*-sensing to improve the *post-crash* outcome. In other words, these modern technologies also play an important role in the field of secondary vehicle safety in the meantime, due to their extremely fast operation before and during the crash process. We are, nevertheless, talking about two fundamentally different approaches, where primary characteristics aim to prevent the crash, and secondary measures try to mitigate the consequences.

In the Sustainable Safety vision, the principle is to change the crash safety focus fundamentally: *from car occupant safety to compatibility*, which includes the other crash party. This should not be limited just to passenger cars mutually, but also include SUVs and vans. The principle also needs to be extended to include the improved crash safety of vulnerable road users (pedestrians and cyclists). At the other end of the mass range, the challenge is to limit the crash aggressivity of heavy vehicles, particularly in the case of passenger cars. In the first case, this means mainly an *improvement to the car* (car front), whereas in the latter case, the solution will have to be found primarily in offering protection against the dangerous zones of *heavy goods vehicles*.

In both cases, there is a limit to the possibilities (in terms of crash speed). For pedestrians (and cyclists) this lies in the area of 30 to 40 km/h. For the frontal impact between lorry and passenger car, this limit will, for the time being, not be higher than the achievable crash speed for car-to-car collisions: around 65 km/h, in accordance with the crash speed used in EuroNCAP.

Currently, there is much movement in the area of primary safety, particularly around ITS that will be further discussed in *Chapter 6*.

The positive effect of advancing improvements in cars has its drawbacks. Driving comfort will, without doubt, be increased by quieter engines, better sound insulation, higher performance, more entertainment and information during the trip. There is a danger that these latter characteristics will distract the driver more than offering support in the execution of the driving task. Moreover, we indicated that the mass of passenger cars (and also other types of motor vehicles) is increasing steadily. The effect of this can be called positive for the occupants of these vehicles, but it will certainly not benefit the other crash party. Careful and timely monitoring and anticipation of future developments are desirable here.

This chapter laid a bridge between developments in the area of vehicles and of infrastructure by an assessment of crash conditions that are acceptable and unacceptable in Sustainable Safety. We recommend that these points should be further developed as a central element in the Sustainable Safety vision.

6. Intelligent Transport Systems

The application of artificial intelligence in road traffic finds itself in an upward spiral. A large number of developments have taken place in the area of information and communication technologies (ICT), electronic support and driver support systems (Advanced Driver Assistance Systems – ADAS). These are generally named Intelligent Transport Systems (ITS), as an umbrella term.

Intelligent transport systems can make a unique contribution to improving road safety and therefore deserve a prominent place in the Sustainable Safety vision. Systems that aim directly at safety raise particularly high expectations. For all OECD countries together, safety-orientated ITS are forecast to deliver a casualty reduction of 40% (fatalities and injured) (OECD, 2003).

However, in reality, ITS do not yet contribute very strongly to road safety. This is because a large part of these systems is not yet (fully) developed, and their implementation in traffic is limited. In addition, the overall effect of many of these systems is still somewhat uncertain due to their often unclear interaction with human behaviour (such as risk compensation) and the complexity of large-scale implementation (European Commission, 2002). Another reason why ITS do not currently contribute strongly to better road safety is because the introduction of ITS has been guided to date by improving traffic management (flow and accessibility) and by driving comfort. Road safety aspects are not always addressed and possibly even undermined. Despite this situation and these uncertainties, ITS potentially offer many opportunities to improve road safety further (see *Frame 6.1*).

The power of ITS: flexible and dynamic

The current traffic system has been organized highly statically, whereas traffic has to be safe for a variety of road users in highly changing conditions: both under busy and quiet conditions, and both in fine weather and under slippery conditions and fog.
To this traffic system, ITS add dynamics (changes in time) and flexibility (adaptation to circumstances). With the right information at the right place and at the right time, ITS offer the possibility to respond to specific conditions. This contributes to inherently safe road traffic.

Frame 6.1.

This chapter will outline an updated vision of the contribution of ITS to sustainably safe road traffic. Only those ITS applications have been included that are capable within Sustainable Safety, at least to some extent:
- of doing what only can be achieved by ITS, and not by other measures;
- of doing what can be done better or more efficiently by ITS compared with other measures;
- of doing what can be done more efficiently in combination with ITS.

Just as for other measures, the objective of the implementation of ITS in a sustainably safe traffic system is to prevent crashes from happening or to prevent crashes from having serious consequences at the earliest stage possible. The more the ITS application makes road safety independent of individual choices and behaviour of road users, the higher the Sustainable Safety level of that application. These starting principles lead to a number of tangible ITS measures that can contribute to sustainably safe road traffic. In addition, the interaction with other, more traditional measures is an important issue.

Before we discuss these tangible measures in this chapter (*6.2*), we will first discuss a number of general characteristics of ITS (*6.1*) that are important to an understanding and assessment of the subsequent sections. Since the implementation of ITS measures is more complex than that of more traditional measures, this chapter will conclude by looking at the stakeholders that play (or should play) a role in implementation, and the initiatives that are required for a proper implementation (*6.3*).

6.1. Characteristics of ITS

The contribution of ITS to sustainably safe road traffic can take place at various levels of automation. The next section will outline the different levels and will indicate to what extent these are expected to contribute to sustainably safe road traffic (*6.1.1*).

The effects of intelligent transport systems may, in the end, turn out to be different than expected. This is because, on the one hand, citizens or road users who deal with intelligent transport systems will have to accept them before they can be implemented and, on the other hand, because the addition of ITS to the traffic system can cause unintended changes in human behaviour that may undermine the functioning of the system. The second section will outline the factors that play a role in this respect (*6.1.2*).

In order to understand the tangible ITS applications that can contribute to sustainably safe road traffic, we will address the different ways in which ITS applications can function in the final section (*6.1.*3). The reader will also be acquainted with some jargon that will be used later in this chapter.

6.1.1. From providing information to automation

ITS can act on the process of traffic participation at various levels of automation. The most far-reaching form of ITS-supported traffic participation, and also the most far-reaching form to prevent dangerous road user actions, is *complete automation* of the traffic task. Here, the vehicle can travel automatically, and the driver has only a supervising function. However, this is a long way off, and the question arises as to whether or not this will ever happen, given the complexity of road traffic. In other modes of transport, such advanced automation is already a fact, for instance in aviation and rail transport. The most important reason for this is that these modes have a much higher uniformity in the traffic system, so most actions can be managed automatically. According to Professor Wagenaar of Leiden University (Van Weele, 2001), the possibilities for automating road traffic in the future have to be sought by increasing uniformity, as is already the case on motorways. According to Wagenaar, complete automation of road traffic would eventually create a safe situation, irrespective of all our ‘robot fear’.

For the time being, road safety can be improved by less advanced forms of ITS automation. Here, ITS mainly offer support for human capacities. One level lower than complete automation, we find *intervening* ITS, whereby part of the driving task is taken over (usually in specific situations), and the driver is informed accordingly. At this level, the driver is still responsible for the driving task and possible consequences. Examples of intervening ITS are automatic braking systems to prevent collisions and the intervening variant of the Intelligent Speed Assistant (ISA, see *6.2.2*).

One level lower again, we can find *warning* ITS. In this form, the system first makes a suggestion that becomes increasingly noticeable if not followed. In extreme forms, it can initiate a corrective action. An example of such warning systems is ISA where the driver gets haptic (force) feedback from the accelerator if the speed limit is exceeded.

At the lowest level of automation, ITS can contribute to safe traffic participation by *informing* the driver. At this level, the driver has to interpret information and has to decide if actions are required based on this. Examples of informing ITS are systems that provide information about the road and traffic environment, driver monitoring systems and informative ISA (see *6.2.2*).

The theoretical safety effects are higher with higher levels of automation (Carsten & Tate, 2005), but the largest effects for the not too distant future are expected from informative and warning systems. This arises from the expectation that systems that intervene in the driving task will at present find little application because they are much more difficult to implement. Other issues that have their origins in how people interact with systems are also relevant (see *6.1.2*).

6.1.2. The human factor as an important component in the effects of ITS

Positive effects are expected from a number of safety-orientated ITS applications (see *6.2*), but these systems will only realize their potential if they a) are implemented, b) are well applied, and c) have no harmful side effects (Jagtman, 2005).

In advanced forms of automation, where the human operator only has a supervising function, there is a danger that too much confidence in the correct functioning of the system will arise and that functions previously performed by the human operator will disappear from the task repertoire. In order to make sure that the human operator can take over functions in time when the system fails, and that he or she knows what the use of the system still is, systems can be designed in such a way that they 'fail safely' by so-called 'graceful degradation'. Here, the user is alerted that the system is failing, which mode the system is operating in, etc. Education also plays a role in the optimum interaction between man and machine (Twisk & Nikolaou, 2005). Another danger in process automation is behavioural adaptation or risk compensation (see e.g. Evans, 2004) which can result in a reduction in potential safety effects.

At the other end of the automation spectrum, particularly for information provision systems, we have to be careful that drivers are not overloaded with information at those critical moments in which the traffic situation is unclear or complex. This can be especially dangerous for less skilful road users who are, by definition, able to handle less information. Information can also distract from more relevant traffic matters if the system is not well designed or if combinations of systems are not well tuned to each other. This may inadvertently cause crashes (see e.g. ADVISORS, 2003). A good system and display design is essential to prevent such problems from occurring. 'Good' here means: the correct information, in the right quantity and at the right moment. We also need to think of dividing the information load over several perception modes, so not just visual information, but also auditory or haptic. We also need to prevent ITS applications changing vehicle behaviour such that it becomes erratic and/or impossible to interpret, for instance by abrupt deceleration or acceleration (Houtenbos et al., 2004).

What is technically feasible will, in the end, only have the desired result if people accept the systems and operate them well. Acceptance of ITS applications by road users is not a problem as long as a clearly personal interest is served, and if personal freedom is not at stake. There is, for instance, much support for navigation systems and fatigue detectors by car drivers, and there is positive public support for the crash recorder (a black box for logging data just prior to a crash; Christ & Quimby, 2004). A significant number of car drivers also indicate their interest in voluntary driving task support (Van Driel & Van Arem, 2005). Perhaps, the provision of more information about risks in traffic and the possibilities of reducing risks – the notion that many crashes and casualties are avoidable – will bear fruit in the future in the form of the introduction of safety-orientated ITS applications. Other advantages of these systems, such as reliable travel times and a more fair detection of violation behaviour, should also be promoted.

6.1.3. How do intelligent transport systems work?

Very generally speaking, we can state that intelligent transport systems operate based on information collected from the environment by means of sensors. This information is subsequently processed by one or more computers, eventually leading to a specific response depending upon the system's objective (see e.g. Bishop, 2005). If the system's objective is to provide information to a road user, it is more flexible (and arguably cheaper) if it takes place in individual *vehicles* rather than with intelligent *roadside-based* systems.

If the location of one or more vehicles is important, ITS systems currently determine these locations by means of autonomous vehicle sensors, such as radar and Global Navigation Satellite Systems (GNSS). Within a few years, the European Galileo system will be operational next to the Global Positioning System (GPS). Location information from these systems can be linked to a digital road map. These maps contain not only static information, but also dynamic information, such as real-time road network and traffic condition data, will be available for use in individual vehicles.

Apart from functioning *autonomously*, ITS can also function *cooperatively*. Here, direct information exchange takes place among vehicles, and between vehicles and roadside beacons. Both vehicles and beacons then function both as transmitters and as receivers. The operation range of cooperative systems is larger than that of systems that gather data autonomously. Cooperative systems can also achieve greater accuracy. In cooperative ITS, spontaneous (ad hoc) communication networks can be set up (at least) while managing risky situations for instance. The functionality of cooperative ITS, of course, depends heavily on the equipment rate and the extent of their use in the vehicle fleet.

Information gathered by an intelligent transport system can be processed *locally* (at the location where the information is needed) and *centrally* (in a central point, at another location where the information is gathered). Local information processing has the advantage of being quicker compared to processing through a central point. Moreover, it is more robust because failure of the central point does not affect it. Such facts are highly important for those applications that are time critical. For non-time critical applications and for applications that require data at network level, central control is suitable.

6.2. ITS contributions to sustainably safe road traffic

Sustainably safe road traffic benefits from preventing dangerous human actions that can cause crashes at the earliest possible stage (see also the phase model by Asmussen & Kranenburg, in Sanders-Kranenburg, 1986). In a number of cases, this is possible by excluding people from road use, or by influencing people's modal choice at strategic level. In *6.2.1,* we will discuss the systems that fit within this framework.

Even if as many dangerous conditions as possible are filtered out beforehand, it is important to provide good support to road users and to prevent unintentional errors and intentional violations. ITS offer a wide range of possible applications (see *6.2.2*).

The systems that will be reviewed later represent only a handful of the total number of possible ITS applications. This selection is mainly based on overviews by the OECD (2003), ETSC (1999a), and the European Commission (2002). We will discuss here both ITS developments primarily aimed at safety, and developments that aim at other objectives but that may incidentally have a meaning for safety. It is also worth remarking that most ITS applications concern motorized traffic (primarily cars). Nevertheless, the subject of vulnerable road users will be addressed when discussing the interaction of this group with fast traffic.

6.2.1. Preventing risky road use

Alcohol, driving licence and seat belt interlocks, and other smart-card applications

Road users (particularly car drivers) who have consumed (too much) alcohol or who do not comply with driving skill requirements, represent a high road traffic crash risk (*Chapter 2*). Car drivers who drive without their seat belts run higher severe injury risks if involved in a crash. Therefore, it fits within sustainably safe road traffic to deny these people access by means of a kind of 'lock', or to prevent them from starting their engine if they do not comply with set requirements, thus preventing them from causing crashes or becoming severely injured in traffic. The development of smart cards offers opportunities to this end that were not available before. In this context, a smart card is a kind of individual starting permit for the car.

User data can be stored on a smart card, such as possession of a driving licence (with or without re-

Figure 6.1. ***Diagram of an intelligent transport system.***

strictions, validity, and suspension), and of vehicle usage conditions (e.g. a curfew for specific age categories). The smart card cannot only be used to alleviate pressure on enforcement, but also for specific measures targeted particularly at less proficient road users (such as novice drivers and the elderly; see also Davidse, 2006). In this way, the smart card can be used in the application of a graduated driving licence (*Chapter 11*) or for engine performance restrictions for driving licences, thereby matching the driving task to the driver. Yet another possible application of the smart card concerns the physical adaptation of the vehicle (seat, head restraints and other safety devices) to the anthropometric characteristics of drivers, and the adaptation of information and control systems to drivers' cognitive, motor and perceptual characteristics.

The application of locks combined with legislation around traffic access is expected to be potentially highly effective. This is the experience with alcolock systems (for repeat offenders driving under the influence of alcohol; *Chapter 10*), for example. However, it is clear that just adding a device is in itself insufficient. Such devices need to be integrated within a broader programme.

Influencing mobility choice

ITS applications that are not primarily aimed at road safety, but which may certainly contribute to it, are 'mobility management systems', that may aid people in making well-considered choices in their mode of transport. By supporting people in their choice of transport mode and the time spent in traffic, etc., this system may reduce risky traffic participation.

6.2.2. Preventing dangerous actions during traffic participation

Vehicle control support

Single-party crashes where the vehicle runs off the road often occur, and the consequences are, in combination with crashes against e.g. trees, serious (see *Chapter 2*). Some of these crashes can be prevented by aiding drivers in vehicle control, both in longitudinal and lateral directions. Firstly, the vehicle can monitor itself, as happens with Electronic Stability Control (ESC; see *Chapter 5*). Vehicle control in a lateral direction can be supported by the Lane Departure Warning Assistant (LDWA) that gives a warning when the car is about to cross longitudinal road markings (monitored by in-car cameras). These systems are already on the market, albeit that they have been mainly integrated as a comfort-enhancing system. A test with heavy goods vehicles has shown a small positive safety effect (Korse et al., 2003). An option that intervenes more through power steering, called Lane Keeping System (LKS), is thought to have a larger safety effect.

For longitudinal control, a positive effect on road safety can be expected by ensuring an appropriate speed on curves. This can be achieved by means of a digital map, or communication with roadside beacons. Such a system can be coupled with ISA and also takes into account local and temporal circumstances, such as road surface (pavement) condition, skid resistance, and so on. In the United States, the introduction of this application is considered to be a likely candidate for the introduction of road safety measures in the short term (CAMP, 2005), but we have not reached this stage yet in the Netherlands. Vehicle-to-vehicle communication may play a role here in the longer term (Reichardt et al., 2002; www.cartalk2000.net).

Support for perception, interpretation and anticipation of traffic situations

In complex daily activities such as traffic participation, human reaction times are generally a minimum of one second. At a speed of 100 km/h, a vehicle travels about 30 metres in a second. If this distance is not available, a collision with a sharply braking vehicle in front cannot be avoided. Therefore, timely perception of changes in the environment is highly important. In this respect, electronic systems perform easily a factor of 10 times better than humans and can help to detect hazards more rapidly. It is estimated that rear-end collisions can be reduced by a maximum of up to 90% if drivers are warned 4 seconds in advance (Malone & Eijkelenbergh, 2004). For 3 and 2 second advance warnings, the reductions are 55% and 10% respectively. Depending on the implementation option (warning or intervening) and the extent of presence in the fleet (10% to 50%), a reduction in rear-end collisions is expected between 7% and 44% (mainly on motorways). Positive effects are also expected for head-on and side impact crashes on the secondary road network, but these are less obvious. Another application of ITS that prolongs the reaction time for road users concerns the detection of oncoming crossing traffic. Detection of this traffic takes places with cameras around intersections, by means of vehicle-infrastructure communication, in-vehicle sensors, or vehicle-to-vehicle communication. The road user then receives a message on dynamic road signs or in-vehicle (www.prevent-ip.org; www.invent-online.de). The same approach can be followed on road sections to make turning of vehicles safer.

Systems aimed at pedestrian detection also offer perception support. Work on this topic is being carried out in a European framework. Apart from object detection by in-vehicle sensors, we can also think of systems that enhance vision during night-time (night vision systems). It is expected that such systems can strongly reduce crash risk between fast traffic and pedestrians, but actual effects and implementation timescales are still unclear (see e.g. www.prevent-ip.org). When collisions cannot be avoided, timely pedestrian detection is expected to result in reduction of injury risk in two ways. Firstly, by reducing crash speeds, and secondly, by preparing available safety devices in and around the vehicle for the imminent crash. This is also known as 'pre-crash sensing' (see *Chapter 5*). Examples are seat belt pre-tensioners, multi-stage airbag initiators, and 'pop up' car bonnet to protect vulnerable road users.

The range of sight of the human eye is usually adequate under normal traffic conditions, but not under bad vision conditions (night-time or fog; situation awareness level 1; see *Chapter 1*). Additionally, in the interpretation of the situation, for exemple of the road image (level 2), and in the extrapolation of information for use in the near future (level 3), people can draw incorrect conclusions, which make them fail to realize, or realize too late, that they are in a dangerous situation or that they are behaving unsafely. ITS can contribute to better situation awareness in traffic, for instance by projecting an 'electronic horizon' on the windscreen by means of a 'head-up display' (similar to systems used in aviation). By offering information in such a structured way, drivers can be assisted in drawing correct conclusions about the situation and to adapt their behaviour accordingly. Such a system can be particularly valuable in singular and unexpected situations (such as road works, slippery conditions or unexpected manoeuvres by road users) and for less skilful road users, such as novice drivers.

Recognition of reduced task capability

As well as road users who are less skilful in their participation in traffic due to a limited task capability, there are also skilled road users who are temporarily less capable due to their situational state (see the model by Fuller, 2005; *Chapter 1*). In addition to the applications already mentioned, such as the alcolock, intelligent transport systems also offer possibilities to detect the road user's reduced task capability while driving. Systems are in development to detect fatigue and loss of attention (www.awake-eu.org). In Japan, cars are on the market in which a sensor in the steering wheel detects whether or not a driver still has sufficient attention for the driving tasks. We have to keep in mind that drivers should not become too dependent on such a system or start to explore the system's boundaries, thereby endangering safety.

Achieving optimum task difficulty

As stated before, ITS can be of help in recognizing one's own situational task capability, depending on which access to motorized road traffic it denies. One step further, ITS can also provide support in achieving optimum task difficulty for individual road users in traffic. Here, the system connects the driver's situational state with his or her specific characteristics as stored on a smart card, for instance. This connection results in defining the actual task capability (see Fuller, 2005; *Chapter 1*). The system also makes a judgment of the appropriate actions required in traffic at that moment and in the immediate future. To this end, the environment is being scanned with in-vehicle sensors and, in combination with the vehicle's own data, interpreted and translated into actions. Subsequently, the system sets priorities for task execution, and gives advice to the driver. Actions concerning acute, time critical situations are recommended by the system to determine the highest priority; others are either deleted from the action list or put on hold and are recommended when the traffic situation permits (www.aide-eu.org; Zoutendijk et al., 2003). The system can also recommend that the task difficulty is lowered, for instance by reducing speed or by taking a break.

Preventing and registering unintentional or intentional rule violation

Speed: dynamic limits and ISA

Apart from supporting road users in the optimum execution of the driving task, ITS can also contribute to preventing unintentional and intentional traffic rule violations. We reviewed the alcohol, driving licence and seat belt interlocks earlier, but more is possible, for instance in the field of speed.

The benefits of driving speed management are undisputed (see e.g. Aarts & Van Schagen, 2006) and, not surprisingly, are also an important component of sustainably safe road traffic. Much has been achieved with traditional measures in this area, but without corresponding widespread compliance with speed limits (see Van Schagen et al., 2004). Substantial future improvements may be expected from ITS. There is, for instance, a proposal to make speed limits dynamic depending on local and time specific conditions (Van Schagen et al., 2004; *Chapter 9*).

In addition to a system of dynamic speed limits, Intelligent Speed Assistance (ISA) is a promising ITS application. European authorities take much interest in ISA (www.prosper-eu.nl; www.speedalert.org). ISA can be provided in various options: informative, warning, or intervening (see also *6.1.1*). ISA can also work with (current) static and (future) dynamic speed limits. In the static version, speed information is available via a digital road map, and positioning via the vehicle. Such an application can be combined with navigation systems. The dynamic version makes use of local vehicle-to-vehicle communication and/or vehicle-infrastructure communication with a central traffic centre.

Estimates of savings in the number of fatalities and severe injuries run from 5% for the informative/voluntary ISA version, to about 60% for the intervening/compulsory version (Carsten & Tate, 2005). These estimates assume a high level of penetration of ISA in the traffic system, something that does not seem to be very realistic in the short term, particularly for intervening options.

It would perhaps be best to introduce ISA firstly in target groups, such as professional vehicle fleets, young drivers or repeat offenders. However, this requires some further developments, such as establishing digital road maps that include actual speed limits for all traffic situations, and setting up pilot projects to gain experience. Apart from development of ISA, investments still have to be made in more traditional speed management measures. In addition, safety is not the only consideration. The interests of traffic management at road and network level (flow, trip planning, route choice) and the environment (fuel use, emissions, noise) also have to be incorporated into further developments.

Black box and Electronic Vehicle Identification
In addition to the various interlock and ISA applications to prevent violations, it is also possible for ITS to facilitate the efficient detection of violations to achieve a 100% probability of being caught, and in this way to increase the deterrent effect of enforcement (see also *Chapter 8*). A black box in the vehicle can facilitate forms of automatic policing (100% surveillance of all violations). Such equipment registers driver behaviour, which can be checked for violations by the authorities. Occasional offenders can be tracked more easily and fined automatically by means of devices such as Electronic Vehicle Identification (EVI; EVI project consortium, 2004) and a black box. EVI also offers opportunities for registering vehicle movements for different ways of road use pricing. EVI may also help to reduce injury consequences because it can help emergency services reach a crash scene more quickly by accurately pinpointing the vehicle's location. In order for these systems to be effective, undesirable behaviour requires sanctions. At the same time, the system also offers opportunities to reward good behaviour (Van Schagen & Bijleveld, 2000; DGP, 2004), an effective behavioural measure that is currently used infrequently (Hagenzieker, 1999). Insurance companies are currently experimenting with offering an insurance premium reduction in exchange for the installation of a black box in the cars of novice drivers. Research into the effects of a black box has shown that these can also have a beneficial effect on road safety (Wouters & Bos, 2000).

Red-light running
There are developments aimed at presenting the status of traffic lights in the vehicle, aiming at decreased red-light running and use of appropriate approach speeds. In the United States, this application is considered to be a likely candidate for introduction in the short term (CAMP, 2005).

Support for route choice and homogenizing travel speeds

Systems that help to distribute traffic flows and that try to influence road user route choice are not a primarily aim, but can contribute to road safety.

The guiding principle for route choice in sustainably safe road traffic is that the functionality of a chosen road has to fit with the objective of the trip. This means that the longest part of the route should be negotiated on through roads, that departure and arrival should be along access roads, and that the connection between these categories along distributor roads should be as short as possible. Providing information about the safest routes and recommended route structure increases the opportunities to manage traffic according to this principle (Eenink & Van Minnen, 2001). Such information provision can be pre-trip (taking into account predicted conditions) and on-trip (real-time actual data, based on congestion and travel time information). For in-vehicle information provision, navigation systems based on a digital map and GNSS positioning are booming. To date, these systems are aimed primarily at recommending the shortest or fastest route. Since the uncertainty of, and searching by drivers is reduced, a positive effect on road safety can be expected (Oei, 2003). Moreover, navigation systems offer the possibility to use safe routes as a selection criterion. One further step is to deploy ITS to give access to specific road users to selected roads at selected times. This could help to separate incompatible traffic flows.

Apart from safe individual route choice, a correct distribution of flows across the available road network is also important. This encourages uniform/homogeneous travel speeds. This is important for flow management, the environment and road safety. On motorways, for instance, traffic flows can be distributed with Dynamic Route Information Panels (DRIP), Motorway Control and Signalling Systems (MCSS) combined with Variable Message Signs (VMS) for indicating speed limits and lane closures, and motorway access control or ramp metering. On the secondary road network, adaptive road traffic control systems are, for the time being, the most important method. Traffic flows can be optimized by tuning nearby traffic light installations (e.g. by Split Cycle Offset Optimization Technique, or SCOOT) or by dynamic advisory speeds ('green wave'). For urban areas, dynamic parking guidance systems are available.

In-vehicle ITS applications can also contribute to the homogenization of speeds, for instance by a blind spot warning system for lane changing. This is a system that detects vehicles in the 'blind spot' in the adjacent lane. An example is the Blind Spot Information System (BLIS) announced by Volvo that works via a camera in the wing mirror. Also, more active support for lane changing and merging is being researched. Vehicle-to-vehicle communication can warn drivers on a timely basis if major speed changes are required (Morsink et al., 2003). When drivers brake in good time, which is in itself good for road safety, this can prevent unstable traffic flows (yo-yo or harmonica effect). Braking in time produces safer, cleaner, more comfortable and better flowing traffic (www.cartalk2000.net).

Adaptive Cruise Control (ACC), a system that is becoming available in more and more cars, can also contribute to greater homogenization of speeds. The system is an extension of normal cruise control that aids (partly by intervention) speed and distance control. It is intended to be used on uncongested motorways. A study in the EU project ADVISORS (2003) shows that the system works less well in other situations, and that it may even have a negative effect on road safety, for example, by encouraging shorter following distance than normal. For a greater safety effect, the system would have to be extended with collision warning and avoidance functionality (Hoetink, 2003).

Nowadays, traffic information is mainly sourced from traffic management and information centres, and is based on inductive-loop data. However, in the future, vehicles will become part of the information chain. The term *floating car data* is used to indicate the two-way transmission of information between a vehicle (e.g. position, speed) and a traffic centre resulting in a higher quality of information (more up-to-date and more reliable). Road safety may also profit from this. A combination of several ITS applications that promote a correct network structure and speed regime, can eventually lead to optimal traffic distribution over the road network, where safe and fast routes combine (Hummel, 2001).

6.3. ITS implementation

As indicated in the previous sections, much is possible in the ITS area, and many of these applications are promising with regard to their contribution to road safety. However, this will only happen if ITS are implemented properly. For effective implementation, safeguards have to be established that harmonize ITS applications with other, more traditional measures. This requires coordination, but with many stakeholders from very different sectors being active in the field, coordination proves to be difficult to achieve. The following section outlines some factors that are important in implementation; it considers who the most active stakeholders are and how they can be coordinated.

6.3.1. The importance of an integral approach

ITS applications can only live up to the high expectations of them if, as well as being adapted to 'man is the measure', they are implemented harmoniously with other measures, such as those in the area of infrastructure, vehicles and education. For example, it is important that the information provided by ITS applications fits seamlessly with road design and traffic rules in force, and that coordination or integration takes place of vehicle and road information systems. Since most ITS applications are not developed from a road safety perspective, it is important to integrate 'safety' with other, sometimes more dominant objectives, such as accessibility, traffic flow and comfort. The final result then is an integral safety system in which 'safety' has been built in as a system characteristic in traffic.

Particularly when well coordinated with other measures, ITS can lead to shifts in emphasis in the application of measures. An example of this are ITS contributing to preventing crashes or violations by intervening prior to the traffic process or in an early phase of that process. Previously, this was the domain of infrastructure design and traditional police enforcement (see also Ammerlaan et al., 2003). The expectations are that such a shift of emphasis to vehicle-related ITS will be cost-effective because it can be deployed in a much more specific way than more traditional measures.

Nevertheless, it is not just good coordination with the more traditional measures that is required for the optimal functioning of ITS applications. ITS applications also have to be well tuned with each other, and they have to complement each other. The development of one application often also necessitates the development of another (see *Frame 6.2*), particularly if several objectives have to be combined and reconciled, such as traffic flow and safety.

Facility systems and services (such as digital maps, allocation of frequency bands for data communication, communication protocols, etc.) have to be uniform and geared to each other. This means that ITS applications built upon widely agreed standards will no longer be specific to a location or manufacturer. In Europe, for instance, the automobile industry works on a standard for vehicle-to-vehicle communication.

6.3.2. Stakeholder interaction

Many different parties are involved in the introduction of ITS: public authorities, road authorities, industry and the road user or consumer. Public authorities at European, national and local level are interested in ITS applications to achieve for instance better accessibility, and traffic and product safety. Road authorities are also interested in ITS in order to provide reliable, swift and safe traffic management on the existing infrastructure. The considerations of public and road authorities are primarily policy-orientated. At the other end of the spectrum, there are more market-orientated parties involved in the introduction of ITS. In the first place, industry is involved as producer of a) components, such as radar, b) end products, such as cars and traffic management systems, and c) services, such as traffic information. A second market-orientated stakeholder is the consumer who purchases products on an individual basis. In most cases, consumers will do this only if there are sufficient benefits available at the right price.

There are many opportunities for stakeholders (particularly public authorities and industry) to meet, inform and influence each other: conferences, ERTICO, etc. However, there is a lack of coordination. Coordination is required both at national level and the international level. Without coordination, developments take place at a slower pace than is possible, they are less efficient, and they may not lead to the desired result seen from a road safety perspective. For the effective implementation of ITS applications, the public and the private sector will have to join forces. However, the interplay of forces between these two parties in the implementation of ITS is much more complicated than, for instance, in the field of vehicle regulation, where a number of clear agreements have been made at European level and where the number of

An example of integration of measures

There is often great pressure on infrastructure capacity because of the general increase in mobility. The possibilities for improving traffic flows on existing motorways are, therefore, explored. A system has been conceived in which the number of available lanes on a road is not static by means of painted road markings, but dynamic, for instance by means of LEDs in the road surface. In this way, the number of lanes can be increased during congestion. Of course, this means narrower lanes, because the total road width remains unchanged.

Narrowing lanes, however, can cause problems for safe road use, particularly by heavy goods vehicles and buses. A solution to this problem is, for example, to equip the car fleet with a Lane Departure Warning Assistant (LDWA) to support driving within a lane. A test with this system nevertheless showed that drivers often switched it off because it gave too many warnings (Korse et al., 2003). Another possibility is a Lane Keeping System (LKS). Lane keeping support systems require that sensors can read lane markings easily.

Another method is to register the vehicle position relative to the road by means of GNSS, and to link this data to a digital map (both facilitating systems). This application requires that positioning is highly accurate and that the map exactly corresponds with the actual situation. Developments are underway in the areas of positioning and digital maps, but it is still unclear when these systems can comply with the requirements set. This means that, for the time being, speed adaptations are also necessary, which can be coupled with ISA.

The above illustrates how applications and facilitating systems are interwoven: one application requires another, and the development of facilitating systems can also be deployed for several ITS applications. In order to make this type of development a success, road authorities, the ITS industry, vehicle manufacturers and transport operators need to cooperate. So: integration!

Frame 6.2.

stakeholders is much smaller than in ITS (see *Chapter 5*). Nevertheless, there are some breakthroughs. There are, for instance, no irreconcilable differences between representatives from the car industry and public authorities concerning the development of Advanced Driver Assistance (ADA) systems (Bootsma et al., 2004), but it has become apparent that the role of different stakeholders in this interaction is still unclear.

Role of national public authorities

Most European public authorities, from EU to regional level, follow technological developments in the area of driving task support, and try to include these in their policy (Ostyn et al., 2004). The public authorities' role can be put into action in various ways (OECD, 2003; Ostyn et al., 2004). These are discussed below.

Coordinating, regulating and standardizing
ITS applications are expected to deliver much to improve road safety. The necessity to attune various ITS applications to each other, to other measures and to other objectives, calls for coordination which can be best carried out by public authorities. Firstly, this is because they have (at least in the Netherlands, but also in most other countries) the responsibility for the quality of the overall traffic and transport system, and therefore benefit from a well-coordinated implementation of ITS. Secondly, public authorities are in the best position to coordinate because this requires an overview of what is available in the market, and how various applications can interact.

Regulation and standardization of various applications is highly important to the effective implementation of ITS. These are activities that often take place at a global level, and always in concert with all parties involved (including the private sector). Regulation can prohibit products that endanger road safety or that are insufficiently tested from being installed in vehicles. In addition, a legal framework has to be established for product liability issues if a crash occurs when road safety enhancing systems are applied.

Standardization is particularly important for the interconnection between various ITS applications, and for the functioning of various ITS applications based on a uniform array of facilitation systems (radar, sensors, positioning systems, etc.). Standardization is, for instance, possible by prescribing standardized procedures and tests and attaching certification to this.

Facilitating and investing
In order to get the best from the implementation of ITS applications in traffic and transport, further research and knowledge is required. Where research and development from the market is inadequate, public authorities can play an important role, for example, by starting up relevant research activities themselves and by taking part in demonstration projects. They can also contribute by sharing available knowledge, and by coordinating implementation requirements for ITS applications at European level. In order to know how the various ITS applications will eventually affect road safety (and also other objectives), it is necessary to develop good instruments that enable scientific and independent assessment. Finally, public authorities can offer fiscal and financial incentives to consumers to promote the implementation of ITS with a high safety potential.

Providing information
Authorities responsible for road safety are also the appropriate party to inform citizens about the importance of road safety and the role that citizens themselves can play, for instance by purchasing certain systems. Authorities can also promote systems that are preferable when seen from the perspective of road safety. Authorities can also play a role with respect to the use of systems by providing information.

6.3.3. A strategy proposal

Developments in the ITS field and uncertainties concerning implementation in a complex environment, demand a strategic implementation approach. Such an approach facilitates the formulation of expectations of ITS for the short and long term. An ITS implementation strategy may also guide coordination with developments in other fields, and the setting up of road safety plans.

A first requirement for such a strategy is the establishment of a generally accepted framework for ITS policy at national and local level, with the participation of all parties involved, and aimed at mutual cooperation. To achieve this (at least in the Netherlands), a road safety agreement for ITS implementation might be the appropriate form (Wegman, 2004). Such an agreement should reduce uncertainties for public authorities, road operators, manufacturing industry, and service providers about the pace and direction of developments, and by setting a course for the future of safety-orientated ITS. A separate safety ITS policy should not be developed, but rather be linked up with other objectives and developments.

To outline the path for ITS developments and implementation, we distinguish four successive stages based on frequently used product development curves in the ICT world. These range from relatively simple intelligent transport systems, in line with current market developments, to more complex ITS currently in their infancy.

1. *Initiation: exploration of application possibilities.*
2. *Popularization: individual applications.*
   Separate applications that have part-proven themselves, are increasingly used.
3. *Control: combined applications.*
   Separate applications that by linking achieve a larger effect.
4. *Integration and coordination: coherence by coordination.*
   This is the ultimate goal in terms of:
   – an integral safety system in which ITS have obtained a clear position in relation to other safety interventions;
   – a harmonious safety system in which ITS have obtained a clear position in the overall traffic and transport system (integration of objectives and parties);
   – optimum mutual interconnection of various ITS applications;
   – insight into the effects and coherence of various ITS applications;
   – wide support for investments in ITS developments because the benefits outweigh the costs and are clear to all parties.

These stages can be illustrated with two scenarios. In the first scenario (*Frame 6.3*), there is an interest by consumers in a given ITS application. Implementation takes mainly place through market mechanisms. The initiative lies in the market. If the market fails, public authorities can supply momentum, for instance by subsidies, facilitating research, or acting as a partner in demonstration projects (see also *6.3.2*).

The second case (*Frame 6.4*) concerns ITS applications that are expected to deliver large scale safety benefits, but that are not expected to be popular with road users (consumers). This unpopularity will lead to the development of such an application not being taken up by the market. Support needs to be established here. When sufficient support has been gained, implementation can be started, if necessary by compulsory measures or other pressure from the government.

Example of mainly market-driven implementation of Intelligent Speed Assistance

Initiation (2005-2015)
The vehicle fleet is increasingly fitted with Cruise Control, Adaptive Cruise Control and navigation systems. Added to this, voluntary, non-intervening ISA is introduced: static speed warning by road type. Information is provided based on a digital map and GNSS positioning, covering the whole road network. Awareness and support are increased by equipping professional vehicles and by supplying target groups such as young and novice drivers with ISA.

Popularization (2008-2018)
Static speed warning at locations with increased risk (e.g. near schools), as well as systems that warn for appropriate speeds in curves, 'predictive cruise control' and warning for traffic jams and bottlenecks. The driver experiences speed information as normal. Also, systems are available that warn for vulnerable road users and obstacles. Information is gathered based on a digital map and GNSS positioning, autonomous car sensors and vehicle-to-infrastructure communication.

Control (2012-2022)
Dynamic speed warnings depending on local conditions. Forms of limited intervention by the system in case of speed offences in selected circumstances, based on positive experiences and observed effects from trials. Information is gathered by methods mentioned before and by vehicle-to-vehicle communication.

Integration and coordination (2015-2025)
Integral speed control system: safety has been incorporated in harmony with other objectives in the traffic system. Bi-directional information exchange exists between vehicles (drivers) and the infrastructure. The driver receives support when needed. Traffic is optimally organized at individual locations and at network level.

Frame 6.3.

For both implementation types (user demand versus public authority driven), implementation is reinforced by integration with other developments and objectives.

Example of mainly governmentally driven implementation of ITS applications for road traffic access control (smart cards)

Initiation (2006-2011)
Alcolocks are required for repeat offenders (as part of a rehabilitation programme). Temporary speed limiters are introduced for multiple speed offenders. The first signal from authorities/politics may come from alleviating police enforcement, and from public support in dealing with serious offenders.

Popularization (2009-2014)
In addition to the systems mentioned above, a smart card is introduced that registers the validity of the driver's licence for the vehicle concerned. Introduced possibly for young and novice drivers initially.

Control (2012-2017)
The smart card is an electronic driving licence with personal data, and is also used for individual preference settings in the vehicle.

Integration and coordination (2015-2025)
The smart card gives access to the vehicle, programmes the car to individual characteristics, and links personal data with the system that jointly coordinates the driving task. The system supports the individual driver by giving task priorities in dangerous situations.

Frame 6.4.

