Traffic & Transport

Road safety manual

Record 26

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Road safety manual

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Preface

Knowledge about road safety in the Netherlands is fragmented. That is a good thing, because road safety should form an integral part of traffic, transport and mobility. Even before a road is constructed, its safety is already taken into consideration.

So why are we now attempting to cluster all this knowledge? This manual arose from the pressing need for a comprehensive overview. For aren't we missing something as specialists? Do all experts have the same knowledge and perception of the profession? What about our vision of the future? And if even specialists lack a complete overview, just imagine the search students have to conduct when they set out on their studies. So what we need is an exhaustive reference work and effective study material containing both 'hard' technical information about such aspects as road layout and mechanics and 'soft' information on aspects like influencing behaviour and education.

Who better to write such a book than specialists with hands-on experience in one of the most traffic-safe countries in the world? Over the past two years, a mixed group of specialists have dedicated themselves to gathering knowledge and linking that to a healthy measure of practical experience. I am grateful to the many authors, reviewers and members of the steering committee, the working party and the core team, particularly for the level of involvement with which they acquitted themselves.

My special thanks go to Adriaan Walraad and the NHTV Breda University of Applied Sciences. It was on the recommendation of the NHTV and under the authority of CROW that Adriaan Walraad assumed the extensive task of collating all contributions – some of which he himself wrote – to create this manual. I would also like to thank the SWOV, the Institute for Road Safety Research. Their dedication and contributions have helped make this a high-quality manual.

In addition to CROW, the following organisations made financial contributions to this publication: NHTV Breda University of Applied Sciences, Regional Consultative Bodies for Road Safety, the Ministry of Transport, Public Works and Water Management, the Knowledge Platform for Traffic and Transport, and the Fund for Collective Research.

I hope that this manual, which came about thanks to the dedication of many professionals, will find a broad basis of support and thus contribute to even greater road safety in the Netherlands.

CROW
dr. ir. I.W. Koster

Project organisation, authors and reviewers

This 'Road safety manual' is the result of the input of dozens of specialists who have been active in the field for many years. They each have their own approach and they all work for different organisations, which gives the manual a foundation that is as broad as it is solid. The book is both a unique reference work for professionals and a unique learning tool for students.

A steering committee, a working party and a core team were set up to produce this publication. The steering committee monitored planning, financing and the overall content. The working party was responsible for developing subject matter and composing this manual. The core team was in charge of the day-to-day organisation and supervision.

E.C. Westdijk supervised the process on behalf of CROW.

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The experts listed below have made valuable contributions to this manual by reading and reviewing one or more chapters:

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C. Wildervanck of De Paauwen PenProducten edited the final draft of the manual in terms of language, subject matter cohesion and consistency.

Contents

Summary

Knowledge about road safety in the Netherlands is fragmented. This manual clusters all this knowledge. It is aimed, on the one hand, at students and lecturers of traffic engineering and traffic-related educational programmes at higher professional education and university levels. On the other hand, it also contains relevant information for professionals in the fields of traffic, transport and related areas, as well as for politicians and people from the media who require a certain degree of knowledge of road safety in the context of their work.

Because all relevant disciplines have contributed to it, the manual provides a balanced and structured picture of traffic practice in the Netherlands. However, a number of remarks should be made here. First of all, this manual discusses relatively 'timeless knowledge', such as models, methods and technology. Up-to-date information should be gathered from the internet. Moreover, to keep the manual manageable, its depth has been limited. This is solved in part by including bibliographical references and providing overviews of relevant websites and knowledge institutes. Finally, the manual is aimed specifically at road traffic and not at other transport systems.

The manual consists of three parts. Part 1 seeks to get a handle on the subject of road safety, discussing various perspectives on road safety that are complementary to one another and that together present a complete picture of the subject. Part 1 comprises chapters 1 to 5: theory; trends and developments; policy; data collection and data analysis; and practical research.
Part 2 addresses measures that can be taken, focusing on the three Es and the three Ps. Engineering, Education and Enforcement are the three classical instruments with which traffic behaviour can be influenced, while Push, Pull and Persuasion are the three ways of utilising these instruments. Part 2 comprises chapters 6 to 10: spatial planning and the road environment; infrastructure; vehicle safety; traffic education; and traffic enforcement. Part 3 presents an overview of practical problems and how these can be tackled. Assimilating the items discussed in part 1 and part 2 into integrated approaches to road safety, this part explains that everything is interconnected. Part 3 comprises chapters 11, 12 and 13: risk-enhancing behaviour in traffic; specific groups of road users; and practical examples. Finally, the epilogue gives a glimpse of the future, where there are opportunities for a better infrastructure and better vehicles. But even if the prerequisites for optimum road safety are met, people and their behaviour will always remain the weakest link in the traffic and transport system.

Learning objectives for students:

- to gain an understanding of what road safety is and how it is perceived by society;
- to gain an understanding of how this manual is set up.

Introduction

Introduction

I.1 That won't happen to me...

In 2001, 2002 and 2003, there were over 1,000 traffic fatalities a year in the Netherlands. In the period between 2004 and 2007, this number dropped to just over 800 a year. That is still quite a bit, but not as bad as the record year 1972, when there were 3,264 deaths. In recent years, the number of hospitalised traffic victims fluctuated between 18,000 and 19,000 a year. This number is dropping as well, but not as rapidly as the number of traffic fatalities. So although we can say that much has been accomplished in terms of road safety in the past few decades, traffic is not entirely safe and never will be. Risks cannot be completely eliminated, for human activity always entails risks and it is not realistic to assume that one day we will no longer need emergency services or trauma care.

It has been said that road users who are (overly) confident of their safety run the greatest risk of getting involved in a traffic accident. But how often, on average, is a road user in the Netherlands confronted with an accident? A rough calculation provides the answer.

- There are about one million traffic accidents a year in the Netherlands (including damage-only accidents).
- Each accident involves two people on average. In other words: two million people are involved in a road traffic accident each year.
- As there are some sixteen million people in the Netherlands, this comes down to once every eight years, on average.

In other words: every Dutchman is involved in about ten road traffic accidents in his or her lifetime. Usually, the damage from the accident is limited, but sometimes the outcome is serious or even fatal.

Yet a lot of people often think 'That won't happen to me…'. But think again! It just might! So we have every reason to improve the situation.

I.2 About this manual

Road unsafety is an undesirable side effect (as well as a quality aspect) of traffic and, consequently, of transport and mobility. Seen in that light, it is desirable and no more than logical that every publication about a traffic-related subject also includes a section on road safety.

And now we have decided to dedicate an entire manual to the subject of road safety. There were several good reasons for doing so:

- Although we know a lot about road safety, that knowledge is quite fragmented, the SWOV observed in its publication 'Door met Duurzaam Veilig' (Advancing Sustainable Safety): 'Existing forms of knowledge dissemination should be better harmonised in order to provide road safety professionals efficiently with high-quality knowledge'. [I.1]
- Traffic and transport programmes at higher professional education and university levels reached a similar conclusion: the Netherlands is lacking a comprehensive reference work on road safety.

- Road safety is often only a small part of a traffic engineer's set of tasks. It is not easy for traffic engineers to gain a complete overview of road safety and to keep up to date on the subject; this applies even more to people for whom traffic, transport and mobility are only a few aspects of their work.

A 'Road safety manual' can help solve these problems. Having said that, road safety will have to remain an integral part of traffic, transport and mobility in the future.

I.2.1 Target groups

This manual is intended for the following target groups:

- students and lecturers of traffic engineering and traffic-related educational programmes at higher professional education and university levels;
- traffic and transport professionals, such as traffic planners, traffic engineers, traffic technicians, policy officials and scientists;
- professionals working in disciplines related to traffic, such as spatial planning, town planning, urban planning, logistics, civil engineering and mobility;
- other professionals, varying from municipal councillors to journalists, who require knowledge of road safety to carry out their work.

What these target groups have in common is that although they have a certain degree of knowledge of traffic, transport and mobility, they are not road safety experts. Yet they are required to put such knowledge to use in their jobs, which obviously means that they need to be able to acquire that knowledge somewhere.

I.2.2 Objectives

Even though it might be tempting to discuss road safety separately, the consensus is that road safety should be considered an integral part of traffic engineering. Although there are separate objectives, standards, guidelines, et cetera, for accessibility, quality of life and road safety, it would be illogical and inefficient to keep taking road safety measures separately. Ideally, every foresight study, every programme and every plan should focus on road safety.

This manual enables readers:

- to better point out the significance of road safety (such as the need for and objectives of road safety), even in situations in which it is at odds with other interests.
- to get to know the meaning of (specialist) terms and the relevant organisations and their specialities.
- to propagate and transfer knowledge about road safety;
- to assess the safety of a certain traffic situation;
- to work on road safety themselves. To that end, they will need to master general theory and be able to translate it into practical measures. For example:
  - they must be able to find up-to-date information and judge the validity of information;
  - they must be aware of the distinction between working on road safety reactively or proactively;
  - they must be able to develop knowledge about road safety at applied and scientific levels themselves;
  - they must be able to assess the work of others;

- they must be able to create links and build bridges between safety and related fields of knowledge.
- to form an idea of other people's concrete practical experiences.

I.3 Document structure and reading guide

Some of the knowledge of road safety, such as models, methods and technology, is relatively timeless, while other knowledge, such as policy and accident statistics, is subject to change. This manual addresses the relatively 'timeless knowledge'. Rapidly changing topical information is better found on the internet.

Because all relevant disciplines have contributed to it, this manual provides a balanced picture of traffic practice in the Netherlands. It proved impossible to incorporate everything we know about road safety and still keep the manual manageable. This is why it only has limited depth. Where appropriate, the text contains references to other sources. To optimise user-friendliness where possible, the different topics are discussed in relation to one another.

The manual consists of three parts. Part 1 seeks to get a handle on the subject of road safety, part 2 focuses on measures, and part 3 presents an overview of practical problems and how these can be tackled. Finally, the epilogue gives a glimpse of the future. Every part is introduced separately.

Different sections of the manual are relevant to different target groups. Table I.1 serves as a guide: the darker the colour, the more relevant that particular section is for that particular target group.

The manual offers different ways of finding (more) information:
- readers can look for subjects in the table of contents;
- readers can look for subjects in the index;
- readers can look for subjects in the questions and answers section;
- the manual includes practical examples;
- the manual includes references to other publications;
- the sources on which the text is based are listed;
- the manual contains listings of relevant websites and of key libraries and knowledge institutes

Table I.1. Relevance of the subjects for each target group

Level of relevance dark blue: high blue: medium pale blue: low	Students of traffic engineering and traffic-related studies	Professionals: Traffic-engineering	Professionals: Traffic-related disciplines	Professionals: Other areas (politics, media, etc.)
Introduction	high	medium	low	high
Part 1				
1 Theory	high	medium	low	high
2 developments and trends	high	high	medium	high
3 Policy	high	high	medium	high
4 Data collection and data analysis	high	medium	low	low
5 Practical research	high	high	low	low
Part 2				
6 Spatial planning and the road environment	high	high	high	low
7 Infrastructure	high	high	high	low
8 Vehicle safety	high	high	high	low
9 Traffic education	high	high	high	low
10 Traffic enforcement	high	high	high	low
Part 3				
11 Risk-enhancing behaviour in traffic	high	high	medium	low
12 Specific groups of road users	high	high	medium	low
13 Practical examples	high	high	high	low
Epilogue	high	high	medium	medium
Questions and answers	high	high	low	low

Working on road safety

Ensuring road safety can take the following forms:
- removing the causes of unsafe traffic situations;
- dealing with the liability for creating unsafe traffic situations;
- the will to redress such unsafe conditions;
- allocating specific tasks to all parties involved in tackling road safety, with all related responsibilities.

Taking responsibility for road safety involves adopting legislation and setting up organisations with responsibility for the tasks defined.

Generally accepted views of road safety play a role at all levels of working on traffic, transport and mobility. On the one level, these are questions of how to create a safe traffic and transport system. On another level, in more practical terms, it means addressing such questions as 'How to design a safe school environment?'

In other words, responsibility for road safety takes different forms at different levels of government. Moreover, road designers approach the subject from a different angle than traffic enforcers. The trick of designing effective and efficient road safety policy is to create synergy among road safety initiatives at different levels and from different angles in order to achieve the best possible result.

A key challenge for road safety proponents is how to effectively include generally accepted views of road safety. This goes for administrators seeking collaboration between parties and in decision-making processes, for designers who want to encourage desired behaviour in traffic by means of the infrastructure, for law practitioners who translate social norms into legislation, and for police officers whose task it is to enforce and propagate the chosen standards.
This challenge is what this manual is about [I.2].

I.4 Delineation

I.4.1 Safety of the road traffic system

This manual addresses the safety of all users of roads and streets in the Netherlands. This comes with two important limitations:
- it is about road safety and not about other kinds of safety;
- it is about the road traffic system and not about other kinds of transport.

Moreover, this manual applies specifically to the situation in the Netherlands.

The introduction of Sustainable Safety in the Netherlands (see paragraph 1.1.4) moved attention away from a curative approach to the road unsafety (tackling situations that have proven to be unsafe in retrospect) towards a preventive approach ensuring that unsafe situations do not occur in the first place. It goes without saying that prevention is better than cure. That said, the preventive approach has not yet made the curative approach superfluous. Firstly because, unfortunately, there still are local differences in safety levels, and secondly because it is not socially acceptable if nothing is done about a site, road section or area that has proven unsafe. That is why, on a daily basis, both preventive and curative measures are taken. Both these approaches are discussed in this manual. On occasion, road safety is wrongly reduced to being just a matter of stricter enforcement by the police, or presented as something technical that has to do with roundabouts and speed control humps. But these are just elements of road safety. The manual presents a cohesive discussion of all elements of the road traffic system – infrastructure, vehicle, man, travel budget and activity locations – and their relationship to potentially unsafe situations.

I.4.2 Different kinds of safety

This manual focuses exclusively on road safety and not on other kinds of safety. Safety and unsafety take different forms. In terms of traffic, transport and mobility, a distinction can be made between external safety, social safety and road safety:

- External safety relates to the safety of the environment of a traffic flow, such as the risk that an LPG tanker explodes, with all the consequences this will have for the surroundings. Key issues in this respect are standards in combination with theoretical mathematical models for individual risk and group risk.
- Social safety also plays a role in traffic, for instance the social safety of cycle tunnels. Social safety is determined by such factors as a facility's design, lighting, the presence of other people, different kinds of supervision, the possibility of early detection of trouble and reporting of trouble.
- Road safety is directly and inextricably bound to traffic. Road safety includes undesirable side-effects of traffic – such as a car hitting a pedestrian – as well as the safety of road workers or such concerns as to the age at which children use roads independently. Nobody wants things to go wrong, but people do make mistakes in traffic, always and everywhere.

The combination of these three kinds of safety is called integrated safety. In practice, however, they are three entirely separate disciplines in different phases of development.

In order to prevent people from throwing stones onto cars on the motorway below, the Directorate-General for Public Works and Water Management installed a number of screens on viaducts. However, this stone-throwing has nothing to do with external safety, social safety or road safety – it is an act of vandalism, plain and simple.

Table I.2. Differences between the road traffic system and other traffic systems

	Degrees of freedom of the transport system	Operated by	Complexity of operation
Helicopter	Forward/backward Up/down Completely lateral	Professional operator, on sight and on instruments	Very great
Aeroplane	Forward only Up/down Lateral to limited degree	Professional operator, on sight and on instruments with support from traffic control	Moderate to very great (depending on flight stage)
Road traffic	Forward/backward Lateral to limited degree	Diversity of operators, on sight and on instruments sometimes with advice from traffic control	Moderate to very great (depending on road type)
Shipping	Forward/backward Lateral to limited degree	Operator (sometimes professional), on sight and by radar; sometimes with advice from traffic control	Moderate to very great (depending on type of ship and available waterway)
Railways	Forward/backward Lateral to limited degree	Professional operator; traffic control and safety system determine prerequisites	Limited
Lifts	Up/down	Fully automated, no operator	Slight

I.4.3 Different kinds of transport

This manual discusses road safety. The road traffic system differs significantly from other traffic systems, as shown in table I.2.

The different types of transport have different degrees of freedom and different operating systems. Operation is sometimes highly complex, sometimes simple, and sometimes human error is completely eliminated. The level of professionalism of the operator also differs greatly. As a result, different transport systems have different levels of safety. An estimate of the number of fatalities at a European level shows that [I.3]:

- there are 45,000 fatalities on the road;
- there are 1,300 fatalities in railway traffic;
- there are 186 fatalities in aviation;
- there are 180 fatalities in shipping.

There is no data on accidents involving lifts.

Road users run relatively great risks. Unlike aviation and railway traffic, road traffic was not designed with road safety in mind. The road traffic system has expanded over the years and adjusted itself to accommodate the greater need for mobility and faster types of transport. These adjustments were gradual, and safety was barely more than a consideration in terms of such adjustments, never a strict prerequisite [I.4]. In road traffic, the need for individual freedom is often in variance with road safety. Moreover, traffic (and, consequently, road safety) often has to compete with other social interests.

For types of transport that already are relatively safe, the costs of increasing safety even further are relatively high. The (political) question is where, in future, the investment limit will be drawn to bring down the number of road traffic fatalities even further [I.4].

A high level of safety is often related to a limited or even relatively low transport capacity. For instance: if the '2 seconds distance' rule were strictly observed on motorways, a lane's capacity would be lower than the capacity currently applied by the Directorate-General for Public Works and Water Management. In everyday practice, road users keep much less distance, accepting much less safety.

A high level of road safety therefore has its price: it requires investments in infrastructure and in vehicles, as well as strict regulations that curb the freedom of the individual road user.

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Part 1 - Getting a handle on road safety

Road unsafety manifests itself in a number of ways. It is not always easy for those who are not involved in road safety on a daily basis to get an accurate picture of what it means, let alone to formulate road safety policy: what is it, what is it about, what is important?

This section of the Road Safety Manual is aimed at gaining an understanding of road safety, which will be approached from various perspectives. These perspectives are complementary and together they provide a complete picture of the subject matter. The reader is given an insight into the problems, causes, objectives and solutions with regard to road safety.

The chapters of part 1

1 Theory;
2 Developments and trends;
3 Policy;
4 Data collection and data analysis;
5 Practical research.

Chapter 1 ‘Theory’ describes the theory surrounding road safety. Key terms are defined and developments in thinking about road safety are described, including Sustainable Safety. Human factors play a key role in road safety, as do the mechanical properties of the traffic system.

Chapter 2 ‘Developments and trends’ describes key factual material from experiences in the Netherlands. The facts and figures are also shown in a European perspective. The Netherlands is one of countries with the highest levels of road safety.

Chapter 3 ‘Policy’ is limited in scope. Information that is current at the time of writing becomes antiquated quickly in a manual. For this reason, this chapter is limited to providing a general overview.

Chapter 4 ‘Data collection and data analysis’ and chapter 5 ‘Practical research’ describe the possibilities for conducting research. Chapter 4 is primarily interested in available data such as accident statistics, while chapter 5 focuses on research with a more applied character, which is conducted at particular locations.

More information on road safety

This road safety manual is specially written for use in the Netherlands.
The following international standard works are also available (in English):

- Human Factors in Traffic Safety, R.E. Dewar, P.L. Olson. Lawyers and Judging, 2007
- The handbook of road safety measures, R. Elvik, T. Vaa. London, Elsevier, 2004
- Highway design and traffic engineering handbook, R. Lamm, B. Psarianos, T. Mailaender. New York, McGraw-Hill, 1999
- Traffic Safety and Human Behaviour, D. Shinar. Elsevier, 2007
- Road Safety Manual. Quebec, PIARC Technical Committee of Road Safety, 2003

Learning objectives for students:
- to be able to define road safety and related subjects;
- to have knowledge of the main underlying theories for tackling lack of road safety, of which Sustainable Safety is the most important.

Theory

1 Theory

1.1 Terms and approaches

1.1.1 Key terms

In everyday usage, road safety terminology is not always clear and sometimes even confusing. To avoid misunderstandings, we will first define the key terms used in relation to road safety.

Safety and unsafety

Unsafety refers to a situation in which safety is lacking. It is, therefore, also referred to as 'lack of road safety'.

Traffic is essentially unsafe and many traffic situations are dangerous. But apparently people accept a certain level of danger and sometimes even look for it, not just in traffic but also in other areas of daily life, such as sport. Nevertheless, the risk of death or physical injury in traffic is socially unacceptable.

In this manual, lack of road safety is defined as:

- the presence of danger in traffic;
- an unacceptable degree of risk in traffic.

The presence of danger

Danger can be described as a critical combination of circumstances that occurs and/or may occur in traffic and that may result in an accident.

All collisions are accompanied by a transfer of energy onto structures. In road traffic, those structures are not or not sufficiently protected and are, therefore, vulnerable. Train wagons that 'collide' in order to be coupled are constructed in such a way that they are able to withstand the resultant energy transfer.
A child hit by a car, however, is not.

An accident by definition involves damage. 'Damage' in traffic may refer to fatalities, injuries, psycho-traumatic effects, material damage and damage to the road environment.

Lack of road safety is:

- the total of potential and existing critical combinations of circumstances in the process of traffic and transport;
- unplanned events or an unplanned series of events that involve the transfer of energy onto vulnerable structures that are not protected against it;
- the possibility of damage to or loss of people or materials as a result of traffic (death, injury, permanent disability, psychological trauma, material damage and damage to the road environment).

Essentially, lack of road safety means that, at some point in time, a critical situation occurs in the traffic and transport process. An example is an encounter between two road users crossing each other's paths that threatens to turn out badly. This critical situation can be reversed if the parties react in the correct manner, but it can also become more critical if either of them fails to react or reacts incorrectly. An incorrect reaction will lead to a succession – a chain – of ever more critical (combinations of) circumstances. If that chain is not broken, an accident is inevitable. The series of critical combinations of circumstances may even continue as the crash takes place and the damage occurs.
For example, if the necessary medical assistance is slow in arriving at the scene of an accident, injury may become worse due to blood loss.

The consequences of a traffic accident

A lack of road safety is manifested in the different forms of damage that are caused by traffic accidents. The definitions of the consequences are categorised in accordance with accident registration:

- death: death occurring within thirty days of an accident. This is the internationally recognised definition;
- hospital: hospitalisation for at least one night, but no death occurring within thirty days;
- emergency assistance (EA): transported to hospital by ambulance, but not hospitalised;
- not hospitalised (NH): injured, but not transported to hospital;
- material damage only: no personal injuries.

In addition, the following groups are distinguished:

- Serious injuries: fatalities and hospitalised injuries combined.
- Slight injuries: EA and NH together. Current injury registration does not properly distinguish between EA and NH. EA casualties are often worse off than NH casualties, but they are often registered as NH casualties.

Permanent consequences such as disability, psychological trauma, permanent sorrow due to the loss of loved ones and its effects are not registered. Every year, the numbers of people disabled in traffic accidents increases.

An unacceptable degree of risk

Risk can be defined as follows:

> Risk is the chance of an unwanted or harmful consequence of participating in an activity or of exposure to a dangerous situation.

'The chance of' is the probability of an unwanted event occurring with all the related harmful effects. In other words:
risk = chance × consequence.

> Traffic risk is the chance of getting involved in a traffic accident resulting in death, injury and/or damage.

How much damage is acceptable? To answer that question, the significance and benefits of participating in a certain activity must be weighed against the sacrifices that may have to be made and the harm caused by the damage that may result. The more benefits an activity has, the higher the acceptance of risk. A driver who starts out too late for an important meeting will accept more risks than one who has left on time for a leisure destination. In the first instance, the chance of arriving too late outweighs the increased chance of an accident. Peer group norms play a role in that consideration as well. Young drivers take more risks because their peers find daring and 'testing limits' important and, moreover, because they underestimate the risk. Whether a traffic risk is acceptable is a social and political issue. The answer is influenced by a variety of factors, which are roughly the same as those that determine how people generally experience risks.

The voluntary nature of participating in traffic and taking risks
A playing child does not participate in traffic voluntarily. Socially speaking, the death of a playing child in a traffic accident is given about a thousand times more weight than the death of a motorist, who is assumed to have chosen to drive to his destination voluntarily. Risks taken voluntarily on an individual basis (including deep-sea diving, driving a motorcycle and bungee jumping) are also given much less weight than danger faced involuntarily.

The catastrophic or chronic nature of the risk
Socially, a single plane crash with a hundred fatalities is given more weight than a hundred traffic accidents that occur over a longer period of time and have a single fatality each. In society, the severity, scope and 'concentration' of an accident are more important than its frequency.

The degree to which people think they can control the risk themselves
Much less risk is accepted for plane, train, tram and bus passengers than for motorists or cyclists. After all, public transport passengers depend on a driver without being able to influence his behaviour, while motorists and cyclists take part in traffic themselves, often contribute to the risk by their behaviour, and control the risk themselves.

The degree of protection
The risk for unprotected pedestrians is socially less acceptable than the risk for a motorist in his steel cage.

The degree of familiarity with the risk
Children are hardly capable of estimating the risk they run in traffic, whereas in most cases adults are. Risks that cannot be perceived or assessed by traffic participants are given more weight than risks that can.

The avoidability of risks
In situations in which the risk could have been avoided – for example by means of a solution implemented by the road authority – the risk is considered less acceptable than in other situations.

Mathematical definition
Alongside this descriptive definition of risk, there is also a mathematical one. Analyses and, above all, comparisons of lack of road safety always entail the need for data on ex-posure. Exposure is the degree of participation in or exposure to all potentially existing combinations of circumstances in the traffic and transport process.

A degree of exposure is taken to mean:
- a measure for participation in traffic, for instance per 1 billion kilometres travelled per mode of transport or the number of hours of participation in traffic;
- a measure for the exposure to danger in traffic, for instance per number of encounters or the number of fatalities per 1,000 casualties per type of accident.

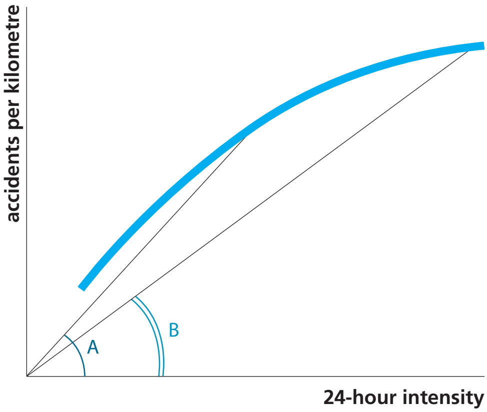
The following then applies in the mathematical definition:
road unsafety = risk × exposure

In an elaboration of this mathematical definition, the risk or chance can be seen as a combination of the accident rate (chance of an accident) and the severity rate (chance of a serious outcome: the consequences of the accident). This results in the following formula:
road unsafety = accident rate × severity rate × exposure

This formula is used mainly to analyse differences in road unsafety.
Three measures for risk often used in practice are:
- accident frequency: number of accidents per vehicle kilometre travelled;
- injury frequency: number of accidents with personal injury per vehicle kilometre travelled;
- accident density: number of accidents with personal injury per kilometre of road.

Studies have demonstrated that the number of accidents per kilometre of road is not quite proportional to traffic volume: the increase in the number of accidents levels out the more the intensity increases. This also means that the risk (chance of an accident per intensity) decreases as intensity increases. If the number

Figure 1.1. Number of accidents plotted against intensity



of accidents is plotted against the intensity, this yields the curve as represented in figure 1.1. Angles A and B represent the risk at low and high intensity. That angle is a value for the number of accidents per kilometre divided by the 24-hour intensities, making it a measure for risk. Angle A is greater than angle B, which means that the risk at high intensities is lower than at low intensities.

There are several possible explanations, such as road layout and the behaviour and mutual influencing of road users.

Accident

The translation of the Dutch legal definition of a traffic accident is: 'An incident on a road that is open to motorised and other traffic that is related to this traffic, involving at least one moving vehicle and resulting in damage and/or the death and/or injury of one or more road users' [1.67].

Statistics Netherlands uses the following definition: 'An accident on a public road involving at least one moving vehicle and resulting in the death or injury of one or more road users'.

This Statistics Netherlands definition is used for accident registration. As a result, not all types of accidents are registered, as non-injury accidents and accidents that do not involve a vehicle are not covered by this definition. Based on this definition, an incident in which a pedestrian falls and gets injured after tripping over faulty pavement is not a traffic accident. Neither is a dent in a car caused by a clumsy parking manoeuvre.

Near-accidents and conflicts

Near-accidents and conflicts are encounters between traffic participants with an inherent danger, without this encounter actually resulting in an accident. As the danger increases, a near-accident or conflict is considered more serious. There are different uses of the terms near-accident and conflict. There also are different types of conflict, such as: transverse conflicts or passing conflicts.

Traffic-related quality of life

In practice, several other terms are used, such as traffic-related quality of life, which can be described as the combination of all – positive and negative – influences of traffic on the quality of the living environment in the area. Negative effects are a road unsafety, but also all forms of nuisance (such as noise, air pollution, stench, fine dust, barrier effect) and the hampering of social activities. The layout of the public space largely determines whether the area can absorb the impact of traffic. The term traffic-related quality of life dates back to the 1970s, and comprises more than just road safety. Generally – but not always – the interests of road safety, traffic-related quality of life and the environment are aligned [1.68-1.70].

1.1.2 Different perspectives on road safety

Road safety can be approached from different angles. This section discusses a number of examples.

Subjective and objective safety

First of all, there is a difference between objective road safety and subjective road safety. Objective road unsafety is a real road unsafety, with a high chance of an accident occurring, while subjective road unsafety has more to do with people feeling unsafe, making it a matter of perception (which is not to say that it is less important). Objective road unsafety can be measured by and substantiated with unambiguous and objective standards (such as accident statistics), while subjective road unsafety is more difficult to determine unambiguously and objectively (for example the feeling that people drive too fast through a narrow residential street). Subjective road unsafety can, however,

be measured indirectly, for instance by means of surveys or interviews.

A subjective road unsafety is also called 'traffic threat' and is related to and individual's perception of the risk in a given situation. A feeling of unsafety can never be entirely dispelled and, moreover, a certain degree of feeling unsafe is necessary for preservation of life; if people no longer feel unsafe, they will not be prepared to behave in a safe manner. A feeling of unsafety is unpleasant, but it is thought to keep road users alert and encourage responsible and safe behaviour. However, even for alert and responsible road users, there are limits to what people can do and can cope with (see section 1.2).

Objective and subjective road unsafety need not be opposites, but they do not necessarily coincide either. They are just two different aspects of safety and unsafety.

Table 1.1. Objective and subjective road unsafety

	Objectively safe	Objectively unsafe
Subjectively safe	Optimum situation: safety	Very unfavourable situation: false safety
	Example: a well-designed residential street with a calm traffic situation	Example: an apparently clearly laid out distributor road that tempts drivers to drive too fast, or a comfortable car that induces the driver to drive too fast
Subjectively unsafe	An unpleasant situation that generates mainly complaints	Unfavourable situation: road unsafety is evident and clear
	Example: a narrow street in a historic city centre without view of a side street	Example: a residential street that is used as a short cut where people drive too fast

Both objective and subjective road unsafety require measures, but the approach is fundamentally different. First of all, it is important to determine for whom objective and subjective road unsafety is a problem, so that a situation can be created that is both objectively and subjectively safe for all users.

Essentially, road safety issues feature most prominently when a situation is objectively unsafe but not perceived as such by the road user. After all, the road user who does not perceive danger, will not or only insufficiently adjust his behaviour to the unsafe situation. In other words, there is a false sense of safety.

Measures aimed at solving problems in terms of objective safety may – as an unexpected and unwanted side-effect – have consequences for subjective safety. For instance, redesigning an unsafe intersection may reinforce the position of motorised traffic, but in doing so may inadvertently impair the position of slow traffic. Likewise, a measure aimed at problems in terms of subjective safety may – as an unexpected and unwanted side-effect– have consequences for objective safety. An example is a motorcyclist who has attended a supplementary course in vehicle control, after which he considers himself to be so safe that he takes much greater risks than before.

Road unsafety as a coincidence

A second perspective on road unsafety is that of unsafety as a coincidence. An individual accident is coincidental, that means it cannot be predicted. And because it is coincidental, it is not always possible to prove the safety or unsafety of a certain situation based on a single accident.

There are bound to be more accidents in unsafe situations than in situations that are safe. The fluctuation in observed road unsafety as a result of its coincidental nature decreases with longer observation times or higher traffic volumes. In other words: coincidence is excluded by considering the road unsafety over a longer period of time or over greater

Table 1.2. Double counting the causes of an accident

Composition of causal percentages [1.25]

Human error **Total: 64-93%**	57%: exclusively human error	26%: also road and road environment	6%: also vehicle	4%: also road/ road environ-ment and vehicle
Road/road environment **Total: 12-34%**	3%: exclusively road/road environment	26%: also human error	1%: also vehicle	4%: also human error and vehicle
Vehicle **Total: 4-13%**	2%: exclusively vehicle	6%: also human error	1%: also road/ road environ-ment	4%: also road/ road environ-ment and human error

N.B. These figures do not mean that almost all roads and vehicles are 'safe'. The figures do indicate, however, that human error is the leading cause of accidents and that certain combinations of causes of accidents occur more frequently.

intensities. This creates a more balanced picture of the real chance of an accident, so that it is easier to determine the safety of the situation in question.

However, practically speaking it is not always possible to consider a situation over a longer period of time, usually because there is a lot of social pressure 'to do something about it'. Moreover, there are ethical considerations that argue in favour of not waiting too long before taking measures: 'Will someone have to die first before something is done about it?' Sometimes, comparable traffic situations can be found. By combining the findings from different traffic situations, more substantiated conclusions can be drawn.
An alternative is not to look at accidents, but at near-accidents or conflicts. These occur much more often than accidents, but are generally not as predictive of road unsafety.

Road unsafety from the point of view of the cause
A third perspective on road unsafety is that of the cause of an accident. An accident is caused by a confluence of circumstances. This means that every accident has several causes, or factors of influence. This results in a double count of the causes of an accident. Table 1.2 visualises this.

A road user's behaviour largely determines his own safety and that of the people around him. A lot of people are perfectly capable of quickly reading complex situations or even anticipating them. Every day, road users routinely make countless correct assessments and decisions. However, even experienced road users still make mistakes. And although everyone makes mistakes in traffic, some make more than others. Research has demonstrated that human behaviour and human error are by far the most frequent cause of accidents [1.25, 1.71].

Other causes include faults or shortcomings in road design (including a road's environment) and design implementation.
Defects in vehicles, accessories and vehicle parts may also cause accidents. Technical innovation does not necessarily make traffic safer.

The main conclusion that can be drawn from these accident statistics is not so much the absolute value of accidents, but the fact that the total number of causes of accidents exceeds 100%. This is because an accident is always the result of a confluence of circumstances.

Road unsafety from a systems approach
In the systems approach, it is the design of the road traffic system that influences human behaviour and, consequently, the ultimate performance of the road traffic system. As such, road safety is a characteristic of the road traffic system as a whole. Road unsafety is an unwanted effect of the system as a whole, interwoven with all facets of that system. As a consequence of this systems approach, literally every assessment, every choice and every action (or omission) that is related to the road traffic system has a direct, and occasionally considerable, impact on road safety. This systems approach forms the basis of sustainable safety.

1.1.3 Developments in the concept of road safety through the years

Views of road safety have changed over the years, which explains the different strategies and tactics pursued to tackle road unsafety.
A first distinction that can be made is between the 'single cause theories' adhered to until 1960 and the 'multiple cause theories' that were advocated after 1960. The different views are described in the following sections.

1900-1920: every accident is unique
Every traffic accident was considered an autonomous and unique problem that needed to be solved immediately. The cause of that unique accident had to be found. The consensus was that removing that single cause would solve the entire problem. This view of road unsafety is a thing of the past, as it is impossible to deal with the many registered accidents, accidents with personal injury and even fatal accidents this way. Moreover, there also are a number of objections to this monocausal view:

- looking for the cause produces a subjective result: one person sees one thing as the cause, another something else;
- removing the cause of an accident often creates new problems, leading to new (different) accidents;
- missing the opportunity to solve more than one problem with a single measure.

1920-1950: accident-prone
This view, which did not have the desired effect, was followed by the notion that almost all traffic accidents are caused by the behaviour of road users. The question of who caused the accident was emphasised – not least by insurance companies. In most cases, unadjusted behaviour by the road user was seen as the cause. Being involved in or causing a traffic accident was considered to be conditional on coincidence to a certain degree, even if the driver was to blame. However, causing or being involved in more than one accident cannot be a mere coincidence, and such drivers had to be banned from driving or forced to improve their behaviour by means of punishment and re-education.

This 'accident-prone view' assumes a level playing field, which means that everyone has the same chance of meeting with an accident. The fact that some users are on the road longer than others or that some travel at other (more dangerous) times is overlooked. There are several other objections to this view:

- Attempts to identify accident-prone people fail; psychological tests aimed at spotting the really accident-prone are never foolproof and will inevitably and unjustly pinpoint some other, 'competent' road users as being accident-prone as well.
- Controlling road unsafety is limited to measures targeting the human factor, neglecting improvements in behaviour by improving roads, vehicles and traffic situations.
- Traffic accident registration indicates that human errors are the most important cause of traffic accidents. Other causes, such as defects in vehicles, roads and unclear traffic situations (which often lead to human errors) are rarely registered.

This view has yet another unexpected effect on road users. People who have never been involved in an accident before wrongfully conclude that this means they are more skilled road users, as a result of which they may behave less carefully.

1940-1960: serious research into the cause of accidents

In the period after 1940, the first serious research into the cause of accidents was conducted. Still only single causes were considered, not only in terms of behaviour, but also in terms of technical aspects (poor secondary safety of vehicles) or dangerous locations (black spots or red spots).

1960-1980: the systems approach

Gradually, the limitations of the monocausal views were recognised and multicausal views of road unsafety emerged. Traffic accidents were considered coincidences with more than one cause. Everyone who participates in traffic runs the risk of getting involved in an accident. Different factors play a role in this. Awareness grew that there was a lack of knowledge about the correlation between the different factors, leading to an approach in which interrelated factors were seen as a cohesive whole and that focused on the factors themselves as well as on the interrelationships between them. Key point was to identify the critical relationships between (combinations of) characteristics of the following system elements: road users, vehicles and road environment.

The Haddon matrix plots the system elements human factor, vehicle and road on the vertical axis and the crash phases precrash, crash and post-crash on the horizontal axis. By filling in the matrix for a certain accident, the factors that have contributed to that accident can be classified. The Haddon matrix shows that an accident never has just a single cause, but is always the result of a confluence of circumstances.

This static systems approach also has its shortcomings:

- the complex of critical relationships is too unstructured and can be too comprehensive: it is often impossible to unravel the tangled web of critical relationships;
- this approach overlooks the dynamics of the traffic and transport process in which the accidents occur.

The dynamic systems approach emerged in the late 1980s. It looked at how an accident takes place and saw it as a single, continuous process, in each part of which you can avoid the accident, and if it occurs nevertheless, you can exert a positive influence on its consequences (injuries, fatalities) and the way it is dealt with (how soon does emergency service arrive).

The dynamic systems approach distinguishes between the following phases:

- mobility phase;
- traffic phase;
- encounter phase;
- incident phase;
- collision phase;
- injury and damage phase;
- treatment and convalescence phase.

It is possible to describe the phases of each accident that occurs. However, this is not very useful, because it does little more than identify the fairly unique circumstances of that particular accident. Descriptions such as these are often used in rail and shipping incidents, which have high casualty rates and receive a lot of public attention. Because such accidents are rare, people want to know as much as they can about them. Road accidents, on the other hand, are numerous, and the number of casualties per accident is limited. As a result, little public attention is paid to individual accidents. This is clearly the result of the catastrophic versus chronic nature of the risk (see section 1.1.1).

As regards road traffic, it makes more sense to conduct analyses of accident clusters, for example accidents that involve elderly people or accidents between bicycles and lorries. A description of all phases of a certain cluster of accidents helps us understand why such accidents occur and what options there are to prevent them or, if they do occur, positively influence their outcome.

Figure 1.2. Haddon-matrix [1.26]

Haddon-matrix	Pre-crash	Crash	Post-crash
Human aspect	Physical condition • fatigue, • alcohol and medicine use Mental state • stress • distraction High-risk groups • age • gender Experience • driving experience • knowledge Behaviour • speed • manoeuvre Protection • seat belts • crash helmet	Physical condition • reflex Making errors • assessment • manoeuvre Behaviour • brake • evade	Physical condition • resilience Mental state • shock Behaviour • manoeuvres following the collision Experience • calling in emergency relief services • protecting the location of the accident
Vehicle	Technical properties • brakes • tires Mechanical condition • state of repair • damage Driving conditions • load • loose objects	Passive safety • airbag • crumple zone	State of the vehicle • possibility of getting out of vehicle
Road and surroundings	Geometry • alignment • road design Design • road marking • signposting Pavement • skid resistance • unevenness Surroundings • bustle • distraction	Crash objects • obstacles • special circumstances such as roadwork Escape routes • hard shoulder • soft shoulders	Protection • warning • cleaning up

Figure 1.3. Asmussen's phase model

Transport phase	*transport concept*
→ Traffic Phase	*traffic situation*
→ Encounter phase/conflict	*incident situation*
→ Crash phase	*accident situation*
→ Injury and damage phase	*injury situation*
→ Treatment and convalescence phase	*recovery situation*

A detailed example of the phase model:
We drive into town to go to the cinema:
→ we are going by way of the ring road, it is dark, raining, puddles in road ruts;
→ there are not many cars, a pedestrian, head tucked inside his collar, crosses the street;
→ pedestrian jumps and freezes, car cannot swerve and skids;
→ quite a crash, pedestrian is hit full on;
→ police and trauma helicopter arrive quickly, pedestrian services but is disabled, and driver has trauma from the accident.

Phase	Relates to	Examples of variables
Transport phase	Transport concept	Reason for journey, destination, time mode of transport, route chosen
Traffic phase	Traffic situation	Behaviour in traffic, anticipation, circumstances, number of cars on the road

It is not always possible to give a complete description. The description on the accident form gives a lot of information about the crash phase or the injury and damage phase of an accident or cluster of accidents, but there is generally only little information about the other phases. For this, additional information is needed. The phases are mostly described as logically sequenced events (scenarios) that may have led to the group of accidents being studied. The further away a phase is from the ultimate accident (the mobility phase is furthest removed), the harder it is to demonstrate how the circumstances in that phase are related to the accident.

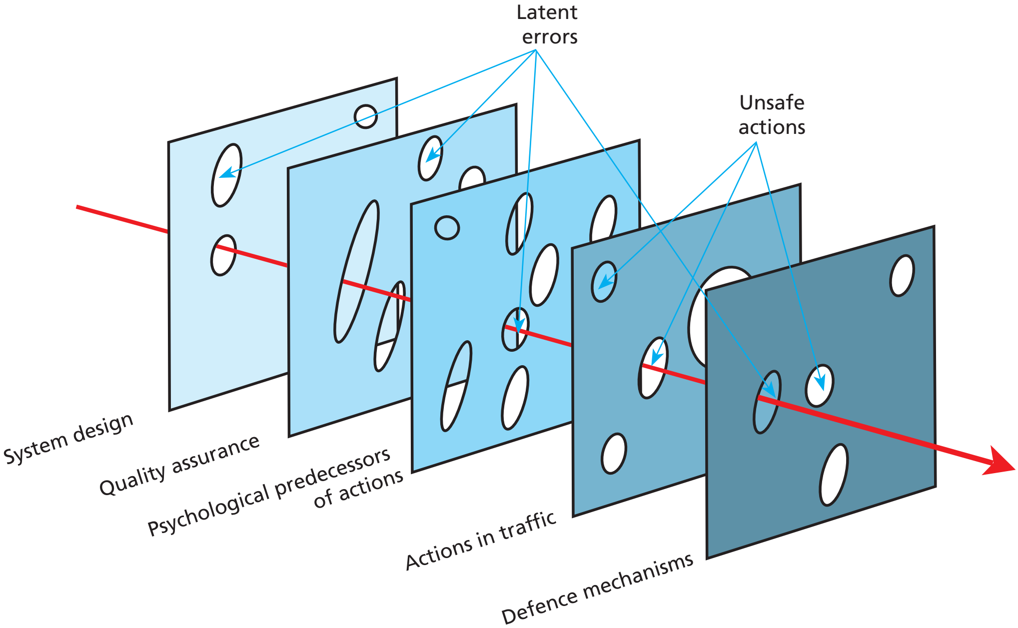
An example of this dynamic systems approach is Asmussen's phase model [1.8], which is based on the following principles:

- The traffic and transport process is a dynamic process: it is a temporally progressive complex of critical circumstances and events. Every state is, therefore, just a moment in time with a past and a follow-up. The follow-up is determined by both the past and the road user's intended objective and behavioural alternatives available to him.
- The process becomes increasingly critical, especially when in a given phase the critical states can no longer be 'controlled and removed'. The time and space for observing, deciding and acting become smaller and smaller. The earlier the intervention in this chain, the more effective that intervention will be.
- Every phase comprises different critical combinations of circumstances, different behavioural alternatives and different relations between individual behaviour and the surroundings.

It is possible to zoom in on or out of certain phases of this phase model. It is also possible to detail a phase using other models such as traffic flow models or crash models.

Figure 1.3 presents the essence of the phase model.

Figure 1.4. Schematic representation of the development of an accident (red arrow) as a result of latent error and unsafe actions [1.43, 1.64]



Leiden University developed a simpler model: the latent error model [1.62]. This expresses the same message and also explains that people take decisions in the early phases of an accident that may cause an accident in a later phase. An important message of this model, too, is that early intervention is useful. Accidents are very rarely the result of a single unsafe action; they usually involve a chain of circumstances and events that result in an accident. Figure 1.4 is a visual representation of a combination of latent errors present in the system [1.43]. This so-called 'Swiss cheese model' also indicates that all kinds of errors will have to occur more or less simultaneously (that is, linearly in the schematic representation) in order to result in an accident.

1980-1990: man as dominant link

Man was seen as the dominant link in the chain [1.25, 1.71]. Against this background, behavioural adaptation was also considered as a cause. Solutions were sought mainly in influencing behaviour.

1990-present: towards a preventive approach of road unsafety

The previous approaches culminate in the Sustainable Safety approach. The Sustainable Safety vision was published in 1992 as a collection of ideas on how to advance road safety in a systematic manner. The systems approach to road safety thus shifted from curative to preventive. 'Repairing what went wrong' becomes preventing serious accidents from occurring and, if that is not possible, at least reducing the severity of the outcome of accidents. The ergonomics perspective plays a key role in this approach: the surroundings (vehicle, road and surroundings) must be brought down to a human scale.

Sustainable Safety is a comprehensive approach that was initially implemented mostly at the infrastructure level (Sustainable Safety start-up programme). Later, emphasis shifted to other system components and instruments (education, traffic enforcement, ITS, et cetera): 'Advancing Sustainable Safety'. Sustainable Safety is the leitmotiv for theoretical notions in current road safety policy in the Netherlands [1.64, 1.72].

1.1.4 Sustainable Safety

The road traffic system is inherently unsafe: the design of the current system is such that it causes accidents and serious injuries. The inherent road unafety and the fact that this notion should be the starting point for improving safety is inspired mainly by developments in other sectors, such as aviation and the process industry, where this awareness had dawned much earlier. In short: Sustainable Safety replaces the accepted curative approach to unsafe locations by a proactive and preventive approach.

Sustainable Safety involves testing the entire traffic system against its requirements. Elements that do not meet these requirements (for example, points where bicycles and cars meet) are eliminated. This means that a traffic system that meets the requirements of sustainable safety is a system designed in such a manner that road safety does not depend as much on the choices of individual road users.

Sustainable Safety is defined as system in which man is the measure of all things in an integrated approach towards the components road, vehicle and human. The infrastructure is geared to human capabilities and limitations, the vehicle offers support in the driving task as well as physical protection and people are sufficiently trained while, moreover, their behaviour is also controlled.

Sustainable?

The word 'sustainable' is inspired by the Brundland report on sustainable development: development that meets the need of the present generation without compromising the ability of future generations to meet their own needs.

Sustainable Safety was launched as a concept in the early 1990s, implemented in subsequent years and updated in 2005. The updated version was published as 'Advancing Sustainable Safety' and is characterised by:

- building on the successes of the past (further improving the safety of the infrastructure);
- increased attention to and detailing of education, regulatory framework and traffic enforcement;
- more emphasis on technological developments;
- a plea for a quality assurance system;
- a plea for a comprehensive approach to road safety in terms of measures, safety principles and policy;
- emphasis on the importance of sound evaluation, knowledge assurance and knowledge exchange.

Sustainable Safety seeks to prevent crashes and, where this is not possible, eliminate the risk of injury wherever possible. In order to achieve the objectives of Sustainable Safety, man is taken as the measure of all things. After all, people are the linchpin in traffic and, moreover, the main cause of the road unsafety.

Table 1.3. The five principles of Sustainable Safety

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

The human scale is defined by two characteristics:

- however well educated and motivated, people make mistakes and do not always follow the rules; as a result, people are the key cause of accidents;
- people are physically vulnerable and therefore susceptible to injury.

Sustainable Safety is aimed at reducing the chance of errors and traffic violations or dealing with their consequences.

The following points are the essence of Sustainable Safety:

- the prevention of (serious) crashes and, where this is not possible, the almost total elimination of the risk of severe injury;
- the premise that man is the measure of all things due to his physical vulnerability and cognitive capabilities and limitations (such as fallibility and offence behaviour);
- an integrated approach to the elements human-vehicle-road which is tuned to the human scale;
- a proactive approach to bridging gaps in the traffic system.

These points have resulted in the five sustainable safety principles presented in table 1.3.

The functionality of roads

Traffic has two functions: to flow and to exchange. These are very different functions and they each require a specific infrastructure and specific use requirements. This traffic engineering distinction was inspired by the functional categorisation of roads according to Buchanan, who viewed the traffic system as a system of 'rooms and corridors' [1.73].

The Sustainable Safety principle of functionality is based on this traffic engineering distinction. According to this principle, roads ideally fulfil just one single function (monofunctionality). Through roads are meant to enable traffic to flow as much as possible and must be designed in such a way that traffic can move safely from A to B at high speed. This road type is specifically suited for through traffic. It would be preferable if traffic could drive the largest part of a journey along through roads. Access roads are meant to provide access to destinations. On these roads, fast traffic mixes with vulnerable road users such as pedestrians and cyclists. Residence is the main function here and motorised vehicles are guests. This traffic function also requires its own infrastructure. Finally, connecting roads have been defined and are called distributor roads. This road type has a flow function on road segments and an exchange function at intersections and connects through roads with access roads as well as through roads with through roads and access roads with access roads.

Figure 1.5 shows the different road types in a network.

Homogeneity of mass, speed and direction
In a crash, the human being's vulnerability comes into play. Injury is the result of a combination of released kinetic energy (mass × speed), biomechanical properties of the human body, and the physical protection that the vehicle offers its occupants (the more kinetic energy is released, the greater the injury). The homogeneity principle states that, where road users or vehicles with large mass differences use the same traffic space, the speeds should be so low that the most vulnerable road users and transport modes come out of a crash without any severe injuries. There where the traffic uses high speeds, road users should be physic-

Figure 1.5. Three functional road types as the basis of sustainably safe road traffic [1.64]

Table 1.4. Proposal for safe speeds in different situations

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

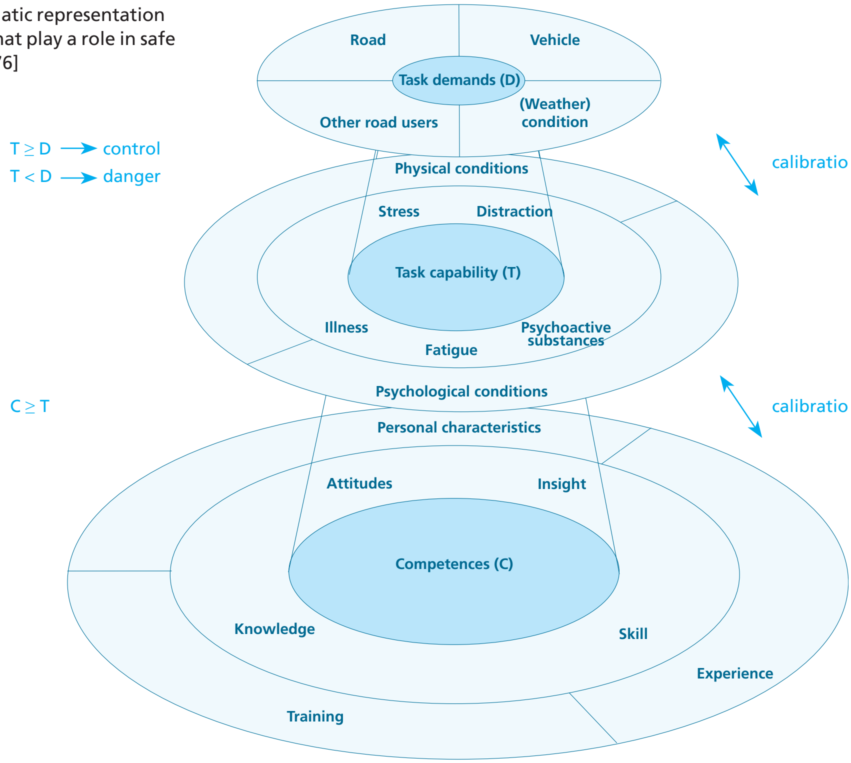
ally separated from each other as much as possible and be protected by their vehicle. Studies of collisions between pedestrians and cars [w1.1] and the Swedish Vision Zero study [1.74] have resulted in the following recommended safe speeds in different situations. These are included in the updated Sustainable Safety vision, see table 1.4.

Physical forgivingness: environment
Forgivingness is also an important factor in preventing injury. Forgiving environment ensure that the consequences of errors remain limited. This is particularly important in traffic situations where people drive fast. In the elaboration of this principle, one could think of safe (for example, matted) shoulders, obstacle-free zones, or collision-friendly obstacle protection.

Social forgivingness: road user behaviour
Traffic is a social system in which crash causes can partially be traced to the interaction between road users. Therefore, it is important that road users allow for each others' shortcomings. This is the social elaboration of the principle of forgivingness. Forgiving road behaviour, particularly of the more competent road users, could increase the possibility for less competent road users to commit errors without any serious consequences.

Recognizability
A recognizable layout of a road prevents unsafe actions in traffic as much as possible because road users know what to expect both from the behaviour or other road users and their own behaviour. This can be achieved by consistency in road design and continuity in road course. Ideally, the road layout supports the road user expectations along the whole length and the road design elements correspond to these expectations. This is related to the principle of credibility. The road layout must be credible in terms of the rules in force and the use of the road. People appear to make fewer mistakes if they have to react to situations that they expect compared to unexpected situations [1.57]. People also make fewer mistakes and fewer dangerous mistakes if their actions are routine [1.42, 1.43]. In these senses too, a recognizable road layout plays a supporting role, which is of vital importance when high speeds are involved.

Figure 1.6. Schematic representation of the elements that play a role in safe road use [1.75, 1.76]



State awareness

The principle of state awareness involves a road user being capable of assessing his task competences for the given task requirements of traffic. Traffic must be sustainably safe for everyone, not just for the 'average road user'. People have more or less stable characteristics (competences), but can also be temporarily influenced by factors such as alcohol, stress or fatigue [1.75]. The combination of competence and the actual situation determines how capable a road user is to cope with the driving task (see figure 1.6). The task requirements are determined by environmental factors, but the road user can adapt them by, for example, driving faster or slower.

1.2 Psychological aspects

The human factor is instrumental in almost all accidents. It is important, therefore, to take the possibilities and limitations of road users as starting point for designing the road and traffic environment: man as the measure of all things. People are imperfect, make mistakes or are still learning. Moreover, some people deliberately look for risks. As such, 'man as the measure of all things' does not refer to a perfect human being, but to a regular, 'standard', vulnerable road user with all his shortcomings who should be taken into consideration as much as possible in the traffic system.

Human causes of accidents

A study of human errors [1.25] showed that almost half of all accidents with human causes had to do with perceptual errors:

- Improper lookout occurred frequently on intersections. Drivers would look, but failed to see other road users, did not pay attention, or failed to look in the right direction.
- Inattention often had to do with drivers failing to see on time that the car before them stopped or braked.
- Internal distraction also played a key role.

Figure 1.7 shows what happened immediately before the accident, to what extent various human factors played a role and in what percentage of accidents this may have been a contributing factor. The study in question used two data sets (2,258 accidents that were extensively analysed 'on-site' and 420 accidents that were extensively analysed after the fact ('in-depth'). The data sets produced similar results.

The dark blue bars indicate the percentages of accidents in which the researchers were 'certain' that the factor in question was one of the causes (reliability interval 0.95 - 1.00) and the light blue bars show the percentages including the cases in which the researchers classified the factor in question as 'probable' or 'possible' (reliability interval 0.80 - 0.94).

Figure 1.7. Traffic-related causes of accidents and their relative contributions to accident numbers [1.47]

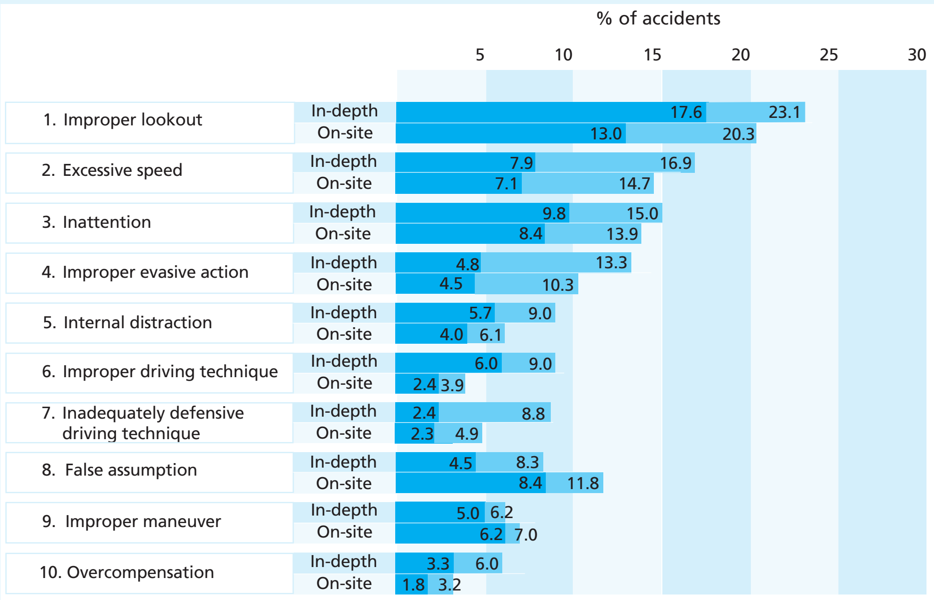
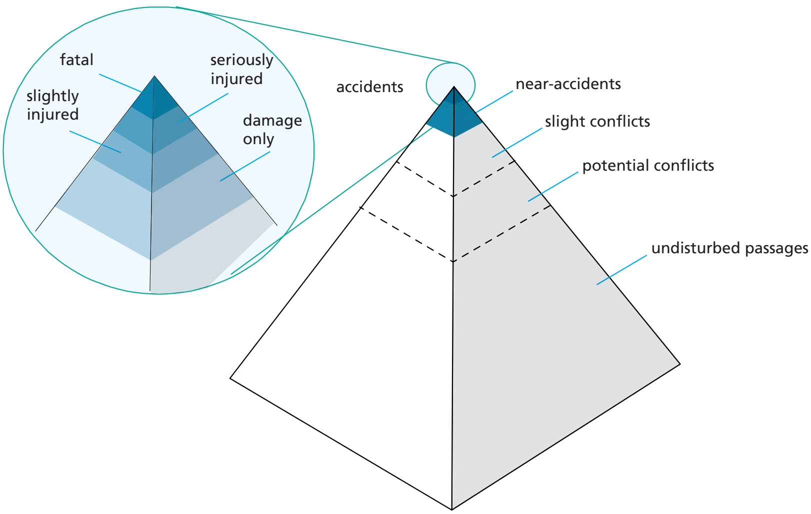


Figure 1.8. Continuum of traffic events, from undisturbed journeys to fatal accidents [1.77]



With training, however, people can get better at performing a task, perform it more smoothly and make fewer mistakes. Moreover, people have certain skills that technology cannot yet take over, such as anticipating complex situations and dealing with them instantly. Every time they make a journey, people make decisions, and most of them are the right ones. The pyramid in [1.77] clearly illustrates that most of the time most of what happens in the traffic process turns out right, with only the occasional incident (figure 1.8).

1.2.1 Road unsafety caused by the road user
Human errors are the main cause of traffic accidents. Based on this general observation, it would seem useful to investigate what type of human error immediately precedes an accident. The question remains as to how the cause of the accident came about. For example: what was the reason why a driver was distracted from driving? Was he under the influence of alcohol? Countermeasures cannot be taken until the real reason is known. An inventory that drew a lot of attention from road safety experts was the '100 car naturalistic driving study' in the US. As part of this study, 100 cars were fitted with a video camera filming the driver's face and events outside [1.40]. This showed what happened immediately prior to an accident and under what circumstances, such as roads, weather conditions, and what the driver was doing. If, for example, an accident happened while the driver was making a phone call, this could be compared to other situations in which drivers were calling but no accident happened. This gave a good assessment of the real risk related to making phone calls while driving. This is an extremely valuable study, because it also provided information on the non-occurrence of accidents under the same circumstances.

A special category of disturbed concentration is thinking about other things, such as home, work, daydreaming and the like. This is not a case of deliberate external distraction, but rather internal distraction. Obviously, it is difficult to ascertain what proportion of accidents is caused by this type of distraction. The '100 car naturalistic driving study' does give an impression of external distraction, but, understandably, gives no indication of the driver's thoughts. At best, the observation made in the event of an accident is 'looked but failed to see.' It will then be necessary to study why the object in question was not seen. Research has shown that 'looked but failed to see' played a role in 10% of the accidents studied. If accidents caused by alcohol and drowsiness/ fatigue are disregarded, the percentage 'looked but failed to see' was as much as 22.8% [1.13, 1.61]. Accident analysis only yields information about the accident and seldom provides any pre-crash information. As such, we should be wary about interpreting accident statistics too quickly. The American '100 car naturalistic driving study', for instance, demonstrated that almost all accidents happened on straight roads. But then again, most non-accidents also occurred on straight roads. The fact of the matter is that the majority of roads are straight. It would be wrong to conclude from the fact that in 85% of the accidents the driver was calling, making phone calls while driving is extremely dangerous . For if, generally speaking, it appears that 85% of people are making phone calls while driving, then that figure is meaningless and presents nothing more than a starting situation. This example clearly shows the importance of knowing how frequently something occurs in non-accident situations (exposure degree).

The American study shows that doing something else (secondary task) while driving affects the chance of an accident. However, fatigue is one of the principal contributors to the chance of an accident (see table 1.5).

This clearly shows that certain activities considerably increase the chance of a (near-)accident. 'Insect in car', for example, has a high score, but this happens so infrequently that it is difficult to ascertain whether there is a real effect. According to this study, a passenger in the passenger seat significantly decreases the chance of a (near-)accident. Apart from the fact that the presence of a second person may affect a driver's behaviour (for instance through the passenger's sense of responsibility) or keep him alert, the passenger can also help monitor what happens on the road and give a warning, if necessary. Incidentally, the effect of certain influencing factors depends on the target group. A different study showed that the presence of male peers does increase the chance of young men getting into an accident. A few simple theories on how people process information will be described below. In general, the processing of information is understood as cycle of perception > assessment > decision > action. Seeing (visual perception) plays a key role in road use. It should be noted that not everything that is visible is always seen. Perception is not a passive process, but an interaction between seeing and the road user's expectations.

Table 1.5. Type of distraction and the factor with which the chance of a (near) accident increases or decreases

Type of distraction	Increase/decrease in chance of accident or near-accident (1 = neutral)
Moderate to severe fatigue	**6.23**
Complex secondary task1)	**3.10**
Normal secondary task2)	**2.10**
Simple secondary task3)	(1.18)
Reaching for a moving object	**8.82**
Insect in car	(6.37)
Looking at external object	**3.70**
Reading	**3.38**
Applying make-up	**3.13**
Dialling a number on mobile phone	(2.79)
Changing CD	(2.25)
Eating	(1.57)
Reaching for non-moving object	(1.38)
Talking in or listening to mobile phone	(1.29)
Passenger on passenger seat	**0.50**
Passenger on back seat	(0.39)
Child on back seat	(0.33)

Comment:
Factors that deviate significantly from 1 are presented in bold; these lead to an increased or decreased chance of an accident.
The figures between brackets do not differ significantly from 1 (no increased or decreased chance of an accident).
1) A complex secondary task includes dialling a phone number, using a PDA, reading, applying make-up, et cetera.
2) A normal secondary task includes having a telephone conversation, holding a mobile phone, changing a CD, eating, et cetera.
3) A simple secondary task includes adjusting the radio, talking with a passenger, drinking, smoking, et cetera.

1.2.2 The driving task

The driving task is often considered a single task, but is, in effect, a combination of tasks: operating the vehicle (with sub-components such as steering, accelerating and braking), keeping an eye on other traffic (checking in mirrors, watching vehicles in front, et cetera), keeping an eye on traffic signs, lights and the like and driving a certain route (for example choosing the right route based on signposting). Personal characteristics, motivation, attitude and ambitions all play a key role in performing the driving task.

The driving task can be described in a model comprising three levels: the strategic level, the tactical level and the operational level ([1.37]).

- The highest level is the strategic level, which includes the planning aspects of the driving task, such as the destination (where am I going?), the choice of transport mode (will I take the car?) and the route to take (what road will I take to my destination?). At this level, information processing and decisions take place only occasionally while driving (after having left home), at minute- or even hour-long intervals (on longer journeys). Information processing at this level is almost entirely conscious.

- The middle level is the tactical level, which concerns tasks related to the interaction with the road/road environment, such as bends, lanes, signs and traffic lights, and with other road users (other drivers, but also cyclists and pedestrians). There are frequent activities at this level, at intervals of several seconds to a few minutes. Information processing at this level is partly conscious, partly automatic.
- The lowest level is the operational level, which entails the actions needed to control the movement of the car, such as steering, accelerating, braking. Activities at this level are most frequent, almost continuous, with the occasional brief interruption (at intervals of only seconds or even tenths of a second). Tasks at this level are almost entirely automatic – which is a good thing, because some decisions must be taken within a split second.

To do justice to the personal aspects of road users, Keskinen [1.30] distinguishes a fourth driving task level 'on top of' the three levels described above: the level of Goals for life and Skills for living. This level is included in the GDE matrix in Chapter 9.

Alexander and Lunenfeld [1.5] distinguish different levels of complexity in the driving task (driving inside the lines is less complex than finding a route in an unfamiliar city) and different levels of urgency (see figure 1.9). The most urgent task always has priority. This is always the task at the next lowest level (tactical or operational level). A sudden gust of wind or flat tyre will shift all attention to the lowest level (operational level) in order to keep the vehicle on the road, completely interrupting information processing for the route to be followed at strategic level.

The way in which a road user performs the tasks depends largely on routine. While some tasks require a driver's undivided attention, others are more or less automatic. These different levels of performing tasks are often described using Rasmussen's SRK model of human behaviour [1.42] as knowledge-based, rule-based and skill-based behaviour.