6.4. Epilogue

This chapter gives an outline of what ITS can contribute to improving road safety. Many of these contributions fit perfectly within the Sustainable Safety vision. This is the case when ITS intervene or warn before a dangerous situation occurs or might occur. This makes road user behaviour less dependent on the individual choices of road users. A good example of this is the package of measures made possible by using smart cards. We may have to call these 'road safety cards', because they help to give traffic access only to road users who have sufficient qualifications, authorization and task capabilities. However, other systems that help road users in recognizing road course, in perceiving other road users or dangerous collision objects, and in controlling the vehicle and driving speeds, are examples of ITS applications that fit within Sustainable Safety. In the case of electronic enforcement (possible with smart cards, black boxes and EVI), a large increase in efficiency can be gained relative to current practice. In the case of driving task support, such as driving at appropriate speeds, following the road, or avoiding collisions, benefits can be reached by combining with existing measures. We also recommend that road safety should link up with other developments and objectives (such as in the fields of traffic flow and environment), and to extend systems that do not have road safety as their primary objective by introducing safety enhancing characteristics. Developments in the functionality of navigation systems are of particular interest because of the widespread and rapidly growing usage of this equipment.

Nevertheless, there are reasons for expressing some reservations concerning the positive expectations of ITS. ITS do not always function as expected because people adapt their behaviour in such a way (e.g. risk compensation) that the potential safety effects of ITS applications are diminished. There is also uncertainty about the public support for various ITS applications, about consumers' willingness to pay, about the position of industry, and about the role of the authorities, in short: about whether or not the potential can achieve full growth. However, a net safety loss cannot reasonably be expected, and would not, of course, be acceptable. We can expect that informing and warning ITS options will be more effective than intervening variants in the not too long term (and that they will result in casualty reduction in practice). This is because the first two systems mentioned have more public support and can thus be implemented more quickly. To increase the prevention of human error, more and more will have to be automated in the longer term in order to attain truly sustainably safe road traffic.

To achieve sustainably safe road traffic, it is very important that ITS developments that have been initiated can be continued, and come to fruition as actual applications. The usage level of ITS has to be high before substantial safety effects can be expected. Technological problems will probably be less significant than organizational and institutional problems. For example, a sufficient level of standardization has to be put in place to guarantee functional uniformity. This is highly important for responsible use and for a proper embedding of various ITS forms in the vehicle and infrastructure.

Large-scale ITS implementation is no simple matter because of the coordination of different interests, the lack of clear policy objectives and ready-to-roll market models. Roles and interests have to be mutually tuned, and have to be presented as one single clear vision across departmental and institutional boundaries. Public authorities (both European and national) should fulfil a coordinating function. The ultimate goal is an integrated safety system where ITS has a clear position in relation to other safety interventions, and in which safety effects of ITS applications concur with other objectives, such as traffic flow, use of the existing road network, travel time, comfort and environment. As long as it is not clear which systems can serve all these objectives, a step-by-step, long-term approach that starts off relatively simply is required. A requirement for further development is that all parties involved (government, road authorities, industry, knowledge institutes, interest groups, consumer representatives, etc.) jointly undertake responsibility for establishing and maintaining ITS on the right path. For the Netherlands, we recommend that a road safety agreement is established on Sustainable Safety and ITS.

7. Education

7.1. Man – the learner – and education

Learning in traffic and learning about traffic are essential to participation in the traffic system. Every novice, in whatever traffic role, is faced with learning complex tasks, where errors are relentlessly penalized. Even the skilled road user continually learns new behaviour in a traffic system that is dynamic and continuously developing. Traffic volume is growing steadily, the infrastructure changes, and telematics (or ITS) are being used increasingly on the road and in the vehicle. To behave safely, it is implicit that road users recognize and respect their limitations (OECD, 2006). The latter is true for all road users: for novices, the experienced, and the elderly. Since road users learn almost continuously from their own experiences and from examples provided by others (independent, *'informal'* learning), there is an implication that a relatively small part of this learning is the result of formal, vocational activities. Take, as an example, a novice driver whose whole learning path to a reasonable safety level covers hundreds, if not thousands, of hours. In the Netherlands, this learning path includes on average only 50 hours of formal driver training.

This means that *formal traffic education* can only be one of the many influences in the learning process. Hence, the central question in this chapter is: 'How can formal traffic education make an effective contribution to this continual learning process, assuming that formal education implies a time-intensive learning process?' This perspective differs from the implicit vision of education presented in the original version of Sustainable Safety, where formal education guides the whole learning process on all possible aspects of traffic education. The observation in the advanced vision is that formal education can never fulfil this role, given the fact that only a limited time span is available for vocational activities in driver training and education, and given the weak base of traffic education in schools. Therefore, a strategic vision on formal traffic education is needed, with a realistic starting place. Furthermore, a targeted vision needs to be developed with regard to the interface between informal education, or independent learning, and formal education.

We want to position formal and informal traffic education in the most effective way. This requires clear aims and objectives (attitude, actual behaviour, acceptance of measures, etc.). There is much to be said for combining education and other interventions (enforcement, regulation, infrastructure, and so on) into this process (Peden et al., 2004). The contrast that is sometimes suggested between infrastructure and education is trivial in the Sustainable Safety vision, which requires them to be complementary not mutually exclusive.

It remains for us to describe in this chapter what we mean by formal traffic education. We include education (activities within schools), instruction (training outside schools aimed at specific traffic roles), and campaigns (messages that are often widely distributed but not through personal contact). Thus, traffic education addresses knowledge, understanding, attitudes and skills of the citizen and the road user, aimed at improving road safety. The first analysis in this chapter addresses the human role in the sustainably safe traffic system (*7.2*). This analysis leads to the identification of road user behaviour that is important in Sustainable Safety, and where education can play an important role. In the second analysis, the playing field of education is central (see *7.3*). We will look at the influence of the social and political context regarding traffic education from the perspective that this context determines the practicability of traffic education in terms of support, priority and approach. These building blocks subsequently lead, in *7.4,* to choices in the ways in which traffic education can be most effective. In order to reinforce coherence with other measures, this chapter will conclude with an overview of the relationships between education and other measures (*7.5*).

7.2. Behavioural themes for Sustainable Safety

In Sustainable Safety, five behavioural themes can be distinguished. Each of these five themes represents a great potential danger for personal safety and that of other people. They are also all relevant for comparatively large groups of road users, they can all be tackled appropriately by education, and remedial action is feasible. The five themes are:

1. insufficient awareness of road safety problems and limited acceptance of Sustainable Safety measures;
2. no or insufficient use of strategic safety considerations in traffic choices (choice of vehicle, route);
3. intentional violations;
4. undesirable or incorrect habits;
5. poorly prepared novices.

These five themes cover a wide area, and they considerably enlarge the field of traditional education. The themes fit perfectly into Sustainable Safety. Therefore, education remains an inherent element of the Sustainable Safety vision. The themes and the role of education in them are discussed below in more detail.

7.2.1. Insufficient awareness of problems and limited acceptance of Sustainable Safety measures

Through the years, several surveys have shown that citizens attach great importance to road safety. However, when road safety measures are considered for implementation, public acceptance and support often diminishes, and is sometimes even too low to allow implementation. The reasons for this are hardly ever studied, but one possible explanation is that social dilemmas arise in the implementation of a measure. It is not always easy for people to accept a collective benefit (increased safety) when there are disadvantages at an individual level (e.g. having to make a detour). Another explanation is that people may not be convinced of the relationship between a proposed measure and the positive effect on safety. This public rejection of safety measures is a problem that cannot be neglected, and contradicting social interests are difficult to reconcile. Although strong evidence is not available yet, it is frequently stated that a lack of public support results in a low compliance with the (controversial) rules (Yagil, 2005). Evidence shows that it is only after implementation, when road users have had positive experiences of a measure, that acceptance subsequently increases. However, in many cases, the positive effects of many road safety measures are not directly noticeable for individual road users. For example, think of the effect of lower speeds on the environment and safety. Although, at a collective level, a speed of 100 km/h on a motorway results in fewer crashes, most likely the individual driver will not feel safer than at a speed of 120 km/h. This demonstrates that education is a prerequisite for compliance and public support, in particular with respect to those measures in which the effects and relationships between measures and effects cannot be perceived directly by road users themselves. Education is, above all, the instrument that can make the relationships visible, and that can communicate the general social interest. To date, education concerning Sustainable Safety has not been very convincing, nor has this been the case with regard to the vision in general (Wegman, 2001). This is illustrated by the fact that, even though the speed regime system is one of the cornerstones of Sustainable Safety (see *Chapter 1*), and the speed limit system has been enlarged to 30 and 60 km/h zones, communication about these fundamental elements to citizens has not been very visible.

7.2.2. Use of strategic safety considerations

Preventing problems is better than having to solve them. From a safety perspective, Sustainable Safety, therefore, attached great importance to the proactive attitude of road users. Some routes, times, and manoeuvres of transport are safer than others. The desirability of a proactive attitude is dealt with explicitly in the Sustainable Safety philosophy in which two rules for safe use of the sustainably safe traffic system were established (Koornstra et al., 1992). These rules are still unabridged and in force, and a third rule has been added (see *Frame 7.1*). This third rule refers to the importance of 'self-knowledge' in assessing and preventing the hazards mentioned.

Rules for a safe use of a sustainably safe traffic system

1. Do not use the system unnecessarily (i.e. travel as few kilometres as possible).
2. Do not use the system unnecessarily dangerously (use the safest transport means on the safest roads).
3. Know your own limitations (task capability) and do not exceed these.

Frame 7.1.

The three rules ask for active decisions by the road user at strategic level, such as vehicle choice, purchase considerations, route choice and self-assessment of 'fitness' to drive or ride. However, application of the above rules requires road users to have knowledge in the first place. It requires an overview of road traffic as a system and an understanding of the relationships of the elements in this system (including of themselves as road users).

Education can, above all other means, provide knowledge that enables road users to understand the system and its functioning in general terms. Through education, road users can also gather an understanding of their own strengths and weaknesses and the consequences of them when participating in traffic.

7.2.3. Deliberate violations

In addition to knowledge, willingness to take account of the constraints of the traffic system ultimately determines behaviour. This willingness is only partly determined by safety considerations, as other attainable objectives, such as wanting to be in time for an appointment, can lead to speed limits being exceeded. In order to understand the background of violations and to be able to position the role of education, it is important to distinguish whether or not a violation is or is not collectively accepted. There are violations to which we turn a blind eye, and violations that we do not accept, such as tailgating, overtaking dangerously, excessive speeding, or drink driving. Both types of violations, and their consequences for education, are discussed below.

Frequent violations that are often considered acceptable

Adults have an internalized system of norms and values, founded in their youth. This system determines mostly what we do and value, irrespective of possible punishments or rewards. In general, we stick to our internal rules, and non-compliance results in feelings of remorse and shame. This normative perspective does not seem to apply to traffic laws, as can be concluded from the huge amount of violations, such as speeding and running of red lights. This image is reinforced by the observation that these violations, rarely evoke feelings of remorse. This type of rule or norm is 'without value' in the perception of the road user.

The explanation for this phenomenon has rarely been a subject for research. Nevertheless, there is no direct relationship in the perception of road users between legal rule, safety and preferred behaviour (Yagil, 2005). The results of research on car drivers into the relationship between preferred speed and safe driving speed are an illustration of this. The results reveal that the speed preferred by road users is systematically higher than the subjectively estimated safe speed, and that this, in turn, is often higher than the legal speed limit (Goldenbeld et al., 2006).

Collective violations and the perception of 'absence of value of rules' are undesirable from a road safety point of view for two reasons. Firstly, the behaviour exhibited can lead to dangerous situations, and secondly, dangerous behaviour will become more of a habit. After all, traffic is forgiving (see *Chapter 1*), and a violation seldom leads to a serious crash. The result of a violation is, therefore, mostly positive for the perpetrator: gets home sooner, in more comfort, no unnecessary waiting, etc. People 'learn' from this, and they will continue breaking the rule, or even offend more often. This type of 'learning' particularly leads to problems when novices are more or less encouraged to violate the rules, as is the case when learner drivers are advised to exceed the speed limit during driving lessons in order to 'go with the flow'. This means that novices learn from the start that some rules can be safely violated, and consequently have 'no value'.

Despite this, the number of frequent 'minor' offences can be reduced by police enforcement. To fight these offences, we partly need to step out of the narrow range of influences by punishment and reward. In effective enforcement, the key issues are to give road users an understanding of the background, to learn to recognize the general societal interest, and to understand their own motives. In addition, interaction between road users is not only based on rules, but also on taking responsibilities and on cooperative behaviour. This cannot always be combined with a rigid application of traffic rules. Recognizing this interaction, understanding the importance of rules, and understanding the relationship with safety provide the basis for compliance with the rule and its correct application. Knowledge may not necessarily translate into behavioural change, but it is, according to ethicist Dupuis (2005), a prerequisite for moral action: "*Morally responsible action, by definition, implies that one has understanding of the context of such action, and this is unconditionally valid in traffic, and above all for car drivers. All this is also true for cyclists and pedestrians, but in a different way. The difference is that these road users, when erring, primarily harm themselves and run a much lower risk of harming others. In this sense, their moral responsibility is definitely lower. But also for this group, a correct understanding of the situations in which they find themselves, can prevent much misery; primarily for themselves.*" Education, in various forms, is the most appropriate instrument to distribute this knowledge.

Socially unacceptable violations

There are also types of behaviour in traffic that impede, irritate and frighten us, and that we do not accept, such as tailgating, overtaking dangerously, driving or riding at excessive speeds, drink driving, etc. This type of behaviour cannot be classified as considering traffic rules to be 'without value'. For many people, 'aggressive' traffic behaviour is nowadays a source of annoyance. This behaviour causes irritation and people hold the opinion that it endangers safety. Drink driving, for instance, is a particularly interesting exception to the 'absence of value' view of traffic rules. Where alcohol and traffic are concerned, there are many references to the social norm: 'alcohol use and participation in traffic is unacceptable'. Corrections often come from the social environment, and justification of behaviour are often related to the norm rather than to the risk of being caught. This has not always been the case. In the 1960s, driving under the influence of alcohol was quite normal, and there was hardly any social disapproval. As yet, there is limited understanding of those developments that result in certain behaviour becoming unacceptable, and of how this stage is reached. However, when this stage is reached, education does not have anything to do but support the social norm, because it is no longer necessary to convince the road user of the relationship between behaviour and safety.

7.2.4. The pitfalls of routine behaviour

Automatic behavioural routines are essential for the correct execution of complex tasks. This is also the case for complex tasks involved in taking part in traffic. Without automatic behavioural routines, we would not even be able to drive from Amsterdam to Brussels: we would react too slowly, make too many errors and be extremely exhausted because of the continuously high workload. The reason for this is that human capacities are, in fact, too limited for traffic tasks other than pedestrian tasks (*Chapter 1*).
Since frequent actions are executed more or less automatically in time, the traffic task can be carried out safely. People have to pay hardly any attention to (parts of) automatically executed tasks, and these are executed more or less repetitively in a standard manner. Automatic behaviour is, therefore, useful and necessary, because it enables people to develop and to perform tasks that would otherwise be too complex. The ease with which the traffic task is performed is the result of a long learning process. This learning process is therefore a prerequisite for the performance of complex tasks, regardless of human limitations.

However, there is also a downside to automatic and routine behaviour. Routine behaviour is less flexible than conscious task execution. The expectations that road users build up are dominant, and therefore, routine behaviour is less appropriate in new traffic situations. Moreover, in automatic behaviour, errors can slowly creep in. Behaviour that is chosen or developed by experience often remains the same for too long, and resists adaptation. This is because, by nature, the traffic system is not the ideal context for learning and maintaining complex skills. It is 'forgiving': errors are often overlooked, and the quantity of feedback on performance is low. Thus, potentially dangerous errors can develop and stay unnoticed for a long time. Another problem is that a good routine can sometimes be applied in a situation where it is not appropriate. For example, a car driver could be crossing what is assumed to be a one-way cycle path and so starts up the corresponding correct routine, but does not notice that the cycle path is, in fact, two-way. In addition to loss of flexibility and unintentional errors, a third characteristic of automatic behaviour is 'lack of attention', causing untimely switching from automatic to intentional behaviour.

Learning and maintaining correct behaviour plays an important role in road safety and the faultless execution of a traffic task. This places high demands on the quality of the learning process. Education has much to offer to deliver and maintain the correct skills and behaviour by:

- Ensuring the correct development of automatic actions and habitual behaviour, with the caveat that established automatic behaviour is difficult to change and requires a long learning process.
- Periodic testing of developing habitual behaviour. Think, for instance, of giving additional feedback after the driving test through revisiting days; or the possibilities of in-vehicle ITS applications aimed at personal monitoring and feedback.
- Learning to recognize safety effects of choices at a more strategic level. Some routes, times, and manoeuvres of transport are safer than others. It is desirable to make more conscious choices concerning for instance route, speed, position and role in traffic (see also *7.2.2*).

7.2.5. Behavioural issues for novice road users

A novice is faced with both a new role in traffic and a new traffic environment. Several pitfalls, some general and some specific, can be identified.

From the foregoing, it can be seen that a novice road user has a long learning process ahead before reaching a reasonable level of automatic behaviour. Car drivers are estimated to need at least 5000 kilometres (or over 3000 miles) of driving experience before the risks associated with novices fall substantially (OECD, 2006). For mopeds and bicycles, the need for a long period of practice was established as long ago as the 1980s. When Sustainable Safety was introduced, there were optimistic expectations about its influence on risks for novices. It was hypothesized that a simplified traffic task in a uniform and easily recognizable traffic environment could significantly reduce risks for young people and the elderly. It was expected that halving the number of 'non-uniform and difficult to recognize or unpredictable environments' was certainly possible and that this could halve the increased risk of young people and the elderly. However, it transpires that the number of serious traffic crashes has decreased across the board for all age categories, and not just for novice road users, i.e. people younger than 24 years of age. Whether or not this refutes the original reasoning of the Sustainable Safety vision (that young people in particular would benefit from a sustainably safe environment) obviously depends on more factors. We recommend continuing to investigate if and how novices can realize safety benefits in sustainably safe traffic conditions. Nevertheless, it is clear that traffic has become significantly safer for children up to 10 years of age, and it seems reasonable to assume that there is a relationship between this and the less complex traffic environment they now experience.

The risks for novice car drivers and moped riders have definitely not decreased further over the past decade when compared with the risks for other groups of road users. The reason for this is still subject of further research. However, one thing is certain. For this group it is not only the *complexity* of the driving task itself that is the important issue, but also the extent to which novices make the task difficult for themselves. This is certainly the case for cyclists and moped riders but also for a large proportion of novice car drivers. By keeping headway distances that are too short, driving too fast, driving under adverse visibility conditions and driving while excessively fatigued, etc., the novice driver makes the task (too) difficult for himself/herself, and consequently increases exposure to risk. A safe beginner is able to find a good balance between traffic task complexity and their own competence. This process is also called calibration (see *Chapter 1*). Education has to focus on encouraging novices to develop self-understanding and, where this is too difficult for young children, on instructing parents how to assess the child's capacities and to moderate the complexity of the traffic task for this child. Moreover, education also needs to be used to decrease exposure to risk. Young pedestrians should not just be taught how to cross a street, but also when and where *not* to cross. Young drivers should identify the conditions that are most dangerous (or too dangerous) for them, so that they can make well-informed decisions.

7.3. A closer look at the social and political context of traffic education

There are a number of important behavioural themes that are appropriately addressed by education, and this arena is larger than in the past. This section is concerned with defining the boundaries in which education can and should operate. Four subjects will be discussed:

1. support for in-school traffic education;
2. individual responsibilities and those of the authorities;
3. vision of man's role in Sustainable Safety;
4. lack of knowledge of the effects of traffic education.

7.3.1. More support for traffic education in schools

Although, from a social perspective road safety is seen as a societal problem, as yet, doubts are expressed about the political will to implement safety measures. The same can be said for traffic education. Past experience shows that traffic education has its own difficulties, both in primary and secondary education. Road safety is only one of many themes that education is asked to address. In the late 1980s and early 1990s politicians earmarked the environment and environmental education as very important societal themes. Now, at the start of the 21st century, other themes are considered to be very important, for example, integration of ethnic minorities, social security and crime. But not only that! It is also expected that, in addition to these themes, young people are taught about 'social norms and values', sexual development and health, as well as road safety. Schools are expected to devote attention to a great many societal problems and road safety has to compete with a number of other societal themes within the school for time and attention.

Societal discomfort only arises when people are struck by the severe consequences of a traffic crash in their own circle, for instance, in family or school. Suddenly, education is found to be essential, and the school is regarded as having an important role to play. Opportunities for public authorities to control the contents of in-school activities, such as traffic education, are ever-decreasing. Greater freedom continues to be given to secondary schools to include or remove traffic education from the curriculum. The fact that public authorities have only few instruments for implementation and stimulation of traffic education seems only of concern to road safety organizations. Apart from these organizations, there has been hardly any opposition and none in the political sphere.

The heavy emphasis on other societal themes and the high number of them coupled with the comparatively low priority of road safety means that traffic education does not have 'a place of its own', and will have difficulty in winning one. It seems that the only possibility is to take advantage of momentary needs in schools, what is called 'windows of opportunity'. Moreover, we have to be concerned that specific road safety expertise within the general structure of the curriculum will diminish. It is therefore important to safeguard and maintain access to traffic education expertise, as well as to material that addresses tangible questions, and to develop teaching formats that are attractive to teachers and pupils. A centre of expertise for traffic education could be a promising way of approaching this (see also *Chapter 15*).

7.3.2. Not just individual responsibility

A central point of discussion in society and politics is the division of responsibilities between the citizen and public authorities. On the one hand, public authorities have to preserve the safety of their citizens as part of their protective task. On the other hand, citizens should take care of their own safety without deferring to public authorities. The emphasis depends on the social and political vision prevalent at a given time. For education, this means that, when the vision in favour of individual responsibility dominates, public authorities play a less active role in the field of traffic education. It is then left more to individuals to inform and train themselves adequately. It is also the case that the societal role of public authorities is not always self-evident when seen from the perspective of individual citizens. For instance, additional requirements for obtaining or keeping a driving licence invariably meet with opposition from citizens, who argue that it is the driver's responsibility to behave safely, and that governmental interference is an unjust limitation of individual freedom and the right to mobility. In the end, this is not a widely held opinion, as shown by the many public interventions to promote road safety that quite often lead to a limitation of individual liberties. When referring to the safety of the individual road user, Dupuis (2005) states that "*in the end, his attitude and (lack of) sense of responsibility is the decisive factor in whether or not a crash occurs*", then this puts individual responsibility at the centre without also designating societal and public authorities' responsibility.

The political decision making process always weighs how the public authorities' protective role in public safety relates to the individual freedom of the citizen.

7.3.3. Different views on human roles in Sustainable Safety

Views on the role of man in road safety influence the positioning and content of traffic education. Initially, Sustainable Safety described man mainly as 'the task performer, the doer'. At that time, it was stated that "*as man is not infallible, the question arises if efforts to further improve the behaviour of the average road user can make any substantial contribution to road safety. Such efforts are only useful insofar as they are aimed at specific road users that are not yet, or are no longer sufficiently competent (e.g. groups of novice road users). Other groups are better banned from traffic (e.g. drink drivers).*" The present chapter describes a new and broad vision of traffic education (see the five behavioural themes of *7.2*), that fits perfectly within Sustainable Safety. This is expected to give a new stimulus to traffic education in the Netherlands.

Nowadays, we also see the picture emerging of a road user who may have difficulty in accepting Sustainable Safety measures. Some people consider speed humps or roundabouts as obstacles, and some speed limits are violated to a great extent. Citizens have to be convinced of the necessity for Sustainable Safety measures, and their thoughtful participation in public hearings which decide on infrastructural measures is also an educational aim.

7.3.4. Lack of understanding of the effects of traffic education

In the discussion around the importance of traffic education the nature of expected results and costs play a crucial role in decisions about measures. A worldwide overview of best practices (ROSE 25, 2005) and a literature study of the effects of traffic education (Dragutinovic, to be published) confirm the prevailing view that traffic education programmes are seldom (well) evaluated. This leads to questions such as 'How effective is education?', and 'Which requirements should effective programmes meet?' not being answered. Another issue deals with the question whether traffic education needs to change crash figures, or that a change in behaviour, or intermediate variables, like improved knowledge attitudes or behaviour intentions, is sufficient. Arguments in favour of the crash criterion are: 1) measures can only be compared on a *one-to-one* basis when the effects at crash level are known, and 2) in the end, the crash criterion is used to measure the effect of measures. However, because of the way in which education influences behaviour and subsequent crashes, it is seldom possible to carry out such an evaluation due to the scarcity of crashes and the role of chance in crashes. *Moreover, education has to be seen as an integrated part of a package of measures, and not as a separate part.* It is certainly possible to determine the theoretical added value of education in such a package, but it requires a large-scale and consequently expensive evaluation study. A study into the effects of safety-related road user behaviour and the backgrounds of this behaviour is expected to produce a greater understanding of the issue (see also OECD, 2006).

It is, by the way, remarkable that, despite the lack of knowledge about effectiveness, the importance of traffic education is not disputed. This is reflected in the fact that all countries have some form of traffic education.

7.4. Traffic education as a matter of organization

Section *7.2* provided a focus for traffic education in terms of content. An analysis of content has led to the identification of five behavioural themes where education can contribute and where safety benefits can be realized. Methods of deployment of education were also indicated. Conclusions are as follows:
– Most behaviour is acquired and adapted outside formal education.
– Formal education mainly plays a role in:
  - training correct behavioural routines;
  - understanding connections (that are not understood based on experience);
  - supporting norms;
  - stimulating self-knowledge;
  - developing higher-order skills such as hazard perception;
  - avoiding exposure to risk.

The traditional forms of formal education take place in schools and in driver training. In this chapter, we make the case to change the direction of this formal education in terms of its content. Moreover, we propose to complement and to coordinate formal education with informal education. We will elaborate further on this topic in the following section.

7.4.1. More strategic elements in formal education (schools and driver training)

Until now, traffic education and driver training have been built mainly on a collection of learning objectives and a systematic treatment of subjects and skills. We now have a different view. We now recognize that previous experiences of pupils and candidates should be leading for subsequent training and teaching programmes. Moreover, education should not only target skills, but should also confront road users with the boundaries of what is and what is not acceptable. Thus, education has to be aimed at the interpretation of rules rather than simply teaching the rules just as simple facts.

In this respect, schools and driver instruction should aim more at transferring knowledge at strategic level and developing higher-order skills. Topics that need to be addressed in this respect are:
– Design and functioning of the traffic system.
– Change of perspective and seeing the context. The perspective changes between one's own safety and the safety of others, and between safety and other areas (environment, noise, etc.).
– Sustainable Safety principles. Encourage people to take safety into account when making decisions about transport mode, vehicle, routes, etc.
– Hazard perception and risk acceptance, and recognizing and respecting one's own and other people's limitations.

Application of this more strategic knowledge plays a role in actual road use and, therefore, may be an important part of the optimal functioning of sustainably safe road traffic. The subjects mentioned are currently not raised in education and training sufficiently, and require specific expertise of teachers and instructors. To remedy this, additional investment in promoting expertise and method development is required.

7.4.2. Parents and carers also have an important role

We have concluded that the social environment is very important in traffic education and in generating socially preferred behaviour. Parents have to be stimulated to take more (or perhaps 'reclaim') responsibility in promoting safe road user behaviour. We mean here that they are responsible for supporting the child and young person in adopting preferred behaviour which becomes automatic when reinforced from a young age. The positive Swedish practice of assisting novice drivers by allowing them to practice under the supervision of experienced drivers during driver training is an example of the potential safety impact of such a division of roles. A crash reduction of 30% (OECD, 2006) resulted from these additional kilometres of experience, and was achieved without high additional costs. Alongside this, parents are recognized to be the appropriate people for communicating and supporting norms and values in traffic, particularly by setting a good example.

Supervised driving as a part of the training programme is not allowed in the Netherlands. In general, parents and carers presently play a minor role in the learning process of their children. To date, insight into the possibilities, needs and knowledge of parents on this point has been lacking. Therefore, investment is needed in terms of both content and funding, particularly in the following areas:

- research into the needs, knowledge and insight of parents and carers to (be able to) play a role in assisted driving;
- information for parents about the essential role they play in traffic education;
- catering for the knowledge needs of parents in an attractive way.

7.4.3. Any other interested parties?

There are many more parties with an interest as well as those traditional stakeholders mentioned above. We can think of employers, insurers, health carers, sporting clubs, etc. They all have an interest in ensuring that their personnel, clients and members do not get involved in traffic crashes. Of course, there is a financial implication. However, a serious crash in the immediate social environment is detrimental both to working atmosphere and general well-being. All these organizations are capable of contributing to a better road safety culture whilst acting in their own best interests.

7.5. Relationship of education with other measures

Finally, we ask the questions: 'Is education a panacea?', 'Can all behaviour be changed or taught by educational efforts?' 'Where are the limitations, and how does education relate to other measures?'

7.5.1. Human error and the traffic system

Education is sometimes regarded as the means to solve virtually all road safety problems. This view is primarily based on the fact that the vast majority of crashes can be traced back to human error. However, education is only the adequate measure if these errors are attributable to a lack of knowledge, insight, motivation and/or skill. Errors can also be evoked by the complexity of the traffic task, or the lack of logic and consistency in a given traffic situation. The Sustainable Safety vision should act as a guide here. First and foremost is the search for opportunities to adapt tasks to human capacities, and then teach road users how they should deal with them (see also *Chapter 1*).

7.5.2. Some people make more errors than others

Some people make more errors than others, in spite of training. This may be an indication that these people are not ready; that they are not (yet) or are no longer able to perform a task properly. For example: a four-year old child is not yet ready to take part in traffic independently, it needs to be protected. Training in street-crossing skills, for instance, is not effective at this age, and should be discounted. In this case, education should not aim to instruct the child, but to inform the carer. The same goes for the novice driver. In order to control the often serious results of inevitable errors, the novice should gain experience in a controlled environment, for example by avoiding the most dangerous conditions (such as night-time, with alcohol, passengers, etc.). It is indisputable that this approach is effective (Vlakveld, 2005). A graduated driving licence, that gives the novice access to traffic in stages, remains an effective instrument that deserves a serious consideration in the Netherlands.

7.5.3. The violation of traffic rules

Earlier in this chapter, the point emerged that education can, to some extent, play a role in deliberate violations of traffic rules. Violators or their social circle of friends and family can be persuaded that violations are inappropriate. This is particularly true for specific knowledge (e.g. the importance of headrests) or behaviour that can easily be performed. However, it is more difficult to change habits. Changing behaviour that has become automatic (habits) requires much effort, and education can only play a limited role here.

If road users exhibit dangerous behaviour on a large scale, and moreover if this behaviour yields personal benefits and is not penalized, then we create fertile ground for its proliferation. In this case, education is a necessary but insufficient constraint in attempting to induce people to behave safely. The effectiveness of educational measures increases if they coincide with measures in the field of police enforcement, and vice versa. In this respect, traffic education is in a more privileged position than other forms of 'education aimed at prevention'. Since safe behaviour has been laid down in law, it can also be enforced. Where motivation is a problem, only penalties can induce appropriate behaviour which must have its basis laid in education.

7.6. Summary

In the vision presented here, *man as a learner is the measure of things,* this 'homo discens' learns continually and particularly from daily experience. This learning process can be influenced by formal education, but also in other ways, for instance by imitation, and by punishments and rewards. Despite the fact that much can be learned from traffic itself, there are five areas (see *7.3*) where *formal* education is necessary: problem awareness, strategic choices, violations, habitual behaviour and novice road users. These areas are relevant for road safety, as the road user cannot directly deduce from traffic itself what the safest choices are, and how good he performs. These five areas widen the arena for education much more than we are traditionally accustomed to. This also defines a unique position for education within Sustainable Safety. Education is not a panacea, and it cannot be a substitute for other interventions (a sustainably safe environment for the road user), but it is an essential addition to them. Formal education is the only way to communicate the necessary insights and knowledge in these five areas. Formal education is also required to *teach* correct behavioural routines. However, *extensive practice* of these routines cannot be the task of formal education, because, in terms of time, this exceeds the capacity of formal education. To this end, the environment of the novice road user needs to be brought into play, involving parents, carers and other interested parties. Creating such a 'learning environment' requires coordination between organizations, but also support in terms of content, so that sufficient knowledge and resources are available to assist novice road users.

This vision of education within Sustainable Safety has, as its ultimate goal, to equip road users to take part in traffic with the correct skills, knowledge and beliefs, by the joint effort of many parties, through formal and informal methods. To discern whether or not young people have an adequate store of knowledge currently, the *learning objectives document* (Vissers et al., 2004) is the best touchstone. This document indicates what a road user needs to know, defined by traffic role and age category. Public authorities have an important directorial role in the described renewal process for traffic education. Since so many stakeholders are involved and no single party can successfully operate on its own, and as education has to take place in so many different conditions and settings, and as formal and informal learning have to be coordinated, and as knowledge has to be acquired on the basis of what works and what does not, direction is vital. If this cannot be provided, then inexperienced and vulnerable road users will be left to their own devices.

8. Regulations and their enforcement

The original Sustainable Safety vision (Koornstra et al., 1992) started from the premise that the first priority for road safety is to adapt the road user environment (infrastructure and vehicles) in such a way that it fits human capacities and limitations. The assumption was, and remains, that a well-designed environment leads, in a sustainable way, to safe road user behaviour, and that safe behaviour is not dependent on individual road user choice. Therefore, measures within the Sustainable Safety vision have a sustainable character.

This base is built on further by requiring road users to be well informed and trained in order that they can take part in traffic with a package of basic skills. This is an important prerequisite, but it cannot guarantee safe behaviour. Therefore, it is important, ultimately, to check if people actually behave safely. Thus, enforcement of desirable behaviour is important to the achievement of sustainably safe road traffic.

But what is desirable behaviour? Both road users and enforcers have to know the boundaries within which road users may move, both literally and metaphorically speaking, and this requires regulations[13]. Without rules, norms and agreements there is nothing to comply with and to enforce. This chapter begins by addressing exactly how regulation forms a base, what its reach is, and the extent to which it can support sustainably safe road traffic (*8.1*).

Road users do not always obey set safety rules[14]. The causes for this may be very diverse (see also Rothengatter, 1997). On the one hand, violations can be the result of actions that are intended to violate rules; we then speak of *intentional violations* (see also *Chapters 1 and 2*). The involved person is always to blame for this type of behaviour. This aspect of potentially dangerous road user behaviour was not so much emphasized in the original Sustainable Safety vision. It was then assumed that this would be the cause of only a very small proportion of road safety problems. Nevertheless, intentional violations should not be neglected as a cause of road safety problems (*Chapter 2*). On the other hand, actual violations can also be the result of an *unintentional error*. The distinction between these two causes of violation is important because they each requires a different approach (see also Rothengatter, 1990; 1997). For violations caused by unintentional errors, infrastructural measures, educational solutions or driver support systems are most relevant. Detecting and penalizing rule-violating behaviour are particularly relevant to dealing with intentional violations. All this can be summarized under the term 'enforcement', which is addressed in the second part of this chapter (*8.2*).

8.1. Regulation

8.1.1. Safety always comes first

The generic legislation of the Dutch Road Traffic Act contains three basic principles: safety, flow (no disruption of the traffic flow), and trust (Simmelink, 1999). Of these principles, the *flow principle* provides the basis for current regulation because increased mobility requires increased order in the traffic system (although the legislation leaves unclear what exactly is meant by the traffic system). The *principle of trust* provides the basis for the functioning of the social system that underlies the traffic system. People must be able to trust their expectations of other people's behaviour. This serves both the flow principle and the safety principle. The *safety principle* forms the normative aspect of regulation, and overrides the other principles.

In the Netherlands, the safety principle is contained in article 5 of the Road Traffic Act, which prohibits road users to "*….. behave in such manner that causes or may cause danger on the road, or that road traffic is impeded or may be impeded.*" This law requires road users to break specific rules if safety is served by doing so. Furthermore, the rights based on the flow and trust principles do not exonerate road users from the duty to be attentive to errors by others at all times and to avert a crash if necessary. Only when this is not reasonably possible, the road user may appeal to the other two basic principles.

[13] We aim at 'regulations' in the broadest sense of the word. This comprises formal laws and regulations within law (see *8.1*).
[14] Regulation in the field of road transport comprises more than just laws and rules to improve safety, but this chapter will particularly address regulation concerning road safety.

Structuring of traffic safety regulations in the Netherlands

The Dutch regulations referring to road safety can be subdivided into functions as follows:

– *General rules* for road traffic. These concern specific agreements about where road users may travel, the position on the road that they should try to maintain, stopping for red traffic lights, speed limits that need to be complied to, compulsory safety devices, etc. This type of regulation is communicated to road users by means of codes (e.g. red lights, road markings, and road signs). These rules are also used by intermediate parties (such as road authorities) who are responsible for implementing the traffic system in conformity with them.
– Rules concerning the *quality of the road system* in all its facets. These are regulations for infrastructure design (although only road signs are part of regulations; infrastructure design itself is contained in various recommendations, handbooks and guidelines set by CROW (the Dutch information and technology platform for infrastructure, traffic, transport and public space), requirements for vehicles, and driver/rider training. These elements of the traffic system are amenable to safe road traffic measures and indirectly determine road user behaviour (see also *Chapter 15*). Regulations of this type are particularly aimed at reducing latent system errors (see *Chapter 1*).
– Regulations concerning *road user risk factors*. These are, for example, rules on the use of alcohol and drugs, driving and rest times for professional drivers, and access to the road network based on adequate driving skills. This type of regulation refers either to permitted behaviour or the condition of the road user.

As mentioned above, Article 5 of the Dutch Road Traffic Act provides the overarching legislation for road user behaviour.

8.1.2. Intentional and unintentional rule compliance and violation

Regulation as a basis for road safety (and Sustainable Safety) can only limit crash risk if there is road user compliance. Regulation itself cannot prevent these limits from being infringed, either intentionally or unintentionally, and consequently increasing crash risk. Nor can regulation in itself be considered sustainably safe: aids are needed for that. In the first place, rules have to be made known to the target group(s) (road users or intermediate parties). This can be by means of education, documentation, and road signs within the traffic system. However, making rules known does not prevent them from being easily violated. This can occur both intentionally and unintentionally.

Intentional rule compliance and violations

Behaviour is only partly determined by rational processes, and therefore, the same is true of compliance with, and violation of rules (see *Table 8.1*). We can distinguish three processes that form the basis of intentional rule compliance or violation. These are illustrated by and correspond with the evocations suggested by Van Reenen (2000), in which he identifies three guiding motives.

At the top level we find spontaneous compliance based on a normative point of view. This level is represented by 'the Reverend' (Van Reenen, 2000): it refers to people who obey the rules from inner values (intrinsic motivation), independent of the situation (Yagil, 2005; see also *Chapter 1*). Intentional compliance or violation is nevertheless often a matter of balancing the costs and benefits, represented by 'the Merchant' (Van Reenen, 2000; the instrumental perspective, Yagil, 2005; see also *Chapter 1*), or simply fear of the threat of punishment (represented by 'the Soldier', Van Reenen, 2000). These forms of intentional rule violation necessitate the enforcement of correct road user behaviour and penalties for rule violation (see *8.2*).

All forms of intentional compliance with a rule require knowledge of the rule. In addition, rules must be clear, specific and understandable (see e.g. Goldenbeld, 2003; Noordzij, 1996; Rothengatter, 1997). However, the rule that road users should not impede or endanger other road users, for example, is not specific and, moreover, it is not clear how it can be complied with in practice. The link with safety should also be clear. However, this is a long way from always being the case because it depends on a specific situation (see also Noordzij, 1989). For example, driving, walking or cycling through a red light is only dangerous if there are other road users around. Violating rules when there is no other traffic is more of a threat to the state's authority than a threat to safety.

It also has to be 'easy' to observe rules, and violations have to be easily identifiable or observable. People only obey rules from a normative perspective if they consider the rules to be justified and if they can assume that the rules are applied fairly and neutrally. Road users should

Behaviour	Violation cause	Conformity cause	Evocation
Intentional behaviour	Perceived costs < benefits	Normative viewpoint	Reverend
		Perceived costs > benefits	Merchant
		Fear of punishment	Soldier
Unintentional behaviour	Imitating incorrect behaviour of others	Imitating correct behaviour of others Environment incites correct behaviour	
	Environment provokes incorrect behaviour		
	Unintentional error		

Table 8.1. ***Different processes underlying intentional or unintentional rule-compliant and rule-violating behaviour. For intentional rule-violating and rule-compliant behaviour, also the three evocations by Van Reenen (2000) are represented.***

not think that they will be fined for reasons other than the prevention of future violations.

Unintentional rule compliance and violations

A large part of people's behaviour is, nevertheless, not based on rational processes, but occurs automatically (*Table 8.1*). People do not always make a rational calculation of costs and benefits when violating certain rules. Ten to fifteen percent of Dutch car drivers report exceeding the speed limit without being aware of it (Feenstra et al., 2002). However, there are also other examples of violations that are probably committed unintentionally (see also Aarts et al., in preparation).

One of the reasons for unintentional rule violation is that people automatically follow other road users' behaviour, or are led by habits (see e.g. Yagil, 2005; *Chapter 1*). A second important component is the way in which the design of the road user's direct environment guides behaviour. The design of the vehicle and the infrastructure evoke certain behaviour which automatically draws road users to it (insofar as they are not led by conscious processes). Consequently, a regulation that is not well adapted to the environment can lead to unintentional rule violation. Thirdly, people also make unintentional errors, and thereby break rules (see *Table 8.1*).

Intentional non-compliance has several causes. In the first place, there is a tendency in our society towards intolerance and overt antisocial behaviour in which people do not follow the rules spontaneously (see also *Chapter 2*). Another and probably more important basis for (large scale) violation behaviour lies in the relationship between regulation and the road user environment. For instance, many road users do not judge a speed limit to be logical or corresponding to the road image (Van Schagen et al., 2004; Goldenbeld et al., 2006; see also *Chapter 9*). Van Schagen et al. estimate that more credible speed limits (that fit the road image better) would have a considerably higher compliance percentage of about 70%-90%.

A number of rules also appear to be unrealistic because they do not take road user limitations into account adequately (see Rothengatter, 1997). They are, for example, always expected to anticipate unexpected events, but people can only do this to a limited extent. The rule that one should always keep sufficient headway is also unrealistic because people have difficulty in estimating how much distance they need for an emergency stop. Moreover, most of the time, people assume that they will not have to make an emergency stop.

Yet another reason why rules are easily violated unintentionally is that many of them do not represent a dichotomy and can be partially or slightly violated (see Yagil, 2005). This makes it possible for people to violate traffic rules without feeling that they have committed an offence. A good example is comparatively minor speed limit offences. A car driver has to be constantly alert to observe the speed limit, and, consequently, the possibility that this is neglected for a short while is always present. This is different where rules present a dichotomy, such as using or not using a seat belt, which only occurs once per trip. Compliance with rules that present a dichotomy is therefore generally better than with rules that aim to influence road user behaviour continuously.

8.1.3. Making rule violation impossible, or bringing about spontaneous compliance

Sustainably safe road traffic is best served in conditions where rules reasonably cannot be or can hardly be violated. If this is not possible – and practical experience compels us to make this observation – then the next most desirable situation is where people observe the rules spontaneously, either because people experience the situation (automatically) as being natural, or because they are or become inherently motivated to observe the rules. Violating basic rules and rules on road user risk factors increases the risk of dangerous errors and, consequently, the risk of being involved in a crash, or suffering serious consequences as a result of a possible crash (see also *Chapters 1 and 2*).

However, widespread spontaneous rule compliance is not (yet) a reality. The fact is that traffic rules, particularly speed limits, are currently violated on a large scale (e.g. Van Schagen et al., 2004). But one could also say that most people observe the traffic rules, given the number of rules which exist and of the subsequent opportunities that arise not to comply (see also Yagil, 2005). However, our appraisal is that compliance can be better, and that it has to be better for sustainably safe road traffic, given the fact that not only unintentional errors but also intentional violations give rise to road safety problems. The question then is how to attain better compliance?

Formulation of traffic rules

The preceding sections show that regulations have attracted a variety of criticisms. These criticisms often stem from the general and vague way in which regulations are often described. From a social science perspective, the recommendation should be to go through the rules systematically and adapt them to human capacities or the 'human measure' wherever possible. However, the Dutch legislature has consciously chosen to use general terminology when defining regulations and has limited revisions to their essential characteristics. In the past, the Dutch regulations described all kinds of situations in detail, but this became very hard to monitor. These detailed rules were also frequently violated but without dangerous consequences, arising thus reducing their authority. In the case of the current, more general description of traffic regulations, compliance is left to the road user more than it was previously. The public authorities have made this choice in order to be perceived to be less patronizing.

We can, therefore, posit that both forms of regulating (a detailed description versus a more general one) have disadvantages, seen both from the viewpoint of road user and legislator. However, it remains to be seen whether or not better formulation of regulations can contribute substantially to a better observance of rules.

Better correspondence between regulation and traffic environment

The concept of reducing dependency on (the formulation of) regulations while at the same time encouraging better compliance and safe (and fast) traffic management, is already an objective of current Dutch legislation and one which corresponds very well with the Sustainable Safety vision. This concept proposes to adapt the road user environment in such a way that desired behaviour is induced more or less automatically. Where this is not possible, regulation can be used to help influence road user behaviour. This approach will also prevent the road user from getting lost in a profusion of traffic rules and road signs and yet it should be remembered that road signs or supplementary explanations on why these signs are useful here may be informative or act as a reminder for road users (think of the speed limit signs at city borders). Generally speaking, it is better to receive a visual cue than to rely on memory. However, this is not reality today. The current infrastructure (often rooted and developed in the past) is often unclear and is also inadequately supported by traffic rules and road signs (think of roads that 'invite' excess speed). This means that road users are confronted with conditions that are less recognizable and less predictable (see also *Chapter 15*). If there were to be more uniformity in infrastructure design on the part of road authorities, then regulations could be much less in evidence and would only need to be applied where no alternative was available.

The imposition of restrictions by public authorities is not compatible with their desire to promote more individual responsibility, especially amongst those who already feel overly patronized (particularly on the road). From a road safety perspective however, a strong public authority that sets clear boundaries is preferable. We need to rely less on regulations for road users and more on prescriptive regulations for the intermediate parties who are responsible for the design of elements of the traffic system (see *Chapter 15*). Where measures, aimed at directly influencing road user behaviour, fail or do not address perceived needs adequately, then enforcement measures can be brought into play (*8.2*).

8.1.4. Conclusions on regulation

Regulation in itself does not result in improved road safety, but rules do contribute to safety because they are the point of reference for desirable and safe road user behaviour, and for enforcement of this behaviour. The first requirement is that these rules are made known. The second requirement is that they fit with the design of other elements of the traffic system (e.g. infrastructure and vehicles). It can then be expected that compliance with rules (automatic and large scale) will follow (see also *Chapter 15*). Where adaptation of the road user environment does not lead to rule compliance, enforcement becomes necessary for the enforcement of safe road user behaviour (see *8.2*). This may reduce the opportunities for intentional or unintentional violation of rules by road users, and consequently, increase road safety.

8.2. Enforcement of rule compliance by road users

While road users continue to violate rules, partly due to sustainably safe measures not being implemented throughout the road network, then police enforcement remains an important measure. One of the recurring points of discussion in the cooperation between road authorities and the police is whether or not additional police enforcement should be deployed as a temporary measure where the implementation of Sustainable Safety policy is (too) slow. Since the 1990s, traffic policing has been guided by the principle that there will be no enforcement on roads that do not have Sustainable Safety characteristics[15]. However, even when roads comply with Sustainable Safety, police traffic enforcement remains important. Traffic violations, such as road use under the influence of alcohol or drugs, failing to wear a seat belt, motorcycle or moped riding without a crash helmet, and specific forms of aggressive behaviour, cannot now or in the future be prevented by safer road infrastructure implementation or safer vehicles. That is why it is important for road users to know that they are being watched, and that, if necessary, they will be apprehended and punished for violating rules. Police enforcement is, therefore, more than just a postscript to a Sustainable Safety approach, but it is an inherent part of it.

The following section deals with the role of police enforcement and enforcement in traffic within the Sustainable Safety vision, and discusses the issues regarding the organization and implementation of police enforcement in the coming decade. We focus firstly on what is known in general about the functioning of police enforcement in traffic. We then look in more detail at the opportunities to improve road safety through traffic rule enforcement in the next ten years, and the types of enforcement that fit best in sustainably safe road traffic.

8.2.1. Police enforcement is effective

When we speak about the functioning of police enforcement in traffic, there are three related terms, that is, 'traffic rule enforcement', 'police enforcement in traffic' and the 'police traffic task' that are useful. The term 'traffic rule enforcement' encompasses all aspects of the judicial process, police enforcement, judicial proceedings and actual penalties, all of which aim to make road users behave safely and in conformity with the intentions of legislation and regulation. With 'police enforcement' we mean the actual checking on rule-violating road user behaviour. The term 'police traffic task' comprises more than just the actual checking, and includes the general attention that the police devotes to traffic services, such as registration, advice, education and information. The knowledge and experience gained from 'police traffic care' and the legal authorities operating in the traffic enforcement framework are essential prerequisites of good implementation of police enforcement in practice.

The functioning of police enforcement can be described as follows (*Figure 8.1*). Roadside police checks increase perception of the probability of detection, which can be called enforcement pressure. Based on this enforcement pressure and on what people see or read in the media or hear from friends or acquaintances, road users estimate the probability of detection for violating traffic rules (*subjective* probability *of detection*). The literature (e.g. Zaal, 1994; Goldenbeld, 2005; ETSC, 1999b; Mäkinen et al., 2002) concludes that traffic enforcement should

[15] This guideline nevertheless leaves some room for own interpretation. In some police districts, the police may enforce intermediately on roads that are part of soon to be realised Sustainable Safety implementation.

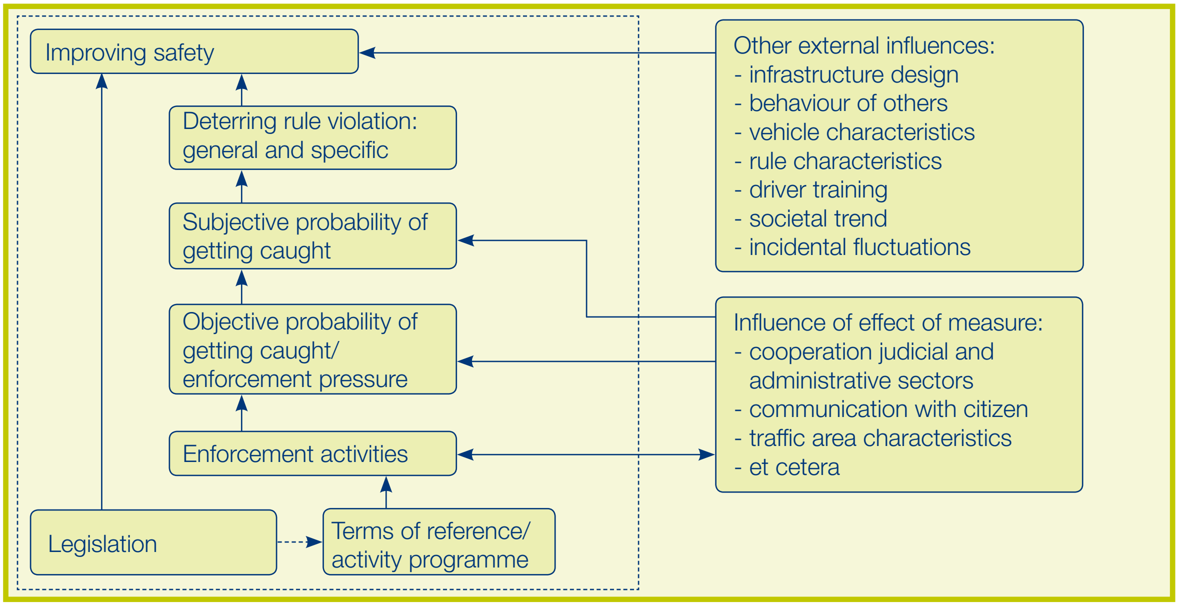


Figure 8.1. ***The assumed mechanism of police enforcement (inside dotted frame), including the influence of external factors (outside dotted frame) according to Aarts et al. (2004).***

aim more at general prevention (preventing violations by the threat of penalties) than at specific prevention (catching and punishing the actual violators). For road safety, it is more important that traffic enforcement succeeds in exerting a normative influence on millions of road users by threatening with punishment, rather than changing the behaviour of violators by punishing them. The actual safety gain that can be achieved by traffic enforcement strongly depends on the extent to which traffic violations can be prevented. Detecting and punishing severe violators is of great importance for credibility and, consequently, for the acceptance of police enforcement. In this sense, generic prevention by general threat of sanctions fits within the Sustainable Safety vision, and specific threat does less so. Nevertheless, specific prevention is a necessary component of achieving generic prevention. The preventative effects of police enforcement are generally speaking greater when the perceived probability of detection and the certainty of punishment are higher, the penalty follows more quickly after the violation, and when societal acceptance of the necessity and usefulness of enforced traffic rules is greater. Each of these elements constitutes a link in the enforcement chain and – to carry this metaphor further – the total chain is only as strong as its weakest link. If, for example, the perceived probability of detection is small, then the penalty and the certainty and speed of punishment will make little difference for preventing violations. A higher perceived probability of detection can be achieved by publicising enforcement activities, ensuring that checks are highly visible, using an unpredictable pattern of random checks, carrying out selective checks at times and locations with a high probability of actually catching violators, and carrying out checks that are difficult to avoid.

Enforcement of traffic rules primarily affects the extrinsic motivation of road users. Road users refrain from violation for fear of a fine or penalty. This does not necessarily contradict the starting point of Sustainable Safety, which strives for the appropriate intrinsic motivation of road users. A change in inner values often occurs after a change in behaviour regardless of this behaviour being induced by extrinsic motivation. It is clear that enforcement alone is not enough to lead and keep road users on the straight path. Training and communication have to contribute to develop intrinsic motivation to obey the rules, in order to bring about a sustainable change in behaviour. Therefore, it is important always to supplement traffic enforcement with good communication about the reasons for enforcement. Meanwhile, the motto of public road safety information campaigns in the Netherlands is: 'no communication without enforcement and no enforcement without communication' (Tamis, 2004).

8.2.2. Lessons from the past

Several evaluations show that traffic rule enforcement in the period 1978-2000 in the Netherlands, achieved successes in the field of driving speed, drink driving and seat belt use (see Goldenbeld, 2005). Based on data from eleven studies, Elvik (2001b) derived a general relationship between enforcement pressure (speed enforcement level) and the change in the number of injury crashes (see *Figure 8.2*). From this it follows that:

– The current enforcement level conserves the current level of road safety (equilibrium).
– Decreasing the current enforcement level decreases safety (injury crashes increase).
– Increasing the enforcement level improves safety (injury crashes decrease).
– The marginal effect of increasing enforcement gradually decreases, that is: increasing the amount of enforcement eventually results in a smaller increase in safety (law of diminishing returns).

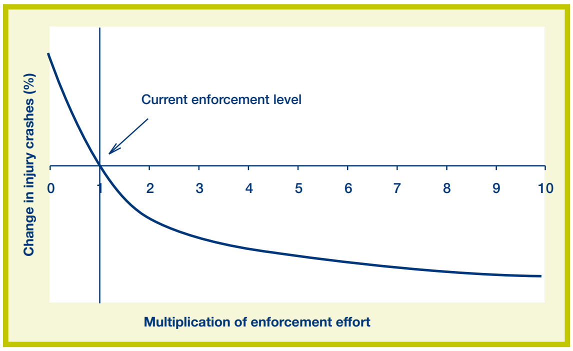


Figure 8.2. ***Relationship between speed enforcement and change in the number of injury crashes according to Elvik (2001b).***

Thus, an important conclusion is that the relationship between enforcement pressure and road safety is non-linear. With a progressive increase of the enforcement level, it can be expected that additional safety gain will diminish, and this raises questions about the efficiency of increasing police enforcement. It should be noted that the curve in *Figure 8.2* is based on the average figures in the eleven studies investigated by Elvik, and that it is not a prediction for the possible intensification of all police enforcement in the Netherlands.

8.2.3. Room for improvement in traffic enforcement

An international literature survey (Zaidel, 2002) about the effectiveness of police enforcement in traffic observed that crash reduction due to police enforcement can vary between 10% for normal enforcement levels and 20 to 25% for intensified police enforcement. According to theoretical arguments and calculations, a maximum effect of 40 to 50% could be reached, but these figures have not yet been achieved. The challenge for the Dutch police is to achieve crash and casualty reductions of 20%-25% from the current base of 10%. For the longer term, perhaps higher percentages can be reached with forms of enforcement that have not been used in practice yet, such as alcolocks, speed assistance (mandatory ISA version), seat belt interlocks, and electronic driving licences.

Effectiveness of police enforcement (behavioural effects) is only one of the factors that determine the integral quality of enforcement. Other relevant factors are efficiency (yields per unit of effort) and credibility (public acceptance). Integral, high-quality traffic enforcement means that the total traffic enforcement chain has been optimized. Now that several new enforcement methods and tools exist (laser gun, video car, road section speed control), guidelines aimed at effectiveness, efficiency and support can be formulated. This will enable traffic project managers to take better decisions with regard to the deployment of personnel and tools. We recommend evaluating and formalizing this knowledge in expert groups, as happens currently in the field of infrastructure. This will not only facilitate the assimilation of new knowledge about effective enforcement but will also make the knowledge more accessible so that it can be better and more frequently used in daily practice.

In the continuation of this section, we will investigate where opportunities for optimum police enforcement exist, or where potential should be developed to address the specific priorities of drink driving, speeding, use of seat belts, aggressive behaviour and severe violations.

8.2.4. Enforcement: past, present and future

Selective checks for drink driving versus random checks

Driving under the influence of alcohol has decreased greatly in the Netherlands over the past three decades, particularly in the 1970s and 1980s (*Figure 8.3*). A large effect on behaviour and, consequently, on road safety has been achieved with a range of legal measures, primarily aimed at improving police enforcement of drink driving. A rule of thumb is that each doubling of the level of alcohol enforcement results in a decrease of one quarter in the number of violators (see *Chapter 10*). Despite this, road use under the influence of alcohol is still one of the main road safety problems; about 25% to 30% of severe traffic crash casualties in the Netherlands are are the result of the use of alcohol (estimation based on Mathijssen & Houwing, 2005).

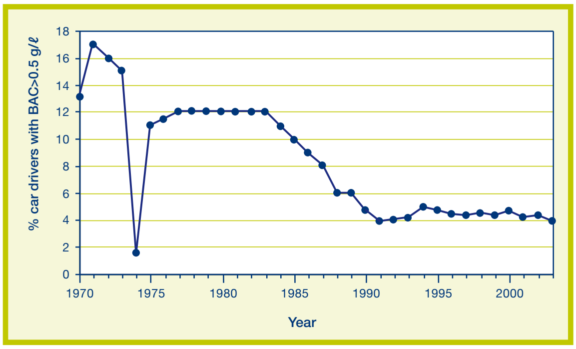


Figure 8.3. ***Car drivers with a blood alcohol content (BAC) of more than 0.5 g/ℓ during weekend nights in the Netherlands. Source: SWOV, AVV Transport Research Centre.***

There are strong arguments to target the enforcement of drink driving in the coming years on: a) road users with a high BAC, b) drivers combining alcohol and drugs, and c) drink driving by young males. Three specific measures offer opportunities to increase efficiency of police enforcement of drink driving further (*Chapter 10*):

1. Additional enforcement of drink driving at times and locations with an increased risk, with no change of the standard level of random tests.
2. The introduction of a lower BAC level for novice drivers. This measure was introduced on January 1st, 2006.
3. The introduction of an electronic alcolock in vehicles of convicted drink drivers. Several experiments show that an alcolock is more effective in preventing recidivism than driving licence suspension.

Enforcing speed limits

Speed plays an important role in traffic crashes (*Chapter 9*). Speed limits are often violated on a large scale, and on certain roads, high speeds lead to above-average risks. Since road or in-vehicle measures cannot always be introduced at short notice, a higher level of speed enforcement is, for the time being, the only measure to make above-averagely dangerous road locations safer. Speed violations could be reduced considerably by applying credible and more dynamic speed limits that inform road users appropriately and correctly at all times (Van Schagen et al., 2004). For greater effectiveness, speed enforcement itself should also become more credible. It is important to dedicate more effort to reducing speed violations along extended road sections (i.e. section speed control) and to addressing the problem of more serious violations and persistent violators. Specific recommendations are given in *Chapter 9*.

Enforcing seat belt use

The use of seat belts in the Netherlands in the 1990s lagged behind countries such as Germany and the United Kingdom. Seat belt use by drivers was lower than 70% in urban areas and below 80% in rural areas. However, after 2000, a clear improvement was seen. In 2004, the wearing of seat belts by drivers in urban areas increased to 88%, and to 92% in rural areas. This is a significant improvement compared to 1998, when these percentages were 67% and 80% respectively. Intensified police enforcement on seat belt use, supplemented by national and local campaigns, have contributed to this. Current police enforcement levels should be maintained to sustain and further improve this percentage. It is important to have highly visible seat belt wearing checks. Seat belt enforcement can be combined well with a period of warnings (instead of fining), information and personal contact with car drivers. The Dutch police are currently developing a system using video technology to make the enforcement of seat belt use more efficient.

Major traffic offences

Current legislation offers the police adequate opportunities to penalize dangerous and major traffic offences. To use these opportunities to full effect, the police need to have sufficient knowledge and tools to bring a good case. In tackling major offences, the final link in the enforcement chain is particularly important, that is, the effect of the penalty. However, Blom & Wartna (2004) have shown that this fails in a substantial proportion of all cases. Forty percent of traffic offenders[16] are prosecuted at least once again within four years, and in four out of five cases for the same offence (*Figure 8.4*).

[16] In this study, data was compared of all persons who got into contact with the justice department for a violation of the Dutch Road Traffic Act, general traffic rules, or the act on civil liability concerning motor vehicles. Minor offences that were dealt with by administrative sanctions were not included.

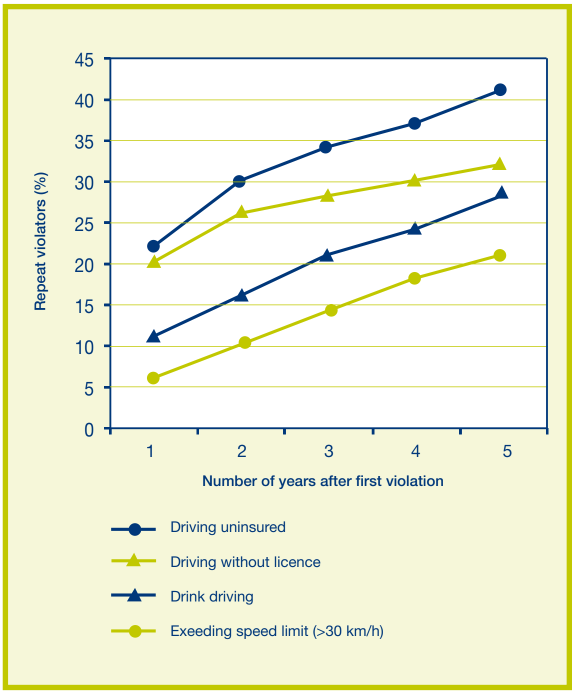


Figure 8.4. ***Percentage of repeat violators in the years after being caught in 1997 for a serious offence.***

According to Blom & Wartna (2004), the most frequently reported road traffic offences are: seriously exceeding the speed limit (by more than 30 km/h), drink driving, driving without a licence and uninsured driving (the latter offence being no threat to road safety). These offences are committed mainly by males (85%); the average age at the first offence was 36.

These figures indicate the necessity of using better tools to target specific groups of traffic violators in order to prevent repeat offences. For alcohol offenders, for instance, introducing an electronic alcolock is recommended. For people displaying aggressive behaviour that is clearly dangerous to others, it would be possible to fit a car with Intelligent Speed Assitance (ISA) or a black box (to be paid for by the offender). Special training courses can also be important for specific groups of violators. To this end, knowledge must be gathered and a strategy developed that can be tested and eventually laid down in clear enforcement policy and supporting legislation.

There is much support from Dutch road users to take a strict line with major offenders and repeat violators. Three quarters of the 1000 Dutch car drivers questioned support either a measure to send repeat excess alcohol offenders on a rehabilitation course, or to test them for alcoholism (Sardi & Evers, 2004; Quimby & Sardi, 2004).

Also the demerit or penalty point system for (novice) road users can have a stronger deterrent effect on potential novice driver offences. Road users who receive a speeding ticket and some penalty points exhibit less risky behaviour in the month following the violation than those who only receive a ticket (Redelmeier et al., 2003). Fines in combination with penalty points may result in more careful car driver behaviour, but research indicates that this effect does not last more than a month. The possible general deterrent effects of a penalty point system are linked to the perceived probability of detection (and, in this case, actual detection) and the associated publicity. However, the effect of penalty point systems is probably small because, if violators are detected at all, this comparatively seldom leads to apprehension, and then the behaviour correcting effect of penalty points decreases quickly (Vlakveld, 2004).

8.2.5. Improved police enforcement

Police enforcement continues to have an important role within Sustainable Safety policy. If we assume that there are no further opportunities to intensify police enforcement in traffic, safety gains may be expected from further optimization. Therefore, we have to strive for greater efficiency and, consequently, greater effectiveness with the existing level of enforcement.

Specific opportunities for optimizing police enforcement are:

- Greater emphasis on alcohol checks targeted at specific categories of violators, but not to the detriment of the general level of alcohol checks (although necessarily to the detriment of something else!).
- Using section speed control (speed enforcement over a stretch of road; see *Figure 8.5*) to permanently lower speeds on dangerous road sections.
- Collecting and providing access to (currently often scattered) knowledge on the effectiveness of traffic enforcement.
- Investing in better dissemination of knowledge within the police organization.
- Developing other, more effective/functional penalties for major violators.
- Communicating better with the general public and with specific target groups in traffic.

Figure 8.5. *Warning sign of section speed control.*

8.3. General conclusions and recommendations

In sustainably safe road traffic, regulation constitutes a basis for the safe management of traffic processes, minimizing latent system errors, and limiting risk factors. The ideal situation in sustainably safe road traffic would be for people to comply with the rules spontaneously without much effort or without experiencing them as something negative. On the one hand, this can be achieved by adapting the traffic environment (e.g. the infrastructure and vehicles) in such a way that it supports the prevailing local rules as much as possible. This would also provide the basis for preventing latent errors in the traffic system because it tackles the causes of rule violations in an early stage. On the other hand, intrinsic motivation could stimulate people to obey the rules spontaneously.

Unfortunately, spontaneous rule compliance in traffic is far from being a reality, and the question is whether or not this is a realistic goal for the future. Not all people are always motivated to obey the rules, not even if the environment has been fully adapted. Coercive measures are required to stimulate these people to observe the rules, for instance by making the costs higher than the benefits by threatening sufficiently severe penalties. Current forms of enforcement can be enhanced by using more effective and efficient methods and tools. Enforcement and checks, aimed at specific target groups before they gain access to the road, fits into sustainably safe road traffic. In order to lower the number of violations substantially, intelligent systems provide a solution for the future. These can be deployed as an advisory instrument to prevent people from violating the rules by accident. However, for some target groups, this type of system can also be deployed as an intervention to prevent undesirable behaviour, for example for repeat offenders and major violators. Further into the future, it is possible that everyone will use far-reaching intelligent systems to prevent violations of traffic rules.

Part III:
Special Issues

9. Speed management

9.1. Large safety benefit is possible with speed management

Speed is a crucial factor in road safety. It is estimated that excessive speeds are involved in 25 to 30% of fatal road crashes (TRB, 1998). The exact relationship between speed and crashes is complex and is dependent on several specific factors (Aarts & Van Schagen, 2006; Elvik et al., 2004). However, in general terms it can be stated that the higher the speed, the higher the crash risk and the higher the risk of severe injuries in such a crash (see *Frame 9.1*). This is exactly what Sustainable Safety aims to prevent. In a sustainably safe traffic system everything is aimed at reducing crash risk, and if a crash occurs to prevent severe injuries as far as possible.

It is not surprising that, while implementing Sustainable Safety, many speed-related measures have been taken. Most well-known examples are the extension of 30 km/h zones, the establishment of 60 km/h zones, the application of roundabouts at intersections, and speed humps or raised plateaux at locations where pedestrians and cyclists meet cars. Speed is the most important priority for enforcement projects.

Despite this level of attention, speed is still a road safety problem in the Netherlands. On average, on Dutch roads 40 to 45% of all car drivers exceed local speed limits (Van Schagen et al., 2004). SWOV calculated that in the Netherlands there would be 25% less road casualties if 90% of car drivers complied with speed limits (Oei, 2001). According to SWOV, speed management is therefore one of the five main policy features aimed at realizing a substantial casualty reduction (Wegman, 2001; Wegman et al., 2004). The Netherlands should aim for all road users to comply with speed limits in force at the time within a period of ten years.

9.2. Speed is a very difficult policy area

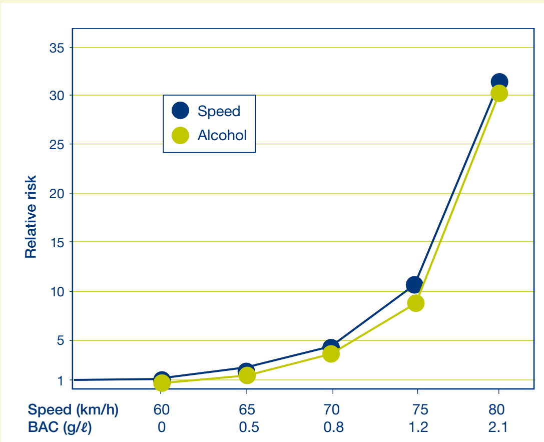
Speed is a very difficult policy area. The function of a traffic system is to transport people and goods quickly, comfortably, reliably, safely, cheaply and in an environmentally friendly way. In a sustainably safe road traffic system all these functional requirements should be brought together harmoniously (see also *Chapter 4*). This is not easy to attain. Tension exists between the requirements 'quick' and 'safe'. In general, higher speeds reduce travel times and increase accessibility, but higher speeds are bad for road safety. Incidentally, this tension is not as great as it may seem because some of the congestion on roads is caused by crashes and the number of crashes would be lower if speeds were lower. Moreover, in some cases lower speeds can create better flows and the same can be said for some cases where speeds become more homogeneous. This is one of the reasons for the initiative to lower speeds on major roads in Dutch urban areas (Novem, 2003).

With respect to the 'environmentally friendly' requirement there are more similarities than differences with the safety requirement. It is important to pursue lower and more homogeneous speeds from both points of view (see also *Frame 9.2*). This link between environment and safety objectives can be observed with increasing frequency. For instance, the initiative mentioned above of lowering speeds on urban major roads also aims to reduce CO_2 emissions with lower and more homogeneous speeds. The introduction of an 80 km/h speed limit on some sections of the Dutch motorway network was originally meant as an environmental measure, and this turned out to have a very positive effect on road safety (RWS-DZH, 2003). Also the *New Driving Force* programme aims to combine environmental and safety objectives (www.hetnieuwerijden.nl).

A second reason why speed is a very difficult policy area is the tension between individual and collective interests. Individual drivers hardly ever experience the negative consequences of speeding but, rather contrarily, they do enjoy the benefits. Many consider driving at high speeds to be pleasant, exciting and challenging (Feenstra, 2002; Levelt, 2003). Moreover, at a higher speed you can just catch that green traffic light and reach your destination earlier, however small the gain in time may be. The negative consequences of speeding, in turn, are only seldom experienced by the individual car driver. The crash risk for an individual driver is, fortunately, only very small, and the

Speeding is at least as dangerous as drink driving

Among other countries, much research has been carried out in Australia into the effect of speed on crash risk. Also, the effect of speed has been compared with that of drink driving. Researchers (Kloeden et al., 1997) found that speeding is at least as dangerous as drink driving. The research was carried out on urban roads, which have a speed limit of 60 km/h. The results show that driving only 5 km/h faster than this speed limit carries twice the risk of being involved in an injury crash compared to a driver who drives at exactly 60 km/h.



Exceeding this speed limit by 10 km/h results in quadrupling crash risk, and exceeding by 15 km/h results in a more than ten times higher crash risk. Crash risk increases exponentially with increased speeds. Increased risk from exceeding the speed limit on the roads studied was about the same as the increased on the same roads with blood alcohol content (BAC) of respectively 0.5, 0.8, and 1.2 g/ℓ.

Higher speeds have consequences not only for crash risk, but also for injury severity. In this respect, the road safety report of the World Health Organization (Peden et al., 2004), refers to the following facts based on research:

- For car occupants severe injury risk triples with a crash speed of 48 km/h, and quadruples with a crash speed of 64 km/h compared to a crash speed of 32 km/h.
- Fatality risk is 20 times higher with a crash speed of 80 km/h compared to a crash speed of 32 km/h.
- Survivability is 90% with a crash speed of 30 km/h between a car and a pedestrian. With a crash speed of 45 km/h or more, survivability is less than half.

Frame 9.1.

likelihood that this crash can be directly and causally linked to excessive or inappropriate speed is even smaller. Environmental effects are generally too far removed from an individual driver. In other words, the benefits of speeding are mainly experienced at individual level, whereas the disadvantages are particularly noticeable at an aggregate, societal level. The resulting message is difficult to convey.

9.3. Nevertheless, much can be achieved in the short term

The fact that this policy area can be described as difficult does not mean that nothing can be done. This was shown by a SWOV study of the possibilities for speed management in the short term (Van Schagen et al., 2004). Key terms in this study are: safe speed limits, credible limits, and good information about those limits. It was concluded that if these starting points are systematically applied on the current, fixed speed limits, about 70 to 90% (dependent upon road type) of car drivers will generally comply with speed limits of their own accord. For the remaining group, (credible) enforcement continues to be important. What would need to happen according to Van Schagen et al. (2004)?

9.3.1. First step: establishing safe speeds and safe speed limits

First of all, we need to establish what a safe driving speed is in order to adapt speed limits. Whether or not a speed is safe depends, at first, on the number and type of potential collisions. Within Sustainable Safety this led to, among others, the requirement that where motorized traffic mixes with vulnerable slow traffic, the speed of motorized traffic needs to be reduced. This requirement is particularly concerned with the large mass differences between the traffic modes mentioned, causing higher crash speeds to have potentially fatal consequences for the 'lighter-weight' party. For the same reason, in establishing safe speeds, account has to be taken of the proportion of heavy goods vehicles on a road. In this re-

Also the environment benefits from speed management

"The environment benefits from low speeds and smooth driving behaviour. The clearest relationship is the one between speed, fuel consumption and carbon dioxide emissions. Carbon dioxide (CO_2) is a direct residual product of burning petrol, diesel and LPG, and it contributes to an intensified Greenhouse effect. A car driver can save litres of fuel if he or she keeps to the speed limits and adapts a smooth driving style (that is: anticipating well, resulting in smooth braking and accelerating, which results in a quite homogeneous speed pattern). CO_2 emissions in grammes per kilometre between an extreme stop-and-go driving profile (very heavy congestion) and a driving profile for normal congestion (40-75 km/h) can e.g. differ by a factor of two (TNO, 2001). Cars going faster than 120 km/h on a motorway can emit 20 to 30% more CO_2 per kilometre compared to cars going smoothly at 120 km/h or slightly slower. The relationship between speed and emission of polluting substances is somewhat more ambiguous. Nevertheless, TNO (2004) concludes that, generally speaking, the emissions of nitro-oxides (NO_x) and particulate matter (PM10) – those substances that are so much under discussion because they cause bad air quality around roads – decrease with a strict speed regime and decreased speed limits. At speeds above 50 km/h, tyre-road contact noise dominates engine noise. Therefore, speed measures at road sections with speed limits above 50 km/h have positive effects on traffic noise load."

Jan Anne Annema, MA
Netherlands Environmental Assessment Agency

Frame 9.2.

spect, large differences exist particularly on 50 km/h and 80 km/h roads.

In several chapters (e.g. *Chapters 1 and 5*) we underline the importance of establishing maximum crash speeds. The complexity of a situation determines the speeds that can be considered as safe. So a safe speed limit has to be based on a safe speed, and this, in turn, has to be based on 1) knowledge of the relationship between speed and crash risk on a given road type under given conditions, and 2) biomechanical laws concerning the release of kinetic energy combined with the injury tolerance of various road users. Knowledge about environmental effects can also be a determining or contributory factor in establishing the limit. Defining an acceptable safety level (and environmental load) remains, nevertheless, a political decision, but one that must be based on the type of knowledge mentioned above.

9.3.2. Second step: credible speed limits

Next, it is important that these safe speed limits are also credible limits. By credible limit we mean that motorized road users regard the speed limit as logical under given conditions and that the limit fits the image evoked by the road. In the Dutch regulations this is already explicitly stipulated. However, everyone knows of examples where this is not or is not wholly the case. For instance, an urban (ring) road with separated carriageways, split-level junctions, and closed to slow traffic, cannot be compared with a cross-town link, with shops or houses along both sides and a mixture of all kinds of road users. At present, both road types often have a 50 km/h speed limit in the Netherlands. In the case of the former, a higher limit seems obvious, and in the latter a lower limit. In both cases, the existing speed limits are not credible to many road users. Another example that illustrates the idea of credible speed limits, concerns the transition between 'urban' and 'rural'. The location of this transition does often not converge with the boundary of the built-up area or other evident characteristics when entering or leaving a built-up area.

Using the concept of credible limits, we can explain why on one road more than 60% of road users exceed the speed limit, while on another road this same speed limit is exceeded by less than 10% of the users (e.g. Catshoek et al., 1994; Province of Zeeland, 2004). This may also explain why the percentage of speed violators decreases considerably on some roads due to police enforcement, whereas this is not the case on other roads with the same speed limit with equal surveillance effort, and the same initial percentage of violations (Goldenbeld et al., 2004).

When a speed limit is not credible (and we still have to determine the exact criteria for this), there are, in principle, two possibilities. Either the road image or the speed limit is adapted. The latter means that sometimes the speed limit can be lowered, and sometimes raised, albeit within the boundaries of a safe limit. Furthermore, a logical consequence of the credibility principle is that a limit transition on a road section always converges with a clear change in road image and conversely that a clear change in road impression always converges with a transition in speed limit. However, we have to avoid changing speed limits too frequently. This is confusing for the road user and does not help traffic homogeneity. In these cases the preference is, where possible, to remove changes in the road image. Less limit transitions are then required, and moreover, this contributes to greater consistency in road design and the road image. Continuity with preceding and following road sections also has to be safeguarded. These and other functional requirements for limit transitions for a given stretch of road will have to be defined later.

Figure 9.1. *Example of an urban road with a speed limit of 50 km/h that is not credible.*

9.3.3. Third step: good information about speed limits

The next requirement is, of course, that road users know what the speed limit is at all times. Road users are often not aware what the speed limit is at a given location. Uncertainty about the speed limit can, for instance, be avoided by giving information on hectometre posts, as is now the case on 100 km/h sections on the motorway network in the Netherlands, or by other forms of marker posts. We can also think of type or colour of road marking. However, this information has to be applied extremely consistently and must be conveyed to road users with great clarity.

Figure 9.2. *Example of hectometre posts indicating the speed limit.*

The time is right for a systematic application of intelligent information systems. Technological developments have indeed advanced to such a stage that speed limit information can be provided not only at the roadside, but also in the vehicle. This can be coupled to a navigation system for example. The project SpeedAlert (ERTICO, 2004) is working on such an approach within a European framework. Automatic speed limit information requires an inventory of current speed limits and moreover, conscientious maintenance of the database in which the information is stored. In the Netherlands, work has started on such an inventory within the framework of activities around *Wegkenmerken+*[17] (Road Characteristics+). The advisory version of the Intelligent Speed Assistant (ISA) has been based on the same principle. However, this system can go one step further by providing information not only about speed limits, but also actively alerting drivers about speed limit changes and by warning when these limits are exceeded. Driving simulator tests have determined the speed effects of such a system, and based on this a potential 10% reduction in the number of injury crashes has been calculated (Carsten & Fowkes, 2000).