Figure 1.9. Three levels of the road user's task and their interrelations, according to Alexander and Lunenfeld [1.5]

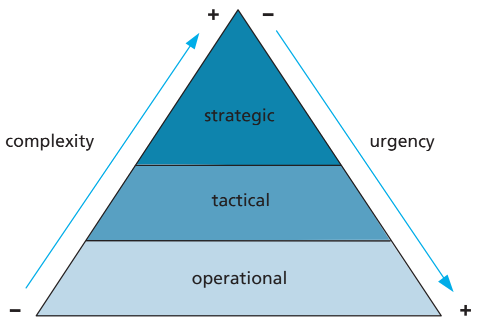
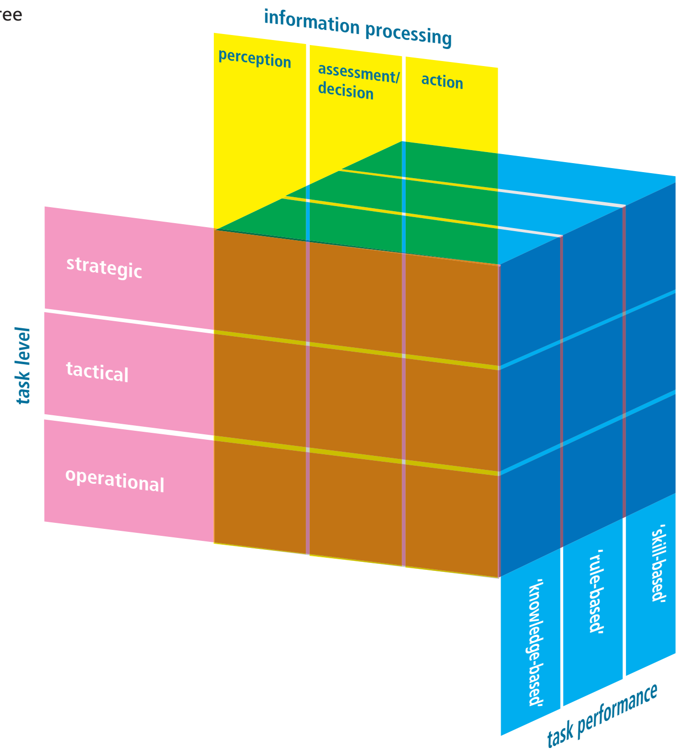


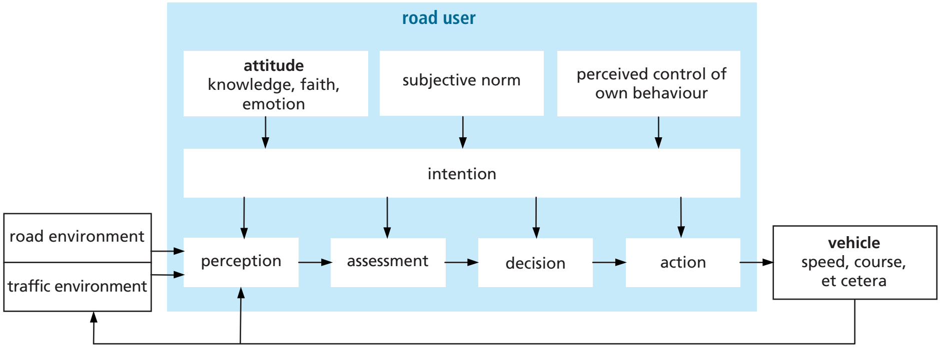
Figure 1.10. The road user's task in three dimensions ([1.54])



Knowledge-based behaviour is often related to new situations. An example is a novice driver who still has to think about switching gears, or a driver driving in the centre of an unfamiliar city. New knowledge is constantly being garnered and applied, in an attempt to see what works best. At this level, information processing and behaviour are very deliberate. This level requires a lot of attention and time, which makes it quite taxing. There is a high risk of making a mistake, particularly when driving at relatively high speed with little time to respond to changing or unexpected circumstances.

Rule-based behaviour is characterised by the use of rules and procedures to select a course of action in a familiar situation. The rules can be a set of instructions, such as if … then …, and can be acquired through experience or taught by someone else. An example is right of way: road users learn that they should give right of way when they see give-way road markings. Rule-based behaviour is generally about interpreting everyday situations and scenarios. Over time, a rule emerges on how to handle a certain situation and recognition will result lead to behaviour appropriate to that situation. A potential problem with rule-based behaviour is selecting and applying the wrong rule. Once started, a series of fixed behaviour patterns is often difficult to interrupt. An example: the approach to a priority intersection

Figure 1.11. Combined behavioural model of factors affecting the behaviour of road users



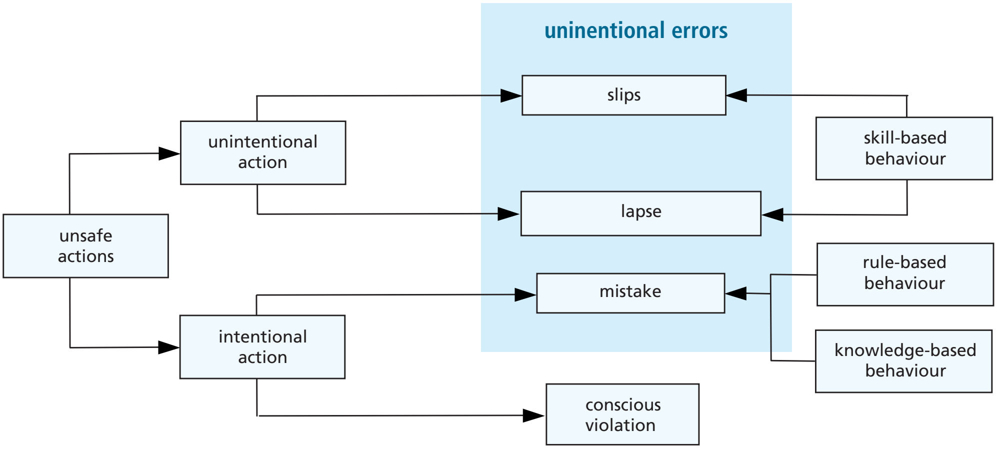
or a regular junction without any designated priorities is often characterised by a different but stereotypical viewing pattern. A driver approaching a regular junction will concentrate mainly on traffic coming from the right. Most people don't even look left. At a priority intersection, drivers first look left, then right. A driver who thinks he is approaching a regular junction (selecting the viewing pattern for a regular junction) and performs the appropriate actions, will easily overlook traffic from the left if it turns out to be a priority intersection. Another example: if a driver is approaching a roundabout and the car in front accelerates, that driver will also start moving and looking out for traffic from the left. But if the car in front then decides to stop, that is easy to miss because the driver expects the car in front to have driven on.

Skill-based behaviour represents a type of behaviour that requires very little or no conscious control to perform or execute an action. An example is a skilled driver who drives inside the lines – this requires no thought and minor deviations in his position will automatically lead to a steering correction. Skill-based behaviour occurs when a task has been trained a lot, such as changing gear. A novice road user hardly has any skills at this third level, and will need to concentrate more or less consciously on the performance of all subtasks.

In general, most behaviour at strategic level will be knowledge-based, at tactical level rule-based, and at operational level skill-based. If these classifications are linked to the cycle of perceptions, this results in a representation of the road user's driving task as shown in figure 1.10.

This model is not so much an explanation of traffic behaviour as a system description. Several other factors affect how the road user experiences or interprets matters, such as the design of the road environment, the behaviour of other people and, last but not least, the driver's characteristics.
A frequently used theoretical model in psychology is Ajzen's theory of planned behaviour [1.2], which suggests that a person's behaviour is determined in part by his intentions. These intentions are, in turn, a function of that person's attitude, subjective norm ('what do I think others think about it') and perceived behavioural control ('am I capable of keeping the car on the road at this speed'). Figure 1.11 represents the application of this model to the perception-assessment-decision-action cycle discussed in the next section [1.22].

Figure 1.12. Taxonomy of unsafe actions [1.64, 1.43]



Unsafe behaviour can be roughly divided into consciously unsafe and unconsciously unsafe behaviour [1.23]. In the case of consciously unsafe behaviour, the road user is aware of the fact that he is doing things that are not permitted or dangerous; he has his own reasons for taking the risk anyway. In the case of unconsciously unsafe behaviour, the road user thinks he is behaving correctly and is, therefore, not aware of the fact that he is acting dangerously. Measures to influence consciously unsafe behaviour are mostly on the level of enforcing correct behaviour and traffic enforcement. Unconsciously unsafe behaviour can be prevented by proper training and information and a road and traffic environment that is optimally geared to the road user's expectations.

An important qualification is that most offences are not committed deliberately or attitude-driven [1.78]. Primary reasons for violating the rules are habitual behaviour, social manipulation such as copy-cat behaviour and – as taught in driving class – 'going with the flow', even if that flow is going too fast.

Reason [1.43] has become very famous for his book on human error. His taxonomy of human error is based on Rasmussen's SRK model (see figure 1.12). In considering the human contribution to accidents, the difference between errors and conscious violations is of particular importance. Reason emphasises this difference because they have different psychological origins and demand different modes of remediation. He asked 520 drivers to complete a questionnaire which asked them to judge the frequency with which they committed various types of unintentional errors or violations when driving. Three factors were identified:

- conscious violations;
- dangerous errors (for example not watching what you are doing and cutting someone off as a result);
- relatively harmless slips and lapses (for example switching on the wind-screen wipers instead of the indicator).

Violations declined with age, errors did not.

1.2.3 Cycle of human information processing

The cycle of human information processing comprises four steps:
1 perception;
2 assessment;
3 decision;
4 action.

Step 1: Perception

Visual perception plays a key role in performing the driving task. It is said that approximately 90% of the input, the information that drivers use, is visual. Not everything that is present in the road environment is necessarily actually seen. Perception is preceded by a process of selection: an object has to be selected before it can be assessed. In most cases, selection starts by directing your gaze at it, as in looking at a traffic sign, for example.

This attention process can be controlled in two ways: by the driver himself or based on the information that the driver has to deal with. An example of driver-directed attention is a driver who is looking for a certain street and scanning all street signs until he finds the right one. However, sometimes this process is less explicit, for example when a driver monitors the surroundings based on his expectations – drivers expect traffic signs on the right side of the road, and will look for them there. In the case of information-directed attention, drivers are not explicitly looking for something, but their attention is drawn by an object, such as the brake lights of the car in front, or a car that is overtaking them.

The information offered in a traffic environment is so extensive that road users cannot select and assess all of it. For experienced drivers, the visual selection process of driver-directed attention plays a key role. In this case, perception is an interaction between the road user's expectations and the object he looks at and perceives.

This distinction between driver-directed and information-directed attention when driving is of paramount importance. If a road user is looking for information but does not find it where he expects it, chances are that that information will not be found at all [1.57].
However, expectations may be so strong that a driver looks at the traffic sign without its real message sinking in [1.33] – the driver sees what he expects. The surroundings of the new sign does not affect the driver's selection process as much as the driver's search criteria.

With knowledge-based tasks, the driver attempts to divide his attention as efficiently as possible, trying to take in everything. Inexperienced drivers hardly have any self-directed control. This means that there is considerable competition between the information offered, because every element from the surroundings could be selected, depending on its conspicuity. That carries a risk, because a driver cannot look at everything and, lacking experience, may look at things of minor importance. At the rule-based level, the driver uses a self-directed approach in which he has clear expectations, clearly directing his attention toward certain elements. In most cases, his expectations will match the important objects. The problem is that the self-directed approach is so strong that things that are equally important but are not in line with the driver's expectations are sometimes not selected or are looked at but not consciously perceived. A classical example is the looked-but-failed-to-see accident described earlier.
A lot has been written about this phenomenon

in the literature, because it is remarkable that a driver did look in the right direction yet failed to see the cyclist coming toward him. The driver kept on driving and hit the cyclist, shocking the driver because he was convinced that he had looked but that there was nothing there. This type of accident frequently occurs with cyclists and motorcyclist (but sometimes with larger vehicles as well). The explanation often given is that a driver actually looks to see whether there is another car, as this is what occurs most of the time. So whereas cars do meet the expectations, cyclists and motorcyclists do not. In these cases, drivers want to act safely and do look, but false expectations result in dangerous situations and accidents.

It is important, therefore, to check whether the nature of the information and the location at which it is offered fit the road user's expectations. If not, the information will have to have extremely information-directed characteristics (large size, striking colours, a background plate for signs or blinking lights) and be capable of actively attracting attention.

Perception means becoming aware of something through the senses. In traffic, sight is most important, but hearing plays a role as well. Sometimes even sense of balance comes in, alerting a rapidly accelerating driver to the chance of going off the road or tilting.

All senses have a number of elementary properties in common:

- There is an absolute perception threshold. The amount of energy reaching the senses (light, sound) must exceed a certain minimum to be perceived. A slight noise, for instance, will not be heard. There is a difference threshold. The difference between two stimuli (for example two sounds or two colours) must be large enough to be able to perceive the difference. The threshold value for this difference is a roughly constant ratio (the Weber fraction) between the change in the stimulus and the original stimulus. For example: when someone has 100 coins in his hand, he will not notice the addition of a single coin. That only happens after about five coins. But if the starting situation is 1,000 coins, the difference is not perceived after five coins, but after about fifty. The Weber fraction, or the just noticeable difference, for weight equals about 5%, but this fraction is different for each of the senses.
- Senses demonstrate adaptation: The longer a constant stimulus is continued, the more the sense's response to that stimulus decreases. Adaptation of the eye to light is an everyday example: when you drive into a dark tunnel, you will at first see very little, until our eyes have adjusted to the dark and you will start seeing again. Adaptation to darkness is slower than adaptation to light. Adaptation to a truly dark environment may take up to an hour, while adaptation to bright light happens in a matter of seconds. It is for this reason that tunnel entrances are more dangerous than tunnel exits.
- The relation between the strength of the stimulus expressed in physical units and the resulting perception is (almost) never linear. If, for example, the light intensity of a lamp is doubled, the subjectively perceived light intensity only increases by 25%.

Expectations and road environment

Because the expectations of road users play such an important role, the road design, the roadscape and the traffic situation must be optimally geared to these expectations and automatically elicit traffic-safe behaviour. This notion is at the core of the recognisability principle of Sustainable Safety and the concept of Self-Explaining Roads (SER).

Roads are self-explaining when desired behaviour matches the road users' expectations [1.55, 1.56]. The expectations that road users have or develop concerning a certain category of roads is related to both the infrastructure design and the intended use by himself and other road users. Unexpected traffic situations simply demand more of the road user's time to detect them, perceive them, interpret them, assess them and respond to them in the correct manner. A transition from one category of road to another or from one method of directing traffic to another requires a carefully designed environment. Moreover, the road user must have sufficient time to adjust his behaviour. Alexander and Lunenfeld [1.5] distinguish between a-priori expectancies (which are long-term and based on past experience, such as 'red' for danger and 'green' for safe) and ad hoc expectancies, which are short-term and based on recent situations encountered when driving. An example is that if a sign warns against a number of bends in a winding road, this creates the expectation that there will be warnings against all sharp bends.

Both forms of expectation not only play a key role in recognising and understanding (see also section 2.2.4.2) road situations, they are also important in handling certain traffic measures. If, for instance, an elderly driver no longer wants to drive in the dark, but is not averse to driving a familiar road section where he knows there is sufficient public lighting, a measure such as switching off or considerably dimming the public lighting at night (dynamic public lighting) will come as an unexpected surprise to him, resulting in insecurity and possibly incorrect behaviour.

Conspicuity

The degree to which information carriers or objects draw attention differs: the visual conspicuity of objects varies. There are objects that inevitably catch the eye. Advertising companies know all about this, but have to then do everything in their power to explain that their messages are applied in such a way that they do not draw the attention of passing drivers and are not, therefore, a safety risk …
Conspicuity can be expressed as the maximum angle from which an object can be detected without looking at it directly [1.18]. The larger the angle, the more conspicuous the object has to be. There is an optical instrument that can quickly and reliably determine the conspicuity in concrete situations (the 'conspicuity meter' [1.65]). It is a known fact, for instance, that lights that switch on can attract a large measure of attention. The drawback is that something that attracts attention can also distract from other important issues. Advertising should, therefore, for safety reasons, have to meet certain requirements: not too conspicuous and preferably not located in places where the driver already has a stressful driving task, such as at route choice locations, entries and exit roads.

Perception threshold and difference threshold in perceiving movement and speed in traffic

The absolute threshold value for movement of an object lies in an angular dimension (so that the change in the angle at which an object is viewed) in the order of two minutes of an arch per second. At an equal angular dimension, the moving object may be close by and moving slowly or further away and moving rapidly. Without indications as to distance, the eye cannot distinguish which it is.

Table 1.6. gives examples of differences in speed a driver can perceive between himself and the vehicle in front. When driving 40 m behind the other car, a driver can perceive a difference in speed of 5 km/h. If the distance is 160 m, the difference must be as high as 27 km/h in order to be perceptible and at a distance of 320 m 64 km/h.

Table 1.6. Smallest perceptible speed difference with vehicle in front (measured in the dark, thus based on perception of the relative movement of the rear lights of the vehicle in front)

Perception distance (in metres)	Perceptible speed difference (in km/h)
40	5
80	11
160	27
320	64
640	151

As a result, it is very difficult to formulate rules as to what people can and cannot estimate. Human perception is strongly influenced by specific circumstances. For similar reasons, it is difficult for people to ascertain whether they are nearing an object or the object is nearing them.

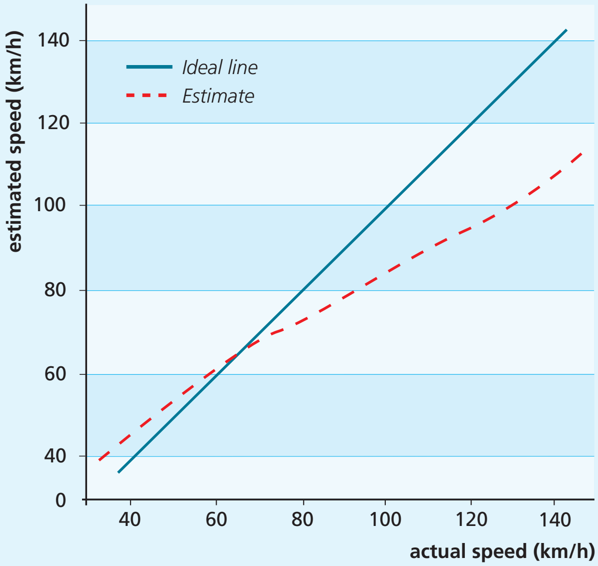
Adaptation in perceiving movement and speed in traffic

The phenomenon of adaptation also occurs in the perception of movement and speed. Habituation to your own driving style is an important factor to consider here, for instance when turning off a motorway onto a lower-order road. Having driven at the same high speed on the motorway then gives the driver the idea that the lower speed is illogically low, as a result of which he will increase his speed – an undesirable situation to say the least.
It has also been found that adaptation to a higher speed is completed within a short period of time (1 to 2 minutes on the motorway), while getting used to a lower speed is a much slower process. This may have as a result that a driver does not want to drive too fast, but, looking at the speedometer, constantly finds himself doing so. This is clearly not a case of 'consciously unsafe' behaviour (taking the risk of driving too fast) but more of 'unconsciously unsafe' behaviour.

Non-linear relation between subjectively perceived and objective own speed

Figure 1.13 presents the relationship between objective and subjectively perceived own driving speed. Actual and perceived speed differ: up to approximatly 65 km/h, there is subjective overestimation, at higher speeds underestimation.

Figure 1.13. Relation between actual and perceived own speed



Another contributing factor is the height of the driver in relation to the road surface. The impression of speed appears to be proportional to the number of the person's eye levels above the road surface someone covers in the direction of movement per second. A pedestrian covers approximately 1 eye level per second, a driver in a passenger car approximately 10 and a lorry driver approximately 4. This is the reason why driving in a lorry appears so much slower than driving in a passenger car at the same speed. In the extreme case of an aeroplane, this ratio is in the order of 0.03.

The environment, too, determines how fast we think we are driving. In a narrow street with lots of vertical elements (buildings or trees flanking the street) and a rough surface (for example cobblestones) drivers think they are going fast, while when driving at the same speed on a motorway with broad lanes they believe they are going very slowly. If we want to take measures to influence the perceived speed, these and similar factors will have to be taken into account.

Step 2: Assessment of information

The previous section (on detecting and perceiving information) discussed a number of fundamental properties of the senses. This section addresses the subsequent phases of recognition and interpretation of information.

Recognition

'Recognition' or identification takes place when the information offered corresponds to what a road user knows or has experienced before. This, of course, comes in different stages: some things he sees every day, others hardly ever. When you have expectations regarding what is to come (for instance the word Amsterdam on traffic signs), recognition and identification happen quickly when the sign contains the expected word.

This can be illustrated by means of the debate on what is known as the reading time formula, which represents the relation between the number of names on a sign and the time required to read the sign. This formula is as follows:

$$T = N/3 + 2 \text{ (seconds)}$$

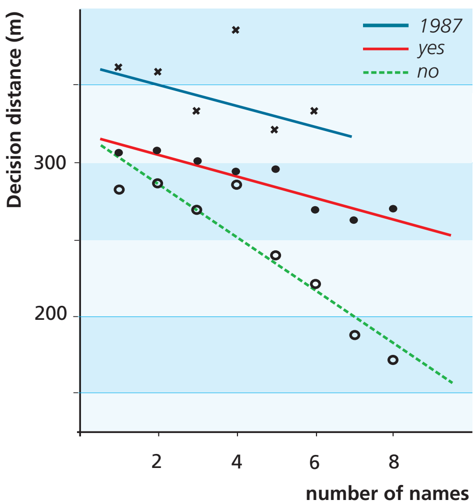
Where: T = required reading time, N = number of information elements on the sign.

This formula can be used to determine the maximum number of names on a sign at a certain driving speed. That number would always be low: never more than five or six on signs on motorways. A considerably more realistic starting point is that drivers do not have to read all names when looking for a specific destination because they know what they are looking for. If the destination in question is on the sign, a driver will have to read only half of the names on the sign, on average, before finding the right name.

The visual representation will also help the driver to recognise the name he is looking for. Studies based on this principle [1.3, 1.4] concluded that the number of place names on traffic signs could well be higher than hitherto assumed on the basis of the reading time formula (see figure 1.14).

The distance at which the driver is capable of determining whether the destination looked for is on the traffic sign decreases only slowly with the number of names on the traffic sign. Even if there are ten names, decision distances are not overly short. If the name is not on the sign ('no' in figure 1.14) decision distances are shorter, of course, because a driver will

Figure 1.14. Decision distance as a function of the number of names on a traffic sign [1.4]



Data from a previous study [1.3] is also plotted for 'yes' cases, i.e. those cases in which the name looked for was on the traffic sign.

then have to read on until the very last name. In that case, the line slopes more steeply. However, this situation is not as critical as the 'yes' situation, although ten names will probably be the practical maximum.

A hard requirement for placing signs above or alongside the road is that the road user must have finished looking for the right name before the sign is out of his range of vision. The last thing we want is a situation in which drivers slow down to read the signs. In order to prevent this, signs along the road must be placed at a distance of $a/\tan\alpha$, where a is the lateral distance between the driver and the sign and α the angle between the line observer/sign and the line perpendicular to the sign. This means that the distance to the sign on which the search process must be completed is approximatly 50 m. The value is similar for signs and panels above the road.

A second hard requirement for signs is that the letters and symbols must be large enough for road users to be able to read what they say. At a given font, the maximum legibility distance of the text depends on the observer's visual acuity, the letter height and the legibility coefficient of the letter used. This coefficient is expressed in the maximum legibility distance in meters per cm of letter height. The visual acuity of Dutch road users aged 18 and over is distributed normally, with an average of 1.61 and a standard deviation of 0.54. It follows that 85% of this population has a visual acuity of 1.06 or higher. This 85th percentile value is usually taken as the basis for the design of texts.

Understanding
Even while a message is clearly legible and identifiable, it is not necessarily understandable. The understandability of a message can be expressed as the chance that users give it the intended meaning. Figure 1.15 is about the understandability of a pictogram near the exit of a building.

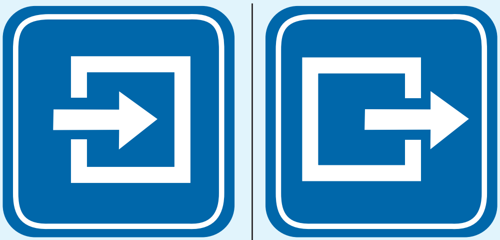
For a message to be understandable, it is better to use existing symbols than new ones. There may be occasions on which a new design is easier to understand, but because people already know the meaning of the initial pictogram, they fail to grasp the new symbol. Linking up with existing meanings wherever possible has proved to be effective. Here, too, expectations play a clear role. People are very bad at combining different signs. An example is a prohibitory sign with a sign below it stating: 'This applies to'. In such cases, it is often not clear what you are allowed to do and what not (figure 1.16 on the left). Different encodings with the same meaning (prohibition) can also result in problems with understandability (figure 1.16 on the right).

Understandability of pictograms

The example in figure 1.15 [1.66] illustrates the understandability of pictograms that are supposed to represent the entrance to and exit from a building. Of the more than 300 subjects that were asked to point out the symbol for 'entrance', 93 selected 'exit'. When asked to point out the symbol for 'exit', 264 of the more than 350 subjects selected the correct symbol, while 87 selected the symbol for 'entrance'.

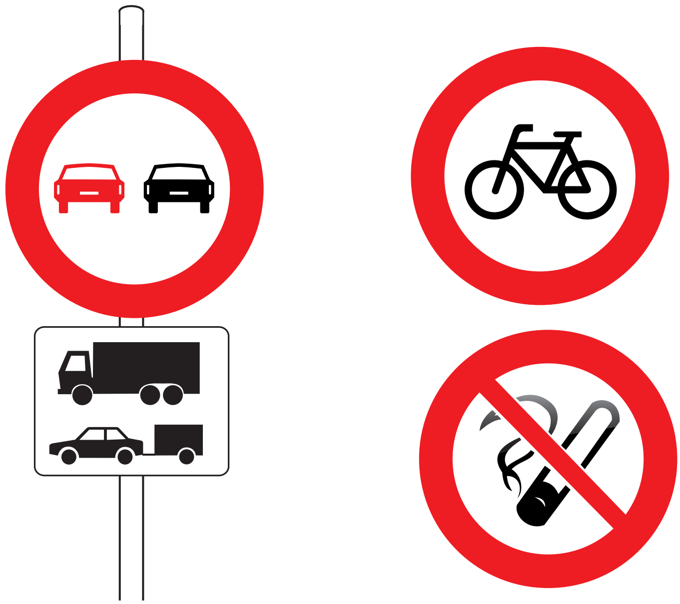
Figure 1.15. Understandability of graphical messages (pictograms): the confusion between 'entrance' and 'exit'

symbol selected



asked for the symbol for:	(entrance)	(exit)
entrance	219	93
exit	87	264

Figure 1.16 Example of a sign that is difficult to understand due to a combination of messages (left) and prohibitory signs with different encodings (right), without and with red line through the pictogram



It is not easy to give a general indication of when a road design is understandable. What is certain is that unambiguity is important. There has been a lot of debate in recent years about extra lanes during rush hour, which are emergency lanes that can be used as extra driving lanes. Initially, extra lanes had discontinuous markings (11 m of white line, 1 m interruption) to make it clear that drivers were allowed to cross this line. However, outside rush hour a red cross had to be shown on the digital traffic signs to indicate that this lane was not to be used.

The Ministry of Transport, Public Works and Water Management did not think it was a good idea to have a red cross over the lanes for most of the day, while there was nothing in particular going on; they were afraid of devaluation of the function of the red cross. It was decided, therefore, to use a continuous line to mark the extra rush hour lanes. Such continuous lines could be crossed when indicated by a green arrow above it. But because people have learnt not to cross continuous lines, the message to the drivers was ambiguous. First of all, drivers had just got used to the concept of an extra rush hour lane and the road layout that went with it. Secondly, that layout then confused the message of the continuous marking. It is not inconceivable that drivers would then think they could also cross continuous markings at will in other situations.

Because this solution has since been shown to cause problems (with drivers using the extra lane during rush hour even though it was closed), the road authorities have reverted to showing a red cross above a closed extra lane. Research is currently being conducted into a final solution that is acceptable to all.

Step 3: Decision

Once the road user has collected and assessed the information, he has to decide what to do with it.

Even if the process of seeing and assessing information has gone smoothly, different road users may take different decisions on what to do with that information. A study by Lewis and Cook [1.32] illustrates this well. The warning sign for falling rocks – well known in alpine countries – is an excellent sign in terms of perceptibility and understandability. Lewis and Cook asked their subjects what they would do if they saw this sign. Half of them said they would speed up to decrease the chance of being hit by a rock falling at that precise instant. The other half said they would slow down in order to be better able to swerve around rocks on the road. So even an excellent sign can lead to divergent decisions.

A second element in the decision-making process is that road users are not led solely by information just gathered, but also by their own motivations. A driver may decide to ignore a clearly visible and understandable sign because it disallows what the driver wants to do. An example is the sign prohibiting U-turns. A lot of drivers still make them when they have taken a wrong turn or want to go back the way they came, despite the presence of the sign. This constitutes a conscious choice to violate the rules.

Risk adaptation
An interesting phenomenon in decision-making behaviour is risk adaptation, which is also called risk compensation or risk homeostasis. This is the fact that, following a safety enhancing measure, drivers adapt their behaviour to such an extent that they counteract or even eliminate the favourable effect of that measure.

Three questions with regard to risk adaptation must be answered:

- *Why do road users change their behaviour?* The answer: not because they want to be annoying, but because they think it is useful or beneficial. Because objective safety has improved, road users feel that driving faster is less dangerous and 'no problem'. The measure, then, does not result in 'increased safety' but in 'improved mobility'.
- *When, in what situations, in what circumstances, do road users display such adaptive and possibly counterproductive behaviour?* This question cannot be answered in general. Studies have shown that behaviour changes unfavourably when people start driving cars with ABS [1.7] and when they start wearing seat belts [1.27]. The use of a porous friction course has a similar effect, in the sense that driving speeds are higher when roads are wet. Not every safety-enhancing effect is by definition counteracted by risk adaptation, but the safety effect achieved is often less than expected (when calculations failed to include this phenomenon of risk adaptation). On balance, there usually is only a slight effect.
- *How can risk adaptation be suppressed or preferably prevented?* If it is assumed that road users deliberately weigh the costs and benefits of safety and factors such as travelling time, classical measures such as information and education will not be very effective, because any information they provide is already known or will be included in a new consideration with the same counterproductive result. One option would be to adjust the balance of costs and benefits by a selective use of rewards and penalties for safe and unsafe behaviour, as is already the case with no-claims bonus insurance systems. A second option would be to integrate additional safety systems in cars without telling the drivers. But because car manufacturers also use these safety systems to compete with other manufacturers, this will probably not be feasible.

Risk adaptation can also work the other way around. If a driver drives a car whose brakes are not working properly, he will brake sooner and keep more distance to the car in front. Elderly people who have trouble seeing and interpreting everything on time, will also slow down. In that sense, risk adaptation can also have a positive effect. Here, too, the adaptation will not correspond to the additional risk.

The phenomenon of 'accident migration' as described in the literature is another manifestation of risk adaptation. Accident migration refers to a situation where action to reduce road traffic accidents in one black spot may result in them resurfacing in a nearby location where no action has been taken yet. The question as to how this can be explained has been discussed for many years. In addition to a statistical explanation called 'regression to the mean', risk adaptation may also provide an explanation. Accident locations are said to keep road users sharp. If such a location is made safer, road users might not be as alert, resulting in more accidents in nearby locations.

Risk adaptation not only occurs after technical measures, but also following measures directly aimed at people, such as education. There are strong indications that attending an anti-skid course results in more accidents on slippery roads [1.17].

A special case of 'increased risk' is the frequently observed risk of being caught in the event of traffic enforcement. This is discussed in Chapter 10.

Step 4: Action

Once the driver has decided what needs to be done, he will have to act. An important aspect of action is reaction time: the time that has elapsed from the moment at which the event requiring a response occurred until the actual response itself. Although this reaction time is not 'visible' until the action is performed, it is, of course, the total of all previous stages of information processing.

Reacting in skill-based behaviour works differently. Here, a stimulus offered results directly in a reaction without any intervening conscious decision-making process. Even if you wanted to, this reaction cannot be suppressed. In traffic, such behaviour is often extremely safe because the reaction time is so short, as when a driver brakes to avoid a suddenly braking car in front of him. However, the reverse may also be true, one example being immediate automatic opposite lock steering when you have run off the road with the result that the car hits a tree on the other side of the road.

The difficulty with taking reaction time into account is that it does not have a fixed value, even though that impression is usually given. AASHTO [1.1], for example, uses a standard value of 2.5 seconds for road design purposes, which is the sum of 1.5 seconds for perception + assessment + decision and 1.0 second for the actual response. However, reaction time depends on numerous factors, which means that using a fixed value is not really sensible.

The key aspect concerning reaction time that must be included in road design is the situation in which a driver has to respond . When a driver has his foot on the accelerator, he needs a certain amount of time to release it, take his foot off the accelerator, move it to the brake and push down the brake pedal. The reaction time between seeing and action must be added to this. Moreover, at a given speed, a car needs a certain amount of time and distance to stop. Time and distance increase quadratically with speed. Taking into account the reaction times and the situation in which action is required results in a differentiation in starting points to be used for the design (stopping sight distance, deceleration sight distance, driving sight distance, overtaking sight distance, approach sight distance, crossing sight distance and steering sight distance) (see for example [1.19]). An important fact for the entire process of information processing is that people cannot do everything at once – their mental capacity is limited. How large that capacity is differs from person to person and from situation to situation. In terms of traffic facilities it is safe to assume that people are, in principle, single-channel processing systems: they can only concentrate on one thing at a time. If they can do more, that is a bonus, but it is safer to assume that they cannot. There are strong indications that some people have more difficulty than others shifting attention rapidly and monitoring different objects at the same time and that this directly affects involvement in accidents. This is especially true for elderly road users. Ball et al. [1.10] showed that for elderly people aged 55 and over this span of concentration, which is called UFOV, or Useful Field of View, is highly predictive of their involvement in traffic accidents. So this, too, is a somewhat more complex aspect of action that cannot be described with a single parameter. A computer test has been developed to measure someone's UFOV, and there also are tables with scores on the basis of which people can be advised to stop driving altogether. It is currently not possible to indicate how the limitation of the road user's mental capacity can be included in road design.

1.2.4 Characteristics of road users and road safety

The previous sections discussed the general characteristics of perception, decision, et cetera. However, people differ in their response to these processes in terms of quality and speed. There are differences between elderly road users, people with little driving experience, men and women, people with a more aggressive driving style and people who adopt a careful driving style, etc. How important are these differences between people in relation to road safety and how can these be incorporated into the traffic system?

Classification in terms of road user characteristics

Janssen and Van der Horst [1.29] indicate that, in the literature, individual differences are almost always related to driving behaviour or involvement in accidents. Thorough overviews include those by Janssen, Lourens and Göbel [1.28] and Stembord and In 't Veld [1.48]. However, the resulting picture is quite diffuse.

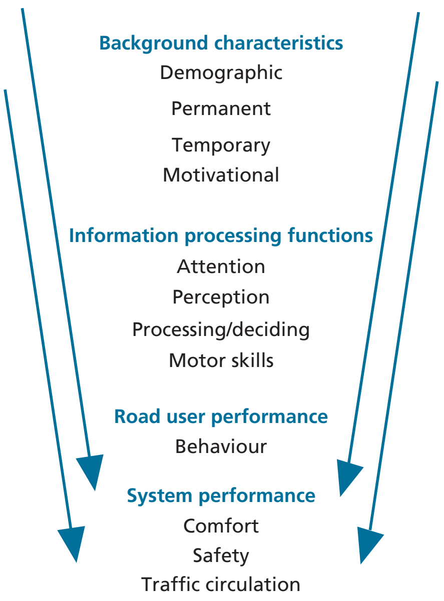
In order to give some structure to the data, they have classified characteristics into background characteristics, information processing functions, road user performance and, ultimately, system performance in a 'funnel model' (see figure 1.17). Background characteristics of road users determine how certain information processing processes are performed. This then results in certain behaviour on the road, which ultimately leads to certain system performance qualities, such as safety, traffic flow and comfort.

Of importance to road safety is the distinction between human characteristics that can be changed (e.g. by means of education and train-

ing), characteristics that cannot be changed but that can be used for selection purposes (for instance by means of an entrance exam), and characteristics that cannot be changed but that are so vital that road design must be modified to accommodate them.
This last category is important for safe traffic systems. Several fundamental questions play a role:

- What characteristics affect the risk of accident the most?
- Who and what is taken into account, and to what extent? After all, it is impossible to design roads for people who drive poorly, are virtually blind or deaf, or who drive aggressively. In other words, there is a certain cap on what groups to allow for.

Figure 1.17 Organisation of (categories of) road user characteristics



Road designers often use 85% of a population as the basis. This means that the design does not take into account 15% of the population that is taller, heavier, has poorer eyesight, et cetera. This part of the population will just have to fend for itself. Asmussen [1.8] lists a set of functional limitations in such a manner that 90% of the population is included as a road user (see box on the next page).

Should all key characteristics be included, or are there reasons to exclude them? For example: should roads be so wide that even drunk drivers can stay on the road? The more key characteristics there are, the smaller the chance that a design meets all requirements. The following questions remain: can characteristics be grouped, are there sufficiently high correlations between characteristics to combine them, and how can future developments and trends such as aging and other demographic developments be anticipated?

People with functional loss and functional limitations [1.8]

Today's traffic and transport system is geared mostly to strong road users: 20 to 55-year-olds without functional loss or functional limitations. Some six million people in the Netherlands suffer a temporary or permanent functional loss or limitation. These include people with a visual impairment or people in wheelchairs, for example, but also more everyday cases such as parents with prams wanting to get on a train. In the near future, as the population ages, this problem is only set to worsen [1.9]. It is important that sufficient allowance is made for these groups.

Table 1.7. Number of people with a functional loss or limitation [1.8]

Number of people with a functional loss	
Wheelchair users	70,000
Blind people	15,000
Deaf people	20,000
Total	**105,000**
Number of people with a functional limitation	
Children aged 0-14	2,800,000
Walking impaired	400,000
Disturbance of equilibrium	400,000
Limited stamina (limited lung and heart function)	400,000
Severe visual impairment	300,000
Hearing impaired	300,000
Cognitive and mental limitations	400,000
Temporarily disabled persons	500,000
Parents with prams	500,000
Total (incl. 3,500,000 elderly people, overlap)	**6,000,000**

With the addition of this carefully selected list of functional limitations, 90% of the population are included as road users. Key aspects of functional loss or functional limitation in terms of road use are slowness and the degree to which this can be compensated. Road design can take this into account by creating a continuous network for cyclists and pedestrians in residential areas, traffic arteries without steep elements (such as bevelled kerbing) with a view to crossing the road, and the possibility of always crossing the road in two stages, thus by way of the refuge.

Demographic characteristics and road safety

Elderly people

Elderly drivers are in a traffic category of their own. The risk of death for the 65-74 bracket is about twice as high as for the 30-64 bracket. For people aged 75 and over, this risk is over eight times higher. The risk of death of elderly drivers is considerably lower than that of death of elderly cyclists and pedestrians [1.51].

Because of their physical vulnerability, elderly people run a higher risk of severe injury. Not only is their risk of getting into an accident higher, the consequences are also more serious. Elderly car drivers have to deal with a number of functional limitations: they process information slower, they cannot process several things at the same time, and they have decreased flexibility of the neck and body (which is important when looking over their shoulder before making a turn). Accidents that occur when turning left at a crossing are a case in point, as drivers need to look over their shoulder, act quickly and keep an eye on traffic from various directions. Elderly people often avoid certain situations because they make them feel unsure of themselves, such as driving in the dark, rain or mist or during the rush hour. Elderly people often do not drive alone and avoid busy intersections.

The routes to the most commonly visited destinations such as shopping centre, doctor and community centre are important to the elderly, especially as slow road users. Such routes must be suitable for rollators, mobility scooters, et cetera. Urban designers have to take into account that a neighbourhood should accommodate people of all ages. Disabled people often have the same needs as elderly people (such as wheelchair-friendly kerb edges), but also need specific facilities, such as tactile paving and/or audible traffic signals for the vision impaired.

Children

At the other extreme of the age range are children. Special attention must be given to children in traffic, particularly in their direct living environment, as children still need to master the different skills needed to participate in traffic. This means that children must have the opportunity to be introduced to traffic in a safe manner and must be able to make mistakes without this having serious consequences. Table 1.8 presents the mobility development of children.

Table 1.8. Mobility development of children

Age	
1 year	Crawling Exploring the home
2 year	Walking Discovering the area around the home, being included in groups of older children
3 year	Riding a tricycle on the pavement of their own street (100 metres to the left and right of home), establishing contact with neighbours
4 year	First attempts at cycling Exploring other streets in the area (around the block), playing with children of the same age, establishing contacts with the adultworld (such as running an errand)
5 year	Going to kindergarten (in a 1-km radius) Visiting school friends
6 year	The school route is self-evident Action radius is the neighbourhood or village (walking or cycling)
7 year	Exploring small town, longer cycling tours are possible, opening up a larger area. Use of public transport in the home town becomes a matter of course
10 year	The city and neighbouring municipalities come within reach, sports facility and swimming pool are visited. Cycling in the area is normal, as is use of public transport

Today's traffic does not always do justice to children's development needs, which means that traffic curtails some children's development. Children's routes to school, the school environment and play areas therefore require special attention.

Man-woman

Alleged differences between men and women who participate in traffic are a popular topic of conversation. Weber [1.63] already proved that men and women drive under totally different circumstances. According to him, the difference in their involvement in accidents can be traced back to these exposure variables rather than to the quality of the way in which men and women perform the driving task. Women are involved in fewer accidents, but also drive fewer kilometres a year than men. Corrected for exposure, the connection between aggression and the male hormone testosterone explains most of the difference in the accident involvement of young people.

Young, inexperienced drivers

The accident risk of young, inexperienced drivers (18-24 bracket) is more than four times higher than that of experienced drivers. The risk of young male drivers is even six times higher. This higher risk is due to two factors. Firstly, the lack of experience, as a result of which they misjudge certain risks, and secondly, age-related characteristics that come with a higher risk (for example risk-seeking behaviour). Young people want to try out new things and impress their friends, and they often drive in dangerous conditions, such as under the influence of alcohol or drugs and on weekend

nights [1.59]. This is also why insurance premiums for young people are higher.

Chapter 12 discusses the different risk groups in detail.

Judging own driving ability

One aspect that plays an important role in traffic is whether people are able to judge whether or not they are good drivers. Logically speaking, someone running a risk will try to minimise this by means of behavioural compensation, for example waiting longer to cross the road, driving slower, or taking greater care.

As early as the 1970s, it was assumed that most drivers think they are better than the average driver. Americans and Swedes in a lecture theatre were asked to give themselves a mark for their driving skills and their level of safety compared the other people in the audience [1.39]. Around 80% of them believed they were safer drivers than the average other road users in the group. Of the Americans in the group, 93% believed they were better than the average drivers in the group; of the Swedes this was 69%.

Preston and Harris [1.41] compared a group of road users involved in accidents with severe injury (with hospitalisation) with a group of road users that had never been involved in an accident before. When asked about their driving ability, the two groups gave themselves the same score. Even the road users involved in serious accidents believed they were better than average. In about 70% of these accidents, the police report indicated that these drivers were to blame. The drivers in this group had also been involved in more previous traffic violations than the group that had never been in an accident before. The fact that this over-assessment of one's own driving ability can lead to unsafe behaviour is self-evident. Not for nothing has state awareness (the ability to assess one's capacity to handle the driving task) been included in 'Advancing Sustainable Safety' [1.64] as a sustainability principle.

Fatigue

Fatigue is a temporary factor that can have major consequences for driving behaviour and road safety. This varies, of course, with the level of fatigue. Drivers who actually fall asleep behind the wheel will stop steering and probably veer off the road or collide with another car, with all the consequences this entails. Fatigue is a gradual process, with an increasingly negative impact on driving behaviour and, consequently, safety.

Chapter 11 discusses the issue of fatigue in traffic in detail.

Alcohol, drugs and medication

Everybody knows that the use of alcohol and drugs in traffic negatively impacts road safety. This is why legal limits for alcohol consumption in traffic have been included in Dutch legislation. A blood alcohol concentration (BAC) of 0.5‰ is the statutory limit; for inexperienced drivers, this is 0.2‰. The limit for inexperienced drivers is lower because they are often young people, who run a higher accident risk and who cannot hold their drink too well. Different rules apply in different countries; the statutory limit in Italy and Switzerland is 0.8‰ (less strict), that in Sweden and Norway 0.2‰ (stricter). The 0.2‰ limit represents no alcohol: the human body always contains a certain level of ethanol that is unrelated to the consumption of alcohol, which is why the permitted level has been set at 0.2‰.

A large-scale study in the 1970s proved that the relative chance of an accident increases greatly with increasing BAC [1.11]. The relationship is not linear; not every sip (step) of alcohol increases the chance of accident by the same amount (step). The relationship is exponential: the chance of an accident increases at a greater rate than the blood alcohol percentage.

Accident analyses sometimes estimate the risks related to alcohol based on BAC measurements of people involved in an accident. The single observation that people involved in an accident have been drinking is of little use to calculating the risk of alcohol in traffic. If, for example, it is found that 10% of accidents involved people who had been drinking, this says nothing about the relationship between safety and accidents. The only conclusion that can be drawn from this figure is that 10% of all drivers get behind the wheel after they have been drinking. The risk must, therefore, be calculated in a different manner. Borkenstein et al [1.11] made an in-depth comparison of people involved in an accident and BAC, on the one hand, and people not involved in an accident and BAC, on the other. The key conclusion of this study was that under 0.4‰ there is no relationship between BAC and the chance of accident, but that this chance increases strongly from 0.4 to 0.5‰. This is confirmed by other studies ([1.35], for example). The best-known effect of alcohol is a longer reaction time, causing people to respond more slowly, to careen more and have less attention for the driving task. Risks may also be misjudged, with underestimation especially leading to safety problems.

Where alcohol in traffic is concerned, matters are relatively simple: the relationship between alcohol and blood alcohol concentration has been proven and the law prescribes a statutory limit. The situation with drugs and medicines is quite different. The dose-effect relationship is often less clear, and there is no statutory limit. The law does stipulate that drivers are not allowed to be under the influence of a substance that can reasonably be assumed to affect the ability to drive. Certain medicines come with a warning that they can influence the ability to react, thus shifting the responsibility to the driver. The effects of certain medicines on driving behaviour can be worse than that of alcohol [1.12]. Sleeping pills and sedatives are known to have a protracted numbing effect. Soft drugs like marihuana or hashish may also affect driving behaviour and, therefore, road safety.

Chapter 11 discusses the issue of driving under the influence of alcohol, drugs and medicines in detail.

Emotions in traffic

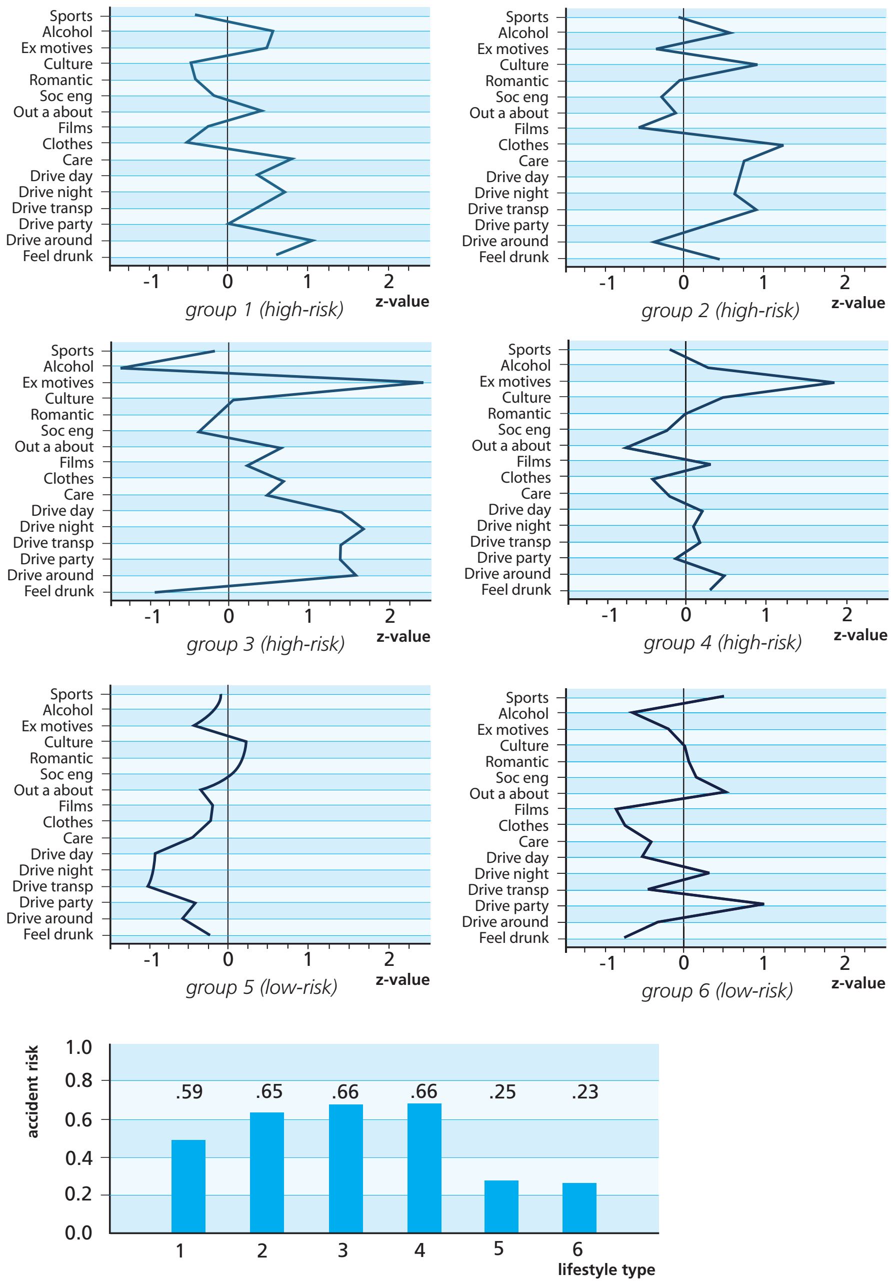
Emotions may also influence road safety, as they may affect the behaviour of road users. Well-known emotions are frustration and aggression, which may cause drivers to tailgate or cut in front of each other. Often, however, emotions will not run so high. Mesken [1.36] studied the role of emotions in traffic and found that happiness is the most common emotion in traffic, although it is completely unrelated to the traffic situation itself. Emotions are highly personal and some people react emotionally to certain situations more quickly than others. People who generally tend to respond with anger or aggression say they are prone to respond that way in traffic as well. Near-accidents occur more frequently when people are angry, probably because the anger led to more risky driving. There is a relationship between anger and aggression, on the one hand, and risky driving behaviour, on the other ([1.15], for example).

Chapter 11 also discusses the role of emotions in traffic in detail.

Lifestyle

As early as 1949, psychiatrists Tillman and Hobbs already wrote: ‘A man drives as he lives’. A Swedish study [1.20] defined lifestyle as a certain profile based on a number of everyday variables, such as frequency of going to the disco, alcohol consumption, interest in sport and music, which was then related to accident involvement. Four different lifestyles were identified that were associated with a higher accident involvement, and two lifestyles – mainly among women – that were associated with a lower accident involvement. Figure 1.18 shows several details.

Figure 1.18. Relationship between lifestyle and accident involvement per profile



The four high-risk and the two low-risk lifestyle profiles in Gregersen and Berg's study [1.20]. Every profile consists of a number of interests and activities in a number of fields, as judged by the subjects themselves (top) and the relationship between lifestyle and accident involvement (random sample n = 1774).
Apart from the actual content, the significance of these types of study is that they focus on patterns instead of on individual characteristics such as accident chance predictors.

Driving behaviour and weather conditions

How does the weather affect driving behaviour? Various studies (including [1.21, 1.34]) have shown that bad weather is strongly correlated to the chance of accidents. Causes include decreased visibility when it is raining and reduced friction due to a wet road surface. A recent Finnish study showed that the number of injuries due to accidents resulting from a wet road surface is many times higher than the number of injuries in dry weather [1.34]. A Swiss study has shown that the accident risk on motorways in rainy conditions during the daytime is five times higher than in dry weather; the accident risk in rainy weather at night is more than eleven times higher than in dry weather [1.58]. Recent Dutch research has shown an increase between 35 and 182% in the number of accidents that happened in rainy weather on national trunk roads [1.49]. The accident risk correlates with the speed limit and the time of day.

A comparison of accident victim statistics (based on averages for 1973 - 2001) in dry and wet weather leads to the conclusion that the chance of accidents on wet roads is five times higher than on dry roads [1.14]. Reduced visibility during bad weather causes a larger variation in average speed, which is often considered an indication of unsafe behaviour. Remarkably, however, accidents that occur during bad weather are often less serious than accidents during dry weather. This suggests that road users are aware of the increased risk and try to compensate for it. Such compensation may take the form of reducing speed and, to a lesser degree, increasing the distance to the car in front. Yet this is often not sufficient: bad weather causes an average decrease in speed of only 4 km/h [1.46]. In foggy conditions, drivers tend to drive even closer to the car in front, which, combined with reduced visibility, may increase the accident risk [1.21].

1.3 Mechanical aspects

The category assigned to a road determines its functional and technical requirements and, consequently, to an important degree its design. The classification of a road already determines most of the prerequisites for use of such a road, as well as which users share a road and the conditions in which they meet. Network classification is strongly related to spatial planning.

The choice for separating or mixing traffic is related to the homogeneity principle of Sustainable Safety: equality of speed, direction and mass at moderate and high speeds.

1.3.1 Energy transfer during a collision

The mechanical properties of the traffic system are a key principle for road safety concepts. Mechanical properties are subject to the laws of physics, where energy transfer during a collision is defined on the basis of the law of conservation of momentum. Momentum comprises three components:

- speed;
- mass;
- direction.

It is assumed that the two objects that collide are not deformable and therefore do not absorb collision energy.
In reality, however, road users and their vehicles are most certainly deformable.

> The formula for momentum P is
>
> **P = mass × speed**
>
> where speed not only has a magnitude, but also a direction.
> If no external force is exerted on a system, the total momentum will be conserved. This principle is applied to the collision of two objects (such as billiard balls).
>
> The components speed, mass and direction also determine the amount of energy E that is absorbed (and ultimately converted into heat) when two objects collide. The formula is
>
> $$E_{kinetic} = \frac{1}{2} \times mass \times speed^2$$

That is why resilience – the ability to absorb collision energy – of the two objects is important alongside mass, speed and direction. A car's resilience is determined by the combination of a safety cage and a crumple zone. Humans can only absorb very little energy without being damaged, especially in view of the large amount of energy released in a crash.

1.3.2 Differences in speed

It is sometimes suggested that 'a few km/h above the speed limit does not influence road safety'. This is demonstrably incorrect. Even small speed violations affect road safety. Speed is important for several reasons. It determines the available response time and, therefore, the accident risk, but it also determines the speed of collision and, consequently, the seriousness of the crash.
Incidentally, most speed-related accidents are not a result of violations of the speed limit, but of cars driving too fast given the circumstances.

Speed determines reaction distance and speed of collision
When a road user has to react to avoid a collision, the car's speed determines the amount of time available to respond. Consequently, driving at high speeds requires considerably greater anticipation than driving at low speeds.

An example (from the 'stopping slide', published by Overijssel Regional Road Safety Body): assume a stopping distance of 15 metres. This equals a situation in which a child runs onto the street three parked cars down. Under favourable conditions (a braking deceleration of 8 m/s^2 and a 1-second reaction time, this gives the following picture:

- drivers going 30 km/h can stop in time and avoid a collision;
- drivers going 40 km/h collide at a speed of 25 km/h (similar to a 2-metre free fall);
- drivers going 50 km/h collide at a speed of 45 km/h (similar to an almost 10-metre free fall);
- drivers going 60 km/h have not reacted yet at the moment of collision (similar to a 14-metre free fall).

Under less favourable conditions (such as a slippery road), the differences in stopping distance increase even further. This sharp increase in stopping distance was the reason for introducing 30 km/h zones.

It is generally assumed that 30 km/h is a safe speed. However, the risk of a fatal collision with a car going 30 km/h is still five times higher than a car that is driving at walking pace (15 km/h) in a home zone (see table 1.9).

Table 1.9. Relationship between collision speed and the risk of death

Collision speed (km/h)	15	30	50
Chance (%)	1-2	5-10	50

By driving at walking pace (15 km/h) instead of 30 km/h, the chance of a collision also decreases. Table 1.10 shows the reaction path, the brake path and the stopping distance as functions of speed. Reaction path is the distance covered during the reaction time, while the brake path is the distance covered while braking. The sum of these two distances is the stopping distance.

Table 1.10. Reaction path, brake path and stopping distance as functions of speed

Speed (km/h)	15	30	50
Reaction path (m)	4	8	14
Brake path (m)	2	8	22
Stopping distance (m)	6	16	36

braking deceleration 8 m/s^2 and a reaction time 1 second

Driving at 30 km/h certainly decreases the risk compared to the original speed of 50 km/h, but driving at walking pace increases safety considerably more. In addition, it considerably improves a road's residential function and usability in terms of social activities for young and old. In other words: 30 km/h is safe, but 15 km/h is safer.

Speed determines the severity of the crash

There is also much to be said about the relationship between speed, the chance of an accident and the severity of that accident.

Theoretically, a change in average traffic speed and the consequences in terms of accident risk are related as follows [1.16, 1.17]:
- the effect on the number of accidents is quadratic;
- the number of severe accidents is proportional to the power of three;
- the number of fatal accidents is proportional to the power of four.

This calculated connection does not, however, include any other important aspects, such as road categories.

Speed and risk

The differences in the relationship between speed and risk reverberate in the different design requirements for the different road types. These requirements are geared to the amount of information road users can effectively process. A motorway is less complex than the underlying road network. Because of this lower level of complexity, risks increase more slowly with increasing speeds on a motorway.

In order to be able to predict the effects of a change in speed on road safety, it is important to at least consider the specific conditions. Moreover, a change in speed limit may also bring about an increase in speed differences.

The relationship between speed differences and risks manifests itself in two ways:

- Roads with a broad range of speeds are less safe.
- Vehicles that drive faster than average run a higher risk. Vehicles that drive slower sometimes appear to run a higher risk, sometimes no change in risk is found [1.79].

1.3.3 Differences in mass

The difference in mass determines what portion of collision energy is absorbed by the collision partners. Mass differences between a lorry and a passenger car may be a factor 10; mass differences between cars may be up to a factor 3, while mass differences between vehicles and vulnerable road users vary between factor 10 and 700. In the event of large differences in mass, an accident may have serious consequences even at very low speeds.

A separation in time (for instance using traffic lights) or space (for instance with bicycle tracks) is a way of eliminating collisions, thus making mass differences irrelevant. However, a separation in time or space is not always practically possible. For instance, heavy traffic driving through residential areas is not a desirable situation, but there may be no alternatives in ribbon developments; besides, relocating companies that come with a lot of heavy traffic often costs a lot of money.

Where separation is reasonably impossible, both weaker and stronger road users must be given a fair chance of behaving in a safe manner. They should know that there are other road users, should be able to see each other and judge each other's (potential) behaviour, and, finally, they must be willing to take responsibility for their own behaviour. This is not as self-evident as it appears. It is usually not possible to see whether a lorry is heavily loaded or not, but this makes all the difference in terms of braking behaviour for the cars behind it. And predicting drivers' attitude is something that is completely unclear.

Resilience

The vulnerability of road users (and their vehicles) is often related to the difference in mass: lightweight road users are usually less protected than heavier road users. Because some groups of road users, such as pedestrians, cyclists, moped and motorcycle drivers do not have a protective cage, seat belts and airbags that can absorb the collision energy for them, these groups are vulnerable. This is even more the case with elderly people, who are physically weaker and more vulnerable to begin with. Falling can have serious consequences for them, a collision even more so. This is an aspect that must be taken into account given the aging of the population. Vulnerable road users are discussed in chapter 13 'High-risk groups'.

The resilience of car passengers has increased considerably. Cars often achieve the maximum score possible in crash tests, while a safety cage, crumple zones and one or more airbags have become standard features. The safety of children also receives considerable attention.

The reverse is true for the safety of pedestrians and cyclists in the case of a collision with a car. A collision-friendly car front has been the subject of study for a few decades now, but this aspect does not feature much in crash tests, where the focus is more on collisions with other vehicles and concrete surfaces. It took a long time before a car achieved the maximum score for collision-friendliness with vulnerable road users in the EuroNCAP test.

1.3.4 Differences in direction

Based on the differences in direction of the different road users, various groups of conflicts exist:

- passing conflicts in the same driving direction, such as rear-end collisions;
- conflicts in almost the same driving direction, such as when changing lanes;
- crossing conflicts, with driving directions at more or less right angles, such as with right-of-way mistakes;
- unilateral conflicts with a stationary object, such as an obstacle by the side of the road;
- frontal conflicts with opposite driving directions, such as frontal crashes.

The severity of a conflict depends in part on the fact that the modes of transport and, therefore, the vehicles, have a different level of resilience in different directions. The front of a car is more resilient than the side or the back.

1.4 Summary

This chapter discussed the frame of reference for the terminology used in this manual, describing key concepts and key visions of road safety. Theories on road safety have changed dramatically over the years: where initially only one dominant cause was sought, this has now shifted to a systems approach in which all factors that determine road safety are considered in their interrelations. The Sustainable Safety principle was developed on the basis of the available knowledge. The frame of reference forms the basis for describing road safety and motivating measures.

Most unsafe traffic situations can be traced back to human errors. This was discussed in terms of unsafe behaviour by road users, a general description of the driving task, the cycle of human information processing (perception, assessment, decision, action) and the way in which people perform tasks. The individual characteristics of and main differences between humans and the relationship with accident risk were also discussed.

Laws of physics are also relevant alongside human behaviour. This refers to the mechanical characteristics of the traffic system. A collision causes a transfer of energy that is determined by speed, mass, resilience and differences in directions. This transfer of energy may cause injury and damage, and as such, it is crucial to the end result of the accident.

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Website

w1.1 European New Car Assessment Programme (Euro NCAP), www.euroncap.com

Learning objectives for students:

- to get an idea of the key trends and developments in road safety and the measures taken over the years;
- to gain an understanding of the social costs of a road unsafety; to know the meaning of material and immaterial costs;
- to be able to put road safety figures into an international perspective.

2 Developments and trends

2 Developments and trends

2.1 Developments in road safety over the years

The first fatal traffic accident in the Netherlands occurred in 1905 [2.4], when a car rolled down a hill during a military exercise in Valkenburg and came to rest against a farmyard gate. The German observer in the car died on the spot, after which the shocked military officer informed the Royal House by telegram. In 2006, over 100 years later, the number of fatal traffic accidents had risen to approximately 680 a year, in which 811 people were killed. In the same period, there has been an enormous increase in traffic mobility from 0 to more than 135 billion vehicle kilometres travelled every year.

Between 1950 and 1972, there was a significant increase in the total number of traffic fatalities, peaking at 3,264. Since 1973, the number has decreased steadily. In the early 21st century, this decrease appeared to stop at approximately 1,080 traffic fatalities per year. In 2004, however, this number dropped sharply to 881. The figures for 2005, 2006 and 2007 (817, 811 and 791 respectively) appear to show a structural improvement in road safety.

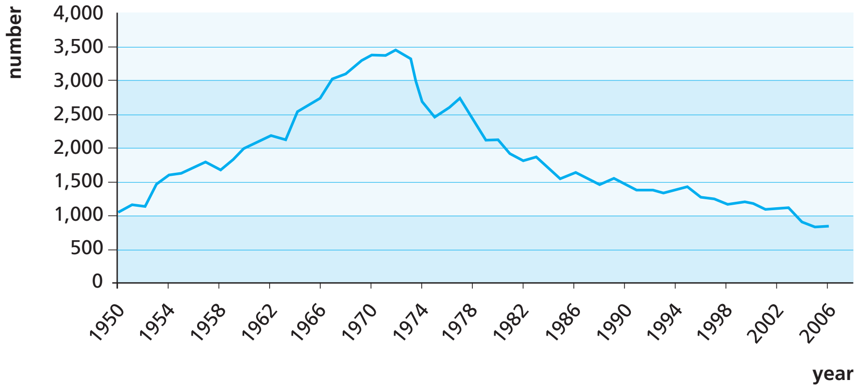
The first fatal traffic accident

On 17 August 1896, Bridget Driscoll became the first known traffic fatality. She was also the first pedestrian ever to be hit by a car. The accident happened in Great Britain on a terrace near Crystal Palace in London. The car was owned by an Anglo-French car company that was putting on demonstrations for the public. Witnesses spoke of the car hitting the victim at extreme speed: the driver was doing 4 miles per hour.

That driver was Arthur Edsell, an employee of the car company. He had been driving for three weeks, in an era when there was no such thing as driving tests or driving licences. He had apparently tampered with the transmission, which caused the car to double its intended speed. He was also talking to one of the passengers in the car when the accident happened. In the court case that followed, the jury passed a verdict of accidental death. Neither the driver nor the car company were sued but the judge said that the verdict should stand ('I trust that this sort of nonsense will never happen again').

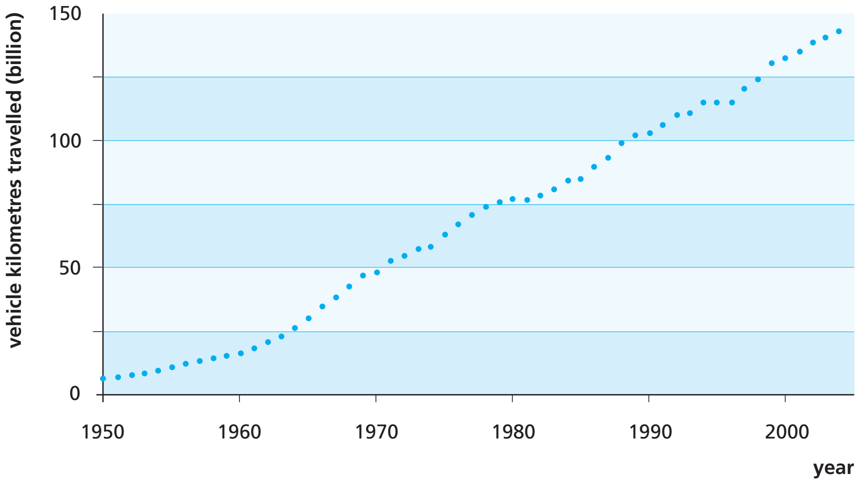
The first case of victims to die in a car occurred three years later when, on 25 February 1899, Edwin Sewell, an employee of the Daimler Company, lost control of his motorised 'wagonette' while driving at high speed down a steep hill in Grove Hill Road in Harrow (northwest London). He was giving potential buyers a demonstration of the vehicle. Major James Miller, who was sitting alongside him, also died from his injuries. The accident was caused due to the wheels collapsing at 20 miles per hour, which was considerably quicker than the speed for which the car had been designed.