9.3.4. Fourth step: location and dimensions of physical speed reducing measures

When there is harmony between the (safe) speed limit, characteristics of the road and the environment, the role of physical speed reducing measures, such as speed bumps, can be reduced. The application of speed bumps, raised plateaux, and roundabouts should be limited to 'logical' locations, for example,

[17] 'Wegkenmerken+' is a software package that AVV Traffic Research Centre has developed together with regional road authorities and SWOV. General and specific characteristics are recorded by road section, such as road type, number of lanes, intensities and speed limits, using digital maps and the Dutch National Roads Database.

a pedestrian crossing, an intersection or a school entrance. Physical speed reducing measures force lower speeds but they also have to be considered as a part of the road image. In this way, they contribute to the predictability of the road and expectations of the desired speed (see also *Chapter 4*).

Car drivers frequently complain about physical speed reducing measures such as speed bumps and roundabouts, and their widespread application. We expect that the opposition will decrease considerably if such measures are only used in logical locations that refer to the traffic conditions. There is also a case for re-evaluation of the size of physical speed reducing measures. Finally, road users should more than nowadays be informed about the objectives of speed bumps, roundabouts, etc., and their (impressive) effects on the number of road casualties.

9.3.5. Fifth step: credible enforcement

The number of speeding offences is expected to decrease with safe speed limits, with credible limits, and with adequate information about the actual limit. However, as long as road users can choose their own speed there will always be a group that will frequently exceed the limits. Enforcement will be required to affect the behaviour of this group (see also *Chapter 8*).

According to surveys, the Dutch public supports existing speed enforcement and believes that it could be more stringent (Quimby et al., 2004). At the same time, current enforcement practice is the subject of much discussion. Among frequent complaints, often fed by the media, are that only minor offences are tackled, usually when there is no-one else on the road, and that speeding tickets are only meant to provide revenue for the Treasury. In other words, there is still something to be done about the credibility of speed enforcement. Our ideas include:
- explaining why speed limits need enforcing (e.g. safety, environment, quality of life), where possible supported by information about the effects;
- always challenging the false argument that enforcement is meant to generate income;
- being less concerned with just momentary speed violations.

Regarding the latter point, road section controls and, in the future, electronic vehicle identification (EVI) offer the possibility of checking speeds over longer distances. In the absence of a thorough evaluation, we expect that this is not only more credible but also more effective. The effects of conventional enforcement measures such as speed cameras and mobile radar controls are very limited by time and place.

It is important for the credibility of enforcement that 'zero tolerance' is the point of departure and that repeat offenders and serious offenders are caught as well as trivial offenders. Enforcement with inconspicuous video-equipped police vehicles and highly visible arrests both play a positive role. An idea may be to change current policy on speed cameras. This involves putting a functioning camera in all speed camera posts and randomly setting them to detect violations of the current limit and also a higher limit. Road users, of course, would not know which regime is in force at any given time or location. The likelihood of serious violators being caught is then close to 100%. Combined with good communication about this idea, the credibility of enforcement is enhanced because road users see that excessive speeding is always penalized. In due course the deployment of forced ISA for repeat offenders of serious speed violations may have a role. This is comparable to the deployment of alcolocks for excess alcohol offenders.

9.3.6. Sixth step: making speed limits more dynamic

The point of departure in the preceding sections is the current system of fixed speed limits. Local and transitory conditions are not taken into account in this fixed system. A fixed speed limit is, in fact, nothing more than an indication of how fast one can drive on average on that road. However, during daylight, in dry weather and when traffic is light, driving speeds could be higher than during the night-time, when it is raining or foggy, or during evening rush hours.

We should, therefore, strive for arriving at a system of dynamic speed limits that applies the safest limit for specific conditions. A dynamic system of speed limits also contributes to credibility, because it does not only take into account the average conditions, but also the actual conditions. On Variable Message Sign (VMS) equipped motorways a certain form of dynamic speed limits is applied, for example, during congestion or poor road or weather conditions. Recently the decision was taken in the Netherlands to lower speed limits on motorways at road works, depending on the presence or absence of road workers.

Another relatively simple form of dynamic limits that can be applied in the short term, is a weather con-

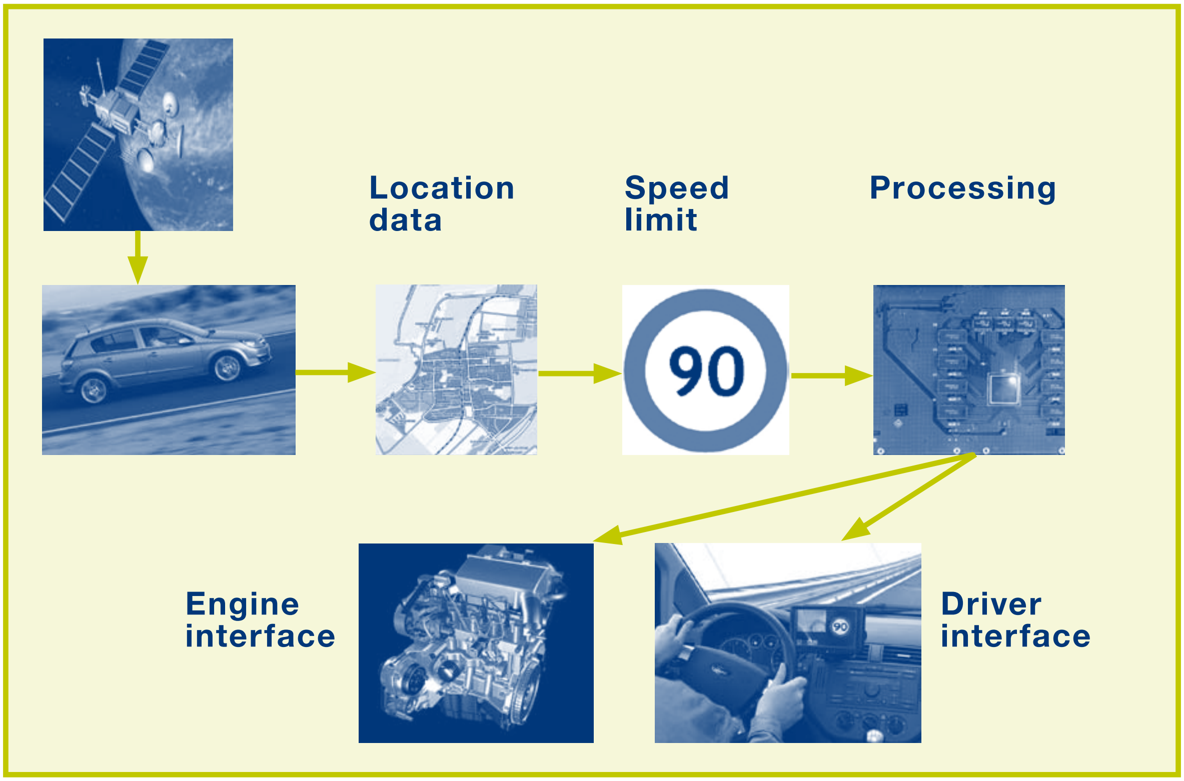


Figure 9.3. *Diagram of an intelligent speed assistance system.*

dition dependent speed limit. A lower speed limit in rainy conditions has been applied in France for over twenty years. This rule can be easily perceived by road users in as much as the windscreen wipers have to be switched on when it rains. Yet another possibility is raising the speed limit at times when traffic volume is very low, without, of course endangering safety. When, in these circumstances, speeds cannot be increased due to noise or other environmental reasons, there are ways in which this can be indicated (such as with the German supplementary subsign '*Lärmschutz*', or noise protection). Low traffic volumes are difficult for the road user to perceive and are more accurately indicated by supply controlled VMS. For this reason traffic volume dependent speed limits have to be restricted to main roads for the time being.

9.3.7. Finally: a completely dynamic, ISA supported speed limit system

Ultimately, we would like to arrive at a complete system of dynamic speed limits in which in all locations and at all times, the legal speed limit is displayed in the vehicle and in which the speed limit is based on local and momentary conditions. Such a system will have to be fed by some form of ISA (see also *Chapter 6* and *Figure 9.3*). Whether or not this form of ISA simply informs, or provides a warning or even actively intervenes when a posted limit is exceeded, is a subject for further discussion. The most advanced form of ISA is preferable from a safety point of view as it is expected to result in the largest reduction in casualties (Carsten & Fowkes, 2000). However, societal and political support will play an important role in deciding priorities in this area. Whatever the chosen form, the necessary technical details need to be developed before an ISA-supported dynamic speed limit system can be implemented. Considerably more knowledge is also needed to identify the speed limits that will deliver an acceptable level of safety and the conditions in which they will operate effectively. However, we can already conclude that the achievement of an effective system of speed limits requires a greater differentiation in limits than is now legally possible.

9.4. Conclusions: towards sustainably safe speeds in four phases

As outlined in this chapter, there is ample opportunity to create a more effective speed management policy, and subsequently to deliver a considerable reduction in the number of road casualties. It is also important to start preparing for the longer term. Translating the opportunities into tangible actions leads to the following phased plan:

1. Research institutes should establish the criteria and functional requirements for safe and credible speed limits, and establish the minimum requirements regarding information for road users.
2. Road authorities should survey the road network on the basis of set criteria for safety, credibility and information, and adapt speed limits, road image, or traffic situation where appropriate.
3. Relevant parties should reconsider enforcement, from the assumption that only deliberate violators and excessive violations have to be dealt with, by a zero-tolerance approach.
4. In parallel with the previous phases, relevant parties can make preparations for the creation of a more dynamic speed limit system and for introducing the related intelligent information technologies, developing a policy vision and, also within an international framework, defining technical and organizational constraints.

With respect to speed management policy, road safety objectives cannot be separated from objectives in the areas of environment and accessibility. To an increasing extent, we will have to seek an effective balance between safe speed, 'clean' speed and accessibility.

10. Drink and drug driving

10.1. Scale of offending and trends

In the Netherlands, the proportion of drinking and driving offenders has decreased by more than three-quarters over the last three decades. Since alcohol is such an important crash risk factor, this decrease indicates a highly successful policy at first sight. However, the effect on the alcohol-related road casualty toll is, to some extent, disappointing. The proportion of alcohol-related serious road injuries (i.e. the sum of fatalities and hospital admissions) has decreased a lot less than the proportion of offenders. Data about severe road injuries have only been available since 1980. Between 1980 and 2004, the proportion of offenders decreased by two-thirds, but the proportion of alcohol-related serious injuries decreased by only a quarter. The *number* of alcohol-related injuries decreased by about half in the same period, but this is not a good measure with which to calculate the effectiveness of alcohol policy. This measure is influenced by factors that have nothing to do with drinking and driving, such as developments in mobility, improved safety of roads and vehicles, increased seat belt use, etc.

Figure 10.1 shows the indexed developments of the proportion of drinking and driving offenders and the proportion of alcohol-related severe injuries side-by-side.

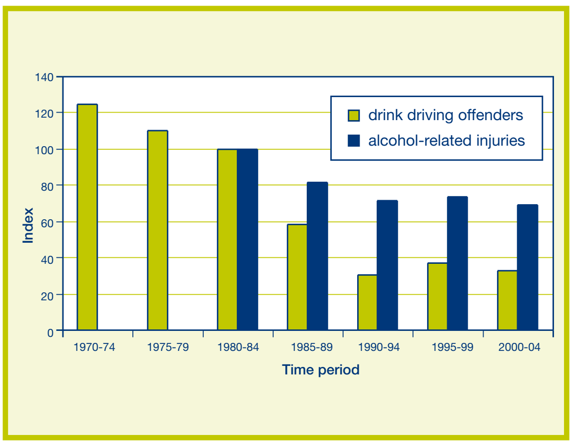


Figure 10.1. ***Indexed development of the proportion of drinking and driving offenders and of alcohol-related severe injuries (1980-'84 = 100).***

Exact data on the number of alcohol-related road injuries is not available in the Netherlands. Alcohol use by drivers involved in crashes is not well reported and we know that there is serious underestimation of the alcohol problem in the official figures. A recent study carried out by SWOV in the Tilburg police district (Mathijssen & Houwing, 2005) indicates that, in the time period 2000-2003, about 25%-30% of severe injuries among car drivers were attributable to drinking and driving. In one out of three cases, a combination of alcohol and drugs had been used. Therefore, the problem of alcohol in traffic can no longer be dealt with separately from the drugs problem in traffic. The Tilburg study also revealed that the use of drugs alone is a considerable problem. About 8% of severe injuries were attributable to drugs-only and in most cases this involved a combination of two or more drugs.

Probably, about half of the alcohol and drug-related severe injuries in the Netherlands are related to alcohol alone, one quarter to drugs alone, and the remaining quarter to the combined use of alcohol and drugs. The total cost of the alcohol and drug-related road casualty toll between 2000 and 2004 is estimated to have been more than 2 billion Euros annually in the Netherlands.

10.2. Problems associated with night-time and recreational road use by young males

Young males, between 18 and 24 years old, are over-represented in the Netherlands, both as victims and instigators of alcohol-related serious injury crashes. In the time period 2000-2004, young males constituted 22% of all alcohol-related road fatalities and hospital admissions. They also constituted 24% of all road users under the influence of alcohol involved in serious injury crashes (AVV, 2005). However, they constitute only 4% of the total Dutch population. In the Tilburg police district, most users of alcohol-drug and drug-drug combinations were found in this group of young male drivers. Around 3% of these tested positive for one of these extremely dangerous combinations, whereas 'only' 0.6% of all other drivers tested positive.

Driving under the influence of alcohol and/or drugs takes place mainly during *night-time hours* (22.00-04.00). In terms of the proportion of offenders, there is not much difference between weekend nights and weekday nights, but the number of offenders is higher during weekend nights due to larger traffic volumes. *Table 10.1* gives the percentages of alcohol and drug users for three time periods in Tilburg and the surrounding area.

Time period	Only BAC ≥ 0.5 g/ℓ	Only drugs	Alcohol + drugs
Weekend nights	4.5 %	7.6 %	2.0 %
Weekday nights	4.3 %	9.3 %	1.2 %
Rest of the week	0.7 %	4.8 %	0.3 %

Table 10.1. ***Percentages of alcohol and drug users in the Tilburg police district, by day of the week and time of the day, 2000-2004.***

The places in which drinking and driving offenders have consumed alcohol on weekend nights are known (AVV, 2005). In the time period 2000-2004, on average 55% of them had consumed alcohol in a *public drinking place* (pub, bar, disco or restaurant), 6% in a *sports club canteen*, and 20% at a *social visit or a private party*. The fact that fewer offenders came from a sports club canteen than from a restaurant or bar, is mainly because there are fewer sports club canteens, and national roadside surveys take place during night-time hours.

10.3. Policy until now mainly alcohol-orientated rather than drugs-orientated

Measures implemented to date to address driving under the influence have mainly focused on alcohol use, rather than on drug use. The following types of measures can be distinguished:
1. legislation,
2. police enforcement,
3. information and education,
4. prosecution and punishment,
5. rehabilitation and disqualification.

10.3.1. Legislation

Efforts to tackle the *drinking and driving problem* in the Netherlands did not truly take off until 1974. New legislation was passed that made driving/riding under the influence of alcohol with a blood alcohol content (BAC) above 0.5 g/ℓ a criminal offence. At the time of introduction, this limit was considered somewhat low. Most European countries had or accepted a 0.8 g/ℓ limit, while the limit in the United States was as high as 1.0 g/ℓ. In early 2004, as the result of a European process of harmonization, ten out of fifteen EU countries had a 0.5 g/ℓ limit. The United Kingdom, Ireland and Luxemburg still had a 0.8 g/ℓ limit, whereas Sweden had a 0.2 g/ℓ limit. With enlargement adding ten new EU Member States that year, the variety of limits increased again. Seven out of the ten 'new' countries had different limits: Cyprus (0.9 g/ℓ), Malta (0.8 g/ℓ), Lithuania (0.4 g/ℓ), Estonia (0.2 g/ℓ), Czech Republic (0.0 g/ℓ), Hungary (0.0 g/ℓ) and Slovak Republic (0.0 g/ℓ).

Proponents of limits lower than 0.5 g/ℓ primarily base their arguments on the supposedly general preventative effect. Opponents point to the criminalization of drivers who do not demonstrably influence road safety negatively and to reductions in the effectiveness and efficiency of police enforcement. SWOV always considered itself part of the latter group (Mathijssen, 2005). This was also because the effects of lowering the limit from 0.5 to 0.2 g/ℓ in Sweden were not unequivocal. Alcohol-related fatalities decreased to some extent, but this could be fully explained by the sharp increase in police surveillance following the lowering of the limit. A lowering of the limit in Portugal had to be reversed only months after its introduction. On the other hand, since 1992, SWOV has clearly advocated a 0.2 g/ℓ limit for young and inexperienced drivers. There are two important reasons for this:
1. For car drivers under 25 years of age with a BAC between 0.2 and 0.5 g/ℓ, crash risk increases as much as for older drivers with a BAC between 0.5 and 0.8 g/ℓ (Noordzij, 1976).
2. Young male car drivers are strongly over-represented both as victims and as instigators of serious alcohol-related road crashes.

Since 1997, a third argument has evolved. In Austria, the number of novice drivers involved in alcohol-related serious injury crashes decreased by 16.8% after a legal BAC limit of 0.1 g/ℓ was introduced for them

(Bartl et al., 1997). This was enough evidence for the European Transport Safety Council (ETSC, 1997) to recommend a similar measure for all EU countries. In the Netherlands, a 0.2 g/ℓ limit for novice drivers was introduced on January 1st, 2006.

Legal limits for *drugs* do not yet exist in the Netherlands although they can be found in its neighbouring countries, Germany and Belgium. Dutch law stipulates that it is prohibited to drive under the influence of any substance, such that the driver no longer has proper control over the vehicle. Until recently, it had often been difficult for the police and public prosecutors to produce the evidence. In most cases, the driver had to have caused a crash or have exhibited dangerous driving behaviour. However, a ruling of the Dutch High Court of December 2004 has significantly alleviated the burden of proof (*onus probandi*) for public prosecution. The High Court ruled that a driver can also be prosecuted and convicted based on toxicological analysis together with a corresponding expert judgement regarding the effects on fitness-to-drive.

Due to the absence of legal limits, drug driving convictions are still rare in the Netherlands. Drug users can be more easily dealt with through *administrative measures* (see *10.3.5*), that is, revoking their driving licences. Whether or not this is effective without additional rehabilitation has not yet been fully investigated.

10.3.2. Police enforcement

At the same time as the legal 0.5 g/ℓ *alcohol limit* was introduced, Dutch police were issued with equipment to measure alcohol levels. For detection purposes, chemical test tubes were used, and for evidential purposes, a blood test (and in rare cases a urine test). As a result of the publicity associated with the amendment of the law, Dutch road users perceived for a while that the risk of being apprehended if they offended was almost 100%. Shortly after the introduction of the law, only 1% of the car drivers were over the 0.5 g/ℓ BAC limit during weekend nights. Before the introduction, this was no less than 15%. When, after a while, it became clear that the risk of being apprehended was not so high, old behaviour was to a large extent restored, but nevertheless a significant effect remained. In 1977, the proportion of offenders was about 12%, and this remained the same until the mid-1980s. In the intervening period, the level of enforcement changed only slightly, and annual publicity campaigns had no noticeable positive effect on drinking and driving. Between the mid-eighties and the beginning of the nineties, enforcement levels gradually increased, supported by the subsequent introduction of:

1. electronic screeners to replace the expensive and unreliable chemical test tubes (since 1984);
2. evidential breathalysers to replace the time consuming and expensive blood test (since 1987);
3. fines immediately imposed by the police (since 1989), to relieve the public prosecutor and the courts.

In line with the increased enforcement level, the proportion of offenders started to decrease again, generally by a quarter with each doubling of the enforcement level. The (temporarily) lowest level of drink driving was reached in 1991 and 1992 at 4% of offenders during weekend nights. A temporary end to this positive trend came when the Dutch police force was restructured, which led to a considerable decrease in enforcement levels in 1993 and 1994, and to an increase of a quarter in the proportion of offenders (5% during weekend nights). A gradual restoration of enforcement has occurred since 1995, and the number of offenders has stabilized around 4.5%. The setting up of regional traffic enforcement teams, since 2001, gave a new impetus to drinking and driving enforcement, which has roughly doubled. It is estimated that the police tested around 2 million road users for alcohol in 2004. This again resulted in a decrease of the proportion of offenders to around 3.5% in 2004 (AVV, 2005).

Publicity around intensified enforcement played an important role in the pace at which behavioural changes came about. The introduction of the alcohol law of 1974 and the introduction of electronic screeners in the eighties generated much publicity, and resulted in the swift (over-)reaction of the public. A significant increase in police enforcement in the city of Amsterdam (since 1995) was accompanied by little publicity, and led to a very gradual but also substantial decrease in drinking and driving in the long run. Between 1994 and 1998, the proportion of offenders during weekend nights decreased from 7.8% to 4.7%; in other parts of the Netherlands, change has been negligible during this period (Mathijssen, 2005).

Dutch police are poorly equipped for detecting *drug use*. This is related to the lack of legal limits but also to the fact that, until recently, no acceptable screening methods were available. Blood tests are not usable for roadside detection. Urine tests are difficult to perform and prone to fraud; they violate the integrity of the human body, and they are likely to produce many false-positive readings particularly for cannabis, which is by far the most widely used drug. For the near future, hopes are pinned on saliva tests, which have developed rapidly in the past few years. They can easily be used at the roadside, they are less prone to fraud compared to urine tests, and they produce less false-positive readings. Sensitivity to some drugs is not yet all that it should be, but the question is whether or not this disadvantage outweighs all the advantages mentioned. For evidential purposes, the police can already demand a blood test and in exceptional cases a urine test, based on suspicion of drug use.

10.3.3. Campaigns and education

Since the introduction of the alcohol law of 1974, mass media publicity campaigns are held every year in the Netherlands to point out to the general public the risk of *drinking and driving* and the possibilities of separating drinking from driving. Since the early 1990s, drinking and driving education has been incorporated reasonably well into driver training and into secondary and tertiary education. Self-reported public tolerance of drinking and driving is low (Sardi & Evers, 2004).

The effects of campaigns and education on drinking and driving are difficult to measure. In periods with an unchanged enforcement level, no directly measurable changes in drinking and driving occurred as a result of publicity campaigns or education programmes. However, this does not mean that campaigns and education should be abandoned. These instruments contribute demonstrably to increasing knowledge and changing attitudes, and consequently to the acceptance of unpopular though effective measures such as stricter enforcement. The 'BOB campaign', running since 2001 in the Netherlands, scores exceptionally highly in terms of reach, acceptance, knowledge increase and attitude change. The concept of the campaign, which was copied from Belgium, is that of the designated driver. Before friends go out for an evening drink together, a driver is designated who promises not to drink any alcohol. The proportion of drink drivers decreased by 15-20% between 2001 and 2004 (AVV, 2005), although this can also be fully explained by the doubled level of enforcement, based on thirty years of SWOV research into drinking and driving. A direct influence of the BOB campaign on drink driving cannot be demonstrated. However, publicity campaigns such as the BOB campaign can contribute to reinforcing (internalizing) desired behaviour. Evidence for this can be found in the Netherlands particularly in the 1990s when despite a large decrease in police enforcement, driving under the influence of alcohol increased only slightly.

Very little is known in the Netherlands about the risk of driving under the influence of *drugs and psychoactive medicines* (particularly sleeping pills and tranquillizers). There are no mass media campaigns, and the brochures that exist are not widely distributed and do not always contain useful and correct information. This is, without any doubt, due to the lack of knowledge about the crash risks associated with the use of drugs and (prescribed) medicines. The earlier mentioned study carried out in the Tilburg police district has provided much new information. Multi-drugs users have a 25 times higher severe injury risk than sober drivers. The highest risk, however, is associated with the simultaneous use of drugs and alcohol. Car drivers who combine drug use with a BAC above 0.8 g/ℓ have a 100-200 times higher risk than sober drivers.

Users of codeine (for severe colds and coughing) and benzodiazepines (sleeping pills, tranquillizers and anxiolytics) seem to have a slightly elevated injury risk. However, it is not clear if this is caused by their illness or by their use of medicines. It is possible that untreated patients run a higher risk than users of prescribed medicines. In an experimental study at the University of Maastricht (Schmitt et al., 2005), evidence was found that depressed subjects who use antidepressants display better driving skills than untreated subjects. Nevertheless, the antidepressant users were less able to drive than healthy subjects.

The use of benzodiazepines is strongly correlated with age and gender, and is concentrated in females over fifty years of age. Given the ageing Dutch population, it is important to find a definite answer to the question of whether or not prescribed medicines lead to increasing risk. The European Commission is engaged in setting up such research and the pharmaceutical industry has also contributed to the reduction of medicine-induced traffic risks. Meanwhile, many dangerous benzodiazepines have been replaced by less dangerous alternatives and the same holds for antidepressants. Users of (tricyclic) antidepressants showed no increased risk at all in the Tilburg research.

10.3.4. Prosecution and penalties

Novice drivers in the Netherlands are prosecuted for drinking and driving above a BAC of 0.22 g/ℓ, other drivers from a BAC of 0.54 g/ℓ. Prosecution limits have been set somewhat higher than the legal limits in order to minimize the risk of wrongful conviction due to measurement errors.

Penalties in the Netherlands depend on the BAC level, repeat offence, and the level of danger (type of vehicle, dangerous driving, causing a crash). Currently, the lowest fine is € 220 which the public prosecutor sets for offenders with a BAC up to 0.8 g/ℓ. The fine can amount to up to 1000 Euros, and can be accompanied by driving licence suspension (up to 10 months unconditionally). In the most extreme cases, judges may, in addition to licence suspension, impose a prison sentence. Public prosecution guidelines do not yet explicitly refer to the combined use of alcohol and drugs.

Compared to other European countries, penalties for drinking and driving are relatively mild in the Netherlands. Whether more severe penalties would result in a substantial decrease of offences is, nevertheless, disputable. In any case, a substantial increase of fines in 1992 did not result in a reduction of drinking and driving, but this may be due to the fact that not much publicity was given to the measure. However, there are clear indications that the severity of penalties is a less influential factor than the risk of being apprehended. A comparison between the situation in the Netherlands and Belgium also points in this direction. In 2003, the proportion of drinking and driving offenders in Belgium was about twice as high as in the Netherlands (Vanlaar, 2005), whereas the severity of penalties was comparable. Police enforcement was, however, at a considerably lower level in Belgium.

10.3.5. Administrative measures: rehabilitation and disqualification

Rehabilitation and disqualification of drinking and driving offenders in the Netherlands have been dealt with through administrative measures that can be imposed by the Minister of Transport, without judicial intervention. The actual execution of these measures is in the hands of the Dutch Driving Test Organisation CBR, based on police reporting.

The Educational Measure Alcohol and traffic (EMA) is one such administrative measure. EMA comprises a three-day course imposed on first offenders with a BAC between 1.3 and 1.8 g/ℓ, and on repeat offenders. In 2003, the lower limit for novice drivers was set at 0.8 g/ℓ. EMA participants have to pay the total cost of the course (more than 500 Euros). A study into the effectiveness of EMA showed increased knowledge about drinking and driving, but no effect on recidivism (Vissers & Van Beekum 2002). A more up-to-date study by DHV (2004) came to the conclusion that EMA can save four to six alcohol-related fatalities annually.

Another administrative measure is the revoking of driving licences following a medical/psychiatric assessment of fitness-to-drive. The assessment is imposed on first offenders with a BAC of 1.8 g/ℓ or higher and on repeat offenders who do not qualify for EMA. Large-scale licence suspension or revocation may have a general preventative effect but the extent of this effect has never been established. What has been established is that disqualification does not prevent some people from continuing to drive.

While a penalty/demerit point driving licence system is being prepared in the Netherlands, great doubts have arisen in France about its effectiveness. In 2003, French police caught more than 20,000 disqualified drivers, and concluded that in total there are some hundred thousands of them driving around. According to some, this is not such a large problem because disqualified drivers will think twice before committing serious offences that run the risk of being detected by the police. Unfortunately, this is not proven in practice. Research from the United States and Canada shows that drinking and driving offenders whose driving licence has been revoked, commit repeat drinking and driving offences twice to three times more often when compared with offenders who are allowed to drive an alcolock-equipped vehicle (Bax et al., 2001). In Sweden, it was observed that for participants in alcolock programmes, the decrease in repeat offending was as high as 90% (Bjerre, 2003). After these results became known, a legislative bill was proposed in Sweden to make alcolocks compulsory in all new passenger cars from 2012.

10.4. Possibilities for effective new policy

To be able to execute an effective policy against the negative effects of alcohol and drug use in road traffic, we first have to identify the most important points of action. Subsequently, we have to look for the most effective measures with the best cost/benefit-ratio. The effectiveness and efficiency of new measures is often not well known. In this case it is wise to test these measures in small-scale or short time span experiments. If, in the end, a promising measure does not produce the expected result, it can be relatively easily withdrawn and replaced by a better one. This is much more difficult in full-scale experiments because of the many parties involved and the extent to which they have committed themselves. Withdrawing measures based on full-scale experiments could result in a loss of face.

10.4.1. Legislation: not sufficient for drugs

Dutch legislation on *drinking and driving* is generally well formed, and is recognized as exemplary in the EU. Nevertheless, this does not alter the fact that further improvements are possible, such as the recent lowering of the legal BAC limit for novice drivers from 0.5 to 0.2 g/ℓ. This law came into effect on January 1st, 2006. According to SWOV estimates (Mathijssen, 2005) this measure has the potential to save about ten fatalities and one hundred severe injuries annually. A concomitant advantage is that this measure can contribute to combating the combined use of alcohol and drugs, which is particularly prevalent in, and dangerous for, young males.

Current legislation concerning *drug-affected driving* does not make detection and prosecution particularly easy, while related road safety problems are increasing. These problems are predominantly caused by the combined use of several drugs or of alcohol and drugs. In the Tilburg police district this was the case in more than 17% of all severely injured drivers. The problem might be dealt with more effectively by setting the lowest possible legal limits for these combinations. Such limits are called *zero limits*, although they are in fact somewhat higher due to limitations in toxicological analyses. This efficiency could be counteracted if the zero limits were also introduced for drugs that are not used in combination. Epidemiological research carried out in various countries (Drummer, 1995); Marquet et al., 1998; Longo et al., 2000; Lowenstein & Koziol-McLain, 2001; Movig et al., 2004) came to the conclusion that users who do not combine cannabis, cocaine, amphetamines, or ecstasy with each other or with alcohol, do not experience much increased risk. The problem is greatest in effectively detecting cannabis users. In Tilburg road traffic, 4.5% of all drivers had used cannabis, but only 0.6% of them had also used other drugs and/or alcohol. Cannabis users were the largest group of drug users but also the group with the smallest proportion of combination users. In practice, however, problems of effectiveness need not occur if the police detect suspects by means of saliva tests, which have a relatively high sensitivity to cannabis. With these tests, cannabis users who are actually under the influence and/or have used cannabis very recently can be detected. Australian research into driver fatalities (Drummer et al., 2004) has shown that cannabis users are at considerably increased risk. If saliva tests are used to detect cannabis users, the likelihood of wrongful arrest is very low.

10.4.2. Enforcement: more selective police surveillance?

Drinking and driving has decreased significantly in the past decades, mainly through intensified police enforcement. However, the cost-effectiveness of considerable further intensification of such enforcement is questionable. In order to reduce the number of violators by a quarter, enforcement would have to be doubled. According to the law of diminishing returns, benefits will cease to justify costs after a certain point, and new ways will have to be found to produce measures that are cost-effective. The fact that doubling enforcement between 2001 and 2004 had no noticeable effect on extreme offenders, suggests an urgent need for new surveillance strategies. Since about three-quarters of all serious alcohol crashes are caused by a small group of drivers with a BAC above 1.3 g/ℓ, attempts should be made to increase considerably their (perceived) risk of being apprehended. This could be achieved by dedicating part of police capacity (say 20%) to drinking and driving enforcement targeted at heavy drinkers. Heavy drinkers are likely to be found near restaurants, bars and sports club canteens, particularly around closing time. It would be sensible to introduce such a change gradually in a few police jurisdictions on an experimental basis. Raising public awareness of more strict police surveillance of high-BAC drivers would be important, but of course specific times and places of enforcement activities should not be announced. This would only lead to a lowering of the perceived risk of being apprehended, and therefore just encourage drinking and driving at other times and places

Drug driving enforcement is still in its infancy, mainly because current legislation prevents effective and efficient detection and prosecution. Present knowledge of crash risk as well as the availability of non-invasive detection methods such as saliva tests, seem to offer opportunities for new, and better legislation regarding screening for drug use. Saliva tests do not (yet) allow large-scale random roadside testing as is the case with alcohol. This is because saliva tests take between ten and fifteen minutes to conduct and cost between ten and twenty Euros. A more selective test strategy that targets crash scenes, suspicious or dangerous driving behaviour or places where numbers of drug users congregate, can, nevertheless, have a specific deterrent effect by increasing the perception of risk of being apprehended. When accompanied by sufficient publicity, a general deterrent effect can also occur for all road users.

10.4.3. Campaigns and education: BOB appreciated, drugs underexposed

The mass media BOB campaign seems set to continue for a little while longer. The campaign and linked regional and local actions on *drinking and driving* are highly successful in the sense that young people are particularly attracted by it. In this way, the campaign can play a positive role in forming habits around alcohol use and participation in road traffic. It is easier to learn good habits than to try and break bad habits. The quality and quantity of drinking and driving education in (driving) schools seems variable. Little is known about its effectiveness, but the opportunities for increasing knowledge of the subject are greater here than in mass media campaigns. Therefore, it is important that teachers and instructors are properly motivated and their skills and knowledge are brought up to standard or improved.

To date, mass media campaigns addressing *drug-affected driving* have not been conducted, mainly because its quite disastrous effects were not well known until recently. For the same reason, existing information material is not particularly useful. This indicates room and opportunity for improvements to be made. The risks of multi-drug use and the combined use of drugs and alcohol merit a particularly important place in information and education. Patients could perhaps be better and more systematically informed about the use of psychoactive drugs by the pharmaceutical industry, health care professionals and pharmacists. In particular, the latter two groups need to be better informed about the risks and the conditions in which these risks occur. Information such as: "Use of this medicine may lead to deteriorated reaction and concentration", "Many daily occupations (such as road use) may be impeded" (Pharmacotherapeutic Compass) or "This medicine may impede driving skills" (the 'yellow sticker') are far too vague. Moreover, the yellow sticker is used far too widely, whereas the red sticker with the text "Do not operate a vehicle when using this medicine" is hardly ever used.

10.4.4. Prosecution and penalties: two bookings and you're out?

Because of the extremely high crash risk associated with the combined use of alcohol and drugs (or psychoactive medicines), we recommend that this combination is included explicitly as an aggravating condition in the guidelines for the prosecution of driving under the influence offences. The intended introduction of licence revocation in case of drinking and driving recidivism within a five-year period ('two bookings and you're out') may have a deterrent effect on repeat offenders. It is difficult, however, to estimate the size of that potential effect. On the other hand, licence revocation may turn out to be a paper tiger, since it is much less effective in preventing repeat drinking and driving than having the offender take part in an alcolock programme (see *10.4.5*). Therefore, it is desirable that judges receive the authority to rule that recidivists participate in an alcolock programme instead of being obliged to use the harsh and unconditional licence revocation.

10.4.5. Administrative sanctions: introducing the alcolock?

An alcolock is a breathalyser that is connected to the ignition system of a motor vehicle and that functions as an immobilizer. It prevents a driver from starting the vehicle if his BAC exceeds a predetermined level. The alcolock is seen internationally as a promising means of combating drinking and driving, particularly repeat offences. In the United States, Canada and Australia, tens of thousands of drink driving offenders are already using vehicles with alcolocks installed. In Europe, only Sweden and Finland have introduced alcolocks and only to a limited extent, but experiments are being carried out in various other countries. There are several research studies that show the use of alcolocks results in 65-90% less repeat offending than licence suspension or revocation. From these studies, recommendations can be derived for the successful application of an alcolock programme in the Netherlands (Beirness & Robertson, 2002):

- In order to achieve a high level of participation, alcolock programmes have to be *mandatory*. This means in practice that the offender can only get his full driving licence back after successfully completing the alcolock programme.

– Alcolock programmes should be part of *administrative law* and should be administered by the licensing authority. In the United States, the courts were not able and/or willing to execute a consistent prosecution and sentencing policy, and to enforce compliance with court orders. However, this should not prevent judges from sentencing offenders to mandatory participation in an alcolock programme.
– *Driving licences* should record that the driver may only drive an alcolock-equipped car. Otherwise, police enforcement is unduly hampered.
– *Compliance* with the programme requirements needs to be enforced properly. This is achieved by regularly, i.e. monthly, checking the alcolock system for (attempted) fraud, and by simultaneously downloading and analysing data from the alcolock's data recorder.
– *Contents and duration* of the programme need to be flexible and tailored to specific target groups. This is not only important for an effective outcome, but also for differentiating and lowering the cost of less serious cases.
– Attention needs to be given to the costs for indigent offenders.

An alcolock programme can easily be fitted into the Dutch system of administrative measures against drinking and driving. Following the example of Sweden, even alcohol-dependent drivers could be eligible to use an alcolock. The Educational Measure Alcohol and traffic (EMA) procedure that is currently followed by offenders with a BAC between 1.3 and 1.8 g/ℓ, could then be reserved for drivers with a somewhat lower BAC, e.g. between 1.0 and 1.3 g/ℓ. Mandatory participation in an alcolock programme could then be demanded from serious and repeat offenders, and reinforced by licence revocation. A conservative estimate suggests that this could save 35 to 40 alcohol-related fatalities per year. This leaves the four to six fatalities saved by EMA (see *10.3.5*) far behind. The costs of a two-year alcolock programme are estimated at about 3,000 Euros, about six times the cost of a three-day EMA course. In short: an alcolock costs extreme drinking and driving offenders money, but they certainly receive something in return.

Finally: in sustainably safe road traffic, no road users are under the influence of alcohol and drugs. Many ways have been reviewed in this chapter to achieve this objective and yet the question remains. In the long run, could this objective be achieved without an alcolock in every motor vehicle?

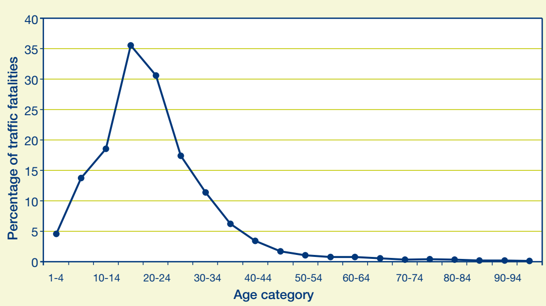
11. Young and novice drivers

11.1. Young people and Sustainable Safety

Man is the measure of all things in Sustainable Safety. However, the human measure is not the same for all road users. There is no such thing as a 'norm-person'. The measure of things is clearly different for young people who are taking part in road traffic for the first time, independently and in new roles (as a cyclist, moped rider or car driver), than for older, more experienced road users (see *Frame 11.1*). We define young people in this chapter as being between 12 and 24 years of age. We have chosen this age category firstly because truly independent road traffic participation with a means of transport starts around the age of 12 (first time by bicycle to secondary school), and secondly, because socially and psychologically children become young people around this age. Until the age of 25, new traffic roles are regularly experienced, and from the viewpoint of developmental psychology, 'true' adulthood is reached at the age of around 25 years.

Traffic is the prime death threat to young people

The figure below shows by age category the percentage of all people killed in the Netherlands in 2003 in a traffic crash (source: Statistics Netherlands). Of young people between the age of 15 and 20 years, a little over 35% were killed in road traffic. This makes traffic the largest cause of death for this age category.



Frame 11.1

11.2. High risks that decrease slowly

In the Netherlands, the casualty risk (expressed in casualties per kilometres travelled) is considerably higher for young people than for children and adults. *Figure 11.1* represents the average number of traffic casualties in the years 2001, 2002 and 2003 by age per billion person kilometres (made up of fatalities, hospital admissions and injuries). Person kilometres on the road are travelled in different transport modes (bicycle, car, bus etc.) and in different roles (driver/rider, passenger). It is interesting to distinguish the development of crash risk of the driver/rider role – in which we consider pedestrians also as 'drivers' – from the role of passenger. That is why *Figure 11.1* also depicts the number of casualties per billion driver/rider kilometres and passenger kilometres separately, as well as the number of casualties per total kilometres travelled.

The graph shows the casualty risk for 12 to 24-years olds as independent road users to be relatively high. After a decrease in middle age, risk again increases as people become older. Fifteen to 17-years olds, in particular, run an exceptionally high risk. Young people also run a comparatively high risk as passengers, though the passenger risk peaks at a slightly older age (18-19 years). This peak is also considerably lower.

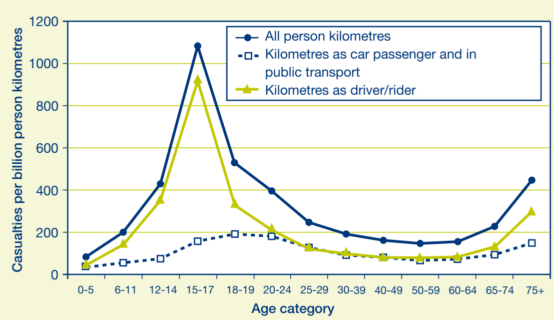


Figure 11.1. ***Average number of casualties (killed, hospital admissions, injured) in the years 2001, 2002 and 2003 per billion person kilometres (all person kilometres, kilometres as passenger and kilometres as independent road user). Sources: AVV Transport Research Centre and Statistics Netherlands.***

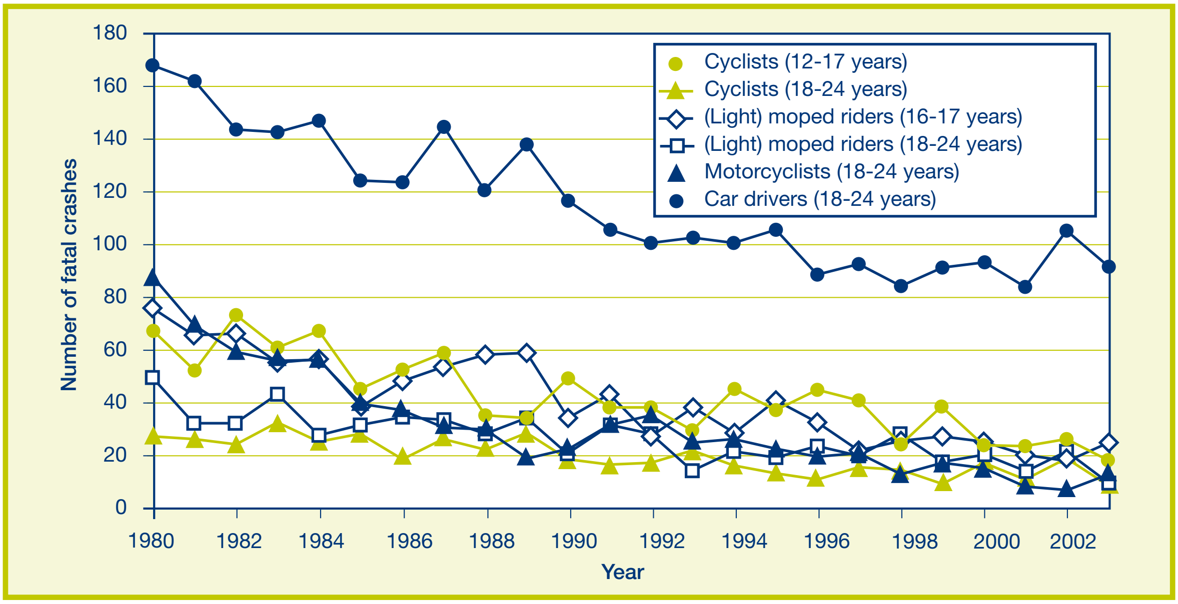


Figure 11.2. ***The development over time of fatal crashes for different groups of young people. Source: AVV Transport Research Centre.***

Figure 11.2 shows the development over time of the absolute number of fatalities among young people by traffic role.

For all traffic roles, involvement in fatal crashes decreases gradually over the years, although the decrease is larger for specific roles. However, we can also see that the decrease gradually levels off over the years for almost all traffic roles (ignoring yearly fluctuations). Furthermore, it is significant that young car drivers, in particular, are involved in large numbers of fatal crashes. *Figure 11.3* depicts the same as *Figure 11.2*, but shows the involvement of crashes with one or more injured persons requiring hospital admission.

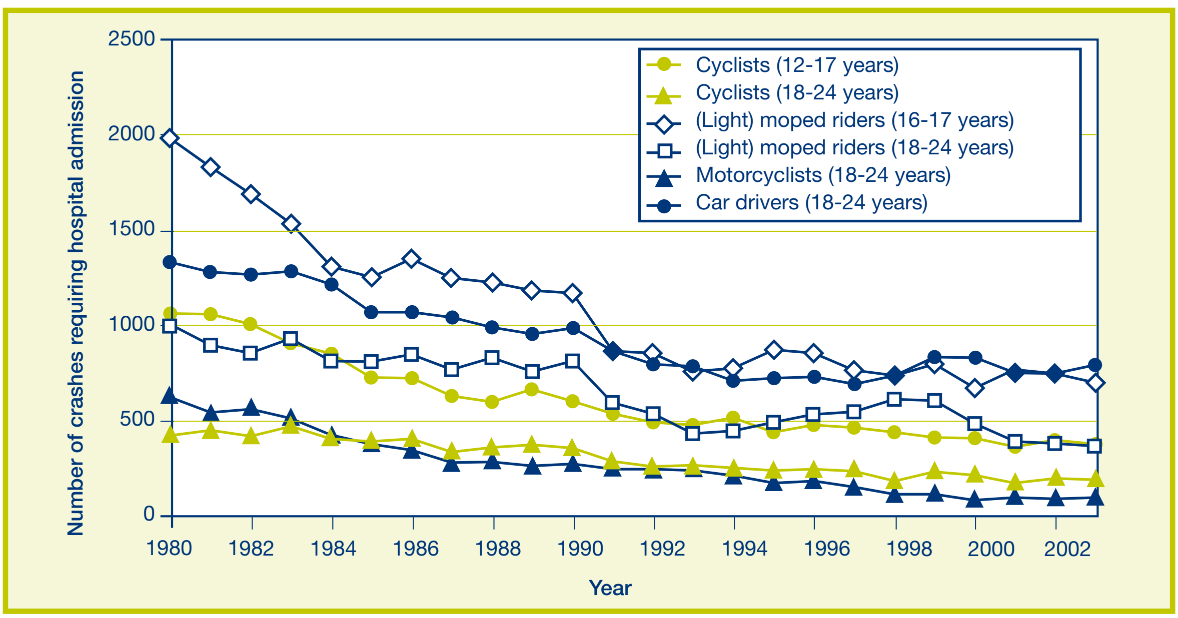


Figure 11.3. ***The development over time of crashes requiring hospital admission for different groups of young people. Source: AVV Transport Research Centre.***

Figure 11.3 shows even more clearly than *Figure 11.2* the decrease and also the levelling off. In *Figure 11.3* the high number of young moped riders (16-17 years of age) involved in crashes requiring hospital admission is significant.

The gradual decrease in crash involvement in *Figures 11.2 and 11.3* may be due in part to young people travelling fewer vehicle kilometres, but may also be due to improved road user behaviour and/or improved safety of their vehicles and/or safer roads to travel on. It is doubtful if the behaviour of young people has improved over the years. Unfortunately, the sample of young people driving or riding certain vehicles in the national mobility surveys is so small that the mobility data for young cyclists and moped riders are not very reliable. It is, therefore, not possible to establish the crash risk of these young road users with absolute certainty. Mobility data for young car drivers 18 to 24 years of age are, nevertheless, sufficiently robust. *Figure 11.4* shows the relative risk for young (18 to 24 years of age) car drivers of being involved in a fatal crash compared to older car drivers (30 to 59 years of age), per kilometre travelled.

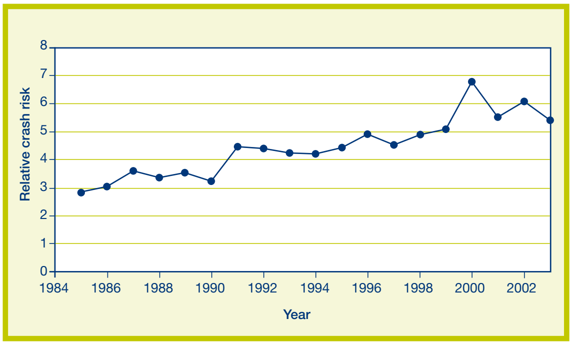


Figure 11.4. ***The fatal crash involvement risk per kilometre of 18 to 24-years old drivers compared to that of 30 to 59-years old drivers in the period 1985-2003. Values higher than 1 indicate higher risks for young drivers. Sources: AVV Transport Research Centre and Statistics Netherlands.***

The graph shows that the relative crash risk of young car drivers is growing steadily. In 1985, the risk of being involved in a fatal crash for young car drivers was about 3 times higher than the risk for older, more experienced car drivers, and by 2003 this has gradually grown to 5.5 times as high. Whereas the total number of fatal crashes decreases (*Figure 11.2*), relative risk increases (*Figure 11.4*). From this we can see that young car drivers benefit far less from safer roads and vehicles than older car drivers. The increase in relative crash risk can be almost completely attributed to young male drivers. The cause for this could lie in an increase of young male drivers whose lifestyle and behaviour in road traffic invite risk. We recommend that further research is carried out in this area.

11.3. Causes: a combination of age, experience and exposure to danger

Several causes can be given for the high crash risk of young people in traffic. These causes can be classified into three categories: age characteristics of young people, lack of experience in a given traffic role and the exposure to dangerous conditions.

11.3.1. Age-specific characteristics

The ages between 12 to 24 years embrace puberty (that nowadays starts around the age of 10), adolescence and early adulthood. In the first of these phases in developmental psychology, puberty, people begin 'to sow their wild oats'. This peaks in the adolescence phase around the age of 16/17, and subsides gradually in the phase of early adulthood. Characteristic of these 'wild oats' are: the major influence of friends and peer groups, the need for exciting events, the desire to experiment, the desire for adventure, opposition to the existing norm (wanting to be independent from parents), having the idea that nothing can happen to you, overestimation of one's own capacities, and emotional instability (or in German: *Himmelhoch jauchzend, zum Tode betrübt*: Rejoicing from the heavens, until death in grief).

Not all age-specific characteristics occur in each of these three phases with the same intensity. In the adolescent phase, in particular, motorized road use is not only a way to go quickly and comfortably from point A to point B, but is also a way to express oneself and to let off steam.

Of course, not every young person's behaviour is affected to the same degree. However, on average, boys are more affected than girls. A *biological cause* that is often given as an explanation for this difference is the sharp increase in the production of the hormone testosterone in boys. For boys, testosterone levels around the age of 16 can be up to twenty times as high as just before puberty. Testosterone levels in girls also increases from pre-puberty to adolescence but only quadruples (Arnett, 2002). It has been proved that an increase in testosterone levels can increase aggressiveness.

The development of the brain also plays a role. There is an area just below the side of the frontal cerebral cortex (the *dorsolateral prefrontal cortex*), that has the function of retrieving stored data from the emotional and autobiographical memory. It also 'keeps things in mind: to form plans and ideas, and to make decisions (think first, then act), and suppresses other impulses. This part of the brain is only fully developed around the age of 25 (Giedd, 2004; Gogtay et al., 2004). A well-developed dorsolateral frontal cortex is a prerequisite for the development of what are called 'higher-order skills'. This comprises for exemple the ability to focus attention on objects and events in traffic that are relevant for road safety, the ability to judge traffic situations, and the ability to adequately predict at an early stage how traffic situations may develop. Hazard perception is an example of a higher-order skill, and so is the ability to arrive at a realistic estimation of one's own competences and to adapt to the task load accordingly. The most skilful road user is not always the safest road user. The point is to engage in only those tasks in traffic that have been effectively mastered, and to avoid risks. Someone who is less skilful but who does not overestimate his or her capacities participates more safely in traffic than someone who is more skilful but overestimates his or her skills. Adapting traffic tasks to skills is called calibration (see *Chapter 1*). However, we may not conclude that young people cannot learn higher-order skills because their brains have not yet fully developed in a certain area. There is an interaction between innate or inherent personal characteristics, and influences from the environment to which that person is exposed. If young people are offered the correct conditions (e.g. in a training situation) it is possible for the maturing process of the dorsolateral frontal cortex to speed up. However, it seems plausible that there are limits to the higher-order skills very young novice drivers can learn.

Not only biological factors play a role in age-specific characteristics, there are also *socio-cultural factors*. Swedish research (Gregersen & Berg, 1994) showed that the crash risk of young people with certain lifestyles is higher than that of young people with other lifestyles. 'Yuppies' with a 'sportive' driving style and entertainment-seeking types have a higher crash risk than young people who consider car driving and going out not to be important. Qualitative research among young people between the age of 13 and 18 years into the significance of moped riding (Nelis, 2002) shows that clearly distinct lifestyles can be distinguished below the age of 18. It is certainly possible that, as mentioned before, the increase in relative crash risk as presented in *Figure 11.4* is caused by the growth in certain lifestyles with higher increased crash risk. According to Woltring (2004), commercials probably play a role in the development of lifestyles. On the one hand, young people are being exposed to commercial information that encourages them to behave responsibly in traffic (e.g. the dedicated driver BOB campaigns), but on the other hand there is far more advertising that presents a fast and carefree lifestyle with 'sporty driving behaviour' which aims to stimulate young people to purchase mopeds, motorcycles and fast cars.

It is not clear if *ethnicity* is an explanatory factor for high crash risk in young people. A number of research studies show above average crash risks for young people from some ethnic groups (Thomson et al., 2001), with the immediate caveat that it is almost impossible to disentangle the effect of ethnicity from other factors such as socio-economic position and exposure (for example, children of immigrants often live in neighbourhoods with less safe roads when compared to neighbourhoods where no immigrants live). Blom et al. (2005) investigated the relationship between ethnicity and criminality. This research showed that young people aged between 18 and 24 years of foreign descent are suspected of a crime twice as often as indigenous people of the same age group. For traffic violations, this relationship is just the opposite. Here, indigenous people in this age category are suspected of a traffic violation 1.5 times more often than young people of foreign descent. We need to be aware that the relatively low number of traffic violations of foreign young people may be caused by the fact that they travel less in term of vehicle kilometres.

11.3.2. Lack of experience in new traffic roles

Between the ages of 12 and 24 years, young people need to familiarize themselves with new traffic roles. Despite the fact that virtually all Dutch can ride a bicycle at the age of 12 (at least in the Netherlands), going by bicycle to school independently is a new experience. This often involves a distance of a few kilometres. An estimated 13% of all young people at the age of 16 (legal limit to ride a moped) use a moped or light moped as their most important transport mode. After turning 18 and obtaining a driving licence, driving a car is possible. The 'initial risk' is high when entering each new traffic role. Of course this is not only the case for new traffic roles between the ages of 12 to 24 years, but also for earlier ages (first time walking on the street without parent's company or the first time alone riding a bicycle). As people gain more experience in a new role, crash risk decreases. This rate of decrease is high at first, but levels off gradually. This can be seen in *Figure 11.5* which shows the crash risk for drivers who began to drive a car at the age of 18 years (Vlakveld, 2005).

Figure 11.5. ***Crash risk and years of driving experience of car drivers who received their driving licence at the age of 18. Source: Periodic Regional Road Safety Survey data 1990 to 2001.***

On the basis of these data, crash risk trends can be described for people who obtained their driving licence at later ages. *Figure 11.6* gives the results. For clarity, only the trend lines are presented.

The curves represent the combined effect of age and experience on crash risk. The line that connects the peaks of the four curves represents only the age effect. From *Figure 11.6* we can derive the view that

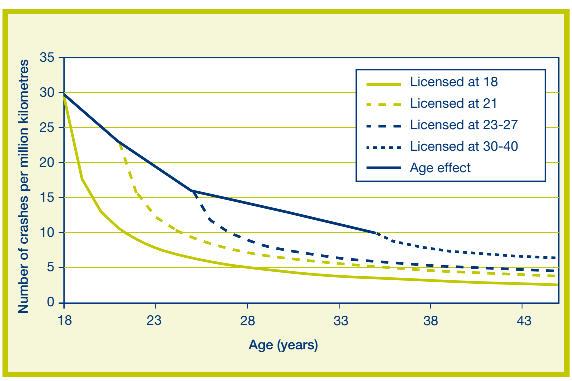


Figure 11.6. ***Decrease in crash risk for car drivers licensed at the age of 18, and for car drivers who started driving at a later age. Source: Periodic Regional Road Safety Survey data 1990-2001.***

for car drivers who started at the age of 18, around 40% of the reduction in crash risk can be attributed to the age effect, and around 60% to the lack of driving experience. Nevertheless, we have to keep in mind that *Figure 11.6* shows trends that may, in reality, be different. People make a decision to obtain their driving licence at an early or at a later age. Differences in personality characteristics between relatively young novices and relatively old novices may also have contributed to the differences in initial crash risks.

The high crash risk due to lack of experience at the start of each new traffic role has to do with a lack of basic skills (driving/riding and operating the vehicle) and, moreover, to a lack of higher-order skills (traffic insight, self-understanding, hazard perception, see *11.3.1*). In the very beginning of a new role, control over the vehicle is not all it should be. Though people may be able to operate and drive/ride the vehicle, it takes a comparatively large amount of mental effort. This makes vehicle control slow and sensitive to error. In the process of gaining driving experience immediately after obtaining a driving licence, vehicle control increases rapidly (Sagberg, 1998). If vehicle operation and control can be executed more or less automatically (after about 5,000 kilometres), this does not necessarily mean that driving will be as safe as that of drivers who have been driving for a couple of years. This is due to a lack of higher-order skills. It is proven that these higher-order skills improve with driving experience (Senserrick & Whelan, 2003). This happens much more slowly than in the acquisition of basic skills such as vehicle control. It takes about seven years of driving experience to bring the crash risk down to a stable, low level. The exact details of higher-order skills acquisition are still not fully understood.

11.3.3. Exposure to danger

People are vulnerable on a bicycle and moped because these vehicles offer virtually no protection. Since the speed of a moped can be fairly high, the crash risk of moped riders is relatively high (see *Chapters 2 and 3*). In this connection, it is remarkable that around the age when young people are 'sowing their wild oats', they can take part in motorized traffic with a vehicle that offers hardly any protection. To the extent that protection is possible, not all moped riders use it. Around 10% of moped riders and around 25% of all moped passengers do not wear a crash helmet (Van Velzen et al., 2003).

Passenger cars offer more protection but even in cars young drivers are more vulnerable than older drivers. When young people drive their own car (i.e. not their parent's car or a hire car) these are often older and offer less primary and secondary safety features even if they have passed the periodical vehicle test. However, it is not only the vehicles that increase risk but also the way in which they are used. Novice drivers often drive in conditions that are difficult for any driver. They drive more often at night (worse visibility and fatigue) and with distracting passengers. Although young drivers are, comparatively speaking, not the most frequent drink drivers, the influence of alcohol on young, inexperienced drivers is more devastating than on older, more experienced drivers (see also *Chapter 10*). Drug use is also more prevalent among young people. In the case of combined use of drugs and alcohol, crash risk is extremely high.

11.4. We can do something about it!

The number of road traffic crashes involving young people, can be reduced by decreasing their crash risk and/or by lowering their exposure to danger. Crash risk can be decreased by improving young people's competences and task capabilities (see *11.4.1*). Lower exposure to danger can be established by less exposure to travel (person kilometres) and by lowering task requirements (see *11.4.2*). From Fuller's task capability model (Fuller, 2005; see *Figure 1.3*), we can derive the action points to improve road user behaviour and the requirements for this behaviour.

11.4.1. Improving competences and task capabilities

A competence is the combination of knowledge, skills, attitudes and personality traits that people use to function according to the requirements of a specific context. In this case, the context is traffic. How well people use their competences depends on their psychological and/or physical condition. For example, one can be a highly skilful driver (possessing many competences) but under the influence of alcohol drive dangerously. What remains of the competences, given the psychological and/or physical conditions of the moment, is called task capability.

Competences increase with experience and education. The workings of this process in education have been discussed in *Chapter 7*. A good opportunity to gain experience in protected conditions is offered by the graduated driving licence. A graduated driving licence (Senserrick & Whelan, 2003) aims to offer experience in such a way that the novice driver and other road users are exposed to a minimum of danger. As (higher-order) skills increase, experience can be acquired in more risky conditions. The aim is also to increase motivation to drive safely by removing limitations only when the driver has not committed any traffic violation and/or the driver has not been involved in a crash during a prescribed period of time.

A graduated driving licence usually has three phases. The first phase is the 'learner phase' in which only accompanied driving is allowed. Typically, the supervisor and the student need to keep a logbook of manoeuvres and performance. Often, mileage travelled also has to be recorded. In some graduated driving licence variants, people in the learner phase do not have to take driving lessons from a qualified driving instructor prior to or during this phase, but in other cases this is required. The duration of the learner phase can vary from six months to one year.

The learner phase is followed by an 'intermediate phase'. In some types of graduated driving licence, the student has to take a test before entering the intermediate phase, and in other types they do not have to. Where the test is not compulsory, evidence has to be produced that the student has driven a sufficient number of accompanied kilometres.

During the intermediate phase, students are allowed to drive unaccompanied, but only in conditions with a small crash risk. Prior to driving, the consumption of alcohol – even in the smallest quantity – is almost always prohibited in this phase. Often, there is also a curfew for driving at night, and driving with people of the same age as passengers. The duration of this intermediate phase varies greatly. In the United States, it lasts six months to one year, but in Australia it lasts for three years. The duration can be extended where the student has violated traffic rules and/or caused a crash. At the end of the intermediate phase, the student usually has to take a 'normal' driving test. This driving test is different from the current driving test in the Netherlands, and is aimed more at testing higher-order skills and often comprises a hazard perception test.

The 'provisional phase' follows the driving test. This phase operates under the same conditions as the current provisional licence in the Netherlands. This means that more stringent rules apply during the first years of licence ownership (e.g. concerning alcohol and a more punitive penalty/demerit point system) than for experienced drivers. If a traffic violation is committed, the offender may be required to take a compulsory course ('driver improvement training'), but they can also be put back into the previous phase of the graduated system. In all countries where the graduated driving licence has been introduced it has led to a decrease in crash risk for novice drivers. The level of decrease may be as high as 40%. Many different evaluation studies (Senserrick & Whelan, 2003) reveal that the efficiency of the graduated driving licence decreases when fewer elements are integrated into the graduated driving licence system.

Accompanied riding/driving is not possible for motorized two-wheeled vehicles. However, the intermediate phase can be used for motorized two-wheeled vehicles. Moped riders can start to gain experience on a light moped. A prerequisite is that the light moped engine must not be enhanced in any way. At the next stage, when the student is allowed to ride a moped, riding could be limited to relatively safe conditions (not in the dark, not with a passenger, and only in a restricted area). It is difficult for the police to enforce limitations in vehicle type and riding conditions; nevertheless the requirements are complied with to a reasonable degree in countries where a graduated licence has been introduced. This is because in this system parents are involved in training, and because the force of law helps parents to impose and check restrictions (Simons-Morton et al., 2002).

If it is not possible to bring the competences for a certain traffic role up to an acceptable standard, then selection has to take place. A well-known selection criterion is age (not being allowed to ride a moped under the age of 16, or drive a car under the age of 18). Bearing in mind age-specific characteristics (see *11.3.1*), the initial age for riding a moped should not be lower than 18 years. According to an estimate by SWOV in 2001 (Wegman, 2001), 35 traffic fatalities could be saved in the Netherlands annually by raising the age limit from 16 to 18 years. Of course, there are also driving/riding tests and medical examinations that offer selection criteria, and there is self-selection. Parents can, for instance, encourage their children not to ride a moped. This can be done e.g. by promising to pay for car driving lessons later if the idea of a moped is relinquished.

In order to prevent young people from reducing their task capabilities consciously (use of alcohol and/or drugs) and subsequently engaging in tasks that exceed their task capabilities (e.g. by speeding) we normally rely on police enforcement. When drivers/riders know that their actions are being monitored they are not inclined to violate deliberately even if the penalties are relatively low. Seen in this light, it is of benefit that mopeds in the Netherlands are fitted with proper licence plates.

Similarly, when people know that they are being monitored, they are less likely to behave excessively. This disciplinary effect can also be attained with devices that register and log behaviour, and which are frequently interrogated. This can be done by fitting novice drivers' cars with journey data recorders. The requirement to drive with such a device could be included in the provisions of the novice driving licence. However, the costs of this equipment (some hundreds of Euros) are considerable. Another possibility is a system that continuously registers vehicle speed together with the speed limit of the road. Such systems can be combined with navigation systems which are being fitted to cars with increasing frequency. We can also think of links with equipment that may be required in the future, as in, for example, charging for location and time dependent car use. Car manufacturers already fit cars with electronic data recorders (EDR) to control airbags (see *Chapter 5*). Such EDRs could be given additional functionality for registering and storing driving behaviour data. Fitting such equipment in novice drivers' cars during the second and third phase of a graduated driving licence would enable speed to be monitored. If a novice was found to be breaking the speed limit frequently, the decision could be taken to prolong the relevant phase of the graduated licence system.

In addition to these advanced methods, we also have regular police enforcement. However, it is not only the police that can help people to behave safely in traffic. Parents, peers and institutions to which young people belong (schools, sports clubs, employers, etc.) all have a role to play. The police cannot do much more than apprehend and punish, but parents, peers and institutions can also reward good behaviour. Novice drivers in Norway pay higher insurance premiums than experienced drivers, just as in the Netherlands, but when they have driven for five years without claiming, the difference in premiums is paid back to them (plus interest). Vaaje (1990) conducted research into the effect of this special form of no-claim for young novice drivers (18 to 22 years of age). Vaaje found that the number of damage claims during the first five years of holding a licence dropped by 35%. After taking into account the general decrease in the number of claims, a net decrease of 22% remained. Of course, we have to keep in mind that minor damage may have been kept quiet in order not to loose the no-claims rebate.

11.4.2. Lowering task requirements and decreasing exposure for young people

Although the crash risk of young car drivers has not decreased over the years and has even increased, crash involvement does decrease (see *Figures 11.3 to 11.5*). Twisk (2000) mentions the introduction of public transport passes for students as one of the most important explanations for this. The availability of this pass has motivated students to use the bus and train instead of using their own transport. We can expect that the number of casualties will reduce dramatically where reliable and cheap public transport for young people is made available (e.g. buses that run all night to or near entertainment centres). Safer choices of transport mode can also be stimulated in other ways, for example, parents can simply forbid their children to ride a moped or promise a reward if their children do not ride a moped.

Young people should be able to commute between home and school along safe roads. A sustainably safe infrastructure is essential for cyclists. Sustainably safe cycle routes are especially important because of the behaviour of adolescents (crossing streets impulsively and without looking, cycling with several people next to each other and not observing traffic).

11.5. Conclusions

Young people behave unsafely in traffic more often than other age categories. The causes for this are various (biological, social and psychological factors), and are not the same for all young people. We recommend an integral approach to tackle the problem.

Apart from measures that aim to reduce crash risk (safer road user behaviour, safer vehicles, safer roads), measures also exist that can reduce the mileage travelled by young people, in particular as a driver or rider in dangerous conditions.

Now more than in the past, the emphasis in education should be less on teaching basic skills and more on acquiring traffic insight and knowledge of one's own limitations (see *Chapter 7*). It is also important to adapt formal learning (e.g. during driving lessons) and informal learning (in gaining driving experience) to each other. This is possible in a graduated driving licence system, and this system fits very well within the Sustainable Safety vision.

In the area of information, we can think of a code of conduct for advertising that prohibits the relationship between a fast and carefree lifestyle and 'sportive' driving behaviour. As regards police enforcement, young people have to realize fully that road traffic is not the place to 'sow their wild oats'. If the risk of being caught is perceived as being high, then the number of deliberate violations and consciously taken risks will fall. The introduction of a 'proper' licence plate for mopeds in the Netherlands is a good first step, but this will only be of use if moped speed checks are actually carried out. In addition, monitoring and hence disciplining intelligent transport systems (ITS) in the vehicles of novice drivers will, when they are technically feasible and financially viable, bring about safer driving behaviour. Safety can be improved by rewarding desirable behaviour as well as penalizing undesirable behaviour. A possibility is a special, 'rewarding' no-claims rebate for novice drivers.

For decades, (young) moped riders have managed to tune up their moped's engines to make them go faster than the legal limit. It should be technically possible (by constructing a more or less solid engine block that cannot be taken apart) to make tuning up considerably more difficult. With regard to infrastructure, constructing and implementing safe cycle routes (to and from schools) and cycle paths remains of the utmost importance.

12. Cyclists and pedestrians

12.1. Walking and cycling – important transport modes

Walking and cycling are transport modes that take people unprotected through traffic with low speeds and mass. This makes pedestrians and cyclists vulnerable. By far, they suffer the most severe consequences in collisions with other road users because they cannot protect themselves against the speed and mass of the other party. Preventing collisions between fast and slow traffic is, therefore, one of the most important requirements for sustainably safe road use by pedestrians and cyclists. Other measures have to be sought in the 'disarmament' of the crash opponent.

For everyone, and particularly for young and old people, walking is an important form of travel. People aged over 75 years make one-third of their trips on foot (see *Table 12.1*). They use the car slightly more often (38%), but considerably less often than younger adults aged 25 to 74 years, who use this vehicle for more than half of their trips. The bicycle is considerably less popular for elderly people: they use the bicycle for only 17% of all trips. Together with people aged between 25 and 29, they use the bicycle the least.

The bicycle is more important in the youngest age categories. Children in the age group from 0 to 11 years travel by bicycle as often as they walk (both 29%). The same is the case for young adults aged between 18 and 24 years. Next to walking (20%) and cycling (23%), public transport (18%) is a commonly used mode of transport among them. For young people in secondary school (12 to 17 years of age), the bicycle is by far the most important vehicle: they use their bicycle for no less than 52% of all trips.

12.2. Large safety benefits have been achieved

When looking at past developments, we can draw some largely positive conclusions (see *Figure 12.1*). The number of pedestrian and cyclist casualties has fallen dramatically in past decades, while cycling has become more popular (by 30% since 1980), walking has remained about the same, and there have been huge increases (about 75%) in motorized traffic (the collision opponent). The number of fatally injured pedestrians has decreased by two-thirds since 1980, and the number of fatally injured cyclists has decreased by half.

It is neither easy to attribute these positive developments to specific measures, nor, for instance, to the implementation of the *Start-up Programme Sustainable Safety*. The fact that cycling has become safer may be explained by the continuous increase of high-quality bicycle facilities in the Netherlands.

Mode \ Age	0-11	12-17	18-24	25-29	30-39	40-49	50-59	60-74	75+
Walking	29%	18%	20%	19%	18%	17%	18%	25%	34%
Cycling	29%	52%	23%	17%	20%	23%	22%	24%	17%
Moped/light moped	0%	3%	2%	1%	1%	1%	1%	0%	1%
Motorcycle/scooter	0%	0%	0%	0%	0%	0%	0%	0%	0%
Car	40%	17%	37%	56%	56%	55%	54%	46%	38%
Bus	1%	5%	8%	2%	1%	1%	2%	2%	4%
Tram/metro	0%	1%	3%	2%	1%	1%	1%	1%	1%
Train	0%	2%	6%	3%	2%	2%	1%	1%	1%
Rest	1%	1%	0%	0%	0%	0%	0%	1%	3%
Unknown	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%

Table 12.1. ***Used transport modes per trip by people from different age categories in the period 1999-2003. Source: Statistics Netherlands.***

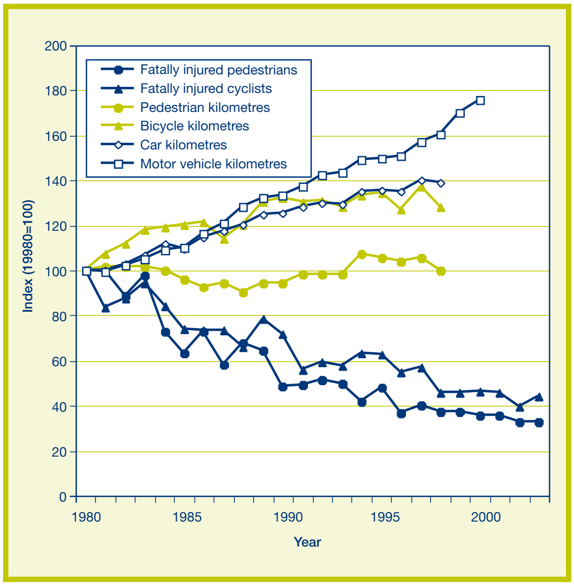


Figure 12.1. ***Development of the number of fatally injured cyclists and pedestrians against the mileage travelled by cyclists and pedestrians, and by motor vehicles (the collision opponent). Index numbers for the time period 1980-2004 (1980=100).***

Although pedestrians and cyclists both belong to the group of vulnerable road users, they often have different types of fatal crashes or crashes resulting in hospital admission. That is the reason for their separate treatment in this section. These crash types determine which measures need to be taken to reduce further the number of vulnerable road user casualties.

12.2.1. Pedestrians

Crossing the road is the most risky manoeuvre for pedestrians. Sixty-four percent of pedestrian fatalities died as a result of a crash while crossing the road (AVV Transport Research Centre, figures 1999-2003). Passenger cars and heavy goods vehicles are the most important collision opponent. Of these fatalities, 25% were crossing at a zebra or another kind of pedestrian crossing. Of the elderly, 75% of pedestrian fatalities die as a result of a crash whilst crossing the road. Of these, 38% were crossing the road at a pedestrian crossing (probably they are also more inclined to cross the road at a pedestrian crossing).

Most fatally injured pedestrians fall within the 75 years and older age group. This is also the case when taking into account the size of this population or the mileage that they travel. Most hospital injuries are sustained by children aged under 11 years. When plotting the number of victims against the number of pedestrian kilometres, it becomes clear that pedestrians aged 75 years or older also have the highest risk of hospital admission, followed by primary and secondary school children.

12.2.2. Cyclists

Severely injured cyclists (fatalities or hospital admissions) occur particularly in crashes between bicycles and passenger cars (55%). The crashes often occur in urban areas (58%), and, within these areas, at intersections on 50 km/h roads (95%). There are only a small number of cyclist casualties in 30 km/h zones. Out of the total number of severely injured cyclists, only 6% occurred on these roads, relative to 73% on 50 km/h roads. The manoeuvre that most often precedes crashes between cyclists and passenger cars is where both vehicles are travelling straight on and cross each other's path of travel (Schoon, 2003b). This makes crossing a road the most dangerous activity for cyclists as well, particularly on 50 km/h roads.

Collisions between cyclists and heavy goods vehicles with a serious outcome – that cause 4% of the total number of severely injured cyclists – constitute another crash type. Almost one third of the severely injured cyclist casualties in collision with a lorry, occur in the well-known crash scenario where the cyclist is in the blind spot of a lorry turning right (or turning left in left-hand side driving countries).

Most cyclist fatalities are cyclists aged 60 years or older. After correcting for the numbers of population per age group, young people aged between 12 and 17 years are over-represented in the number of fatalities as well. This is also the case for hospital injuries.

When plotting the number of severely injured casualties against the number of cycling kilometres, then only the older cyclist stands out. The fatality risk of cyclists aged 75 years or more is twelve times higher than the average fatality risk for this transport mode. The risk of hospital admission per billion person kilometres is five times as high for the oldest cyclist compared with the cyclist of average age.

An important cause of the high fatality risk of older cyclists and pedestrians is the physical vulnerability of elderly people. Since their bones are more brittle and their soft tissue less elastic, they are at higher risk of severe injury, even if the crash forces are the same. At the same time, the elderly have a higher fatality risk because locomotive functions deteriorate with increasing years. This deterioration generally consists of slower movement; a decrease of muscular tone, a decrease in fine coordination, and a particularly strong decrease in the ability to adapt to sudden changes in posture (keeping balance). This latter aspect is particularly important for cyclists and pedestrians, but also for public transport users (SWOV, 2005b).

12.3. Sufficiently safe in the future?

When no measures are taken to improve the safety of vulnerable road users, four factors influence the future number of these casualties: 1) demographic developments, 2) spatial planning, 3) mobility policy, and 4) the introduction of new transport means. See also *Chapter 2*. In the next sections, these developments are discussed from the viewpoint of pedestrians and cyclists.

Demographic developments

The composition of the future population has implications for the size of age groups that cycle or walk for a large part of their mobility, that is: young people up to the age of 17, and elderly people aged 75 and above. Both groups will grow in size (see also *Chapter 2*). In particular, the number of people aged 75 years and above will grow considerably, in the Netherlands from 1 million in 2004 to a maximum of 2.1 million in 2050 (from 6.2% to 12.4% of the total population; Statistics Netherlands, 2004). With unchanged mobility patterns this means that, based on demographic developments, the number of trips on foot or by bicycle is likely to increase.

Apart from the general vulnerability of pedestrians and cyclists, the fragility and decreased balance of elderly people plays an important role in injury causation. The influence of imbalance can be reduced by exercise and training. That does not alter the fact that the independent mobility of elderly people as cyclists or pedestrians will be gradually restricted because of their physical limitations, which warrants some form of motorized support. This support can vary from scoot mobiles or four-wheeled moped engine vehicles, to passenger cars. In order to guarantee safe mobility for as long as possible, it is desirable that vehicles and infrastructure are well adapted to the capabilities and limitations of elderly car drivers (Davidse, 2006; SWOV, 2005b; Hakamies-Blomqvist et al., 2004).

Spatial planning

Developments in spatial planning can lead to changing mobility patterns. Relevant developments in this area include the decrease in house occupancy and the consequential dilution and expansion of facilities. For example, fewer facilities for children may result in a postponement of the independent road use of children. Since school is further away, children are more often taken to and collected from school by car. This development also has to do with the increasing commuting distances of parents. If, as a result, parents use their car for commuting, then they will also use it to bring their children to school. Going home to exchange the bicycle for the car is less efficient. In addition, parents who bring their children to school by car will allow their choice of school and kindergarten to be less determined by what is available locally, with the result that trip distances increase (Schoon, 2005). A postponed independent mobility of children can have negative consequences for their future safety. They may be at higher risk as they become secondary school pupils, simply because they have acquired less experience at a younger age.

The development of large-scale facilities such as shopping malls, mega-cinemas, and media-markets in new locations at the periphery of urban areas or in industrial zones results in longer trip distances and more cross-town trips. This leads to greater car dependency, increased parking pressure (both in residential areas and near the facilities), and higher traffic risks particularly for non-car road users (Schoon & Schreuders, 2006). Increased parking pressure will, in turn, increase before and after transport: the distance between the car on the one hand, and home and the service facilitating institution respectively on the other. This means that more kilometres will be travelled on foot. This trend will, however, not be visible in existing mobility statistics because this combination of modes is often not considered.

At the same time, both the decrease in house occupancy and greater car dependency lead to a decrease in pedestrian and cyclist facilities, as well as support for these facilities (Methorst & Van Raamsdonk, 2003). A decrease in house occupancy leads inevitably to an increase in expenditure per capita for road maintenance. Due to greater car dependency (and the increase in car density per household), car-friendly facilities such as parking facilities will then win over pedestrian and/or cyclist facilities.

For elderly people (aged over 75 years), who make the largest share of their journeys on foot, the lowering of the level of facilities has other consequences. A proportion of this group will not be able to move between their own home, facilities and their car anymore. For this group, access to facilities will deteriorate. The same is true for people who do not (any longer) have access to a car. This may mean that, in the future, the elderly will have to rely more on other people's help.