Figure 2.1. Development of traffic fatalities 1950 – 2006 in the Netherlands



(source: AVV)

Figure 2.2. Development of vehicle kilometres travelled in the Netherlands



(source: CBS)

2.1.1 Total number of traffic victims

In 1975, Traffic Accident Registration was established in order to get an effective overview of the number of traffic victims nationwide. This organisation ensured that every accident registered by the police was recorded in a large database. In 1992, the organisation was incorporated into the Directorate-General for Public Works and Water Management's Transport Research Centre (currently the Centre for Transport and Navigation). Over the years, efforts have been made to continually improve registration. Since 1997, it has been customary to use the (estimated) actual number of victims as an indication of the road safety rather than the number that is registered by the police. In 1997, the Ministry of Transport, Public Works and Water Management and Statistics Netherlands (CBS) published the first official estimates of the actual number of traffic victims, based on the following sources:

- CBS statistics regarding 'unnatural death';
- PRISMANT, the National Medical Register;
- Injury Information System from the Consumer Safety Institute.

Traffic fatalities

In the period between 1996 and 2003, the total number of traffic fatalities decreased gradually from approximately 1,251 to 1,088 a year. The decrease was most significant in 2004: 19% compared to 2003. In 2005, 2006 and 2007, the decrease continued, albeit less rapidly. In 2007, there were 791 traffic fatalities, 37% less than in 1996.

Hospitalisations

The number of hospitalisations has also decreased, albeit considerably slower than the number of fatalities. This shows the danger of measuring road safety based on fatalities

Table 2.1. Overview of the actual number of traffic victims between 1996 - 2006

	1996	1997	1998	1999	2000	2001
Fatalities	1,251	1,235	1,149	1,186	1,166	1,083
Hospitalisations	19,420	19,740	18,520	19,330	18,600	18,110
Emergency assistance	91,000	107,900	104,900	115,000	117,000	92,000

	2002	2003	2004	2005	2006
Fatalities	1,069	1,088	881	817	811
Hospitalisations	18,380	19,040	18,060	17,680	16,750
Emergency assistance	91,000	97,000	unknown	unknown	unknown

(source: DVS)

alone. In 2005, 17,680 casualties needed hospital treatment, constituting a decrease of approximately 9% compared to 1996.
An analysis of files from the National Medical Register from 1984 to 2005 also shows that the seriousness of injuries sustained may have decreased.

- The average time spent in hospital fell from 16 to 6 days. However, given that a similar decrease was also evident in other patient groups, it cannot be concluded that traffic accidents have become less serious.

The average number of injury diagnoses in traffic victims decreased from 1.8 to 1.5 per person, a decrease of 17%. This is an indication of improvement in road safety.

- The number of hospitalisations for the sole purpose of 'observation' increased, meaning that the relative proportion of hospitalisations due to injury decreased.
- The number of casualties with at least minor injuries (MAIS 2+, as measured using the Abbreviated Injury Scale) decreased from 84% to 69%. This applied predominantly to motorists and passengers but not to cyclists and pedestrians.

Emergency assistance

The number of casualties requiring emergency assistance has fluctuated around 100,000 for several years.

2.1.2 Registration rate

The number of traffic victims is higher than appears in police reports because not all traffic victims are registered by the police.
The registration rate for different categories of severity is as follows:

- injuries requiring emergency assistance: registration rate circa 10-15%;
- hospitalisations: registration rate circa 55%;
- traffic fatalities: registration rate more than 90%.

Therefore, the more serious the injury, the better the registration rate. The level also differs for different types of accident; it is higher for accidents involving motorised vehicles and mopeds than for accidents involving slow-moving vehicles. Registration of cycling accidents involving no other road users is particularly low. The registration rate of accidents requiring hospitalisation and emergency assistance also appears to have decreased in recent years.

2.1.3 Victims by type of road user

Number of fatalities

The foremost developments in the period between 1996 and 2006 are:

- The number of fatalities involving pedestrians, cyclists and motorists/passengers and delivery drivers clearly decreased up to 2005. However, accident statistics showed that the number of bicycle fatalities in 2006 had returned to the higher level recorded in 2004.
- The number of fatalities involving moped drivers has been stable for years, with a slight decrease between 2002 and 2005 and an increase in 2006.
- The number of fatalities involving motorcyclists increased until 2002, but has decreased annually since 2003.
- The number of fatalities involving passengers in lorries and buses remained largely the same.

Table 2.2. Number of fatalities by type of road user

Mode of transport	1996	1997	1998	1999	2000	2001
Pedestrian	132	132	133	130	114	115
Bicycle	239	264	212	227	233	225
(Light) Moped	102	98	85	105	110	85
Motorcycle	94	98	85	83	95	85
Car/delivery vehicle	626	617	617	615	593	547
Lorry/bus	13	10	7	14	9	18
Other	45	16	10	12	12	8
Total	**1,251**	**1,235**	**1,149**	**1,186**	**1,166**	**1,083**

Mode of transport	2002	2003	2004	2005	2006
Pedestrian	111	107	77	89	73
Bicycle	194	219	180	181	216
(Light) Moped	107	99	87	78	87
Motorcycle	101	96	91	89	73
Car/delivery vehicle	540	549	432	371	361
Lorry/bus	13	8	10	11	9
Other	3	10	4	9	5
Total	**1,069**	**1,088**	**881**	**817**	**811**

(source: SWOV Cognos))

Table 2.3. Number of hospitalisations by type of road user

Mode of transport	2000	2001	2002	2003	2004	2005	2006
Pedestrian	1,240	1,150	1,170	1,040	1,070	1,060	960
Bicycle	6,490	6,270	6,680	7,440	7,110	7,460	7,240
(Light) Moped	3,450	3,360	3,430	3,550	3,340	3,140	2,980
Motorcycle	1,190	1,310	1,290	1,310	1,210	1,170	1,120
Car	6,010	5,830	5,610	5,500	5,150	4,670	4,310
Lorry/bus	150	130	140	80	110	100	80
Other	80	60	60	110	70	80	60
Total	**18,600**	**18,110**	**18,380**	**19,040**	**18,060**	**17,680**	**16,750**

(source: AVV)

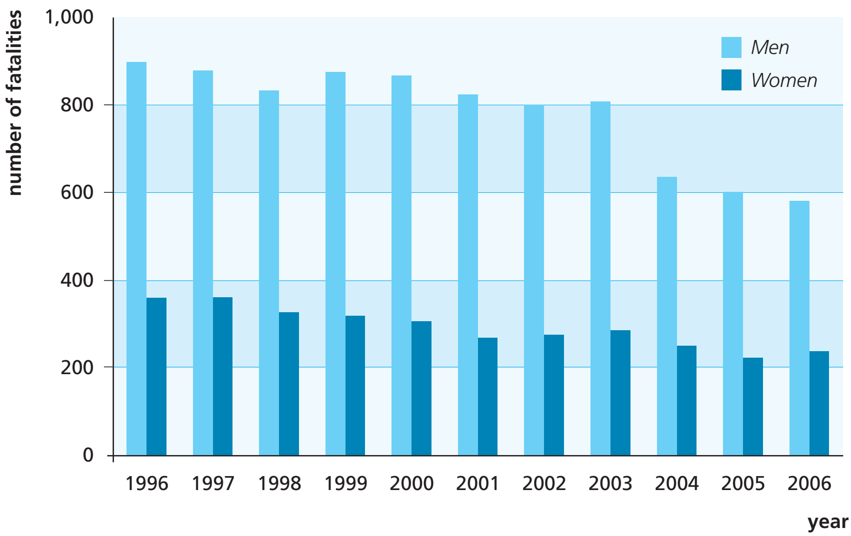
Number of hospitalisations
The foremost developments in recent years are:

- The number of hospitalisations involving car passengers decreased.
- The number of hospitalisations involving pedestrians, moped drivers and motor-cyclists remained largely the same.
- The number of hospitalisations involving cyclists increased between 1984 and 2005 from almost 6,400 in 1984 to almost 8,200 in 2005 [2.7].
- The number of cyclists hospitalised after an accident involving a motor vehicle decreased in the period between 1984 and 2005. In 1984, 2,000 cyclists required hospitalisation after such an accident. In 2005, this number had decreased to 1,500. The severity of the injuries in such accidents also decreased.
- However, the number of cyclists that were hospitalised after an accident involving no other party (e.g. a fall or a collision with a lamp post) increased from approximately 4,400 in 1984 to approximately 6,700 in 2005. The injuries were primarily to the legs, with a further one-third involving head injuries. There is little sign of a decrease in the severity of the injuries sustained.

2.1.4 Victims by gender

Approximately 65% of traffic fatalities involve men. There has been no obvious change to this in recent years.

Figure 2.3. Actual number of traffic fatalities by gender, 1996-2006



(source: CBS)

2.1.5 Victims by age

In terms of age, traffic fatalities do not reflect Dutch society, with considerable to extreme overrepresentation in proportion to their population share of teenagers and people in their early twenties (15-19 years old and 20-24 years old) and the elderly (70 and over). The risk of an accident plays a relatively great role in the former group during their initial participation in traffic (moped and car). As for the elderly, higher vulnerability plays a role. The largest 'underrepresentation' in traffic victims is found in children (0-14 years old), who make up almost 20% of society and only 5% of traffic fatalities. The three age groups between 30 and 59 years old constitute a (smaller) 'underrepresentation' of traffic fatalities compared to their proportion in society.

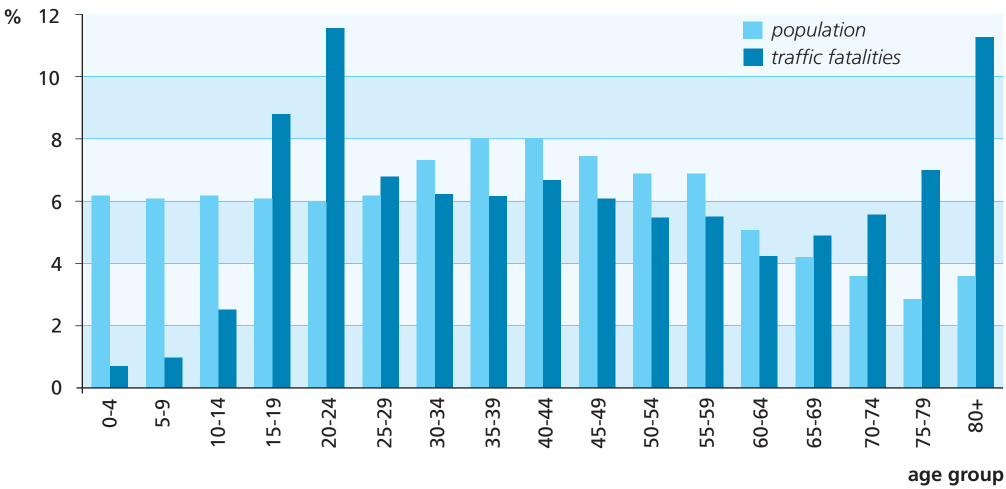
2.1.6 Victims by road type

Fatalities: predominantly on roads with speed limits of 80 km/h

Approximately 50% of all traffic fatalities occur on roads with speed limits between 60 and 90 km/h. The largest proportion of these are probably on 80 km/h roads, with a smaller proportion on 60 km/h roads. The 60 km/h zones were not introduced until the late 1990s, which might explain the decrease in the number of accidents on 60-90 km/h roads in recent years.

Almost 40% of all traffic fatalities occur on roads within built-up areas. This is a slight increase compared to ten years ago. Almost 15% of fatalities occur on trunk roads and motorways, which is a slight increase compared to 15 years ago and is probably attributable to the fact that more kilometres are travelled on this type of road now compared to then.

Figure 2.4. Proportion of traffic fatalities and population by age group in five-year increments, 2004-2006



(source: CBS)

Table 2.4. Number of registered traffic fatalities according to speed limit for the years 1988-1990, 1996-1998 and 2004-2006

Speed limit	1988-1990		1996-1998		2004-2006	
	number of fatalities	%	number of fatalities	%	number of fatalities	%
0 -50 km/h	1,485	35	1,170	34	860	38
60-90 km/h	2,266	54	1,793	53	1,103	48
100-120 km/h	447	11	446	13	321	14
Total	**4,198**	**100**	**3,409**	**100**	**2,284**	**100**
Average per year	**1,400**		**1,140**		**760**	

(source: AVV)

Table 2.5. Number of registered hospitalisations according to speed limit for the years 1988-1990, 1996-1998 and 2004-2006

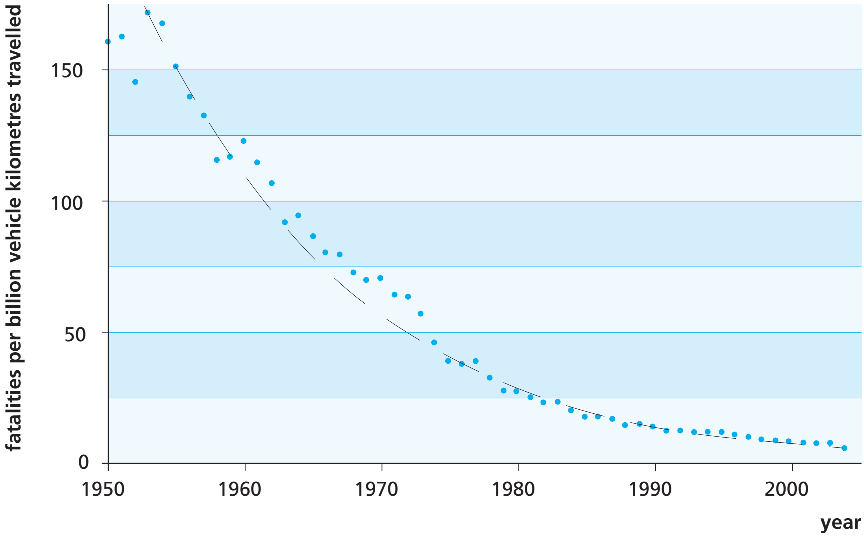
Speed limit	1988-1990		1996-1998		2004-2006	
	number of hospitalisations	%	number of hospitalisations	%	number of hospitalisations	%
0 -50 km/h	24,550	60	19,671	56	15,873	57
60-90 km/h	14,026	34	12,662	36	9,444	34
100-120 km/h	2,383	6	3,081	9	2,622	9
Total	**40,959**	**100**	**35,414**	**100**	**27,939**	**100**
Average per year	**13,650**		**11,800**		**9,310**	

(source: AVV)

Injuries: particularly within the built-up area

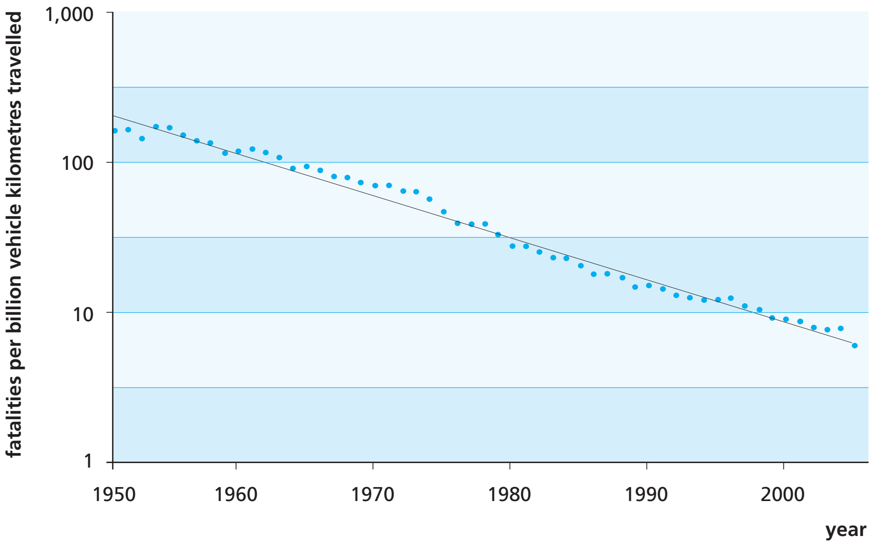
More than 50% of all hospitalisations result from accidents on roads within the built-up area with speed limits of 0 to 50 km/h. This proportion has decreased marginally in the last 15 years. Measures such as the construction of roundabouts, the increased number of 30 km/h zones and 'mopeds on the carriageway' have all contributed to making built-up areas safer. More than 30% of all hospitalisations result from accidents on roads other than trunk roads and motorways outside the built-up area (where speed limits are 60 to 90 km/h). There has been no change in this respect in recent years. 9% of hospitalisations result from accidents on motorways, which is almost double that of 15 years ago. This is also probably due to the increased number of kilometres travelled on these roads.

Figure 2.5. Development of the number of traffic fatalities per billion vehicle kilometres travelled



(source: SWOV)

Figure 2.6. Traffic fatalities per billion vehicle kilometres travelled and the exponential trend (5.9% per year) on a logarithmic scale



(source: SWOV)

2.1.7 Risk

Risk is a measure for the road unsafety. It can be used to compare the safety of modes of transport, age groups, road types and countries, for example. In road safety research, risk is mostly defined as the chance that someone has of being fatally or seriously injured in an accident set off against another unit (the degree of exposure), for example:

- distance travelled;
- time spent in traffic;
- number of people in a certain age category or number of inhabitants in a particular country.

There is also the accident risk: the chance that a road user will be involved in a fatal or serious accident set off, for example, against:

- vehicle kilometres travelled;
- road length.

The most common measure of risk is the number of traffic fatalities per billion vehicle kilometres or kilometres travelled. Between 1950 and 2004, the total number of traffic fatalities per billion kilometres travelled decreased almost continuously. Given that the data concerning the number of kilometres travelled since 2000 is not yet definitive, the risk shown here for the most recent years is
an estimate.

Whenever the same data is plotted on a logarithmic scale, the risk appears to decrease each year with a more or less fixed percentage.

Analysis shows that the decrease in risk differs per period. The largest reduction took place between 1973 and 1985, caused in part by the large-scale road safety measures implemented during that period, which included:

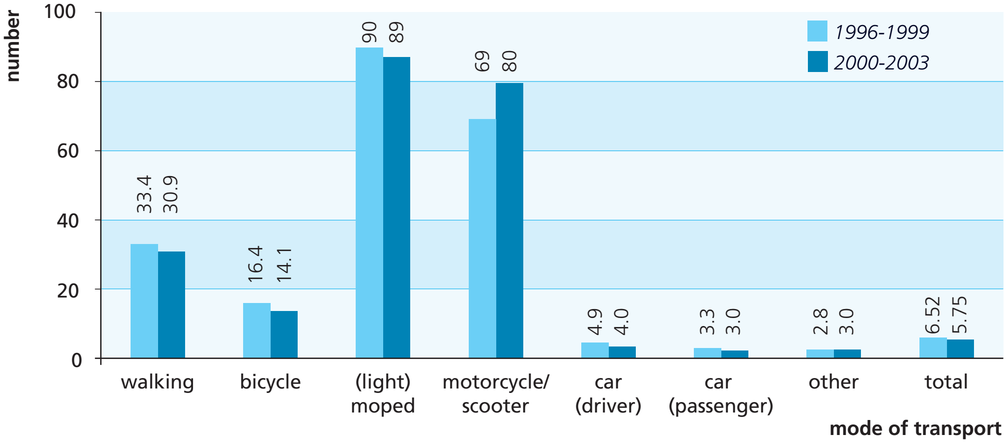
- introduction of speed limits on all roads;
- introduction of a maximum blood-alcohol level and better methods of testing that;
- compulsory use of helmets for moped drivers;
- compulsory use of seatbelts in cars for all passengers.

Table 2.6. Reduction of fatal risk per distance (motor vehicle kilometres travelled) over different periods

Period	Annual average reduction according to distance
1950 - 1962	3.4%
1962 - 1973	5.5%
1973 - 1985	9.2%
1985 - 1991	5.4%
1991 - 1995	1.0%
1995 - 2004	7.5%

(source: SWOV)

Figure 2.7. Average number of traffic fatalities per mode of transport per billion kilometres travelled in the years 1996-1999 and 2000-2003



(source: CBS/AVV)

This period also saw the first attempts to manage the increasing levels of mobility, which included the construction of motorways and bicycle paths. These measures also helped to reduce risks.

The sharp decline in the late 1990s and early 2000s was probably due to the introduction of Sustainable Safety and the increased interest in road safety and introduction of specific safety-related measures that accompanied it. The substantial decrease in the number of victims in 2004 distorts the decline in risk between 1995 and 2004 somewhat. Omitting 2004, the reduction percentage for 1995 to 2003 is 5.8%.

Risk per mode of transport

The risk per mode of transport can also be calculated on the basis of data concerning the number of kilometres travelled. Figure 2.7 provides information on the number of fatalities per billion kilometres travelled for different modes of transport between 1996 and 1999 and 2000 and 2003.

Motorcyclists (motorcycles and (light) mopeds) run by far the greatest risk per distance travelled of being involved in a fatal accident. Pedestrians are also exposed to a relatively high risk. The fact that pedestrians need more time to cover a certain distance should also be taken into consideration, because this means they are exposed to traffic for a longer period per distance travelled. ‘Pedestrians’ also include children playing in the street even though they do not actually cover any distance. Exposure in terms of distance travelled is, therefore, an

inadequate measure. The fact that this is still by far the most common indicator is because it is the easiest to measure. Comparatively speaking, the car has the lowest risk per kilometre travelled.
When the figures for 2000 - 2003 are compared with those for 1996 - 1999, we see that there has been no change in the order of risks for the different modes of transport, with the risks decreasing for almost every mode of transport. One exception is the ‘motorcycle/scooter’ category, which has seen a recent increase in risk. The ‘other’ category has also seen a slight increase.

Risk for different road categories
Data required to show the risk per road category (the number of kilometres driven per road type and the number of accidents per road type) is not readily available as such. The SWOV is currently working on new risk figures for the Sustainable Safety road categories as currently distinguished.

A comparison of the risks in 1986 and 1998 shows that the risk of injury decreased on all road types. The traffic arteries within the built-up area have the highest number of injurious accidents per distance travelled, followed by residential streets. Motorways and trunk roads presented the lowest risk.

Table 2.7. Number of serious accidents per million vehicle kilometres travelled per road type (core figures) in 1986 and 1998

Road type	1986	1998
Outside the built-up area		
Motorway	0.07	0.06
Trunk roads	0.11	0.08
Road closed to slow moving traffic	0.30	0.22
Road open to all traffic	0.64	0.43
Inside the built-up areas		
Traffic artery	1.33	1.10
Residential street	0.76	0.57
Home zone	0.21	0.15
Total road network in the Netherlands	**0.53**	**0.35**

(bron SWOV)

2.2 Road safety measures taken over the years

The number of (registered) traffic fatalities tripled between 1950 and 1972, after which there was a noticeable decline. The number of traffic fatalities is currently under the 1950 level despite the enormous increase in mobility. This can be attributed to various factors, which can be roughly sub-divided into three groups [2.1]:

1 traffic planning measures;
2 road safety measures;
3 external factors.

2.2.1 Traffic planning measures

The total number of trips, the mobility in the Netherlands continues to grow. This has various consequences for road safety:

- traffic becomes busier and more complex and the number of encounters increases, which is bad for road safety;
- increased density leads to lower speeds, which is good for safety;
- a sharp growth in mobility leads – with some measure of delay – to 'regulated' traffic measures by the government, for example, bundling traffic flows, dedicated lanes, separation of slow and fast-moving traffic, all of which are good for safety.

Between 1973 and 1985, several of these traffic planning measures were taken, such as the construction of motorways, trunk roads and bicycle paths. This led to a significant decrease in risk. After 1985, relatively few fundamental planning measures were taken, save in the last few years: temporary overtaking bans for lorries and dedicated lanes.

While on balance, the growth of mobility is bad for safety in the short term, the long-term effect of introducing planning measures will be positive. This reduces the chance of being involved in an accident per kilometre travelled (the risk) despite the fact that more and more kilometres are being travelled.

2.2.2 Road safety measures

A large number of statutory measures were taken in the 1970s and 1990s with the specific intention of improving road safety. Little was done to that effect in the 1980s, however.

The 1970s: radical measures

In the 1970s, a number of important national measures were introduced: the compulsory use of seatbelts and helmets, speed limits outside the built-up area and the statutory alcohol limit, as well as the introduction of home zones. This period also saw significant improvements to the crashworthiness of vehicles.

The 1980s: decentralisation and enforcement

Few new road safety measures were introduced in the 1980s, with developments more on the administrative side: road safety was becoming more of an issue for regional and local government, who were being encouraged to concentrate more on road safety. This was the period in which the Regional/Provincial Road Safety Bodies (ROVs/POVs) were established. The most concrete measures in this period focused on police enforcement:

- Introduction of breath analysis as evidence for alcohol use, which made the supervision of driving under the influence significantly more efficient.
- The possibility of issuing fines based on registration numbers, which made it possible to carry out surveillance of speeding and drivers ignoring red lights

Table 2.8. Overview of road safety measures

Road safety measures taken over the years	Year of introduction
Introduction of the driving licence for cars	1952
Speed limits within the built-up area	1957/58
Seatbelts fitted as standard in new cars	1971
Compulsory use of helmets for motorcyclists	1972
Speed limits outside the built-up area	1974
Introduction of statutory alcohol limit (0.5% blood-alcohol level)	1974
Compulsory use of seatbelts in front seats of car (where fitted)	1975
Compulsory use of helmets for moped drivers	1975
Home zone act	1976
30 km/h zones act	1983
Children aged 0-3 on approved seat in front seat of car	1977
Introduction of breath analysis during checks for driving under the influence	1987
Introduction of quantitative objectives for road safety	1987
New-style roundabouts	1989
Traffic Regulations (Administrative Enforcement) Act ('Mulder Act')	1990
Road traffic facilities contribution scheme incl. construction of bicycle paths	1990
Compulsory use of seatbelts by all passengers, where fitted	1992
Educational Measure on Alcohol and Driving (EMA)	1996
Theory certificate for moped drivers	1996
Combined goal-oriented grant	1996
Sustainable Safety Start-Up Programme	1997
Area-related enforcement projects (regional plans)	1999
'Mopeds on the Carriageway' programme	1999
Right-of-way to slow-moving traffic from the right	2001
Start of the transitional Sustainable Safety arrangement (1997 - 2002)	2002
Ban on handheld phones at the wheel	2002
Introduction of the driving licence for beginners	2002
Start of the Multi-year plan for road safety campaigns	2003
Blind spot mirrors for lorries	2003
Safety Scan for road transport and haulage	2004
Ban on radar detectors	2004
Essential recognisable characteristics for road infrastructure	2004
Combined target distribution scheme incl. budget for local and regional road safety policy	2005
Maximum permitted blood-alcohol level for young drivers of 0.2%	2006
New regulations for child safety measures	2006
Digital tachographs for haulage industry	2006
Registration numbers for mopeds	2006

(source: SWOV and processed by DVS)

without stopping the offender, which is more efficient.
- Introduction of the Traffic Regulations Act (Administrative Enforcement) ('Mulder Act'), which made the handling of minor infringements simpler and quicker.
- The formulation of the spearhead policy, which focused on the most endangered groups of road users and the riskiest behaviour. Furthermore, the first national quantitative goals were set in 1987. Collision safety for vehicles has also continued to improve.

The 1990s: Sustainable Safety

In the early 1990s, it was clear that there was little more improvement to be had in road safety and hence a more structural approach was needed to achieve the objectives set for 2010. 'Sustainable Safety' was introduced. The essence of this approach was the avoidance of encounters between road users with largely differing masses, speed and direction. This approach was designed to lead to an inherently safe traffic system in which accidents and serious injuries would be as good as excluded. In late 1997, the national government, provinces, water boards and municipal councils signed an agreement for the Sustainable Safety start-up programme, which obligated them to implement the first series of measures towards the realisation of a sustainable safety system. The programme primarily focused on:
- distinguishing between traffic arteries and traffic-calmed areas;
- expansion of 30 km/h zones;
- expansion of 60 km/h zones in rural areas;
- right-of-way on traffic arteries;
- uniform right-of-way on roundabouts;
- mopeds on the carriageway;
- bicycles and mopeds from the right have right-of-way.

The Start-up programme began in early 1998 and ran until 2002.

The early years of the 21st century

The beginning of the new millennium saw the completion of the Sustainable Safety start-up programme, including the introduction of the 'right-of-way for slow-moving traffic from the right' rule. Measures followed that were primarily focused on tackling the significant risks posed by new, often young, motorists. Road safety policy was further decentralised: 'decentralise where possible, centralise where necessary'. The new National traffic and transport plan, the National traffic and transport strategy memorandum, was established in 2005.

2.2.3 External factors

There are several external factors that are not directly concerned with traffic but have an influence on road safety nonetheless. These factors can explain short-term developments such as the annual fluctuations in the number of casualties on the one hand, and long-term developments on the other.

Short term: the weather

The weather is a key factor in looking at short-term fluctuations in the number of traffic casualties. Extreme weather conditions are often the cause of large deviations in the number of casualties.

The weather influences safety in three ways:
1 traffic density (the exposure);
2 the way in which people travel (mode of transport as well as road user behaviour);
3 risk during a journey.

Long term: age, possession of a driving licence and 'collective learning'

Age

The most important cause of long-term fluctuations is the age distribution in Dutch society. Some age groups have a greater chance of being involved in a traffic accident than others. The groups constituting the highest risk are the 16 to 24 year olds and those aged 65 and over. The more people in the group, the more casualties.

Since the early 1970s, the so-called 'pill effect' has caused the annual birth rate to drop by almost 30%. This is clearly visible in subsequent accident data in terms of the number of victims in high-risk age groups, with a dip in the number over the last thirty consecutive years among:

- young pedestrians and cyclists;
- moped drivers;
- young motorists/motorcyclists.

However, the latest dip, which included young motorists and motorcyclists, is now a thing of the past.

In the meantime, there is another age group with a relatively high risk of being involved in a fatal or injurious accident: the over 65s. This increase will be gradual until 2010, after which it will rise at an exponential rate due to the wave of post-war births who will then reach the age of 65.

Possession of a driving licence

There is a steady increase in the number of driving licences being issued in the Netherlands, particularly among the elderly: in the last twenty years, this group has seen the number of driving licences double.

The number of driving licences issued to young people decreased slightly in the early 1990s, possibly due to the introduction of the annual public transport pass. Since 1995, the number of driving licences issued has risen again, although in the last four years, this increase has been slight.

Table 2.9. Development in the possession of driving licences in percentages

	18+ years old	18 to 24 years	over 65
1985	68.2	59.6	30.0
1990	72.2	58.8	38.0
1995	76.4	56.8	45.7
2000	78.2	59.5	51.2
2004	80.2	60.6	56.2
2005	79.6	60.5	57.7
2006	80.2	61.1	59.9

(source: SWOV Cognos)

'Collective learning'

The current generation of road users has considerably more experience in traffic than the generation immediately after the Second World War, and more experience leads to a lower accident risk. This experiential effect on road safety has been shown for specific groups for relatively short periods of between five to ten years.

2.3 The social costs of road unsafety

Traffic accidents have social consequences: medical costs, loss of production, material and immaterial costs, handling costs and congestion costs. These costs are shouldered by society and are considered social costs. In addition, there are the costs that are passed on to the individual such as the costs of all sorts of (extra) safety features on cars or the choice of a more expensive car on account of its safety considerations. This group is not included in the social costs, and neither are the costs of road safety research [2.8].

Medical costs

Medical costs are the result of the treatment of casualties, such as hospital costs, rehabilitation costs, medical costs and the costs of adjustments made for the disabled.

To determine these costs, different data sources are used, including CBS statistics and the National medical register. Information includes the average number of days that a victim is hospitalised, the average daily cost of care in a hospital or nursing home and the number of ambulance journeys a year.

Loss of production

The costs resulting from the loss of production stem from the temporary or permanent incapacity to work of those injured and killed in traffic accidents.

The calculation assumes the potential loss of production, which is to say the (financial) contribution that someone could have made if they had not been injured or died prematurely. It is irrelevant whether the individual victims were employed prior to the accident and whether they would have worked in the future.

Material costs

Material costs are the result of damage to goods such as vehicles, freight, roads and road furniture. The estimation of these costs is based on insurance details such as claims for damages paid, estimates of damages that have not been claimed and the excess to which the insured party is subject.

Immaterial costs

Immaterial damage or 'human loss' relates to the loss of quality of life for casualties and their next-of-kin. These are 'costs' in the form of grief, pain, sorrow and the loss of enjoyment of life. It might seem peculiar to translate human grief into financial costs, but it is nonetheless an instrument that helps to concretise the importance of road unsafety.
In the Netherlands, immaterial costs are determined using a survey into the amount that people are prepared to pay for a particular reduction in accident risk. This research determines what is known as the 'value of a statistical life (VOSL)', which forms the basis for the calculation of immaterial damage. The VOSL is adjusted for the loss of consumption of traffic fatalities because this is already included in the costs of loss of production.
Little is known about the immaterial costs of non-fatal injuries. On the basis of a study conducted in the UK, the immaterial damages per injury requiring hospitalisation is currently estimated at 10% of that of a fatality.

Table 2.10. Social costs as a result of a road unsafety

Social costs	1997 *Amount in millions (€)*	2003 *Amount in millions (€)*
Medical costs	232	232
Loss of production	2,449	1,294
Material costs	1,625	3,866
Immaterial damages	2,573	5,549
Handling costs	640	1,262
Congestion costs	100	125
Total	**7,618**	**12,327**

(source: AVV)

Table 2.11. Costs of road unsafety per traffic casualty

Type of casualty	Cost (€)	
	1997	2003
Traffic fatalities, total	2,032,980	2,426,650
Hospitalisations, total	212,242	249,482
Emergency assistance, per casualty	5,318	7,909
Minor injury, per casualty	2,566	4,618

(source: AVV)

Handling costs
Handling costs are the result of dealing with accidents and the resultant damage caused to organisations such as the fire brigade, police, the judicial service and the insurance companies. Handling costs are estimated on the basis of CBS statistics and insurance details.

Congestion costs as a result of accidents
Congestion costs are the result of the time lost due to traffic congestion caused by an accident.

To determine congestion costs, use is made of research into the total congestion costs and the proportion of time lost due to congestion caused by accidents. This proportion appears to be approximately 13%.

Total cost of a road unsafety
The total costs of traffic accidents in 2003 is estimated at 12.3 billion euro. The individual costs are shown in table 2.10.

The costs per casualty type in 1997 and 2003 are shown in table 2.11.

2.4 The Netherlands in an international perspective

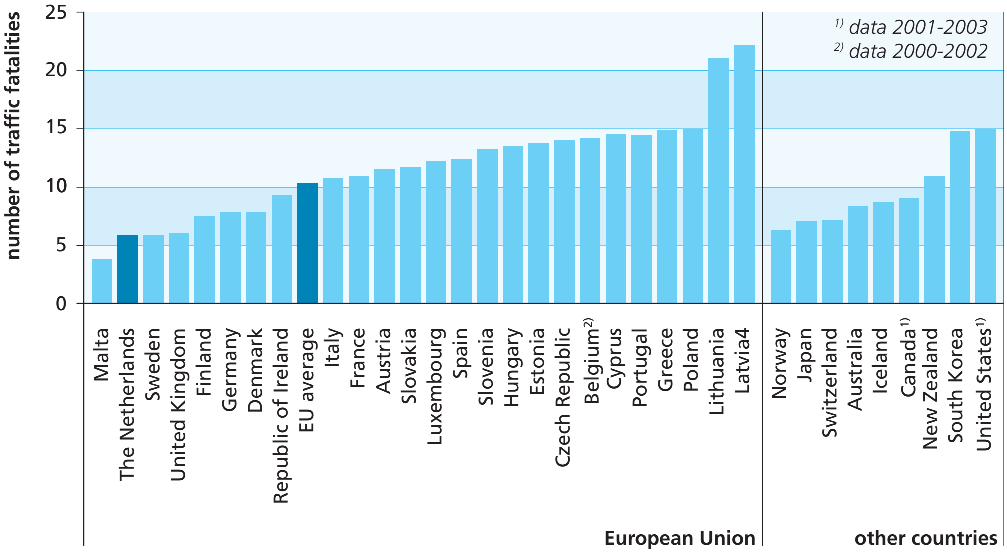
The reduction of traffic fatalities in the EU
Compared with many other countries, the Netherlands is one of the top three countries in the field of road safety. The reduction in the number of traffic fatalities in the past 15 years is comparable with the average reduction in the 14 other 'old' EU member states (Austria, Belgium, Denmark, Germany, Finland, France, Greece, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden and the United Kingdom) [2.1]. The ten 'new' member states (Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovenia and Slovakia) are less developed in this respect.

The number of traffic fatalities in the EU has decreased steadily, with a 42% decline in the old member states between 1990 and 2004 – exactly the same as the percentage in the Netherlands over the same period.
The EU has set road safety goals that aim to halve the number of traffic fatalities by 2010 compared to 2001. In comparison to 2001, the old member states have achieved a reduction of 18%, which is approximately 30% of the intended reduction. In this period, the Netherlands has seen a 19% reduction, although this can be attributed in full to the favourable figures achieved in 2004. By contrast, the ten new member states have experienced a slight increase in traffic fatalities since 2001, which, if this continues, will prevent the EU from achieving its targets.

Mortality: the number of traffic fatalities per 100,000 inhabitants
In terms of the number of traffic fatalities per 100,000 inhabitants, the Netherlands is second in the EU after Malta, with Sweden and the UK following close behind. The diagram in figure 2.8 shows the average figures over a three year period (mostly 2002 - 2004) for the 25 member states and the average for these countries (EU). Several non-EU countries are also represented. This road safety measure does not take into consideration the total amount of (motorised) traffic in the country, nor does it include foreign vehicles driving through the country.

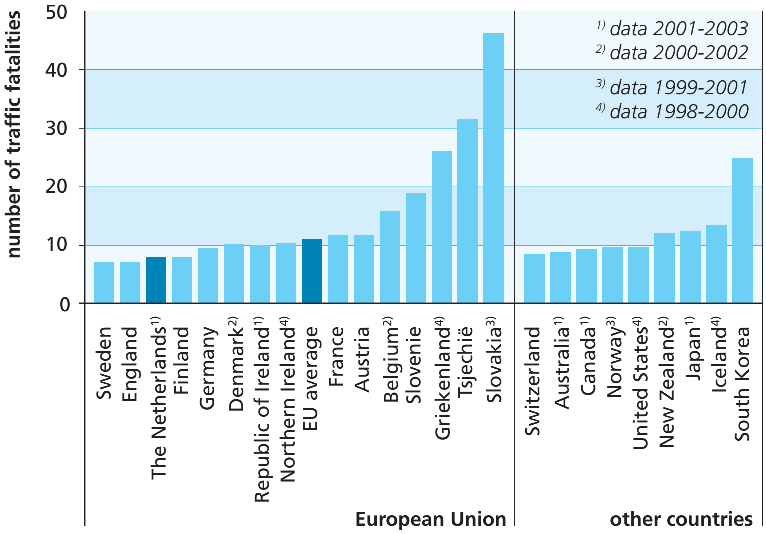
Risk: the number of traffic fatalities per billion kilometres travelled
Another indicator for road safety aside from the number of fatalities per number of inhabitants is the number of fatalities per vehicle kilometres travelled. Given the lack of information concerning kilometres travelled, many countries use the number of motor vehicles instead. The diagram in figure 2.9, therefore, is incomplete and incomparable in terms of the period shown. Within the EU (in so far as data is available), Sweden and the UK have the lowest number of traffic fatalities per vehicle kilometre travelled, followed by the Netherlands and Finland. The Netherlands scored slightly higher than such countries as Australia, Canada, the United States and Japan.

Figure 2.8. Number of traffic fatalities per 100,000 inhabitants in different European and non-European countries (average 2002-2004)



(source: IRTAD)

Figure 2.9. Number of traffic fatalities per billion vehicle kilometres travelled in different European and non-European countries (average 2002-2004)



(source: IRTAD)

Global trend

According to the World Bank, more than one million people are killed in traffic accidents worldwide every year, with many millions more seriously injured. The World Road Association's (PIARC) Road Safety Manual puts the total number slightly lower at between 800,000 and 950,000 fatalities in 2002, but expects a substantial growth in the number of fatalities worldwide by 2020: between 1.1 and 1.3 million.
The increase in traffic accidents is not attributable to the Netherlands and the other 'rich' countries, where the number is actually decreasing. The decrease in safety throughout the world is particularly prevalent in 'poor' countries. The table below illustrates the global trend alongside that of rich countries.

Prognosis of the development in the number of fatalities as a result of road traffic between 2000 and 2020, divided into World Bank regions

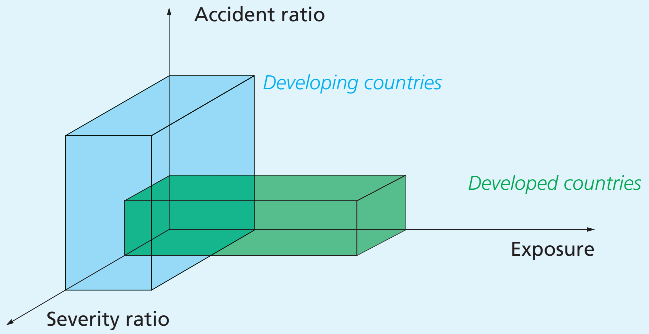
South Asia	+ 144%
East Asia/Pacific	+ 80%
Sub-Saharan Africa	+ 80%
Middle East/North Africa	+ 68%
South America/Caribbean	+ 48%
Europe and Central Asia	+ 18%
Subtotal	**+ 83%**
'Rich' countries	– 28%
World total	**+ 66%**

(source: [2.17])

In the coming years, the difference between 'rich' and 'poor' countries is expected to become even greater. This is a worrying development, all the more so because a road unsafety is coupled with high social costs.

Road unsafety is the result of being exposed to a particular risk. If risk is split into an accident ratio (chance of an accident) and a severity ratio (chance of a serious outcome), the following image emerges for developing and developed countries.

What strikes one first is that the exposure in developed countries is higher than in developing countries due to the fact that there are more kilometres travelled in developed countries. The reason that safety is better in these countries is related to the accident ratio and the severity ratio: both the risk of an accident and the risk of being seriously injured in one are smaller.
The consequence of the differences between developed and developing countries is that the latter require different types of measures with regard to road safety (and efficacy) than developed countries. [2.9, 2.10]



2.5 Key developments in the future

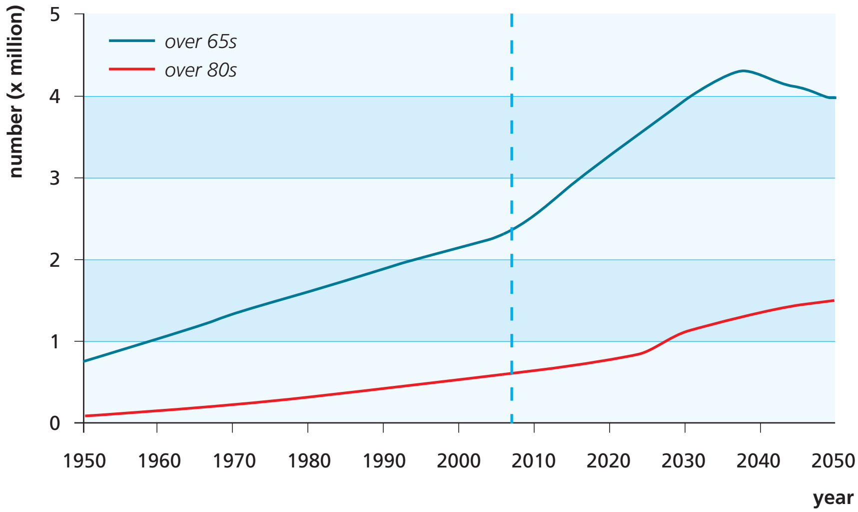
In the coming years, several trends will influence road safety in the Netherlands [2.11]. An aging population and increased goods traffic have already been included in the National traffic and transport strategy memorandum in determining road safety goals.

Aging

Aging will be of critical importance to road safety in the Netherlands in the coming years. Given that the elderly belong to the group of more vulnerable road users, this development will clearly have a negative impact on traffic accident figures. The fact that aging in the Netherlands is also shaped by the decreasing number of children has a positive effect on accident figures because children also belong to the most vulnerable group. Moreover, a decrease in the number of children also means a decrease in the number of new drivers. On balance, however, road unsafety increases as a result of this development. From 2011, the post-war baby boom generation will reach the age of 65, which will mean that the total number of over 65s will increase from 2.37 million in 2007 (14.5% of the Dutch population) to 3.28 million in 2020 (19.6% of the Dutch population).

The road user group that sees a relatively large number of traffic casualties will, therefore, become considerably greater in the future. Furthermore, the consequences and costs of caring for casualties in this group are relatively high.

Figure 2.10. CBS population prognosis (reference year 2008) [2.16]



Growth in passenger traffic

Traffic is expected to increase significantly over the next decade. The National traffic and transport strategy memorandum assumes a growth in passenger traffic of around 20% between 2000 and 2020. However, the Welfare, prosperity and quality of the living environment (WLO) scenario study subsequently published by the Netherlands bureau for economic policy analysis, the national institute for spatial research and the netherlands environmental assessment agency assume growth of between 15% and 40% depending on economic developments. This means, therefore, that the roads will become busier and the chance of traffic accidents will increase accordingly. The fact that this trend is also manifested within the built-up area is particularly detrimental to the road safety of vulnerable road users such as pedestrians, cyclists and the elderly. Since many years one third of the fatal accidents occure on 50 km/h roads.

Growth in goods traffic

According to the National traffic and transport strategy memorandum, goods traffic will increase by 15% to 80% by 2020 depending on international and economic developments. The memorandum's growth scenarios have since been adjusted (upwards) on the basis of the WLO study. Goods traffic will grow more quickly than passenger traffic, which will result in a shift in their mutual relationship. The increase in heavy goods vehicles has a major impact on road safety. Although heavy vehicles are less frequently involved in accidents, the injuries sustained tend to be more serious and more often result in fatalities.

Multicultural society

Statistics Netherlands expects that Western and non-Western immigrants will constitute approximately 21.5% of the Dutch population by 2020 as compared to 19.4% in 2007.
Based on a study into the mobility of Turks, Moroccans, Surinamese, Antilleans and other ethnic minorities in the fifty largest cities in the Netherlands, the Netherlands institute for social research has concluded that immigrants are less mobile. They travel less than native Dutch citizens and cover less distance in the same time. In addition, they also make more use of public transport.

This group also made significantly less use of cars and bicycles than native Dutch citizens, although this is beginning to change. 25% of Turkish, 30% of Moroccan and Surinamese and almost 50% of Antillean households do not own a car. Furthermore, 25% of immigrant households do not have access to a bicycle. Despite relatively low car ownership, Turkish immigrants use their cars more often (64% of journeys) than native Dutch citizens (55%), with Moroccans (51%), Surinamese (50%) and Antilleans (43%) using it less.

In general terms, the travelling habits of immigrants in the Netherlands are good for road safety. In order to retain this positive balance, investments into the quality of public transport are required as well as attention to public spaces from the perspective of the pedestrian. Because integration and emancipation will prompt more immigrants to cycle and drive, this will probably add a group to the (motorised) traffic that previously only participated to a limited extent, which deserves attention in road safety policy.
What these figures mean for road safety is as

yet unclear. However, the trend is important enough to monitor and to study its consequences for road safety.

Internationalisation

The international importance of road safety is linked to continuing globalisation, which was highlighted by the World road safety week organised by the United Nations and the World Health Organisation in April 2007. Worldwide interest stems from concerns about the social costs that result from road unsafety and the sorrow that is caused. Moreover, the worldwide growth in the number of traffic casualties is expected to persist, particularly in developing countries, where road unsafety is the prime cause of death in young people between 15 and 21. In its role as the 'World road safety champion', the Netherlands is seen as an example to all.

European Union

The influence of the European Union as governmental tier and legislator is increasing. In areas such as vehicle technology, the Netherlands depends to a large extent on Europe. In collaboration with other member states, organisations and the European Commission, the Netherlands is endeavouring to improve safety standards in cars. This is increasingly important because many people expect that a key part of the improvements to the road safety of new vehicles will depend on technology. This should make it possible to achieve the goals set for 2020. The fact that there are now more countries with less road safety means that the EU is also performing less well, which is putting pressure on European goals to halve the number of traffic casualties in the period up to 2010 compared to 2003. Countries where road safety is problematic can still take the most obvious measures and make greater inroads into achieving the goals than leading countries such as the Netherlands. The Netherlands can, however, benefit from exchanging best practices with other European countries that are performing well and join those countries in acting as an example to those less developed countries that still have some way to go.

Foreign road users

In the Netherlands, foreign road users account for more than 10% of traffic offences. The opening of EU borders and the growth of traffic throughout Europe as a whole have resulted in an increased level of foreign road users in the Netherlands. Despite driving licence requirements being brought into line throughout the EU, there are still significant differences in education and testing. This is particularly true of the relative unfamiliarity that some drivers have with the prominent role of cyclists in Dutch traffic, which can have serious consequences. Many of the road safety measures in the Netherlands are only applicable to people who live there. Requirements regarding education, testing, vehicle checks and suchlike do not apply to foreign drivers, who are rarely exposed to the relevant information, if at all. Following the severe weather warnings in 2007, for example, Dutch lorry drivers parked along the side of the road for their own safety, while their foreign counterparts continued driving. Extra attention should be focused on both this group and Dutch drivers in foreign countries, where good information in advance can prevent accidents. Although the effects of these developments on road safety are not yet fully known, the developments are important enough to continue looking into more closely.

Technology

There is currently a great deal of new technology being developed, with yet more being launched all the time. Mobility-related technology is becoming ever more advanced, which is a trend relevant to the Ministry of Transport, Public Works and Water Management in terms of its policy goals regarding accessibility, environment and road safety, because new systems can make traffic systems more efficient, cleaner and safer. There is a clear trend towards cars fitted with sensors, which make driving easier, provide risk warnings and/or intervene in the event of danger in the same way that ABS (Anti-lock Braking System) and ESC (Electronic Stability Control) keep the car under control in difficult circumstances such as sudden swerving or braking on slippery roads. ACC (Automatic Cruise Control) helps to maintain distance between cars. While these are sold as comfort systems, they also contribute to safety. ACC is also often combined with an anti-collision system. There are also applications to help drivers stay in lane and maintain a safe speed. One example is the ISA (Intelligent Speed Assistance) system, which the Ministry of Transport, Public Works and Water Management would like to test. Roadside technology such as extra lanes during rush hour, ramp metering and traffic management is also taking on an ever greater role.

In deciding to introduce new technology, attention must be paid to its possible consequences. Drivers, for example, must not be distracted by navigation systems or on-board diagnostics or feel that they are safer as a result of having them and start to drive less safely. Support is also important. Practical experience has shown that innovative products are mostly introduced on a voluntary basis first, which means that acceptance gradually grows. In time, an application is introduced as standard through habituation, possibly by way of a statutory obligation.

Another development is the rise of car entertainment systems such as DVD players, which must be addressed if it poses a danger to road safety.

Relationship between citizens and government

The relationship between citizens and government has changed dramatically in recent decades. Dutch people have become more articulate and more conscious of their power as consumers, which is partly due to the rise of the internet. The government understands this (as witnessed by action plans such as ‘A different government’) and would like to be more reticent in what they regulate and how they regulate it. The government would like to appeal to social forces more often and provide space for the independent citizen who is mature and engaged.
This development demands a government that presents itself as a social ally, that is reliable and that works on solutions in collaboration with citizens. It calls for an alternative philosophy with regard to governance with a better, customer-oriented provision of services, less bureaucracy, more decentralisation and an adroit government organisation. In this new role, the government will pay more attention to dialogue and to listening to and working with citizens through, for example, the use of the internet to provide opportunities to contribute ideas. The government must instil confidence, provide space and equip people to participate fully and shoulder responsibility. The government should be subservient and put the citizen

first. Regulations are still necessary and need to be adhered to, but time will tell if these regulations are actually of any use. The government maintains responsibility, of course, but this does not detract from the fact that policies stemming from dialogue lead to greater involvement, which encourages workability and leads to better results.

2.6 Summary

The key points in this chapter are:

- The level of road safety has increased since 1974, resulting in a decrease in traffic fatalities from over 3,250 in 1972 to 971 in 2007.
- The number of hospitalisations has also decreased, albeit less rapidly.
- The decrease is the result of a number of road safety measures that have been introduced in recent decades.
- In 2003, the social costs of road unsafety ran to €12.3 billion.
- Internationally, the Netherlands is one of the countries with the highest levels of road safety.
- Aging and the increase in goods traffic are identified as factors that have a primarily negative impact on road safety.

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Learning objectives for students:

- to gain an understanding of road safety policy in the Netherlands;
- to know the reasons behind this policy;
- to know how road safety policy is organised and who is responsible for which part;
- to understand the role played by the European Commission.

3 Policy

3 Policy

3.1 National traffic and transport strategy memorandum

The Traffic and transport planning act prescribes the need for a national traffic and transport plan. This plan will be prepared by the Ministry of Transport, Public Works and Water Management in consultation with the national government, the provinces, the Joint regulations act+ (JRA+) regions, municipal councils and water boards. Within 18 months of adopting the national traffic and transport plan, the provinces and Joint regulations act+ regions must have one or more provincial and regional traffic and transport plans in place that elaborate the national traffic and transport plan. While municipal councils do not need to have a specific traffic and transport plan, they must implement a visible traffic and transport policy that corresponds with the national objectives and the provisions of provincial or regional traffic and transport plans. JRA+ regions are also known as Framework Act regions. These are regional public bodies comprising several municipalities in an urban area that are assigned certain statutory tasks. They include: Haaglanden region, Rotterdam region, Twente region, the Arnhem-Nijmegen region, Amsterdam region, Utrecht region and Eindhoven region.

The Planning act also stipulates that 'decisions of vital importance' can be recorded in a separate section entitled 'The essential parts of the policy'. Such essential parts must be developed in the policies and plans of the national and decentralised authorities.

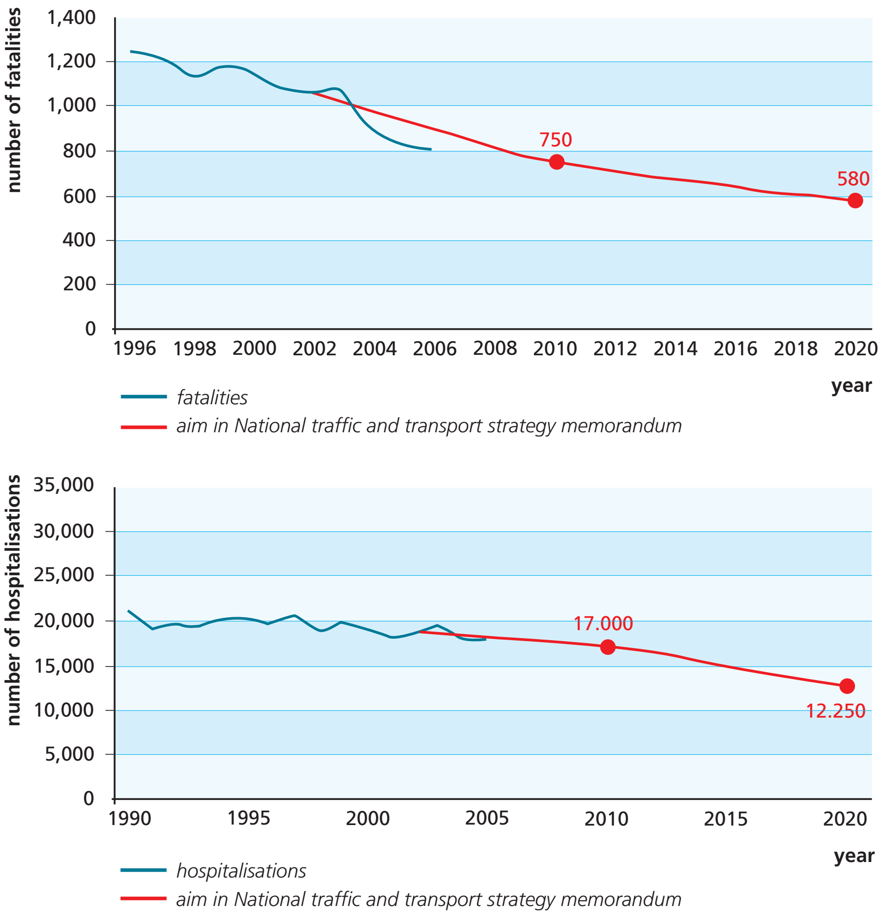
Road safety in the National traffic and transport strategy memorandum

Dutch road safety policy is described in broad outline in the Ministry of Transport, Public Works and Water Management's National traffic and transport strategy memorandum [3.1, w3.1], which is the national traffic and transport plan that provides frameworks and objectives for traffic and transport policy in both the medium term (to 2010) and the long term (to 2020). The Memorandum is valid for 15 years and contains measures that pertain to a strong economy, a safe society, a good living environment and an attractive country.

The Memorandum gives priority to permanent improvements in (traffic) safety. The structural reduction in the number of casualties must be continued so that the Netherlands can retain its position at the top of the European Union. The aim is to reduce the number of traffic fatalities and hospitalisations in the Netherlands to a maximum of 750 and 17,000 respectively before 2010. This equates to a 30% decrease in the number of fatalities and a 7.5% decrease in the number of hospitalisations compared to 2002. The aim for 2020 is a reduction of 45% and 34%, which equates to 580 fatalities and 12,250 hospitalisations.
In terms of finances, this will result in an annual reduction in social costs of more than 5 billion euro. These are not the final aims of the road safety policy, but rather intermediate goals in the attempts to improve safety on a permanent basis. According to the National traffic and transport strategy memorandum, this aim can only be achieved if radical European-wide improvements are made in vehicle technology and a mobility pricing policy is introduced.

One key maxim in the National traffic and transport strategy memorandum is: 'Decentralise where possible, centralise where necessary.' Decentralisation was implemented much earlier in road safety policy than in other transport

Figure 3.1. Aims for 2010 and 2020 in terms of fatalities and hospitalisations



policies, but with the adoption of the National traffic and transport strategy memorandum, however, decentralisation has been universally established. Government contributions such as Sustainable Safety measures and the Combined target disbursement were combined to form the broad goal-oriented grant (BDU). The provinces and Framework Act regions ensure that these financial means are available for regional and local transport projects.

3.2 Road safety strategy 2008 – 2020

In 2008, the Ministry of Transport, Public Works and Water Management published its 'Strategic road safety plan 2008-2020: Safety memorandum of, for and by everyone' [3.2], which elaborates on the policy outlined in the National traffic and transport strategy memorandum. The following is a summary.

3.2.1 Ambitions

- The Netherlands must remain the world champion in road safety;
- continue the success, implement permanent improvements;
- cornerstones are co-operation, an integral approach and Sustainable Safety;
- more attention to the protection of vulnerable groups and dealing with persons responsible for accidents;
- innovation provides a key contribution to the desired reduction in the number of accidents.

Challenging aims, challenging policy

The Netherlands would like to maintain its position as one of the world's safest countries in terms of traffic, which makes the realisation of the ambitious aims set out in the National traffic and transport strategy memorandum of key importance. According to the Ministry of Transport, Public Works and Water Management, this will only be possible if a new and challenging policy is introduced that focuses on vulnerable and weaker road users and in which road users who cause accidents are dealt with firmly. Strategic choices will be necessary that can have far-reaching consequences for the landscape ('no tree-lined roadside verges'), for example, or for the costs of a separate infrastructure that will help to prevent accidents. Moreover, measures may be necessary to change the existing dilemma between freedom of movement and limiting measures (for example an increase in the age at which a person can drive a moped) or to utilise technology to force road users to act in a particular fashion (for example speed limiters in vehicles).

Three cornerstones, two policy lines

In the period between 2008 and 2020, road safety policy will be based on the three cornerstones that have made the policy so successful in recent years:

- co-operation;
- integral approach;
- Sustainable Safety.

Co-operation is sought not only within the world of road safety but outside it as well, with associations being formed with the education sector and, in terms of enforcement, with the police, judiciary and Public Prosecutor, including the collaboration within the local triumvirate (mayor, police and public prosecution service). Countless social organisations also play a role in the implementation of policy.

Not all target groups, vehicles and road types have benefited equally from improved safety in recent years; others are subject to substantial risk. Against this background, policy to improve safety is divided into two distinct lines:

- The first builds on the success of recent years with generic measures (vehicular policy, behavioural measures, and stimulating regional and local measures).
- The second focuses on specific areas of attention, which stem from an analysis of accident data and trends that could influence road safety in the future.

The second line distinguishes between the following two areas of attention:

1 Road user groups that demand extra attention, both victims and perpetrators of accidents. Groups that are the victims of accidents on a frequent basis include such vulnerable road users as the elderly, cyclists

and pedestrians, all of whom run a relatively high risk. The decrease in accident rates in recent years has not been as marked in this group as it has been in others. Other groups that require extra attention are speeding motorists and inexperienced drivers because, consciously or otherwise, they are relatively often the cause of unsafe situations.

2 Roads, especially 50 and 80 km/h roads, and vehicles that require extra care. Despite every effort to the contrary, 50 and 80 km/h roads still see the greatest number of casualties. Vehicles that require policy attention include delivery vehicles and lorries, particularly because of their size and volume.

The key is finding a balance between the generic and the specific; for example, ISA (Intelligent Speed Assistance) will not be imposed on all drivers, but only on those notorious for speeding.

Innovation

Innovative solutions must help realise the ambitions of the road safety policy. Many new technologies are being developed, with yet more being launched all the time. Mobility-related technology such as navigation equipment is becoming ever more advanced. This is a trend relevant to the Ministry of Transport, Public Works and Water Management in terms of its policy goals regarding accessibility, environment and road safety. New systems can make traffic more efficient, cleaner and safer. This is why innovative measures are also part of the package of measures. The role played by innovation is becoming more important as mobility continues to grow. However, we should also pay attention to any undesired side-effects of new vehicular technology, such as when the driver's attention is diverted or when drivers begin to drive more dangerously as a result of such technology lulling them into a false sense of security.

3.2.2 Approach

A mixture of measures will be implemented, all of which include the three cornerstones (co-operation, integral approach, Sustainable Safety). There are different measures focusing on infrastructure, vehicles, and humans and education (after all, the design of infrastructure is also largely intended to affect behaviour).

Generic measures

Generic measures are the more general themes of road safety policy, many of which were introduced years ago and have proved successful. These measures include:

- Vehicular policy. Vehicle safety has increased significantly, with the EuroNCAP programme in particular providing direction. Moreover, European research programmes, in which the Netherlands plays an active and financial role, encourage the vehicle industry to develop active safety systems in vehicles. In addition, Dutch knowledge institutes and market parties also work on the development of such systems such as Adaptive Cruise Control (ACC), Electronic Stability Control (ESC), Stop and Go, and Intelligent Accelerator.
- Education. This involves information and campaigns, road safety education and the Educational Measure on Behaviour and Traffic (EMG).
- Encouraging regional and local measures via the broad goal-oriented grant. Every year, 80 million euro is made available for such measures, although it should be noted that in the context of departitioning, the sum

is not specifically earmarked for safety. The provinces and Framework Act regions determine for themselves how they use the financial means available to them to realise the aims set out in the National traffic and transport strategy memorandum for their region. An integral approach is encouraged.

Tackling areas of attention
The 'Strategic road safety plan' [3.2] distinguishes between the following areas of attention;

- pedestrians;
- cyclists;
- children;
- the elderly;
- new drivers;
- moped or light moped riders, and drivers of single-seat vehicles with moped engines/ mobility scooters;
- motorcyclists;
- drivers under the influence of alcohol, drugs, medication or fatigue;
- motorists who exceed the speed limit;
- single-vehicle accidents;
- 50 and 80 km/h roads;
- lorries and delivery vehicles;

These areas of attention will not be dealt with as separate issues. A cohesive approach on more than one front would appear to be the most effective. In terms of the safety of cyclists, for example, different perspectives are examined such as cars and lorries (collision compatibility), behaviour (driving lessons, danger recognition) and infrastructure (separate cycle lanes and maintenance).

Sustainable Safety approach
Because the principles of Sustainable Safety have borne fruit in recent years, this approach will continue to be used. The following five principles of Sustainable Safety remain the basis for infrastructure design: functionality, homogeneity, forgivingness, recognisability and state awareness.
Of course, it is also important to gauge the efficacy and the social support of measures taken in the context of Sustainable Safety. Prioritisation on the basis of risks is seen as the most useful approach.

Tackling infrastructure
Every road will be provided with the new road markings known as essential recognisability characteristics. The road markings are linked to the categorisation of roads. Chapter 7 will discuss the infrastructure aspects of Sustainable Safety in more detail.

State roads are more dangerous than motorways, even if they are properly designed. A programme is currently underway to eliminate the weak points on these roads. If this approach proves successful, it will also be used on provincial roads.

Innovation and experimentation
The first area of attention for the Ministry of Transport, Public Works and Water Management in terms of innovation and experimentation is that new technological applications are not assessed in isolation but in their complete context. The introduction of ABS has shown the relevance of this approach. From a purely technical perspective, ABS had enormous potential to contribute to road safety. However, drivers' risk compensation behaviour has meant that, in reality, ABS has provided less in terms of safety than was previously expected.

A second area of attention concerns the acceptance of new functions. Not every system that increases safety will be accepted by road users as a matter of course. The boundary between what is technically feasible and what people find acceptable will shift as a result of the developments themselves and through force of habit.
A third area of attention concerns the interaction between driver and technology. Should a system only provide a warning or actively help with driving or even intervene automatically? Independent intervention by technical applications is, in principle, justified if it helps to protect drivers and other road users in dangerous situations (slippery roads) or in emergencies.
The Ministry of Transport, Public Works and Water Management does not advocate compulsory intervention in the generic sense with a normal driving task unless drivers choose such a system themselves. The time isn't ripe for the introduction of compulsory active speed limiters with ISA technology (Intelligent Speed Assistance) across the board, but the Ministry would like to make ISA compulsory for road users who repeatedly exceed the speed limit. As mentioned earlier, the introduction of technological innovations should also include a means of monitoring potential risk adaptation, which is to say that a driver will behave more recklessly due to an enhanced feeling of safety.
ABS is one example of innovation that appears to deliver little in the way of positive results. Section 1.2.3 on the cycle of human information processing discusses this aspect in more detail.

To enable good ideas to prove themselves, the Ministry of Transport, Public Works and Water Management supports knowledge institutes such as SWOV, TNO and the Transumo foundation, as well as facilitating experiments with, for example, in-car technology.

Behaviour: perpetrators and victims
Focus on perpetrators
Repeat offenders should be dealt with firmly, with the principle 'the perpetrator pays' being applied more often. Repeat offenders consciously disrupt the safe environment that the authorities provide and constitute a risk to both themselves and other road users. As the offences or their consequences become more serious, so the freedom of the perpetrator will be more seriously curtailed within the traffic system by using new technology such as speed limiters and alcolocks.
Studies should also be conducted into road use and the construction and maintenance of roads. Road unsafety is not always caused by drivers; an inferior road infrastructure or insufficient maintenance could also lead to dangerous traffic behaviour.

Antisocial behaviour
In addition to a firmer approach to repeat offenders, explicit attention should also be paid to antisocial and dangerous driving behaviour including such offences as cutting in, tailgating, exceeding the speed limit and jeopardising the safety of others such as road workers. In 2008, the Educational measure on behaviour and traffic (EMG) was introduced for these antisocial road users, which is similar to the Educational measure on alcohol (EMA).

Driving licence as permit
In passing the driving test, a learner driver has to show driving proficiency and suitability. However, this does not apply solely to the test; drivers should continue to see to it that they remain proficient and suitable to drive. If a driver appears unable to shoulder this responsibility, taking conscious risks and causing potentially dangerous situations, it should be easier to revoke their driving licence. One such example is the driving licence that is linked to a points system, whereby points are added after every penalty up to a maximum number at which the licence is revoked.

Focus in road safety education
Working on behaviour demands a focused effort in terms of road safety education, which is why this remains a key policy element.