Other developments are also apparent, albeit on a smaller scale. Planning new neighbourhoods in small, compact towns close to the town centre, for example, keeps distances to facilities as small as possible. As a result, the bicycle can play a large role in trips between these new neighbourhoods and the town centre, and further growth in car traffic can be avoided (Kwantes et al., 2005). This has positive effects on the safety of cyclists, since a better balance between the share of cyclists and cars in traffic results in a risk reduction for cyclists (Wittink, 2003). At the same time, increasing bicycle use contributes to more support for cycle facilities, which can bring about further risk reduction.

Mobility policy

Future mobility patterns can also change as a result of public mobility policy. The Dutch *Mobility Paper* states that all public authorities should encourage bicycle use (Ministry of Transport, 2004a). However, the responsibility for bicycle policy is given to decentralized authorities, and particularly to municipalities. Past experience has shown that the improvement of bicycle facilities and bicycle safety is dependent upon the policies and characteristics of the municipalities involved (Ministry of Transport, 2004a). Should the policy intentions for better bicycle facilities such as cycle routes and improved bike shelters be implemented, then this will have a positive effect on bicycle safety (Wittink, 2003), possibly followed by an increase in bicycle use.

With regard to public transport, the *Mobility Paper* states as a basic quality rule that central facilities, such as schools and health care, should be accessible to everyone. The *Mobility Paper* also states that public transport growth in rural areas will be limited. In order to provide a good alternative for those elderly that do not (any longer) have access to a car but who wish to live on their own, it is important to offer demand-led transport in those areas. If such facilities are lacking, elderly people will either continue to drive when it is no longer safe, or they will become isolated at home and require more professional care, with all accompanying societal costs (SWOV, 2005b).

> ***Segway: market hit or just a fad?***
>
> The Segway Human Transporter may attract attention in the coming years as a new means of transport. This electronic vehicle consists of two wheels placed next to each other with a crossbar and a handlebar in between. The Segway moves forward when the body moves slightly forward. Moving the body slightly backward causes the vehicle to slow down and stop. The vehicle is very manoeuvrable, it can reach speeds up to 20 km/h, and can be used for a range of about 20 km (after that the batteries need recharging). Introduction of the Segway in the Netherlands may perhaps have the same consequences as those of other means of transport that fit in between walking and cycling, such as skeelers. This would mean that discussions will follow regarding the Segway's place in traffic (see Remmelink, 2000). Should it be on the footway or would it be allowed on the carriageway? The answer to this question could have consequences for pedestrian safety, although in the Dutch magazine *Verkeersknooppunt* (traffic interchange) the statement was made that, according to Dutch legislation, the Segway by definition falls in the same category as a moped (Enkelaar, 2005).
> However, the introduction of the Segway can also have positive consequences, especially for the elderly and for people who have difficulty with walking. The Segway enables people to travel longer distances with less effort. The question is whether or not the equilibrium disorders associated with ageing will prove too great a barrier to the widespread use of the Segway.

Frame 12.1.

New means of transport

Every now and again new means of transport are developed. It is often difficult to judge the extent to which these means of transport will become popular and how they will influence traffic and transport (see *Frame 12.1*). The past has shown that the new design of the light moped in the shape of a motor scooter had a great appeal for young people. The success of this vehicle will undoubtedly have also been contributed to by the fact that light moped riders do not have to wear a crash helmet. The one-seat car with a moped engine is another vehicle of which it is sometimes feared that it will become popular with young people. Until now this fear has not been founded but this could change if the price of these vehicles would be reduced.

Conclusions

Cycling and walking are the most important transport modes for young children, school children and elderly people. For independent road use, these groups often depend totally on cycling and walking. The mobility of elderly pedestrians can become problematic if the distance between home and essential facilities becomes too great. Another problem arises when public space that is currently dedicated to pedestrian use is increasingly occupied by parked vehicles. Finally, the decrease in house occupancy and increase in car dependency could lead to a situation where calls on infrastructure maintenance budgets become detrimental to the maintenance of pedestrian facilities.

12.4. The benefits of Sustainable Safety

The road safety problems of pedestrians and cyclists are not new. They were known when the basic principles for a sustainably safe traffic and transport system were established. Partly due to these problems, safety principles were conceived such as 'separate traffic flows that differ in speed, direction and mass at moderate or high speeds'. The question is now the extent to which the measures from the previous Sustainable Safety vision (Koornstra et al., 1992) and the *Start-up Programme* (VNG et al., 1997) have been (or still are) able to guide cyclists and pedestrians away from the threats mentioned in previous sections of this chapter. This is discussed in *Chapter 2 and 3* in general terms, but this section will discuss the issue from the viewpoint of cyclists and pedestrians.

The introduction of a sustainably safe road traffic has had various positive consequences for vulnerable road users. Examples are: 1) separation of traffic flows that differ in speed, direction and mass, 2) the measure 'moped on the carriageway', 3) the construction of 30 and 60 km/h zones, 4) mandatory side-underrun protection on new heavy goods vehicles, and 5) development of a pedestrian and cyclist-friendly car front. The first three measures are particularly aimed at preventing crashes, and the latter two measures aim to reduce the severity of crashes when they occur. Relatively little is known about the separation of traffic flows because no specific information on this topic has yet been collected. However, this is not the case with the other four topics.

Moped on the carriageway

It is a general aspiration, within the implementation of a sustainably safe road network, to prevent large differences in speed, direction and mass at moderate and high speeds. The moped offers a specific example of a change in the positioning of a vehicle since the introduction of Sustainable Safety. From December 15th, 1999 the moped is no longer allowed on cycle paths in urban areas that have mandatory cycle paths and a 50 km/h speed limit or lower, and must use the carriageway. This move was initially proposed to improve cyclist safety on cycle paths. A first evaluation of the road safety effects of this measure one year after its introduction, confirms positive expectations (Van Loon, 2001).

Figure 12.2. ***Example of separation of traffic flows.***

Construction of 30 and 60 km/h zones

As mentioned in *Chapter 3*, the construction of 30 and 60 km/h zones has proliferated in the Netherlands during the past few years. In 2002, 30 km/h zones were estimated to be almost three times safer when compared to ordinary residential streets. An explanation for this is, of course, the lower speeds at which crashes seldom prove to be fatal. However, relatively more serious crashes took place between motor vehicles and cyclists or pedestrians. The share of this type of crash in all urban areas accounted for one third of all serious traffic crashes; in 30 km/h zones this proportion was almost twice as high. This can be explained by the above-average number of cyclists and pedestrians in urban areas (SWOV, 2004a).

Side-underrun protection for heavy goods vehicles

With regard to vehicle measures, Koornstra et al. (1992) already indicated that lorries could be made much safer for third parties by the application of adequate protection around the vehicle. Such protection prevents the dangerous underrun of for instance cyclists and other two-wheeled vehicles. In 35% to 50% of the crashes between heavy goods vehicles and two-wheelers, injury severity can be limited by side-underrun protection. Moreover, this facility prevents a road user involved in the collision still being run over. The number of traffic fatalities in urban areas due to crashes of this type could be reduced by 10% (Goudswaard & Janssen, 1990).

From January 1st, 1995, all new lorries and trailers have to have side-underrun protection. Due to the long life span of heavy goods vehicles, it will take years before the greater majority of the heavy goods vehicle fleet in the Netherlands is equipped with this protection. In 2001 this was only around 60%. From earlier measurements made by the Dutch Cyclists' Union we know that, when 36% of the lorry fleet was fitted with open side-underrun protection, only 2% had closed side-underrun protection (Van Kampen & Schoon, 1999). For moped riders, cyclists and pedestrians, closed side-underrun protection on lorries is more effective than open protection. Both open and closed side-underrun protection appear in the top ten of relevant measures based on cost-effectiveness (Van Kampen & Schoon, 1999).

Pedestrian and cyclist-friendly car fronts

Requirements concerning a vehicle's construction cannot be decided on at national level (and hence not within the framework of Sustainable Safety). Attention to the development of 'crash-friendly' car fronts does take place at European level (see also *Chapter 5*). It is a step in the right direction that current test requirements for crash-friendly car fronts include the points of the body where pedestrians hit cars to be taken into account. However, the test requirements are not as comprehensive as they could be (ETSC, 2003), and they do not take sufficient account of cyclists. In a crash, cyclists hit a car on a different spot than pedestrians do. Tightening up the test requirements is therefore desirable (Schoon, 2003b).

12.5. Advancing on the chosen path

The first version of Sustainable Safety articulated a great many measures that were and still are expected to have a positive effect on pedestrian and cyclist safety. In particular, measures aimed to reduce the speeds of motorized traffic to speeds that are safe for vulnerable groups. This means that the full implementation of first-generation Sustainable Safety measures will lead to a further decrease in pedestrian and cyclist casualties. This is particularly the case for developments in the field of pedestrian and cyclist-friendly car fronts, side-underrun protection on heavy goods vehicles (see also *Chapter 14*), and the complete Sustainable Safety implementation and upgrading of low-cost 30 and 60 km/h zones. These measures decrease the severity of the outcome of collisions with cyclists and pedestrians. In addition, calm driving behaviour will also help to prevent crashes because people have more time to observe and anticipate, and because stopping distances are shorter (Schoon, 2003b).

As stated earlier, this implementation of 30 km/h zones had a positive effect on road safety. However, the way in which this implementation has taken place has raised a number of discussion points. For example, some residential areas are too small to accommodate all the facilities they need, making it necessary for pedestrians to walk from one residential area to another and to cross distributor roads. A second disadvantage of some 30 km/h zones is that the choice was made to use a low-cost construction method, with for example speed control measures only at 'dangerous' locations (Infopoint Sustainable Safety, 2000). Because of this, optimal safety results have not yet been attained.

The problems of small residential areas and the associated lack of facilities existing in one neighbourhood means that additional measures are needed to make facilities safely accessible. One example of this is creating better ways to cross major roads safely (SWOV, 2004a). This can take various forms, such as a median traffic island that makes phased crossing possible, and speed limiting measures.

In a publication on Sustainable Safety especially targeted at pedestrians and cyclists, Slop & Van Minnen

(1994) mentioned additional elements that cause travelling speeds of fast-moving traffic to decrease at locations where pedestrians and cyclists cross the road. Examples of such elements are raised zebras and pedestrian crossings at roundabouts. Meanwhile, provisional implementation requirements have been established for sustainably safe pedestrian crossings on a stretch of road (CROW, 2000). Such a crossing ought to be constructed only at urban distributor roads with a speed limit of 50 km/h and 2x1 lanes. The most characteristic requirement of such a crossing is the speed reducing measure. A motor vehicle should approach such a crossing with a speed of no more than 30 km/h (see e.g. SWOV, 2005c, and also *Chapters 1 and 5*). Detailed requirements of this type have not yet been established for cyclists, but work is underway to revise the publication *Sign up for the Bike* (CROW, 1993). Perhaps the Netherlands should follow Great Britain and introduce a new type of crossing that can be shared by pedestrians and cyclists, the 'Toucan' ('Two can cross'). The Toucan is a high-quality crossing facility (see *Frame 12.2*).

Another matter requiring attention is the equivalent intersection, where cyclists and all other drivers and riders coming from the right take priority since May 1st, 2001. Lowering the speed of approaching traffic is desirable here. This can be achieved by applying infrastructure measures such as a roundabout or a raised intersection (SWOV, 2004b), but also by equipping vehicles with a speed limiter. In urban areas, Intelligent Speed Assistance (ISA) can contribute effectively in this context. Conspicuity of pedestrians and cyclists in rural areas can be improved by equipping cars with night vision systems that aid the driver to detect crossing pedestrians and cyclists earlier (see *Chapter 6*).

Perhaps other creative infrastructure facilities can be devised that fit well into the Sustainable Safety vision, and that particularly serve pedestrian and cyclist safety. *Frame 12.3* gives an example.

12.6. And what about the behaviour of (some) pedestrians and cyclists?

With regard to pedestrians and cyclists, we argue in this chapter that it is appropriate to proceed on the chosen path: mix at low speeds, separate where speeds become too high, and apply targeted speed reductions where pedestrians and cyclists cross the flow of motorized traffic. In short: a sustainably safe environment is particularly good for pedestrians and

A Toucan in the Netherlands

There is much to be said in favour of combining crossing facilities for pedestrians and cyclists, because a greater number of people crossing at one time reduces risk. One possible method is the 'Toucan crossing' currently used in Great Britain (see e.g. Ryley et al., 1998). This crossing facility is named Toucan because both pedestrians and cyclists can use the same facility ('two can cross').

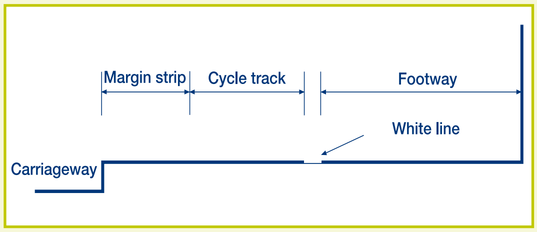
C. Ford

The advantage of a combined crossing is that it is more visible for fast-moving traffic travelling on the major road. In addition, Toucans can detect the numbers of crossing pedestrians and cyclists. These systems enable a fairer distribution of waiting times for fast and slow traffic, and they often establish shorter waiting cycles. Introduction of the Toucan crossing in the Netherlands would require an amendment to the prevailing administrative provisions, because traffic lights have to be moved. At a Toucan crossing, the traffic lights are usually placed at the opposite side of the road, whereas in the current situation in the Netherlands the lights for cyclists are often placed on the near side. For cyclists, this would mean an amendment to the current rules. Positioning a traffic light at the opposite side presents a risk though if there are separate public transport lanes. Pedestrians and cyclists might think that they can also safely cross the public transport lane when the lights are green. But often, public transport lanes have no signalized crossing, and public transport has right-of-way. To prevent crashes, we recommend also introducing a controlled crossing facility on public transport lanes (Davidse et al., 2003).

Frame 12.2.

Two-path for pedestrians and cyclists

A 'two-path' is a shared space for pedestrians and cyclists (see also Kroeze, 2004, and the sketch). On busy, narrow roads the choice is often made nowadays to use a bicycle lane as the traffic space for cyclists. However, Sustainable Safety recommends separating fast and slow traffic. On such roads the footway is a safer place for cyclists. In order to keep it safe for pedestrians, a visual separation is required between cyclists and pedestrians. Nevertheless, there is a speed difference between the users of this path, but the larger speed difference between motorized traffic and cyclists is avoided. One additional advantage of the two-path is the reduced risk for single-party bicycle crashes, because cyclists no longer have a high kerb next to them, and because there is less risk from opening doors of parked cars. (On a two-path the cyclist rides at the car passenger side.)



Sketch of a two-path (DfT, 2004).

Frame 12.3.

cyclists. Let us assume that, in this way, we are able, gradually, to establish predictable, recognizable and credible traffic situations, and to achieve even fewer pedestrian and cyclist road traffic casualties. Would it not then be logical to start talking to cyclists and pedestrians about their responsibilities in terms of safe behaviour in traffic? Tell them that they should behave more predictably and for instance not ride without proper lights and/or run red lights? Then this source of crashes could also be removed.

13. Motorized two-wheelers

13.1. Do motorized two-wheelers actually fit into Sustainable Safety?

The brief answer to this question is no, because Sustainable Safety speaks of achieving a considerable reduction of risks and of numbers of casualties. We could say that motorized two-wheelers (motorcyclists and moped riders) would fit within Sustainable Safety if the risks for this group were reduced to a similar level to that of car drivers and pedal cyclists. Currently, the risk is still 75 fatalities per billion person kilometres for motorcyclists, and 91 for moped riders, whereas the risks for car drivers and pedal cyclists are respectively 3 and 12 fatalities per billion person kilometres. Such a sharp decrease in risk is inconceivable without draconian measures. It is difficult even to conceive of Sustainable Safety measures that could lead to a substantial reduction in the number of victims of crashes involving motorized two-wheeled vehicles. One of the very few measures that harbours any potential for such a reduction is a general speed limitation or specific speed limitation at intersections, such as roundabouts (provided the actual design does not lead to new problems for motorized two-wheelers).

Are we then to conclude here that not much can be done to make riding a two-wheeled vehicle safer? It would perhaps go too far to state that nothing can be done but it would be wrong to expect too much. Should we conclude here that safety falls completely under the responsibility of the vehicle's rider? A potential rider of a two-wheeled vehicle knows, or at least could be expected to know, that riding a motorcycle or a moped is associated with relatively high risks (see e.g. *Frame 13.1*). The rider accepts these risks more or less voluntarily unless they fall within the category of 'captive users' (people who really do not have a serious alternative) which is limited in number. It could, at least, be 'society's' responsibility to bring this high risk to the attention of this group of motorcyclists and moped riders. Furthermore, the relatively high risk of motorized two-wheelers calls for a discussion concerning the acceptance of risk in a risk society ('How safe is safe enough?'); what should reasonably and responsibly be done to reduce risks ('As low as is reasonably achievable'); and finally, into the distribution of individual and collective responsibility concerning behaviour that implies risk, etc. Much has already been studied and written about risk, the probability of harmful effects and their size (see e.g. De Hollander & Hanemaaijer, 2003), and we know from psychological research that this probability and the nature and size of these effects only partly determine whether or not the citizen regards this risk as acceptable. Apparently qualitative characteristics also play a role in risk acceptance, such as (perceived) freedom of choice in risk exposure, fairness of intervention in this choice, risk control, or familiarity with the activity or its societal usefulness.

This discussion awakens memories of times when wearing of seat belts and crash helmets were made compulsory. The question arose then as to whether or not individual freedom of choice could be restricted if personal risk and safety were at stake. In order to convince the opponents of these measures the issue of the societal costs of not using these safety devices was introduced into the discussion. This refers to the fact that society also bears part of the costs when individuals die in traffic. In the meantime, this discussion has been settled in virtually all highly motorized countries in such a way that motorized two-wheeler users have to wear crash helmets, and car occupants have to use seat belts in both front and rear seats.

Another issue for motorized two-wheelers is that, by making this activity safer, other road users (the crash opponents) run less risk. This adds a different dimension to a view of activity in which only the person involved runs the risk (parachute jumping, deep-sea diving, etc.). On average, about 27 people are killed annually in the Netherlands (2001-2003) due to a crash with a motorized two-wheeled vehicle. For motorized two-wheelers themselves, this figure is on average 178 fatalities annually.

Motorized two-wheeler interest groups are undoubtedly concerned with their target group's safety, but as soon as matters of individual freedom or increased costs arise, then they may not always support the safest solution.

Furthermore, we can see that when it comes to discussing ways of riding a motorcycle or moped more

Motorcyclist crashes

During the weekends and when the weather is amenable, motorcyclists use their vehicles more and this is reflected by crash statistics. Out of all motorcyclist casualties, 35% occur at the weekend. There are also more casualties in spring and summertime than in the other seasons of the year. We list more motorcycle crash characteristics below.

Location

- Motorcyclist casualties and serious motorcycle crashes occur to an equal extent in urban and rural areas.
- In rural areas, 70% of all motorcycle crashes occur in a bend, the same for left and right bends, and 30% on a straight section of road.
- Almost 20% of crashes in rural areas occur at four-way intersections.
- Crash location by road authority:
  - Municipal roads: 67%
  - Provincial roads: 18%
  - National roads: 14%
- Crash location by road type:
  - Motorway: 7%
  - 80 km/h road: 40%
  - 50 km/h road: 50%

Conflict type

- In 34% of severe injury motorcycle crashes, no other vehicles are involved, but obstacles (17%) or no crash opponent at all (17%). Motorcyclists have slightly fewer single-party crashes than car drivers (32% obstacle and 8% no other party).
- In 60% of fatally injured or injured motorcyclists, the crash opponent is a passenger car or a van. In these crashes, the motorcycle is most often hit in the front, both in head-on crashes, side impacts and rear-end collisions.
- Annually, 40% of motorcycle-car crashes occur on sections of road, and 60% at intersections.
- Crashes with motorcycles probably often occur because car drivers do not give right-of-way or free passage. We can draw this conclusion based on the fact that the police often indicate that motorcyclists are not to blame.
- In the majority of crashes, car drivers do not give right-of-way when emerging from a side-road.
- In a comparatively small proportion of the crashes, car drivers making a left turn do not give right-of-way to an oncoming motorcyclist.

Speed

- On roads with a 50 km/h speed limit, about half of surviving motorcyclists report having exceeded the speed limit shortly before the crash; 15% riding over 100 km/h according to their own reports.
- On roads with an 80 km/h speed limit, 40% of surviving riders exceeded the speed limit according to their own reports.

Sources: Vis (1995); Van Kampen & Schoon (2002); AVV Transport Research Centre

Frame 13.1.

safely, little compassion is shown in political decision making. Of course it is always a political consideration to weigh possible safety benefits against other, possibly less attractive consequences (restriction of personal freedom, damage to commercial interests, supplemental environmental taxes, diminished accessibility, higher costs to citizens, more legislation, less employment, etc.).

The following is an illustration of the positions of political and interest groups. In 2004, the Dutch Parliament did not endorse a proposal to raise the minimum age for riding a moped from 16 to 17 years, although the safety benefit was undisputed (“a full bus load per year that *does* arrive home at night”, as the transport minister said). Nevertheless, a number of disadvantages were raised that in the end tipped the balance. Incidentally, the proposal was inspired by the idea of raising the age limit to 18 years and for young people to make a decision between the various transport modes at their disposal (Wegman, 2001). Nevertheless, Parliament did agree that more strict measures would follow if the announced measures (licence plates and banning the tuning up of engines) had little or no effect. This evaluation is still awaited.

We confine ourselves in this book to just reporting the above observations and to making proposals based on known practical solutions. We are not attempting to be radical but we seek to offer proposals that are expected to contribute to the safer riding of mopeds and motorcycles. We also recommend engaging in a fundamental discussion around safety and risks of motorized two-wheelers, not only in the Netherlands but also in Europe, and to explore the boundaries of policy in order to promote safety of this category of road users.

13.2. Risk factors and measures

The ambition is high in Sustainable Safety. It is to (almost) exclude crash risk and severe injury. Here, we will review risk factors for motorized two-wheelers and possible measures in relation to infrastructure, vehicle and rider. First, we will briefly dwell on some characteristics of the rider and his or her vehicle.

The motorized two-wheeler is appealing as a means of transport to the mobility requirements of specific user groups. Pleasure and leisure play an important role in the motivation for usage. For some people, riding a motorbike is a 'lifestyle' in its own right. With a moped, you may impress the circle of people around you. There is also an increased commercial/professional use because of high manoeuvrability during congestion (police, courier services, pizza delivery services, etc.). Since the 1990s, the scooter style has again become popular because of ease of use and comfort. The scooter style now appears in three categories: as a light moped and as a moped (both < 50 cc), and as a motor scooter (≥ 125 cc).

Compared to four-wheeled motor vehicles, the motorized two-wheeler has a number of characteristics that increase traffic risk for the rider:
- instability, with the consequent risk for falling off;
- higher manoeuvrability (at lower speeds) and fast acceleration, making behaviour for other road users less predictable;
- less conspicuity, because e.g. of smaller size;
- smaller size and position on the carriageway, causing motorcycles and mopeds to be hidden behind cars and heavy goods vehicles;
- no rigid occupant compartment, providing less protection in case of a crash or fall.

A British study investigated behaviour and attitudes of motorcyclists in relation to crashes (Sexton et al., 2004). This was a questionnaire study gathering data reported by crash victims themselves. The results showed that five groups of crash causes can be distinguished: 1) unintended errors, 2) speed behaviour, 3) stunt riding or very dangerous riding behaviour, 4) use of personal safety devices, and 5) preventing unintended errors. This study confirmed again that the number of miles travelled is the most important variable for motorcycle crashes, but that this relationship is non-linear (the crash rate increases less strongly with increasing mileage). The relationship between crash risk and age and experience was also confirmed (see also *Chapter 2*). With respect to behaviour, the most important explanations for crash risk are risk awareness and perception skills. Riding style, enjoying motorcycle riding and the desire to speed turned out to be good predictors for unintentional errors (and these are crash predictors). This led the researchers to conclude that the safety problems of motorcyclists are related to the motivation for riding a motorcycle in the first place.

Some characteristic crash data are given in *Frame 13.1*.

13.2.1. Limited possibilities through safer infrastructure

Limited possibilities for separation of traffic modes

According to Sustainable Safety, vehicles that differ too much in speed and/or mass should be separated. Cars and motorcycles are equivalent in terms of speed, but they are incompatible modes in crashes due to differences in mass and structure (among other things). The motorized two-wheeler offers virtually no protection when compared with drivers in passenger cars. The problem becomes more serious at higher speeds.

With the measure of 'moped on the carriageway' (introduced on December 15th, 1999; see also *Chapter 3*), the Sustainable Safety principle of separating moped and bicycle traffic in urban areas was partly met. However, this caused a mix of car and moped traffic on carriageways in which travel speeds, or in any case the maximum permitted speed limits, were not made homogeneous.

The moped continues to be restricted to the cycle path in rural areas, but the current speed limit (of 40 km/h) results in a too large speed difference with light mopeds (speed limit 25 km/h) and even more so with bicycles. Plans exist in the Netherlands to lower the speed limit for mopeds on rural cycle path to 30 km/h, making the speed difference with light mopeds smaller, but a large difference with bicycles remains. The reality is that mopeds are not welcome on cycle paths.

Necessity for an obstacle-free zone for motorcyclists

Road shoulders should be 'forgiving' (see *Chapters 1 and 4*). The shoulders should be free of rigid and/ or sharp obstacles. Road authorities should choose broad and obstacle-free zones wherever possible because this would benefit all road users. However, this happens infrequently due to lack of space or funds. The consequence is that motorway crash barriers designed for passenger cars are installed, but that they create a particularly high risk for motorcyclists.

Some objects along the road require no shielding devices for cars, such as poles for road signs and aluminium lighting columns. In a crash with a passenger car, these simply break without causing high vehicle deceleration for car occupants. For motorcyclists, however, every object causes danger. The CROW handbook *Motorized Two-wheelers* (CROW, 2003) discusses a range of problems in road and shoulder design for this category when they are only designed with the passenger car in mind. In 2006, a European equivalent of this Dutch handbook is made by the motorcycle manufacturers ACEM (2006). We recommend the integration of these handbooks into existing guidelines and design handbooks for road infrastructure.

13.2.2. Vehicles: modest improvement possibilities

Combined brake systems offer stability but a safe rigid occupant compartment is still lacking

Brake systems, such as ABS and CBS (combined brake systems), offer much support in braking manoeuvres for the novice motorcyclist. The more experienced motorcyclist also benefits in emergency braking manoeuvres. No research has yet been carried out into the effect of these systems. Nevertheless, experts emphasize that they may prevent falls. For this reason, there is an added value for motorcycles in contrast to ABS in passenger cars, for which the effect is neutral. Currently, ABS and CBS are only fitted as standard on a few brands and/or types of motorized two-wheeler. Nevertheless, motorcycle manufacturers have promised within the framework of the European Road Safety Charter to make 'advanced braking systems' available on all models in the short term.

The two-wheeled vehicle itself does not offer protection to the rider. An attempt by BMW with the C1 (a motor scooter with a crumple zone, rigid occupant compartment and seat belt, and no obligation to wear a crash helmet) was not commercially viable, and has been withdrawn from the market. Honda has brought out a motorcycle fitted with an airbag. Such an airbag will prevent injury if the motorcycle crashes frontally and if the motorcycle does not roll.

From a safety viewpoint, lightweight motorized two-wheeled vehicles are speed limited. For light mopeds the speed limit is 25 km/h, combined with an exemption for wearing a crash helmet. From the point of view of Sustainable Safety, a crash helmet would be preferable as is advocated for pedal cyclists (and which is even obligatory in some countries).

Tuning up mopeds: a recurring problem

Tuning up moped engines is a problem. We have not yet managed to prevent tuned-up mopeds from circulating in road traffic. Neither domestic regulation nor European regulation has solved the problem. At this moment, we are not far from the view that the problem is insoluble as long as engine blocks can be opened and tuning kits can be ordered easily on the internet. In 2007, the Dutch Ministry of Transport will evaluate the industry's covenant to fight tuning up engines. No reliable overview of the percentage of tuned-up mopeds exists, or of the mileage travelled at speeds faster than the 'construction speed'. The extent to which tuned-up speeds play a role in crashes is also unknown. The Motorcycle Accident In-Depth Study (MAIDS, 2004) revealed that 18% of mopeds involved in crashes had been tuned up (visual inspection); for the control group this was 12%.

Insufficient distinction between vehicle categories

The development of clearly distinguishable vehicle categories fits extremely well into Sustainable Safety. This requires as many similarities as possible within categories, and as many differences as possible between categories (see also *Chapter 1*). The lack of clear distinction between mopeds and light mopeds provides an example of the problem. This lack of distinction is most salient for the scooter-shaped model which both mopeds and light mopeds are designed in and which leads to confusion. In urban areas, the scooter-shaped moped has to be on the carriageway and the rider is obliged to wear a crash helmet. The scooter-shaped light moped should be on the cycle path, and wearing a crash helmet is not compulsory. The fact that wearing a crash helmet on similarly looking vehicles is either compulsory or not, probably induces less helmet wearing. Introducing a licence plate for mopeds improves distinction, but even this is not ideal. The licence plate that distinguishes the two categories can only be seen at the rear of the vehicle.

Limiting the number of vehicle categories – one of the basic ideas in Sustainable Safety – can be achieved by choosing two clearly distinguishable categories: a moped (crash helmet wearing compulsory) on the carriageway in urban areas, and a bicycle with an auxiliary engine (crash helmet wearing not compulsory) on the cycle path. We invite the Ministry of Transport, having made the current light moped form legally possible, together with industry and interest groups, to end this undesirable situation.

Poor conspicuity?

The MAIDS study (2004) shows that in more than 70% of all crashes, the crash opponent had failed to see the motorized two-wheeler. To put this percentage into perspective: failing to see the other party is also a cause in 50 to 80% of road traffic crashes in general. Furthermore, the MAIDS study shows that in 18% of crashes, travel speeds of the motorized vehicle differed from other traffic, and that this speed difference had contributed to the crash occurrence. This percentage is on the low side, because travel speeds in motorcycle crashes cannot always be established accurately by means of brake or skid marks. A (somewhat older) SWOV study (Vis, 1995) showed that about half of motorcyclists who had had an injury crash indicated that they exceeded the speed limit at the time of the crash (see *Frame 13.1*). This is a subject for further (in-depth) research into the causes of motorized two-wheeler crashes, in which the various types of two-wheelers need to be distinguished.

At this time, almost all motorcyclists ride with Daytime Running Lights (DRL). More conspicuous clothing and crash helmets can reinforce the DRL effect. Despite much research into improving conspicuity, no solutions have yet been found. Translated into crash and injury prevention, this means that the motorcyclists have to assume in potential conflict situations that they will not be seen. This means that training oneself to anticipate well (being particularly alert and riding more slowly) is the only remedy.

Can electronic devices be deployed?

Motorcyclists as well as car drivers can benefit from systems which support the driving/riding task. Experiments are being held now in Japan with systems to detect oncoming crossing traffic. Such a system seems useful for motorcyclists. An advisory or informative ISA system is also suitable for motorcyclists, but an intervening ISA cannot be applied without modifications due to instability problems.

It is worth remarking that, whilst intelligent transport systems for motorized four-wheeled vehicles receive a great deal of attention, developments for two-wheelers do much less.

13.2.3. It has to come from the rider

Personal protection

The only protection that a motorcycle or moped rider has, is a crash helmet, clothing, gloves and footwear. Moped riders do not all wear a crash helmet (helmets are worn by around 90% of riders and 75% of passengers). Despite additional police enforcement, helmet wearing percentages have not increased. We expect that increased enforcement efforts directly after the introduction of the licence plate will be effective.

By making proper clothing compulsory for the motorcycle riding test in 2003, a first step was taken in raising awareness. Quality requirements for clothing would be a second step. Currently, this only comprises separate protective material within clothing (for shoulders, elbows, knees, etc.). Legislation, testing and information such as we know for crash helmets and seat belts, are the appropriate instruments to define performance requirements. We recommend research into how to promote the wearing of safer clothing by motorcyclists. It is interesting to note that clothing manufacturers are experimenting with inserting airbags into their products!

Skills in combination with riding experience are important

Two-wheeled vehicles are unstable. This implies that skills are required for elementary vehicle control, such as maintaining balance and braking adequately. The practical motorcycle-riding test in the Netherlands has had some skills added to it since 2004. At the same time, knowledge is indispensable to take part safely in traffic. Learning can be rapid when knowledge alone is to be acquired. However, a long process is required for acquiring skills for complex tasks. It takes a novice car driver more than 5,000 kilometres of experience before crash risk begins to decrease, and more than 100,000 kilometres before we can speak of a car driver as experienced. For motorcyclists these figures could well be higher due to the complex nature of the task of riding a motorcycle. It is problematic that most motorcyclists are 'seasonal riders' (a fact borne out by the many serious motorcycle crashes during the first weekend of the year with fine weather!) and consequently repeatedly lose the routine skills they build up. It is, therefore, possible that there is a group of motorcyclists that never gains sufficient experience, or for which the first kilometres every new year are comparatively dangerous ones. The question as to how this learning process evolves in motorcyclists is a topic for further research.

A lack of riding experience implies an increased safety risk for (both young and older) novice riders (see also *Chapter 2*). Young riders of motorized two-wheeled vehicles are over-represented in crash involvement. In this respect, often a distinction is made between *novice risk* and *young person risk*. The *novice risk* manifests itself in problems of the traffic system that are experienced as complex. The *young person risk* refers to additional, age-related risks due to reckless and risk-seeking behaviour (Noordzij et al., 2001). Specific to young motorcyclists is their tendency to seek risky situations to show their (often overestimated) riding skills to others. Added to a lack of riding experience and risk awareness, this behaviour makes motorcycle riding even more dangerous. This is not much different from young car drivers, but an incident is more likely to be fatal for motorcyclists.

The number of young motorcyclist casualties has nevertheless sharply decreased during recent years, simply because of the decrease in their exposure. Of the riding test candidates in the first six months of 2005, only 12% was younger than 21 years of age.

An unequivocal relationship between an increased risk for young motorcyclists and engine performance has never been established (Vis, 1995). This has also been confirmed by the MAIDS investigation. The current form of the graduated driving licence in the Netherlands nevertheless starts from the possibility of such a relationship. People can ride a light (less powerful) motorcycle from the age of 18 years, and a heavier (more powerful) motorcycle at a later age. The preference, therefore, is to introduce a form of graduated access based on acquired experience, instead of age. We will deal with this in more detail later.

For moped riders the same story applies as for all other modes of road use: the first access is associated with high risks that gradually decrease as experience increases. This, in combination with the fact that young people are often novices, results in comparatively high risks. For more information, we refer to the SWOV fact sheet on young moped riders (SWOV, 2004c).

The nation-wide introduction of the moped certificate in the Netherlands has resulted in a strong improvement in traffic knowledge and insight, but it has not led to safer road user behaviour in the long term (Twisk et al., 1998; Goldenbeld et al., 2002). It is worth noting that around 30% of moped riders report their participation in traffic without such a certificate.

Training courses not always successful

Rider skill training courses are often regarded as a means to prepare riders of a motorized two-wheeled vehicle for their task. However, research has shown that this is not always successful. A meta-analysis of twenty studies into motorcycle training courses from all over the world resulted in the following (Elvik & Vaa, 2004):

- A *compulsory* rider training course and exams result in a slight decrease in the number of crashes.
- A *voluntary* rider training course does not result in an unequivocal effect on the number of crashes.
- *Postponing riding* on a heavy motorcycle has no effect on the total number of crashes.

We should note that these meta-analyses deal with 'average effects' and that in individual cases more positive effects were found. We should also note that motorcyclists can show risk compensation behaviour due to rider training. This reveals itself in more dangerous and sensational riding behaviour originating from a feeling of competences being acquired from learned skills. It is therefore important to combine riding skill training with training in traffic behaviour and risk perception.

With respect to *moped rider training*, a trial has been conducted in the Netherlands with young moped riders who followed a sixteen-hour practical training course. This trial showed an improvement in their vehicle control and traffic behaviour, but the effect subsided after one year (Goldenbeld et al., 2002). One obvious conclusion is that this (limited form of) training perhaps helps for a year, but that gaining experience normally also leads to risk decrease, albeit later than after having followed a training course.

Risk perception and awareness

The larger proportion of motorcyclists generally feels safe in traffic; only a small share does not (Elliott et al., 2003). The positive safety judgement is based on:
- confidence in their own defensive riding style;
- the notion of sufficient riding experience;
- the notion that a motorcyclist has a better overview and is more manoeuvrable than other traffic;
- the perception that with an increase in the total number of motorcyclists, other road users will take them more into account more readily.

In reality, according to Sexton et al. (2004), risk is higher than that perceived by motorcyclists. This means that motorcyclists do not have a correct risk perception and awareness, which means that motorcyclists:
- often do not adapt speed to conditions and traffic situation;
- do not recognize dangerous situations well enough;
- do not take account of other road users' perception capacities well enough;
- lack skills in an emergency situation;
- are not sufficiently aware of their own vulnerability in a crash.

Graduated driving licensing for motorized two-wheelers

Following many other countries in the world (see *Chapter 7*), thoughts are frequently voiced in the Netherlands concerning a graduated driving licence for novice car drivers. The concept is to extend and phase the learning path. When the student masters (higher-order) skills, he/she can acquire more driving experience in more risky conditions. This is also desirable for motorcyclists, strongly emphasizing anticipation skills. The intention to introduce a hazard perception test for moped and light moped riders fits well into this framework. In addition, recent Australian research emphasizes the importance of hazard perception and risk management, and according to this study, simulators can be used effectively to train students in these skills (Wallace et al., 2005).

In line with the graduated driving licensing for car drivers, three phases can be used for both motorcyclists and moped riders. The duration of a phase can be different for trainee moped riders and motorcyclists. These three phases are:

1. *Learner phase.* In the learner phase, the trainee learns to ride supervised by an instructor. The learner phase ends with a test.
2. *Intermediate phase.* In the intermediate phase, the student can ride independently in relatively safe conditions: e.g. no alcohol, no passenger, and not during night-time. This phase is concluded by a 'normal' driving test, including e.g. a hazard perception test.
3. *Provisional phase*. During this phase, stricter rules apply for novices than for more experienced motorcyclists or moped riders (e.g. no alcohol or a stricter penalty/demerit point system). The novice can also be demoted into the intermediate phase after committing a serious traffic violation. Engine performance restrictions are not directly necessary for novice motorcyclists. After concluding the third phase, motorcyclists and moped riders receive a full licence.

13.2.4. Enforcement

Enforcement is likely to become easier now that the licence plate for mopeds is being introduced in the Netherlands, In addition, camera surveillance becomes possible (for red-light running, speed violations and not wearing a crash helmet). Specific to mopeds is the fact that the vehicle itself is speed limited (the 'construction speed'), similar to heavy goods vehicles. This enables specific vehicle checks. The question remains whether or not the stated penalty for tuning up a moped engine works sufficiently as a deterrent; the vehicle can only be impounded after the third warning. If technical measures are not sufficient, a strict enforcement regime and appropriate penalties are the only remedy.

Speeds of motorized two-wheelers are difficult to restrict by means of (safe) infrastructure measures. As long as no vehicle measures are available, speed checks are indispensable, in rural and urban areas.

13.3. In the end, it's about risk awareness and avoidance

The risk factors outlined in this chapter make it clear why motorized two-wheeler risks are considerably higher than those of pedal cyclists and car drivers. The first things to mention are high speeds relative to cyclists, and with the lack of protection compared with a car. Furthermore, the motorized two-wheeler has less limitation physically compared with a car, and the motorcyclist has strong feelings of freedom which are not always easy to being controlled.

The following measures can reduce the general risk level, but they do not have the potential to do this substantially (e.g. to the same level as bicycles): obstacle-free zones, advanced braking systems, ITS to influence speeds and conspicuity at intersections, licence plates for mopeds in combination with additional enforcement. In choosing which measures to apply, it is wise to make a distinction between young and novice motorcyclists on the one hand, and more experienced motorcyclists on the other, because the problems for each group are very different. For the first group, measures in the field of training are more relevant. The possibility exists to introduce elements of the graduated licence to this group, and to combine the training of skills with training in traffic behaviour and risk perception. The most important items for this are 'the ability to recognize and to avoid risks' and 'the development of skills to safely control risks'. This has to be learned first, and to be applied subsequently.

More experienced motorcyclists perhaps use their skills when seeking pleasure and excitement in riding a motorbike. They will have to learn to develop a careful, safe and responsible riding style. The will to avoid risks is connected with attitude towards motorcycle riding. If the will to avoid risks is well ingrained, then riding a motorcycle whilst still not being inherently safe can have significantly reduced risks. If this is not well ingrained, risks will remain to be high. This is also valid for moped riders, where the emphasis has to be changed to the problems of novices, given the often short period for which these vehicles are ridden.

There is considerable interest for safety from the motorcycle organizations (including manufacturers), both at national and international level. At European level for instance, an in-depth investigation into motorcycle crashes was co-financed by motorcycle manufacturers. The Dutch motorized two-wheeler industry contributed financially to a handbook of safe road design, established a safety plan regarding mopeds, and has stated that it is in favour of self-regulation. Motorcyclist organizations are also to be seen more often nationally and internationally in recent years, asking for attention to their target group's safety. Examples of this are the establishment of safety-orientated training courses for motorcyclists, and actions against dangerous infrastructure such as road markings, grooves and ruts in roads, and crash barriers.

A good starting place would be provided by these motorcyclist organizations and public authorities jointly supporting choices to reduce substantially the actual risks of motorized two-wheelers. They could begin by discussing the fundamental issues mentioned in section *13.1* on the question 'How safe is safe enough?' for motorized two-wheelers. Unfortunately, such a platform does not (yet) exist for moped riders. A hole in the market?

14. Heavy goods vehicles

14.1. Fundamental problems requiring fundamental solutions

The economic importance of the freight transport sector in the Netherlands is high. The *Mobility Paper* (Ministry of Transport, 2004a) states that reducing mobility is not an option: “Mobility is not only the carrier of economic growth, it is also a societal need”. *Unnecessary* mobility nevertheless needs to be avoided, both from an economic and from a safety viewpoint. Possibilities to this end are: smart spatial planning, transport management (e.g. ICT applications) and transport savings (by modifications to product and production processes).

Prognoses indicate that freight transport will further increase (strongly) in the future. Vehicle mileage increases at a higher rate than transported tonnage (see *Frame 14.1*). Based on long-term scenarios of the Netherlands Bureau for Economic Policy Analysis (CPB), predictions are made for a 15% to 80% growth between 2000 and 2020. The first question that arises is what are the implications of this growth for road safety? A second question that arises is how we should organize road traffic in such a way that freight traffic – particularly heavy goods vehicles – and other traffic can circulate in a sustainably safe way?

More kilometres, less tonnage

Road freight transport has grown considerably in past decades. The number of freight transport kilometres has, nevertheless, grown much more than the tonnage transported. A cause of growth in general is the growth in trade. The ‘skewed growth’ between tonnage transported and vehicle kilometres is probably caused by changes in logistics (e.g. more ‘just-in-time deliveries’) and by a change in the composition of goods flows: less bulk (relatively heavy and low-value) and more end and semi-finished products (relatively lightweight and high-value).

	Growth 1975-2002
Gross domestic product	95%
Trade	225%
Consumption	90%
Tonnage road freight	45%
Road freight vehicle kilometres	125%

Source: DGG (2004)

Frame 14.1.

In this chapter, we develop a long-term vision of heavy and light freight transport on the basis of Sustainable Safety, with an implementation time scale of between 20 and 30 years. The vision is based on the theme that large and heavy vehicles do not mix well with other road users, even at low speeds. Developing this, in practice, means two road networks, two types of goods vehicles, and two types of driver training. Therefore, this vision has far-reaching consequences for the way in which we now manage road freight transport.

The vision of sustainably safe freight transport attempts to give an answer to a fundamental problem: the enormous mass differences between heavy goods vehicles and other road users. Poppink, working for the Dutch Employers Organisation on Transport and Logistics (TLN), also describes this problem: “Per kilometre driven, serious crash involvement of heavy goods vehicles is relatively low […] But because of goods vehicle characteristics – heavy and rigid – the consequences are often severe. Involvement in traffic fatalities therefore is comparatively high: more than 14% on average” (Poppink, 2005). The incompatibility between heavy goods vehicles and other traffic, also at relatively low speeds, is a fundamental problem that requires a fundamental solution.

Vans only make up a small proportion of goods transport; an estimated 10%. For this reason, this chapter will only deal with road freight transport with heavy goods vehicles. Safety aspects of vans are discussed in *Chapter 5*.

14.1.1. Transport volume and fatal crashes

Freight transport involvement in fatal crashes is relatively high. This is mainly due to the inequality rela-

Transport mode other party	Relative share in %			Total	
	National roads	Provincial roads	Local roads	Absolute	Proportion
Walking	2%	2%	14%	9	7%
Bicycle	1%	14%	41%	27	21%
Moped	1%	6%	8%	7	6%
Motorcycle	4%	4%	7%	7	5%
Passengar car	69%	64%	27%	66	51%
Van	12%	5%	2%	7	6%
Lorry	8%	2%	0%	4	3%
Other	3%	4%	1%	3	3%
Total killed	36	42	51	130	100%

Table 14.1. ***Other party fatalities in crashes with heavy goods vehicles. Annual averages over the years 2001 to 2004 (AVV Transport Research Centre).***

tive to other transport modes and road users. *Table 14.1* shows road traffic fatalities in crashes with heavy goods vehicles. On national roads and provincial roads many fatalities are passenger car occupants (about 65%); on local roads particularly cyclists (about 40%). On average, there are 130 other-party fatalities annually; this represents a share of 14% of all traffic fatalities. The average number of lorry occupant casualties (on average 11 fatalities) is low relative to the number of crash opponent casualties.

Heavy goods vehicle crash problems have an essential component for the transport sector, and that is public support. As more (serious) crashes occur with heavy goods vehicle involvement, societal support for this sector can be expected to fall. This is particularly the case if the absence of professionalism within the sector is the crash cause, such as roll-over trucks on motorways with long traffic jams behind, or fatigued drivers. Great (economic) interests are at stake and so there should be high motivation for the sector to increase road safety further.

14.1.2. Crash causes and long-term solutions

At high speeds (in rural areas), the large mass and the open, rigid construction of the lorry contributes to the fact that there are many fatalities among crash opponents. However, there are also many single-party crashes as a consequence of jack-knifing and roll-over of heavy goods vehicles (Hoogvelt et al., 1997). In urban areas (at lower speeds) poor field of vision of the driver and poor vehicle design create danger for other road users including cyclists and pedestrians. Even at very low speeds, the consequences can be fatal, for instance involving children at play who may end up under the wheels of a reversing lorry in a 30 km/h zone. The business community is not always sufficiently aware of the extent of safety problems related to lorries (Gort et al., 2001). Studies performed by the Dutch Employers Organisation on Transport and Logistics (TLN, 2002) and SWOV (Van Kampen & Schoon, 1999) provide further information about heavy goods vehicle crashes.

We are dealing here with the inherent problems of freight transport which, nevertheless, have diminished in time because of safer vehicles and further improvements to driver training. However, fundamental problems still remain. In the quest for a fundamental solution, it is interesting to make a comparison with other transport modes (rail, inland waterways), and to see what (new) insight this brings.

14.1.3. Comparison with other transport modes

The road freight transport share is more than half of all freight transport (see *Table 14.2*). This also accounts for most fatalities involving other crash parties, both in absolute and relative terms.

Given the low number of casualties in inland waterways and rail freight transport, it is interesting to compare these two transport modes with road freight transport. In both the other transport modes we can recognize principles similar to Sustainable Safety principles, as discussed below.

Transport on own infrastructure
Rail and inland waterway transport have their own main networks with limited branching into the secondary road network. There is only a limited traffic

Transport mode	Transport share	Number of fatalities per year
Road transport	58%	137
Inland waterways	28%	2
Rail transport	1	<1[18]
Pipelines	12%	–

Table 14.2. ***Comparison of transport modes by transport tonnage share and their safety (road transport excluding delivery; sources: CBS Statistics Netherlands, AVV Transport Research Centre and NEA, 2002).***

mix: on rail infrastructure there is a mix of freight and passenger transport, and on waterways there is a mix of freight and pleasure boats.

Rotterdam has the only separate road freight transport infrastructure in the Netherlands. This 'dedicated lane' in fact has been constructed to manage road freight transport flow during congestion. The safety effects of this dedicated lane are modest (RWS-DZH, 2004). A separate freight transport infrastructure, nevertheless, fits well into Sustainable Safety. The mix of heavy goods vehicles and passenger cars sometimes leads to disastrous outcomes in rear-end collisions. On a dedicated lane with one single lane and a physical barrier along both sides, heavy goods vehicles have restricted movement, which virtually excludes rolling over.

Freight bundling

The bundling of freight has been common practice in rail transport for a long time, and this has also been the case in inland waterway container transport. *Distrivaart* (transport on water), a logistics concept for transporting pallets with barges, has nevertheless not been successful since its introduction in 2004.

Road freight transport also has bundling of goods, particularly in express courier and regular line services. Furthermore, there are goods distribution centres to supply supermarkets. Trials with urban distribution have nevertheless not been very successful. Currently, a trial is being held with 25-metres long articulated heavy goods vehicles instead of 18 metres. This trial also includes exchange of trailers on locations along motorways.

Limited number of loading and unloading locations

Rail and inland waterways have a rough grid of infrastructure and (hence) a limited number of loading and unloading locations.

Heavy goods road transport can load and unload everywhere. A national road infrastructure with terminals is lacking. In the southern provinces in the Netherlands, a start has nevertheless been made (the Incodelta project). At regional and local level 'logistics routes' with industrial zones and shopping centres are lacking. However, there are developments aimed at creating a 'quality network' for freight transport (see *Frame 14.2*) where the infrastructure will be adapted to heavy goods vehicles (for the four Dutch regions North, East, South and West, as well as regions such as Utrecht, Rotterdam and Amsterdam.

The Freight Transport Quality Network consists of a coherent network of connections between the economic centres that manages economically relevant traffic responsibly (MuConsult, 2005). In order to create a freight transport quality network, a method has been developed (*Frame 14.2*) to obtain relevant information concerning:

- the important economic centres in the region;
- the quality infrastructure network to connect these centres;
- the bottlenecks in accessibility, safety and environment and priorities for resolving them.

Based on this information, policymakers can make well-founded decisions concerning the best approach to tackling the freight transport bottlenecks mentioned above, in order to create a freight transport quality network.

Low average speed

The average speed on rail is 40 to 50 km/h (NEA, 2002), and 15 to 20 km/h for inland waterways.

The speed of goods vehicles heavier than 12 metric tonnes is limited by an in-vehicle speed limiter that is, in practice, set at 89 km/h. New vehicles in the category of 3.5 to 12 metric tonnes also have to be fitted with a speed limiter as of January 1st, 2005.

Limited freedom of movement and no crossing traffic

The degree of freedom in a lateral direction is very limited for inland waterway and rail transport, with little crossing traffic.

To some extent, this is also the situation for motor-

[18] The number of crashes in rail freight transport has been estimated, because no separate figures exist. In all rail transport there are about 50 fatalities in the Netherlands under rail workers and at level rail/road crossings.

ways. Nonetheless, heavy goods vehicles run off course for various reasons, causing crashes and congestion. The exact causes and the extent of the problem are clearly issues which deserve attention. On non-motorways roads, turning manoeuvres and crossing traffic contribute to safety problems.

Clear and often safe priority rules

As a result of, among other things, the limited braking performance of trains, there is in most cases an automatic right-of-way. On water, commercial ships always have right-of-way over pleasure boats.

In road traffic, there are no separate priority rules for heavy goods vehicles, despite their large mass and size. This means e.g. that a turning lorry has to give priority to a cyclist who is travelling straight ahead on the same road, which often ends in problems. If the cycle path is bent out, a cycle crossing is created just ahead, and the cyclist then has to give priority to the lorry.

Professionalism of the sector

Inland navigation and rail transport have professional skippers and drivers respectively. For truck drivers in the Netherlands, this is usually also the case. However, a safety culture has not developed in the same way as, for example, rail (Gort et al., 2001).

Safety control systems

Rail transport has advanced most in terms of 'intrinsic' safety by the use of automated safety systems. Professional navigation communicates by marine telephone with shore staff at e.g. locks and ports.

Navigation and route guidance systems in road traffic are effective in reducing the need to search, although they can be dangerous if used while driving, as is the case with other communication equipment. Equipment to support the driving task, such as detecting fatigue and lane departure, are, for the time being, only information devices. The danger of risk compensation always lies in wait for such equipment, but whether or not it is, on balance, good for road safety requires investigation.

Time of transport movement

Rail freight transport often takes place at night due to high occupancy with passenger movements during daytime.

Road freight transport occurs during evening hours and at night-time to avoid congestion. Therefore, distribution centres are often open during night-time, and a variety of other businesses can be supplied after hours by means of night safes. However, the transport sector also faces restrictions due to environmental legislation (noise nuisance) and time bans.

Freight Transport Quality Network

The method for a Freight Transport Quality Network (*Kwaliteitsnet Goederenvervoer* or *KNG* in Dutch) is a broad approach that devotes attention both to road freight, rail and inland waterway transport. Spatial economic developments are also integrated in the approach. The use of the KNG method has two main objectives:

1. to facilitate goods flows, without introducing an additional burden for the environment and traffic safety;
2. to stimulate the economy by improving accessibility of important economic centres.

The process orientated parts of the KNG method are very important, because there is a high number of parties with at least as many viewpoints. It is increasingly acknowledged that only common agreements can lead to common arrangements that can be actually implemented. The question is how to arrive at the necessary win-win situations. The KNG method involves parties at the start of the process, such as decision makers at various public authority level, interest groups (e.g. the Dutch Employers Organisation on Transport and Logistics, Dutch Traffic Safety Association 3VO, and environmental groups) and experts (economists, spatial planners, and traffic planners).

Freight transport operates within a variety of administrative levels and modes, from international to local level. Freight transport is pre-eminently suited for a chain approach, provided that the various levels and modes are adapted to each other. The KNG method offers a framework for this. A local project, e.g. at municipal level, where the KNG method is applied, is supposed to fit seamlessly with a regional KNG project, that overarches the local project.

(MuConsult, 2005)

Frame 14.2.

For road safety, night-time transport is favourable if separation from other traffic takes place.

Dangerous manoeuvres
We saw that in inland navigation and rail traffic, mixing with other traffic hardly occurs. Dangerous manoeuvres are, therefore, exceptional.
Current road freight traffic has to make frequent manoeuvres that are inherently dangerous, even if speeds are (extremely) low. The skill to navigate a large vehicle in special manoeuvres, such as reversing, requires much driver professionalism. Other road users are not always prepared or consciously aware of this. It would be better if the construction of roads made such dangerous manoeuvres unnecessary.

14.2. A new vision: vision 1 + vision 2 + vision 3

14.2.1. Vision 1: two road networks for road freight transport

In situations of incompatible transport modes, one of the Sustainable Safety principles is to separate these in place and time. From a Sustainable Safety perspective, physical separation with proper protection between heavy goods vehicle and other traffic is preferable (see also *Frame 14.3*). Separation in time is also possible, but here the problem of enforcement is relevant. Separation in time also requires intelligent solutions, because to free a lane when a lorry arrives necessitates planning for both scenarios. This issue deserves further development. This chapter concentrates on physical separation. Apart from the many benefits (*Frame 14.3*), two important problems for separate infrastructure for road freight transport need mentioning: the costs and finding sufficient physical space.

The previous section shows that the high level of safety of rail and inland waterways stems from the use of a main network with logistics nodes. From the Sustainable Safety vision such a network is also preferred for road transport. However, we should remember that these three modes (rail, inland waterways, and heavy goods road transport) would then all require road transport to and from the nodes by light goods vehicles. This transport would also have to fit within the Sustainable Safety principles.

This brings us to the secondary road network: the 'regional and local logistics routes'. Both networks need to earn the label of 'quality network' for freight transport, and they have to be included in a routing system by means of direction signing and electronic navigation and route guidance. The network can be opened only after Sustainable Safety requirements are fulfilled.

Benefits of separate infrastructure for road freight transport

- Traffic on main roads becomes safer for passenger cars and vans, because incompatible heavy vehicles mainly disappear.
- There are no longer problems with merging and exiting, because lorries do not form queues.
- The main road network is relieved, so there is less need for new roads and road widening.
- Wear and tear of the main roads is greatly reduced because there is hardly any corrugation; 'light roads' become relevant.
- Road construction design can become more focussed.
- Roll-over is a thing of the past if a separated infrastructure for road freight transport is narrow and provides physical protection along both sides.
- A 'freight motorway' can, after some time, be automated, perhaps for unmanned transport of containers, tank and bulk transport, and city boxes.

Frame 14.3.

A national road freight transport network

Assuming that, for the time being, a completely separate infrastructure for freight transport is not economically viable, a good alternative is to restrict heavy goods traffic (articulated vehicles) to the network of through roads (motorways and single-lane through roads). This is a network with split-level junctions.

Incidental application of dedicated lanes for heavy goods vehicles is desirable to limit the use of the secondary network. Examples of dedicated lanes are entries and exits at terminals and industrial zones, or bus lanes used by goods transport. This latter example not only has safety benefits, but also economic and environmental advantages because goods vehicles do not have to brake and accelerate in urban traffic. A trial in the city of Utrecht has shown that in general, a responsible co-use of bus lanes by goods vehicles requires situation dependent adaptations (Van de Puttelaar & Visbeek, 2004).

Regional and local logistics routes for (light) goods transport

In principle, heavy goods traffic should remain limited to the main road network. Trips begin and end, in principle, at industrial zones and terminals. This means that before and after transport takes place with lighter, unarticulated vehicles on the secondary road network. These roads, regional and local logistics routes, should require this type of transport by their design. Roundabouts with short radii for instance, are a barrier for heavy, articulated vehicles, but allow light, non-articulated vehicles. To avoid too many vehicle movements, this regional and local transport ought also to be bundled with the use of specific containers (such as the city box; NDL et al., 2005).

Logistics routes in urban areas are made up of distributor roads that fulfil safety requirements adapted to the means of transport. Shop supply should take place at unloading locations that have a direct connection with these logistics routes (Schoon, 1997).

14.2.2. Vision 2: two vehicle designs adapted to road and traffic situation

Different types of goods vehicles circulate on both types of road networks. Mixing with other traffic on those road networks makes specific safety requirements for both vehicle types necessary. These concern both primary safety (crash prevention) and secondary safety (injury prevention).

Requirements for heavy goods vehicles on main road network

The objective is to allow heavy, articulated vehicles and passenger cars to take part in traffic within the same space (that is, the main road network) and to allow high travel speeds. In this process, we have to take action to prevent severe injury in the event of a crash, and to this end, we distinguish the differences between primary and secondary safety.

Primary safety. Longitudinal vehicle stability (braking) and lateral stability (skidding, jack-knifing) have to be as equal as possible between heavy goods vehicles and passenger cars. The automatic brake force distributor between truck and trailer, combined with electronic stability control (ESC) is an important facility on heavy goods vehicles to achieve this. Certain ITS systems should be implemented earlier on heavy goods vehicles than on light vehicles, such as adaptive cruise control (ACC) and the lane-departure assistant. Traffic jam and fog detection should be standard. In foggy conditions, separating heavy goods vehicles (outer lane) and passenger cars (inner lane) is in any case desirable, but further research is needed to indicate if there are not more and better options to allocate heavy goods vehicles (with their speed limiter!) and other traffic to their own lanes.

Secondary safety. Rear-end collisions are most frequent on a main road network. Apart from inherent mass and structural differences, large speed differences between heavy goods vehicles and passenger cars cause even more incompatibility. Heavy goods vehicles, therefore, have to be equipped at the front and rear with energy-absorbing underrun protection (see *Chapter 5*).

Requirements for light goods vehicles on local logistics routes

Lighter, non-articulated lorries that are deployed on local logistics routes have to be fitted with safety facilities that are adapted to mixing with slow traffic. Here we also use the Sustainable Safety principles.

Primary safety. The driver has to have a direct field of vision from his driving position of vulnerable road users in front of, and next to the cabin. This means a lot of glass and a low seating position. For viewing other locations, the driver should have mirrors and electronic detection. Vehicles deployed in night-time distribution should be equipped with vehicle contour marking.

Secondary safety. The vehicles should have closed bodywork or closed side protection.

Vehicles that are adapted to the roads mentioned above should not circulate on access roads. For unavoidable freight traffic, such as removal trucks or vans and waste collection trucks, this implies that their dimensions have to be adapted, supplemented with facilities for primary and secondary safety that sometimes are in use already.

14.2.3. Vision 3: two types of drivers with different professional requirements

Road and traffic characteristics of the two road networks are so different that they require different skills. The graduated driving licence system (see *Chapter 7 and 11*) can also be introduced for professional drivers. The first phase is general truck training, and in the second phase experience can be acquired either with an articulated heavy goods vehicle on the main road network, or with a non-articulated lorry on regional and local logistics routes. If this phase is concluded successfully, a full driving licence for the vehicle type concerned can be issued. Simulator training seems to fit well with this approach and can serve as a useful addition to formal training on the road.

14.3. Safety culture within companies

Safety culture is a particular form of organizational culture within a company. We can distinguish the presence of a safety culture at three different levels (AVV, 2003):
- at macro level: present in the whole sector;
- at meso level: present in management of a company;
- at micro level: present in staff.

Sector organizations such as TLN (Dutch Employers Organisation on Transport and Logistics), EVO (Dutch Association of Transport Users) and KNV (Royal Dutch Association of Transport Companies) are active in various platforms in the road safety field, guaranteeing a safety culture at macro level.

At meso and micro level however, there is little evidence of safety culture in practice (Gort et al., 2001). Since certain investments in safety may be societally cost-effective but do not offer enough business benefits, companies do not tend to invest (Langeveld & Schoon, 2004). Fierce competition may cause companies to invest only if this improves rather than endangers their competitive edge. It seems that only legal measures that are properly enforced stimulate change in the sector and in individual companies. Opportunities to improve the safety culture include the implementation of crash and damage analyses, and the establishment of damage prevention plans (Lindeijer et al., 1997). Companies can take this action independently, or aided by insurance companies. The *Safety Scan* – a tool developed by transport sector organizations together with the Ministry of Transport (2004a) – enables companies to determine how they can reduce crashes and related damage and costs. Next to this, the number of crashes can also be reduced by using on-board computers and crash recorders (by about 20%, according to Bos & Wouters, 2000), provided these are embedded in a safety culture. Since heavy goods vehicles are already equipped with electronic tachographs, it seems obvious to integrate these into an on-board computer (Langeveld & Schoon, 2004). The Dutch Transport and Water Management Inspectorate, that already checks tachographs in companies, can also play a role in inspections after the introduction of on-board computers. This enforcement is an inherent element of quality assurance for the transport sector (see *Chapter 15*).

Much improvement can be made to the logistics pressure that is often put on drivers. Shippers (that use transport companies) also have a responsibility here. Shippers can place safety requirements on transport companies, as is the norm for the transport of dangerous goods. Transport companies can distinguish themselves by certification as is already the case with coach transport companies (certification with a quality mark for coach transport companies has a 60% coverage).

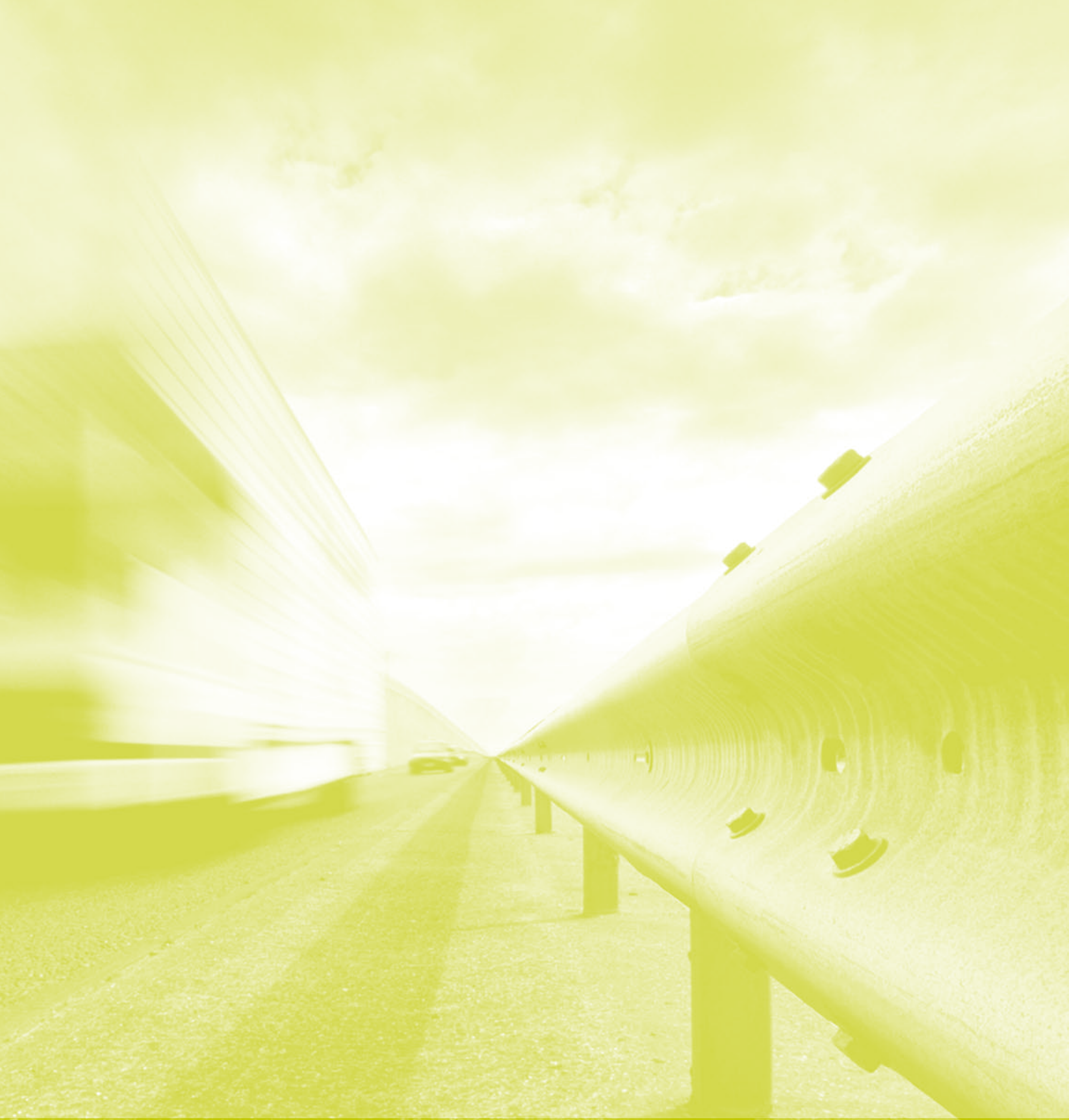
14.4. Epilogue

The economic importance of the road transport sector is high in the Netherlands. Transport sector organizations together with public authorities are considering the question of how to reinforce the sector in such a way that a healthy (international) competitive sector operates responsibly. For the sector, of course, the economic viewpoint and competitive edge is of primary importance, but also socially responsible entrepreneurship and a good sector image are essential. We should investigate how to merge both viewpoints in the future, while looking at socially responsible entrepreneurship from a road safety perspective.

Achieving the outlined vision is, without doubt, complex and will only take place in the long term: so many stakeholders, so many interests, so much economic activity, so much marginal benefits. Bundled freight transport on the main road and on logistics routes network, requires cooperation between private companies and regional and local authorities. A start was made with the establishment of 'Freight Transport Quality Networks', and a phased rolling-out of this concept seems an obvious follow-up. In particular, the process-oriented side of the method for Freight Transport Quality Network can be used to bring together numerous of decision makers and interested parties.

The benefits of a Sustainable Safety approach are obviously increased if we look beyond the direct consequences for road safety. If road freight transport has a separate infrastructure, then benefits can also be achieved in road capacity, road maintenance and more reliable (and perhaps also cheaper) transport.

It must be emphasized that this chapter only suggests the bare outline of a long-term vision for discussion. It is not a solution that can be realized tomorrow. It is nevertheless a vision with far-reaching consequences and a vision that requires many parties in its development and implementation. It is worth investigating these consequences further to identify those problems that still need to be solved.



Part IV:
Implementation

15. Implementation

The political and governmental context for the implementation of road safety measures has changed dramatically in the Netherlands since the start of Sustainable Safety in the early 1990s. The new governmental context partly determines whether or not the ambitions of Sustainable Safety can be realized in the future. Section *15.1* outlines how this affects policy implementation.

The changes in the governmental setting may offer ample opportunities for the implementation of Sustainable Safety. However, we note that for proper coordination between the various components of Sustainable Safety one important link is still missing: quality assurance. Section *15.2* outlines the vision of a quality assurance system for road traffic.

The implementation of Sustainable Safety in the Netherlands requires many billions of Euros. Even with implementation taking place gradually over a time period of twenty to thirty years, quite some financial resource is needed. SWOV has investigated three options for funding infrastructural measures, in particular, and these are discussed in *15.3*.

The implementation of Sustainable Safety is expected to run better and more easily if attention is also given to four other issues. These are brought together under the term 'accompanying policy': integration, innovation, research and development, and knowledge dissemination, and will be reviewed in *15.4*.

15.1. Organization of policy implementation

Since the end of the 1980s, Dutch government can be characterized by a distinct trend towards decentralization. In a variety of policy areas, policy design, development and execution has been devolved to local and regional levels. This also applies to road safety policy. Local and regional authorities can, independently, undertake the implementation of road safety measures and deliver tailor-made solutions for their areas. At the same time, the idea has taken hold that organizations other than local and regional authorities are also important stakeholders in road safety policy. For example, non-governmental organizations and interest groups, driving schools, business drivers and transport companies also determine what happens in road traffic. The implementation of Sustainable Safety has, therefore, become much more complex in recent years, and in the hands of local and regional authorities and interest groups to an increasing extent. We can speak of a network of decision making that runs across society.

15.1.1. Implementation perspectives

Implementation perspectives in the original Sustainable Safety vision

At the beginning of Sustainable Safety, the view of implementation had the following characteristics (Koornstra et al., 1992; Wegman, 2001):

- Sustainable Safety is a scientifically founded, integrated approach to the traffic system, aimed at reducing the possibility for road user error. The approach strives, amongst other things, for a functionally established road network, predictable traffic situations and homogeneous road user behaviour, where subsequent implementation needs to be sustained over many years, leading to the maximum possible reduction of road traffic casualties.
- Sustainable Safety requires coordination of different tasks, whereby the freedom of the public organizations involved to deviate from the content of Sustainable Safety is limited to some extent, and where the necessary funding has to be provided based on rational considerations (often expressed in cost-benefit and cost-effectiveness considerations).

It has become clear that the diverging interests and perceptions of road users and public organizations are potential problems. The same is the case for decentralization policy, reduction of expenditure, and the lack of governmental organization and legal framework to allow stakeholders to commit themselves to Sustainable Safety and to provide funding.

The question raised is the extent to which the new implementation context necessitates a change in perspective on implementation. In answering this question, we were inspired by a discussion about the nature of implementation problems that was held some time ago in the public administration field. From this discussion, it appeared that implementation problems can be viewed from more than one perspective. The first perspective is that of *rational programming*. This perspective seems to line up closely with the original Sustainable Safety view on implementation as described above. A second perspective is that of implementation as a *coordination process of mutually dependent parties* (see *Table 15.1*).

Public administration perspectives on implementation

In the perspective of implementation as rational programming (also called the classical control paradigm or 'closed' approach), implementation problems are seen as the partial, changed, or completely failing implementation of stated policy (see *Table 15.1*). These are caused by formulation of policy objectives which is either vague or too broad and which, whilst offering much freedom in policy, results in it foundering on barriers within executive organizations and target groups. These barriers can be characterized as 'not knowing how to' (lack of proper information and communication), 'not being able to' (lack of competence and capacity), and 'not wanting to' (reticence). The solution lies in specifying policy objectives, adapting policy programming to the characteristics of executive organizations and target groups, and limiting their freedom in policy and power of veto. In the extreme, this leads to the search for 'perfect administration': policy programming that takes account of every implementation contingency, so that the originally stated policy is achieved as consistently as possible (Pressman & Wildavsky, 1973; Mazmanian & Sabatier,1981).

The approach of implementation as rational programming has been strongly criticized by adherents of a 'multi-stakeholder perspective'. This perspective on implementation as a coordination process between mutually dependent stakeholders differs from the first perspective, because it considers policy implementation from the position of executive organizations and target groups. This perspective is partly based on a bottom-up approach of implementation, also called the 'open' approach of implementation (Hanf & Scharpf, 1978; O'Toole, 1988). Adherents of this approach argue strongly from the position of decentralized executive organizations and target groups. They emphasize the importance of the autonomy of these stakeholders, while advocating the reinforcement of their position by providing additional resources from central government. The policy network approach is a second source of inspiration for the multi-stakeholder perspective. The network approach emphasizes mutual dependency between parties and sectors, as well as the need for cooperation and coordination (Mandell, 1990; Kickert et al., 1997). In the

Characteristics	Implementation as rational programming	Implementation as coordination process in a multi-stakeholder setting
Problem of failing implementation	Partial, changed, or completely failing policy implementation.	Policy lines up insufficiently with specific implementation situation.
Failure factors	Unclear objectives and deficient policy programming.	Rigid objectives and policy programmes that do not fit local conditions.
	Barriers in implementation organization, implementation arena, and target groups.	Lack of information, capacity, and freedom in policy to adapt policy to specific conditions.
	Too much freedom in policy and impediment power.	Lack of freedom in policy and resources.
Remedies	Define more precise objectives and policy programming.	Keep objectives and programming broad, facilitate information and communication.
	Limit freedom of policy and impediment power.	Leave more to executive parties and provide them with resources to cater for policy.
	Reinforce policy design by research and feasibility studies.	Use knowledge and resources of other sectors, executive organizations and target groups by involving them in policy.

Table 15.1. ***Overview of public administration perspectives on implementation.***

multi-stakeholder perspective (see *Table 15.1*), policy implementation fails if:

- rigid objectives and policy programmes leave executive organizations and target groups with insufficient room to adapt policy to specific circumstances and conditions for implementation;
- insufficient resources are made available;
- policy does not line up with the objectives, opportunities and knowledge of executive organizations, policy makers in other sectors, target groups and stakeholders.

This diagnosis leads to recommendations that are diametrically opposed to those of the first approach: to keep objectives and programming broad, acquire support from other sectors, executive organizations and target groups, and provide them with opportunities (resources, information and freedom in policy) in order to contribute optimally to the fulfilment of this policy, and use their knowledge of specific conditions and practical viewpoints for the improvement of the policy content (Dowding, 1995; Marin & Mayntz, 1991; Marsh & Rhodes, 1992; Kickert et al., 1997).

15.1.2. Fragmented policy context as the point of departure

Given the recent changes in the policy context of Sustainable Safety to a fragmented and decentralized network, the multi-stakeholder perspective, in particular, offers ways forward for optimizing implementation. The new implementation context can be described as having a faceted character (Sustainable Safety is considered against other interests and sectors) and a strong tendency towards decentralization, therefore necessitating coordination between mutually dependent stakeholders. We now discuss the consequences of the multi-stakeholder perspective for Sustainable Safety.

Sustainable Safety as implementation programme or guiding concept

One of the fundamentals of Sustainable Safety is that a certain amount of uniformity is required (see *Chapter 1*). This seems to be at odds with the concept of decentralization and the multi-stakeholder perspective. However, decentralized implementation or implementation as a facet of an area-wide approach certainly does not exclude uniformity. In many sectors, uniform standards and decentralized production go hand in hand, as in construction engineering, for example. It is, nevertheless, important to use existing knowledge in decentralized authorities and other sectors in the establishment of uniform policy measures. This knowledge is indispensable to adapt the uniform package of measures to specific conditions. This requires measures to be developed in dialogue with local authorities. For Sustainable Safety this can be done by gaining the commitment of local authorities through the creation of road safety agreements with provinces and/or other municipalities (Wegman, 2004). High-quality requirements need to be put into the management of this interaction in order to assure progress and quality (see *15.2*).

Moreover, Sustainable Safety could as a 'strong brand' also fulfil a role as a 'sensitizing concept'. Apart from being seen as a collection of road safety measures, it can be regarded as a mobilizing and motivating idea that induces people to think about road safety. In this way, Sustainable Safety is considered more as a paradigm or framework for a quality assurance system than an operational implementation programme (see *15.2*). It is a management concept that supports authorities in decisions with road safety implications.

Allies, unwilling partners and new coalitions

Central government was an obvious ally in the original implementation context of Sustainable Safety. The central government arranged funding and set rules and frameworks to create uniformity. However, this role has become much smaller in the new fragmented and decentralized environment. Local and regional authorities expect, nonetheless, a stronger involvement in road safety policy in terms of funding and content from central government, as became apparent in what is called the COVER evaluation, (Terlouw et al., 2001). According to this evaluation, sufficient central resources for Sustainable Safety, co-responsibility for enforcement and education and sensitivity to the views of the regions were important tasks for central government. Finally, as was noted, the central government pays too little attention to monitoring and evaluation of regional projects, and has missed the opportunity to be guided by the results of regional policy (Terlouw et al., 2001).

Interestingly enough, local and regional authorities emerge as important road safety advocates. In participation processes for the *Dutch National Traffic and Transport Plan (NVVP)* and the *Mobility Paper,* they frequently emphasize the importance of ambitious targets and adequate levels of resource (Bax, forthcoming). Local authorities are frequently directly addressed by citizens about crashes and dangerous traffic situations. It may be the case that decentralized authorities are the natural allies of Sustainable Safety. This would fit very well in the perspective of implementation as a coordination process between mutually dependent stakeholders. In a multi-stakeholder context, policy success does not only depend on the support of the central policymaker simply because none of the parties is able, in isolation, to implement successful policy. Success depends on the capability to build new and thrusting coalitions.

15.1.3. Sustainable Safety as a home or away game

The perspective of implementation as rational programming starts from a situation in which sectoral policy is already established: it is developed in a separate, 'vertical policy category'. However, Sustainable Safety measures are, increasingly, established within the framework of broader traffic and transport policy. Road safety policy is less and less an isolated stand-alone policy category. This presupposes that as well as a sectoral approach, a faceted approach is required: at various levels of government, interaction with other sectors is essential, and this broadening of scope offers new opportunities (see also *15.2*). For example, benefits can be gained by coordinating and embedding Sustainable Safety within urban development and spatial planning. In other words, Sustainable Safety is less frequently a home game: it often has to play away. This fits with the perspective of implementation as a coordination process between mutually dependent actors.

Playing away does not make the implementation of Sustainable Safety any easier. People have to be involved in the arenas of traffic and transport policy and spatial planning, and they have to make a strong case for road safety interests. Moreover, they have to negotiate their case in these arenas. Knowledge from cost-benefit analyses can be of service here. At the same time, back-up is essential from forums such as regional dialogue groups where road safety interests are discussed. However, the change of institutional rules (due to policy decentralization) simply makes playing away necessary.