Enforcement
Traffic enforcement remains an important instrument in tackling road safety. Where necessary, the current enforcement standards will be continued at least at the same level, which requires efficient collaboration between the Ministry of Traffic, Public Safety and Water Management, the Ministry of Justice and the Ministry of the Interior.

However, enforcement is not considered an autonomous instrument. Cohesion between repression (enforcement) and prevention (infrastructure and communication) is of paramount importance. The general principle is that enforcement only takes place at a certain location when no improvement can be made on the road design. Chapter 10 on traffic enforcement will discuss this in more detail.

Efficient enforcement requires risk analyses of factors that determine road unsafety. These can be divided into a minimum of three types, including:
- traffic violations;
- road users;
- locations.

The approach taken by the police to traffic violations is primarily focused on a number of spearheads: the correct use of crash helmets, wearing a seatbelt, stopping at a red light, no alcohol in traffic, and enforcing maximum speed. This approach has already made an important contribution to the improvement of road safety. The spearheads will continue to apply even as their relevance is subject to periodical evaluation.

Research has shown that the objective and the subjective (instinctive) probability of detection has a considerable influence on the extent to which drivers conform to normal traffic behaviour. The objective probability of detection will be increased by making use of new technologies that make it easier to detect traffic violations. This will be discussed in more detail in chapter 10 on traffic enforcement.

Reward
In addition to sanctioning, rewarding is also used as an instrument to influence behaviour. For smaller target groups, rewarding is a particularly successful addition to conventional police repression, being in line with the strategy to focus measures on specific areas. An organisational framework will be designed for the development and implementation of the reward instrument with intermediary and interest groups playing a key role.

Knowledge
The implementation of an effective and efficient road safety policy requires knowledge, for example of the trends that are relevant to road safety, the volume and background/causes of accidents and the effects of potential road safety measures. Knowledge must be made accessible in good time to the proper parties: policy makers/administrators and implementing parties at national, regional and local levels.

Direction
The adoption of the National traffic and transport strategy memorandum signified the decentralisation of many tasks and responsibilities in the field of road safety. However, the Ministry of Transport, Public Works and Water Management remains responsible for the effective progress of the process as a whole, stepping in if things are not running smoothly at a decentralised level. Initially, they will act as a catalyst in the event that processes are wavering. If this still results in insufficient progress or unfavourable influence on road safety, they can then employ a more rigid central control mechanism. If the problem is infrastructural, the Ministry can formulate compulsory regulation. In terms of permanent road safety education, the regional parties would appear to play a key role in the development of a more structured approach.

The market
Private parties can play an important role in the realisation of road safety objectives. The following are a number of key issues:

1 Responding to consumer needs. Safety must be linked to the market principles of profit, practicability and pleasure, making it interesting for market parties to directly or indirectly contribute to road safety.
2 Ensure that companies and organisations can distinguish themselves on the market. One such example is EuroNCAP: which car deserves the most stars?
3 Consider the costs and show hidden cash flows. How much, for example, do traffic accidents cost the transport sector?
4 Where can the authorities provide help by eradicating the problems of others whilst increasing road safety?
5 What do government authorities have that the business sector finds interesting enough to want to implement or exchange?

3.2.3 Alternatives
This approach will still result in 580 traffic fatalities and 12,250 hospitalisations by 2020. In a sense, this is an admission that in 2020 fifty fatalities a month is acceptable and that this is the collective price of freedom.

However, an alternative scenario exists that would reduce the number of fatalities in 2020 to a maximum of 250. This demands that choices of an alternative and more radical nature be made:

1 investing billions of euros in the infrastructure through the stringent application of the principles of Sustainable Safety;
2 limiting the freedom of mobility: prevent accidents through limiting or banning mobility for high-risk target groups;
3 a combination of 1 and 2.

3.3 European road safety action programme EU

The 'European Road Safety Action Programme' [3.4] states that a high price is being paid for increasing mobility. In Europe, 1,300,000 personal injury accidents a year result in more than 40,000 fatalities and 1,700,000 injuries, with direct and indirect costs being estimated at 160 billion euro a year, or 2% of the EU's gross national product (GNP).

The main causes of traffic unsafety at European level are:

- Excessive and improper speed, the cause of about one third of all fatal and serious accidents and a major factor in determining the seriousness of injuries.
- The consumption of alcohol and drugs, or fatigue. Drinking and driving is responsible for about 10,000 deaths each year. The problems of driving under the influence of drugs and fatigue are also increasing.
- Non-compliance with the driving/rest times by professional drivers, which leads to fatigue.
- Failure to wear a seatbelt or crash helmet is a major aggravating factor in accidents; proper use of these safety measures could save almost 7,000 lives a year.
- The lack of sufficient protection provided by vehicles in the event of impact. Analysis of accidents indicated that 50% of all injurious, fatal and disabling accidents could have been avoided if protection had been better.
- High-risk accident sites (black spots).
- Poor visibility of other road users or an insufficient field of vision for the driver. The lack of visibility in the blind spot towards the rear of vehicles alone causes 500 deaths a year.

The action programme aims to reduce the number of fatalities by 50% by 2010, or in other words, save the lives of 20,000 people a year. Incidentally, road unsafety varies from country to country.

The recommended areas of action were:

1 Encouraging road users to improve their behaviour;
2 Using technical progress to make vehicles safer;
3 Encouraging the improvement of road infrastructure;
4 Safe commercial goods and passenger transport;
5 Emergency services and care for road accident victims;
6 Accident data collection, analysis and dissemination.

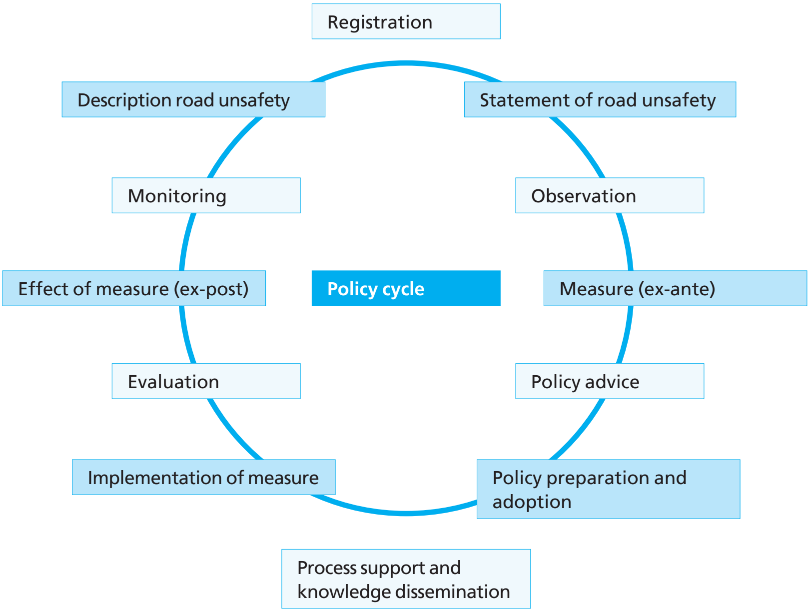
In 2005, there were some 41,600 traffic casualties in Europe – a 17.5% decrease in four years. If this reduction rate continues, the number of casualties will reach 32,500 by 2010, far short of the intended maximum of 25,000.

Many issues that are prescribed at European level can be 'politically sensitive' because they concern the sovereignty of member states and personal freedoms, or what is known as the subsidiarity principle. There is little debate in the EU about the desirability of designing safer cars and infrastructure. Similarly, no-one in the EU disputes that Brussels has an important role to play in the promotion of road safety as a quality aspect of the transport policy, which is also the 'lubricant' of the European internal market.
However, as soon as the behaviour of road users and monitoring of this behaviour comes up for discussion, decision-making processes become more difficult. This touches upon such issues include alcohol use, speed limitations and driving/rest times in the haulage industry, for which the EU member states have widely varying regulations, particularly concerning alcohol [3.5].

One successful action in Europe is the European New Car Assessment Programme (EuroNCAP) for impact testing. EuroNCAP is a joint initiative between a number of countries and organisations, which initially included the EU. The costs are borne by the participating organisations. EuroNCAP successes are currently centred on making cars safer for passengers. Unfortunately, less has been done to improve the safety of cyclists and pedestrians. The EU sometimes has an unfavourable effect on road safety in the Netherlands. The transfer of powers of member states to the EU has both positive consequences – including the improvement in the safety quality of vehicles – and negative consequences, like the obligation to allow less safe vehicles such as the single-seat car with moped engine into the country. Moreover, EU expansion will lead to more foreign drivers and hauliers, which will result in increased traffic risks, as foreign companies often lack a safety culture.

In terms of the daily practice of traffic engineering, the EU has had only a limited influence in the past. It is highly possible that Europe will have a greater influence on road safety policy in the near future. Europe determines to a large extent the requirements placed on cars, which is why European legislation is often incorporated into its Dutch counterpart (the Road traffic act and the Motor vehicle regulations). Moreover, innovations are also prepared in what are known as European Framework programmes. Vehicular innovations developed in collaboration between car manufacturers, research institutes and European governments may be especially influential for the development of road safety in the period after 2010. In addition, the collaboration between countries within the EU will also be encouraged, particularly with regard to measures on the Trans European Road Network (TERN).

Figure 3.2. Road safety policy cycle



3.4 Policy development

Policy is developed according to the policy cycle: identifying a problem and the accompanying need for policy, formulating policy, implementing, measuring and evaluating and, if necessary, adjusting it.

Figure 3.2 shows the cycle for road safety policy. Road safety problems are identified on the basis of accident data or other sources. Advance assessments of the effects of possible measures must indicate which measures can provide a solution that will reduce the road unsafety observed. A popular method for conducting advance research is the use of pilots, in which measures are initially tested on a small scale. One example is the 'Mopeds on the carriageway' programme, where a number of road sections in three different cities were tested first before the programme was implemented nationwide. Before a measure can be implemented, there must be evidence that the initiative has the support of a substantially large proportion of the Dutch population. Every year, the Ministry of Transport, Public Works and Water Management assigns a large-scale survey of the Dutch population – the Periodic regional road safety survey – in which people are asked to voice their opinions about the new measures as well as their own behaviour (also in terms of speeding) and involvement in accidents. Due to their legal consequences and because they encroach upon the specific freedoms of Dutch road users, new measures such as 'Mopeds on the carriageway' are submitted for approval to the Upper and Lower Houses in the form of a legislative proposal or a Governmental Decree (AMvB). After implementation, new measures are monitored and evaluated again after a number of years. Where possible, the effect is quantitatively recorded, although this is not always possible given that road safety measures are often not autonomous but take place in an environment that is subject to other changes as well. Monitoring developments and evaluating policies help policymakers understand the extent to which measures have been successful and whether they require adjustment.

Not all measures are formulated on the basis of the policy cycle. Some also originate from political parties that regularly put forward proposals for the implementation of new measures. An example is the preparation of the demerit points driving licence, which is the result of an amendment presented by the parliamentary parties. In addition, many measures come from the EU, particularly requirements that apply to vehicles. Member states are obligated to include the new regulations in their legislation.

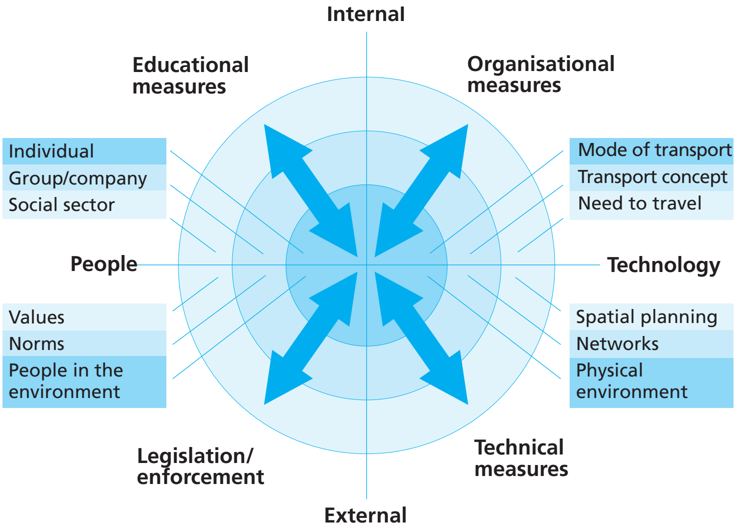
3.5 Organisation of responsibilities

The national government seeks optimum collaboration between public and private parties. In that context, it is important that responsibilities are properly organised and processes appropriately co-ordinated. The Ministry of Transport, Public Works and Water Management distinguishes four levels of policy implementation:

1 International policy. The Netherlands plays an active role (for example in vehicular programmes and EU framework programmes) in the development of international legislation such as the European driving licence guideline and the vehicle-related guidelines and legislation.
2 National policy. In addition to measures oriented towards people, vehicles and infrastructure, the national government is also responsible for the knowledge infrastructure. It has its own knowledge services (such as the Centre for transport and navigation) and subsidises several knowledge institutes such as SWOV, TNO, CROW and KpVV, all of which play their own role. The national government is also responsible for issues such as driving licence policy (learner's licence, lower alcohol limits for new drivers, driving lessons and exams, driving licence documentation, moped licence), enforcement policy (Bureau for Traffic Enforcement of the Public Prosecution Service and regional enforcement teams), information (Multi-year road safety campaigns programme) and legislation.
3 Regional policy. The provinces and the city regions are seen as the directors of regional road safety policy, with the national objectives being translated into regional objectives. In order to achieve these, the regions formulate a traffic and transport plan in collaboration with their partners such as provinces, municipalities, water boards, police and the Public Prosecution Service, companies, citizens and lobbyists. The national government makes money that is not otherwise earmarked available to the regional authorities for their regional and local road safety policy. This is known as the BDU, the broad goal-oriented grant. The regions determine their own set of measures, set their own priorities and divide the money within their own region. Moreover, regional and local means must also be used to achieve the objective.
4 Local policy. Municipal councils and water boards take measures to improve road safety, such as the construction of the 30 km/h zones and 60 km/h zones, road safety education and enforcement.

Actor	Why is this necessary?
Regional and provincial road safety bodies /Provinces/City regions	Co-ordinator of education and regional campaigns
Central office for motor vehicle driver testing (CBR)	Expertise in driving lessons, driving tests, driving licences, educational measures
Knowledge platform for traffic and transport	Supports decentralised government agencies with the implementation of transport policy
Dutch traffic safety association (VVN)	Expertise in traffic behaviour and safety
Dutch association of the bicycle and automotive industries (RAI)	Vehicular expertise
Information and technology platform for transport, infrastructure and public space (CROW)	Development, dissemination and management of practically applicable knowledge in the fields of infrastructure, traffic, transport and public spaces, focused on all levels of government
BOVAG (the association of motor car garage and allied trades)	Vehicular expertise
Dutch cyclists' union	Expertise in bicycles and cycling
Dutch organisation of public transport users (ROVER)	Expertise in public transport
Dutch transport operators association (TLN)	Expertise in haulage
Dutch confederation of agriculture and horticulture (LTO)	Expertise in the agricultural sector
Royal Dutch touring club (ANWB)	Interest group for road users
Public transport companies	Expertise in public transport products
Emergency services and hospitals	Expertise in the consequences for emergency services
Enforcement/Bureau for traffic enforcement of the public prosecution service	Expertise in and use of traffic enforcement
The various road authorities	Necessary for co-ordination
The various tiers of government	Necessary for co-ordination, application of available means, legislation, implementation of regulations
Institute for road safety research (SWOV)	Scientific experts in road safety
Centre for transport & navigation (previously known as the Transport Research Centre)	Basic information on road safety, knowledge centre for road safety for the Ministry of Transport, Public Works and Water Management
Netherlands organisation for applied scientific research (TNO)	Expertise in vehicle safety, human factors
Consultancies	Expertise in traffic engineering and traffic technology

Figure 3.3. Pizza model



Parties in road safety
Road safety is the responsibility of many different parties, all of whom have their own role to play. The key is to involve the right parties early enough when making decisions that impact road safety. The overview on the opposite page can be used as a general checklist. For some decisions, other parties such as citizens and associations of shop owners may need to be involved.

3.6 Policy strategies

3.6.1 An integral approach
Just like road safety itself, decision-making processes and responsibilities of the various tiers of government can be based on either a preventive or a curative approach.
The best way to promote road safety in policy is to take a preventive approach. Many aspects of policy have direct or indirect consequences for traffic, transport and mobility and, therefore, also for road safety. One such example is the scale increase in the education sector, which has caused an increase in the distance between the schools and the pupils, and which, in turn, will have a negative influence on road safety. Including road safety as an integral element in the various deliberations from the early stages of the decision-making process will save substantial amounts of money and effort afterwards.

Irrespective of whether the approach is preventive or curative, road safety policy is based on different strategies, which are characterised by the following unique working points:
- organisational measures, focused on transport concepts;
- technical measures, focused on the physical environment;
- legislation and enforcement, focused on human interaction;
- educational measures, focused on individual human behaviour.

The four different aspects are shown together in the pizza model above (see figure 3.3) [3.8].

This model clarifies a number of issues. Firstly, road safety policy demands a cohesive approach to different aspects. Policies that focus on only one or two of the four aspects while excluding the others is less effective and certainly less efficient. For example, introducing measures designed to reduce speed while the car and the roadscape invite the road user to drive too fast has little effect and is inefficient. The second issue is that of stratification: measures need to be consistent within and between the various tiers. For example, there is little point in charging and fining a lorry driver if his company pays the fine for him.

3.6.2 Safety management and safety culture

Safety management
Safety management is a widely known term in the process industry, where large-scale disasters in the oil/gas and nuclear industries have prompted companies to analyse risks proactively, to develop the necessary management measures and to learn from their mistakes. The structural and demonstrable management of safety risks is called safety management.

Government authorities, like industry, have processes that they need to implement. For road authorities, for example, this involves the management, construction and maintenance of roads that are made available for public use. Unlike industry, most authorities are not yet familiar with safety management. While not compulsory for government authorities, it is often imposed on companies and the aviation industry. However, disasters such as the firework factory explosion in Enschede (2000) and the café fire in Volendam (2001) have prompted authorities to stop and think, and safety management is now seen as a key instrument for government bodies to be in control.

Safety management aims to prevent casualties and political damage/damage to an organisation's image. It focuses on the people and the means that are applied to achieving safety in the broadest sense of the word within the organisation, as well as on the procedures and supervision of all related aspects. Without safety management, an organisation has no structural overview of the risks, cannot structurally manage those risks and cannot structurally interfere in the event of emergencies, let alone structurally prevent them from occurring. In addition, a key aim of safety management is to permanently improve the organisation and production. An organisation that learns from its mistakes and uses those lessons to directly or indirectly improve its primary processes will in time function better, suffer less damage and be valued as a good and attractive employer that invests in the welfare of its staff.

A safety management system (VMS) comprises the following elements:
- a risk inventory;
- a system for reporting incidents (safely);
- an incident analysis; for instance using PRISMA, SIRE, TRIPOD;
- a system for managing improvement measures and recommendations from incident investigations and audits.

Chapter 1 deals extensively with (research into) the causes of accidents and the processes that precede accidents.
The chances of being involved in an accident and/or the seriousness of the consequences of an accident are not the same for all types of risk. It is important, therefore, to introduce a means of prioritisation. Formulating what is known as a 'risk matrix' allows an objective consideration for prioritisation. The criteria required will differ per organisation and will depend on the organisational objectives.
A road authority whose primary aim is the permanent flow of traffic will not only give a high priority to the prevention of serious accidents but also to accidents that cause long-term traffic jams such as those involving overturned lorries. A lot can also be learned from near-misses and incidents. The registration of serious accidents only provides a limited picture of the actual scope of road unsafety and is, therefore, only the tip of the iceberg. This is why it is vitally important that employees report even the slightest incident, a precondition for which is a system by means of which this can be done safely.

Safety culture
An important condition for the success of a safety management system is a sound safety culture. A safety management system is not possible in an organisation that does not actually subscribe to the importance of safety, where the desire to learn is minimal and where the issue of responsibility is not discussed.

According to Reason [3.9], a safety culture is characterised by a number of aspects:

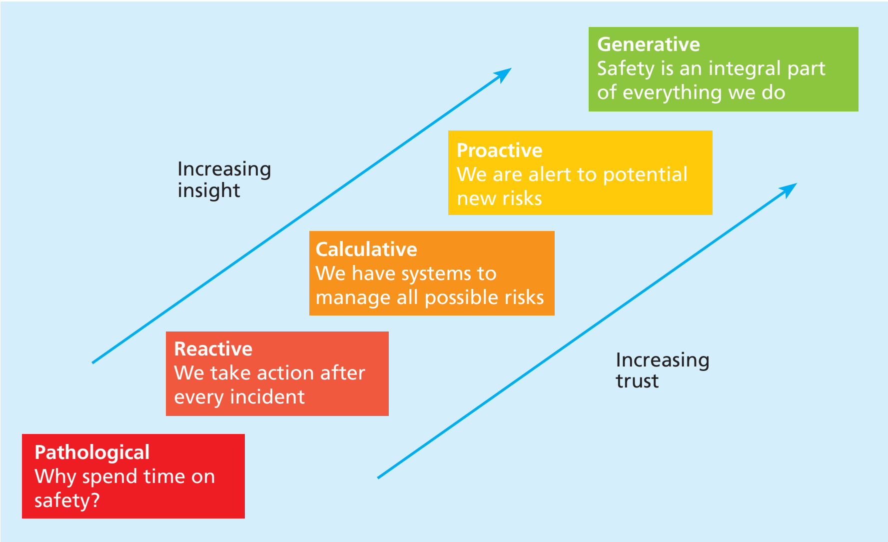
Being informed:	Managers and employees know what is going on in the organisation.
Reporting:	Employees are prepared to report faults and incidents.
Just/honest:	Trust is prevalent within the organisation and there is a low-blame culture.
Flexible:	The organisation has a high tempo and a large measure of routine in its operations, but is flexible when required.
Learning:	The organisation is prepared to learn.

Quality assurance

Quality assurance in traffic management is experiencing a new development in that tendering sometimes takes place on the basis of functional requirements (rather than on the basis of a plan that indicates the product's specification).

When introducing a new product, a suitable amount of attention should be paid to aspects of road safety precisely because of these functional requirements. There is little point in referring to statutory requirements because they are already mandatory. There is not yet a standard formulation with regard to road safety, but a concrete contribution that is commensurate with the existing ambitions and aims with regard to road safety would seem logical. An ambition or aim with neutral effect is insufficient; in that case, separate additional measures for road safety should be introduced upon completion.

Figure 3.4. Different safety cultures employed by Shell [3.3]



Hudson [3.10] added a sixth aspect here:
Cautious: The organisation always expects the unexpected, is very vigilant.

Figure 3.4 shows the different safety cultures employed by Shell.

3.7 Legislation and regulations

Legislation regarding road traffic is contained in the Road traffic act (WVW 1994) [w3.3], which is the basis for the regulatory framework. This is elaborated in Governmental decrees (AMvBs). Only those regulations that are extremely detailed or require constant adjustment are laid down in ministerial regulations instead of Governmental decrees.

The Road traffic act includes five Governmental decrees:
- 1990 Road traffic and traffic signals regulations; rules and indications regarding the behaviour of road users;
- Administrative provisions (road traffic) decree (BABW); regulations for making decisions regarding traffic and the placement of road signs;
- Motor vehicle regulations: technical vehicle regulations;
- Vehicle registration regulations: vehicle registration;
- Driving licences regulations: driving proficiency/driving licence.

The following ministerial regulations are particularly important to road authorities:
- BABW implementing regulations with regard to road signs;
- 1991 Traffic lights regulations;
- Disabled parking badge decree;
- School crossing patrol decree.

In addition to various legal sections and Governmental decrees for many specific cases, the Road traffic act also contains generic legislation, which in turn contains three basic principles: safety, fluency (or flow) and trust. The principle of safety forms the normative aspect of legislation and takes precedence over the other principles. Section 5 of the 1994 Road traffic act states that road users are not permitted to "...behave in such a way that precipitates or could precipitate danger on the road or that results in traffic being hindered or potentially hindered." The section does not provide precise regulations concerning behaviour in a concrete situation, indicating instead that, irrespective of the situation, the driver should always behave in a way that does not or could not precipitate danger on the road. Rights based on the principles of fluency and trust also do not release road users from their obligation to be alert to the faults of others and where necessary to avert a potential accident. The general character of 'catch-all section' 5 of the WVW makes it more difficult for the police to prove that someone has acted in a dangerous manner than if the section had stipulated a number of concrete acts that are deemed to be dangerous. The principle of fluency is important because the increase in mobility demands increased regulations in order to ensure that traffic keeps moving.
The principle of trust articulates, in a sense, the social system on which traffic is based. People have to be able to trust that other road users will act according to the law.

Liability

In the Netherlands, road authorities are liable unless they can prove otherwise. They can be held liable for negligence. Potential liability is important in relation to accidents and damages, and relates in this sense to physical failings of the road itself as well as, for example, insufficient safety measures during road works.

With regard to shortcomings on the road, the liability of road authorities is stipulated in Section 6:174 of the Netherlands Civil Code:
'The owner of a structure that does not comply with requirements that might be reasonably expected of it in particular circumstances, and that, therefore, constitutes a danger to person and property, is, in the event that that danger is realised, liable, unless there is no liability on the basis of the previous section in the event that they knew about the danger at the moment at which it occurred.'

Section 6:162 of the Netherlands Civil Code stipulates the liability of the road authority if the road is in order, but is not, for example, clean. Contrary to the previous section, the burden of proof here rests with the victim and not the road authority.
'Anyone who is responsible for an attributable unlawful act towards another is obligated to compensate for the damages suffered by the other party as a consequence. Unlawful acts are considered to be infringements of a right and an action or omission that is contradictory to a statutory obligation or that which befits an unwritten right in society, all of which is subject to justification'.
Section 174 describes an extra (risk) liability for owners of 'structures' in addition to general liability due to unlawful actions.
As such, it is applicable to road authorities.

Guidelines

For the design and equipment of a road, the road authorities have various CROW guidelines at their disposal [w3.2]. However, these guidelines have no legal status, which means that road authorities can deviate from them, although it is advisable to motivate deviations and, where necessary, at the very least take measures to guarantee safety.

3.8 Monitoring and evaluation of policy

Policies and measures have to be evaluated periodically and developments monitored. These phases in the policy cycle of preparation, decision-making, implementation, evaluation and monitoring are essential in determining whether the correct measures have been effective and whether policy requires adjustment.

It is also important to monitor developments. Autonomous developments can cause gradual changes that can harm road safety. One example of a development that has increased road unsafety is the introduction of the mobile phone. On the other hand, new technologies in vehicles have also often resulted in decreases in serious injuries or have even prevented accidents from occurring in the first place.

In order to follow national road safety developments, various data sources can be consulted and analysed. The Centre for transport & navigation feeds every accident registered by the police into a national accident database. Other sources of data include Statistics Netherlands (data concerning the causes of non-natural deaths), the National medical registration system and the Consumer safety institute. The Ministry of Transport, Public Works and Water Management and Statistics Netherlands publish their figures on a yearly basis. At regional and local level, the Dutch registered accidents database (BRON) is primarily used to record dangerous situations. It should be noted, however, that registration has declined sharply in recent years. The police do not register every accident because they no longer always visit the scene of the accident or because they are limited to such tasks as securing the scene or the distribution of claim forms. The less severe the injuries are, the lower the registration rate. This will also be discussed in chapter 4. For a more comprehensive picture, other sources are also available, such as local police and municipal monitors and reports by road workers and road inspectors.

Every tier of government will evaluate and monitor road safety policy in its own way, for which the policy impact statement is a useful instrument.

3.9 Summary

This chapter discussed road safety policy in the Netherlands. The National traffic and transport strategy memorandum [3.1] contains an outline of road safety policy up to 2020. A more detailed version of this is the Strategic road safety plan of, for and by everyone [3.2], which was issued in 2008. Road safety is also an issue at European level with the European road safety action programme [3.4], which aims to cut the number of traffic fatalities by 50% by 2010. The chapter also discussed the influence of the EU on road safety in the Netherlands.

The policy cycle of preparation, decision-making, implementation, evaluation and monitoring was also discussed, as was the organisation of responsibilities on national, provincial/regional and local levels. The chapter highlighted the strategies required to design policies and looked at their evaluation and monitoring. The relevant regulatory framework was also mentioned. Legislation on road traffic is contained in the Road traffic act (WVW, 1994). This is primarily elaborated on in Governmental decrees (AmvBs). There are also ministerial regulations.

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Learning objectives for students:

- to know what information is necessary to answer the research question;
- to know where to find this information and what any accompanying problems might be;
- to know the different ways of gathering additional information;
- to be up to date on key analytical techniques;
- to be capable of assessing research proposals;
- to be capable of interpreting research findings;
- to understand the key terms of road safety research.

The chapter contains the glossary.

4 Data collection and data analysis

4 Data collection and data analysis

4.1 Introduction

This chapter contains a glossary and aims to help to understand assignments relating to road safety research and read and assess the results. This chapter also provides support in formulating the correct research questions, reading scientific reports and assessing the quality of research carried out on behalf of a third party. Because an understanding of the terminology used is so important, this chapter reviews all the basic terms.

When assessing the quality of research, it is also important to know what type of research is suited to what research question, what the advantages and disadvantages are of different types of research and what the pitfalls are when conducting road safety research. This chapter deals with the various types of research, from simple descriptions of a single characteristic of road safety, such as the number of accidents in a certain region, to experimental research that evaluates the impact of a measure that has been implemented. This chapter also discusses what data is required, the manner in which data can be collected, the way in which data can be analysed, and the conclusions that can be drawn from the results. Key terminology will also be explained.

4.2 Traffic and safety data

4.2.1 Required data

Irrespective of the type of research to be conducted, information is necessary to describe the situation. In terms of road safety, this information usually comprises three principal data groups:

- number of accidents or casualties;
- exposure data or, in other words, the level of exposure to traffic (for example distance travelled in kilometres);
- risk data (for example accidents per billion vehicle kilometres).

These three data types can be used to describe all kinds of situations, from the general road safety situation in the Netherlands to that of an intersection in a random municipality. In order to explain or understand road safety in any given location, more information is required, including:

- the way in which the traffic situation is organised (road design, road environment);
- which road users use this traffic situation (age, gender, experience);
- which vehicles are used (type and accessories);
- how the road users behave (speed, behaviour in terms of overtaking, behaviour in terms of right-of-way, use of crash helmets, et cetera).

Developments over time can be explained by data for different moments in time. This is called a time series.

4.2.2 Available data

A great deal of information is available at national level regarding these aspects of road safety. The following sections will deal with the different data sources and their quality and representativeness. Despite international data sources as IRTAD, CARE and SARTRE, these sections will be limited to Dutch data.

More information concerning these and other data sources can be found in the knowledge base section of the SWOV website [w4.1].

Accident and casualty data

By far the most important source of data concerning accidents on the Dutch road network is the Dutch registered accidents database (BRON), which was created by the Ministry of Transport, Public Works and Water Management on the basis of registration forms supplied by the police. These registration forms provide concise information about the key characteristics of the accident and the road users involved (see table 4.1).

Table 4.1. Characteristics that are registered on a police registration form

1	Time of accident
2	Location (municipality, street, buildings)
3	Speed limit
4	Road authority
6	Nature of the location
7	Temporary circumstances
8	Light conditions (daylight, twilight, darkness)
9	Road lighting (none, on, off)
10	Weather conditions (dry, rain, snow, et cetera)
11	Road surface (dry, wet/damp, snow/ice)
12	Pavement (bricks, concrete, asphalt, porous asphalt, et cetera)
13	Nature of the accident (side impact, rear-end collision, single-vehicle accident, et cetera)
14	Details of those involved (vehicle, driving licence, gender, date of birth, alcohol use)
15	Insurance details of those involved
16	Description of material damage
17	Details of casualties (injury, passenger or driver, date of birth, gender, hospital)
18	Brief description of the accident and a sketch of the scene

According to the international definition [4.21], a traffic accident is an ‘incident on a public road that is related to traffic and results in damage to objects and/or injury to persons and which involves at least one moving vehicle’. In theory, accident data should contain every accident that occurs on the public road network, but in reality, the level of registration would appear to be dependent on the severity of the accident (the more serious the accident, the better the level of registration) and the modes of transport involved. Someone who breaks a leg falling off his bicycle satisfies this definition. In practice it is often seen as a ‘minor accident in which someone has fallen’ rather than a ‘traffic accident’. This is why one vehicle accidents involving only one bicycle often go unregistered in the accident data.

The incomplete nature of registration is largely due to the fact that:
- the police are not always informed and, therefore, not always aware that an accident took place.
- the police do not always register and inform the ministry about reported accidents.

Table 4.2. Level of registration per road user and seriousness of injury

Road user	Level of registration			
	Death (CBS, 2000)	Hospitalisation (LMR, 2000)	Emergency assistance (LIS, 2000)	Other injuries (OBiN, 1997/98)
Car/lorry/ motorcycle	95%	84%	25%	38%
Moped	96%	67%	14%	26%
Bicycle	88%	33%	4%	13%
Pedestrian	94%	55%	21%	
Total	**93%**	**60%**	**13%**	**24%**

Accidents are registered more frequently (see table 4.2):

- The more serious they are.
- If a motorised vehicle is involved. The average level of registration for hospitalisations is 60%, while for casualties in/on motorised vehicles (car, lorry, motorcycle) and mopeds it is more than 80%. The level of registration for accidents involving cyclists and pedestrians is well below 60%, but registration of accidents involving a collision between a cyclist or pedestrian and a motorised vehicle is more complete than registration of accidents where no motorised vehicles are involved.

The actual volume and level of registration are determined by comparing the Traffic Accident Registration to other sources such as CBS statistics relating to the causes of death, the National Medical Registration (LMR), the Safety Institute's Injury Surveillance System (LIS) and the results of the Injuries and Physical Activities in the Netherlands (OBiN) study.

Traffic accident data can be consulted in various ways:

- the Ministry of Transport, Public Works and Water Management's data portal [w4.2] offers different products that provide an initial impression of road safety in a particular region, including 'blackspots on the map' (BLIK), a geographical tool to look at locations where there has been a proliferation of accidents (see also chapter 5).
- the 'online table elaboration' (AUTO) application provides insight into regional or municipal developments in the number of traffic casualties by allowing the selection of an accident or casualty characteristic of which the development is to be studied (for instance the age of the casualty or the weather conditions at the time of the accident).
- on the SWOV website, any kind of table containing accident and casualty data can be created with the help of Cognos; different characteristics can be combined in one table.

Extra information concerning the cause of traffic accidents can be found in the official reports (PVs) drawn up by the police. The PVs for serious accidents often contain a report from the regional office of the police's Traffic accident analysis unit (VOA). In some regions, this office is called the Forensic technical research unit (FTO) or the Technical accidents unit (TOD). These reports contain a substantial amount of information concerning the vehicles involved and the location of the accident. PVs of traffic accidents can be requested via the PV Foundation in Zoetermeer or directly from the regional police. The advantage of PVs is that they contain more information per accident than BRON. However, like BRON, PVs are not available for all accidents and their content often has a legal tone. Police registration is primarily intended for the legal handling of the accident, which is why the police are especially interested in who violated the Road traffic act and is, therefore, responsible for paying the damages incurred.

Exposure data

Exposure to traffic can be expressed in different ways using statistics, based on either road users, vehicles, or means necessary for a vehicle to drive. The outcome varies and not every statistic gives an equally accurate image of the exposure. In practice the choice of type of exposure data is often determined by the availability of statistics for the area, the roads or the type of road user to be analysed. While the types of data below can all be used as exposure statistics, the top four provide the best indication of exposure to traffic:

- traveller kilometres: the total number of kilometres travelled by individuals (as passengers or drivers of a vehicle);
- vehicle kilometres: the total number of kilometres travelled by vehicles;
- volume of traffic: the total number of vehicles that pass a certain spot during a certain time;
- journeys: the total number of journeys made by people;
- vehicle numbers: the total number of vehicles in use;
- total number of residents in the region concerned;
- fuel consumption (can be linked to vehicle numbers).

The time that people spend in traffic will also provide an accurate image of their exposure, because it also takes into account the fact that cyclists and pedestrians spend much more time in traffic than motorists, even if they only cover a distance of five kilometres. However, the time that people actually spend in traffic is rarely recorded, if at all.

Traveller mobility and trips
Information concerning the distances covered by travellers and the number of trips people make is collected in the Ministry of Transport, Public Works and Water Management's Mobility study (MON). Until 2004, this study, conducted by Statistics Netherlands, was conducted under the name National travel survey (OVG). Both the OVG and MON are surveys of the mobility of the Dutch population, which is sent to a random number of households every year and which asks the inhabitants of that household to record every trip that they make on a particular day.

For each trip, the following information must be recorded:
- place of origin and destination, distance travelled;
- time of departure and arrival, total time necessary to make journey;
- modes of transport used;
- reason for trip (commuting, shopping, family visit, et cetera).

Further background information is also requested including age, gender, province, vehicle ownership and driving licence.

The mobility of approximately 50,000 people forms the basis for the data collection, which is of key importance for road safety research because it is used to calculate risks. However, the OVG/MON do not fully describe mobility on Dutch roads. The primary deficiency is the lack of information concerning the mobility of freight transport, foreign vehicles and Dutch holiday traffic. In addition, the OVG/MON contain no information about journeys divided according to road category or the distinction between journeys within or outside the built-up area.

When using this data, it is good to note that the annual figures are based solely on the journeys made by these 50,000 people on a particular day. This might seem a lot, but when looking at a particular group of road users such as moped drivers over the age of 75, for example, the information concerns a very small number of journeys (28 in 2006). This renders the statistics vulnerable to peaks. A moped driver who, on the day they have to fill in the MON survey, makes an unusually long journey, for example, will strongly influence the average. It is important, therefore, to use wide margins around the figure shown for those specific groups.

More information on the MON can be found on the Ministry of Transport, Public Works and Water Management's MON website and in the SWOV's knowledge base. Data files with the total number of kilometres travelled and journeys made can be downloaded via the MON website and consulted on the Statistics Netherlands website and in the SWOV's knowledge base.

Vehicle mobility
Until 2000, data concerning the distances covered by vehicles were based on different sources such as road counts and the car panel. Since then, however, similar figures have not been published, but Statistics Netherlands is expected to start publishing information concerning vehicle mobility again in the near future. This will be accompanied by a breakdown according to vehicle type.

Traffic volumes
Approximately 700 permanent counting points measure the number of vehicles that use state and provincial roads outside the built-up area (traffic volume). Every month, the traffic volume percentage compared with reference year 2000 is recorded for each road category. These figures can be consulted on the Statistics Netherlands website. In addition, 24-hour averages can also be consulted on the Ministry of Transport, Public Works and Water Management's data portal [w4.2].

Fleet numbers
There are (at least) two sources concerning vehicle ownership in the Netherlands. Statistics Netherlands bases the number of motorised vehicles in the Netherlands on vehicle registration by the Government road transport agency (RDW). Ownership of bicycles, mopeds and light mopeds can be determined on the basis of the above-mentioned MON survey. Both sets of statistics can be consulted on the Statistics Netherlands website [w4.3] and in the SWOV's knowledge base [w4.1]. In comparison with the above-mentioned exposure data (travellers kilometres, vehicle kilometres and traffic volumes), vehicle numbers have the disadvantage that they do not describe actual exposure but rather potential exposure. The only thing that is shown is the number of vehicles that could have participated in the traffic rather than the actual number that did and the degree to which.

Resident numbers
The use of resident numbers as a measure of exposure has the same disadvantage as using vehicle numbers since they only provide an indication of potential exposure. While revealing the potential number of road users, they do not show the actual number of people who used the roads and the extent to which they did so. However, developments in resident numbers and composition of the population can be used to estimate future exposure. The main source of information for resident numbers by age, gender and region is Statistics Netherlands [w4.3], which also publishes prognoses regarding future developments in population size and composition.

Risk data
Risk data can be calculated by combining the data from the previous two sections. Frequently used risk data includes:
- the number of casualties per billion vehicle kilometres travelled;
- the number of casualties per billion passenger kilometres travelled;
- the number of casualties per 100,000 residents;
- accident involvement per billion passenger kilometres travelled;
- the number of accidents per kilometre of road.

Risk data variants can be obtained by filtering according to the degree of injury (for example fatalities) and/or a particular type of road user. A comparison of risk data for different road user groups (according to age or mode of transport) shows which road users have an increased chance of being involved in a traffic accident (see chapter 12 for a discussion on the different risk groups). Different tables containing risk data can be consulted in the SWOV's knowledge base. When groups of road users are combined, it is important to aggregate instead of adding up, otherwise the risk data is accumulated rather than being recalculated.

Road and road environment characteristics

At national level, information collected on the road and the area around the locations where accidents occur is not very detailed. The only accessible source for this information is BRON. The PVs that the police draw up sometimes contain extra information concerning the road layout, but this source is neither well-structured nor openly accessible. Reference data concerning roads and characteristics of road environments – data that indicates how roads and the road environment are generally laid out in the Netherlands or in a specific region – is barely available, if at all. The information that is gathered, is done so by (or at the request of) the road authority. With regard to the state roads, this has led to the WEGGEG file, which comprises data at road section level on maximum speed limits, overtaking bans, types of road surface, number of lanes, lighting and the layout of roadside verges. This file can be requested from the directorate-general for Public Works and Water Management's data ICT department. In addition, work is currently under way on a national file containing the road characteristics of every type of road. This project is known as 'Wegkenmerken+' (Road characteristics+).
Both files can be linked to the National road file (NWB). This geographic file contains the roads of every road authority on the condition that they contain a street name or number. This means that footpaths, cycle paths and unpaved roads are included in the NWB as long as they have a name.

Road users

Information concerning road users can be derived from the above-mentioned resident numbers in terms of age and gender published by Statistics Netherlands and from driving licences. Statistics Netherlands derives its information concerning the number of people in possession of a driving licence sub-divided into age, gender and type of licence from the results of the MON.

Vehicle data

Information concerning the vehicles on Dutch roads is available via Statistics Netherlands and the Dutch association of the bicycle and automotive industries (RAI). The latter's website [w4.4] also features publications with subdivisions of vehicle numbers according to make and subtype.

Behavioural data

Road user behaviour is a key explanatory factor in terms of traffic accidents. Different forms of (risk) behaviour are distinguished (see also chapter 11 on risk behaviour), including:

- speeding;
- no stopping at red lights (red light negation);
- parking where it is prohibited or stopping on the carriageway;
- driving under the influence of alcohol and/or drugs;
- failure to use lights on bicycles;
- failure to wear a crash helmet;
- failure to wear a seat belt.

These forms of behaviour are regularly measured at national and regional level. In most cases, this involves research conducted on behalf of the Ministry of Transport, Public Works and Water Management. The directorate-general for Public Works and Water Management, for example, studies the developments in the use of protective measures such as car seat belts and child restraint seats, adjusting the head restraints, driving under the influence of alcohol and the use of bicycle lights in darkness. The findings of this research can be found in publications by the Centre for transport and navigation [w4.5]. Longer time series are kept in the SWOV's knowledge base. However, measurements over the years were not always made by the same body or in the same way, which impacts on the comparability of the annual figures.

The Ministry of Transport, Public Works and Water Management also continually measures speed-related behaviour at a number of measuring points on trunk roads and motorways in the Netherlands. The data is summarised per speed limit into an average driving speed, a percentage of people who exceed the limit and the V_{90} for cars and articulated or unarticulated vehicles (the V_{90} is the speed that is not exceeded by 90% of the drivers). The results of these speed measurements are not published. This may change in the future within the framework of the National data warehouse (NDW).

Given that risk behaviour can lead to fines, the annual figures from the Central fine collection agency also provide an indication of the scope and development of the number of traffic violations. The knowledge base on the SWOV website also contains a table of the most important traffic violations (speed, parking where it is prohibited, stopping on the carriageway and driving through a red light). This table is updated annually with the most recent figures. When using these figures, it is important to realise that an increase (or decrease) in the number of fines issued is not necessarily the result of an increase (or decrease) in the number of traffic violations. The development in the number of fines issued can also be the result of policy-related measures such as regional enforcement projects concerning helmets, seat belts, red lights, alcohol and speeding, as well as more intensive policing on motorways in particular (section control). In addition, developments in mobility can, of course, also influence the number of fines issued.

A final source of information concerning traffic behaviour comes from the results of the Periodic regional road safety survey (PROV), which is a large-scale biennial survey of approximately 8,000 Dutch residents over 15 years of age. The PROV survey asks about experiences in traffic (accidents and fines), self-reported behaviour (driving speeds, driving under the influence, use of safety devices), motives for adhering or disregarding road traffic regulations and opinions regarding measures taken. In most cases, the results are divided into the type of vehicle (car, motorcycle, moped, light moped, bicycle) and/or region (province or framework area). If the PROV data is used for information concerning traffic behaviour such as driving speeds, it is important to take into account that the reported behaviour can deviate considerably from actual behaviour (see section 4.2.3). The results of the PROV surveys can be found in publications by the Centre for transport and navigation [w4.5].

4.2.3 Collecting extra data

Some information is only available at national or provincial level. Information regarding the situation in a specific city or region will need to be specially collected for research purposes using one of the following three methods:

- observation;
- interview;
- questionnaire.

Observation is most suitable for measuring actual behaviour such as speed-related behaviour, alcohol use and seat belt and helmet use, as well as for counting the number of vehicles that pass a particular point (volume). CROW publication 248 'Traffic survey handbook' [4.9] includes an extensive description of how such measurements and counts should be taken. A unique form of behavioural observation is described below: conflict observation. This technique can be used to learn more about dangerous situations without actually having to wait for an accident to happen.

Interviews and questionnaires are useful means of finding out the opinions of road users regarding, for example, the safety of traffic situations, the occurrence of traffic accidents, and the motives behind adhering to or disregarding traffic regulations such as speed limits and the compulsory use of a seat belt or crash helmet. Questionnaires can also be used to gather behavioural data, which often relates to reported behaviour. In this case, it is important to be alert to distortions of reality due to the unwillingness of respondents (the people who answer the questionnaire) to be truthful in answering questions about their own behaviour. It appears that respondents cannot effectively estimate the distances they have travelled. Distances travelled by car are overestimated by an average of 8%, distances travelled by bicycle by as much as 20%.

Data quality: reliability and validity

Being alert to the accuracy of the findings is not only important in questionnaire-based research, but in all forms of research and data collection. Luckily, precautionary measures can be taken when setting up a study. For example, when collecting data it is important that agreements are made concerning what is being measured and how the correct value will be determined. If a measurement is being repeated for a particular object (e.g. the length of a road section), the same measurement should preferably be found to have the same value, also if the measurement is carried out by another person. This makes it a reliable measurement. Reliability can be increased by using calibrated measuring equipment or – in the case of definitions – by properly defining in advance what the existing classes are. For example, is a delivery vehicle defined as a 'passenger car' or a 'commercial vehicle'? If two people take the same measurement, it is possible to check in retrospect whether the definitions used were helpful. This can be done by comparing the results of each assessor (or observer) in what is known as interassessor reliability. The aim is to achieve optimum interassessor reliability and, therefore, identical results. Intra-assessor reliability can be used if an assessor is required to take measurements over a longer period of time: is the assessor consistent in his assessments? Intra-assessor reliability can be measured by having the assessor measure the same object at regular intervals. The results of these measurements should be the same, which would suggest a high level of intra-assessor reliability.

It is also of critical importance that the measurements actually measure what should be measured. This is called the validity of the measurement. For example, the actual length of a road section is measured in metres with a measuring tape. However, if the researcher is unaware of the fact that the lines on the measuring tape are consistently 1.2 metres apart rather than 1 metre, this means that while this length of road section can be reliably measured (because repetitive measurements will provide the same result time and again), there is a systematic error being made because the length of the measured road section is underestimated with this instrument. Where the road section is actually 500 metres long, this invalid instrument measures it incorrectly at 416.7 metres. Problems with validity play a role in indirectly observable variables such as intelligence, risk, extraversion, etc. The validity of questionnaires and interviews can play a role if suggestive questions are posed or socially desirable answer categories are used. Such measurements do not reflect public opinion but what people think the researcher wants to hear [4.1, 4.3, 4.9].

DOCTOR conflict observation technique

A unique form of observation is conflict observation. One such technique, which was developed in the Netherlands, is DOCTOR (Dutch Objective Conflict Technique for Operation and Research). This is a standardised observation technique with objective and defined observation units that is conducted by trained observers [4.15]. Over a certain period of time, these trained observers observe a location (for example an intersection) or an area and register and assess the conflicts that take place there. This technique defines a conflict as a critical traffic situation in which two or more road users approach each other in time and space to such an extent that there is a risk of collision and a real chance of physical injury or material damage if their direction and speed remain unchanged. Critical traffic situations are those in which the space available to manoeuvre (to avoid one another) is smaller than the space that is necessary under normal circumstances. The severity of the conflict is determined on the basis of both the chance of a collision and the scale of (physical and/or material) damage if the collision were to take place.

The chance of a collision is determined by means of the ‘time to collision’ (TTC) and/or the ‘post encroachment time’ (PET). The TTC is defined as the time required for two vehicles on a collision course to collide if they continue at their present speed and on the same path. The lower the TTC, the higher the chance of a collision. The TTC can only effectively predict the chance of a collision if two road users are on a collision course. If road users experience a near-miss at high speed without changing their speed or direction, this does not, technically speaking, constitute a collision course despite the chance of a collision being very real in such situations. A minute alteration in speed or direction could easily lead to a collision. In such cases, the chance of a collision can be determined by the PET, which is defined as the time lapse between the end of encroachment of the turning vehicle (t1) and the time that the through vehicle actually arrives at the potential point of impact (t2). The lower the PET (= t2-t1), the higher the chance of a collision.

The severity of the consequences of a potential collision depends of the potential collision energy and the vulnerability of the road users involved. Factors that influence these aspects include mutual differences in speed, the avail-

able and the necessary room to manoeuvre, the angle of approach and the type of road users (and their protection). The mass and the manoeuvrability of the vehicles in particular will determine the severity of the consequences. Estimating this severity requires an indication of the road users involved, an estimation of the speed and the nature of the evasive action (incl. braking, accelerating, swerving).
When indicating the type of road users involved, it is also important to note who is approaching who. A cyclist approaching another road user has, given a particular speed and distance, more chance of making an evasive manoeuvre than a lorry.

In practice, DOCTOR can be used for a preliminary study into a particular measure and a post-study for its evaluation or for the assessment of suspected road unsafety (for example complaints by local residents) in which case an analysis of the nature of the road unsafety can also be carried out. In both cases, conflict observation has the advantage that large numbers of observations can be made in a short space of time, which quickly produces sufficient material for reliable conclusions; which is quicker than waiting for accidents to happen. In this sense, conflict observation can be compared with incident registration. It is also important to count the number of non-critical encounters. This produces an indication of the situation's relative road unsafety. The safety at intersections should not be related solely to the volume of traffic but also to the chance of an encounter, which is determined by the distribution of traffic over the branches. Since its development, the DOCTOR method has been employed relatively sparingly due to the fact that it is fairly labour intensive. However, this method is still recommended by a number of consultancies.
More information on the advantages and disadvantages of DOCTOR can be found in [4.10].

Interview or questionnaire

There are different reasons for choosing interviews or questionnaires instead of observation. Firstly, it is sometimes impossible to observe the aspect being researched, because it relates to something personal such as motives, opinions, values and norms, because it relates to behaviour that is highly irregular or takes place in private, or because the behaviour took place in the past. Secondly, the use of questionnaires or interviews is often more attractive because data collection is easier to standardise and also more efficient in terms of money, time and manpower. After having decided in favour of survey research – the collective name for research based on questionnaires and interviews – a choice must be made between holding interviews and using questionnaires. One advantage of interviews is that they provide more opportunities to explain unclear questions or continue to ask questions in regard to unclear answers. In addition, interviews offer more possibilities to motivate the respondents to answer the questions in as concentrated and thoughtful a way as possible. Interviews also provide a higher response rate than questionnaires, with the percentage of people who are willing to participate being higher. By contrast, however, the use of questionnaires is cheaper (you can send more for the same amount of money), they are anonymous, which will mean that some people will respond more truthfully to intimidating questions and the answers will be less influenced by the interviewer. Given that respondents have no opportunity to ask for an explanation about what is intended when filling in a questionnaire, it is important that the questions can be understood by everyone [4.1, 4.2, 4.3, 4.4].

Representativeness of the sample

Survey research often studies a section of the population with the intention of drawing conclusions about the entire population (or a relevant subgroup). In order to do so, the group being interviewed (the sample) must be representative of the group for which the conclusion is to be drawn (the population). One such example is the Mobility Study Netherlands (MON), which is conducted in order to get information on the travelling habits of every household in the Netherlands (the population). In order to estimate these habits, a sample from the population is asked to fill in a questionnaire on which all members of the households keep a written record of every journey they make on a particular day.

It is crucial in such a study to use a sample that is representative of the Dutch population. This requires choosing a random sample of households. A random sample means that each person in the Netherlands has an equal chance of being asked to participate. In the MON, a random sample is taken from the total number of private and mixed addresses in the Netherlands (addresses at which private individuals live and where companies are established). It would also have been possible to take the sample survey from the Dutch telephone directory, but then the selection would not be random because it excludes people who do not have a telephone, which can give a distorted picture of the mobility of the Dutch population: it is possible that people without a telephone travel more or indeed less than those with one.

In order to check whether the MON sample is representative, the collected data is used to investigate whether the characteristics of the respondents (such as age and gender) correspond with those of the Dutch population as a whole. This is almost never the case because some groups are more inclined to participate in research than others. This problem is known as the problem of non-response, for which a correction is made by weighing information regarding travelling habits in such as way that the distribution of variables in the sample corresponds with the distribution in the population figures. In addition, the travelling data per person per day is incrementally generalised for the entire country and for the entire year [4.1, 4.3, 4.12].

4.3 Summarising and comparing data

Until now, the focus has been on data. However, individual data says little about road safety in a certain area or about the safety of a particular group of road users. It is, therefore, necessary to summarise or analyse the data in any one of a number of different ways.

The following section discusses a number of terms that are frequently used when describing research results.

4.3.1 Basic terminology

The first term that is often used is variable. Every characteristic of casualties, accidents, road users, vehicles and infrastructure can be used as variables in research. Age, for example, can be a variable, as can type of intersection. If the researcher wants to know the age of a specific road user, this relates to the value of age as a variable of that road user (for instance 36 years old). In this case, the road user is the object of the research. An intersection can also be the object of research in which the different aspects of the intersection are studied, for example, and for which the type of intersections such as the 'T-junction', 'Y-junction', 'four-way intersection' and 'roundabout' is used as a variable. Other variables that can be used to describe intersections include volume of traffic, the number of lanes and right-of-way rules.

Once the value of a variable has been determined, the calculations can be carried out. However, variables are not the same and it is not possible to perform the same calculations for all variables. For example, there is an average 24-hour traffic volume, but there is no such thing as an average mode of transport. This has to do with the level at which the variable is measured. There are four types of measurement level or scale:

- nominal;
- ordinal;
- interval;
- ratio.

Variables that are measured at a nominal level are also called categorical variables. Measurements that relate to these variables consist solely of the division of research objects into different categories. One example of a categorical variable is the mode of transport with one of the following values: lorry, car, motorcycle, moped, bicycle, et cetera. When the data from the questionnaire are entered into a database, each category of this variable is given a number (for example lorry = 1, car = 2, motorcycle = 3), but these numbers do not have any significance. For example, it is impossible to say that a lorry (= 1) is smaller than a motorcycle (= 3), or that the difference between a motorcycle and a car (3 – 2 = 1) is the same as the difference between a car and a lorry (2 – 1 = 1). Nominal variables do not allow for the calculation of mean values.

An ordinal measurement level is created if the above-mentioned modes of transport are classified according to weight (0-100 kg, 100-500 kg, 500-1,500 kg; 1,500-5,000 kg; > 5,000 kg) and each class is given a number (1 to 5). The successive classes have a meaningful order. It is then possible to say that vehicles in class 1 are lighter than those in class 2 and that vehicles in class 5 are heavier than those in class 4. However, it is not true to say that the weight difference between vehicles in classes 1 and 2 is as big as those in classes 3 and 4. Ordinal measurements do not allow for the calculation of mean values either.

If there is a variable that shows the weight of a vehicle in kilograms, the total number of potential values is much bigger. In terms of these values, it is possible to say that the weight difference between vehicles of 1,200 and 1,300 kg is just as big as the difference between those weighing 1,500 and 1,600 kg. These are measurements at interval level. It is not only useful to say that X is bigger than Y, but the intervals can now also be meaningfully compared. Variables on this measurement level can be used meaningfully to calculate mean values.

The values of the variable 'weight in kgs' are, in effect, values at ratio level, the condition being that there is a natural zero point. Examples of variables with a ratio measurement level include length in centimetres and weight in kilos. A typical interval variable is time. It is possible to say that the difference between 2 o'clock and 4 o'clock is equal to the difference between 8 o'clock and 10 o'clock, but not that 4 o'clock is twice as late as 2 o'clock. This is different for weight: a vehicle that weighs 1,000 kg is ten times as heavy as one that weighs 100 kg [4.19].

4.3.2 Description of individual data (one variable at a time)

Researchers usually want to average the values measured for a variable. The most commonly used measure for this is the mean. The previous section indicated that it is not possible to calculate a mean for every type of variable. Other summarisers or central tendencies are the mode and the median.

The values of nominal variables can only be averaged using the mode, which is the most prevalent value or category, in other words, the value with the highest frequency. Assume that 'vehicle type' is used as a variable. The values for this variable can vary from 1 to 5, with each value designated to a particular vehicle. Eight vehicles have been scored and this results in the following series of numbers: 1, 2, 2, 2, 3, 4, 4, 5. The mode is then equal to 2 (see table 4.3 for more examples). For ordinal values, the median can be calculated by placing every value in a scale from low to high and then determining the middle value. If the total number of numbers is even – such as the series above – there is no middle value. In such cases, the median is the average of the middle two numbers, in this case 2.5.

Table 4.3. Overview of central tendencies per measurement level

	Mode	Median	Mean
Nominal (vehicle type: 1=bicycle, 2=moped, 3=car) 1, 1, 1, 2, 2, 3, 3, 3, 3, 3	3	not meaningful	not meaningful
Ordinal (annual kms: 1= <10,000, 2=10,000 – 14,999, 3 = 15,000 – 19,999) 1, 1, 1, 2, 2, 2, 3, 3, 3, 3	3	2	not meaningful
Interval (total number of fines) 1, 1, 1, 1, 1, 2, 2, 2, 3, 3	1	1.5	1.7

For interval and ratio variables, the mode, median and mean value can all be calculated. There are two types of mean: the arithmetic mean and the weighted mean. The arithmetic mean is the most well-known of the two, being calculated by adding up all the values measured and dividing this by the number of values measured. The mean age of a group of six learner drivers, for example, is (18 + 18 + 18 + 18 + 19 + 20) : 6 = 18.5. This is mostly indicated with M or μ.

The weighted mean is calculated when data from two samples of uneven size are added together. Assume that there is a second group of four learner drivers with an average age of 19.5 years old. The weighted mean age of these two groups is not (18.5 + 19.5) : 2 = 19. This is because the first group is larger, which means that the mean of this group must weigh heavier. This is done by multiplying the mean with the group size for each group: 18.5 × 6 = 111 and 19.5 × 4 = 78. The sum of these two totals is then divided by the sum of the total group for the two samples together: (111 + 78) : (6 + 4) = 189 : 10 = 18.9.

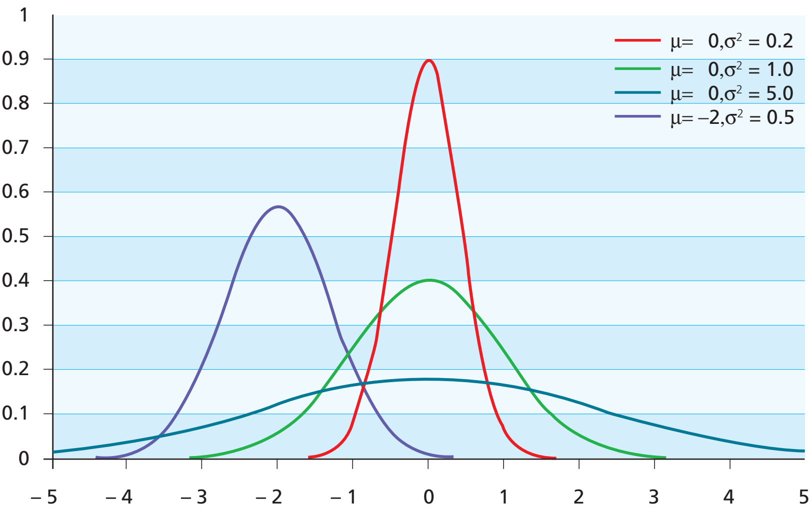
It is also possible to work out the distribution of values for variables at interval or ratio level: do they have roughly the same value or are there significant differences? This is mostly calculated using the standard deviation, which is usually indicated with s, sd or σ. The greater the standard deviation, the greater the mutual differences and the less the values equate to the mean. In other words: the smaller the standard deviation, the more homogeneous the values measured. Another quantity that is used to determine the distribution is the variance, which is the square of the standard deviation.

The standard deviation and the arithmetic mean can help to determine when an individual value should be considered as extreme. In the social sciences, a normal distribution of values for the variable is often assumed. In a normal distribution, more than 68% of the values measured lie between the averages, plus or minus a standard deviation. Furthermore, in a normal distribution, 95% of the values measured lie within approximately twice the standard deviation of the mean. To be precise: 95% of the values lie within $\mu \pm 1.96\sigma$. Figure 4.1 shows a number of examples of normal distributions. The differences between these distributions is determined by the mean (μ) and the standard deviation (σ).

In order to determine whether a distribution is normal, the central tendencies can be compared. In a completely normal distribution, the arithmetic mean, the mode and the median of a series of numbers all have the same value. But if these central tendencies differ, distribution is not normal but asymmetrical, showing a skewness and/or peakedness (kurtosis), as it is called. An example of such an unbalanced distribution is a distribution that is skewed to the right. In that case, the mode is smaller than the median, and both are smaller than the arithmetic mean. Rather than the top of the curve being in the middle, it is off to the left. At the same time, there is a larger tail on the right-hand side of the curve. Distributions that skew to the left are characterised by a mode that is larger than the median, both of which are larger than the arithmetic mean. In such cases, the top of the curve is off to the right and the tail on the left-hand side of the curve is disproportionately large (or long).

The qualities of a normal distribution can be used to determine whether a certain value should be considered extreme. A value that deviates from the mean by more than 1.96 × the standard deviation is extreme. Such values occur in only 5% of all observations. For example, a group of motorists have taken their driving tests and the average score is 110 and the standard deviation 20. Than 95% of the scores lie between 110 – 1.96 × 20 = 70.8 en 110 + 1.96 × 20 = 149.2. Scores outside this range are relatively rare. Only 2.5% of the motorists will achieve a score lower than 70.8 and similarly only 2.5% of motorists will achieve a score higher than 149.2. It is, therefore, unlikely that a new score of 60 will come from the same group. Such a score could be said to deviate significantly.

Figure 4.1. Several examples of normal distributions



Extreme situations in a normal distribution are also considered extreme in other statistical phenomena such as the assessment of the differences between two groups (learner drivers or provinces). Is it likely, based on their performances (in driving tests or in terms of accident risk), that they are equal, or does one group perform better than the other, which results in differences? In statistical terms a difference is significant if the chance that a similar difference occurs by coincidence (while the groups are, in fact, equal) is less than 5%. Although it is not 100% certain that the groups differ, a 5% margin of error will be accepted. It will be concluded that in 5% of the cases the groups differ while in reality this is not the case. If the margin of error needs to be even smaller, a significance level of 1% is maintained and the marginal values lie at $\mu \pm 2.58\sigma$. The significance level, therefore, indicates the chance that something is accepted as true while in reality it is not.

If a result is statistically significant, this does not automatically mean that the result is also of practical importance. Significance should not be confused with importance. Whether a particular result is significant largely depends on the size of the sample. The larger the sample, the more likely it is that the result will be significant. In large-scale samples, differences that have little meaning can be significant nonetheless. Should, for example, value be attached to a 0.2% reduction in the percentage of people who wear their seat belts if this is measured in a sample of 100,000 motorists? Significant simply means that a result is not founded on coincidence.
The question is whether practical consequences should always be attached to significant differences (for example set up a campaign focusing on the importance of wearing a seat belt) [4.19].

4.3.3 Connections between variables

Relational research concerns a combination of data from two or more variables, and studies the connection between a dependent variable and one or more independent variables. The dependent variable is the event studied. In general, it is a variable at interval measurement level or higher: the number of accidents, the number of casualties, the driving test score, the percentage of people who drive under the influence of alcohol. The independent variables are variables that could explain or influence the values for the independent variable. These variables are often manipulated in experimental research (see section 4.5) to study whether, for example, the type of driving instruction has an influence on performance during the driving test. In this case, the driving instruction is the independent variable and the performance during the driving test is the dependent variable.

Different analytical techniques can be used to determine whether the connection between two variables is positive or negative. A connection is deemed positive if high values for one variable correspond with high values for the other variable. A negative connection is characterised by high values for one variable and low values for the other. It is also possible to test whether the connection is more profound than could be expected based on coincidence. The statistical tests that are available for this differ in terms of measurement level of the variables that are being compared. The Chi-square test (X^2) or Cramer's V is used to test the relationship between two nominal variables, Spearman's rho is used to assess the connection between two ordinal variables, and Pearson's correlation-coefficient is used to test the connection between two variables at interval level or higher.

The correlation between a quantitatively independent variable (interval or ratio) and a dependent variable can be studied with the help of regression analysis. This technique is used to predict the values of the dependent variable on the basis of the values of one or more independent variables (see section 4.4.1). The influence of a qualitatively independent variable (nominal or ordinal) on a dependent variable can be determined on the basis of t-tests or variance analysis (see section 4.4.2).

The problem with relational research is that, in contrast to purely experimental research (see section 4.5), it can never be established with complete certainty whether the correlation between the dependent and the independent variable cannot actually be explained by a third variable that is not included in the research. This is called the 'third variable problem'. If, for example, the number of firemen who tend to a fire and the scale of the damage that the fire causes are measured, these two variables are positively correlated. The more firemen, the greater the damage. It may be clear that it would be absurd to conclude that an increase in the number of firemen is the cause of an increase in the scope of the damage. The real explanation for this correlation is the following (unmeasured) third variable: the scale of the fire [4.1, 4.12].

4.4 Common analysis techniques

Different techniques are available for the analysis of road safety data. The following sections discuss the techniques most commonly used in scientific articles and reports.

4.4.1 Regression analysis

Classic linear regression is a technique that is used to work out how accurately the scores for a variable (the dependent variable) can be predicted from the scores for one or more other variables (the independent variables). This requires more than just the connection between the variables. A regression weight is calculated for every independent variable, which indicates whether the connection with the dependent variable is positive or negative. For every regression weight, additional assessments can be made as to whether the relationship with the dependent variable is significant or not. The basic principle of this technique is that the correlation between the dependent and the independent variables is linear. This means that the measuring points in a diagram lie along a straight line (with the exception of measuring errors). The further assumption is made that the measuring errors (residues) of the model are independent of one another and normally distributed with similar standard deviations. A residue is also called an error of estimation or a prediction error and is the difference between the estimated value and the observed value [4.12].

Classic linear regression has many variations and extensions. Multi-level models [4.16], for example, take into account the fact that observations display a hierarchical structure. In research into the performance of school children, for example, children are ‘nested’ within school classes, school classes are ‘nested’ within schools, et cetera. While the data is analysed collectively, the differences between school classes and schools are also taken into account. In research into the voting behaviour in households, the household members constitute one level and the household itself a second level. If linear regression fails to take such structures into consideration, this can lead to incorrect conclusions concerning the correlation between dependent and independent variables.

4.4.2 Variance and co-variance analysis

Variance and co-variance analysis are the appropriate techniques for analysing data that is collected in an experimental setting (see section 4.5). A variance analysis is also known as an ANOVA, the acronym for ANanalysis Of VAriance. Variance analysis is a technique that is used to simultaneously compare a number of group means. The analysis studies whether the variance between groups is greater than might be expected on the basis of the variance within the groups. If this is the case, the groups differ from one another, which is tested using the F-test. In some cases, a non-random distribution of people over the groups being studied might be suspected. A comparison of the number of accidents in two groups of intersections, for example, may indicate that a difference in traffic volume has influenced the outcome of the analysis. In this case, a co-variance analysis may be opted for, which is adjusted to incorporate the effect of the interfering traffic volume variable included as a co-variant. The values for the dependent accident variable are then cleared from the influence of the traffic volume variable. Interfering variables are also known as confounding variables. For more information on this technique, see [4.13].

4.4.3 Principal component analysis and factor analysis

Principal component analysis and factor analysis are techniques that are used to reduce a large number of variables to only a few core variables. They are, therefore, very well suited for the reduction of large amounts of information. These techniques are also used to reduce questionnaires that have long lists of questions to only a few subscales.
In a study into the road safety education [4.20], school children were asked to answer a questionnaire containing forty questions that were all concerned with how the children behaved in traffic. The principal component analysis showed that the answers provided by the children could be reduced to a new variable that varies between unsafe (with a low score) and safe (with a high score) traffic behaviour. In these analyses, Cronbach’s alpha describes the extent of internal consistency of the items by using a number to indicate how well the original variables are represented by the newly construed variable. These analyses were initially developed for the analysis of variables with an interval measurement level. Principal component techniques were later generalised in the analysis for variables of mixed measurement level, see [4.12].

4.4.4 Time series analysis

One of the key tasks in a road safety study is to monitor, describe, explain and predict developments in road safety. If this occurs in a quantitative manner, analysis techniques are required to implement these activities in a responsible fashion. As the term ‘development’ already implies, the analysis concerns a very special type of data, which always comprises repetitive measurements over time of a particular aspect of the traffic process, such as the total number of traffic fatalities. This type of information is also called a time series.

An important characteristic of the observations in a time series is that, for the most part, they are not independent of one another: after all, the number of traffic fatalities observed last year is often a pretty good indicator of the fatality statistics for this year. Given that standard techniques stem from independent observations, the analysis of time series data with standard techniques such as regression analysis (see section 4.4.1) often results in residues that are also mutually correlated, even when statistical tests and reliability limits are based on the crucial assumption that the residues found are random, and, therefore, independent of one another.

The ARMA, ARIMA and DRAG models have been specially developed for the analysis of time series. Generally speaking, these models take greater consideration of the dependencies in the observations than the classic regression models, linear or otherwise. A more recent development in the analysis of time series are structural time series models or state space models. These models are very flexible: they can easily handle missing observations and are simple to expand into multivariant time series analysis models. Another advantage of structural time series models is that the results of these models can be directly compared with the results of linear regression models.

Time series analysis, therefore, can be used to describe developments in road safety as well as:
- to evaluate the effects of measures and other variables on developments in road safety;
- to study whether newly published figures deviate from expectations based on the past;
- to forecast future developments in road safety.

COST 329 [4.7] compares several different time series models in terms of their suitability for analysing developments in road safety. The SWOV factsheet on this subject is an accessible introductory text on the time series analysis. For introductory textbooks on these techniques, see [4.5, 4.6].

4.4.5 Meta analysis
Meta analyses are used to summarise the results of different studies into the effect of a particular measure on road safety. Since each individual study can result in varying estimations of the effect, integrating the different effects into a collective analysis may result in a better estimate of the measure's effect and the expected variations. Examples of meta analyses in road safety include [4.14] and [4.11] into the effects of daytime running lights (MVO) and [4.20] into the effects of the different forms of road safety education.

4.5 Experimental road safety research

4.5.1 Research question
Like every other study, setting up an experimental road safety study begins by formulating a research question. The nature of the research question is important to decide on which type of study is to be conducted in order to answer the question. The following section discusses how to go about road safety research on the basis of the following research question:

> Has the conversion of intersections into roundabouts had a positive effect on road safety?

This question concerns the evaluation of the effect of a road safety measure. The first thing that can be said about this research question is that it is so vague and general that no significant research could stem from it. Actually, this research question itself raises two important questions.

The first is: 'What is meant by road (un)safety?' Is it the number of accidents that occur at intersections and roundabouts (regardless of the outcome)? Or is it the total number of accidents with fatal consequences? Or the total number of fatalities? And are these the figures as registered by the police? Or by insurance companies? Or hospitals? The answers to these questions ensure that a relatively abstract concept such as road (un)safety is concretised such that it can also be measured. In research, this transition is also known as the operationalisation of variables.

The second question is: 'Does this relate to every type of intersection?' Or is it only focused on those within the built-up area or on four-way intersections, etc.? The answers to these types of question relate to the determination of the population about which a conclusion is to be drawn after the research has been completed. This is also important in determining what sample of intersections will be used in the research.

It is agreed, for example, that 'road unsafety' will be measured as the total number of fatalities and hospitalisations as registered by the police over a particular period of time. It has also been decided that the research question should be limited to intersections in the Netherlands outside the built-up area.

Now that it has been determined what is meant by 'road (un)safety' and which population of intersections will be studied, we can go through the next steps of an experimental study.

4.5.2 Experimental study design

Firstly, a random sample of, say, sixty intersections is taken from the population of intersections in the Netherlands outside the built-up area. The word 'random' means that every intersection in the population of intersections has an equal chance of being part of the sample. Only then will it be permitted to generalise the findings for the sample of sixty intersections after the research has been completed to the population of intersections outside the built-up area.

The next step is to divide the sixty intersections in the sample into two equal groups of thirty by means of random allocation. The thirty intersections in one group will be converted into roundabouts and belong to the experimental group. The other thirty will not be converted and belong to the control group.

The aim and importance of random allocation to an experimental and a control group are that every possible a priori difference between the intersections in relation to their road safety (for example the volume of traffic over a 24-hour period, lighting) is divided as evenly as possible over the two groups.

This is followed by a measurement of the number of fatalities and serious injuries at each of the sixty intersections – over a well-considered period of time – prior to the conversion into roundabouts of the intersections in the experimental group. This is called the pretest. The thirty intersections in the experimental group are then converted into roundabouts, after which – again, over a well-considered period of time – the number of fatalities and seriously injured casualties is measured for each of the sixty locations being

Table 4.4. The ideal test design

		Pretest	Posttest
Experimental group	s1	17	8
	s2	22	2
	...	...	...
	s30	24	12
Control group	s31	8	17
	s32	12	25
	...	...	...
	s60	23	26

studied. Of these locations, thirty are now roundabouts (the experimental group) and thirty are still intersections (the control group). This second measurement is called the posttest.
A 'well-considered period of time' means a period long enough to measure sufficient numbers of casualties. In addition, the start and end dates for the period in which the measurements will be taken must, of course, be the same for all locations.

After the experiment has been completed, the data found can be presented in a table such as table 4.4, in which the numbers 17, 22, et cetera, are the numbers of fatalities and seriously injured casualties that were observed during the study. Together, they form the dependent variable. The independent variables are 'time' (with two levels: pretest and posttest), 'condition' (with two levels: experimental and control group), and the interaction between 'time' and 'condition'. The letter s in the symbols 's1', 's2', et cetera, in table 4.4 is short for 'subject'. Because the objects of observation in experiments are often subjects, English handbooks on research design tend to use this abbreviation. Although the objects of the observation in table 4.4 are not subjects but intersections, this conventional notation system is maintained nonetheless.

4.5.3 Analysis

The data in table 4.4 can be analysed using variance analysis, the results of which are presented in table 4.6. This table shows a number of tests that can assess whether the different data mean in table 4.4 differ significantly from one another or not. The relevant data mean are shown in table 4.5.

Tabel 4.5. Data mean in table 4.4

	Pretest	Posttest	Mean
Experimental group	20.3	9.2	14.8
Control group	19.5	20.1	19.8
	19.9	14.7	17.3

The heading 'SS' above the second column in table 4.6 is the abbreviation for Sum of Squares, 'df' above the third column stands for degrees of freedom, 'MS' above the fourth column is short for Mean Squares, the value of which is equal to that of 'SS' divided by 'df'. The fifth column of table 4.6 (with the heading 'F') shows the value of the F-test that is used to determine whether the differences between the mean significantly deviate from zero. The figures in square brackets indicate what values in the 'MS' column are divided in order to arrive at the value of the F-test. In determining, for example, the effect of 'time' in table 4.6, the following value is calculated: [1/3] = 826.9/23.1 = 35.8. This manual is too limited to go into the details of every calculation in an ANOVA table, which is why we refer to the many handbooks on variance analysis [4.13].

The first F-test with the value 35.8 in table 4.6 (for 'time') indicates that the mean number of fatalities and serious injuries in the pretest is significantly different from those of the posttest, irrespective of whether this relates to the intersections in the experimental group or the control group. These means equate to 19.9 (pretest) and 14.7 (posttest), see table 4.5. The significant difference between the two is shown by the value of p in the final column of table 4.6, which indicates the chance that the zero hypothesis for equal means is unjustly rejected. The p value for 'time' equals 0.000. Given that this number is smaller that 0.01, the chance that the zero hypothesis will be unjustly rejected is less than 1%. We can, therefore, conclude with great certainty that the pretest and posttest means differ from one another.

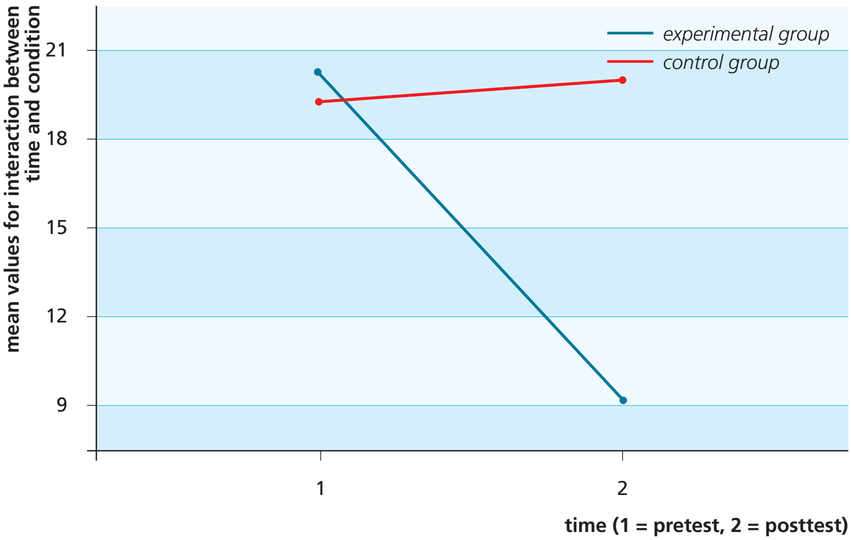
The same is true for the mean of the experimental (14.8) and the control group (19.8), irrespective of whether it concerned pretest or posttest (see the means in table 4.5 and the F-test with the value of 27.5 for 'condition' in table 4.6). These two means also differ significantly at 1% level. The tests for 'time' and 'condition' are both significant, therefore. These variables, however, are not important in answering the research question, with the interaction between 'time' and 'condition' being the only relevant aspect of the research design.

Table 4.6 also indicates that the F-test for the interaction between 'condition' and 'time' – with a value of 43.5 – is significant at 1% level. This means that the change between pretest and posttest in the number of fatalities and serious injuries in the experimental group was different to the control group. How different they were can be most easily seen by presenting the four means for this interaction (for instance 20.3, 9.2, 19.5 and 20.1, see table 4.5) in a diagram such as figure 4.2.

Table 4.6. ANOVA table for the data in table 4.4

Source	SS	df	MS	F	P
1 time	826.9	1	826.9	[1/3] = 35.8	0.000
2 condition x time	1003.4	1	1003.4	[2/3] = 43.5	0.000
3 error(1)	1339.2	58	23.1		
4 condition	765.1	1	765.1	[4/5] = 27.5	0.000
5 error(2)	1615.4	58	27.9		
6 total	5553.0	119			

Figure 4.2. Means for the interaction between time and condition



This diagram clearly shows that the pretest means of the experimental and the control groups are more or less the same. This is the result of the random allocation of the sixty intersections into two groups. It is also clear in figure 4.2 that the control group means remained more or less the same for pretest and posttest, while those of the experimental group were lower at posttest than pretest.

This indicates that the conversion of thirty intersections into roundabouts is linked to a reduction in the number of fatalities and serious injuries. A pleasant side effect of this experimental design is that it can also be concluded that the measure (the conversion of intersections into roundabouts) was the cause of this reduction. If the sixty intersections form a random sample from the population of intersections outside the built-up area, then it is permitted to generalise the conclusions drawn from this study to incorporate every intersection outside the built-up area. The final conclusion of this study is, therefore, that the conversion of intersections outside the built-up area into roundabouts results in a reduction in fatalities and serious injuries. The scale of the reduction can also be determined, as can the expected variation (lower and upper limits).

4.5.4 Alternative designs and consequences for the conclusions

A number of alternative studies will now be dealt with that can also be used to answer the above-mentioned research question. We will look at how they differ from the ideal design and what the consequences are for the conclusions that can be drawn from the research results.

Experiment without pretest

The first alternative study design is identical to that dealt with in section 4.5.2, with the only difference being that no pretest is carried out (table 4.7). The only independent variable in this study design is 'condition'. The mean number of fatalities and serious injuries in the posttest was 9.2 for the experimental group and 20.1 for the control group.

Table 4.7. No pretest

		Posttest
Experimental group	s1	8
	s2	2
	...	...
	s30	12
Control group	s31	17
	s32	25
	...	...
	s60	26

Table 4.8. ANOVA table for the data in table 4.7

Source	SS	df	MS	F	P
1 condition	1760.4	1	1760.4	[1/2] = 76.4	0.000
2 error	1337.2	58	23.1		
3 total	3097.6	59			

As is clear from table 4.8, the test for 'condition' is significant at 1% level ($p < 0.01$), which means that the zero hypothesis for equal means in the experimental and the control groups can be rejected.

Can it now be concluded that the measure has led to a reduction in the number of casualties? The answer is yes, but only if the sixty intersections were randomly allocated to the experimental and control groups. If this was not the case, an alternative explanation for the impact that the measure was found to have had is that the experimental group and the control group differ in other aspects that also relate to the dependent variable. If, for example, the traffic volume over a 24-hour period at the intersections in the control group is coincidentally much higher than on the roundabouts in the experimental group, these differences form a potential alternative explanation for the effect found. In the analysis, such a characteristic can be statistically adjusted with the help of a co-variance analysis if this characteristic was also measured.

Experiment without control group

Another alternative study design is shown in table 4.9, and features pretest and posttest but no control group.

The only independent variable now, therefore, is 'time'. The average number of casualties during the pretest was 20.3 and in the posttest 9.2. The result of the variance analysis of this data is shown in table 4.10. The test for 'time' is significant at 1% level ($p < 0.01$), which means it can be concluded that the conversion of the thirty intersections into roundabouts is linked to the reduction in the number of traffic casualties.

The question now is whether it can be concluded that the measure brought about a reduction in the number of traffic casualties? The answer is no, because the reduction could just as easily have been caused by other measures such as:

1 a generally declining trend;
2 regression to the mean;
3 changes in registration;
4 external circumstances other than the measure.

A combination of these four alternative explanations is also possible. This is briefly explained below.
The first relates to the fact that the number of fatalities and serious traffic injuries in the Netherlands has been gradually declining since the 1970s. This could constitute a (partial) explanation for the differences between the pretest and posttest in the first alternative explanation above. The second explanation is relevant if the thirty intersections studied in the pretest phase show an above-average number of casualties. In this case, the number of casualties in the second measurement could have shifted towards the mean on the basis of coincidence alone, which in itself results in an apparent reduction in the number of casualties. This phenomenon is called statistical regression to the mean. In the third explanation, the number of casualties could only have apparently decreased if the police are less accurate in registering accidents in the posttest phase

Table 4.9. No control group

		Pretest	Posttest
Experimental group	s1	17	8
	s2	22	2
	…	…	…
	s30	24	12

Table 4.10. ANOVA table for the data in table 4.9

Source	SS	df	MS	F	P
1 time	1826.0	1	1826.0	[1/2] = 94.6	0.000
2 error(1)	559.5	29	19.3		
3 error(2)	687.8	29			
4 total	3073.3	59			

than in the pretest phase. An example of the fourth alternative explanation is that, between pretest and posttest, the cost of petrol has risen so sharply that people are travelling less by car.

This illustrates the extreme importance of including a control group in the research design and of the random allocation of the intersections into two conditions. If there is evidence of a generally declining trend, statistical regression, a change in registration, other external circumstances, or a combination of all four, the intersections in the experimental group and those in the control group will be influenced by the factors in equal measure between pretest and posttest. If the interaction between 'condition' and 'time' is significant in this case, only one possible explanation remains for the effect found: the measure itself.

Finally, it will be clear that a simple pre- and post-study in which the change in the numbers of casualties before and after the conversion of just a single intersection into a roundabout is studied would provide significant room for criticism of the conclusion that the measure taken has had an effect. If a reduction in the number of casualties is found in such a study, the alternative explanation for the effect of the measure would be that the reduction is purely coincidental [4.13].

No random allocation into control or experimental groups

It is sometimes impossible for practical or ethical reasons to randomly allocate research objects into experimental or control groups in road safety studies. One example is the research question of whether motorists who drive under the influence of alcohol, drugs or medicines (or a combination) have a greater risk of being involved in an accident. It is clear that, in this case, it is not possible to randomly allocate a random sample of motorists into experimental and control groups and to then allow the motorists in the experimental group to drive under the influence. In general, it is not possible for ethical reasons to randomly allocate subjects to circumstances that can result in physical injury.

In such cases, what are known as quasi-experimental research designs can be used instead. Quasi means 'resembles' and quasi-experimental research designs are, therefore, designs that resemble real experimental designs in a number of aspects. Given that traffic accidents occur relatively infrequently, the above research question can be answered using a case-control study, in which two groups are specified: the cases and the controls. The cases are traffic casualties that have required hospital treatment as the result of an accident and for whom a blood sample analysis is being carried out to determine whether they used psychoactive substances. In this sense, the cases resemble the experimental group in a real experimental design. The controls are a random sample of road users who have not been involved in a traffic accident, but who resemble the cases in every other respect.
A study is also carried out on this group of road users to see if they have driven under the influence of psychoactive substances. As the name suggests, the controls resemble the control group in a real experimental design. The biggest challenge for case-control studies is to determine what controls resemble the cases in every other respect as fully as possible.

In a case-control study, the dependent variable consists of only two categories, namely whether the road user is a case or a control (which is to say: involved in an accident or not). The independent variable also has only two categories, i.e. whether a road user is under the influence of a particular substance or not. Given that the dependent and independent variables are both nominal, the Chi-square test (see section 4.3.3) can be used to study whether they are connected. However, in contrast to the ideal experimental design described above, no concrete cause-and-effect conclusions can be drawn from case-control studies. For more information on setting up case-control studies and the analysis of data that stems from them, see [4.18].

4.6 Points of attention when evaluating research

The evaluation of road safety research comprises a wide range of aspects, all of which were discussed in the previous sections. The following is a list of the key points of attention:

1 Has the data been measured in a reliable manner? In other words: if they were measured again or by someone else, will the outcome be the same?
2 Are the measurements valid? In other words: did they measure what was supposed to be measured?
3 Have the correct statistics and analysis techniques been used, taking the measurement level of the variables into account?
4 Have the correct statistical tests been used?
5 Has the data been checked to see whether they conform to the hypotheses of the analysis technique used?
6 Are there any possible alternative explanations for the relationship between the dependent and the independent variables? Is there perhaps a third variable?
7 How representative is the sample used for the population about which the conclusion is to be drawn?
8 Is the research sufficiently well described so that another researcher could conduct it again purely on the basis of the report?

4.7 Summary

This chapter discussed data collection and data analysis, knowledge of which is important when commissioning road safety research and for reading and evaluating the (quality of the) results of such research.

The chapter first dealt with the data necessary to conduct research into road safety, which was divided into three main groups:
- the number of accidents or casualties;
- the exposure data or, in other words, the level of exposure to traffic;
- the risk data.

Various national and international data sources can be consulted. The Dutch registered accidents database (BRON) is by far the most important source of data concerning accidents on the Dutch road network. This database is based on police registration forms.

Sometimes the data required is not available, so it has to be gathered by means of observation, interviews or a questionnaire. A unique form of observation is conflict observation, for which the DOCTOR technique can be used. It is important for all forms of research and data collection that the data is reliable and valid.

Individual data does not say much about road safety in a particular area or for a particular group of road users, which is why this chapter discussed the summation and comparison of data. A term that is frequently used in this respect is variable. Of the various techniques that can be used to analyse road safety data, the most common ones are: regression analysis, variance and co-variance analysis, principal component analysis and factor analysis, time series analysis and meta-analysis.

This chapter also touched on experimental research, looking into the choices that need to be made when designing and conducting experimental research and the consequences of these choices. The chapter ended with the key points of attention in the evaluation of road safety research.

Glossary

Most of the terms used in this chapter are listed in alphabetical order below. A more detailed explanation of some of these terms can be found in [4.19].

Categorical variable
Variable with values that are measured at nominal measurement level. The 'value' of a class (1,2,3…) is nothing but a name for that class.

Central tendency
A numerical summary of the values measured. Examples are mean, median and mode.

Chi-square test
Test that is used to study the relationship between variables at nominal measurement levels.

Correlation
Relationship between two variables at interval or ratio measurement level.

Dependent variable
The variable whose values the study endeavours to explain and understand. Examples include the number of accidents, the number of casualties and the accident risk on a particular road. This is a variable that is typically beyond the influence of the researcher. Regression and variance analysis attempt to explain the different values of these variables based on the values of one or more independent variables (see also independent variables).

Distribution
Distribution relates to the extent to which the values of a variable differ.

DOCTOR
Dutch Objective Conflict Technique for Operation and Research (see section 4.2.3).

F-test
Variance analysis test that determines whether the variance between groups is greater than might be expected on the basis of the variance within the groups.

Independent variable
This is a variable that might explain or influence the values of the dependent variable (the variable that is being studied). In the context of experimental research, an independent variable – unlike a dependent variable – is a variable that can be manipulated by the researcher (see also dependent variable).

Interassessor reliability
The reliability of different assessors. Are they capable of finding the same values for an object to be measured or evaluated with the same measuring instrument or on the basis of the same instructions? Interassessor reliability is determined by having two people measure a number of objects. If the measurements correspond for each object, interassessor reliability is high.

Intra-assessor reliability
The reliability of the same assessor. Is this assessor capable of finding the same values for an object to be measured or evaluated with the same measuring instrument or on the basis of the same instructions at different times? Intra-assessor reliability can be determined by having the same person measure a number of objects at different times. If the measurements correspond for each object, intra-assessor reliability is high.

Mean
The average value of a series of quantities. This value is calculated by adding up all the quantities and then dividing by the total number of quantities. This is also called the arithmetic mean. Calculating the average value of a series of quantities is only meaningful for variables at an interval or ratio measurement level. At lower measurement levels, the median or mode is used to summarise the series.

Median
The median is the middle value of a series of numbers that is ordered from low to high. Determining the median is only meaningful for variables at an ordinal measurement level or above.

Measurement level
The quality of numbers that are attributed to characteristics, such as hair colour, age or height. There are four different measurement levels: nominal, ordinal, interval and ratio. At the lowest level (nominal), the numbers offer very little information, being nothing other than a label that is attributed to a characteristic. At the highest level (ratio), objects can be compared and the mean value can be calculated. It is possible to say, for example, that one car is twice the length of another car. It is also possible to calculate the mean length of a group of vehicles (see section 4.3.1 for a more detailed description of the different measurement levels).

Mode
The mode is equal to the most common number in a number series, and, therefore, the value with the highest frequency. The mode is used to calculate all types of variable regardless of the measurement level.

Non-response
The percentage of people who refuse to participate in research or who refuse to answer particular questions on the questionnaire. A high non-response level is a threat to the representativeness of the sample because certain groups refuse more often than others, for example people who have no time because of work, people who travel a lot or people who are simply not interested in the subject. This latter situation creates the danger that only those people interested in the study will respond.

Operationalisation
The transition in which a theoretical concept or term (road safety or intelligence, for example) is translated into something that can be measured (the number of fatal traffic accidents a year or the results of an intelligence test, for example).

PET ('post encroachment time')
Measure for the chance of collisions. The PET is defined as the time lapse between the end of encroachment of the turning vehicle (t1) and the time that the through vehicle actually arrives at the potential point of impact (t2). The lower the PET (= t2-t1), the higher the chance of a collision. See also TTC (time to collision).

Population
The total group of objects or persons about which the study aims to reach a conclusion. Examples include 'all 30 km/h zones in the province of Utrecht' and 'all Dutch motorists'.

Posttest
The measurement of a dependent variable after the intervention (a road safety measure, for example), the effect of which is to be determined in an experimental design.

Pretest
The measurement of a dependent variable before the intervention (a road safety measure, for example), the effect of which is to be determined in an experimental design.

Random allocation
The experimental research procedure that ensures that every object of research in the sample has an equal chance of being included in the control or the experimental group. Random allocation prevents variables that have not been measured in the study from offering an alternative explanation for any effect that the measure is found to have had.

Random sample
A sample whereby every member of the population has an equal chance of being included.

Reliability
The reliability of a measuring instrument in the sense that if the same object is measured repeatedly (for example the length of a road section), it will provide the same value. Reliability can be determined by measuring the same object several times. If all measurements concur, the instrument is deemed reliable.

Representative
A sample is representative if the characteristics of the objects or persons in the sample correspond with the characteristics of the objects or persons in the population about which a conclusion is to be drawn. A sample of Dutch motorists, for example, is sufficiently representative if the age division within the sample is equal to that of the entire population of Dutch motorists, with the same applying to the percentage of men and women. It would be even better if the annual kilometres travelled by each motorist, the use of the road network and the division throughout the provinces also corresponded.

Residue
A residue (also known as an error of estimation or a prediction error) is the difference between the value predicted by a model (for instance linear regression) and the observed value of a variable. The smaller the residue, the more the model can predict the value of a variable.

Respondents
People who have completed their study questionnaires.

Response
The percentage of people that returned a completed questionnaire or that are willing to take part in an interview or study.

Standard deviation
Standard deviation is the most commonly used measure for the distribution of variables at ratio or interval level and indicates to what extent the values of a variable differ from one another (and, therefore, from their mean). The greater the standard deviation, the greater the mutual differences between the values of a variable (and the greater the differences between the values of the variable and their mean). Standard deviation is equal to the root of the variance and expresses the distribution in the original measurement unit of the variable concerned (see also distribution and variance).

Statistical regression to the mean
This refers to the phenomenon whereby extremely high and extremely low values of a variable during a second (later) measurement have the tendency to shift in the direction of the mean of that variable – therefore becoming less extreme than during the first measurement – due to the fact that a proportion of the values at the first measurement was coincidentally high or low.

Sample
The proportion of the population interviewed or studied in order to learn more about the population (see also population and random sample).

Survey research
Collective name for research based on questionnaires and/or interviews.

TTC ('time to collision')
Measure for the chance of collisions. The TTC is defined as the time required for two vehicles on a collision course to collide if they continue at their present speed and on the same path. The lower the TTC, the higher the chance of a collision. The TTC can only effectively predict the chance of a collision if two road users are on a collision course. If road users experience a near-miss at high speed without changing their speed or direction, this does not, technically speaking, constitute a collision course despite the chance of a collision being very real in such situations. A minute alteration in speed or direction could easily lead to a collision. In such cases, the chance of a collision can be determined by the PET.

Validity
The extent to which a measuring instrument is capable of measuring what is supposed to be measured. In contrast to an unreliable measuring instrument (which results in random measuring errors), an invalid measuring instrument leads to systematic measuring errors. In terms of questionnaires and interviews, for example, validity can be compromised if suggestive questions are asked or socially desirable answer categories are used. The validity of questionnaires and interviews can play a role if suggestive questions are posed or socially desirable answer categories are used. Such measurements do not reflect public opinion but what people think the researcher wants to hear.

Variable
A characteristic that can vary from person to person or object to object. A variable that relates to a person, for example, is age, and a variable that relates to an object is, for example, vehicle type (see also dependent and independent variables).

Variance
Variance is a second commonly used measure for distribution and also indicates to what extent the values of a variable differ from one another (and, therefore, from their mean). Variance is equal to the square of the standard deviation (see also distribution and standard deviation).

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5 Practical research

Learning objectives for students:

- to be able to list a number of pragmatic methods that are used to gain insight into road unsafety;
- to make a conscious choice for a particular tool or combination of tools based on the study question.

5 Practical research

5.1 Introduction

This chapter deals with applied research into road safety. Applied practical research focuses on collecting specific information in a specific location, and consequently provides more depth.

From problem to evaluated solution

Despite the improvements that have been made to the way in which road safety has been approached over the last decade, there is still a tendency to employ an ad-hoc approach: one or two accidents take place at an intersection, reports follow in the press, questions are asked in the municipal council and parties are tempted to tackle that one problem at the cost of all others. Specific solutions are also frequently thought up before the problem has been thoroughly looked into (We want speed humps! We want traffic lights! We want more police checks!). An alternative to this unco-ordinated way of working is the more methodical 'PCOSE' approach.

Each of the successive phases in this approach – Problem (exploration), Cause (determination), Objective, Solution and Evaluation – leads to solutions that can be used as input in the phase that follows.

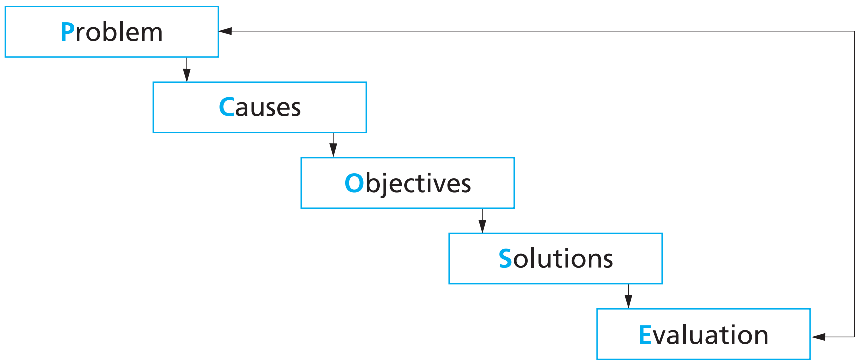
Problem analysis

Both this and the previous chapter contain comprehensive explanations of how an analysis of the problem at hand can be reached. Analyses of road safety problems involve listing the different data sources and ordering, processing, and analysing the data to be used.

Determining the cause

The following step is to see who and/or what the cause of the observed and analysed problem is.

Figure 5.1. PCOSE approach, a systematic approach to problem-solving



Choosing an objective

The objectives of the road safety measures to be taken can be listed using the 'SMART' checklist, which means that an objective is:

- Specific. Not, therefore, 'an improvement in road safety', but 'fewer victims at intersection Y', or 'a 5% increase in the use of helmets by moped riders at regional level'.
- Measurable. The objective must indicate a standard that can be used at a later stage to measure whether the objective was achieved. Zero measurements are often required in order to have a reference against which the results of the measures can be compared.
- Achievable and Action-oriented. Optimum motivation can only be achieved if the objectives are supported by all parties.
- Realistic. The objectives must be achievable with acceptable effort.
- Time-bound. A deadline must be given for realisation of the objective.

The primary purpose of objectives is to enable people to agree on what is to be achieved, as well as to check as they go along whether the objective will be achieved or whether adjustments are required.

Solution

The solution to a road safety problem will almost always be a question of combining measures. These could be infrastructural (engineering), educational (education) and enforcement-related and are often a combination of the three. See the introduction concerning the three Es in part 2 of this manual.

Evaluation

An evaluation can be a process, product or effect evaluation. Effect evaluation relates to the question of whether the intended effect (for example lower speed, fewer victims, fewer complaints from residents) has been achieved. Process evaluation focuses on how that effect was achieved. Key elements in this respect are sticking to the schedule and observing agreements made between those involved.

The PCOSE approach is already several years old, but it still offers a useful structure for tackling problems and places a useful and effective fence round the pitfalls of the ad-hoc approach.

The PCOSE approach is by definition a curative rather than a preventive approach, and is therefore not the same as Sustainable Safety, but the two are not necessarily in conflict. Whatever the case may be, solutions that result from a PCOSE approach should not contradict the Sustainable Safety philosophy.

Both this chapter and chapter 4 primarily address problem analysis and determining the causes in the PCOSE series. Following chapters discuss the solutions at various levels.

Know what you are measuring

Road safety also adheres to the maxims to measure is to know and know what you are measuring. The following question illustrates this: which two-wheeled vehicle is the least safe – the bicycle, the moped or the motorcycle? Table 5.1 features a comparison of the three different groups of two-wheeled vehicles for the criteria number, severity and mutual risk [5.1].

Table 5.1 Comparison of three different groups of two-wheeled vehicles

	Absolute magnitude			**Mortality (relative severity)**			**Risk of victims**		
	Death	Hosp*	EA**	Death	Death +Hosp*	Death / Hosp*	Death	Hosp*	EA**
Bicycle	high	high	high	low	low	low	low	low	low
Moped	medium	medium	medium	medium	high	medium	high	high	high
Motorcycle	low	low	low	high	high	high	medium	medium	medium

* hospitalisation
** emergency assistance

It can be concluded that many more cyclists and moped riders are victims of accidents than motorcyclists. However, it can also be concluded that the risks connected to cycling are far lower than those connected to mopeds or motorbikes. Both conclusions are valid, but the differences remain.

Another point is that while accident figures provide information about the safety of the road user, they do not say anything about the influence this has on the safety of other road users. A cyclist very rarely kills a pedestrian or a motorist in an accident, but the same cannot be said of the motorist with regard to the other two. The conclusion that many pedestrians and cyclists are traffic victims does not mean, of course, that cycling or walking less will result in an increased level of road safety.

Absolute values concerning road unsafety

The key advantage of absolute values concerning road unsafety is that they form a simple criterion. If the absolute number of accidents is the basic principle, emphasis is automatically on busier roads; after all, more accidents can be expected to occur there. One problem of working with absolute figures is what is known as thinning: serious accidents are relatively scarce and the number of accidents is so low that coincidence plays a substantial role. This renders it difficult to make any statistically significant judgements: fluctuations in safety levels are coincidental rather than resulting from policy or measures that have been implemented. This means that for research into the road unsafety at a particular location on the basis of serious accidents it is often necessary to consider the road unsafety over a number of years before drawing any valid conclusions.

Road unsafety in terms of exposure
It is important to be very careful when calculating the risks and charting the road unsafety against the volume of road users (exposure). The following risk in terms of personal risk per billion kilometres travelled can be calculated for various modes of transport from the incremental figures taken from accident statistics and Statistics Netherlands' mobility figures for 1999-2001.

	Total number of kilometres travelled per year	**Traffic fatalities per billion kilometres travelled**	**Injuries requiring hos-pitalisation per billion kilometres travelled**
Pedestrian	3.25	33.25	408
Cyclist	13.00	15.08	536
Moped rider	1.25	77.60	2448
Motorist and other	158.10	3.63	40

Apparently, the moped rider runs a significant risk and the car is by far the safest mode of transport.
The cyclist and the pedestrian occupy a more neutral position. In this table, the number of victims is charted against the total number of kilometres. Remember that more rapid modes of transport travel relatively more kilometres in the same period than slower ones. It can therefore be concluded that charting the road unsafety against the number of kilometres travelled is incorrect; after all, a car goes markedly faster than a pedestrian or a cyclist. This is why the faster modes of transport stand out as being relatively more favourable than the slower ones. If road unsafety is calculated by time spent in traffic rather than number of kilometres, the same accident statistics would generate the following table.

	Total number of hours in traffic per person per year	**Traffic fatalities per million hours in traffic**	**Injuries requiring hospitalisation per million hours in traffic**
Pedestrian	41.5	0.16	2.00
Cyclist	69.8	0.18	6.25
Moped rider	3.5	1.75	55.21
Motorist and other	276.8	0.13	1.43

In this way, the moped rider still runs the greatest risk, but the motorist, pedestrian and cyclist are now comparable in terms of fatalities. It is important, therefore, to always take a critical look at the figures and criteria used.

Road unsafety in terms of road length and volume
It is also possible to chart road unsafety against road length. A measure often used is accident density: the number of accidents per kilometre per year. This measure does not take into

account traffic volume and the emphasis is on roads that are found frequently in the road network in terms of length: roads of the lowest order.
One variation is working with core risk data that incorporate traffic volume as well as road length for each individual road category. Here, the volumes of motorised traffic (passenger car equivalent) are almost always chosen as the measure. As a result, volumes of other road users such as cyclists on busy school routes are not taken into consideration. This can distort the core risk data and render it useless for further comparison.

The combination of measuring methods
It is clear that the different measuring methods lead to different insights. It makes sense, therefore, not to choose a single measuring method but rather a combination of complementary methods. To define problem areas, the Dutch Institute for Road Safety Research (SWOV) employs the following measures:

- the absolute magnitude of road unsafety such as the number of traffic fatalities and injuries requiring hospitalisation per mode of transport and age category;
- the relative magnitude of road unsafety such as the total number of victims for every kilometre travelled, for each mode of transport and for every age category;
- the vulnerability of different modes of transport in conflict situations;
- trends and developments regarding the above measures over time.

These are also the most prevalent measures used in practical research into road safety.

View of policy formulation
It is also important to know what you are measuring when determining how specific and measurable policy should be. Is the aim to minimise the total number of victims? Or should all road users be provided with a certain level of safety (or exposed to a maximum risk)? Is policy focused on the dominant group or on the most vulnerable group? It is clear that the priorities and the development of policy can differ greatly depending on the answers to the above questions.

5.2 Preventive tools

The preventive approach to road safety can be shaped using different tools. Because they are preventive, it is not necessary to wait until a plan or design has been realised. The tools discussed in this section include:

- The regional road safety explorer. A calculation method that focuses on a prognosis of the cost and effect of road safety measures.
- The road safety audit. This can be introduced in different planning phases and involves an expert opinion (from a certified auditor) that uses a standard approach to arrive at a judgement.
- The conflictogram. This is ideal for urban planning designs and provides an insight into the expected conflicts.

There are also numerous other standards and guidelines (such as those by CROW and PIARC) that study road safety in more depth [w5.1, w5.2].

5.2.1 Regional road safety explorer

The regional road safety explorer (RRSE) is a calculation method that makes an estimate of the costs and effects of road safety measures. The SWOV developed this method at the request of the Ministry of Transport, Public Works and Water Management in order to help the different regions in the Netherlands with their traffic and transport plans. Using the RRSE, these plans can be tailored to regional road safety objectives. Road maintenance authorities and regional policy-makers can also use the calculation method to choose cost-effective measures, for which they must enter information in advance about the road network, mobility and accidents, expected relevant developments and intended road safety measures.

The most prevalent measure used to calculate risks within traffic engineering is the number of traffic fatalities or the number of serious casualties per billion kilometres travelled (vehicle or traveller). Risk figures for road sections are calculated by dividing the total number of serious casualties per period by the exposure (traffic volume × road length × period). Risk figures for intersections are calculated on the basis of the number of times an intersection is crossed. Risk figures can be used to compare road safety on different roads.

In the future, the RRSE will be used as a calculation method that can be introduced into third-party software applications and linked to a Geographical Information System (GIS). This road safety module will also be capable of calculating the accessibility and environmental effects of road safety measures.

5.2.2 Road safety audit

In contrast to the road safety inspection, which is aimed at existing situations, a road safety audit primarily focuses on the different design phases. It is an independent assessment of a road construction project designed to identify potential bottlenecks in road safety, preferably before a road is opened to traffic. This can relate to both the assessment of the design of a new road and the reconstruction of an existing one. A road safety audit can be implemented in four different project phases:

- the feasibility study;
- the draft design;
- the final design;
- in practice, just before the road is opened.

The aim is to identify and remedy unsafe aspects at an early stage. Three central questions are:

- Have all the possibilities to optimise road safety been used?
- Does that apply to all road users?
- Does that apply under all circumstances?

This method can be completed within several weeks and is not expensive.

The SWOV developed the road safety audit for the Netherlands. This audit demonstrates the consequences of road safety choices made at an earlier stage. According to SWOV protocol, an audit is only an audit if the following three conditions are met:

- The client approaches an auditor with a signed, written request.
- The auditor records his findings in writing.
- The client informs the auditor in writing what action will be taken regarding the findings, which recommendations will be followed and which will not and why.

Once they have received the project data, the auditors can request an explanatory meeting, if required.

The audit is carried out by an audit team, which generally consists of two members, both of whom are independent and certified road safety auditors that are in no way connected to the project. It goes without saying that (any semblance of) a conflict of interests must be avoided. The auditors must have a thorough knowledge of and experience with the road safety effects of design elements, the implementation of accident analyses and traffic technology. Because the method is carried out by independent and certified road safety auditors in accordance with a standard approach using checklists, it can be considered reasonably objective. At the moment, road safety audits are rarely conducted in the Netherlands, but experiences so far, however few, promise a positive effect on road safety, as was the case in countries where audits have been carried out. Courses are available to become a certified auditor [5.2-5.4].

Checklist for the road safety audit

Different checklists are available for carrying out an audit. The checklist must ensure that the auditor does not miss any of the main aspects to be checked and is linked to different planning phases:

- For a categorisation plan, feasibility study or road section study, the audit focuses on the following:
  - the scale of the project, function of the road, traffic composition;
  - spatial planning, land use, future developments;
  - network effects, future expansions;
  - function in relation to (expected) use by road user groups;
  - road location with distributor and through functions in relation to key (economic) destinations
  - connection to (functions of) the existing road network;
  - mesh of different road categories;
  - continuity, design speed, traffic;
  - number and type of connections.

- For a general design, the audit focuses on:
  - consistent elaboration of the road categorisation;
  - access to private property, sewers and other services;
  - cross-section, horizontal and vertical alignment;
  - intersection design;
  - position of/facilities for slow-moving traffic, pedestrians, cyclists;
  - position of/facilities for public transport and emergency services.

- For a detailed design or specification, the audit focuses on:
  - consistent elaboration of the draft design;
  - intersection design;
  - traffic lanes, carriageways and pavement width;
  - types of speed-reducing measures;
  - signing and marking;
  - lines of sight and visibility;
  - connections to properties;
  - obstacle-free space and road restraint systems;
  - public lighting;
  - traffic management (road work zones);
  - objects, barriers and fences, central reservations;
  - design of facilities for slow-moving traffic, pedestrians, cyclists, public transport.

- Prior to opening, the audit focuses on:
  - differences between design and construction;
  - lines of sight and visibility;
  - facilities for cyclists, pedestrians, et cetera;
  - objects, verges, protection;
  - markings, carriageway separation;
  - road surface, skid resistance, contrast;
  - drainage, landscaping, services;
  - location and visibility of signs and marking and signposting;
  - public lighting.

5.2.3 Conflictogram method

The conflictogram method can be used in the creation of plans for residential areas (renovation of existing areas or new housing). The underlying design principles of this method include: to develop as large residential areas as possible tailored to slow-moving traffic, a minimum number of conflicts between access system for motorised traffic and the access system for bicycles, keeping open the possibility of public transport to the heart of the residential area and bundling of crossing movements of slow-moving traffic over distributor roads.

This method uses a plan of the area to indicate where conflicts are expected and how serious they are likely to be. This creates an idea of the expected road safety problems. The conflictogram method focuses on the different groups of users of public space rather than modes of transport. It can be carried out in different degrees of detail. It is recommended to apply the method on a broad scale first before going through it again at a deeper level.

In the first phase, a plan of the area indicates who the user groups are, where they are located and where they are going. The locations where the lines intersect are conflict points, which in turn create a conflict diagram.

In the second phase, the severity of the conflicts is determined. Table 5.2 can be used for this purpose.

- groups of school children:
  - primary school [A];
  - secondary school [B]).
- residents:
  - children < 4 years of age [C];
  - residents [D];
  - elderly/disabled [E];
  - shopping public [F]).
- workers:
  - commuters [G];
  - work to work [H]).
- leisure seekers:
  - tourists [I];
  - visitors [J]).
- through traffic:
  - motorised traffic [K];
  - slow-moving traffic [L].

Potential conflicts are indicated in grey and black; serious conflicts in black. These serious conflicts must be addressed first.

The third phase looks at whether the conflicts can be prevented by altering plans. The larger the number of journeys or the more vulnerable the user group, the more important it is that origin and destination are close together. In every situation and whenever possible, vulnerable user groups should be prevented from coming into conflict with cars and lorries, and the need to cross traffic arteries should be minimised.

This method is described in the publication 'Road safety and spatial planning' by the Verkeers- en Vervoersberaad Drenthe (Traffic and transport council) [5.7], which also contains indicative figures, key characteristics

Table 5.2. Determining the severity of the conflicts

	A	B	C	D	E	F	G	H	I	J	K	L
A							potentially serious conflict	potentially serious conflict			potentially serious conflict	
B							potentially serious conflict	potentially serious conflict			potentially serious conflict	
C							potentially serious conflict	potentially serious conflict	potentially serious conflict	potentially serious conflict	potentially serious conflict	potentially serious conflict
D							potentially serious conflict	potentially serious conflict			potentially serious conflict	
E							potentially serious conflict	potential conflict	potentially serious conflict	potentially serious conflict	potentially serious conflict	potential conflict
F							potentially serious conflict	potential conflict			potentially serious conflict	potentially serious conflict
G											potential conflict	potentially serious conflict
H											potential conflict	potentially serious conflict
I											potential conflict	potential conflict
J											potential conflict	potential conflict
K											potential conflict	potential conflict
L												potential conflict

potential conflict
potentially serious conflict

and the degree of risk faced by each user group. A simplified (and also more inaccurate) version of this method is to draw circles on the plan around the concentration points where vulnerable road users are based (such as schools and homes for the elderly); locating elements of the access structure (the traffic arteries) within these circles is undesirable.

5.3 Curative tools for objective road unsafety

There are different tools for combating road unsafety. The most important tools available each have their strong and weak points regarding:

- Gaining insight into a certain situation, focused on factors that lead to an objective or subjective road unsafety.
- Diagnosing a certain situation, substantiated in qualitative or quantitative terms.
- Implementing measures to improve a certain situation, in the existing situation or in different planning phases.
- Evaluating measures that have been taken for a certain situation, ex-ante or ex-post.

The following list provides an initial impression of the main tools for studying an objective road unsafety. The methods addressed in this section are:

- High-risk location approach;
- Sustainable Safety Indicator;
- Sustainable Safety module in a network management procedure;
- EuroRAP;
- Roadscape analysis;
- Road safety inspection;
- External behavioural observation;
- Internal behavioural observation.

In addition, there are review possibilities, the police have road safety knowledge and information can be gathered from people living in the area.

5.3.1 High-risk location approach

The high-risk location approach is one of the most traditional ways of improving road safety. This reactive approach tackles unsafe situations at locations with the most accidents. Firstly, a selection process takes place, which determines the best course of action: can the road unsafety be related to a specific location/road section, area or target group? Three different approaches exist:

- AVOC (black spot or traffic accident concentrations analysis) focuses on accident groups that occur in a certain location, thus a road section or intersection.
- AGEB (area analysis) is the method used when accidents occur in a certain continuous area (this can also be a route).
- ASPE (Analysis to groups of specific accidents) is the method used when accidents occur with the same characteristics but in different areas.

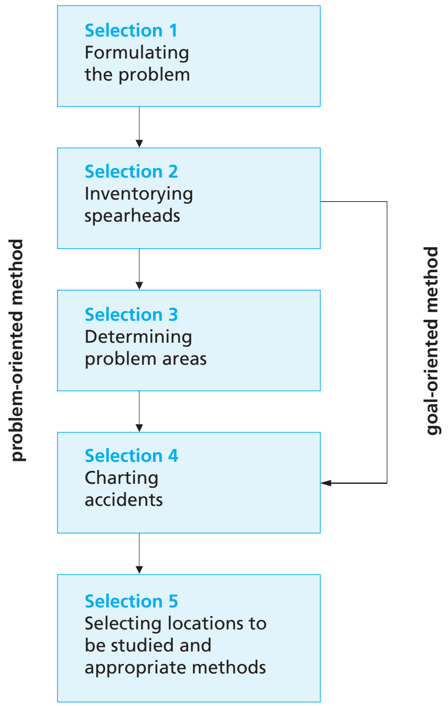
The complete 'Manual on high-risk location approach' consists of six volumes. The first volume focuses on the selection of dangerous situations, the second is about reference figures (AVOC, AGEB and ASPE), the third to the fifth describe the three methods and the sixth comprises the directions for use [5.7-5.12].

The selection

This method is based on a thorough and objective analysis of registered road unsafety (and is, therefore, curative in nature). Selecting high-risk situations is necessary because it is generally impossible to simultaneously tackle every accident location and it demonstrates which analysis method is the most suitable.

This method involves the following steps:

- Selection 1: formulating the problem, which must be concrete and unambiguous as well as clear in terms of the organisation responsible. For example: X fewer victims in year Y in comparison to year Z.



- Selection 2: list local spearheads. Which specific issues are being looked at: road users, traffic situations or accident types? For example: attention to school routes.
- Selection 3: tracing and determining problem areas that stem from an objective road unsafety over a period of three to five years. This selection itself comprises the following steps:
  - examining road characteristics;
  - dividing into classes;
  - tracing problem areas;
  - determining priorities.
- Selection 4: charting accidents. Illustrating relevant road safety.
- Selection 5: selecting the locations to be studied and the appropriate method.
  - AVOC for locations in which ten accidents have occurred in three to five years or five accidents with common characteristics.
  - AGEB for a group of connected intersections and road sections where at least twenty accidents have taken place in three to five years or ten accidents with common characteristics.
  - ASPE for situations in which accidents with common characteristics have taken place in different areas.

The AVOC analysis

An accident concentration exists if the number of accidents that occur at a particular location exceeds a certain number. The following definition is used: if ten accidents have been registered in a period of three to five years or five accidents with ‘a common characteristic’ (for example accidents involving bicycles or accidents with injuries in general), this constitutes a high-risk situation. In practice however, an older definition is also used, namely six accidents with injuries in a period of three years. The steps for the AVOC analysis used at each location are as follows:

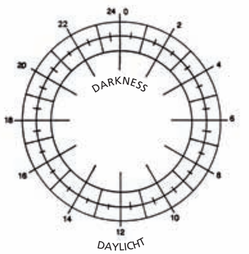
- Gather data: accidents, manoeuvre diagrams, traffic volumes, situation sketches, groups of road users, additional information (for example information from police) and any discrepancies in this image during the research period.
- Conduct an analysis to determine the single largest common denominator in the accidents. The manoeuvre diagram often gives an idea of the dominant accident types, although

Figure 5.2. AVOC worksheet

High-risk location approach — AVOC worksheet

AVOC 2. Conducting analysis
Time analysis table

Road maintenance authority: ______
Location: ______
Client: ______



Day

Year	Mon	Tue	Wed	Thur	Fri	Sat	Sun	Total
Total								

Month

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Total													

there is not always a relationship between the types of accidents. In such situations, it should be determined whether it is possible to arrive at another dominant accident type based on other characteristics. The significance of the similarities and the conclusion that can be drawn from this is the essence of the analysis.

- The analysis is then used to formulate one or more hypotheses for the potential causes of accidents for each of the dominant accident types. The hypotheses must be formulated in such a way that they can be answered in the affirmative or the negative.
- Testing the hypotheses. The AVOC analysis is not a statistical test but a (subjective) sound estimate of the local traffic situation, where possible under the same circumstances as those in which the accident took place. Both findings that are confirmed and findings that are rejected by the hypothesis are recorded.
- If testing the hypotheses proves insufficient, an additional study can be conducted, which can examine conflicts, traffic behaviour and emotions, subjects that, until now, have only been discussed indirectly. If the additional study also fails to provide results, the AVOC research must be wound up without success.
- In order to formulate the causes of accidents, the findings from the hypotheses and the dominant accident types are classified. This is necessary because while they sometimes complement one another, they are often incompatible too. In addition, the different dominant accident types can have one or more common underlying cause(s).
- Only after the causes of accidents have been established is it possible to determine the measures necessary to eradicate them without creating major undesirable side effects. The situation that arises as a result of the measures taken must form a logical and cohesive whole for the road users.

The official worksheets enclosed in the manual should be used in order to ensure comparability of AVOC analysis [5.10].
Although none of the three methods employs the preventive approach according to Sustainable Safety, the proposed measures must satisfy the intentions of Sustainable Safety. While the AVOC analysis is – in contrast – a curative method, it nonetheless fits within the basic principles of Sustainable Safety in the sense that the selection of measures offers possibilities to prioritise when Sustainable Safety is implemented.

Evaluation studies have shown that in locations where the AVOC analysis was applied, the number of accidents fell by an average of 32% and the total number of accidents with injuries by 45%. It should be noted, however, that in half of the projects evaluated using an AVOC analysis there was no reduction in the accident rate in the key accident groups, perhaps due to the experimental nature of the measures applied. In addition, the actual percentages tend to be lower due to the effect of 'regression toward the mean'. In this sense, regression toward the mean signifies, for example, that at an intersection where numerous accidents occurred over a certain period of time due to, among other things, coincidental fluctuations, this number will decrease in the period thereafter. If measures have been taken at that intersection in the meantime, it is tempting to attribute the reduction to those measures. In general, extremely high scores will almost always be followed by low scores tending towards the mean, regardless of the measurement. In this example, the results of preliminary and follow-up studies into the effects of a road safety measure can be put into perspective by looking at how many accidents occurred in the same period in high-risk locations in areas where no measures were taken [5.6].

The AGEB analysis

The AGEB analysis is applied in a geographically continuous area such as a housing estate or an outlying area. The AGEB method is used if in a period of three to five years at least twenty accidents have occurred or ten that share common characteristics. The way the AGEB analysis works is opposite from the AVOC in that, rather than reasoning the cause from the effect (AVOC), the AGEB analysis determines the effect (accident picture) from the cause (design and use of available infrastructure) and then assesses the reasoning. This approach is taken because the cause can result in different types of accidents. While an analysis of accident characteristics would provide a diffuse image in this case, the AGEB analysis can provide a practicable result. The AGEB analysis was also developed for the period before Sustainable Safety, in that it allows particular combinations of functions while Sustainable Safety only permits one function for a road. The original AGEB analysis must therefore be used in reference to current insights [5.9].

The ASPE analysis

The ASPE analysis focuses on people, vehicles and infrastructure. The traffic task is not only a human issue but also relates to vehicles and the infrastructure. Behavioural models play a key role in the ASPE analysis because people are often designated as the cause of accidents in this method, which lends itself to analysis of more diffuse accidents that share common accident characteristics. Examples are ASPE analyses of rear-end collisions or manoeuvres in bends [5.11].

Software for accident analysis

In the development of the Dutch accident registration system – which has resulted in the current accident database – a new method of registering traffic accidents was chosen in which quality plays a substantial role.

The database distinguishes between a spatial component (the place where the accident happened, divided into road sections and intersections and – on hectometred roads – the hectometre points as well) and an administrative component (factual data concerning the accident, the different parties involved and the casualties).

- Each road section has a unique number – the road section ID. In the Dutch Registered Accidents Database (BRON), each location, intersection and road section can only appear once. Updated by the Centre for Transport and Navigation (DVS), the network consists of the current situation on the road network as well as situations from the past, which together are called the 'defunct road network'.
- Each intersection also has a unique number, and defunct intersections exist as well. The situation described above, therefore, also applies to intersections.

The accident is linked to an intersection or a road section. Within any one road section, DVS (previously AVV) does not provide a more exact location, but rather x/y co-ordinates for the middle of the section; these are used exclusively for presentation purposes. For hectometred roads, the accidents are positioned on a road section at hectometre points, which provides an accuracy of 200 metres.

All accidents are provided with x/y co-ordinates, which implies an accuracy that cannot be realised in practice. The establishment of BRON introduced the 'level link', which indicates whether the accident is linked exactly, at street level, at intersection level or at municipal council level. For a limited number of intersections, it is possible to request manoeuvre data from DVS – this data relates exclusively to accidents that occurred at intersections and not those that occurred on road sections.

The broad accident registration database cannot be used manually, which is why various internet applications and software packages have been developed that can reproduce and analyse the accident registration data. The three key functions are:

- managing databanks;
- composing accident groups;
- analysing and presenting data.

The two best-known software packages are Viastat from VIA and Veras from Grontmij (two Dutch consultancies). At one time, the use of advanced programs required thorough training, but software has become more easily accessible; with some packages reports on different subjects can be printed, including text and explanations.

The most common mistakes when using software are:

- careless or mistaken selections or cross-sections;
- failing to bundle or incorrectly bundling intersections that consist of multiple intersection areas (compound intersections. For example, a T-junction on a dual carriageway);
- incorrect interpretation of the results.

5.3.2 Sustainable Safety indicator

While expert opinion is key to the road safety audit, EuroRAP and the Sustainable Safety Indicator work with quantitative scores. These scores indicate the extent to which the characteristics of existing or planned roads correspond with safety guidelines.

The Sustainable Safety Indicator is an application that has been developed to test infrastructural plans in terms of their Sustainable Safety requirements. It was developed by the Institute for Road Safety Research and expresses the Sustainable Safety level as a percentage, which is worked out by calculating the extent to which the roads meet the Sustainable Safety concept, based on the following fourteen road characteristics:

- the current speed limit;
- the presence of speed humps or raised junctions;
- the road pavement;
- the presence of private property connections;
- parking;
- obstacle-free spacing;
- public transport stops;
- breakdown provisions;
- advance sign of signposting;
- carriageway separation;
- edge marking;
- parallel facilities;
- cycle and moped facilities;
- exclusion of certain groups of road users.

A point is scored for every characteristic that is met. The total number of points is then divided by the highest possible score, fourteen.

The Sustainable Safety value of intersections is calculated in the same way but based on the following five intersection characteristics:

- intersection type;
- right-of-way rules;
- traffic light control system;
- signposting;
- speed reduction.

It is also possible to calculate the Sustainable Safety value for multiple roads by multiplying the road length per road section with the Sustainable Safety value; that total is then divided by the total road length. In order to determine the Sustainable Safety value for multiple intersections, every intersection is equally weighted.

This test can be carried out at different design phases, therefore not just after realisation of the infrastructure. In this case, various quantifiable aspects of the design (indicators) that relate strongly to the Sustainable Safety requirements are looked at [5.13].

Road characteristics+

To achieve road safety targets, various authorities work together on a file that contains information on speed, road haulage and management data: 'Road characteristics+'. This can also be used to record traffic volumes.
Key characteristics of registered road sections include:

- traffic function (road category);
- speed limit;
- road type;
- pavement;
- carriageway separation;
- edge marking;
- exclusion of certain groups of road users;
- moped/bicycle facilities;
- obstacle-free zone;
- possibly: traffic volumes.

And for intersections:

- type of intersection;
- presence of traffic light control system;
- elevation (presence of raised junctions);
- right-of-way rules.

For (through) road haulage, it is determined whether there is a desirable (for example: quality network for road haulage) or an undesirable route (for example: a shortcut) and whether any of the roads are closed to road haulage. 'Road characteristics+', therefore, goes beyond a category overview of the roadmap.

'Road characteristics+' is suitable for safety analyses and determining the cost effectiveness of infrastructural measures. In addition, this overview of road characteristics is important in loading navigation systems because it can inform lorry drivers of the extent to which a particular route is suitable for lorries. It also provides new perspectives for modified accident registration and for Intelligent Speed Assistance (ISA). Moreover, 'Road characteristics+' can be used for traffic engineering methods and technologies that are not aimed at road safety, but at tackling noise pollution or emissions, for example [5.14, 5.15].

5.3.3 Sustainable Safety module in network management procedures

Network management is a procedural approach for the development of a regional system of operational traffic control. The aim is ultimately (with a time horizon of 5 to 10 years) to introduce and implement a traffic management system as a tool for the better utilisation of road capacity. Network management enables regional partners to collectively indicate what they would like to achieve in terms of traffic management and what measures this requires. Network management employs a phased approach to achieve an optimum end-result, from policy principles to control strategies to reference frameworks to bottlenecks to measures.

Network management is a useful tool for road safety, and its result can be either positive or negative. If, for example, extra traffic is sent via access roads or, worse still, over existing accident black spots, reduced levels of safety are to be expected. Traffic should not be sent via (potentially) unsafe roads. Conversely, there are often causal connections between safety problems (traffic taking shortcuts) and accessibility problems (congestion on motorways). Everyone benefits if two problems are solved in one go. If road safety is recognised as a key aspect from the outset, network management can be effectively combined with Sustainable Safety.

At the beginning of a network management procedure, the question is what place road safety occupies in the overall picture. Is road safety one of the objectives or is it a precondition? Or, more concretely, must network management contribute in accordance with existing policy objectives or are additional efforts required? After all, it would not be logical to develop a scenario whose effect on road safety is either non-existent or negative and to then take separate road safety measures. Table 5.3 illustrates how the causes and effects of unsafe situations can be elaborated into objectives.

A network management procedure may uncover a conflict of interests between road safety and accessibility. In such cases, it is better to explicitly designate the problem and weigh all relevant aspects – with or without measures designed to reduce negative effects – than to neglect it.

When formulating the control strategy, it goes without saying that the available network and the road categorisation according to Sustainable Safety should be integrated and traffic should be directed via roads that are suitable for the purpose. The functional requirements of Sustainable Safety can also be incorporated here:

- construct continuous residential areas that are as large as possible;
- allow a minimal amount of the traffic onto unsafe roads (access roads are safe thanks to the low levels of traffic);
- journeys should be as short as possible; the shortest route should also be the safest;
- avoid situations in which road users have to search to find their way.

Table 5.3. Elaboration of causes and effects of unsafe situations into objectives

	Causes	Objectives
Network	Regional traffic on access roads rather than on through roads or distributor roads	Network management measures must contribute to a reduction in the number of casualties in this area
Local	Traffic taking shortcuts	Road safety in accident black spots must be improved

When formulating the frame of reference, the question of whether road use and road category are in tune with one another plays a role at local level. At network level, the question is whether traffic uses low risk roads. The extent to which this is the case not only has an effect in terms of accident numbers but also on subjective safety (or lack thereof).

Unsafe locations are identified and analysed in the phases that follow. On the basis of this, measures are proposed that influence the needs and the distribution of traffic.

In terms of network management, it is important to keep in mind that road unsafety often leads to new congestion; road safety is beneficial for accessibility [5.16, 5.17].

5.3.4 EuroRAP

EuroRAP stands for 'European Road Assessment Programme', and the EuroRAP method assesses roads objectively on the basis of road characteristics and accident figures. EuroRAP is a collaboration between European motorists' associations such as the Royal Dutch Touring Club (ANWB) and road authorities, with the objective being to reduce the number of casualties in Europe. This is to be achieved by working together and developing instruments such as Risk Rate Mapping (risk maps) and Road Protection Scores (attributing stars to safe roads, comparable with EuroNCAP's crash tests). Risk Rate Mapping focuses on road safety potential. In the Dutch situation this hardly adds anything, which is why emphasis in the Netherlands lies on the Road Protection Score. The RPS uses stars to show the extent to which safety measures have been taken for a road. This is based on risk tables per road category that have been translated into a star score of 1 to 4. Measures can be taken to improve road safety for roads with a low score.

As part of an ANWB initiative, the provincial roads in the province of Zuid-Holland were tested according to this RPS method. Of the 751 kilometres tested, 31% was awarded the maximum four stars, 51% three stars and 17% two stars [w5.3].

5.3.5 Roadscape study

Whenever there is reason to suppose that road safety is the consequence of a problem in the roadscape, a roadscape study can be carried

out. The aim of such a study is to trace and eliminate these problems, which is why roadscape studies are largely conducted by road authorities. The roadscape study focuses on the roads themselves (horizontal and vertical alignment, dimensions), the ‘decoration’ (roadside objects) and the road’s environment. A roadscape study investigates the roadscape on the basis of eight quality-related criteria:

- amount of information;
- continuity in the information;
- anticipatory overview and guiding elements;
- functional correspondence in terms of visual dominance;
- visual structure;
- recognisability of visual elements;
- orientation possibilities;
- attractiveness.

These criteria are described in detail in the Road design handbook (guidelines for the design of non-motorways) [5.18-5.21].

5.3.6 Road safety inspection

The road safety inspection (VVI) has a great deal in common with the road safety audit, with the key difference being that with an inspection the existing road network is regularly and systematically checked visually for deficiencies. The VVI works most effectively when it is carried out systematically and periodically.
The initiative for the VVI lies with the road authority, who can hire external inspectors or carry out the inspections themselves. A course and certification for road safety inspectors may be organised in the future, as is currently the case for auditors.

The inspection can be approached in two ways. The first is that an entire network is inspected periodically, independent of the number of registered accidents. The second approach is that road sections are selected on the basis of the number of accidents. Road sections that have a higher than average number are given priority in the VVI. This approach is very similar to the high-risk location approach, see section 5.3.1.

There are no standard procedures for the implementation of a VVI. Visual inspections record the condition of the road surface and the subterranean situation is measured using specialist equipment. On the basis of the results, priorities are established and reconstruction designs drawn up that will be implemented in the long or short term. These measures can be combined with major or minor road maintenance work, as required [w5.1, w5.2].

5.3.7 External behavioural observation

In terms of accident registration, observations have the important advantage of showing results relatively quickly. In the case of registration of unsafe situations, several years may go by before any conclusions can be drawn about safety and unsafety.
Conversely, it is not certain as to what extent conflicts can actually predict any ensuing road unsafety. Hence, observation techniques are especially useful in identifying and analysing road unsafety rather than predicting it.

When choosing observation techniques, it is important to first determine the reasons for observing: what do you want to find out? In terms of external observations, a distinction can be made between structured observations (observations according to a particular technique) and unstructured observations (observing traffic in an unbiased way).

Specific behavioural observations

Specific behavioural observations accurately describe the driving task and driving environment, after which a study is conducted to see whether road users actually use the desired routine. The simplest forms of behavioural observation are studies into behaviour that does or does not occur, such as the percentage of motorists that wear a seat belt.

Disruptions in the traffic picture and deviations in intended behaviour are of particular interest because they provide information on the basis of which improvements can be introduced in the design of the road, in traffic enforcement, et cetera. This method is also known as the 'complete event sequence'.

Expectations are that, in the future, behavioural observations will increasingly use high-quality technology and automation such as video, GPS and gsm tracking, which will change the way in which information is gathered: where the question used to be where the information came from (there was often a shortage of information), in the future, the question will be how the correct information can be filtered out of large datasets (a glut of information).

Speed measurements

Another structured observation method is measuring speed. Speed measurements can provide a reasonable impression of road safety. A speed measurement can be taken as a section measurement (average speed over a particular distance) or as a spot measurement (radar, laser gun, using loops in the pavement, et cetera). Speed measurements also take place at network level. It is also important to know what is being measured in this respect: 'everything that passes' or only the 'free riders': drivers whose speed is not influenced by other road users. Furthermore, sufficient observations are required to obtain an accurate picture of the situation.