Sustainable Safety as the measure of things: attaining targets by interweaving objectives

The relationships between stakeholders have changed due to the new implementation context. This also has repercussions for the way in which objectives and targets are set and maintained for road safety policy, both in general and for Sustainable Safety. Despite the fact that, in theory, central government can impose targets on local and regional authorities, in practice they have to secure the commitment of these authorities and other (societal) parties. In the established multi-stakeholder environment there is a need to combine individual objectives with those of other parties. This does not mean making compromises such that none of the parties attains its objectives, but finding solutions that can lead to the unification of diverging demands and interests. In reality, the implementation of Sustainable Safety becomes less of a sectoral or stand-alone policy, and more one that it is weighed against other interests. It is sometimes effective to compete with other interests but it can also be effective to identify and take advantage of opportunities that interweave Sustainable Safety measures with other objectives and measures. Perhaps by combining financial resources, comparatively expensive Sustainable Safety measures can be funded. Coordination is, therefore, necessary with specific investment cycles that other parties follow. Road authorities already do this (Wesemann, 2003), however, opportunities for further improvements exist.

The bridge between knowledge and policy: series and parallel connections

These new settings also have implications for knowledge management and research organizations. Since a variety of stakeholders are involved in negotiating policy development, more parties require more knowledge that must be made available at earlier stages of the policy development process.

The multi-stakeholder perspective anticipates a different connection between science, research organizations and policy. This involves the quality assurance of road safety solutions selected by executive stakeholders. That is why, in future, a parallel and multi-faceted connection between scientists and policy makers according to the principle of 'concurrent science' is more appropriate than a serial connection (Jasanoff, 1994; De Bruijn & Ten Heuvelhof, 2003; Koppenjan & Klijn, 2004). Research organizations can play a facilitating role in policy development in practice. They can support the dialogue between stakeholders about the design and implementation of policy measures by offering scientific views and insights and by evaluating proposed solutions. The challenge is to prevent 'negotiated nonsense' and to

Implementation as rational programming	Implementation as coordination process in a multi-stakeholder setting
Sustainable Safety is an effective concept that has to be implemented as completely and uniformly as possible.	Sustainable Safety is not static. It is about realizing uniformity and an adequate adaptation in dialogue with executive organizations.
Central control is the best guarantee for a complete and uniform implementation.	Central control leads to adaptation problems and alienates potential partners, whereas central government failed as an ally in the past.
Area-orientated policy and faceted policy are detrimental to uniform and complete implementation.	Area-orientated policy and faceted policy offer opportunities for adaptation of Sustainable Safety at decentralized level and proactive involvement of related policy areas.
Success is the extent to which the realized measures comply with the ideal of Sustainable Safety.	Success is comprised of road safety benefits relative to existing situations.
Research institutes contribute to the content of Sustainable Safety based on their scientific knowledge.	Knowledge about Sustainable Safety facilitates regional and local authorities and other stakeholders in the preparation of measures with road safety impacts.

Table 15.2. ***Two visions on the implementation of Sustainable Safety.***

carry out policy measures that are tenable in the light of scientific knowledge: 'negotiated knowledge' (De Bruijn et al., 2002).

15.1.4. Conclusion: towards a new vision of Sustainable Safety implementation

In conclusion, *Table 15.2* shows the characteristics of both perspectives in respect of the implementation of Sustainable Safety. Given the decentralization process of recent years, and the consequent increase in mutual dependence between parties in the implementation context, it is necessary to base a vision of implementation for the next phase of Sustainable Safety on the perspective of implementation as a coordination process in a multi-stakeholder environment.

15.2. Quality assurance

Following decentralization, it is noticeable that more independent organizations are now responsible for the management of the road traffic system. Arguing from a Sustainable Safety view, these organizations should develop and implement policy in conjunction with each other. A good example of this is offering road users a recognizable and consistent road design to improve the *predictability* of road course. To date, there has been no guarantee of the consistency of implementation. Recognizability and predictability can only be achieved if all road authorities in the Netherlands agreed to a certain amount of uniformity, or if they are compelled to do so.

A second observation (e.g. see *15.1*) is that road safety has to be considered against other interests (less sectoral, more faceted). At the moment, these are not always taken into account. If they are made, the consideration may not be explicit, nor transparent, nor sometimes with sufficient knowledge. Nevertheless, what these considerations have in common is that they are made in complex organizations that operate in a complex social environment. It is not always clear how road safety is dealt with in these circumstances.

The third issue is that currently, where compromises are made in policy design and implementation, there are not enough safeguards against them being too far out of line with the Sustainable Safety vision. Such compromises are, therefore, not optimal in terms of safety effects (also characterized as 'dilution of measures').

Finally, many autonomous organizations do not have a tradition of working in a multi-stakeholder setting.

We take this opportunity to plead for cooperation in achieving Sustainable Safety and point out the vision's essentially integral character. Moreover, the results and content of such cooperation need to fit into the Sustainable Safety vision. In fact, the Netherlands does not have good mechanisms, agreements, covenants, rules, laws, or any other form of binding arrangement with which to create such a collective development of one single vision.

To give an accurate impression, it is, nevertheless, important to note that stakeholders in the road safety field, and more particularly with reference to Sustainable Safety, are building up an impressive track record. The *Start-up Programme Sustainable Safety* covenant is an excellent example of advancing jointly, making agreements, and following them up. The 'covenant' is supported financially by the central government and supplemented by persuasion – in the form of providing knowledge about potential measures – and has delivered many good developments (see *Chapter 3*). However, the sum of all these individual decisions made by all these autonomous organizations must have led to a less than optimal outcome, and will continue to do so in future if no additional agreements are made. Challenges, therefore, remain.

15.2.1. Tackling latent errors

Sustainable Safety requires a quality assurance system aimed at excluding latent errors in the road traffic system (see *Chapter 1*). This quality assurance is an important translation of the preventative or proactive approach in Sustainable Safety: do not tackle road users' dangerous actions before eliminating the latent errors introduced by providers of various road traffic components (such as road authorities, transport companies, car manufacturers, ITS providers, driving instructors, etc.).

A fundamental problem is that there is no established pattern of using a proactive approach to latent system errors in road traffic, or of systematic consideration of critical processes leading to (near) crashes. An attempt to implement this by, for example, the introduction of road safety audits, has failed in the Netherlands up until now. Public authorities responsible for road traffic fail to take sufficient heed of the lessons from road crashes, and even less from near-crashes. In road traffic crashes, the final error made by the road user very often stands out as the crash cause. In other transport sectors, the whole system and its (latent) errors as contributing factors to crashes are considered, and this has been the established practice for a long time. Finding latent errors in road traffic should be considered as a profession in its own right: estimating chances and risks, establishing causal relationships, and understanding statistical relationships. Professionals in this field can make an important contribution to achieving sustainably safe road traffic.

The current legal basis as a source of non-commitment

The support that providers receive under current legislation is contained in guidelines and recommendations, and these often have quite a *non-committal* character. For example, road authorities ought to provide a safe road infrastructure, but the requirements of this have not been formally laid down. Road authorities are also not called to account generally speaking, or only in special cases. Transport companies ought to incorporate safety into the heart of their activities (safety care system) but at the moment the legal responsibility for this is not a function of road traffic operations (except for the transport of dangerous goods). The police enforce traffic rules, but there is no formal basis on which to assess quantity or quality. How do we know when the police perform their tasks sufficiently well?

At present, the foundations of a traffic system where latent errors are banned and eliminated in a way that is recognizable to road users are insufficiently solid. There is, nevertheless, room for weak and less than ideal solutions which results in a lack of consistency and uniformity in the road and traffic environment.

15.2.2. Organization and development of a quality assurance system

It is justifiable to expect that a quality assurance system could be 'the missing link' in road safety, for example, by means of road safety inspections or audits. Incidentally, in order to avoid any misunderstanding, inspections on their own cannot and will not solve the quality assurance problem (Wegman, 2003).

It is necessary first for each stakeholder to organize the quality of their own activity: an underestimated problem! To this end, expertise in terms of content and up-to-date, scientifically sound knowledge are indispensable. The situation where safety is an add-on to other work needs to be avoided. Promoting road safety is a profession in itself. Even experts sometimes have difficulty in assessing opportunities, risks and effects of measures, and in understanding statistical relationships. Therefore, this difficult profession needs the full attention in road traffic.

If we speak about quality assurance, we first need to define the term ‘quality’, and next we need to set out what this quality comprises and to communicate this well to decision makers. In other societal fields incorporating quality assurance, it is customary to lay down the quality processes in terms of rules or sometimes laws (objectives and constraints). Subsequently, mechanisms have to be established to ensure compliance with agreed rules.

Mix of instruments for a quality assurance system

For quality assurance inspection of intermediary parties within the road traffic system, we traditionally think of central involvement on a legal basis. Based on this assurance system, we can then assess compliance with, in most cases, the possibility of penalty in the background. However, inspections can also be implemented in more up-to-date ways, such as:
- surveillance and action, particularly in the field of issuing and suspending licences;
- advisory and mediating action, predominantly aimed at acquiring and sharing knowledge;
- action with respect to policy preparation, decision making and implementation, mainly aimed to integrate quality in planning transparently and at an early stage.

Inspection in the modern sense is an integral part of quality assurance, and a final assurance action in the policy development process.

The essential element in choosing the mix of instruments (see the above list) is to ascertain how 'enforcement' takes its shape. Can information and the dissemination of knowledge (persuasion) suffice? Can parties (including public authorities at various levels) close contracts where they can work in each other’s interest (self-certification)? Or does a certain coercion and central involvement have to be established for, otherwise, the desired outcome (of safety control) would not be within reach? One overarching philosophy is to have as few additional regulations as possible. The choice of instruments for implementation mainly depends on the extent to which the various stakeholder interests run in parallel, and on the possibilities of creating additional external pressure from consumers and interested parties. In principle, there is a parallel interest of parties in road safety: none of the actors wishes to kill or to be killed. This makes self-certification an obvious option.

Public authorities as road infrastructure providers and road traffic managers find themselves in a special position. Safety is a primary task of public authorities. At the same time, there are other interests that need to be considered, such as accessibility and environmental problems. In this process, public authorities make the investments, but they do not harvest the corresponding benefits. The benefits do not return as a general rule, they cannot be calculated and charged, and neither are they directly visible (see *15.3*). Both effective legislation and strong external incentives are lacking with respect to safe and uniform implementation of road infrastructure. Therefore, changes in this area are needed, even if these changes are considered to be difficult both politically and governmentally.

Recommendations for first developments

SWOV recommends the development of a quality assurance system for road authorities as a starting point. We envisage expertise requirements for staff, precise procedures for planning preparations and implementation, road design guidelines, evaluation procedures and analyses of near-misses. This will not lead to substantial changes. A quality assurance system should, nevertheless, make clear to all people involved both inside and outside the road traffic profession that quality is something which requires commitment. It is definitely not the intention to limit the competences of organizations. The intention is to anchor quality assurance not only in organizations, but to ensure quality assurance in an overarching way, for example, by means of supervision.

We recommend starting with four topics:
1. Requiring the Minister of Transport not only to report on recent road safety developments to Parliament, but also on progress made by other key-stakeholders.
2. Implementing road safety audits.
3. Requiring road safety impact assessments of sizable investments, for instance within the framework of road planning and environmental impact assessment studies.
4. Revising existing guidelines and recommendations for road design in the Netherlands, so that these

can be used in the quality assurance route advocated here.

It is noteworthy here that the European Commission develops a proposal to invite the Member States to report about the way in which the audits and impact assessments mentioned under 2 and 3 are carried out.

15.2.3. Revolutionary?

The proposal for a quality assurance system seems revolutionary because it is something new for road traffic, with the exception of the transport of dangerous goods. However, it already exists in a score of other policy areas and organizations. Examples are: health care, rail transport and, of course, aviation, to mention a few. The aviation approach, in particular, may serve as an example and inspiration for road traffic. Its main characteristics are the absence of a non-committal approach and an obligatory learning process that necessitates action.

Quality assurance is, in fact, the management philosophy of Sustainable Safety. Quality care can be a fully-fledged element of every road authority's 'regular quality assurance' (Wegman, 2003) aimed at eradicating non-commitment. Sustainable Safety requires more commitment regarding 'management and learning'. It is, nevertheless, clear that at the present time, it would not be very appropriate to advocate an additional quality assurance system, neither for road authorities nor for other stakeholders (professional freight transport organizations, public transport, police, driving schools, etc.), The current trend is for public authorities to draw back from more centralized government in order to cut costs and to downsize, and a new period of decentralization has just been embarked upon. It is interesting to note a different development in practice that is at odds with this trend: more independence combined with stricter supervision.

We note that the quality of the road traffic system requires supervision that does not have to be radically different from that in other countries. Many countries have already implemented, for instance, a road safety audit system (www.roadwaysafetyaudits.org). However, it might also be prudent within the prevailing political culture to prescribe a basic set of rules, and to enforce these seriously.

The approach presented here is not targeted at final outcomes in terms of numbers of casualties, as set out in the Netherlands in the *Mobility Paper*. The approach targets the processes that lead to achieving high-quality sustainable safety in road traffic, starting with the road authorities. The idea is that road authorities and, ultimately, road users, benefit from supervision. In order to avoid any misunderstanding, the issue is not to establish Sustainable Safety more deeply and quickly through some form of supervision. Agreements within the regular political-governmental arena already facilitate this process. The issue is to anchor quality assurance not only within the organizations themselves, but to anchor it firmly. Who could object to that?

15.3. Funding

This section addresses the funding of road safety measures. It addresses not so much the means by which road safety can be improved, but how and by whom these can or should be funded. The character of the safety measure and the fact that it cannot be regarded separately from the (dis-)functioning of the road safety 'market' itself is also addressed.

Our analysis is primarily based on the economic theory of social welfare. Aside from this, policymakers and decision makers have the responsibility of deciding about the implementation and funding of measures. At the same time, other considerations than social welfare play an important role. Decision makers have to reconcile all these interests.

15.3.1. Market failure and governmental intervention

The 'market force' is an important point of departure in modern micro and welfare economic theory (see e.g. Varian, 1992; Atkinson & Stiglitz, 1980; Johansson, 1991). If a number of presuppositions have been satisfied (see below), the free market will ensure that the so-called 'Pareto optimum' will establish itself. In this optimum, the production of socially optimal quantities of all services and goods will take place as efficiently as possible; that is: at minimum social cost. In such markets, individual behaviour aimed at maximizing individual wealth will lead to a market equilibrium in which the social Pigouvian welfare (the sum in monetary terms of individual levels of wealth of individual actors) is maximized. It is not surprising that policy advice to governments in such markets would be not to intervene: "If it ain't broken, don't fix it".

The conditions in which the above 'market force' will function are, nevertheless, quite hypothetical, and have to be regarded first as a hypothetical ideal type. Nonetheless, this ideal type offers a good starting point to consider the extent to which, and for what reasons, this attractive characteristic of a market economy does not occur, or is disturbed. Such an approach provides insights into the question of whether or not to intervene in the market process, and if intervention is called for, how to intervene most efficiently. An intuitively logical result from a market economy is that a government, if needed at all, adjusts a market most efficiently by intervening policy as closely as possible to the source of market failure (the cause of the divergence of the abovementioned ideal type).

There are several reasons why a market can fail, and each of these has its own policy implications. *External effects* will occur if the behaviour of an individual has a direct effect on welfare of another individual without paying the costs (i.e.: not primarily through price changes). *Market power* will occur if a corporation is large enough, relative to the total market size, to influence prices. This is often the result of *economies of scale and/or production indivisibilities*. *Public goods* are those goods for which the price mechanism cannot function well, because individuals cannot be excluded from consumption (non-exclusiveness) and because the consumption by one individual is not to the detriment of the consumption of another individual (non-rivalry). An example is embankment protection against flooding. *Imperfect information* and *uncertainty* are another category of market failure.

Specific examples of this category that play a role in road crash damage insurance, are *moral hazard* (this may occur if the behaviour of one insured person is influenced by having insurance or not or by the insurance form, whereby a change in behaviour cannot be observed by the insurer) and *adverse selection* (this occurs if individuals from different risk groups are insured against damage, whereby the insurer cannot observe beforehand to which risk group an individual belongs). Also *transaction costs* can impede proper market functioning. Seen from an economic viewpoint, this may call for public intervention, for instance if the transaction costs come from a lack of publicly accessible information or from the lack of market institutions that facilitate swift transactions. *Merit and demerit goods* are the final category, and these are relevant if the government considers that individuals do not estimate certain goods at their proper monetary value. This can also be regarded as a special case of less than perfect information. Important for the future line of reasoning is to ascertain which forms of market failure can be important in road safety related markets.

Market failure in road safety

Where investments in road safety are (or should be) made within a market setting, we can simultaneously distinguish numerous forms of market failure involving different stakeholders in a highly complex market. There is no need to discuss the different types of market failure here since they all have one thing in common, which is: they reduce incentives for road safety investment below a level that would be societally efficient. This provides an economic argument for public intervention into the road safety market.

The diversity in market failure forms in road safety-related markets provides economic justification for the fact that the public sector has long been active in this area. The most important considerations are, probably, the following:

- The safety of road users can be regarded as a *merit good*, insofar as road users, for example, cannot assess the actual risk rationally and thus underestimate it. Risk assessment is relevant in various behavioural choices prior to and during road use, such as purchasing a vehicle, purchasing safety devices and facilities, route choice, and executing various types of manoeuvres.
- The interaction between road users concerns *external costs* in the sense that the safety risk inflicted by one road user on another is not reflected in market prices. People are liable for damage inflicted on someone else, but this liability does not cover (completely) all forms of damage, such as intangible damage. This deficiency is reflected in insurance premiums which are based on the payments that an insurance company has to make in crash cases rather than based on actual social costs. Furthermore, while insurance premiums are differentiated (annual mileage above/below 20,000 kilometres, region, no-claims bonus systems, passenger car or motorcycle, etc.), this does not come close to the extent to which damage risks differ between individual road users. This is also the case for the differentiation in premiums within the no-claim bonus system following damage caused, and as such is a bad predictor for the future damage risks of the insured person.
- External risk increases with every kilometre driven, which is not taken into account in the insurance premium. Even if all material and intangible damage

to others were to be fully incorporated into insurance premiums, this would not result in a correct price per kilometre for the person who causes a crash. In addition, infrastructural safety devices and facilities (safer asphalt pavements, public lighting, road signs, roundabouts, etc.) are *public goods*, as is the infrastructure to which they are often inextricably attached. They are public goods both in a purely economic sense (non-rivalry and non-exclusiveness), and in the more popular interpretation that governments – in their role as road authority – are usually responsible for these facilities.

In view of what has just been stated, a further road safety improvement, as intended with the introduction of Sustainable Safety, cannot be left to the free market forces. Here, we concentrate on the problem of how the required measures could be funded by government.

15.3.2. Costs and funding of road safety measures

Governments play, and as we have seen have to play a role in many different road safety measures, but these do not always involve high implementation costs on their part. This section discusses whether the most important types of road safety measures also bear high implementation costs.

Organizing road safety education

Road safety education primarily concerns traffic education in schools and providing public information. In the Netherlands, this is mainly financed from public budgets, but the amounts of money are relatively modest. For 1993, an estimate was made of the costs of publicity campaigns (partly funded at central level, and partly from regional contributions). At that time, the campaign budget was about 1% of the total costs for preventative measures (Muizelaar et al., 1995). Even if expenditure for traffic education in schools is taken into account together with a possible increase in the costs of publicity campaigns, this expenditure would probably be only a few percent of the total package of road safety measures in the Netherlands.

Developing and enacting (legal) safety requirements

Safety requirements cover three different types:
- requirements for (driver) education, training, and selection;
- requirements for vehicles (construction and maintenance);
- requirements for road user behaviour.

Central government defines requirements for education, training and selection with negligible costs. The financial consequences of these requirements lie mainly in the higher quality and longer duration of education, training and selection. These are, nevertheless, borne by the novice licence holder.

The same holds *mutatis mutandis* for vehicle requirements. The additional costs are borne by the buyers of these vehicles.

The costs of requirements for traffic behaviour are also negligible for the government. However, this is not the case for costs of the related enforcement (police enforcement, prosecution and sentencing). On the other hand, the most common penalties (fines) represent a substantial source of income for the government, although these are not intended to fund enforcement, but to prevent traffic violations. Nevertheless, the revenue can be used to fund enforcement. In 2003, a total of 570 million Euros was cashed by the Dutch central fine collection agency (administrative penalties, fines and judicial transactions; CJIB, 2004). These mainly comprised penalties for speed violations and some other traffic violations related to dangerous behaviour. The revenues are sufficient to fund surveillance and enforcement of excessive behaviour.

Implementation of safe roads

This measure concerns the safe implementation of new and existing roads by road authorities (both national, regional and local). This comprises an extensive package of measures for implementation over the next 20 to 30 years. Given the length of the road network, the high crash risks and the discrepancies in requirements for a sustainably safe road network, most measures will need to be deployed on regional roads managed by the provinces and municipalities. The corresponding costs are estimated at more than 8 billion Euros (at 2000 prices). A study was carried out recently to investigate sources of available finance for this (Wesemann, 2003). It showed that this implementation can only be partly financed from existing resources (see the next section). In the past, the regions have often piggy-backed road safety measures onto road construction and maintenance. However, the amount of resource will be insufficient if they continue and even reinforce this policy. Depending on the contributions from the general budgets of provinces and municipalities, the deficit is estimated at 2.7 to 4.7 billion Euros. With an investment period of around 25 years, this amounts to 100 to 200 million Euros annually.

Current funding of infrastructural safety measures in the Netherlands.
A recent change in policy is that there are no longer separate funds (such as the subsidy arrangement for the *Start-up Programme Sustainable Safety*) for use by regional road authorities for funding infrastructural road safety measures. The Dutch Ministry of Transport determines the infrastructure fund within its total budget fed by the national budget. This fund serves to finance all kinds of road investment projects that may or may not include road safety measures. Part of this budget is allocated to roads that are managed by the Ministry itself (projects on national roads part of the multi-annual infrastructure and transport plan), and part to regional roads through the 'Broad goal-oriented grant'. In addition to the infrastructure fund, the Ministry also allocates a governmental contribution to this general target subsidy from other parts of its budget. Regional traffic and transport projects, including road safety measures, are (partly) financed from this general target subsidy. As a rule, the national and regional authorities each contribute 50% of the estimated costs.

Regional and local authorities determine the funding for their own road projects. These are allocated within their own budgets, possibly with co-funding from the national government. The revenues of provinces and municipalities are partly fed by national government contributions (the provincial and municipal fund), and partly by surcharges from motor vehicle taxes (by provincial environmental taxes), real estate tax and sewage duties (by municipalities).

Infrastructural road safety measures are directly or indirectly financed mainly from central government revenues. These come from various kinds of taxation and duties. Apart from general taxes (income tax, corporate taxes, value-added tax), we mention here in particular duties related to the use and – particularly – ownership of motor vehicles: vehicle tax, tax on the purchase of new motor vehicles, and fuel tax.

15.3.3. Funding public expenditures: theoretical backgrounds

How can the public sector cover the cost of its own expenditure? This is an important question in the field of public finance. There is no unequivocal answer to this question, but some general lessons can be learned from the literature.

Funding by efficient pricing

As we saw earlier, in a perfect market an efficient price and an efficient quantity is established automatically. This means that there is such a thing as 'an efficient price' and, indeed, this is the case. From an economic perspective, it is advantageous if prices reflect the 'marginal societal costs': the costs that correspond with the last goods that were produced in the equilibrium state. If in certain markets prices are lower than the marginal societal costs – for instance because of the existence of external effects – it is advantageous from an efficiency point of view to lift this discrepancy by regulatory duties. Specific examples of this are the economically attractive *ecotaxes* on activities which pollute the environment and *congestion charges* to combat congestion. A direct result of such a policy is that revenues are generated that could be used by the funding organization (usually a public authority) in different ways. This is, of course, good news if there is a specific need for finance which, otherwise, would have to be recovered elsewhere from interfering with taxation.

Funding by non-efficient taxes and charges

The lion's share of public money comes from taxes that do not decrease the gap between prices and marginal societal costs, but on the contrary create or increase this gap. An important example of this is income tax, which leads to a net discouragement of the labour supply because the marginal labour costs for employers (salary before taxes) are higher than the marginal income of employees (salary after taxes). Such taxes interfere with market functioning (in this case the labour market) and take the economy further away from a Pareto-efficient situation. Starting with theory, various ideas have been developed as to how to minimize the related social welfare losses. An important example is the so-called *Ramsey-pricing,* according to which principle government (somewhat simplistically formulated) can make tax pricing dependent on the price elasticity of particular goods. This results in a taxation scheme that minimizes social welfare losses by taxation, given the public funding need. There is, however, no relationship between the biggest beneficiaries of public expenditure and those who pay the highest net taxes. This can, of course, be regarded as unjust and could be improved by application of the direct-benefit principle (or 'the user pays' principle). Introduction of new taxes would create further interference with market functioning.

Conclusions of funding public expenditures

In order to fund regional infrastructural road safety measures, the Dutch government needs additional funds during the coming 15-25 years. These can be obtained by 1) new taxes for specific groups or 2) increasing the budgets that are based on current taxes and charges. This latter one is possible if the taxes are increased, or there is a different prioritizing when allocating current yields. If a new tax meets the criteria for an efficient price, the first possibility is preferred. However, if this possibility cannot be implemented, has perception costs that are too high, and/or yields insufficient funds, the second possibility must also be examined. These financing possibilities will be further examined in the next section.

15.3.4. And other sources of funding?

Three options have been investigated for funding regional infrastructural road safety measures:
– enlarging crash damage liability coverage;
– pricing policy for road use;
– increasing existing budgets.

On grounds of welfare economics, a combination of the first two funding schemes offers most benefits. Preventative safety facilities on roads can be funded from the revenues of differentiated road use pricing. This source could be supplemented by an additional user charge for motor vehicle users. Even better would be a supplement from for instance a 'Fund to prevent road casualties' that would need to be established. This fund would then be fed by people who cause crashes despite the preventative measures taken. Payments into the fund would include the share of intangible damage to the persons killed (and not to his/her survivors). One could say that the fund replaces the persons killed and receives their share of damage compensation. In theory, both funding schemes also fulfil the requirements for efficient pricing. In practice, however, these systems could not be expected to cover the finance needed for regional road implementation within the near future. While societal and political acceptance is increasing again in the Netherlands for differentiated road use pricing, there would need to be a long lead-time for this measure, even if it was accepted now. At the same time, the possible (limited) additional financial burden for road users will evoke a renewed discussion about the constraint of budgetary neutrality, which seems to have been agreed upon, politically. But why would we not want to engage road safety investments in this discussion and to ask road users their opinion? For the time being, broad societal and political support is lacking for a (significant) enlargement of legal liability for intangible damage for death. At the same time, no strongly differentiated liability insurance premiums that could lead to the sufficient internalization of external costs (and consequently to efficient pricing) seem likely to be introduced.

The third source of funding is increasing motor vehicle fuel tax and/or attaching new priorities within a number of existing budgets (for new road and rail investments, revenues from traffic fines, and ICES[19] money). This type of funding would offer some possibility for the near future. Tax increases could, nevertheless, be only very modest, and existing budgets offer room for targeted new priorities.

15.3.5. Conclusions regarding the funding of Sustainable Safety measures

In addressing how new public sector road safety measures can be funded, we limited our discussion to funding sustainably safe implementation of the regional road network, since there is information available (Wesemann, 2003) and the need for funding is great. In addition to funding from the existing sources, an amount of 2.7 to 4.7 billion Euros will have to be found in the Netherlands in the coming two to three decades. For an investment period of 25 years this amounts to 100 to 200 million Euros annually. For the additional funding of roads of other road authorities, such as national motorways, similar considerations rule as for the regional road network.

Three funding sources have been discussed: enlarging road crash damage liability coverage, a different

[19] ICES = Interministerial Committee for Economic Structural Policy

way of pricing of road use, and more money for sustainably safe roads from regular and existing budgets. With respect to enlarging the liability coverage for crash damage, we conclude that enlarging liability for intangible damage can, in theory, generate more than sufficient resource. In practice, however, this option will not lead to more funding in the short term for the implementation of a sustainably safe (regional) road infrastructure.

A pricing policy for road use is a more efficient way to fund infrastructure compared to the existing funding, and it can also be used to provide the funding for a sustainably safe (regional) road network. If this system has to be introduced budgetary neutrally, this option will not generate additional means to finance sustainably safe measures.

By increasing motor vehicle fuel tax and attributing new priorities to a number of existing budgets (for investments in roads and rail, revenues from traffic fines, etc.) probably sufficient financial room can be found for additional investments in a sustainably safe implementation of regional road networks. It is good to keep in mind that investment in Sustainable Safety is based on cost-benefit analyses, and that the results of earlier calculations are recognized as robust by the Netherlands Bureau for Economic Policy Analysis (CPB et al., 2002). Current infrastructure budget streams from general taxes and charges cannot yet be described as efficient, but that could change with the introduction of a different way of road use pricing.

We have to conclude that there is, in fact, a funding problem for a sustainably safe regional road network, and also for roads managed by other authorities. In order to make additional means available for a sustainably safe regional road network through efficient pricing, we recommend a multi-track approach. We recommend the establishment of a Paying for Sustainably Safe Infrastructure Committee, and giving this Committee the task of addressing this question further. Results in the short term could be expected from adding new priorities to existing budgets and/or a very modest fuel tax increase (one to two Eurocents per litre of fuel). The introduction of a differentiated road use pricing could improve income efficiency in the longer run. Extending the coverage of liability for intangible damage can also generate additional income in the longer term.

15.4. Accompanying policy

For the ultimate success of the implementation of the various Sustainable Safety measures described in the preceding sections, a successful accompanying policy is essential. This accompanying policy is discussed here in four parts: *integration* of road safety policy with other sectors, *innovation* of policy implementation, *research and development*, and finally *dissemination of knowledge* regarding road safety measures (see *Figure 15.1*).

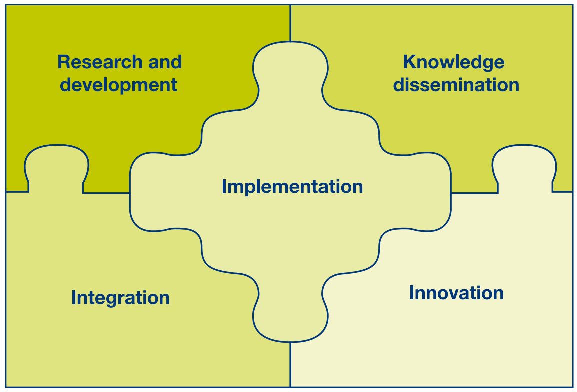


Figure 15.1. ***Outline of the four elements of accompanying policy as an addition to the core: policy implementation (Wegman, 2004).***

15.4.1. Integration

We have, meanwhile, become convinced that the possibilities for sectoral road safety policy implementation are limited. At the same time, there remain unused opportunities for improving road safety as a facet of other policy areas. Seen from a Sustainable Safety perspective, there are arguments in terms of content to strive for good integration with other policy areas. The proactive character of Sustainable Safety makes integration with e.g. spatial planning and urban development inevitable. Road safety is being considered more and more in an integrated way.

Central to the *Mobility Paper* are three objectives – better accessibility, cleaner, safer – and many instruments, measures and interventions will need to be assessed on these three objectives. Based on these considerations, more integrated policy development and implementation become more important to improve road safety in future. Nonetheless, *integration* with other policy areas and policy objectives is a difficult subject.

Policy integration requires a minimum of two or more organizations to be involved. These different organizations need to do several things in parallel: a) know what is expected from them, b) be able to deliver what is expected, such as money, time, knowledge and staff, c) as an organization *be willing* to deliver. The literature (see also Wegman, 2003) reports that such coordination can be problematic for policy development, and even more so when it comes to policy implementation. Securing cooperation between organizations is, evidently, not an easy task.

In order to prevent problems, two requirements need to be fulfilled:

1. Signals to organizations concerning the desirability of a certain policy have to be unambiguous and need to have political support. The organizations have to declare explicitly that they have understood the message, and intend to execute the message. This makes the organization responsible for the delivery of policy and makes the organization accountable.
2. In policy implementation, it is not wise to let organizations take decisions jointly. It is wise to organize the implementation in such a way that organizations are responsible for their own performance, and that they are not dependent on the 'knowledge, ability, and willingness' of other organizations. If organizations have to deliver policy jointly, then additional (and often formally laid down) agreements have to be made. With this general knowledge about cooperating governments in mind, it is recommended that the widening and integration of policy be explored. It is recommended that this is explored from area to area, and from subject to subject.

15.4.2. Innovation

Although we can improve existing measures, new and rather unorthodox measures for road traffic, are necessary for substantial improvement in road safety. In terms of content, we want to broaden policy preparation in the field of Sustainable Safety (more facets, less sectors). The broadening and subsequent integration with other policy sectors is 'always difficult' (see *15.4.1*) and no blueprint exists for best practice. This is even more difficult in the field of Sustainable Safety, because there is not yet a tradition of how to achieve it. Introducing new measures which have not been implemented before, having to work with less than fully known effects (and possibly side-effects) of potential measures, the rare occurrence of total, unconditional societal and political support for measures, establishing new cooperation partnerships are just some of the reasons why step-by-step policy renewal and innovation is needed for nationwide implementation.

We also have to note that past interventions turned out to be sporadic and with a limited continuity (see also Terlouw et al., 2001). New initiatives are developed; pilots are deployed time and time again, the wheel is reinvented, historical knowledge is limited, and new policy all too often has a short life span. It is well-known that this is costly in terms of 'policy energy'. Therefore, there is a need for policy innovation aimed at more continuity in policy implementation.

A new course has been set out in the Netherlands in the past few years in public administration under the banner 'decentralized if possible, centralized if necessary'. This means that known and also effective role models, cooperation partnerships and control mechanisms – which made the *Start-up Programme Sustainable Safety* such a success – are no longer applicable and have to be adapted to the new reality. The *Mobility Paper* announces that central frameworks have to be established to translate national interests into decentralized transport and traffic policy, and road safety is mentioned specifically in this regard. Therefore, policy innovation (monitoring, benchmarking and readjustment if necessary) will also have to take place in this field.

A 'mastermind' can only achieve results with support. A road safety executive director is, at best, one of several players, and never the only one. A lead agency may lead, but it cannot prescribe the law to others. A director can coordinate but cannot prescribe exactly the activity of all involved. A conductor may impose his interpretation, but the orchestral players have to elaborate and perform the details. Coordination is allowed, as long as it is not too demanding for those coordinated; certain competences have always to be borne in mind. This characterizes the current (decentralized) playing field which policy innovation has to address. This does not mean, however, that there is structural unwillingness to cooperate. Many good examples can be given in the road safety field. However, that cooperation has to be organized, since it will not happen on its own. At the same time, if it does exist at any given moment, this does not necessarily guarantee future good cooperation (see also the COVER evaluation, Terlouw et al., 2001). Innovation in policy is not established by itself, but requires a stimulus. We propose that the Ministry of Transport should take on this stimulating role and create a 'facility' to ensure that such policy innovation takes place.

15.4.3. Research and development

Implementing existing measures more efficiently (also those elements from the *Start-up Programme* that have not yet been fully realized) remains an important issue for the coming years. As indicated in *Chapter 3*, our knowledge based on experiences with the implementation of Sustainable Safety to date is sporadic. This makes it more difficult for us to identity the correct next steps. We can only improve the execution of existing measures if we are willing to invest in knowledge: to consider what has been done, how has it been done, and at what cost? From this we can learn. Research and development is the key.

A second and far more important rationale for research and development is to formulate and outline in detail new potential measures within the Sustainable Safety vision. New knowledge is needed here. *Research and development* is, therefore, an essential activity to identify the right direction more precisely as well as how to use our (financial) means. Therefore, new knowledge is needed to improve the implementation of existing measures, to learn from the implementation, and finally to develop new Sustainable Safety interventions.

Approach to research and development

The knowledge required can be tapped from international research that is taking place on an increasing scale. The basic requirement is high-quality knowledge about national or local conditions. This knowledge is required to translate international knowledge appropriately for use in these national or local conditions. This means that an adequate level of basic knowledge has to be available nationally. At the same time, researchers need to have an opportunity to follow international developments, to interpret these, and to translate them into suitable recommendations for national activity.

A second fundamental requirement for road safety research and development is the availability of basic data, particularly with regards to the recording of road traffic crashes. SWOV recommends that an insight into what basic data needs to comprise should be given, and that a link to international developments (International Road Traffic and Accident Database IRTAD, European road safety Observatory) should be made. This should lead to appropriate architecture for all relevant road safety data such as that based on the model for a policy hierarchy developed in New Zealand (*Figure 15.2*; see also Koornstra et al., 2002). By performance indicators we mean quality of behaviour (e.g. prevalence of drink driving), quality of roads (e.g. the level of Sustainable Safety), quality of vehicles (e.g. the penetration in the fleet of EuroNCAP stars), and also the quality of 'post-impact' care (e.g. arrival time of ambulances). The lowest layer of the pyramid describes structure and culture elements that may be important to implement road safety policy and measures. The other layers speak for themselves.

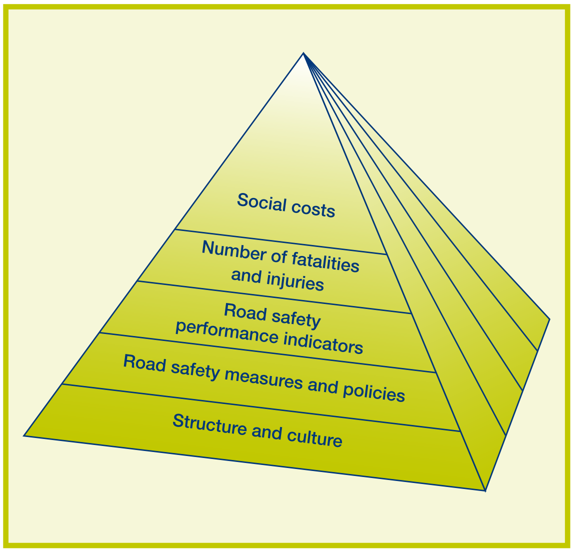


Figure 15.2. ***Road Safety Policy hierarchy (after: Koornstra et al., 2002).***

15.4.4. Knowledge dissemination

The final part of this chapter comprises *knowledge dissemination*. It goes without saying that research and development makes little sense if the new knowledge is not transferred.

Knowledge dissemination to (road safety) professionals

Road safety promotion will be ineffective and inefficient if policy preparation and implementation occurs without expertise. All those professionals who make decisions with implications for road safety (for instance those concerned with regional transport and traffic plans) need to have road safety knowledge. These decision makers also need to be more aware that in order to take good decisions, they are partly dependent on expert recommendations, and can trust the basis of these recommendations. Both the decentralization of implementation, integration (see *15.4.1*), and the proposed policy innovation 'facility' (see *15.4.2*) makes knowledge dissemination the spearhead of accompanying policy.

Knowledge dissemination to citizens

It was decided not so long ago that the Sustainable Safety vision should not be especially communicated to citizens and road users. Of course, communication to citizens and road users did take place about some elements of the vision, e.g. regarding a legal amendment (the introduction of 'priority for cyclists coming from the right') or when 30 km/h zones were constructed. Sustainable Safety has not been used as a vehicle for road safety activity. This means that those who are responsible for communication, have hitherto not chosen to market Sustainable Safety, and to consider it as a vehicle for all communication outputs. Therefore, Sustainable Safety is a little-known brand as far as the general public is concerned, and more as something known 'between road safety professionals'. We recommend that this decision is reviewed. Why would we not make clear in future to citizens and road users what Sustainable Safety stands for? In this way, we can both acquire more societal recognition for road safety, make the Sustainable Safety principles known, and obtain public support for specific measures. Societal organizations and public authorities are invited to come together in this approach.

15.4.5. National Road Safety Initiative

The jigsaw-puzzle pieces depicted in *Figure 15.1* could be facilitated with a road safety agreement (Wegman, 2004) or a National Road Safety Initiative. Its mission is to exchange, disseminate, and develop road safety knowledge and results achieved by all people concerned, in order to foster the (faster) take-up of objectives and tasks in the road safety area. To develop this mission further, four strands of activity have been set out as an addition to, and a stimulus for the activities of national, regional and local authorities:

1. strengthening public and political involvement;
2. disseminating and exchanging achieved results;
3. stimulating research and development;
4. stimulating exceptional effort and innovation.

A National Road Safety Initiative could play an important role in the various elements of this accompanying policy, and could underpin the desired broadening and deepening of Sustainable Safety development.

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