Generally, the V_{85} is used for taking speed measurements, which is the speed at which 85% of drivers drive slower and where 15% drive faster than the speed regime, creating an image of the majority of road users. If the highest value of the speed measurement is added, an image is also created of the excesses. The combination of these values gives a picture of the actual behaviour.

The speed measurements can be taken by various parties. Due to the time it takes to carry out measurements, some municipalities have entered into agreements with Dutch traffic safety association (VVN) to carry out the speed measurements.

It is of primary importance that those responsible for carrying out observation and measurements heed their own safety during these procedures. They should also be conscious of knee-jerk responses from road users, given that some react angrily to a radar gun or camera. Curiosity, (attempted) theft of equipment and even aggressive behaviour should also be taken into consideration. Informing the police of any measurement programmes is advisable.

Figure 5.3. Speed measurements

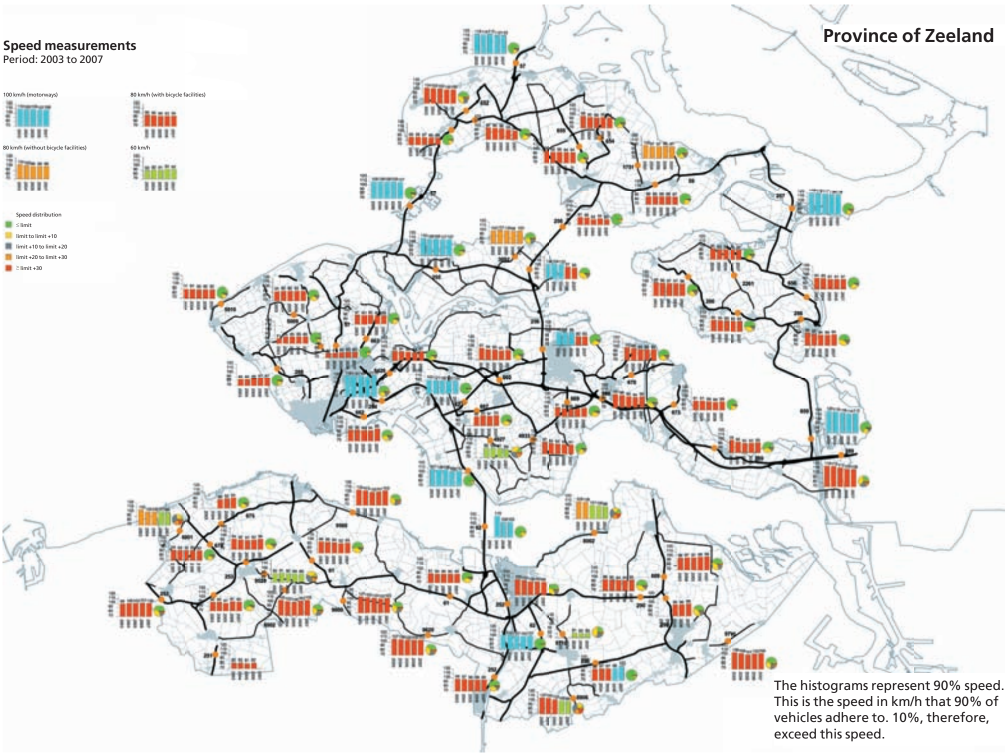


Table 5.4 Combination of V_{85} and the highest measurement

	Highest measurement almost equal to V_{85}	Highest measurement is higher than V_{85}
V_{85} and speed regime in balance	Speed regime is well observed	Speed regime is reasonably well observed but there are incidences of excess. Traffic enforcement is the obvious solution.
V_{85} is higher than the speed regime	Too many drivers exceed the speed regime. A review of the roadscape and speed regime are the obvious solutions; traffic enforcement offers a temporary solution at best	The speed regime is being exceeded and there are also incidences of excess. A thoroughly combined (infrastructural and enforcement) approach is the obvious solution to these problems.

Use control system for traffic observation
Traffic observations can also be carried out using modern traffic control systems. The control programme operates on the basis of such data as the number of times the road surface loops are crossed. This offers insight into the total number of times a red light is ignored and the passing speed at the intersection area, after which the control system software in the control box can be read out by a specialist (mostly the supplier). The numbers that relate to motorists who have jumped a red light are very reliable. In terms of speeding, this is less so. Without speed loops near the intersection, the only reliable conclusion is that the speed at the intersection increases and decreases over the course of a particular period. With loops near the stop line these speed observations can be refined to the number of passing vehicles within a certain speed block within a 10 km/h range. A specialist is also required to read out these details.

5.3.8 Internal behavioural observation

The design of the infrastructure and the road environment must be adapted to the end user, usually a motorist. This requires research into traffic behaviour, human-machine interaction, workload, et cetera. Behavioural observation is possible from the roadside (for example with a camera or from a hiding place), but also from an inconspicuous car in traffic. An alternative to behavioural observation in the field is simulation using a driving simulator. If the interaction with the driver is important, research using a simulator provides good possibilities. The study of traffic behaviour requires a careful choice of the most appropriate methods and techniques, which range from mathematical models on the one hand to roadscape observations on the other.

Using driving simulators for research purposes has various advantages.

- The circumstances in which the studies are conducted are always safe and controlled. In contrast to the roadside, where the weather and driving behaviour of others influence the results, a driving simulator makes it possible to have different end users drive in exactly the same conditions.
- It is easier to measure research data such as driving behaviour and workload. A driving simulator can also result in substantial cost savings.
- Simulation can also study driving behaviour in non-existent situations, for example, a dynamic evaluation of the effects of new infrastructures such as tunnels on the driver.
- As well as research into infrastructure and traffic behaviour, it is also possible to study driving support systems, which can be done at an early stage in the development.

The first advantage is a limitation in that a study of whether or not a test person accepts risks is invalid: they will always feel more or less safe regardless of how realistic the simulator is. However, a simulator is an excellent way of discovering risks in terms of both research and driving instruction.

The possibilities and the limitations of the studies depend on the configuration of the simulator, which is why TNO uses three different simulators, each with its own capacities: the fixed-base simulator, the moving-base simulator and Desdemona:

- the fixed-base simulator has a static mock-up and is used for studies into how people make decisions or comprehend elements in the roadscape;
- the moving-base simulator has a moving platform with a BMW chassis or a DAF truck cabin and is used for studies into the driving behaviour (maintaining direction, speed) of motorists in normal circumstances;
- Desdemona is an advanced motion platform that simulates more extreme manoeuvres such as sharp corners, leaving the road and even crashing.

5.4 Tools for subjective road unsafety

There are different methods for understanding the concept of subjective road unsafety. How safe or unsafe a road user (or person living in a district) perceives a situation to be can be deduced from complaints or experiential research aimed at a certain existent situation. It is also possible to consult future road users in the initial planning phase, even though there are (as yet) no specific methods aimed at road safety.

The subjective road unsafety and the objective road unsafety of a particular situation do not always go hand in hand. Sometimes a situation is subjectively unsafe (the situation is deemed unsafe), but objectively safe (few or no accidents occur) because the road users compensate for the situation and conduct themselves with extra care. In many cases, scant attention is paid to subjective road unsafety, yet politicians deem it to be as important as objective road unsafety.

5.4.1 Complaints

In order to get an overview of subjective (un)safety, it is necessary to gain insight into complaints concerning the existing traffic situation. This is why an effective complaints procedure is so important. Such a procedure comprises:

- A central complaints office.
- Standardised registration:
  - location;
  - group that experiences the road unsafety;
  - time;
  - frequency;
  - contact details of person lodging complaint.
- An immediate confirmation of receipt and feedback about how the complaint will be handled: who is the contact person and how is the complaint being handled. An arrangement must also be in place for cases in which those making the complaints feel they have not been dealt with properly. They should be informed of this arrangement.
- Handling a complaint within a reasonable period of time and reporting the outcome. If the complaint is not dealt with satisfactorily, the reason(s) should be reported to the person lodging the complaint:
  - the outcome of the research into the complaint;

- the decision concerning the complaint;
- the conclusions drawn from the decision;
- the possibility of lodging an appeal.

The police can often provide valuable information about certain situations about which complaints have been lodged. Information is also often available from people who are familiar with the location for other reasons, such as shopkeepers, couriers and postmen. They are in a position to provide a sound judgement about a particular situation due to their own experiences in that location.

Specific subjective experiential research

It is also possible to conduct specific research into subjective safety using what is known as experiential research, in which road users can compare the situation with other situations that they have experienced. These studies usually take the form of a questionnaire. Specific experiential research can also be conducted in the form of a discussion between citizens and road authorities or a survey conducted by a social organisation such as Road Safety in the Netherlands or the Dutch Cyclists' Union.

5.4.2 Consultation with future residents/users

It is also sometimes possible to approach future residents and users of a particular area at an early stage in the planning process. The ways in which future residents can become involved vary from acting as 'sounding boards' with regard to the design to helping with the design or even helping in the decision-making process. Contributions can be either ad hoc or periodic. In this sort of situation, it is important to establish early on a clear picture of what the rules are and make sure that future residents

or users are not given any false expectations. Specialist consultants are available to provide support in such processes.

Different web applications are also available with which public opinion can be assessed on-line. People can give their opinions on a website about the current and future traffic situation in a particular area.

5.5 Summary

There are many pragmatic methods and techniques with which we can anticipate or respond to road safety problems. This chapter discussed methods that focus on objective road safety and a subjective road unsafety. Each method has characteristic strengths and weaknesses.

Many of the methods described differ fundamentally from data analysis; the problem definition determines which method is best in any given situation.

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Part 2 - Making traffic safer

Influencing road user behaviour: the three Es

Chapter 1 states that human error plays a part in as many as 93% of all traffic accidents. Discouraging certain (undesirable) behaviour and/or stimulating new (desirable) behaviour of road users with the help of technical, educational/communicative and legal means, is called traffic influencing. Behaviour is not only influenced through education, information, posters and stickers, but also through measures concerning the infrastructure, as well as legislation and traffic enforcement.

Three categories of tools can influence human behaviour: Engineering, Education and Enforcement: the classic three Es of traffic influencing. They will be briefly touched upon in this introduction and discussed more thoroughly in the following chapters.

- Engineering
  Engineering, through the design of vehicle, road and road environment, is the technical approach. In this context, the most important factor by far is the Sustainable Safety design of the infrastructure according to the principles of homogeneity, functionality, forgivingness and recognisability. This prevents unintended use of the infrastructure (for example rat-run traffic), encounters with significant differences in speed, direction and mass, and indecisive behaviour of road users. What should be kept in mind is that solving existing problems with engineering measures differs from the Sustainable Safety approach, the point of which is to prevent potential problems. Chapters 6 and 7 will examine this in detail. Making vehicles safer is, certainly for a 'conventional' traffic engineer, of lesser importance, although it is helpful to have knowledge of measures in this field. This information is presented in chapter 8.

- Education
  Education generally means 'teaching and training'. Road safety education is the catchall concept for road user education, traffic or driving lessons and traffic information. Education, and hence also road safety education, applies four (groups of) tools:
  - instruction (explaining how);
  - training (practice);
  - modelling (social learning, that is: copying other people's behaviour);
  - punishing undesirable behaviour and rewarding desirable behaviour.

  Chapter 9 discusses road safety education.

- Enforcement
  Enforcement refers to the formulation, publication and imposing of rules by the legislator or the police. Tools for enforcing rules are punishing undesirable behaviour and, where possible, rewarding desirable behaviour, both mentioned in Education. This aspect of road safety education has, in part, been 'tendered' to traffic enforcement.
  Chapter 10 addresses traffic enforcement and also discusses in depth the role of communication (a form of education) in enforcement.

One E is not enough

Employing a single E is not always effective. Changes in road user behaviour (for example driving slower, fewer priority-related accidents) can only be expected with any degree of certainty from infrastructure measures, thus Engineering. Traffic enforcement should be planned together with education: people should know in advance that they can get caught if they do not abide by the rules. The effect of Enforcement is enhanced dramatically by information/publicity about police surveillance. Information can also be a valuable contribution to infrastructure measures. The recognisable road characteristics that indicate the local speed limit should first be communicated before the markings can be expected to be effective. On the other hand, if the infrastructure itself encourages unwanted behaviour, no amount of traffic enforcement and information will help. Especially when it comes to speeding, desirable behaviour should, first and foremost, be made inviting or even be imposed by the design of the infrastructure, thus Engineering. Only after that has been achieved will enforcement make sense (if it is still needed).

To be more specific:
- sometimes one E is a condition for successful application of another E;
- in many cases, the most effective way to influence behaviour lies in the combination of two or three Es.

In practice, the E of evaluation is occasionally added to the three abovementioned Es. Strictly speaking, evaluation is not a measure, but a stage in the (PCOSE) process. Environment, ethics and the euro are also used sometimes, but 'the three Es' remain at the core.

The three Ps

Now the tools are known, how can they be applied? There is a helpful trio for this as well: the three Ps: Push, Pull and Persuasion.

- Push
  Trying to 'push' someone away from undesirable behaviour. For example: discouraging traffic offenders on a certain road by punishing the offences with a fine with a considerable regularity. Also, an insurance company could pay out less or nothing at all if it turns out that alcohol was involved in an accident.

- Pull
  Trying to 'pull' that road user towards the desirable behaviour at the same time (or at least co-ordinated in time), encouraging desirable behaviour by addressing safety advantages. An example of an incentive is handing out BOB ('designated driver') key rings during alcohol inspections to those who have not been drinking.

- Persuasion
  Persuasion is about convincing, about communication aimed at changing road users' knowledge and attitude (and, in the end, behaviour). For instance, in the case of seat belt use: explaining how dangerous not wearing a seat belt is and hence how important to wear one, and that there will be seat belt inspections, et cetera.

The art of influencing traffic behaviour is finding the best combinations of the Es and the Ps.

The chapters of part 2

6 Spatial Planning and the Road Environment
7 Infrastructure
8 Vehicle Safety
9 Road Safety Education
10 Traffic Enforcement

Chapter 6 'Spatial planning and the road environment' describes road safety from a spatial / urban development perspective. Substantive cohesion and interaction between spatial disciplines and traffic engineering are discussed, as is the co-operation process between the different disciplines.

Chapter 7 'Infrastructure' examines infrastructure specifically from the perspective of traffic engineering. Sustainable Safety road categorisation and its effect are pivotal in this chapter, although topics that are less directly linked to Sustainable Safety are also discussed.

Chapter 8 'Vehicle safety' takes a look at measures for improving vehicle safety. The emphasis here is on cars, but other modes of transport are also discussed. Other important subjects are Intelligent Transport Systems and high-quality vehicle technology.

Chapter 9 'Road safety education' explains the concept and highlights the importance of permanent road safety education. In addition, it describes the target groups of education, their traffic behaviour, and the intended development of their skills. These all come together in the GDE matrix.

Chapter 10 'Traffic enforcement' describes the different aspects of traffic enforcement. The organisation, the function, and the intrinsic effects are discussed. Based on that, a deduction can be made as to whether or not and to what extent enforcement will be an effective measure.

The order of the chapters is deliberately chosen. In a dangerous situation, the most fundamental method is to tackle that danger. A second option is to protect people and the third one is to avert that danger. Teaching people how to deal with danger is the final and also least effective option. It is by far most effective to tackle dangers at the source.
Analogously, measures on the road and its environment are the first choice and measures geared to the vehicle the second. If these measures do not lead to an acceptable solution, educational measures and enforcement come into play.

6

Learning objectives for students:
- to understand how road safety is linked to key policy areas such as urban and rural planning, spatial planning, urban design and landscape architecture;
- to understand how they influence one another;
- to know how measures from other policy areas can be utilised to improve road safety.

Spatial planning and the road environment

6 Spatial planning and the road environment

6.1 Cascade approach

Chapter 1 described how road safety is hardly ever the result of a single factor: road safety depends on literally every aspect of the transport system. Every choice that is made in relation to the transport system has an impact on road safety, however great or small it may be. The transport system is embedded in urban and rural planning, spatial planning, spatial development, urban design, and landscape architecture. The choices that are made in these fields (co-)determine road safety. It is not a coincidence, therefore, that spatial planning is one of the pillars of Sustainable Safety.

The cascade approach is an effective strategy to make road safety manageable in a spatial context and is arranged as follows:

Looking at structure:
- urban and rural planning and urban development;
- spatial planning;
- spatial development;
- traffic planning.

↓

Looking at the layout of the location:
- urban development;
- landscape architecture;
- traffic design.

↓

Looking at the use:
- individual behaviour.

This chapter focuses on the first two cascades because they eventually (co-)determine behaviour.
- Urban design, spatial planning and spatial development focus on issues such as planning, use of space, networks, interchanges and transport concepts. Traffic planning also incorporates these aspects.
- Urban design and landscape architecture focus on issues such as the layout of a location or area and the design of residential areas and infrastructure. Traffic design also incorporates these aspects.

However, reality is often more subtle than this rigid division might suggest.

Rather than offering a choice (either/or), these cascades offer a combination (and/and) that can result in effective and traffic-safe public spaces.

6.2 The interaction between spatial disciplines and road safety

Public space must be appealing and easy to use, both now and in the future. On the one hand, residents, companies and their visitors should be able to reach their destinations quickly and comfortably, while on the other, the environment should be pleasant so that everybody – children, adults and the elderly – feels at home in their own street, neighbourhood, village or city.
Practical examples of how this has been implemented effectively are unobtrusive. Examples of less effective situations are usually much more recognisable, such as large flows of traffic directed through a residential street, or pupils who have to frequently cross a busy road because their schools have been combined in a new building on the other side of that road.

In such situations, road unsafety is almost a matter of course. Rectifying problems of this nature usually requires drastic and costly measures, while makeshift solutions cannot undo the consequences of misguided planning. But the opposite is also true: if planning and urban design choices are made carefully, road safety is already guaranteed to an important extent, eliminating the need for costly repairs at a later stage.

The strength of the cohesion and the mutual influence of spatial disciplines on the one hand and traffic and transport on the other are the subject of much debate. It can be argued that the spatial disciplines have a minor and unpredictable influence on mobility, but equally that they are a sustainable, determinant factor for mobility.

History has taught us that there is a certain degree of interaction: urban and rural planning and urban design determine a long-term process – spatial structures can last for centuries – and are co-determinants for traffic and transport in the short and mid-terms. While traffic and transport are particularly prone to problems in the short and medium term – a street may last for 30 to 50 years – they also (co-)determine urban and rural planning and urban design in the long term.
Both misguided and effective decisions regarding public space determine the nature and volume of traffic and transport for many years to come. And it is this sustained impact that make experts in spatial disciplines interesting partners in discussions with traffic planners and engineers. This should be put into perspective, however: the Netherlands is already largely developed and the chances of changing this are limited. In addition, traffic and transport are also determined by other factors, such as social-cultural and economic factors and 'trendy' developments.

The interaction between urban and rural planning and urban design, and road safety should be reflected in planning and planning processes.

6.3 Planning and planning processes

6.3.1 Introduction

Integrating the relationship between urban and rural planning and urban design on the one hand and road safety on the other into policy does not necessarily lead to increased road safety. The following examples illustrate this.
At the moment, spatial planning and development at national level are governed largely by the Land use planning memorandum.
In terms of traffic and transport, this document emphasises accessibility and external safety, rather than focusing specifically on road safety. As such, the document could lead to large-scale rural housing projects, which would in turn result in increased vehicle use and an increased road unsafety.
The extent and the nature of the functional mix in a certain area strongly influence vehicle use. If there are relatively few contacts outside that area, this has a favourable impact on road safety because less journeys are made.

As an elaboration of the Land use planning memorandum, the National traffic and transport strategy memorandum does address road safety. The embedding of road safety in the National traffic and transport strategy memorandum is discussed in chapter 3.

Policy at decentralised government level does not always effectively address the interaction between the surroundings and road safety either. Over ten years ago, the Netherlands Institute for Road Safety research found that *'Road safety has neither a prominent nor an explicit place within statutory procedures, especially when general starting points and strategic spatial choices are under discussion. (...) Road safety is also far from prominent in informal planning process of construction, consultation and participation. This is due in part to the fact that it is difficult to (quantitatively) show what effects spatial choices have on road safety. It is only at a later stage, when the zoning plan is under discussion, that road safety becomes more important.' [6.2]*
Although road safety appears to have gained some ground as an element of urban and rural planning over the past decade, there is still room for improvement. Zoning plans and provincial structural concepts rarely mention road safety explicitly. In practice, many planners and designers feel that while road safety does play a role, it is an implicit one and need not be explicitly included in plans. This suggests that bilateral communication between the various disciplines is critical to solidly embedding road safety in the spatial planning process.

6.3.2 Road safety in the formulation of spatial plans

Road safety can be considered at different levels and at different moments in the formulation of spatial plans [6.3].

- The level that provides the preconditions for spatial development: government memoranda, legislation and regulations, land policy. The preconditions are usually taken as read and are, therefore, not always explicitly included in plans.
- Structural level (regional): strategic long-term choices, such as the structuring and contextualising of living, working, recreation and traffic at macro level. This is reflected in the regional spatial plan formulated by the Provincial Council, which outlines the future of an area. A regional spatial plan has a process-oriented character: it is both a development plan and the integration framework for different memoranda and programmes. A regional structure plan is compulsory for framework areas. Municipal councils can formulate a structure plan, an outline structure plan or a structural concept. In order to give road safety a clear place within such plans, it is important:
  - to combine the strengths of the various modes of transport as effectively as possible and to limit the weaknesses;
  - when choosing locations for new housing projects: to allow the development to connect to existing built-up areas, or concentrate it in larger new autonomous residential centres or larger new housing projects with a functional mix;
  - not to opt for different small locations or to connect to an older urban area; scattering or increasing the density of new developments in such areas is usually unfavourable to road safety;
  - to ensure proper road categorisation: a clear division between roads with a traffic function and roads with a residential function, avoiding roads with a dual function or roads with an undefined character (so-called 'grey roads').
- Location level (area-specific): specific task for a particular area in the medium term, which involves the meso-level elaboration of the choice of the location for new housing or infill development. This results in an outline

zoning plan, which defines the main features of the area and/or statutorily establishes its programme. The regulations and the zoning map are legally binding. Sometimes an outline zoning plan is also used to test the feasibility of plans. In terms of road safety, the following are relevant:
- to anticipate future developments in traffic and transport;
- the extent of the functional mix;
- to aim for large, continuous residential areas;
- to ensure that residential areas connect with traffic arteries in a well-considered manner;
- to prevent avoidable motorised traffic in residential areas;
- to direct traffic over roads designed for this purpose as much as possible;
- (Re-)development level (location-specific): the short-term appearance of the area, which involves a detailed zoning or development plan. The regulations and the zoning map are legally binding. In terms of traffic and transport, it relates to tracing of potential conflicts between modes of transport at micro level.
Formulated more positively: the design of a pleasant and sustainable layout that future residents like to see as an extension of their own homes. In terms of road safety, the following are relevant:
  - to anticipate future developments in traffic and transport;
  - the development of public space on the basis of road categorisation;
  - the final design of the infrastructure.

Alongside these plans, there are a number of other specific plans with a spatial character that can also include traffic and road safety, such as visual quality plans. The appearance of public space and the accompanying ambitions as defined in the visual quality plan must be consistent with road categorisation. Aside from this, a surfeit of traffic engineering elements can diminish visual quality. Consequently, co-ordination and harmonisation are key.

6.3.3 Road safety in the decentralised planning process

The various decentralised plans are formulated in more or less equivalent planning processes that consist of a number of phases. Within each of these phases, road safety can be included in the following specific ways:
- Initiative (idea): in this phase, a qualitative investigation can be made into the positive and negative consequences for road safety.
- Definition (what): in this phase, the qualitative investigation into road safety can be quantified where possible or a road safety audit carried out.
- Design (how): in this phase of the planning process, the consequences for road safety are dealt with more concretely: a design can be adapted to the expected safety bottlenecks. If a road safety audit was conducted during an earlier phase, an audit that focuses on the design can be an effective addition.
- Preparation (how to make the plan): road safety also demands attention during the realisation of the plan; consider, for instance, road unsafety due to construction traffic. Communication on road safety also demands time and attention.
- Realisation (carrying out the plan): in this phase, it is important to ensure that all intentions are actually realised. Unforeseen problems concerning road safety will crop up regularly, and improvisation is required to address these.

- Aftercare (maintenance): in this phase, monitoring road safety is key: immediately after realisation of a plan, it is important to be aware of complaints and, where necessary, make observations. In the long term, safety statistics can provide information on road safety levels.

Decentralised planning is a process in which the level of detail increases over time. There is, therefore, a link between level of scale and sequence [6.4].

Consideration for road safety is wrongly left until a relatively late stage of the planning process. This is unfortunate, given that the possibilities of influencing road safety through spatial planning decrease as the level of detail increases. It is advantageous, therefore, to include road safety at an earlier stage [6.5, 6.6].

6.3.4 Rectifying deficiencies in existing road safety

If road safety problems occur that are relevant to the spatial situation, it is necessary to work out the cause: is the problem a result of a planning mistake in the choice of location or road network or is the problem caused by architectural or landscape layout?

- If the problem is related to planning, it is usually possible to solve the problem elsewhere.
- If the problem is related to layout, it must be solved on the location in question.

Problems may arise in one location but have to be solved somewhere else. Sometimes, however, a problem at road network level is tackled as a layout problem. This short-sightedness leads to 'stopgaps' that, in the best case scenario, merely alleviate the symptoms rather than really solving the problem. Moreover, such solutions are not considered credible by the various users.

Sometimes, road safety problems can be the result of decisions taken at an earlier stage in the planning process. In that case, it is not only important to tackle the problem, but also to learn from it for future planning processes.

6.4 The bridge between urban and rural planning and road safety

Urban and rural planning is a collective term for all spatial developments, within which road safety is to be detailed. In order to clarify the relationship, the catch-all term urban and rural planning can be broken down to its essence: spatial design. A well-developed road network offers beneficial conditions – but no guarantee – for a good quality of the road environment. By contrast, a poor road network can never be remedied by good layout or by taking the quality of the surrounding area into account. Table 6.1 illustrates this and also highlights the consequences.

By designing a good road network, the planner lays the foundations for road safety.

Table 6.1. The relationship between layout and road network

	Poor layout	Good layout
Poor road network	Major problems with traffic and transport system. Consequences: costly measures are required.	Good infrastructure is nothing more than a stopgap. Consequences: costly measures are required.
Good road network	Failed at the final hurdle. Consequences: measures can be relatively simple.	Good result. Consequences: road safety is the natural outcome.

6.4.1 Three road categories

Many traffic planners wrongly see interlocal or regional traffic as a standard for the design of the road network, as a result of which streets are often designed on too large a scale. At most, interlocal traffic is only 50% of the story, and neighbourhoods around the corner are every bit as important as far-off cities.
Once above a certain speed, no-one can gain time without forcing another to lose it [6.7].
In short: connecting and residing must be balanced in a road network.

There used to be as many as seven, nine or even more road categories. This meant that some small residential centres, in imitation of larger cities, also had a large number of road types – a hierarchy that in reality could not be achieved. Moreover, this division was incomprehensible to the road user. In terms of road safety, a clearly recognisable distinction between roads with a traffic function and roads with a residential function is preferred. This is why the choice was made within Sustainable Safety to limit the number of road categories to three:

- through roads: motorways and trunk roads; traffic arteries on which traffic flow is key on both the road sections and at intersections.
- distributor roads: connection between residential areas and through roads; traffic flow is key on the road sections and interaction with the surrounding area is key at intersections.
- access roads: roads with a residential function within connected areas where the traffic function is of secondary importance. This category connects more than just home zones, with 30 km/h zones also being included. Interaction is key on both the road sections and at intersections.

Almost the entire Dutch road network is now categorised in terms of the division of roads as stipulated by Sustainable Safety, the essence of which is that a road never has both a traffic function and a residential function. This subject will be discussed in more detail in chapter 7.

Table 6.2. Old and new names for road types

Old name	Sustainable Safety
Motorways Trunk roads	Through roads
Urban motorway/main collector roads Collector roads District roads Local access road/ local roads	Distributor roads
Local access road/local roads Residential streets Home zones Paths	Access roads

6.4.2 A well-constructed road network

Chapter 7 will also provide a guide to the categorisation of roads. A good road network is clear, logical and – ideally – simple.
There is usually little debate about the designation of through roads: few new motorways and trunk roads are being constructed and if they are, they are subject to a lengthy procedure. Likewise, there is little debate about access roads; it there is any discussion at all, it usually has to do with the fact that too many roads are regarded as traffic arteries.
In practice, then, the debate centres on the middle category, the distributor road, which constitutes a difficult design assignment.

The choice of road category means that much of the road layout and uniformity of the design is predetermined. This way, an optimum balance can be struck between complexity and the chance of error. Uniformity of through roads is essential and of great significance, while for access roads the opposite applies in that a lack of uniformity is a functional advantage. Uniformity in design is often a problem with regard to distributor roads. To clarify: while uniformity does not mean that every profile or material is the same, it does mean that the roadscape is clearly distinguishable and recognisable.

6.4.3 Core risk data

Core risk data can be incorporated into the design for a safe road network. Such data can be put to good use when creating substantiated prognoses concerning road safety. A GIS application is expected to be available in the short term, which will make it easier to work with core risk data (see also section 5.2.1). This will also make it possible to calculate the consequences of different alternatives to the current road network.

6.4.4 Mobility-generating effect

If the law of preservation of travelling times (BREVER law) is taken as the starting point in the design of a safe road network, it is possible to judge the mobility-promoting character of Sustainable Safety. If Sustainable Safety results in a denser (therefore quicker) regional road network, the consequence will be an increase in traffic. At the same time, alternatives will become less attractive: the number of journeys by train and interlocal public transport will decrease. The shift from relatively safe public transport to the car, however, does not compensate for the increased safety of a more dense road network [6.8]. The location of a built-up area close to a motorway induces increased vehicle use (2.0 to 2.4%), but on account of the safer traffic flow, the effect on road safety is, on balance, still positive: 0.8 to 3% fewer casualties. In other words, the effect of the shift to safer road types is, therefore, more pronounced than the mobility-generating effect [6.9].

6.5 Urban design and road safety

It is important to raise the issue of road safety in urban areas. After the explosion of motorised traffic after the Second World War, it appeared that road safety could no longer be guaranteed in the public domain. The number of traffic fatalities reached a record high, which, as the following quote testifies, resulted in a stance being taken against the car and high speed traffic in the 1970s:

'We are using speed humps, barriers, lamp posts, bollards and other physical methods to force motorists to slow down. But cars are manufactured such that speed humps pose no problem. Car manufacturers try to appease the every wish of anonymous motorists: speed and comfort are all-important. No-one wants to ruin the cities. No-one wants to cause accidents. Yet we all accept that sections of the city are disintegrating and people are being killed. The bombardment of cities and villages with speed humps and cars has to stop sometime.' [6.10]

The current generation of traffic engineers is less familiar with this combative behaviour against the car and high-speed traffic: they grew up in a situation in which the rough edges in terms of road unsafety have been smoothed off. It is unusual nowadays for through roads to be constructed to cut through the city or that buildings are knocked down to make way for traffic arteries. Everyone recognises the importance of road safety.

6.5.1 Urban design through the years and the relationship with road safety

There is a clear connection between the stereotypes of the periods of urban design and road safety. Prior to the Second World War, the traffic and transport system was organised along social lines. The car enjoyed respect in society, as did a mayor, doctor, lawyer and teacher. Villages and cities were built for cyclists and pedestrians and carts and wagons, and speeds were relatively low compared to current standards. The post-war reconstruction period saw the rise of large-scale housing projects in which quantity was key. More and more people could afford a car, which became a permanent rather than an incidental phenomenon during the 1960s. This had an impact on the housing estates from that period and beyond, with ever more attention being paid to motorised traffic, and older neighbourhoods and areas being adapted to accommodate this progress. However, the 1970s also saw the downside of what such progress could mean: increasing numbers of traffic casualties and the negative impact of motor vehicles on the quality of life: exhaust fumes, noise and visual pollution. Welfare and the yearning for a cosy, rural life increased and urban neighbourhoods were built with a rural character.

However, this development was countered in the form of neighbourhoods with a more urban allure and a clear structure [6.11]. In the most recent plans, it appears that a balance has been found between accessibility, safety and quality of life, but only time will tell if this assessment proves to be correct.

Developments over the years have made it possible to determine from the street plan in which period a housing estate was built [6.12, 6.13, 6.14]. The periods all have characteristics that to one extent or another can be linked with current views on road safety. It is possible to make overall road safety recommendations on the basis of generalisations, but the approach is still customised. A differentiation has to be made, however, in that road safety also has to do with use and users; it is not solely dependent on the spatial situation.

6.5.2 Historic centres (until circa 1850)

Historic centres have a dense, sometimes chaotic, structure that is usually characterised by:

- an urban and small-scale system of streets and spaces;
- fine-meshed, compact and dense development;
- a strong functional mix;
- a mixture of traffic types.

Another characteristic of historic centres is that the history of their development can be easily determined: they are usually located at the junction of two roads or of a road and river.

Advantages for road safety: the short distances to destinations lend themselves to pedestrianised zones.

Disadvantages for road safety: insufficient space for contemporary notions; difficult manoeuvrability for public transport and goods vehicles; complicated situations. In urban centres, there is usually little or no room for children to play on the street. Even in traffic-calmed areas, playgrounds are thin on the ground.

Road safety approach: only possible to a limited extent in conservation areas; construction of traffic-free/traffic-calmed areas; guaranteeing sufficient space for non-motorised traffic; informal layout to indicate that motorised traffic needs to adapt its driving style; an absolute minimum of traffic engineering interventions. These areas lend themselves to functional mixing and, therefore, not to separation. Traffic engineering alterations to these historic areas demand customisation.

6.5.3 Building zones (circa 1850 to 1920)

Building zones are the layer-like peripheries around the city centre that are usually characterised by:

- wide profiles on arterial roads with amenities on either side;
- relatively dense building blocks between the arterial roads;
- station areas (train stations feature relatively often in these peripheries).

Arterial roads (radials) designed as urban axes are typical and often grafted onto older polder roads.

Advantages for road safety: houses are often situated within walking distance of the city centre; a 'naturally' clear distinction between distributor roads and access roads.

Disadvantages for road safety: many and dispersed crossing movements on distributor roads; insufficient space for parking on access roads, creating a chaotic picture; occasional problems with bicycle parking; little or no room for children to play anywhere other than on the street.

Road safety approach: direct traffic onto the radial roads while retaining the quality of life and crossing facilities, making the most of space in the areas in between. These neighbourhoods are often oriented around the old city centre. It is sometimes possible to gear radials to non-motorised traffic and to provide motorised traffic with an effective alternative via tangential connections.

6.5.4 Open building from 1920 to 1960

Peripheries around the city centre made way for extensions that are largely based on a grid system. In this period, a distinction was made between pre-war areas (often characterised by a good quality of life) and reconstruction neighbourhoods (built at high speed, often in small, cohesive clusters of repetitive buildings). The period between 1920 and 1960 is characterised by the focus on healthy living environments through light, fresh air and space, usually by means of:

- straight (sometimes plain) streets;
- monofunctional residential areas;
- moderately high-density low-rise buildings.

Advantages for road safety: traffic is spread out; often sufficient room for children to play; a flexible structure, so that streets can be made traffic-free without too many problems and reversal is also relatively simple.

Disadvantages for road safety: rat-run traffic; wide and extended profiles; high speeds; parking problems; occasional problems with bicycle parking. Amenities are further away from the homes.

Road safety approach: problem-driven approach that often demands making the most of the little space that is available, add quality by differentiating within the grid system. In so far as they are accepted by residents and local businesses, clear infrastructure choices are preferable to compromises.

6.5.5 The 1960s

The 1960s saw the rise of right-angled structures, which were centred around idealistic progressive thinking and (vehicular) accessibility. A key characteristic is that the focus on light, fresh air and space is implemented in the extreme by using:

- a grid system with moderately high-density high-rise buildings;
- monofunctional spaces and expensive engineering structures (such as bridges and tunnels);
- the rigid division of traffic types.

Advantages for road safety: short distances to city centre amenities; different routes possible; traffic is spread out.

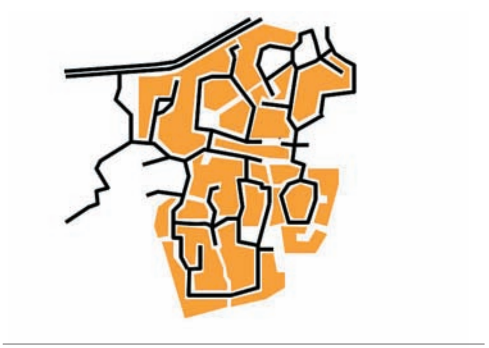
Disadvantages for road safety: measures are often expensive to realise; many streets with through traffic; unmanageable division of traffic unclear road network; many intersections and hence points of conflict; long, straight road sections; barrier effects and, in most cases, no attractive alternatives for non-motorised traffic.

Road safety approach: introduce differentiation into the existing grid; create non-motorised traffic routes and thus drastically reduce the number of roads with a traffic function.

6.5.6 The 1970s

In the 1970s, traffic liveability was the key issue. This period is characterised by a focus on the social cohesion of residential areas, usually by means of:

- formless structures ('cauliflower districts' and courtyards), low-rise buildings with enclosed spaces;
- narrow (or no) carriageways, short straight road sections, short-cuts;
- home zones, sometimes very cluttered creative design, relatively high paving density.



Housing estates with a tree and branch structure

Advantages for road safety: no through traffic on branches; hierarchical structure possible; short, straight road sections. There is usually lots of green space between the courtyards and there are safe playgrounds.

Disadvantages for road safety: relatively busy traffic on branches; long distances for motorised traffic; no alternative routes possible (problem for detours and emergency services); requires a relatively large amount of paving; poor orientation; lack of clarity regarding the front and rear of the house; little social control in the quiet streets; courtyards often lack a good bicycle network.

Road safety approach: differentiation within the uniformity in buildings; improve orientation (add co-ordination points, allow road surfacing to indicate direction).

Housing estates with a loop structure
Advantages for road safety: little through traffic on small loops; clear hierarchical structure possible.

Disadvantages for road safety: busy traffic on the ends of the loop; major differences in traffic volumes on a large loop; straight road sections on the primary loop; many intersections on the distribution loop; moderate orientation; little social control.

Road safety approach: improve orientation on the small loop (add orientation points, allow road surfacing to indicate direction). Force a clear transition on the large loop between intense traffic functions at the loop ends and minor traffic functions at the rear of the loop.

6.5.7 The 1980s and 1990s

The 1980s and 90s saw the rise of more organised structures. This was an exponent of the economic developments of the time: within a rectangular structure, low-rise buildings could be built easily, quickly and, most importantly, inexpensively. Sometimes these structures are manifest as residential streets with straight road sections several hundred metres long, at other times they are only visible from the air. Distributor roads were introduced as a structural element. Sustainable Safety was introduced in the late 1990s, but was not always incorporated into the spatial design.

Housing estate with a central axis
Advantages for road safety: clear, hierarchical structure; good orientation.

Disadvantages for road safety: central axis allows for poor crossing options; the axis has a single profile but the traffic volumes vary significantly; there is occasional through traffic; the profile is often overdimensioned, with long, straight road sections; public green zones are usually oriented towards the road network instead of to the houses.

Road safety approach: complete concentration on the central axis, the ability to cross the axis and the detailed planning of connections to the axis. Residents often find the measures contrived. The task is to create workable connections between the areas that are separated by the urban axis.

Housing estate with distribution ring road
Advantages for road safety: no through traffic within the ring road; clear, hierarchical structure.

Disadvantages for road safety: many roads with a traffic function; busy traffic on ring road; barrier effects, many detours.

Road safety approach: complete concentration on the distribution ring road, the ability to cross it and the detailed planning of connections to it.

6.5.8 Recent years

In recent years, the rise of project development has meant that new housing locations have been more strongly driven by market demands and financial returns. The traditionally dominant role played by municipal councils in such locations has declined sharply, as has their influence on the design of new housing locations.
Current housing estates are characterised by their variation, with many good examples displaying the balance between a clear structure and enclosed character.

Advantages for road safety: everything ranging from private courtyards to majestic boulevards, Sustainable Safety is often incorporated in the planning from the start, which means that few (or no) physical speed reduction measures are required.

Disadvantages for road safety: problems could arise concerning the ability to cross the roads and the detailed planning of the connections to the main thoroughfares; the design is also fairly inflexible.

Road safety approach: because these estates have only recently been built, any restructuring will only be considered at a later date. Guaranteeing road safety will then demand customised solutions more than ever.

6.5.9 Towards three archetypal development locations

Roads and streets can be closed off depending on the composition of the population. This is useful if there are lots of small children and the area surrounding the school requires more 'dead-end' streets for them to play. A grid is flexible and never hampers such a solution; in the case of ring roads, courtyard structure and tree structure, this solution is only possible by means of a constructional and expensive intervention.

Given current design methodology, three general structures can be distinguished:

- a main road with small autonomous neighbourhoods emanating from it;
- a post-modern estate with circles and squares, avenues and lanes;
- a grid of streets, avenues, boulevards and paths [6.15].

Main road with small autonomous neighbourhoods
The focal point in the estate is a main thoroughfare along which smaller neighbourhoods are positioned. These neighbourhoods have parking bays to the rear of the houses and contain autonomous cycle paths. It is a hierarchically constructed traffic system with a separation of

vehicle types. The advantage of this system is that it is a familiar model in many housing estates that were built in the 1970s. It is a clear system with roads for cars and bicycle paths and footways. Due to the concentration of traffic on the road, traffic in the neighbourhoods can be minimised.

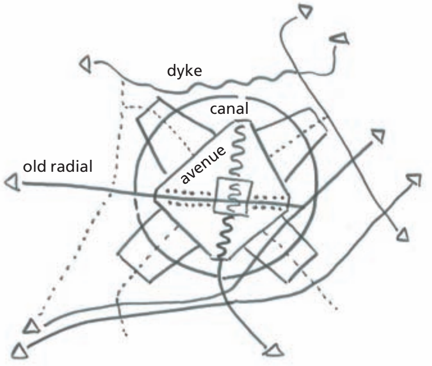
However, the disadvantages are that the main road will handle a substantial amount of traffic, much of which will exceed speed limits. The main road will be difficult to cross because of the tendency to overdimension this traffic artery on account of the Noise abatement act: the more distance between the road and the façade, the lower the noise levels on the façade. In this way, the main road often forms a barrier between the neighbourhoods, while a significant amount of space is wasted and the green zones are difficult to manage and maintain. The system necessitates a double infrastructure for cars and bicycles (double surfacing, double public lighting).

Important aspects for road safety:

- **Access system.** A main road can effectively regulate the driving behaviour of cars. High speeds are technically manageable. However, attention must be paid to bicycle and pedestrian crossing points on the ring road. An excessive number of speeding vehicles constitutes a risk.
- **Separation of vehicle types.** While this is necessary on busier roads, the locations where the difference types of vehicle encounter one another again are dangerous because motorists have gotten used to driving without cyclists on the roads and have become used to acting differently as a result.
- **Overdimensioning.** Overly wide roads and the lack of spatial context encourage speeding. This can only be prevented by road design. Lack of spatial context makes the forced reduction of speed illogical and leads to a lack of understanding on the part of the motorist.

Housing estate with circles and squares, avenues and lanes

There is a circular boulevard with a square of avenues. By preserving a number of elements and sightlines at prominent points in the environment, the area is given a new and recognisable character. The advantage is that this produces a lively map with striking and attractive forms. The plan exudes innovation, but designing the area presents a difficult challenge. Concentration of traffic is possible.



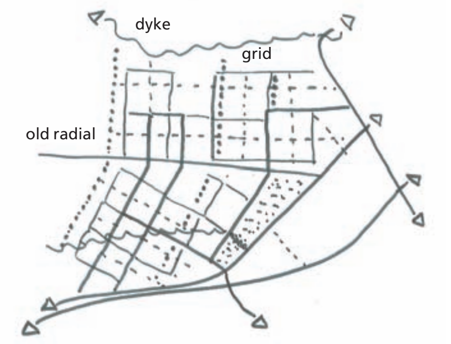
The disadvantage of this structure is that it is difficult to fit into the existing surroundings. The access system looks like a ring road system and is difficult to expand. The oblique and winding forms, circles and ellipses are no guarantee for beauty, practicability or conviviality. There is a relatively large amount of remaining space that is difficult to model.

Important aspects for road safety:

- **Access system.** The boulevard and the avenues are perfect as primary access roads. The radial roads are perfect as bicycle routes. However, attention must be paid to bicycle and pedestrian crossing points on the road. An excessive number of speeding vehicles constitutes a risk.
- **Separation of vehicle types.** The circle is ideal for separate lanes for cyclists and pedestrians, particularly on busy roads. The strict separation of cars and bicycles will depend on the size of the neighbourhood. A mixed traffic system is possible inside and outside the circle.
- **Overdimensioning.** Overly wide roads and the lack of spatial context encourage speeding. The boulevard and the avenues are perfect for 'spatial width', as suggested by the Noise Abatement Act. However, there is a danger that the wide road is at odds with the surrounding area with its residential function. Encounters between cyclists, pedestrians and cars have to be dealt with carefully given the many junctions in the circular boulevard.

Grid system

The area is a system of through roads and paths. Larger squares that form small neighbourhoods between which lie wider boulevards and avenues. It is a clear system without separate facilities for cars and cyclists. Diagonal paths can be laid for cyclists and pedestrians.
The traffic system is linked to the existing environment at a number of points. The grid system results in a distribution of traffic.



The disadvantage of this system is that problems related to quality of life occur in many of the neighbourhoods that are laid out in this way. Moreover, the map is uninteresting and can give the impression that, in conjunction with the rectilinearity, this is the cause of the problems. Cars have unrestricted access.

A key advantage is the simplicity with which the neighbourhood is constructed. Costs are low because there is maximum flexibility in choosing plot sizes and because there is no excess space. Both during development and upon completion, the neighbourhood can be easily modified or expanded. The 'normal' orientation gives the streets a classic image.

Important aspects for road safety:

- **Access system.** The dense system of streets and avenues allows cars unrestricted access but the number of vehicles is 'diluted' and, therefore, manageable. This arrangement is perfectly suited to large residential areas with low speed limits.
- **Separation of vehicle types.** A mixed traffic system is perfectly acceptable within the neighbourhood itself. Separation of vehicle types may be desirable at junctions with existing roads, depending on the type of road.
- **Overdimensioning.** The streets and avenues between the residential neighbourhoods are perfect for a broad spatial layout. Traffic is distributed and can be included in the residential area. The dense network of streets and paths results in multiple conflict points but the distribution of traffic means that few of them are serious.

6.5.10 And the future?

In the coming years, some areas will expand further while others will shrink. Growth can take the form of infill development in existing urban areas. The question is whether these existing areas are able to withstand such infill. Road safety requires extra attention, especially if the area is already relatively unsafe.
Another current trend is upscaling, which leads to larger travelling distances and increased use of cars; from a road safety perspective, this constitutes an unfavourable development.

6.5.11 Accident data per period

Neighbourhoods from the various urban design periods display different accident patterns. The grid systems from the 1950s, 60s and 70s stand out in the negative sense, while there are now also neighbourhoods with a grid system that are relatively safe due to the attention that was paid to road safety from the outset. The introduction of 30 km/h zones appears to have been good for road safety: there was a 45% reduction in the casualty rate and hospitalisation declined by over 30%. Although the introduction of these zones was favourable for all periods, there are certain differences [6.28, 6.29].

6.5.12 Villages

Road safety is also a point of attention in rural areas, where problems are usually spread over a larger area rather than a limited number of points. Potential problems are compounded by the fact that the possibility of implementing measures is often limited. Safety gains are still possible, but there is little in the way of specific literature on road safety in rural areas compared to research into road safety in urban areas.

Many small villages and rural centres have developed over centuries and in that sense have not been consciously planned to any great extent. This is why the principle that traffic in rural areas should travel on roads that were specifically built for that purpose is rarely implemented. This is also partly why it is often impossible to equip rural villages in such a way that they conform with Sustainable Safety guidelines.
On the other hand, communities in rural areas are relatively close and residents and businesses are more than prepared to help think about (and sometimes even invest in) their own quality of life.

This is why it is important to take the structure of the road network into account in these smaller rural centres, many of which mostly have access roads and a few distributor roads with through traffic. Key aspects for road safety are the choice of location and the design of the transition between the various speed regimes of the different road categories. Because villages are limited in size, there is little need for measures to be implemented to keep speed down in the centres themselves.

6.5.13 Passages

A passage is an old national road through a built-up area. Passages in built-up areas are often flanked by shops and services as well as homes. The basic principle of facilitating traffic comes with the following consequences: accidents; problems with noise, vibrations and odour; residents feeling unsafe; disruptions to living, working and shopping; and barrier effects. The need for these through roads is regional, in that they create a link within the network, or because there are plans for a diversion, et cetera.

The key to through roads in built-up areas is taking the location and clarity of the area boundary into consideration. Attention should also be paid to the location and clarity of the transitions between roads with a residential function and roads with a traffic function.
There are generally three speed-regime strategies for passages within the area boundary:

- a function over the entire length of the road (50 km/h);
- an initial distributor function (50 km/h) and a residential function in the centre (30 km/h);
- a residential function over the entire length of the road (30 km/h).

No matter how attractive it might feel to try and make everybody happy (through traffic versus local traffic), ambiguous solutions are not what road users need. When designing passages in built-up areas, the relationship between through traffic or traffic flow on the one hand and local traffic or barrier effect on the other must be clarified. This is a design problem in which urban design and traffic play an equally important role.

This does not detract from the fact that it is possible to choose a narrow road profile for a traffic function that logically results in low maximum speeds. It is also possible to guarantee a certain level of traffic flow with the low speed limits that accompany a residential function. It must be made clear that the car is a 'guest' and must accommodate other road users without motorists having to stop too often [6.30 – 6.33].

6.5.14 Ribbon developments

Ribbon developments place high demands on the contribution made by traffic engineers and urban designers. A ribbon development is a road with a continuous narrow strip of buildings (often on both sides) that stand close to the road. Ribbon developments are often old and do not fit seamlessly into the three Sustainable Safety road categories. The traffic function and the residential function are at odds with one another as well as constituting a conflict of interests. This often makes road safety problems difficult to solve completely.

Key recommendations here include: look at the function of the road within the bigger picture, make a clear choice in terms of the function of the road (or part thereof) and decide between two alternatives. As long as the roadscape and the speed regime are not in balance, other measures will have little or no effect. Table 6.3 illustrates that ribbon developments

Table 6.3. Differences between ribbon developments

	Ribbon development in polder (relatively) recent	Expanded ribbon development, partly historical	Historical ribbon development
Length	2.8 km	7.0 km	4.8 km
Spatial visual	spacious, straight; partially open; free-standing buildings; diverse businesses.	several bends; varied profile width; variable character; free-standing buildings.	small-scale; conservation area; variable character; listed buildings.
Spatial functional	several mild speed-reduction measures; narrow verges; narrow cycle paths; unrestricted parking.	side roads relieve ribbon; cycle path at businesses; localised pavements; speed-reduction measures; parking facilities.	varied profile width; border strips; bus stop on carriageways; unrestricted parking.
Future	no expansion of ribbon development or surroundings.	extra access from distributor road of new housing estate.	possible motorway link.
Traffic policy	small traffic volumes; high speeds; little rat-run traffic; diversity of vehicles.	moderate traffic volumes; variable speeds; local traffic; school route.	slight traffic volumes; agricultural traffic; coaches.
Traffic unsafety	primarily subjective.	moderate accident pattern.	not particularly high; subjective road unsafety.

can vary significantly, thus making it impossible to apply one approach to them all [6.16]. A ribbon development demands an intensive collaborative process between politicians, experts from other disciplines and residents, which results in a customised design.

6.5.15 Recommendations for urban structures

There are fewer possibilities to implement spatial measures for existing urban structures and traffic engineering measures may, therefore, become inevitable. If the ambition to provide high levels of road safety everywhere is unrealistic or infeasible, it is important to ensure at the very least that key connections are safe.

Plans for new developments must be based on an urban structure that fits into the spatial situation and the expected need for mobility. Both strengths and weaknesses need to be anticipated, which means:

- maximum use of the strong aspects of the urban structure;
- optimal prevention of potential problem points and, if that is impossible, minimisation of the volume and severity of the problem points.

This can be achieved by:

- Carefully connecting to the existing buildings, also in terms of safe access to cross-district amenities.
- Paying attention to running lines and natural structures.
- Preventing through traffic in residential areas.
- Opting for large-scale residential areas (up to 1 × 1 km) and a coarse-meshed structure of traffic arteries (distributor roads).
- Opting for a minimum length of traffic arteries within the residential area. Focus on minimisation of barrier effects or unavoidable traffic arteries.
- Ensuring a clear contrast between traffic arteries and residential areas in terms of design, function and use when traffic arteries transect residential areas. By enabling a distributor road to branch off to multiple equivalent access roads, a natural contrast in traffic volume can be created. In this way, traffic from a busy distributor road can branch off to several quieter access roads. Distributor roads in a residential area must be as short as possible.
- Connecting to the primary public transport structure, paying particular attention to public transport routes through and (preferably) around the residential area, with further attention to social safety at bus stops.
- Aiming to have amenities located close by (such as shops and other facilities as well as public transport).
- Orienting functions that attract heavy or a lot of traffic to the edge or the entrance of the residential area.
- Separating functions that attract a lot of traffic with a water feature or solid partition from the residential area, thus preventing an overspill of (parking) problems to and unnecessary traffic in the housing estate.
- Clustering area-specific amenities and other functions for residents where reasonably possible. Safe access to these clusters for all modes of transport must be considered from the outset.
- Enabling possible variations in building density to have a positive impact: smart orientation of densities can minimise the total number of kilometres by cars in residential areas.

- Ensuring a safe layout at street and neighbourhood levels.
- Ensuring sufficient playing areas for every age group in the immediate surroundings.
- Ensuring a socially safe alternative to routes that are not socially safe.
- Involving residents, where possible, in the planning process at an early stage [6.34 – 6.40].

6.6 Outside the built-up area

On roads outside the built-up area, it is key to make sure that road users know what is expected of them. This can in part be realised through traffic engineering measures, but perception of the landscape also plays a role. It is important to ensure that the speed regime (or traffic function) and perception of the road and the road environment are mutually reinforcing. This can be achieved by having the traffic engineer work closely with the landscape architect to draft a collective script, which introduces shifts in decor and their layout. This leads to mutually empowering area-specific and universal measures [6.17]:

- area-specific measures such as tree-lined lanes, planting, reliefs, buildings, transition to landscape;
- universal measures such as roundabouts, speed humps, road markings, public lighting and other traffic engineering measures.

Sometimes there are conflicting interests in existing situations between traffic and the perception of the landscape, for example when trees are too close to a traffic artery. In that case, the obstacle-free zone is too small, which means that the road has insufficient forgivingness in the event of a collision. However, felling the trees is not an option because

that would seriously harm the landscape. Mitigating traffic measures can be applied in the short term but these must not be seen separately from a long-term solution [6.22, 6.42].

6.7 Public space and road safety in detail

The previous sections discussed the first cascade, dealing with urban and rural planning, urban design and road safety at structural level. This section will deal with public space in more detail, with particular attention being paid to residential areas. In the design of public spaces, there is a clear connection between the effect of urban design and road safety, which is the aspect of spatial design that focuses on creating a safe living environment. This section and the next section on Shared Space belong to the second cascade.

6.7.1 The overall picture counts

When designing squares, streets and avenues, there has to be a logical connection between buildings and space, urban design and traffic engineering. The end user experiences space as an overall picture consisting of a spatial image, the activities that take place there, and the traffic engineering image. It is possible to shape the space and steer driving behaviour in the desired direction using buildings, planting, public lighting and, if necessary, roadside fixtures.

6.7.2 Safe distributor roads

In the Sustainable Safety approach, a traffic artery has a dual character. Intersections, like access roads, require the safe interchange of traffic at low speed. On road sections, the flow of traffic is key and safety has to come from a separation of fast and slow vehicles.
The specification of distributor roads demands extra attention whenever the same public space also has strongly structuring elements such as bus or tram lanes. Striking a balance between adaptation and incorporation is one of the most important urban design issues.

Sustainable Safety's intermediate category – the distributor road – also demands customisation in design. The distributor road's potential road unsafety increases the necessity for a good design. Special measures are required, particularly in terms of speed and separation, because the road is used by multiple road user categories.
Most importantly, the design of distributor roads must differ in every respect from the design of access roads and through roads.

'Grey roads' is the collective name for roads with characteristics of both distributor roads and access roads, which, within the built-up area, were often the old district roads or local access roads. After categorisation according to the principles of Sustainable Safety, grey roads should be in a 30 km/h zone, but that requires their complete reconstruction; the 'simple layout' is insufficient in this situation.
However, reconstructing grey roads into true distributor roads is a drastic and expensive measure as well as a difficult one from a spatial point of view. Temporary measures can be implemented to minimise bottlenecks by enforcing a maximum speed limit of 50 km/h.

The traffic engineering consequences of distributor roads are discussed in chapter 7 on infrastructure.

6.7.3 Low speeds in residential areas

In terms of both accident prevention and limiting the consequences of accidents, road safety in residential areas benefits from low speed levels. For the environment, low speed levels come with less objective road unsafety and less nuisance. In many cases, the subjective road unsafety also decreases. Moreover, it is also possible to respond to unexpected situations at low speed and to have better eye contact with other road users. This is explained further in both chapter 1 on theory and chapter 11 on risk-enhancing behaviour in traffic.

It is erroneously assumed that speed is key to the accessibility of residential areas. Travel times change relatively little, because it is the lowest speeds rather than the highest speeds that determine average speed. In a residential area, it is inevitable that drivers will be forced to slow down and accelerate again, meaning that the maximum speed has little influence on accessibility. Furthermore, most journeys are short. Similarly, the argument that low speeds undermine the capacity of the road is also incorrect with regard to residential areas because capacity is determined by junctions, where speeds are almost always lower.

In addition to speed, space for pedestrians (pavements) is also important in making vulnerable road users and playing children feel safe. In home zones and on cycle streets, cars are guests, while roads in a 30 km/h zone are, in principle, for traffic.

In creating a spatial design, it is important to see man as the measure of all things or to focus on the end user. It is also best not to overdo things to influence the behaviour of road users. On the one hand, the layout of a residential area should not be too restrained. In many cases, a 30 km/h sign is not enough to enforce motorists to adhere to the speed limit in residential areas, and more is required to make residents feel safe. On the other hand, however, the area should not be jam-packed with speed humps and other techniques designed to slow traffic. Both passers-by and residents can construe this as discriminatory against cars.

To find the right balance between 'too restrained' and 'discriminatory against cars', it is important to enforce the desired traffic behaviour in a logical manner or to make it obvious to the road user. There are different ways of making low speed levels obvious to road users:

- Visual means:
  - the layout must explain what is happening and what can happen.
- Psychological means:
  - make the motorists feel like they are guests;
  - invite pedestrians to behave informally;
  - eye contact;
  - non-traffic-engineering measures.
- Social means:
  - support;
  - involvement.
- Physical means, as a last resort (= admit failure):
  - speed humps;
  - raised junctions;
  - staggered junctions;
  - chicanes;
  - et cetera.
- Legal means: the home zone act and 30 km/h regulation.

Table 6.4. Effect of buildings on speed

	Speed reduction
Buildings far away versus empty plot	20%
Buildings nearby versus empty plot	30%
Buildings nearby versus far away	15%
Buildings on one side versus empty plot	25%
Buildings on one side nearby versus buildings on both sides nearby	7%
Low-rise versus high-rise	0%
Central reservation versus no central reservation	0%

It should be noted here that a good design works for most road users, but not for all. The design must provide space for vulnerable road users, also if they cannot always display the desired behaviour due to, for example, a disability.
It is reasonable impossible to discount maladjusted behaviour completely through the design of a spatial situation. Although a residential area must, in principle, be 'self-enforcing', a small percentage of road users will continue to display maladjusted behaviour.

6.7.4 The effect of buildings

Research has substantiated what is intuitively logical: the design of the traffic space – the characteristics of the road and the road environment – influences road user behaviour. The presence of buildings, for example, has a marked effect on speed: in undeveloped areas, speeds are on average 20% higher than in built-up areas, irrespective of whether the buildings are high-rise or low-rise.
If the distance from the building fronts to the road is relatively small, speeds are generally reduced. In terms of the impact of building distances, it is immaterial whether there is a wide central reservation or not. This is illustrated in table 6.4. These effects are strong and not dependent on personal factors such as driving experience, number of kilometres driven annually and tendency to speed [6.43].

6.7.5 Legal frameworks

The call for liveable residential areas prompted the creation of the home zone act in 1976, which made it possible to design streets in such a way that motorists had to adapt to pedestrians and playing children. In 1988, the home zone act was changed. The basic principles stayed the same but the possibilities became much more expansive. A home zone is the collective name for home zones, village estates, shopping areas and school zones. This change also saw the introduction of a new traffic sign. It is stipulated that within a home zone:

- pedestrians may use the entire width of a road;
- drivers are not permitted to exceed walking pace (15 km/h);
- motor vehicles are only permitted to park in spaces that have a P-tile or P-sign;
- vehicles adapted for disabled drivers or vehicles with a disabled badge are exempt from the above rule.

Designing a 30 km/h zone requires customisation and is bound by rules and regulations. All road authorities must determine for themselves whether the design meets the implementation requirements stipulated in the Administrative provisions (road traffic) decree (BABW).

- The maximum speed limit to be introduced has to correspond with the in situ roadscape. This means that, where necessary, the circumstances have to be adapted in such a way that the intended speed reasonably ensues from the nature and layout of the road and the road environment.
- Every road within the area concerned primarily has a residential function.
- The road and the road environment must, where necessary, be modified to prevent the residential area from being affected by relatively high traffic volumes.
- In terms of speed management and increased attention levels, extra attention must be paid to potentially dangerous locations such as:
  - places where pedestrians, particularly children and the elderly, cross the road;
  - intersections with a primary cycle route and separate bus lanes.
- The transition to another maximum speed limit must be clearly recognisable from the layout of the road. If the transition to a higher speed limit lies within twenty metres of an intersection, right-of-way is regulated via traffic signs or an exit construction, unless the intersection can be incorporated into the area.

6.7.6 Recommendations for residential areas

The following recommendations can be made for the specification of public spaces in residential areas [6.18]:

- All road users must be able to see from the road and the road environment what is required of them in terms of their behaviour: Sustainable Safety.
- When entering a residential area, low speeds should be enforced by means of a conspicuous, self-explanatory and effective method. This can be a formal exit construction or an informal arrangement with road narrowing measures.
- In residential areas, cars are equal to every other vehicle and mutual respect is a must. Social behaviour is key here: road users must be able to have eye contact.
- Places with lots of pedestrians (schools, cafés, library) must be given priority. Care must be taken when choosing the types of trees, public lighting, fixtures and suchlike. Short cuts and diagonals for non-motorised traffic are desirable.
- The use of the space must be self-evident, paying attention to the location and connecting to existing features. The design must fit into the surrounding environment, without the need for severe measures. A good design is inconspicuous.
- Use non-standard situations to the area's advantage (such as cattle grids as a speed-reduction measure).
- Where possible, desirable driving behaviour must be achieved through architectural choices such as rhythm, colour, gate function, et cetera.
- Traffic engineering measures such as speed humps must not be introduced too hastily. If they are at all necessary, they should be placed at possibly unsafe situations. Irritated motorists are not the safest of road users.
- At infrastructure level, attention must be paid to the wishes of the residents and the users of the design: involvement leads to acceptance.
- The materials to be used should be chosen carefully: good quality and sustainable. Fashionable solutions are soon outdated or no longer functional. Measures must fit

into the surrounding environment.
- Details are important. They are the basis on which residents judge designs.

If it is not feasible to take an integrated approach to an area, the least that should be done is to ensure safe routes for non-motorised traffic, children and the elderly between the key amenities such as school, shops, playgrounds, green zones, sports fields and sport halls, public transport stops and cafés.
In addition, the safe route must also be linked to cross-district amenities [6.44, 6.45].

6.8 Shared Space

In the past, public space was not always evenly structured, with the living environment being harmed by objectives that concentrated on through traffic.
Shared Space is a concept that focuses on the multifunctionality (and thus the relationship between road safety and the surrounding environment) of public space. In this vision, public space is primarily a space in which to live, organising residential space as people space rather than as traffic space. Public space can accommodate various functions that are considered socially important.

6.8.1 Space and behaviour

In terms of Shared Space, public space with a residential function must invite social behaviour. The road user must be able to tell from the characteristics of the road and the road environment which behaviour is appropriate and required. The aim is to encourage interaction and facilitate eye contact. It is assumed that in situations where people are allowed to negotiate the right of way, speed will automatically be lower. It is also assumed that if a person demands respect from another road user, that this person will have to show respect in return. The essence is not to try and eradicate the feeling of unsafety, but rather to use it to best effect. Feeling unsafe is useful. Monderman translates this in the motto 'Better chaotic than pseudo-safe' [6.19].

According to Shared Space, traffic, residential and other functions must be in balance. Where possible, functions must be combined rather than separated as is often the case in current design practices.

Shared Space anticipates the character of the road, the intersection, the buildings and the surrounding area in order to make the road more attractive and safer. The approach employed by Shared Space offers possibilities for respecting and even emphasising the cultural history of a particular place [6.20].

Given that traffic is mixed, the isolation and separation of traffic types on roads with a residential function is not an option. The 30 km/h or 60 km/h speed regime must be clear and self-explanatory. This includes:

- mixing (mostly) and fitting in;
- using a minimum of traffic engineering and artificial objects;
- using coloured asphalt instead of grey/black;
- conscious choice of public lighting and lamp posts;
- encouraging eye contact between road users.

Issues that need to be avoided include noise barriers, roads with multiple lanes in both directions, contrived traffic regulations, conflicting information, confusing situations. The 'slow' network can only function if there is a 'fast' network; the fast network is the focus of for traffic engineering layout and control.

In practice, it can be a problem to guarantee the interests of the most uncertain and vulnerable road users; Shared Space assumes self-aware and self-assured road users and sometimes requires additional measures for this group, such as a zebra crossing in front of a care home.

Behaviour according to Shared Space

It is possible to represent residential behaviour, social traffic behaviour and technical/legal behaviour in their mutual relationships. This yields the following picture:

Comparison of behaviour in residential and traffic spaces [6.57]	Residential behaviour	Social traffic behaviour	Technical/legal traffic behaviour
Characteristics of behaviour	Multiform and pluralistic	Pluralistic	Uniform
Orientation	Unspecific	Specific	Specific
Movement mode	Unfocused	Semi-linear, partly coded	Linear, coded
Speed	Up to 30 km/h	Up to 60 km/h	-
Predictability of behaviour	Largely unpredictable	Limited predictability	Largely predictable
Relation to others	Varying from no interaction to intensive interaction	Eye contact	None
Gear personal behaviour to	People and physical environment as a whole	People	Vehicles and traffic engineering environment
Behavioural context	Society	Society	Traffic engineering and legal system
Determinants of behaviour	Autonomous and through social conventions	Autonomous, social conventions and basic traffic regulations	Determined by government, juridified
People as focus	Signifies autonomous development	Signifies human social factor in traffic behaviour	People as weakest factor in traffic system requiring protection
Signals from the environment	Landscape, design of public space	Landscape, design of public space and contextual references	Observation, traffic engineering, traffic signs and instructions from official authorities

6.8.2 Shared Space in a process-oriented perspective

In the Shared Space concept, politicians have to develop a vision of the environment for the citizens whose interests they serve. This makes the choice between a residential space with shared use of space or a traffic space a political one. On the basis of this choice, public space must clearly indicate the desired behaviour. The Shared Space process can be characterised as follows:

In table 6.5, Shared Space follows the diagonal in order to realise a dual quality: spatial quality (upper left cells) and democratic quality (lower right cells). The way in which the end product is achieved is at least as important as the end product itself [6.21, 6.22].

6.8.3 Shared Space and Sustainable Safety

Shared Space connects seamlessly with Sustainable Safety in residential areas. However, opinions are divided on the question of whether, to what extent and how the concepts of Shared Space are also applicable to distributor roads. This will probably remain the case as long as no large-scale evaluation of Shared Space in this type of situation is performed [6.45 – 6.47, w6.1].

Table 6.5. Shared Space process

	The administration	The design	The implementation
Vision	Gives the instructions People space or traffic space.	Sustainable designs. Social behaviour versus traffic behaviour.	Objective of technology as a tool.
Working method	Holistic. Empowerment and participation. Vision provides direction.	Creativity. Co-operation with other disciplines. Communication.	Co-operation within the organisation. Creativity.
Tools	Process skills.	Participative design methods. Insight into relationship with other disciplines. Communication methods.	Choice and placement of materials. Using new materials.

6.9 The importance of effective co-operation

The contrast between urban designers and traffic engineers is often pointed out. If such a contrast exists, it may be down to the way in which these experts are trained: urban designers from the design and social perspective, traffic engineers from a technical perspective.
An important difference is that traffic engineers and urban designers usually work in different departments in government and consultancies. This can result in less consultation and co-operation, and where this does occur, there are often discrepancies in terms of the level of thinking.

Road safety is seen as the area of expertise of traffic engineers. Yet attention to road safety has been around longer than traffic engineering, which developed as a specialist field within civil engineering. The development of plans for streets and roads became more complicated as a result of increased vehicle use and the need for mobility. In turn, civil engineering and then traffic engineering became part of an organisation that focused on the design of public space. Many cities and villages had an urban architect who regarded and designed public space as a single entity. Nowadays, only a few municipal councils have a dedicated body that is responsible for the overall design of public spaces.

In 1963, Buchanan's study 'Traffic in Towns' was published [6.39]. This extensive study established for the first time the relationship between car traffic in a city and the quality of the environment, and specified the mutual influencing of accessibility and the requirements of the environment. It explained in brief that the better the accessibility for cars, the worse the quality of the environment. Buchanan was the first to propose a division of public space into traffic and residential areas ('corridors and rooms'), distinguishing between living, working, recreation and traffic.

6.9.1 Interdisciplinary approach

'Everyone involved in designing a portion of public space must be aware that it has an influence on public space as a whole'. This is a quote from 'Verkeer en stedenbouw, samen een kunde apart [Traffic and urban design, together a unique field]' [6.56], a publication that expresses the fear that traffic engineers and urban designers fail to create plans together. The authors state that traffic aspects and roads in cities and villages are just one part of the bigger whole of public space. They prefer combining the knowledge and experience of traffic engineers in interdisciplinary teams, which would contribute to the effective functioning of an urban area. Such an interdisciplinary approach requires that rules and standards be formulated first. What are the legal frameworks (administrative provisions)? Can new jurisprudence be developed? In order to work on a collective recommendation, both disciplines must be prepared to work together, complemented by the other players in the field, such as landscape architects, experts who are familiar with the needs of children and experts on listed buildings[6.48].

6.9.2 Formal co-operation

Co-operation between spatial disciplines and traffic engineers can be formalised in a project group, which can take two organisational forms:

- if the disciplines in the project group function on an equivalent level, this is known as a horizontal organisation;
- if traffic planning is part of spatial planning, this is known as a vertical organisation.

A study of fifteen projects showed that nine were horizontal and six vertical. In the projects with horizontal organisations, no unsafe designs were observed in any of the locations. This was not the case for those with a vertical organisation – in which traffic was organisationally subordinate – with four of the six locations being seen as having an unsafe design.

The following recommendations are given for effective formal co-operation:

- Create optimal preconditions for co-operation:
  - appoint an independent project leader/ process manager;
  - organise the project group horizontally;
  - do not start with the development of a plan before the ambitions, preconditions, plans and decision-making moments are clear.
- Timely agreements on the integration of spatial disciplines, traffic planning and traffic engineering:
  - careful choice of project leader;
  - interdisciplinary composition of team;
  - interdisciplinary working method.

The project leader responsible for content and the project group are together responsible for content integration.

- Use concepts to gain an insight into the other's area of expertise:
  - joint approach to the design process;
  - joint terminology and language.
- Continue to work in a project-oriented manner.
- Maintain short lines between the project group and the steering group [6.23, 6.24].

6.9.3 Informal co-operation

Informal co-operation appears to be the best way of enabling spatial experts and traffic engineers to work on an integrated design for public space. Informal collaboration demands a good relationship, which, seeing the preconceptions each has about the other, should not be taken for granted.

- Preconceptions some urban designers have about traffic engineers include: they think too 'mechanically' and work on a pseudo-science, they are difficult and most certainly lack creativity. Traffic engineers often rely on the certainty of technology. These urban designers see themselves as creative, focused on the big picture, and able to think in terms of themes, concepts and metaphors.
- Preconceptions traffic engineers have about urban designers include: they place their own truth above that of the end user and pay little attention to guidelines and legislation. These traffic engineers consider themselves to be result-oriented and able to think in terms of quantity, functionality and standards [6.25, 6.26].

In so far as there is some truth to these caricatures, the challenge facing traffic engineers is to work more contextually and integrally and to put things into perspective more, while the challenge facing urban designers is to open their minds to other disciplines.

Effective informal collaboration can be based on coaching. Urban designers are then coached by traffic engineers and the traffic engineers are required to show a genuine interest in how urban designers think and see things. The traffic engineer's input anticipates the aims and interests of the urban designer. After all, with their knowledge and experience, traffic engineers can indicate how traffic and traffic measures can contribute to the functionality of a village or city. Guidelines are employed as tools and not as crowbars. The urban designer and the traffic engineer each fulfil a complementary role in this approach.

In this way, the traffic engineer creates leeway within the relationship, which, at the same time as clarifying their own objectives, they can use to exercise influence on the urban designer without there being any hint of a formal power structure. The collaborative relationship can be shaped in collective workshops as well as through explanation and discussion. The traffic engineers and urban designers can then coach to manage and direct a project, which is more effective than having to repair the damage after the fact [6.49].

Professionals and their perspective on road safety

Various perspectives on road safety are connected to the role that someone assumes. Each perspective has an individual language and a characteristic view of road safety and road unsafety. The perspectives are generally complementary, but they can also sometimes conflict with one another.

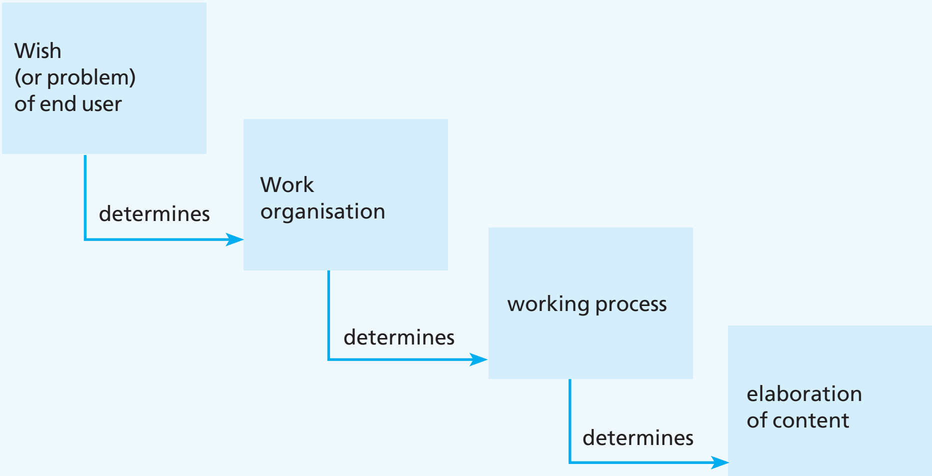
Perspective:	Is focused on:	Has repercussions for:	Accompanying terms:
Expertise	Expert knowledge	Product and subject content	Holistic, consistency
Project leader	Logic and progress	Project plan, planning and investment	Time, money, effort, quality, yield
Politicians/management	Decisions and actions	Choices and priorities	Ideals, norms/values, decision-making
Lawyer/process manager	Formal interaction	Process and justice/legislation	Playing field, rules, interaction
Road user/end user	Feeling, factual interaction	Empathy and experience	Support, marketing, imagineering
Strategist	Image	Organisation and orientation	Development and self-learning ability

Success in terms of road safety, therefore, demands more perspectives than merely that of expert knowledge of road safety. The various perspectives on road safety must be similar and strengthen one another where possible.

Taking a process-oriented approach to road safety

Irrespective of whether a measure is specifically intended for road safety or for another purpose, it is important to get and retain an image of road safety during the process. This necessitates the following points of attention:

- create a sense of urgency;
- forge coalitions with other parties;
- generate short-term successes and make the most of them;
- consolidate improvements before introducing further changes.



Every wish (or problem) begins with the end user: the road user or the person who suffers inconvenience from road users. It is important that the wish or problem is properly substantiated. After all, this is the basis for the choices that are made about which organisation is to be established to realise the wish or tackle the problem.

The choice of organisation is of the utmost importance because it determines to a large extent the perspective chosen for the solution and thus the required budgets. The organisation is largely composed of different parties with different interests. An organisation must have someone with sufficient opportunities to control the process who will take final responsibility. The organisation, in turn, determines the working process.

Likewise, the working process determines the way in which information is exchanged, who takes decisions and when, etc. In addition, the working process also sets preconditions such as lead time and budgeting. It is worth anticipating disruptions in the process. Much can be achieved by employing risk management – even in its simplest form – and quality assurance to manage the working process. The working process also determines the equilibrium in the composition of measures to be taken (surroundings, infrastructure, education and traffic enforcement), the spatial scale level being introduced, the target groups, et cetera. Thus, the working process determines the effect in terms of content.

It is important to realise, therefore, that the effect in terms of content is the result of the three previous phases. Looking at it this way, a significant amount of information is already fixed at the point when the effect in terms of content is reached. But given that this effect is often the only thing that the end user sees, this remains the most important aspect in the end.

6.9.4 Finances and preconditions

It is important to determine budgets and other preconditions before effective co-operation can take place between the spatial disciplines and traffic engineering. These determine a lot of the elements of the planning process. It should be noted, however, that if the budget is too low, this impacts on the design. Conversely, if the preconditions are good, this is not necessarily a guarantee that the planning process will be a success.

6.9.5 Process technology

Process technologies facilitate cohesion between the spatial and traffic engineering disciplines. Some process technologies are aimed at the (re)development of areas and are focused on the long-term, such as local traffic performance and regional traffic performance (LTP and RTP respectively). This approach requires that both the planner and the urban designer play an active role. The aim of LTP and RTP is to make the preferred choice of transport the most obvious for the user by means of well-considered (urban) planning. What that optimal transport choice is depends on the strengths of the different modes of transport: for short distances, walking is unbeatable, for longer distances, the bicycle is a good alternative, and for long journeys, the car competes with public transport as the most viable option. This results in 'reverse designing': not from coarse to fine, but from fine to coarse. Applying these process technologies often allows improvement of the quality of life and safety without compromising accessibility, while reducing energy consumption by traffic and transport. Other process technologies focus on utilising the transport system, such as network management or the area-based approach. These process technologies can also have a beneficial effect on eventual road safety, which is why it is best to explicitly consider the consequences for road safety in such processes [6.50, 6.51].

6.10 Putting the resident first

End users or residents are the binding factor between the spatial and traffic engineering disciplines. Public space belongs to everyone. If there are no residents (yet), it is important that the planners put themselves in the shoes of future residents by posing such questions as:

- How, where and when will the new residents be travelling?
- Are there sufficient amenities in the area?
- Is the estate suitable for every mode of transport?
- Is the estate suitable for every lifestyle, age group and people with disabilities?

This is referred to as the PME check: People, Mobility and the Environment [6.27].

If there are residents, it is useful to invest in participation. There are different forms of participation, including:

- (public) enquiry: citizens can choose from different alternatives;
- initial involvement/participation: helping to think about solutions to problems;
- open planning processes: helping to think about identifying problems.

A clear and concrete problem definition or ambition must be formulated first. Furthermore, it must be clear from the outset what people can influence. The possibilities for residents' input are usually greater for access roads than for distributor roads.
It is also important that communication is conducted carefully and with parity.

The advantage of participation is that citizens:

- know the area better; it is useful to benefit from their knowledge;
- get an insight into the considerations made by planners, which contributes to a better relationship between local authorities and resident and to support from within the community;
- are more inclined to invest as a result;
- feel committed to the plans that they helped to create.

Participation is often a time-consuming investment that is subsequently recouped. It is considerably easier to revise plans before they have been carried out.

In addition to participation in large-scale plans, small experiments are also useful. In this way, urban designers and traffic engineers can retain close links with residents in a new housing estate after the estate has been completed [6.52 – 6.54].

Where residents are concerned, children and the elderly deserve extra attention because they are the ones who use public spaces the most. In a child-friendly design, car use and ownership is no issue as long as it does not interfere with the development opportunities of children. Playing outside must begin at the front door. Children must be able to gradually extend their radius of action over safe pavements and crossings to their friends and playgrounds.

Table 6.6. Different interpretations of speed

Motorist	Objective speed	12-year old child
I am almost stationery, very slow	⟵ 15 km/h, walking pace ⟶	Normal speed on the bicycle
Slow	⟵ 30 km/h ⟶	Quite fast, I can't cycle that fast
Normal	⟵ 50 km/h ⟶	Another world, not mixing, very careful when crossing, preferably at a zebra crossing, collisions are fatal

Cycling is very popular in the Netherlands and gives children a wider radius of action. It is especially important for children on bicycles that they have nothing to fear from other vehicles. Children experience speed differently from motorists. Table 6.6 illustrates the various interpretations of a particular speed.

In child-friendly designs, urban streets are inviting and sufficiently safe for children, who must be able to play. The challenge facing the designer is to create a reasonable balance between traffic and the interests of the children. This does not mean that every street must be suitable for people of all ages. Children are able to handle more and more complex traffic situations during their development through primary school.
Safe mobility is a basic right, irrespective of age or mode of transport, also for children who are playing, walking or cycling.

Research is currently being conducted into the extent to which the terms child-friendly, 'design for all' and design for all ages go together and where other infrastructural requirements surface at detailed level. The old attempts at a 'design for all' approach were primarily focused on accessibility for people with a physical handicap (focus on wheelchairs, rollators, mobility scooters and suchlike). Design for all ages appears to focus predominantly on being 'elderly-friendly' [6.55].

6.11 The final phase: view to implementation and management

Notwithstanding the good intentions of all concerned, there is always the chance that something will go wrong in spatial planning. Effective implementation is not a matter of course. Actively guaranteeing the quality of a design in the implementation and management phases demands the effective transfer of the plans and evaluation of whether the plans are implemented correctly. This is why some respected designers demand that they be allowed to supervise the implementation of the plans.

If a design is properly implemented, the road authorities have to continue to guarantee its safety level. The designer and the road authorities must be able to liaise quickly and easily in the event of deficiencies in terms of road safety – which is not always as easy as it sounds.

6.12 Summary

The two most important related areas of expertise in terms of road safety are urban and rural planning and urban design. Spatial planning and urban design can boost road safety, but not without potential problems occurring. All told, the environment in which road users find themselves plays a key role in their behaviour. Each architectural period provides its own characteristic opportunities and poses its own threats to road safety. But careful planning and architectural choices enable active orientation on road safety.
One tendency that concentrates on the interaction between road users and their behaviour is 'Shared Space'. If its insights are correctly applied in residential areas, road safety will improve naturally and as a matter of course.

In a planning process, content is not the only thing that is relevant – the process of arriving at a solution is also key: the way in which co-operation between the various disciplines is guaranteed and the way in which interaction with the residents occurs. Finally, it is important that all partners are on the same wavelength.

The main message in this chapter is that effective preconditions for road safety are possible by employing a spatial approach, on the condition that the various disciplines have a mutual and sincere interest in the other's area of expertise.

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Website

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Infrastructure

Learning objectives for students:

- to have an overview of the desired configuration and design of the road network;
- to be able to indicate which functions the roads should fulfil within the network (road categorisation);
- to understand the relationship between the function, design and use of roads;
- to know the key design principles and design elements for each road category with regard to road safety.

Infrastructure design is part of the first 'E' – 'Engineering'.

7 Infrastructure

7.1 Introduction

7.1.1 Preventive/proactive approach: Sustainable Safety

Sustainable Safety focuses on making it more difficult to make mistakes or offences in traffic or to absorb their consequences by taking human dimensions into consideration when creating the traffic system.
First and foremost, the surrounding environment, including the road and the vehicle, must be in line with what humans can do, as well as offering support and protection. In addition, people must be well prepared for the traffic task through information and education, and the safety of their traffic behaviour must be assessed [7.1]. In terms of realising a road infrastructure, this approach is a preventive one.

No-one is immune to accidents. Everyone makes mistakes at moments when their guard is down. In most cases, the consequences are not serious because such mistakes only lead to accidents if other conditions at that location and that moment are unfavourable as well.
A mistake, therefore, is usually limited to a conflict or near-accident. The chances of making a fatal mistake are greater if traffic regulations designed to ensure road safety are deliberately disregarded. In order to limit the number of accidents, it is extremely important that safety guarantees can absorb human errors and that there are as few latent infrastructure errors as possible.
In this chapter, this preventive or proactive approach will be applied to the development of the road infrastructure.

7.1.2 Curative or reactive approach: PCOSE

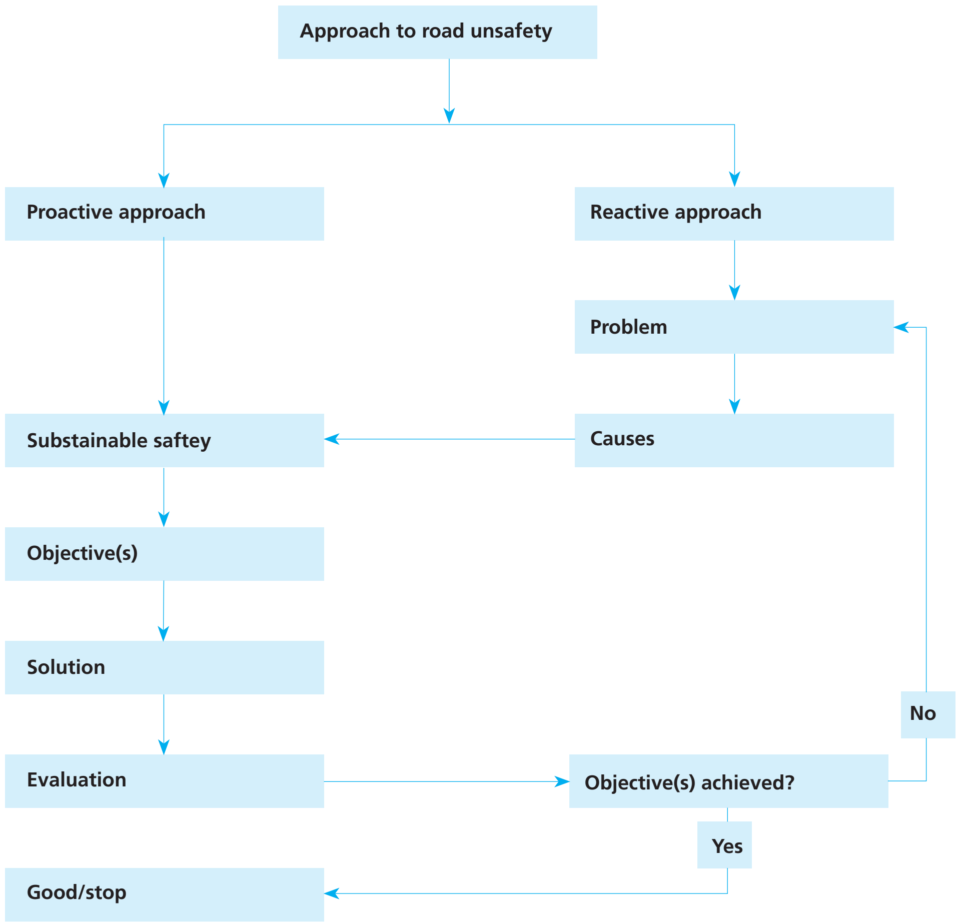
As a result of increased mobility, road authorities are confronted with ever more traffic problems, which predominantly involve service level (capacity problems), road safety and traffic liveability. Apart from the fact that not all traffic accidents are registered, the road traffic system yields a large number of near-accidents as well as complaints (subjective road unsafety, feeling unsafe). This is why, alongside the preventive approach, a curative or reactive approach to the road infrastructure is also necessary through the application of the Sustainable Safety concept. How the proactive and reactive approach relate to one another is shown in figure 7.1. Research methods such as accident analysis can trace the cause of safety problems. The PCOSE approach discussed in section 5.1 can be identified in the curative approach.

7.2 Design principles of Sustainable Safety

Sustainable Safety features five primary design principles, which were discussed in detail in chapter 1. The following is a short summary of these principles:

1 functionality of roads: a hierarchically structured road network comprising three road categories (see section 7.3);
2 homogeneity of mass, speed and direction: equality of mass, speed and direction at moderate or high speeds;
3 recognisability of the road design and predictability of the road course and the behaviour of road users through consistent and continuous road design;
4 forgivingness of the environment (physical) and between road users (social): injury limitation through a forgiving road environment;

Figure 7.1. Proactive and reactive approach to road unsafety



5 state awareness of the road user: the ability of the road user to correctly assess their capacity to handle the driving task.

The (driving) behaviour of the road user is determined largely by the roadscape and traffic volumes. Road users take much of the information they need to carry out their driving task from the roadscape, which results from the road design (cross section, horizontal and vertical alignment, and the road environment) as it is fitted into the landscape or the built-up environment [7.3].

With their possibilities and limitations, people determine the design of traffic facilities, which also takes into account that road users will make mistakes on account of these limitations. The ability to use roads safely requires a certain ability to react and think quickly. It is also vital to have a significant number of physical, cognitive and motor skills. Many people temporarily or permanently fail to satisfy these requirements; people with a handicap, for example, may find it difficult to travel. This is why insights into the limitations of road users contribute to a safer design.

Functional requirements

There are two levels of road design requirements:

- functional requirements;
- operational requirements.

Functional requirements are partly concerned with attributing functions to roads and, therefore, with the categorisation of those roads and their infrastructure. Before the design phase of a road can begin, it must be clear which function the road is going to fulfil. Operational requirements or general design principles stem from these functional requirements. The essential recognisability characteristics also belong to the general design principles (see section 7.3.4). These are of primary importance for the recognisability of a particular road category with regard to the other two categories.

The twelve functional requirements are [7.18]:

1 Construction of the largest possible residential areas. Areas in which the majority of daily journeys take place must be safe. Barrier effects as a result of high traffic volumes or speeds above 30 km/h are undesirable in residential areas. The size of a residential area depends on the possibilities of accessing the area.

2 Maximum part of the journey on relatively safe roads. In principle, every road in the Sustainable Safety concept is equally safe, but in practice this is not always the case.

3 Make journeys as short (direct) as possible. The more kilometres the road user travels, the greater the chance of being involved in an accident. This applies, in principle, to all road users.

4 Combine the shortest and the safest routes. Road users are inclined to choose the quickest route to their destination. This is why the shortest route must also be the safest route when constructing the road network.

5 Avoid situations in which road users have to search to find their way. This requires a clear road network with easily recognisable road categories and effective signposting.

6 Make road categories identifiable. This requirement has two aims: the first is to distinguish the quickest route in the network from the less quick routes. The second is to achieve optimum uniformity in terms of traffic behaviour within each road category.

7 Limit the number of traffic situations and give them a uniform design. Repeatedly confronting the road user with uniform traffic situations increases the predictability of the situation. It can also be expected that the learning process of less experienced road users will be quicker as a result. This requirement is predominantly applicable to through roads and distributor roads. On access roads, however, a recognisable and consistent ‘chaos’ is also a form of recognisability and uniformity.

8 Avoid conflicts with oncoming traffic. High-speed head-on collisions must be avoided. This requirement is applicable to through roads as well as road sections on distributor roads where traffic travels at relatively high speeds.

9 Avoid conflicts with crossing traffic. The chance of conflicts with crossing traffic on through roads must be excluded because of the significant chance of (serious) accidents. For distributor roads, this chance must be reduced by enforcing low speeds for motorised traffic.

10 Separate different modes of transport. An essential principle is that the different modes of transport must be separated as much as possible when the vulnerability of some road users is at issue. In addition to this vulnerability, differences in speed and mass are the key arguments for this separation.

11 Reduce speed at potential conflict locations. Where traffic separation is undesirable or impossible, driving speeds must be reduced substantially.

12 Avoid obstacles at the side of the road. This requirement leads to the elimination, relocation or screening of obstacles on the road side and becomes more urgent when speeds are higher.

There are also other functional design requirements that concern, for example, the view, dimensioning of curves, skid resistance, et cetera. In this respect, no special requirements are laid down in the Sustainable Safety concept in relation to the current situation.

Laws, regulations, guidelines and recommendations

Road infrastructure must meet statutory provisions and regulations, the most important of which are included in the 1994 Road traffic act and the 2003 Buildings decree. The Road traffic act includes such regulations as the Administrative Provisions (Road Traffic) Decree and the 1990 Road traffic and traffic signals regulations.

Guidelines and recommendations comprise possible solutions that can generally be applied. Local circumstances may require different solutions, but strong deviation from the guidelines is not advisable, because this may affect the recognisability and uniformity of the road category. However, uniformity is less important for access roads. If deviating from the guidelines is inevitable, the designer must ask himself the following [7.12]:

- Where and why is the design failing to follow the guideline?
- What extent of deviation is necessary?
- What are the consequences for traffic flow, road safety, the environment and the costs?
- What compensatory measures can be taken to guarantee road safety?

If deviations are unavoidable in a particular situation, their effects must be studied and substantiated (for example to prevent any future liability problems).

7.3 Planning and construction of the road infrastructure

7.3.1 Road categories

The road user's driving task is made easier by a recognisable and continuous roadscape and predictable traffic situations. One means of achieving this is to divide the entire road network into road categories. The way in which each category's function, design and use are geared to one another is decisive for road safety and the quality of the service level.

Traffic accidents appear to be primarily the result of a combination of conflict types and high speeds. This is why a Sustainable Safety road traffic system focuses on the elimination of conflicts or the reduction of speed. In addition, a balance must also be found between liveability, road safety and accessibility.
Given the above, it is logical to first divide public space inside and outside the built-up area into [7.18]:

- *Traffic areas:* public space for infrastructure amenities with a traffic function. Traffic function is understood to mean the possibility of making purposeful journeys on foot or by vehicle at a uniform speed.
- *Residential areas:* places where people live, work or partake in recreational pursuits. In these areas, the residential function takes priority due to the traffic liveability.

Traffic areas are formed by roads that provide access to and link residential areas and connect them to the (national) main road network. Following this line of reasoning, one of the following three functions can be attributed to the different elements of the infrastructure both inside and outside the built-up area [7.12, 7.18]:

- *Through function (through road):* a continual traffic flow. The through function is primarily intended for the flow of (through) traffic over long distances.
- *Distibutor function (distributor road):* roads with a distributor function form the central framework of the road system. Traffic interacts at intersections and flows continuously on road sections between the intersections. A distributor road connects:
  - two (non-adjacent) residential areas;
  - a residential area and a through road.
- *Access function (access road):* roads with an access function provide access to the individual houses, offices, companies, farms, (sports) fields, plots of agricultural land, et cetera, in an area. On access roads, traffic interacts on both road sections (estate connections) and intersections.

The division into residential areas and traffic areas on the one hand and the traffic function of roads on the other leads to a division into 'flow' and 'exchange'.

- Through roads have interchanges or grade-separated intersections and no intersections at grade. Due to their large-scale character, through roads cannot be included in the built-up area. Through roads, however, can intersect a built-up area, but they must be completely isolated from the surrounding environment.

- On access roads, the traffic function is of secondary importance to the residential function: interaction between the road and the surroundings is unrestricted. The road user can expect disruptions everywhere, from the road section to the intersections.
- Distributor roads form an intermediate category: the road sections are there for through traffic and the intersections at grade are there for the exchange of traffic between different roads.

Table 7.1. Provides a summary of this [7.18]

Road category	Road section	Intersection, interchange or connection
Through road	flow	flow
Distributor road	flow	exchange
Access road	exchange	exchange

7.3.2 Categorisation of the road network

Sustainability in terms of road traffic and transport is achieved by a balance between accessibility (including utilisation), safety and liveability. Ever-increasing mobility is a threat to the accessibility of the economic and social-recreational functions, as well as to the liveability of society.
Accessibility, liveability and safety can also be specified at municipal level. For example, decisions concerning locations for schools and business parks and the planning and construction of access roads and residential areas influence the level of (road) safety and liveability. Road safety can be substantially improved by incorporating it in the various policy fields.

The functional use of the road network is understood to mean the use of infrastructure provisions such as roads, intersections, bicycle paths and pavements as intended by the road authority. A distinction is made between the three functional road categories mentioned earlier; for each category, the intended behaviour of the road user must be more or less enforced. However, when determining the desired use of a road network, the road authority must comply with the preconditions that govern the individual and collective interests.

Categorisation must be based on the desired function of roads within the road network as a whole rather than the existing design [7.18]. The desired function can, therefore, deviate considerably from the current function and the corresponding use and design. In principle, Sustainable Safety is based on monofunctional roads (road categories with a traffic function) and agreement between:

- function: the road's task;
- design: the functional requirements translated into road design and traffic measures;
- use: the desired behaviour on the roads.

When allocating functions to roads (categorisation), the existing spatial structure plays a key role. One problem that arises in practice is that there are roads that combine various functions. After all, many existing roads with an access function often have houses or shops built along them. In those cases, engineers and politicians have to make a choice between two potential solutions:

- to adapt the structure of the network so that the only desired function can be allocated to the road;
- to prioritise a particular function and – where possible – take the other function into account by gearing construction accordingly.

In principle, Sustainable Safety assumes a hierarchical structure of the road network. This means that an access road must not connect directly to a through road but via a distributor road only.
When allowing the different modes of transport for each category, the weakest mode will be taken as the standard. Taking into account the most vulnerable groups, the movement options of the strongest road users will be limited, with mass and speed being decisive factors.

The process of road categorisation
Road categorisation follows a fixed routine [7.18]:

- Step 0: determine the basic principles and preconditions for all policy fields concerned.
- Step 1: develop ideals. At this stage, separate ideals for residential areas and key modes of transport are developed, such as pedestrians, bicycles, slow motorised traffic, public transport, emergency services and fast motorised traffic.
- Step 2: combine and harmonise the ideals. This step is broken up into three parts:
  - road categorisation;
  - checking the categorised road network;
  - combining the categorised network with the other ideals.
- Step 3: apply the operational requirements. This step checks whether the operational requirements can be satisfied or whether they lead to problems in terms of feasibility and practicability.
- Step 4: adapt the ideals. In practice, requirements will sometimes conflict (such as the ideal public transport versus the ideal residential area). Such conflicts are often difficult to resolve in practice.
- Step 5: confront the Sustainable Safety ideal with other policy fields. Traffic and road safety are important but there are more interests to be considered, such as liveability.
- Step 6: consider and make a choice. If it is impossible to arrive at a satisfying solution, all the pros and cons will have to be considered. It is important to define the consequences of this choice and to allow the decision to be taken by those authorised to do so.

Journey time criterion

The journey time criterion is based on practical experience and is a measure of the length of time a road user is willing to accept a low speed limit. The criterion is not described in the standard approach for road categorisation, but can provide additional insights for the categorisation process. Journey time criteria give a maximum time during which the motorist may drive on a certain category of road before reaching a higher or lower category. The maximum duration increases if the motorist is driving in a higher (safer) category. Journey times are:
- access roads: 2 to 3 minutes;
- distributor roads: 3 to 5 minutes;
- regional through roads: approx. 8 minutes;
- national through roads: unlimited.

These criteria are arbitrary estimates and are not based on (scientific) research. In addition, the criterion is a generic indicator that is open to exceptions. It also appears to be desirable to distinguish situations within and outside the built-up area. The choice for a shorter journey time criterion on access roads and distributor roads results in a denser network of through roads.

Traffic volume and road safety

The structure of an area and densities as well as the composition of the population and the generation of traffic determine how the traffic and transport system will be used. Although this already gives some indication of the expected road unsafety, some qualification is required. Several rules of thumb regarding traffic volumes are shown in table 7.2. However, it should be noted that these figures are only an indication: while 4,000 vehicles per 24 hours on an access road is not exceptional for a large city, such volumes are too high for a residential street in a small rural village. Moreover, these traffic volume criteria are not theoretically substantiated.

Table 7.2. Rules of thumb for traffic volumes

	Traffic volumes in motorised vehicles/24 hours	Distances in km between intersections
Through road (motorway)	> 20,000	> 5
Through road (trunk road)	< 20,000	> 5
Distributor road	4,000-15,000	2 à 3
Access road	< 4,000 à 6,000	< 2
Access road	Low, < 2.000	< 1

These figures are indicative experiential figures, traffic volumes at which the road function will come out well. The figures apply to the majority of roads, which does not mean that there are no exceptions. Higher traffic volumes are possible but this will demand extra attention during the design phase on guiding the traffic in the right direction.

A completely different line of thought is that it is not so much the traffic volume but the presence of different types of road users that must determine the design of the traffic and transport system. This line of reasoning dictates that residential areas are geared towards non-motorised traffic rather than motorised traffic. In these areas the majority of journeys is made by non-motorised vehicles.

In practice, this approach appears to be most useful within the built-up area. However, it should be realised that a road network that is consistent in terms of Sustainable Safety does not need to be so in terms of urban planning and urban structures. Categorisation could have irreversible consequences for spatial quality and devalue the differences between housing estates and area characteristics. Conversely, the urban planner can sometimes (unwittingly) thwart a clear road categorisation.

7.3.3 Road categorisation and desired behaviour

The road user must be able to tell the difference between the three road categorisations at all times, in as far as they require different behaviour and/or permit other events. The road categories and road types (see sections 7.3.1 and 7.3.5) that demand different behaviour and provoke other expectations are shown in table 7.3 [7.17].

It should be emphasised that table 7.3 is an outline of an ideal situation that cannot be realised in the short term. A physical carriageway separation on all through roads will not be (immediately) possible. The same is true for a

Table 7.3. Characteristics for each road category on the basis of desired behaviour (Sustainable Safety)

	Expectation of:			
	On-coming traffic?	**Crossing traffic at intersection?**	**Crossing traffic on road section?**	**Slow motorised traffic on carriageway?**
Outside the built-up area				
Through road 120 km/h	No	No	No	No
Through road 100 km/h	No	No	No	No
Distributor road 80 km/h	Yes	Yes	No	No
Access road 60 km/h	Yes	Yes	Yes	Yes
Within the built-up area				
Distributor road 70 km/h	Yes	Yes	No	Yes
Distributor road 50 km/h	Yes	Yes	Yes	Yes
Access road 30 km/h	Yes	Yes	Yes	Yes
Access road in home zone	Yes	Yes	Yes	No carriageway

downgrading to access or distributor roads. Money and problems relating to how roads are to be incorporated into the surrounding environment are the key reasons why the wishes of the Sustainable Safety concept cannot be honoured everywhere. In order to eliminate delays, a decision has been made to prioritise the recognisability of the various road categories.

7.3.4 Essential recognisability characteristics

Table 7.4 shows the characteristics that are deemed essential for recognising the various road categories [7.17]. The recognisability characteristics are chosen in such a way that they occur as infrequently as possible at roads other than those for which they are intended and provoke as few incorrect expectations as possible. If characteristics overlap for different road categories, any incorrect expectations must then be corrected using compensatory additional measures. Furthermore, the essential recognisability characteristics have, where possible, been chosen in such a way that they intuitively promote desired behaviour and/or discourage undesirable behaviour.

	Behaviour:		
Mopeds/bicycles on carriageway?	**Maximum speed**	**Right-of-way using traffic signs?**	**Is overtaking allowed?**
No	120 km/h	Yes	Yes
No	100 km/h	Yes	Yes, only on 2x2-road
No	80 km/h	Yes	Yes, on 2x2-road
Yes	60 km/h	No	Yes
No	70 km/h	Yes	Yes, on 2x2-road
Mopeds yes bicycles no	50 km/h	Yes	Yes, on 2x2-road and agricultural traffic
Yes	30 km/h	No	Yes
No carriageway	Walking pace, 15 km/h	No	Yes

Table 7.4. Initial essential recognisability characteristics for each road category and road type

	Through road		Distributor road	
Essential recognisability characteristics	**TR-120 (outside the built-up area)**	**TR-100 (outside the built-up area)**	**DR-80 (outside the built-up area)**	**DR-70 (inside the built-up area)**
(Zone) sign	Motorway	Trunk road	None	Max. speed 70
Edge markings	Continuous (0.20 m)	Continuous (0.20 m)	Broken 3-3 (0.15 m)	Broken or kerb
Carriageway separation	Safety barrier or central reservation	Safety barrier[1]) or central reservation	Double line or central reservation	Double line or central reservation

1) double line with 'filling' is possible in phased planning

The dominant recognisability characteristic in table 7.4 is the geometry of the edge markings and carriageway separation. This was chosen because those markings are relatively easy to apply, highly and continuously visible, and have a particular effect on behaviour. In essence, this means that broken markings invite slower speeds than continuous lines. In addition, studies have clearly shown that carriageway separation comprising two continuous or broken lines is more noticeable and has more impact on risky overtaking manoeuvres than a single centre line. Moreover, carriageway separation leads to a slightly lower average speed than a single line; however, this distinction also results in vehicles driving closer to the shoulder. The first is positive in terms of safety; the second is potentially negative because it leads to an increased chance of vehicles leaving the road. Attention must, therefore, be paid to the provision of a sufficiently wide lane on the right-hand side of the road. The figures below provide examples of the three road categories.

In terms of the TR-100 motorway, it should be noted that the characteristics provided in figure 7.2 (two continuous lines with a green filling) must be seen as phased planning solutions within the context of Sustainable Safety. The safest solution is physical carriageway separation such as used on the motorway. If a trunk road has a risk figure that is too high, it must be downgraded to a distributor road with the accompanying characteristics and speed limits. The essential recognisability characteristics in table 7.4 are unique for each road category and must always be present. For the other characteristics (see table 7.3), there is a certain measure of latitude.

	Access road	
DR-50 (inside the built-up area)	**AR-60 (outside the built-up area)**	**AR-30/home-zone (inside the built-up area)**
None	(Zone) sign 60	Regime or (zone) sign 30
Broken or kerb	None or broken 1-3 (0.10 m)	None
Double line or central reservation	None	None

It is clear that visual information such as recognisability characteristics must be uniformly applied throughout the country in order to achieve the desired effect and ensure that road users will draw the same conclusions from the same information regardless of where they are. Possible measures must be implemented nationwide as quickly as possible to minimise confusion during the transitional period. It is also important, of course, that road users throughout the country are informed about what the measures mean to them.

Figure 7.2. Examples of road categories outside the built-up area

TR-120, motorway

TR-100, trunk road (phased solution)

DR-80, distributor road

AR-60, access road

7.3.5 Road types per road category

In principle, each road category comprises different road types or designs. However, the more road types, the more difficult it is to guarantee the differences between the three road categories and thus the recognisability of each category [7.12 – 7.15]. Road users recognise a road category primarily due to the continual presence of characteristics or design elements in the roadscape. Local characteristics such as uniform intersection solutions also contribute to the recognisability of the category.

Figure 7.3. Examples of road categories inside the built-up area

DR-50, distributor roads

AR-30, access roads

AR, home zone

Possible road types or manifestations for each category must meet the following requirements:

- the essential recognisability characteristics of a certain category may not be applied in another category (unique, easily recognisable characteristics per category);
- every road type in a certain category must contain every essential recognisability characteristic for that category;
- the number of road types must be minimised so that the road category is recognisable as such to the road user.

Through roads

While a large proportion of the single carriageway roads has a through function, their implementation as motorways with 2x2 lanes is overdone on the basis of traffic volume.
Two types of roads are distinguished in the through roads category:

- national through roads (NTR), motorways with 2x2 or more lanes;
- regional through roads (RTR), trunk roads with a through function with one or perhaps two lanes in each direction.

The following designs exist for regional through roads [7.13, 7.17]:

- 2x2 lanes with a physical carriageway separation (traffic volume > 25,000 vehicles/24 hours);
- 2x1 lanes with a physical carriageway separation (traffic volume < 25,000 vehicles/24 hours);
- 1x2 lanes with a carriageway separation comprising a green surface.

Figure 7.4. Principle of the 2+1 through road type, a continuous lane in each direction + overtaking lanes

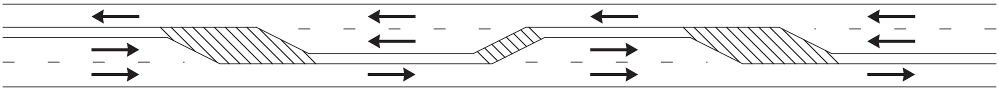


Figure 7.5. Example of a two-lane through road with an overtaking lane

2+1-RTR in the Netherlands (N50)

2+1-RTR in the Netherlands (N50)

The last two designs can be applied with an overtaking lane.
This road type has three lanes in which the middle one is used alternately as an overtaking lane in both directions (figure 7.4). International experiences in terms of road safety and the quality of the service level have been extremely positive, which has led to initial trials on the N50 between Hattemerbroek and Kampen in the Netherlands.

Distributor roads outside the built-up area
Capacity is sometimes the reason that distributor roads are built with two lanes in each direction [7.14]. A distributor road with two lanes in each direction and carriageway separation consisting of a double line only must be advised against on the grounds of road safety, recognisability and perception: outside the built-up area, this separation needs to be a (grass) verge several metres in width. The distributor road category outside the built-up area comprises two road types:

- road type I: 2x2 lanes with a central reservation;
- road type II: 1x2 lanes with carriageway separation or 2x1 lanes with a central reservation.

In practice, the distributor road type II is applied with complete or partial vehicle-type exclusion ruling. The concept of Sustainable Safety assumes complete vehicle-type exclusion due to differences in speed. This would mean that every distributor road would have to be provided with a parallel road, which, in practice, is unfeasible. Downgrading to access road within the regional road network is not always acceptable either.

Drive slow, go faster?

A completely different approach to distributor roads is known as 'drive slow, go faster' (DSGF), which argues that motorised traffic is better off when it travels at uniformly lower speeds rather than 'speeding and braking'. Because no traffic lights are needed, smaller and more attractive intersections are sufficient.

DSGF is based on traffic travelling relatively slowly in uniform groups on the main roads through the built-up area [7.36]. DSGF can be used for distributor roads within the built-up area with a statutory speed limit of 50 km/h. The principle is also applicable to distributor roads through small villages and on ring roads, where the traffic flows and branches off to the surrounding area. DSGF focuses on introducing harmony between the traffic engineering design of the car infrastructure and the requirements of the urban environment. The concept achieves more sustainable and significantly better service levels on urban traffic arteries and increases the urban quality around the arteries and in the surrounding areas.

A careful design of the main road and the road environment prompt road users to automatically drive at the desired speed limit of approximately 40 km/h: a self-explaining road. DSGF roads have narrow lanes that are separated by means of a continuous line or central reservation. On-coming vehicles ensure that cars do not overtake and speed differences result in groups or platoons of vehicles. The slowest vehicles determine everyone's speed, thus keeping speeding drivers in check. The simplified design, central reservation and low speeds (approximately 40 km/h) enable pedestrians and cyclists to cross the road easily and safely by using the (large) gaps between the vehicle platoons. Crossing no longer takes place in one go but rather by lane or in intervals. This significantly increases the road's crossability and it allows for good eye contact between road users. An added advantage of a steady traffic flow is that the barrier effect over the entire length of the road is also reduced. Pedestrian crossing need not be solely concentrated at intersections. In places where traffic lights create gaps in the traffic flow, the idea behind DSGF is not to break up the groups that arose spontaneously. In relation to traffic volumes of over 20,000 per 24 hours, this principle could lead to long waiting times for people that need longer gaps in the traffic flow. Whether this risk is real or not can be calculated with a simple simulation programme, which has recently been expanded with an emissions module for fine dust particles PM_{10} and nitrogen dioxide NO_2 [7.42]. This also allows calculations to be made of the extent to which a DSGF solution can contribute to environmental targets.

The combination of a clear right-of-way principle and a lower speed limit can help to find a better optimum between through traffic flow, road safety and the quality of the surrounding environment. This leads to a more sustainable and significantly better service level on busy traffic arteries where roundabouts are not possible or are inadequate in terms of capacity. The first ten trial projects with this principle are underway and initial evaluations indicate that, in practice, journeys are faster if speeds are reduced. However, it remains an experimental principle with room for improvement. And although it is not (yet) widespread, the DSGF principle can also be applied to road categories other than distributor roads.

In such cases, carriageway separation is realised with broken lines. Sometimes an overtaking ban is created that allows only for the overtaking of agricultural vehicles.

Distributor roads within the built-up area
Within the built-up area, the problem with agricultural traffic (regarding road safety and service level) is less pronounced than outside the built-up area due to the lower maximum speed (50 km/h) [7.11]. As a rule, there are few or no agricultural or other slow vehicles within the built-up area. Furthermore, the difference in speed with other traffic is limited. In practice, therefore, no parallel roads are necessary, and bicycle paths are sufficient. In principle, mopeds can also use the carriageway on roads other than those with a maximum speed limit of 70 km/h for reasons of road safety. The built-up area, however, is subject to many other problems such as limited space, high traffic volumes, insufficient separation of cyclists, parking and a significant number of access roads.

Two types of road are distinguished within the built-up area:
- road type with 2x2 lanes, maximum speed limit 70 or 50 km/h;
- road type with 1x2 lanes, maximum speed limit 50 km/h.

Access roads outside the built-up area
An essential recognisability characteristic of the access road is one driving strip (no centre line) for both directions [7.15]. In practice, the traffic volume on this road category can vary from several hundred to 5,000 vehicles or more a day. A road width of 3.5 m is acceptable for several hundred vehicles, but if the numbers exceed 1,000, the chances that the verges become damaged are substantial and wider surfacing is required. Since the total width of the surfacing must not give the impression of comprising two lanes, this extra surfacing (passing area) must consist of a different material, such as grass tiles. Outside the built-up area, access roads are, in principle, part of a continuous 60 km/h zone. Although a variation in design characteristics is less serious for access roads than for distributor

roads or through roads due to the speed limit, essential recognisability characteristics must also clarify that it is an access road. It is important that the maximum speed limit of 60 km/h reasonably results from the condition of the roads concerned and/or from the speed-limiting facilities implemented.

On access roads, cyclists and slow motorised traffic also use the carriageway. Relatively high volumes of cyclists on a driving strip of approximately 3.5 m is not a sustainably safe situation. As a result, two types of road are distinguished for the access road outside the built-up area:

- access road type I: separation of cyclists (bicycle lanes or separated bicycle paths), a carriageway with matted/hard shoulders, speed reducing measures and, possibly, priority intersections;
- access road type II: complete mix of traffic types, junctions without designated priorities and a lane with matted/hard shoulders, where necessary.

The criteria for choosing between the two road types are:

- the extent to which the road fulfils an access function for the surrounding area, with the corresponding higher traffic volumes;
- the importance of the road in the network of bicycle connections (utilitarian and recreational);
- the management and maintenance of narrow rural roads, in relation with their use (damage to the roadside).

Access roads within the built-up area

Inside the built-up area, access roads are, in principle, part of a continuous 30 km/h zone [7.11]. Although a variation in design characteristics is possible due to the physically enforced low speed limit, the essential recognisability characteristics must also be followed in order to clarify that it is an access road. It is important that the maximum speed limit of 30 km/h reasonably results from the condition of the roads concerned and/or the speed-limiting facilities implemented. The approach and the layout of 30 km/h zones will be discussed in section 7.10.1.

7.3.6 Grey roads

In practice, situations often arise in which a road with an access function is desired for reasons of road safety and liveability, while the road design is based on the distributor function. This creates significant tension between the residential function and the traffic function. Such cases are often referred to as 'grey roads'. In tackling the issue of grey roads, the following considerations play a primary role:

- a high-quality access road can, practically speaking, be made more easily recognisable than a stripped distributor road;
- the lower speed limit guarantees better road safety on an access road type I than on a stripped distributor road.

Figure 7.6. Harmony between the intended function and design of access roads within the built-up area.

Grey road, major discrepancy between the intended access function and the design

High-quality access road, better harmony between intended access function and design

Grey roads within the current 30 and 60 km/h zones constitute a problem for road authorities. In order to balance the function, design and use of the road, an adjustment to the road profile is often the only option. The additional costs of dealing with these roads must then be estimated when the budget is determined.

A simple approach to grey roads is not sufficient. If insufficient financial means are available in the short term, it is better to opt for a phased implementation of the restructuring than a half-baked solution.

7.3.7 Shoulders and obstacle-free zones

The outcome of incidents in which vehicles leave the road and swerve onto the shoulders is largely dependent on the following:

- the distance from the nearby lane to the obstacles;
- the bearing capacity and friction coefficient of the shoulder;
- the density and nature of the fixed objects/obstacles;
- the geometry of the shoulder.

If a vehicle accidently leaves its lane, other road users on adjacent or underlying carriageways can be affected. These lanes must also be indicated as danger zones.

The forgivingness of the road environment means that it is constructed in such a way that collisions with obstacles will end as favourably as possible [7.16]. An obstacle is a fixed object (column, post), a planted element (tree) or a cross-sectional element (bank, ditch) that can cause serious damage to cars and injury to passengers in the event of a collision. These obstacles may be placed on central traffic islands or in the central reservation, on partition verges or on both sides of the carriageway (on shoulders). The layout of the traffic islands and shoulders determines to a great extent the chance that a swerving vehicle has of being involved in an accident. This chance is largely dependent on the width of the obstacle-free zone: the area outside the edge marking, block marking or obstacle-free lane.

Within the built-up area
Given the limited speed within the built-up area, only the distance to the object has to be taken into consideration [7.11]. Objects (fixed or otherwise) on the side of the road can influence the sideways position that the driver takes on the road or the flow of the traffic. If the distance to an obstacle is too small, drivers tend to brake (hard). This also applies to on-coming traffic and when overtaking a stationary vehicle. Fear of the object and, with it, the distance that is maintained to the object depends on the following circumstances:

- the higher the speed, the greater the distance;
- a continuous longitudinal object such as a fence or safety barrier causes less fear than a solitary obstacle;
- the fear of a massive concrete structure support is greater than fear of, say, a traffic sign or a marker post.

The distance to the object that needs to be considered totals at least 1 m for a design speed of 50 km/h on a distributor road within the built-up area. For cyclists, a distance of 0.5 m suffices.

Outside the built-up area
In addition to the distance to the object (> 1 m), the obstacle-free zone is of particular importance on through roads and distributor roads outside the built-up area. Well-constructed shoulders provide drivers who have lost control the possibility of stopping or regaining control of their vehicles in a reasonably safe way and returning to their lane [7.16]. The width of the obstacle-free zone must be based on the distance within which most vehicles remain that drive onto the obstacle-free, flat (grass) verges (see table 7.5).

Three approaches can be distinguished when reducing the number of accidents involving shoulders:

1 prevent cars from leaving their lane;
2 if a car leaves its lane, minimise the chance that the vehicle collides with an obstacle or causes a head-on collision;
3 if the vehicle hits an obstacle, minimise the chance of serious injury.

Numerous measures are possible for each approach. The shielding of an (unavoidable) danger zone with a safety barrier or obstacle protection is the least prevalent measure. This applies far more to access roads than through roads. While safety barriers or obstacle protection are relatively forgiving, a collision will always result in an accident with a risk of injury.

Table 7.5. Width of obstacle-free zones for each road category (outside the built-up area)

Width	Obstacle-free zone (m)			
	Motorway 120 km/h	Trunk road 100 km/h	Distributor road 80 km/h	Access road 60 km/h
desired	13.00	10.00	6.00	2.50
minimum	10.00	8.00	4.50	1.50

Table 7.6. Use of at-grade intersections

	Distributor roads	
	Road type I (2x2 lanes)	**Road type II (1x2 or 2x1 lanes)**
Through road		
motorway, slip roads	roundabout or priority intersection with traffic light control system and, possibly, speed-reducing measure	roundabout or priority intersection with, possibly, traffic light control system and/or speed-reducing measure
trunk road, slip roads	roundabout or right-of-way intersection with traffic light control system and, possibly, speed-reducing measure	roundabout or right-of-way intersection with, possibly, traffic light control system and/or speed-reducing measure
Distributor road		
2x2 lanes	roundabout or priority intersection with traffic light control system and, possibly, speed-reducing measure	roundabout or priority intersection with traffic light control system and, possibly, speed-reducing measure
1x2 or 2x1 lanes	roundabout or priority intersection with traffic light control system and, possibly, speed-reducing measure	roundabout or priority intersection with possible traffic light control system and/or speed-reducing measure
Access road		
high traffic volume	roundabout or priority intersection with traffic light control system and, possibly, speed-reducing measure	roundabout or priority intersection with, possibly, traffic light control system and/or speed-reducing measure
low traffic volume	avoid connections as much as possible	priority intersection with provision for speed-reduction
Solitary cycle/moped path	grade-separated	grade-separated or at the intersection
Public transport lane	grade-separated	grade-separated or guarded crossing

A unique category of accidents is that in which a car lands in deep water. Preventive measures in such cases include:

- barriers between open water and curves in the road;
- effective road design;
- replacement of the soft shoulder by matted shoulders;
- education as to what can be done if you end up in the water in your car [7.6].

7.4 Intersections

In the road network, an intersection constitutes discontinuity and, therefore, a potential hazard. An intersection must meet a number of general design requirements: recognisability, observability, surveyability, comprehensibility, driveability, balance and completeness.
On distributor roads and access roads, intersections are at grade. There are five types of intersection at grade:

- roundabouts on which traffic on the roundabout has right of way;

- priority intersections, at which right of way is determined by traffic signs;
- priority intersections that are equipped with a traffic light control system;
- intersections governed by the rule that cars from the right have right of way;
- exits.

7.4.1 Use of different types of intersection

Through roads and distributor roads are priority roads both inside and outside the built-up area. Priority intersections can be included on access roads if they are deemed necessary.

7.4.2 Roundabouts

Safety

A substantial amount of research focuses on the safety of single-lane roundabouts. Where traditional intersections have been reconstructed into single-lane roundabouts, the total number of registered accidents fell by almost 50% [7.14, 7.19, 7.20] while the number of casualties outside the built-up area fell by approximately 80%. The reduction in terms of cyclists is less than it is for passengers. It has been established that the gain in safety at these roundabouts was also maintained when the traffic loads were high. The largest gain in comparison to other types of intersections (with or without traffic lights) was down to the following:

- Motorists who have right of way and motorists who must give way drive at low speeds. The lower the absolute driving speeds, the lower the chance of a (serious) conflict or an (injurious) accident.
- At a traditional intersection, the number of conflict points is much higher than at a roundabout (32 and 8, respectively). At a roundabout, there is an easily surveyable conflict point at each connecting road and at each bicycle/moped crossing.
- The severe mental pressure at a (busy) junction is spread out over a number of simple T-junctions.

Moped riders/cyclists

A comparative study into the effects of right-of-way rules for cyclists and moped riders on roundabouts has shown that the solution

Figure 7.7. Number of conflict points at roundabouts and four-arm intersections

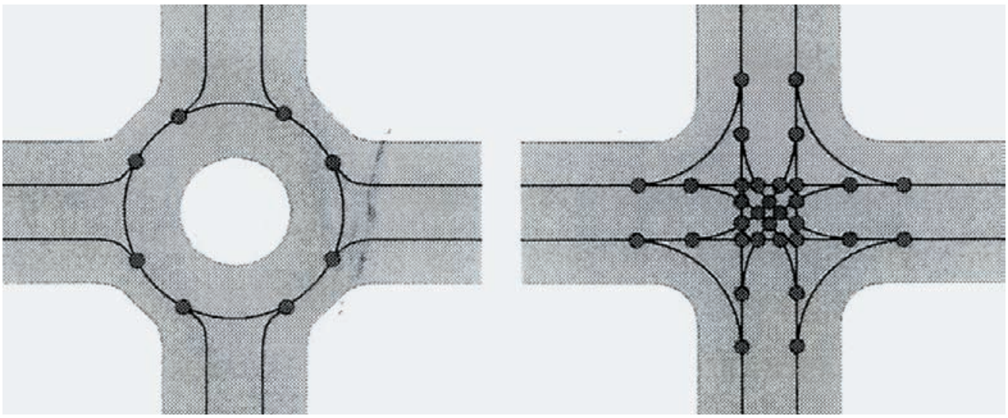


Figure 7.8. Examples of roundabouts

Roundabout with single lane entry and exit road

Multi-lane (turbo) roundabout
(outside the built-up area)

whereby moped riders/cyclists have right of way on separate bicycle paths is, on average, less safe than when they do not have right of way. This applies in particular to mopeds. The following recommendations are based on a number of considerations that are linked with the promotion of bicycle use, road safety, service level, legal aspects and design aspects:

- within the built-up area: cyclists on cycle-paths have right of way (mopeds are mostly on the road);
- outside the built-up area: cyclists on cycle-paths do not have right of way (mopeds are mostly on the moped/bicycle paths).

Service capacity

While the service capacity of a single-lane roundabout is high in comparison to a priority intersection, it has clear limits in connection with the design. As long as the capacity of the roundabout is not reached, the average delay is shorter on a roundabout than at a priority intersection with a traffic light control system. In order to increase the capacity of the single-lane roundabout with single-lane entry and exit roads, the roundabout can be constructed with two-lanes. This enables three combinations of entry and exit roads:

- single-lane entry and exit roads;
- two-lane entry road and single-lane exit road;
- two-lane entry and exit roads.

The measures designed to increase capacity have a negative effect on road safety. The two-lane roundabout with two-lane entry and exit slip roads is less safe than the single-lane roundabout, but safer than other at-grade intersection solutions. Two-lane roundabouts create conflicts where drivers cut in and weave between other drivers between successive entry and exit slip roads. The severity of these accidents is generally limited due to the low speeds at which motorists are driving. This problem was solved with the introduction of the turbo roundabout, which prevents weaving by separating the traffic on the approach to the roundabout in such a way that drivers will not have to change lanes while on the roundabout (see figure 7.8 (right)). In addition, the traffic capacity of the turbo roundabout is higher than that of the two-lane roundabout.

7.4.3 Priority intersections

Without a traffic light control system

Road authorities in the Netherlands agree that right of way on distributor roads both inside and outside builtup areas should be determined by traffic signs. The design of intersections must, therefore, support the rules governing right of way. For these reasons and for reasons of road safety, the following design elements are needed, particularly outside the built-up area (see figure 7.9):

- left turn lane(s) on main road;
- traffic island in the side road(s);
- maximum of one through lane for each direction on the main road;
- maximum of one approach lane on the side road(s).

Speed at intersections can be reduced by applying physical speed-reduction measures such as a raised junction, designed and built for a driving speed of 50 km/h. In addition to exercising extreme care in terms of design, it is necessary to employ a maximum speed limit of 50 km/h and to place a warning sign at intersections outside the built-up area for reasons of liability. In more than 50% of the cases, traffic volume explains the variation in accident figures at priority intersections on 80 km/h roads [7.13]. The influence of the traffic volume on side roads is much greater than that of the volume on the main road.
A comparison of three-arm priority intersections (T-junctions) and four-arm intersections shows that, in general, there are approximately 20% fewer accidents at three-arm intersections than at four-arm intersections.

Vehicles (and lorries in particular) in the right-turn lane take away the view of the main road of drivers who have to give right of way and wish to drive straight on. As a result, right-turn lanes are preferably avoided. In general, the application of left-turn lanes on the main road at priority intersections leads to a 60% reduction in accidents at three-arm intersections and a 50% reduction on four-arm intersections when compared to intersections without left-turn lanes.

Figure 7.9. Examples of priority intersections (outside the built-up area)

Priority intersection outside the built-up area with narrow traffic island and left-turn lane

Priority intersection with traffic light control system, raised road section and red light and speed camera

With traffic light control system
The placement of a traffic light control system at a priority intersection is only considered if [7.14, 7.21]:

- the waiting times of those without right of way on the main road and side road(s) are unacceptably long and other solutions such as the construction of a roundabout will not help;
- road safety leaves something to be desired, on the understanding that the introduction of traffic lights is expected to have a positive effect on road safety and other solutions such as the construction of a roundabout will not help;
- service level must be influenced for traffic management reasons.

In principle, the design of a priority intersection regulated with traffic lights must correspond with that of an intersection without lights as much as possible, because even if the installation is out of action (deliberately or not), the traffic flow must continue as safely as possible.
At intersections that are deemed to be non-standard, the traffic light control system must be operational throughout the 24-hour period (for example with multiple stacking lanes in a particular direction).
Incidentally, the quality of the system (limiting the number of stops/waiting times) has a direct influence on road safety.

Rear-end collisions and accidents resulting from red light running are particularly common at intersections with traffic light control systems. Strictly speaking, a traffic light control system does not fit within the definitions of Sustainable Safety, as the chance of an accident is not eliminated in advance and the severity of the accident is not limited by the traffic light control system. For some road authorities, this is reason enough to combine traffic lights with red light and speed cameras or physical speed-reduction measures.

Service level problems at priority intersections are mostly the result of the volume of motorised traffic. The volume criterion using the ‘Slop’ method is based on this fact [7.11, 7.14].
This criterion can be used when considering the placement of traffic lights at priority intersections. The criterion can also be used to determine the mutual urgency of different intersections.
The criterion is based on the volume during the eighth busiest hour of an average work day. This is the volume that is reached or exceeded during eight hours in a 24-hour period. This principle is employed because the traffic light control system must be useful during the greater part of a 24-hour period. The rush hour periods and other short-term periods where traffic load is heavy are not decisive factors. If the division of the volume during the 24-hour period is very different from the average, another indicative hour can be chosen, such as the sixth or seventh busiest hour.

In comparison to a priority intersection without a traffic light control system, an intersection with such a system has a number of advantages and disadvantages. The advantages are:

- the reduction in waiting times for traffic on minor roads. This applies to a lesser extent to non-motorised traffic;
- the partial reduction in the number and severity of (right of way) accidents;
- the removal of the influences of local circumstances that affect the perception and decisions of road users;

- the ability to provide preferential treatment (when desired) to certain categories of road user (public transport or emergency services);
- the ability to apply dynamic traffic management.

The disadvantages are:
- the reduction in service comfort and confrontation with waiting times on main roads;
- the increase in the number of accidents caused by braking vehicles (rear-end accidents);
- the undesired stimulation of the use of alternative routes (short cuts);
- the introduction of conflicts with vehicles that are allowed to ignore red light under certain circumstances, such as emergency vehicles;
- red light running, thus increasing the chances that relatively serious accidents will occur, because most offenders travel at high speeds;
- an increase in the level of noise and air pollution due to cars stopping and accelerating (environmental impact).

The advantages and disadvantages will have to be considered for each situation. It is important to recognise the fact that experiences with signalised intersections within the built-up area are far more favourable than with those outside it. This is not only due to higher (approach) speeds and a lower level of attention on the roads outside the built-up area, but also on account of the differences in the nature and composition of the traffic.

Speed-reduction facilities are also necessary at priority intersections with traffic light control systems in operation. A maximum speed limit of 70 km/h outside the built-up area is already slightly too high. Initial experiences with the following measures have been positive:
- the construction of a raised section on the main road on the approach to the intersection;
- the introduction of cameras to check speeds and red light running.

Road users can endanger road safety due to their behaviour at intersections with traffic light control systems:
- deliberate red light running: the non-acceptance of a red light of a (credible or comprehensible) traffic light control system;
- habitual behaviour or the erroneous presumption of a green wave, in which road users base their behaviour on expectation;
- unexpected braking, which can result in rear-end collisions;
- failing to see the traffic light control system due to a low sun, for example;
- reacting to the wrong traffic light;
- driving faster in order to 'make' the amber light.

7.5 Exit contstruction

Access roads are preferably connected to a distributor road with a so called exit construction or exit. Drivers that enter the road via an exit must give other traffic (including pedestrians) the right of way (1990 Traffic rules and regulations). In practice, exits are not always easily recognisable as such and are also undefined in the Road traffic act. Cases involving accidents due to such unclear traffic situations are often brought before the court to pronounce judgement on the question of guilt. One of the conditions to prevent indecisive traffic behaviour is a recognisable and predictable traffic situation. This applies in particular to situations where road users can encounter one another such as at exits. In passing judgement, the judge will initially consider how the exit appears to the road users, from both the exit and the main road. Two criteria are of critical importance for this 'recognisability requirement': the destination criterion and the construction criterion [7.33].

Destination criterion

In civil law terms, exits have always been strongly linked to right of ownership. In civil law, it has always been possible to reach the public road from private land or a private building. As long as exits are only built in order to provide access from private homes or premises and the limited destination is conclusively established, the design is of minor importance. After all, the road user sees the building with the driveway, the fence round the premises with a gate, and possibly also a company name. Under the destination criterion, therefore, an exit exists if the destination is limited, such as in the case of a house, garage or business unit. The private nature is clearly apparent.

In the case of car parks, the limited destination is not always clear. It is not only the size of the car park that plays a role but also whether the site belongs to a building (office, shop, apartments). In cases in which the destination criterion provides little or no clarity, the construction criterion must be applied.

Figure 7.10. Exits based on destination and construction criteria

Exit on the basis of the destination criterion

Exit on the basis of the construction criterion

Construction criterion

Road authorities increasingly need to accentuate the limited destination of specific areas, including car parks, home zones and 30 km/h zones. Exits that provide access to such areas quickly assume the character of a connection road, thus rendering their status much less clear. The status of the exit cannot be derived from the characteristics of the surroundings and must be clarified by means of its construction. The construction criterion concentrates on the design of the exit. Important in this respect is to determine whether the road user can immediately recognise the location as an exit on the basis of its design:

- a pavement and/or bicycle path (or bicycle/moped path) parallel to the through road at practically the same level and in the same surface that continues at on the side road;
- the use of so called bevelled kerbing and the absence of connecting curves.

The following can be considered when designing the exit construction:

- Use of deep bevelled kerbing (0.6 m) that gives the exit a relatively gentle incline is strongly recommended. This is much better for all vehicle types (especially bicycles and wheelchairs) than short bevelled kerbstones.
- If necessary, the height difference between the road and the exit construction can be limited to 0.06 m by allowing the kerbstones to slope backwards slightly.
- The width of the exit construction in the cross-section preferably amounts to 4.5 m or more (wheel base on cars is 2.76 m) along the entire width of the side road to prevent damage to the underside of cars.

7.6 Pedestrian crossings

Pedestrians are amongst those vulnerable road users who pose a minimal threat to others but who are subject to significant threats themselves. For children, the elderly and people with a disability, the traffic situation has only become more hazardous as a result of the growth of motorised traffic. Ensuring and tackling the crossability of roads will become increasingly urgent on account of the ageing population. Pedestrians experience the biggest problems when crossing roads [7.10, 7.25], with almost 80% of all accidents involving pedestrians related to crossing the road. In principle, the

Table 7.7. Desired pedestrian provisions for each road category in longitudinal and transverse direction

Road category	Within the built-up area		Outside the built-up area	
	Longitudinal	Transverse	Longitudinal	Transverse
Through road	n/a	grade-separated	n/a	grade-separated
Distributor road	separated	at grade at intersections	separated	at grade/grade-separated at intersections 1)
Access road	separated 2)	at grade on road sections and at intersections	n/a	at grade on road sections and at intersections

1) grade-separated dual carriageway and/or large-scale intersections
2) with the exception of home zones

wishes stated in table 7.7 for pedestrian provisions in the longitudinal and transverse direction of the road apply to all three road categories.

The following should be noted in relation to table 7.7:

- Crossing the road is a form of exchange. In principle, on distributor roads outside the built-up area this exchange takes place at intersections on condition of low speed. This means that facilities such as bus stops must always be situated near intersections.
- In principle, major crossing points on distributor roads within the built-up area should also be situated near or next to intersections. However, when an important pedestrian route crosses a distributor road, this crossing can also be designated as a junction (exchange of traffic). In such cases, a well-constructed pedestrian crossing must be introduced on that road section.

Two aspects are particularly important in connection with the Sustainable Safety concept in conjunction with road function and the importance of the crossing:

- the recognisability and conspicuity of the crossing for both pedestrians and motorists;
- the management of potential conflicts by enforcing a maximum speed limit of approximately 30 km/h at the crossing.

A crossing is a provision for pedestrians where crossability is improved by means of a separation in space, time or free passage at a key or dangerous crossing point, which enables pedestrians to cross comfortably and safely. Crossing is facilitated with such infrastructure tools as good visibility, a traffic island and a small crossing distance. This applies to both intersections and road sections. There are, therefore, four groups of measures for the improvement of road crossability:

- general, more supportive measures (such as central island);

Figure 7.11. Examples of crossing provisions

Crossing (raised section) at the entrance

Crossing (raised section, marking)

Crossing on a distributor road with a raised section and traffic light control system (separation in time)

Grade-separated solution near a bus stop in combination with a bicycle path

- a separation by means of free passage (such as zebra crossings);
- a separation in time (by means of a traffic light control system, for example);
- a separation in space (by means of a tunnel or a bridge, for example).

7.7 Provisions for specific target groups

A provision for a specific target group is an infrastructural facility that favours one or more target groups in traffic over the rest. Such provisions occur in every road category in very different manifestations, with examples including lanes for railway lines, the underground, light railways, express trams and buses. A footpath, a bicycle path or a cycle lane also constitute target group provisions.

The design of both the road and the provision must have a logical and orderly effect from various perspectives:

- the requirement that the road must have a functional use demands that a dedicated lane must be recognisable as such and not create the suggestion of another function;
- the requirement that the road must have a homogeneous use demands that differences in mass, speed, direction, and resilience must be prevented;
- the requirement that the road must have a predictable use demands that the indecisive and unpredictable behaviour of other road users must be prevented. This also places demands on sightlines.

Lanes for railways or underground trains

The infrastructure for the heaviest category of rail transport is usually constructed autonomously, whether that is underground or on an embankment or construction. In cases where this is not possible, intersections with distributor roads are equipped with fully guarded crossings and access roads with guarded crossings.
ProRail (the Dutch railway infrastructure manager) pursues an active policy to minimise the number of level crossings with other traffic, either by removing the crossing or by grade-separating it. The removal of crossings is often opposed by non-motorised traffic.

Lanes for light railways and (express) trams

The contrast between trains and trams is becoming increasingly blurred, which means that there is now a wide range of rail transport, and the question is which of these can still be safely mixed with other traffic. Light railway vehicles, tram-like trains and train-like trams are all vehicles that fall outside the categories specified in the Sustainable Safety concept. Due to their lack of a crash-friendly front, their large masses, their limited capacity to brake and their lack of ability to take evasive action, trains and trams constitute a substantial risk. In an urban environment, the risk of a collision between a train and a slow vehicle is relatively high. The systems used for light railways and trams, therefore, only fit into a Sustainable Safety transport and traffic system under the strictest of conditions.

- The first preference is a separate and autonomous infrastructure for rail transport, on both the road section and intersection. This, however, will not always be possible.
- If spatial separation is impossible, the second preference is separation in time. At points where other road users have to cross the road section at the same level, a (fully) guarded crossing like that of the railway and underground is desirable.
- Where a (fully) guarded crossing is impossible, enforcing low speed limits on rail transport is the final possibility of guaranteeing road safety (at 25 km/h, the braking distance of a train is twenty metres, which is comparable to the braking distance of a motorised vehicle).

Bus facilities

Traffic congestion can cause unwanted delays for public transport. For scheduled bus services, it is important that they run on time, and travel speeds, punctuality and regularity are the key words. Delays and their distribution result in a decrease in travel speeds and a reduction in the quality of the service.
The following priority measures are possible:

- influencing traffic light control with the help of selective detection methods for public transport that does not travel in a separate lane (control technology measures);
- separate bus lanes, combined with influencing traffic light control (spatial measures).

A bus lane is a target group facility for public transport buses only. However, if only BUS is indicated on the road rather than LIJNBUS (which is for public transport bus only), every bus or coach can use the lane concerned. Other motorists are not permitted to use bus lanes. Road designers must take into account that motorists cannot stop their vehicle on a road next to a bus lane.

Figure 7.12. Examples of separate bus lanes

Bus lane, lateral position, bus stop, pedestrian crossing (Utrecht)

Bus lane, central position with intersection with traffic light control system (Eindhoven)

Bus lanes inside and outside the built-up area must be constructed as distributor roads. In urban areas in particular, they are constructed on key traffic axes. An example is the separate bus lane from Utrecht city centre to the Uithof area (hospital, university). In urban settings, the bus lane is often positioned in the middle of two roads (figure 7.12). At bus stops, the partition verge must be widened and the lanes for the other traffic (one-way traffic) must be bent outward. A separate bus lane in two directions constructed on one side of the road can lead to extremely complex situations where the roads meet, with turning motorists regularly entering the bus lane under the misconception that it is a dual carriageway, or being surprised by a bus travelling in the opposite direction.

The location of the bus lane in comparison to the other lanes depends in part on the available space [7.35]. In connection with passengers getting on and off the bus and the space required for the bus stop, it is better to place the bus lane on the right-hand side of the road regardless of whether it is on a road section or at an intersection. Conditions are that the public transport buses can enter the lane free from congestion and that service levels downstream are also guaranteed.

If sufficient space is available, the construction of a bus lane provides no disadvantages for other traffic. This is different when there is too little space and an existing lane is designated a bus lane, reducing the capacity of this road section, and especially that of the intersections, for other traffic. In cases of relatively high traffic volumes, this can lead to congestions and attempts by motorists to look for short cuts.

A centrally positioned bus lane (in one or two directions) could be taken through the middle of a roundabout. In terms of road safety, it is then necessary to install a traffic light control system, which would mean that the key benefits of the roundabout would be lost. In practice, the bus lane is linked in both directions to the road used by other traffic a short distance before and after the roundabout.

A bus lane is a priority road and crossing traffic must always give buses the right of way. In many cases, it is necessary to expand the regulations regarding right of way with a flashing traffic light or (dual colour) traffic

Figure 7.13. Examples of bus lanes outside the built-up area

Distributor road, bus lane on right

Distributor road, raised bus lane, centrally positioned, tidal flow with lane control signing

lights including an acoustic signal. Sometimes, crossings are even equipped with barriers (on the Zuidtangent, for example, which is a rapid bus service linking Haarlem to Amsterdam East via Amsterdam Airport Schiphol). Such crossings correspond closely with level crossings.

A bus lane is a dedicated lane for (public transport) bus services. Under certain circumstances, taxis and vehicles used to transport groups can get exemptions to also use these lanes on the condition that the flow and regularity of public transport vehicles is safeguarded, the traffic light control system is effective and the bus stops are effectively situated.

Points of attention for target group provisions

It is clear that the various dedicated lanes have different points of attention. However, there are also several general points.

- The connection to the other roads and streets because:
  - specific target group provisions have lower traffic volumes;
  - speeds are often higher on specific target group provisions;
  - sometimes traffic engineering details leave a lot to be desired.
- The provisions will be used by heavy traffic in particular. Extra attention should be paid to places where vulnerable road users come into contact with or in close proximity to these provisions, such as bicycle crossings or bus stops.
- Furthermore, the question remains whether the provision should be incorporated into the urban environment or whether the environment should be adapted to the provision.
- In the event that dedicated lanes are heavily used – whenever they have priority at intersections – sufficient possibilities must remain for the other traffic to continue flowing. Long waiting periods can arouse irritation and annoyance, which can have a negative impact on road safety.
- It is also recommended that right of way is made explicit where railway carriages mix with other traffic. This must be explicitly informed about the users of the specific target group provisions, rather than trusting that the other road users know and pay attention to the relevant legislation and regulations. This is particularly important in places where railway traffic turns off.

7.8 Level railway crossings

In 2002, there were approximately 2,050 public level crossings in the Netherlands, of which some 1,750 are guarded [7.34]. More than 1,600 of these guarded crossings are equipped with an AFTLCS (Automatic flashing traffic light control system) or an AHBLC (Automatic half barrier security level crossing).

ProRail policy is focused on minimising the number of level crossings. Unguarded (private) crossings will be removed and (busy) crossings replaced by grade-separated intersections. Work is also being done to improve the safety of existing crossings, for example, by replacing the AFTLCSs with AHBLCs. Various subsidies are available for the discontinuation or improvement of crossings.

The volume and approach speeds of traffic are important factors in terms of accidents at level crossings. Other key aspects include the frequency of trains and the average waiting time at closed level crossings. Waiting times at level crossings close to railway stations are relatively long on account of stationary trains. In general, provisions must be in place to ensure that traffic does not stop on the level crossing. This can mean, for example, that close by the crossing, a 'left turn prohibited' sign is installed to prevent drivers who want to turn left but are held up by oncoming traffic from stopping on the crossing. It may also be necessary to turn intersections before and after level crossings into priority intersections. For effective and safe traffic flow, traffic needs to have a good view at the level crossing.

The most common form of protection at level crossings is AHBLC. This form of automatic protection is permitted for a maximum of three tracks. With more than three tracks, the length of the crossing is too long for the AHBLC and the protection consists of level crossing barriers that close over the entire width of the road, Automatic double barrier level crossing.
With AHBLCs, the minimum cross-section of a two-lane carriageway is 5 m. If there is a traffic island, the width of each lane amounts to at least 2.5 m. The security system is located at least 0.5 m from the side of the road. The length of the barrier is always half the width of the road, rounded up to 0.25 m.

CROW publication no. 168 'Improving safety on or close to AHBLC level railway crossings' [7.34] discusses several measures to improve safety at level crossings. Measures for which the road authority takes primary responsibility are:

- introduction of speed humps or raised sections approximately 20 m before the crossing;
- introduction of a traffic island on both sides of the crossing with a minimum length of 20 m;
- extending footpaths and bicycle paths over the level crossing;
- extending a (wide) centre line marking over the level crossing;
- introduction of edge markings with the possible addition of reflectors on the surface of the level crossing.

Vertical alignment

In principle, the vertical and horizontal alignment of the road at the level railway crossing must be such that:

- low-loaders cannot get stuck on the crossing;
- no damage is done to vehicles or cargo when driving over the crossing at the permitted speed;
- driving is as comfortable as possible (evenness);
- there is sufficient visibility from both the road and the railway line.

Low-loaders run the risk of getting stuck on the level crossing, which is why hazard ratings have been created for level crossings that are not even. ProRail can calculate the hazard rating with the help of their own computer programme. There must then be an official 'risk of grounding' warning sign before the crossing with a secondary sign depicting a grounded low-loader and the number of the crossing. Drivers of low-loaders can consult a booklet they are supposed to carry with them to see whether they can cross the level crossing or not.

Coordinated control

Traffic lights can be installed at level crossings where problems could arise clearing the crossing due to a near-by intersection. Clearance problems are particularly prevalent at crossings with an AHBLC. In order to link the traffic lights to the level crossing protection measures, a dedicated level crossing programme must be incorporated into the traffic light sequencing. Prior to the level crossing protection measures being activated, the approaching train sends a signal to the traffic light control system, which can then see to it that the crossing is cleared of traffic on time.

7.9 Tunnels

Tunnels and canopies (henceforth also referred to as tunnels) are largely or completly closed constructions through which a road or railway line travels. They constitute a particular risk for the people who use them. Safety in tunnels is far from straightforward. The closed nature of the tunnel, the complexity of canopies and tunnel constructions, the combustibility of vehicles and cargo and the serious consequences of accidents in tunnels all require that tunnel safety be given particular attention.
Safety in tunnels – internal safety – is inextricably linked to the safety of those in the vicinity of the tunnel – external safety. Large-scale incidents in tunnels, for example incidents involving a fire, can affect both internal and external safety. Incidents in a tunnel are mostly of a more serious nature in terms of damage suffered by the road user than similar incidents outside the tunnel. After all, hazardous substances cannot escape as quickly and are less easily dispersed in a tunnel than in the open air. Both internal and external safety must be discussed at an early stage and in conjunction with the decision-making process.

The primary aim during the design, construction and use of a tunnel is to provide optimum levels of safety for road users and personnel, paying special attention to:
- the construction of the tunnel;
- the presence of facilities to deal with accidents;
- the tunnel management organisation;
- the ability of tunnel users to cope;
- the deployment of emergency services.

Legislation on tunnel safety was recently amended. It is based on the EU directive 'Minimum safety requirements for tunnels in the trans-European road network', which was adopted on 29 April 2004, and the Policy document on tunnel safety, part A (Process requirements), which was submitted to the Lower House on 7 November 2003, and part B (Safety requirements), which was published in 2005. The legislation comprises:
- WARVW - Supplementary road tunnel safety regulations act;
- BARVW - Supplementary road tunnel safety regulations decree;
- RARVW - Supplementary road tunnel safety regulations;
- Amendments to the Supplementary road tunnel safety regulations (RARVW).

7.10 Residential areas

7.10.1 30 km/h zones

Many people feel that the area in which they live is insufficiently safe, especially in older, more traditional residential areas. Studies have shown that approximately 75% of all complaints relate to traffic. A more effective road infrastructure, therefore, can go a long way to improving the quality of the residential areas.

A residential area (houses and shops) is a continuous area with the primary function of serving the residents. The roads within a residential area have an access function only [7.5]. The activities of the residents all have a direct link to the nature of the buildings: walking, chatting, playing, cycling (children), washing cars, shopping. While (motorised) traffic is present in a residential area, it plays a subordinate role.
A residential area must be as large as possible. Vulnerable road users such as children and the elderly must be able to reach their destinations (children – school; the elderly – local shops) without having to cross a distributor road.

The road unsafety in residential areas is largely subjective in nature and is caused by the perception of excessive speeds and traffic volumes. While accidents do occur, they are usually spread throughout the area. The feelings of road unsafety must be reduced and all activities linked with the residential function must be given a chance. In principle, there should be no traffic signs in a residential area. If traffic measures are necessary, these must be of a physical nature. The low traffic volumes and the low priority of traffic enforcement by the police mean that residents are quick to ignore traffic signs anyway. Two statutory frameworks are available for the layout of a residential area:
1) the 30 and 60 km/h act;
2) the home zones.

The statutory conditions for a 30 km/h zone and a 60 km/h zone (Administrative provisions (road traffic) decree) include:

- The maximum speed limit must correspond with the local roadscape. This means that, where necessary, the situation must be adapted in such a way that the intended speed is reasonably based on the infrastructure of the road and the surrounding area.
- On 30 km/h roads and in 30 km/h zones and on 60 km/h roads and in 60 km/h zones, speed limit signs can only be applied on road sections if certain requirements are met (see section 6.7.5).

The most important requirements of a home zone (see section 6.7.5) relate to residential function and speed. The primary function of a home zone must be residential. This means that the roads within the home zone only have a function for motorised traffic that is going to or coming from a destination within the zone and that traffic volumes may not harm the area's character. The nature of the roads in the home zone must be such (if necessary by means of speed-reducing provisions) that driving at walking pace is a natural consequence of the surroundings (road user equality).

Preliminary and follow-up studies in 30 km/h zones have shown that the introduction of such zones promotes road safety as well as the liveability and mobility of more vulnerable road users. Residents prefer 30 km/h zones to 50 km/h roads, with more than 85% deeming the chosen speed limit to be correct and between 80 and 90% being of the opinion that pavements are necessary or at least desirable.

Road authorities and urban planners currently favour 30 km/h zones over home zones. They are cheaper to build and maintain, and meet the requirements for the layout of a residential area. Although the popularity of home zones is currently waning in architectural terms, they still provide the maximum explicitly permitted space for children to play in, which is not the case in most 30 km/h zones.

Traffic circulation in an area
Many residential areas can be crossed using different routes. Often these routes are shorter in terms of distance or time than the ringroad on the distributor road. The avoidance of traffic lights can also play a role in this respect [7.5, 7.27, 7.28]. Without further measures in terms of traffic circulation, it will be difficult to create good residential quality. Structural measures are aimed at:

- keeping out traffic that does not belong in the residential area;
- directing origin and destination traffic to the surrounding main road network by the shortest possible route so that this area-specific traffic minimises the burden on the area.

The entrance to the residential area (the 'gateway')
The entrance to the residential area (the 'gateway') requires specific attention. The gateway must clearly indicate that beyond it lies an area with a different character and a lower speed limit.

Figure 7.14. Examples of structural measures in residential areas

Barrier created by a green hedge

Barrier, road open to public transport buses only

Figure 7.15. Gateway to a 30 km/h zone using an exit construction

When designing the gateway, attention must be paid to the regulations concerning right of way:

1 gateway with an exit construction where traffic in and out of the area must give right of way to other traffic;
2 gateway without an exit construction; to prevent a lack of clarity, right of way must be regulated by traffic signs (priority intersection).

Design of the area

It is important that measures are taken in places where the chance of accidents is greatest, for example, at an intersection, a short-cut for pedestrians between two houses, school routes, school exits and local shops. These are the locations where facilities are most cost effective. The speed is then lowest at places where the accident risk is highest and the measures are more credible to the motorist. Within an area, speed-reducing measures must not be too far apart in order to prevent speeds being increased between them [7.31, 7.32]. The distances are determined by the desired speed level and the level of speed reduction of the measure (the passing speed). A street's character is also important. The maximum speed limit of 30 km/h must be a logical consequence of the entire streetscape.

Figure 7.16. Raised intersections and speed humps are the most common speed-reducing facilities

Raised intersection

Speed hump

Childstreet

The roads in residential areas are not only used for traffic but also for recreation and playing. An area in which children can grow up safely and can develop normally is not a luxury, it is a necessity. Children (worldwide) have lost the majority of their traditional freedom of movement in the outdoors. This has been caused to a large extent by the increase in motorised traffic. The ability of children to move around freely is of critical importance for their healthy development, both physically and mentally – an issue to which a future-oriented society attaches great importance, and which places emphatic conditions on the layout of urban public spaces and on traffic in particular.

The Delft Manifesto has helped to provide an integrated policy for child-friendly urban spaces. Based on this manifesto, Childstreet provides recommendations for the situation in the Netherlands regarding the (re)design of public and traffic spaces that supplement Sustainable Safety within the built-up area. Childstreet looks at urban public space from the perspective of a child's mobility. An integrated approach is advocated, aimed at design, education and enforcement.

Design
Residential areas within the Sustainable Safety concept (maximum of 30 km/h) deserve further development to render them safe for children to play in. Because 30 km/h is not a safe speed for children, 30 km/h streets are not the areas in which children can always play carefree. In order to provide children with space in which to play, a key part of urban public spaces are home zones in which traffic must drive at walking pace. 30 km/h areas must focus on design, information and enforcement. 30 km/h streets must always have sufficient pavements (if this is not possible, it is better to create a home zone instead). 50 km/h roads must be equipped with bicycle paths, which must be raised at intersections with side streets. In addition, there must be sufficient pavements and crossing points.

Traffic education
Primary schools, parents and the government must collectively provide more traffic education so that every child at primary school takes the practical cycling exam and is proficient when leaving school.

Enforcement
Childstreet aims at proportional enforcement in residential areas and advocates proportional penalties for speeding violations: driving 10 km/h too fast in a residential area is a more serious violation that driving 10 km/h too fast on the motorway (see chapter 9).

KiSS – the Kids Street Scan – has been developed to make the Childstreet concept more tangible. Using indicators, streets are assessed on six aspects: Protection, Freedom of Movement¸ Walkability, Cycleability, Playability and Perception Value. Each aspect is given a mark [7.40, 7.43-7.45].

7.10.2 School environment

Most primary schools are situated in a residential area, which results in significant problems in terms of road safety, particularly around larger primary schools [7.29]. This road unsafety is, to a large extent, subjective. Dropping off and collecting children by car causes chaotic and unsafe situations close to the entrance to the school [7.28]. It is in the areas around primary schools that a traffic-calmed environment, adapted driving behaviour and very low speeds are of the utmost importance.

Figure 7.17. Entrance to primary schools

Space for waiting parents

A study conducted by Dutch traffic safety association of more than 1,300 primary schools showed that almost 75% of primary schools in the Netherlands find that parents are increasingly responsible for the traffic chaos and road unsafety around their school. Only 40% of pupils walk or cycle to school. The number of children who travel to school independently is on the decline in the lower and middle schools in particular. Many children are dropped off in cars because their parents think that the route from home to school is unsafe. However, this choice increases the road unsafety for other children, and creates substantial problems in the immediate vicinity of the school, as well as on the route from home to school. Almost 60% of the children stated that they had to cross dangerous roads or intersections.

Over the years, many organisations have developed activities to draw attention to a school environment with a restriction on motorised traffic. These activities all had different objectives, means/methods and seasonal spearheads. In a Sustainable Safety school environment, the child is the focal point for the layout of public space. The infrastructure must be such that children can move independently and freely. In addition to the infrastructure, education (of parents too!), communication and enforcement are just as important. The problem must be tackled jointly by children, parents, schools, municipal councils and the police.

7.11 Passages

Passages require particular attention [7.26], being not only important in terms of access to the built-up area, but also in terms of access to the surrounding (outer) area. Passages are often flanked by houses and buildings that have a public service function, and sometimes with business as well, and fulfil a central function for the area (see section 6.5.13).

Passages in built-up areas traditionally constitute a specific range of problems, which are primarily concerned with road safety and traffic-related residential quality for the residents, on the one hand, and the flow of through traffic, on the other. Not only do users of public spaces run the risk of being involved in a road traffic accident, the speed, volume and mass of motorised traffic also summon feelings of unsafety. It affects the quality of public space to a lesser or greater extent with traffic noise, exhaust fumes, vibrations and a barrier effect, all of which damage the traffic-related residential quality. Motorised traffic, whether stationary or in motion, places a heavy burden on the available public space.

Suitable solutions must be sought in connection with the road's (network) function. The question needs to be answered as to whether:
- the desired balance between liveability, safety and accessibility can be achieved with a (partial) reconstruction of the existing passage;
- it is desirable or necessary to entirely or partially create a by-pass via existing roads or a new ring road.

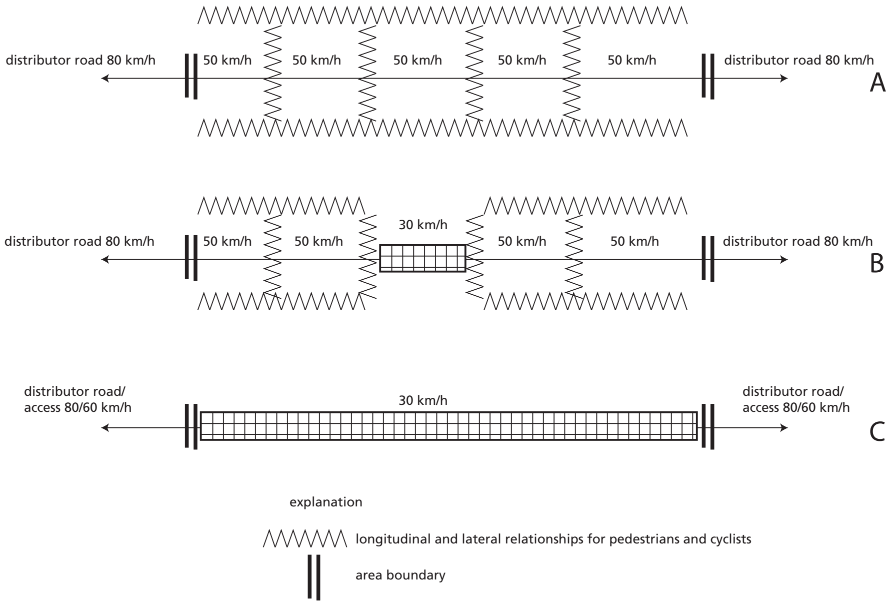
Depending on the road and traffic situation, a consideration must be made as to whether the (regional) through traffic should be diverted in order to create sufficient space for local activities (residential function). The answer depends on the significance of the centre and the road, as well as the concrete spatial environment. Furthermore, traffic to and from the centre (destination traffic) sometimes constitutes such a large proportion of the situation as a whole that a by-pass would be futile.
If restructuring fails to provide a satisfactory solution, the situation qualifies for a (partial) by-pass. However, even after creating such a by-pass, a restructuring of the former passage is also desirable. In the most favourable situation, the proportion of through traffic is reduced to zero and the layout of the public space will be geared to the access and residential functions that the road now has.

The traffic function, the residential function and the functions in the immediate surroundings each place specific requirements on the infrastructure of the public space. Based on experience, there are three design strategies for passages (figure 7.17). The primary question is which function has priority. This is also a problem with regard to grey roads, see section 7.3.6. The outcomes of the categorisation process can help to choose between the three design strategies.

Explanation of figure 7.18:
A The traffic function gets priority, with as much justice as possible being done to the residential function. This is largely the case for passages that are part of the regional distributor road system and where regional traffic has no alternative.
B The residential function gets priority on a certain section of the through road (centre or social core), with as much justice being done to the traffic function as possible and/or required. In many centres, the residential function in the central area is so strong because of its service functions that priority must be given to it. This solution, therefore, features a category transition on the same road.
C The residential function is given priority over the entire length of the passage, with as much justice being done to the traffic function as possible and/or required. This option qualifies if it relates to a compact centre with an intense residential function along the road's entire length.

The (re)structuring of passages includes every facet of the layout of public space. Close cooperation between traffic engineers, urban designers, (landscape) architects and

Figure 7.18. Design strategy for passages



those directly affected is of crucial importance. The latter group are those who use the public space on a daily basis such as local entrepreneurs and residents, as well as organisations such as public transport companies and emergency services. Design teams must understand that a plan is often judged on its details.

Figure 7.19. Transition of road categories

Transition from distributor road to access road (within the built-up area)

Transition in road category, gateway to a 30 km/h zone (within the built-up area)

7.12 Area boundaries

A city or village's place name is shown on a sign at the area boundary. This indication is important for various reasons, but in terms of traffic engineering, the most important is that the area boundary must explicitly show that the road user is entering an area with other rules and standards and that they must act accordingly [7.30]. This traffic function is stipulated in the 1994 Road traffic act. Area boundaries in other legislation and regulations such as the Forestry act serve other purposes or have an administrative function.

Under the terms of the 1994 Road traffic act, the Municipal Council is authorised to determine area boundaries. Determination by decree (not traffic decree) is bound by provisions.

Figure 7.20. Examples of well-structured area boundaries

Area boundary on access road, raised road section and bicycle paths

Area boundary on distributor road, with a large central island

The Administrative provisions (road traffic) decree (BABW) concerning road signs stipulates clear requirements with regard to the location and layout of the area boundary:

- the area boundary is characterised by the beginning of continuous housing estate of such volume and density that the road user can see a clear difference between the character of this road and that of the road outside the built-up area;
- the difference in the character of the road before and after the area boundary must be clearly visible;
- the area boundary need not be indicated on footpaths, optional bicycle paths and bridle paths.

Few area boundaries satisfy these requirements, with many boundaries being in the middle of a field or deep in a forest. The more the road and the surrounding area close to the area boundary have the character of a built-up area, the less need there is for specific speed-reducing facilities in the form of chicanes, axis offset and speed humps.

7.13 Traffic signs

Infrastructure-related traffic measures are preferred to traffic signs as they actually produce the desired behaviour rather than in name only and more or less free of obligation.

All too often, traffic problems at a certain road section are solved by simply erecting a traffic sign or using road markings. For example, if there is a crossing problem on a school route, a school sign or a pedestrian crossing sign (zebra crossing) is chosen. Everyone concerned is more or less satisfied: the road authority because the measure costs relatively little and the citizen because the problem is (apparently) solved. The cause and effect of erecting road signs is given scant attention, while a (minor) alteration in the design would mean that the signs would not be necessary at all.

In the BABW, the use and application of traffic signs are bound by the following conditions:
- traffic signs can only be erected in so far as this is deemed necessary and after infrastructure measures have been considered;
- traffic signs can only be erected if the layout of the road corresponds with that which has been prescribed by each individual sign.

Whether the aim of reserved and careful application of traffic signs is successful or not primarily depends on the way in which road authorities go about it (see www.verkeerstekens.nl).

A physical traffic measure will not always make the corresponding signs superfluous, and will then have the character of a supportive measure rather than an alternative one. For example, with a physical measure that restricts accessibility, the limited access will always have to be clarified to road users with the help of a sign, otherwise the road authority runs the risk of being held liable in the event of an accident. A well-known example of this is when motorists drive into a bus sluice.

7.14 Road markings

For the comprehensibility and recognisability of roads, it is essential that markings are unambiguous and uniform [7.22]. Together with other road characteristics, longitudinal markings are a key distinguishing characteristic for road users. Roads with both (central) dividing lines and edge markings are usually experienced as ‘important’. Roads with no longitudinal markings are seen as ‘less important’, which is why markings should be as limited as possible on access roads within and outside the built-up area and on distributor roads within the built-up area. It is important that within the built-up area in particular, the driving task is supported as naturally as possible.

Markings serve the following purposes:
- they promote the desired driving behaviour;
- they determine the driver’s position on the road and the speed of the other road users;
- they determine the location of obstacles on or next to the road;
- they increase attention levels;
- they increase recognisability;
- they indicate selection points.

Markings can be divided into longitudinal markings (dividing lines, lane marking lines, edge markings and block markings) and other markings (transverse lines, symbols, text and surface markings). The colour of the markings in permanent situations is white. In temporary situations, the markings are yellow. The different marking forms have a legal status and must be interpreted as traffic signs:
- Bus lane. A section of the carriageway marked with continuous or broken lines and on which the word ‘lijnbus’ is written. The bus lane may only be used by drivers of (public transport) buses and vehicles are not permitted to stop on the road adjacent to a bus lane.

- Bicycle lane. A section of the carriageway marked with continuous or broken lines and on which images of a bicycle are drawn. Vehicles are not permitted to stop or park on or next to the bicycle lane.
- Pedestrian crossing: drivers must give pedestrians the right of way. The following rules also apply on or close to a pedestrian crossing:
  - vehicles are not permitted to overtake on or near a pedestrian crossing;
  - motorists are not permitted to stop their vehicles on or within 5 metres of a crossing.
- Widened centre area with chevron striping: road section with oblique lines. Motorists must not drive over this area.
- A continuous line:
  - between lanes in both directions: drivers must remain on the right-hand side of the line;
  - between lanes in one direction: drivers must remain on the right-hand side of the line unless there is a double line and the line on their side is broken.
- Give-way road markings are defined as triangles on the road surface. They have the following meaning: drivers on the road with give-way markings must give way to crossing drivers.
- Stop line: drivers must stop prior to the corresponding stop line if stopping is compulsory.
- Yellow lines: drivers are not permitted to stop along a continuous yellow line and to park along a broken yellow line.
- Blue line: it is not permitted to park in a parking disk zone other than in spaces that are indicated as such or in places that have a blue line. In addition to these markings on the road surface, there is also a blue line that indicates a blue zone (parking disk) and the 'P' in home zones where parking is permitted.
- Block markings: drivers to the right of block markings can overtake drivers on the left of these markings. Examples include block markings at slip roads and weaving areas on through roads and distributor roads.

In terms of road safety, the perceptibility of road markings is also of critical importance when the weather and lighting conditions are poor (rain and darkness). This is why markings that protrude several millimetres above the road surface, such as thermoplastic material, are the preferred option. The height difference can lead to a certain level of discomfort and in some situations road unsafety, for example for motorcyclists.
In particular cases, the marking's profile is such that it activates a buzzing tone when the car drives on the line (acoustic signalling).

Marking and signposting
Safe and comfortable road use necessitates that road users can survey the course of the road, preferably at driving sight distance. In addition to environmental characteristics such as trees and lampposts, the longitudinal markings are of the utmost importance in this respect. These markings are less visible in dark and/or wet conditions and additional guidance is required outside the built-up area in the form of signposting such as reflector posts, curve reflector posts, curve warning signs and barriers.

7.15 Signposting

The aim of signposting is to guide road users to their destination with as much certainty as possible using visual tools [7.23]. A quick, safe

Road works

In order to keep roads in good condition and to implement Sustainable Safety, road works are unavoidable. They can include maintenance, reconstruction work and road widening (such as the construction of an extra lane) or new construction projects. Most maintenance work such as vegetation maintenance, sweeping the road surface and dredging drainage channels, must be carried out every year. In addition, major repairs such as renewing the road surface (asphalting) or changing the road furniture are carried out about every fifteen years.

Road works disrupt the expectations of the road user and influence driving behaviour, which can lead to unsafe situations for both road users and road workers. In addition, they can hinder the traffic flow, which is why road works are subject to measures and provisions designed to limit the negative impact on safety and traffic flow.

Roadwork zone designation and traffic guidance must be clear and explicit so that the road user is aware of the road works in good time and knows what to expect as a result. There must also be enough space or barrier between road workers and traffic. Measures designed to regulate speeds such as traffic enforcement and feedback to road users about the speeds at which they are driving can help to reduce speeds in areas where road works are being carried out. Furthermore, the directorate-general for Public Works and Water Management (RWS) has introduced new and more credible speed limits for road works on motorways and trunk roads, where the speed limit can be differentiated in the cross-section or on the basis of time.

CROW publications 96a and 96b contain guidelines for the uniform preparation, designation and signposting of roadwork zone [7.47-7.57]. CROW publication 96 describes the procedure, the (policy) principles and the responsibilities and obligations [7.46]. The CROW publications are intended for motorways, trunk roads and every other road outside and within the built-up area. As an addition to that, RWS published a guideline with its policy principles in early 2005 [7.58]. It is important that these sets of guidelines (CROW and RWS) are observed during both large-scale and small-scale road works.

and efficient traffic flow is partly determined by signposting. It has a strong connection to the geometric design and the rest of the layout and equipment of the road. This applies in particular to signposts that must be erected a certain distance from the intersection or exit road. If the distance between intersections is too small, this can result in confusion, which is why it is of critical importance that, when roads are being (re)constructed, special attention is paid to the requirements that signposting places on road design.

The four principal requirements signposting must meet are:

- uniformity: uniform design of signposts and use of the same signposts in similar situations;
- consistency: once indicated, a destination will be indicated until it is reached;
- legibility: the contrast between the lettering and the background, the font size, the font and the number of names on each sign;
- comprehensibility: place and object names must be generally known.

7.16 Design faults

The road user performs actions at three levels that demand an increasing level of awareness:

- Skill-based actions that are performed routinely – or on automatic pilot – such as cycling.
- Rule-based actions, which focus more consciously on the question of which skill must be used, for example when approaching an intersection on a bicycle.
- Knowledge-based actions, where road users consciously consider the surrounding area, the potential manoeuvres and their consequences, such as finding your way in an unfamiliar city by bicycle.

In complex situations, the chances of making a mistake increase as the decisions have to be more consciously made.
Skill-based actions seldom or never lead to mistakes, rule-based actions are more prone to mistakes and knowledge-based actions are subject to the most mistakes. This is discussed in chapter 1.

In terms of the performance of a manoeuvre, seven stages can be distinguished, which comprise making a diagnosis, implementing the manoeuvre and evaluating the impact of the manoeuvre [7.41]:

1 The observation of the condition of the surroundings:
- What is the condition of the road environment?
- *Example: is the road slippery?*

2 The interpretation of the observation:
- How do I interpret the condition of the system?
- *Example: if the road is slippery, this constitutes a danger.*

3 The evaluation of the interpretation:
- Discovering the desired condition in comparison to the actual condition.
- *Example: How fast am I driving now, considering I can only drive at 30 km/h on slippery roads.*

4 Intended aim of the manoeuvre:
- What is the function of the system components?
- *Example: I am going to slow down because I am driving too fast; the road is slippery.*

5 Intention to act to achieve the intended aim:
- What manoeuvres are possible and which option is the best?
- *Example: I will drive slower by decelerating (rather than braking).*

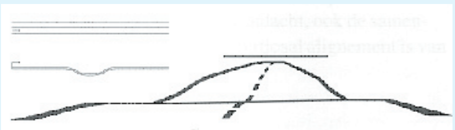
Several examples of design faults in the roadscaped

Sharp sideways bend in the road.
At V_o= 80 km/h, preventable with an L (curve) > 350 m.

Sharp upward bend.
At V_o= 80 km/h, preventable with an R (hollow) > 14,000 m.

Unusual sideways shift in the roadscape.
Preventable by employing very wide radius.

Unusual sideways bend in the road. Preventable by employing very wide radius.



The road appears to disappear.
Preventable by applying a large hollow curve at H < 1.50 m.

6 Translating the intention into a concrete (combination of) manoeuvre(s):
- Performing the chosen behavioural option.
- *Example: decelerate, choose a lower gear, or brake.*

7 Performance of the manoeuvre:
- Is the manoeuvre actually possible?
- *Example: I will decelerate only.*

In terms of road design, this means that:
- the condition of the system and the possible behavioural alternatives are shown;
- it must be based on a good conceptual model of the road user so that the manoeuvres and their consequences are consistent;
- it offers a good insight into the relationship between manoeuvre and consequence or into the actual condition of the system and what is visible of it;
- it gives continual and complete feedback on the manoeuvre.

The PIARC's Human Factors Guideline, which focuses on the prevention of human error, identifies three types of mistake, each of which results in a design requirement:
- The road design must provide the driver with sufficient time – at least 4 to 6 seconds – to react. Disruptions such as intersections and sharp bends must be visible at a distance of at least 300 metres when driving at 100 km/h. The six available seconds enable motorists to familiarise themselves with the situation (what is happening?), to estimate the situation (what am I required to do about it?) and to react accordingly (should I stop or take evasive action?). The best thing to do is improve the visibility of the disruption or eliminate the disruption altogether (or to at least weaken it), but this is often impossible. In such cases, warnings or speed reduction measures are effective options.
- The road design must provide the driver with a good field of vision. A natural field of vision invites appropriate driving behaviour. Possibilities include the careful choice of planting along the roadside and the prevention of a monotonous roadscape. The combination of height differences and bends can easily result in optical illusions. Distant objects can also attract the driver's attention at the expense of objects closer by. Here, too, elimination of the problem is the preferred option. If this is impossible, mitigation and timely warnings are recommended.
- The road design must be self-explanatory to the driver, who has expectations that are based on years of experience. They will not expect a sharp bend to follow a series of gentle ones, for example, or a bicycle crossing on a road section between two intersections after a series of intersections at equal distances with the same rhythm of buildings. It is often possible for the design to be self-explanatory by means of natural, non-traffic-engineering measures.

In principle, there are two different methods of minimising the negative consequences of road design faults:
1. adapting the design elements (for example by increasing the radius) or adapting the roadscape by the placement of furniture or green amenities at crucial locations;
2. emphasising the flaws in the road design so that road users are given a warning that enables them to adapt their behaviour in time.

7.17 Summary

A recognisable and continuous roadscape and predictable traffic situations facilitate the road users' driving task. One means of achieving this is to divide the entire road network into road categories. The way in which each category's function, form and use are geared to one another is decisive for road safety and the quality of the service level. For the road network to be used in a functional way, it must be constructed in such a way that road users use it as intended (by the road authorities). This functional use of the infrastructure is linked to route choice, accessibility and use by different vehicle types.

A distinction is made between the following three functions:
- through function;
- distributor function;
- access function.

There are two levels of road design requirements:
- functional requirements;
- operational requirements.

Functional requirements are partly concerned with attributing functions to roads and, therefore, with the categorisation of those roads and their infrastructure. Before the design phase of a road can begin, it must be clear which function the road is going to fulfil.
Operational requirements or general design principles stem from these functional requirements. The essential recognisability characteristics are of primary importance for the recognisability of a particular road category compared to the other two categories. These recognisability characteristics are unique to each road category and must, therefore, always be present. There is a certain level of latitude in terms of the remaining characteristics. In principle, each road category may comprise different road types or designs. However, the more road types, the more difficult it is to guarantee the differences between the various categories and thus the recognisability of the road category for the road user. The road types within a particular category must have all the essential recognisability characteristics of that category.

When developing or reconstructing a road, the preconditions, principles and objectives can be in conflict. The choice of a particular design element may also influence other design elements, in the same way that a road design can influence other policy areas. Road design must be viewed in relation to the objectives of accessibility, road safety, service level, the environment, management, maintenance and costs.

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Learning objectives for students:
- to be familiar with the most important aspects of vehicle safety;
- to be able to indicate how vehicle safety contributes to increased road safety.

A safe vehicle design is part of the first ‘E’, that of ‘Engineering’.

8 Vehicle safety

8 Vehicle safety

8.1 The concept of vehicle safety

Vehicle safety is the collective term for measures that are taken to make vehicles safer for the vehicle occupants and other traffic. This involves the vehicle itself as well as safety features and systems in the vehicle, such as seat belts and airbags.

Various types of vehicles are allowed on the public road, including cars, vans, lorries and buses, but also bicycles, mopeds and motorcycles. In addition, there are various categories of special vehicles.
Chapter 2 examined the position of the various modes of transport in relation to safety. This chapter focuses on the technical measures required for road vehicles. Rail vehicles are not discussed.

Vehicle safety is generally divided into two categories:

- Primary or active safety: the prevention of accidents, or accident prevention.
- Secondary or passive safety: preventing or limiting injury caused by accidents, also called crashworthiness. This not only involves the protection of the vehicle occupants, but also that of people outside the vehicle, often vulnerable road users.

It seems obvious to focus on primary safety in particular. After all, if there are no accidents, there are no injuries to be limited. However, in the current traffic system, not all collisions can be avoided, so it is effective to work on secondary safety as well. It should be noted that in the past, the emphasis was on secondary safety, with the shift towards primary safety only happening in recent years, partly as a result of the introduction of new technologies (ICT).

Here are some common terms in relation to vehicle safety:

- Integrated safety, a combination of primary and secondary safety, mainly aimed at safety systems that use Information and Communication Technology (ICT).
- Advanced Driver Assistance Systems (ADAS): systems that help drivers to control the vehicle.

Relation to the driver

Obviously, vehicle safety cannot be dissociated from the driver's behaviour:

- the operation of the vehicle and of various safety-enhancing systems depends on the driver's capacities;
- certain systems can lead to risk compensation: the driver will take more risks because he feels safer with these features;
- the effectiveness of safety systems, such as seat belts and crash helmets, partly depends on their (proper) use.

Therefore, the research and development of new vehicles and safety systems pays a great deal of attention to the human factor.

Relation to infrastructure

Vehicle safety cannot be dissociated from the infrastructure either:

- The infrastructure affects the physical (im)possibilities of the vehicle, such as the skid resistance of the road surface which affects the braking distance during emergency stops.
- The design of the infrastructure influences aspects such as driving speeds, the confrontations between road users and the types of accidents that occur. The vehicles and safety systems need to be geared to this design as much as possible.

- In a crash, the infrastructure (roadside objects) can also have an effect on the injuries.
- In the future, safety systems in vehicles will be 'fed' with information from the vicinity (similar to GPS signals in navigation systems).

Accident analyses as a base

Safety measures for vehicles are usually based on accident analyses. Both general analyses of large numbers of accidents and in-depth analyses of smaller numbers of accidents are used. The analyses provide insight into which measures are the most effective and also how requirements and test methods need to be formulated. European countries work together to collect and analyse accident data [8.1, 8.2].

8.2 Safety measures

8.2.1 Primary safety

Primary safety is all about taking measures to prevent accidents. These measures make sure that:

- the moving vehicle is stable and easy to handle and that disruptions can be easily corrected, even in emergency situations;
- the contact with the road surface is maintained as effectively as possible to prevent skidding where possible;
- the driver has a good overview of his environment (road, other road users) in various weather conditions;
- the driver can determine the desired driving situation from the road's environment and additional information, so that he can adapt his driving behaviour;
- other road users can see the vehicle easily.

History of vehicle safety

Vehicle safety became an item soon after the invention of the car. One of the first registered car crash victims was Mary Ward in Ireland in 1869. In the 1930s, plastic surgeon C. Straith and doctor C. Strickland campaigned in the United States for the use of seat belts and padded dashboards. General Motors performed the first 'barrier' crash test (with crash sled) in 1934. In 1944, Volvo introduced the first car with a cage construction. Mercedes-Benz performed extensive crash tests with its prototype cars in the fifties. During that time, the first two-point seat belts came into use, followed closely by the three-point belt. Active safety improvements such as disc brakes made their first appearance around the same time. The Netherlands also contributed to the development of vehicle safety. In the early sixties, 'Pinocchio', developed by TNO, was the first child dummy in the world used for testing child restraint seats. Partly because of the peak in the number of traffic fatalities in the early seventies, new technological inventions and measures were developed at a steady regularity in the following decades, aimed at both primary and secondary safety. This trend is still continuing, partly due to the new possibilities ICT has to offer.

Vehicle-bound systems that contribute to this are:

- the steering and suspension system;
- the brakes;
- the tyres;
- the driver's field of vision;
- information systems for the driver;
- vehicle lighting and marking.

The requirements for many of these systems have been laid down in (European) legislation, such as the brakes, the field of vision and the lighting.

Well-known safety-enhancing systems in vehicles are:

ABS (Anti-Lock Brake System)
ABS is meant for emergency stops and ensures that the braking power of each wheel is limited, so that the wheel does not lock, no matter how hard the driver presses the brake pedal. This keeps the braking distance to a minimum, which is particularly important on slippery road surfaces. The system works with sensors and an electronic control system. Most modern cars and lorries are fitted with ABS. It is an example of a measure that did not yield the expected results, probably because the driver feels safer because of the system and therefore drives faster and brakes later. On average, drivers with cars that are fitted with ABS have fewer collisions with other vehicles, but more single-vehicle accidents (somersaulting, going off the road).

EBD (Electronic Brake Distribution)
EBD optimises the performance of the Anti-Lock Brake System, distributing the braking power over the front and back wheels, depending on the weight of the car and the road situation, but also allows braking harder on one side of the car to increase stability in a bend.

Brake Assist
This system supports the driver by distributing the required amount of braking power to the wheels in case of an emergency. The Brake Assist system determines whether the braking is powerful enough, based on the braking power and the car's speed. If the braking power is insufficient, the system intervenes.

ESC (Electronic Stability Control)
ESC is also known as ESP (Electronic Stability Program) or VSC (Vehicle Stability Control). These are systems that improve the vehicle's dynamic behaviour and controllability, particularly in critical situations. The system has sensors that measure the vehicle's behaviour and intervenes in the braking power at the wheels and in the engine power.

Obviously, these systems are not infallible – certain physical thresholds may be crossed, so the vehicle could become uncontrollable.

Specifically for lorries

View-enhancing systems

A problem with lorries is that the driver's view of the rear, the sides and right in front of the cabin is limited (the blind spots), which is why vehicles are now fitted with view-enhancing systems. These consist of special blind spot mirrors and camera systems, so that the lorry driver can see what is happening next to or behind his vehicle. Since 2007, European legislation requires that new lorries be fitted with a so-called front view mirror which widens the view to take in the front of the vehicle.

Roll-Over Control Systems

These are systems that automatically intervene when there is a danger of overturning. Depending on the situation, the system reduces engine power and applies the brakes to certain wheels. These Roll-Over Control Systems are in fact ESC systems specifically for lorries.

Longer and Heavier Lorry Combinations (LHLC)

The logistics sector is urging the introduction of combination vehicles that are longer/heavier than the legal maximum: a maximum train weight of 40 tons, a maximum length of 16.5 m for articulated lorries and a maximum length of 18.75 m for lorries with trailer. The idea was mainly inspired by logistical and environmental reasons, which is why these combinations are also called 'Eco combinations'. Although not a specific safety measure, there are possible safety consequences. In the meantime, two field experiments with LHLCs have been conducted in the Netherlands and the conclusion is that road safety is not jeopardised. There might even be a safety benefit because, as a consequence of LHLCs, it is possible to have fewer lorries on the road.

Bicycles and mopeds

The main requirements for a bicycle relate to stopping safely, seeing and being seen and heard. This entails: at least one brake that works, pedals with a rough surface and four (amber) yellow reflectors, white reflectors that trace the wheel's outline and a red (non-triangular) reflector at the rear (between 35 and 90 cm above the road surface). The cyclist is required to use lighting on the bicycle between sunset and sunrise: white or yellow in front and red at the rear. The cyclist is not allowed to use more lights or reflectors than legally required. Finally, bicycles must have a working bell.

Mopeds must be fitted with a front and rear brake that work, the frame must not be cracked, et cetera, the wheels and tyres must not be broken, cracked, et cetera, and the tyres must have sufficient tread. Mopeds may not be modified to drive faster than the factory speed,which is 25 km/h for light mopeds and 45 km/h for mopeds. The fuel system must not leak. Two-wheeled mopeds must be fitted with one or two dipped lights, one or two rear lights and a non-triangular red retroreflector at the rear of the vehicle. Furthermore, the mopeds must be fitted with a working horn or bell. Mopeds are tested on a number of aspects; only mopeds that pass these tests are allowed on the public road.

8.2.2 Secondary safety

Secondary safety involves taking measures to prevent or limit injuries of vehicle occupants (and others). These measures ensure that:

- the vehicle construction and safety systems absorb as much collision energy as possible (instead of the people inside);
- the vehicle occupants space remains intact as much as possible after a collision;
- the vehicle occupants remain in such a position that the chance of coming into contact with hard parts of the vehicle or other obstacles during a collision is minimised;
- possible contact with 'vulnerable road users' (pedestrians, cyclists) with the vehicle is 'soft' enough to limit injury;
- cars, two-wheeled vehicles and pedestrians cannot easily end up under lorries;
- the risk of fire during a collision is minimised;
- vehicle occupants can leave the vehicle if it ends up in water;
- emergency services can do their job as effectively as possible (freeing vehicle occupants, for example).

Systems that contribute to this are:

- crumple zones, cage constructions, cushioning materials, et cetera;
- specially designed vehicle fronts;
- safety systems in the vehicle such as seat belts, airbags, child restraint seats and head restraints;
- protective gear such as crash helmets and protective clothing for motorcyclists and moped riders;
- side shield (on lorries) to prevent vehicles driving underneath;
- warning systems that give a warning signal when safety systems are not being used or used incorrectly.

For many of these systems, (European) requirements have been laid down in legislation. The systems are tested for compliance with these requirements by means of crash tests using complete vehicles (so-called full-scale crash tests) or with parts of vehicles and safety systems. Crash test dummies replace people during such tests. These are in fact highly sophisticated measurement instruments for measuring force, acceleration and movement. These measurements, in turn, can be converted into injury ratings. Nowadays, increasing attention is paid to the crash properties of different vehicles and vehicle types in

relation to one another. In other words, the constructions should not only protect the vehicle's own occupants, but also contribute to the protection of occupants from other vehicles and that of vulnerable road users. This is called crash compatibility. This is also important when cars collide with each other, because the differences in weight and size have grown considerably. Compare the large SUVs with the new small, economical cars, for example.

The following specific safety-enhancing measures can be distinguished.

Head-on collision resistance
This concerns the protection of vehicle occupants in case of a head-on collision with another vehicle or an object. The vehicle's cabin must remain as intact as possible (the so-called 'cage construction') and the crumple zone at the front of the vehicle must absorb as much collision energy as possible. Obviously, seat belts, supplemented with airbags, are essential for keeping the vehicle occupants in place and avoiding contact with the hard parts of the interior. Also, synthetic cushioning materials ('padding') are applied in order to soften contact of the head or limbs with hard parts.

Side impact protection
This concerns the protection of car occupants in case the side of the car is hit by another vehicle or if the car crashes sideways into an obstacle. The main aim is to keep the cabin intact by reinforcement beams in the doors, for example. The sides of a vehicle have little space for absorbing energy by means of crumple zones. Padding or side airbags provide protection for the head.

Protection for rear-end collisions
There is only a limited crumple zone at the rear of a car, if at all. Most of the energy is absorbed by the crumple zone of the vehicle that collides with the rear end. One advantage is that the crash speeds during rear-end collisions are lower than during head-on collisions (the vehicles are travelling in the same direction).
However, rear-end collisions may cause a whiplash injury, even at very low speeds (for instance 10 km/h). This injury is caused by the sudden movement of the head and may lead to serious complaints, varying from pain in the neck and head to full incapacity for work. If adjusted correctly, the head restraint is the most important means of preventing or limiting this injury. In addition, the entire system of seat, seat belt and head restraint can be optimised. Most modern cars are fitted with automatic head restraints, which move upwards during a collision as a result of the body's pressure on the back of the seat, so the head is cushioned by the head restraint more effectively, reducing the chance of a neck injury (whiplash).

'Collision-friendly car fronts'
It is not only important to protect vehicle occupants in the event of a crash, it is equally important to limit the injuries to pedestrians and cyclists (the vulnerable road users). 'Aggressive' bumpers (such as 'bull bars') and protruding parts are, or are to be, banned. In addition, the shape and malleability of car fronts (bumpers, bonnets, windscreens, windscreen wipers) are continually being improved. These kinds of measures are very important at lower speeds (< 30 km/h), especially in residential areas.
The first steps towards the mandatory introduction of collision-friendly car fronts have at long last been taken at European level.

Seat belts
Seat belts ensure that the vehicle occupants remain in their positions during a collision and do not come into contact with the hard parts of the vehicle's interior. An additional, and often underestimated, advantage is that seat belts prevent the vehicle occupants from being thrown out of the car, reducing the chance of fatal injury. The seat belt is one of the most effective and economical road safety measures and vehicle occupants should always wear them, even in the back seat. Modern seat belts are highly sophisticated. Pretensioners, for example, make sure that the belt is automatically tightened during a collision, so that it functions more effectively. Moreover, seat belts are geared to the seat and the head restraint.

Airbags
Seat belts cannot always stop the head from coming into contact with the vehicle's interior during collisions. Modern cars are therefore fitted with airbags for the vehicle occupants and increasingly on the sides as well. The entire vehicle's design is aimed at creating an optimum combination of seat belts and airbags.

Child restraint seats
Seat belts and airbags are suited for adults but not necessarily for children. Therefore, child restraint seats are essential. Special versions have been developed for different age categories. These vary from special baby safety seats that can be placed backwards in relation to the driving direction, to seat cushions for older children. Good child restraint seats have been developed and tested for safety in collisions and must be used in combination with the seat belt. Child restraint seats placed backwards are most suitable for babies and small children, who still have a weak neck. Therefore, the chance of (serious) neck injury in a head-on collision is lower with seats placed backwards than with seats placed forwards because the head is supported. It is advisable to switch to seats placed forwards at as late an age as possible.

Exterior airbag on a car?

Every year, approximately two hundred cyclists are killed in traffic in the Netherlands. In around half of the fatal accidents, a car is the collision partner. This proportion was even higher in serious, non-fatal accidents. Speed is an important variable in this matter.
During the National road safety congress (NVVC 2008), the Dutch cyclists union presented a study conducted by TNO into the possibilities of fitting an airbag to the exterior of a car. Exterior airbags on cars could potentially save 60 lives and 1500 hospitalised casualties among cyclists. The windscreen, the roof edge and the A-pillars appear to be the best location to achieve improvements for the cyclist's safety. Such airbags are technically within reach and already exist in prototype form.

Recently, the present EuroNCAP started focusing on the collision-friendliness of the car front for pedestrians. This, however, does not guarantee the collision-friendliness of the car front for cyclists (or at least not sufficiently), partly because the cyclist has a higher position and also a higher centre of gravity. In addition, cyclists travel faster than pedestrians. Including the collision-friendliness for cyclists in the EuroNCAP protocol could be a valuable supplement for the Netherlands [8.3].

Specifically for lorries

FUPS (Front Underrun Protection System)

During head-on collisions between lorries and cars, the car has a major disadvantage because of its lower weight.
Moreover, lorries generally do not have crumple zones, and without special protective features, cars can run under the nose of the lorry, so that the car's crumple zone does not function. That is why lorries nowadays are fitted with features to prevent this underrun. These are rigid systems, meant to activate the crumple zone of the car.
Systems are currently being developed that absorb energy in a certain way. These are called Energy-Absorbing Front Underrun Protection Systems.

Side shield

In order to prevent cyclists and pedestrians from being run over by the back wheels of lorries turning off, lorries are fitted with side shields between the front and back wheels. This is a (lightweight) sheeting on the side that mainly serves as a shield and hardly absorbs energy, if at all.

Specifically for two-wheeled vehicles

Crash helmets

The possibilities for taking secondary safety measures for two-wheeled vehicles are limited. Crumple zones, cage constructions, seat belts and airbags are less obvious for such vehicles, although experiments with such measures are being carried out on motorcycles. The most important protective measures concern protective clothing (especially for motorcyclists) and crash helmets. Crash helmets serve two purposes: on the one hand, they must protect the head against injury caused by sharp objects or prevent them penetrating the head; on the other hand, they must prevent brain damage by cushioning the impact. Crash helmets must comply with various technical requirements.

Cyclists and moped riders can contribute to their own safety by wearing a helmet. Specific groups can benefit from wearing a helmet: school children (because of the fact that a relatively large number of traffic accidents involve children under 18) and racing cyclists (because of their often higher speeds and greater cycling distances). The use of a bicycle helmet is voluntary in the Netherlands. It is not realistic to assume that the helmet will become mandatory for cyclists in the Netherlands, partly due to the experiences with such obligatory measures in other countries, where bicycle use decreased considerably as a consequence of the obligation [8.4-8.6].

8.2.3 On the road to integrated safety

New technology such as ICT (Information and Communication Technology) allows for further improvement of vehicle safety. The term 'Smart vehicles' is also used. These vehicles are part of what are called Intelligent Transport Systems (ITS), where traffic is viewed from a broader perspective. Because systems for primary and secondary safety are integrated, the term integrated safety is used more and more often.

An important future development is that of the 'co-operative systems', where automated communication takes place between vehicles and the infrastructure and between vehicles themselves. These kinds of systems make it possible to further enhance road safety. They can also contribute to a better traffic flow and a lower impact on the environment.

ADA

An important development is that of Advanced Driver Assistance systems, or ADA. These are smart systems that assist the driver with his driving task. These systems give information and advice and are able to intervene when necessary. Below are some examples.

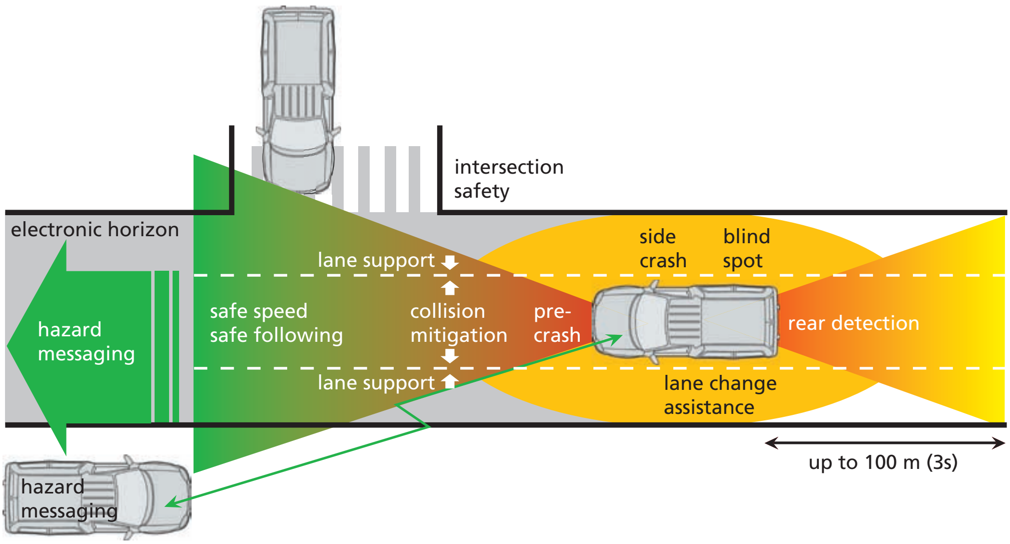
ACC (Adaptive Cruise Control)

This is a system that combines cruise control (fixed speed control) with an automatic monitoring function of the vehicle's distance to the vehicles in front (using radar, for example). When the distance becomes too small, a warning is given or the speed is automatically lowered. This, however, creates a dilemma when traffic volumes are high. Keeping a safe distance in those situations is punished by other traffic constantly merging in front.

LDWA (Lane Departure Warning Assistant)

This system ensures that the vehicle stays in position in the lane by detecting the road markings with cameras. If the vehicle threatens to cross a line, a warning signal is given or the vehicle is steered back to the correct position.

Figure 8.1. Integrated Safety



electronic horizon: field of vision of electronic systems
hazard message: automatic warning of emergency services in case of an accident

safe speed: intelligent speed assistance
safe following: adaptive cruise control
lane support: warning for leaving the lane
collision mitigation: system that activates safety measures when a collision is unavoidable (so before the accident actually occurs) and therefore reduces the severity of an accident

pre crash: system that activates passive safety measures when a collision is unavoidable (so before the accident actually occurs) so that the car is able to handle the collision more effectively

sidecrash: (protection against) side impact accident
lane change assistance: support during lane change

rear detection: detection of traffic approaching from behind

ISA (Intelligent Speed Assistance)
Speed control is an important instrument for increasing road safety. The ISA system automatically compares the actual speed with the speed limit. If the speed limit is exceeded, the driver will receive a warning or the vehicle brakes automatically. The information about the speed limit comes from the navigation system or the infrastructure, for example from the beacons. ISA also offers the opportunity to intervene in the driving speed at a certain location or time, for example when school is out. Such systems are not generally accepted yet, but support is growing, partly due to the fact that the risk of a fine is lowered and insurance premiums may decrease. For that matter, evaluations in Sweden and England show that there is considerably more support for systems informing the driver about (exceeding) the speed limit than for systems that intervene autonomously.

eCall
This is a system in the vehicle that automatically transmits an emergency signal in case of a collision, warning emergency services and directing them to the right location.

Pre-crash sensing
Modern sensors are able to detect if a collision is unavoidable before the collision actually occurs. This allows for the safety features in the vehicle to activate earlier (for example the airbag), so that their protective function is improved.

Occupant monitoring
Systems are being developed that monitor certain physical characteristics of the driver, such as eye movement.
These characteristics are automatically analysed and the system will give a warning signal when the driver appears to be tired or sleeping.

Alcolock
With this system, the vehicle can only be started after an alcohol test has been carried out and the result is negative up to a certain limit [8.7].

8.3 Context

8.3.1 Parties affecting vehicle safety

Various parties affect (the improvement of) vehicle safety.

Authorities
The national or European authorities have a decisive influence on vehicle safety, because they develop policies with regard to vehicle measures, lay down safety requirements in legislation, finance research, inform the public and stimulate improvements in various other ways. Vehicle safety is an important part of the European Commission's plans and programmes regarding road safety. Consultations are held with the car industry on new requirements for vehicles on a European level.

The Dutch national traffic and transport strategy memorandum pays special attention to vehicle technology to improve road safety. The ministerial order from the minister for Transport, Public Works and Water Management that was presented to the Dutch Lower House at the end of 2006, indicates a reduction in the number of fatalities from a maximum of 750 in 2010 to a maximum of 580 in 2020. Technical measures for vehicles that need to be taken at a European level must contribute substantially to this objective. Should this policy fail, the number of traffic fatalities in 2020 may amount to a maximum of 780 instead of the 580 mentioned.

Given the international character of vehicle legislation, regional and local authorities have only limited influence on the safety of vehicles. However, they can help stimulate the use of safer vehicles and encourage drivers to use the safety systems properly. Possibilities to this end are:

- make safety an important criterion when purchasing vehicles for government use (besides functionality, comfort and, obviously, the environment);
- encourage the use of seat belts and crash helmets (through public relations campaigns and suchlike);
- keep track of developments in safety systems based on new ICT and (in the longer term) adapting the infrastructure accordingly;

- facilitate field experiments with new, safer systems initiated by research institutes, the national government and as part of European research programmes.

Industry
Vehicle manufacturers and the suppliers of safety features and systems are free to make their products safer than legally required. A well-known example is the airbag. Despite the fact that they are not legally required, nearly all new cars are fitted with them. Obviously, manufacturers are led by consumers' needs to a large extent, but they can also exert influence on consumers through marketing. Although all manufacturers take safety into account when recommending their products, some manufacturers put more emphasis on safety than others. These manufacturers often lead the way when it comes to introducing new safety measures.
The industry has an important say in the development of new vehicle requirements and legislation, particularly on a European level. Economic interests weigh heavily for the industry in this matter.

Consumers
Consumers can influence vehicle safety through their buying behaviour. This can be done, for example, by purchasing a vehicle that scores high on safety or by purchasing additional safety-enhancing systems. Of course, consumers are led by the price as well.

Interest groups
Consumers often seek advice from consumer organisations, such as the Dutch consumers' association and the Royal Dutch touring club (ANWB). These organisations regularly pay attention to the safety of vehicles, for example by publishing EuroNCAP results. Dutch traffic safety association (VVN) aims to inform the public, for example by encouraging the use of safety features such as seat belts and child restraint seats.

Car fleet managers
Car fleet managers (such as lease companies) and employers can also have an effect on vehicle safety through their purchasing behaviour.

Transport companies
Transport companies can affect vehicle safety by purchasing safety-enhancing features or systems. In practice, however, their influence is limited, because costs weigh heavily in the highly competitive market in which they operate.

Research and test institutions
Many of the safety improvements to vehicles are the result of research and development activities performed by research institutes, whether or not in co-operation with the industry. Furthermore, research institutes function as 'test houses' for performing tests and measurements with regard to inspections, product reviews and such. In the Netherlands this work is mainly done by TNO (both a research institute and test house). The Dutch institute for road safety research (SWOV) also conducts research on vehicle safety, based on accident analyses. KEMA is the Dutch quality-control institute that serves as a test house in the field of vehicle lighting.

Insurance companies and courts of justice
Insurance companies can exert influence by employing differentiating premium policy concerning safer vehicles. Generally,

companies are a little conservative when it comes to this. When it turns out that no seat belts were worn during an accident, the court may decide on a lower compensation for bodily injury [8.8-8.10, w8.1].

8.3.2 Legislation and programmes

Legislation

The most important improvements in the field of vehicle technology are imposed by the government through legislation. In the past, this was done on a national level, but nowadays vehicle requirements are laid down on a European level (through European guidelines) and there is also a European system for testing and authorisation.
Every country has its own national body for the authorisation of road vehicles. In the Netherlands, this is the Rijksdienst voor het Wegverkeer (Government road transport agency). Whenever a vehicle is authorised by this body, this authorisation is valid for the entire European Union. The authorisation is based on the so-called type approval. The various tests and measurements that are needed for this purpose are performed by the test houses under the authority of the manufacturer - in the Netherlands, these are TNO and KEMA. After approval of the vehicle, the manufacturer must prove that his production process is designed to ensure that his product remains in compliance with the requirements (so-called Conformity of Production). This is monitored by the authorisation body.

A disadvantage of EU legislation is that it often requires a long introductory period and often compromises have to be reached that are not representative of the latest technology. The member states are free, however, to introduce their own rules of conduct, for example, which roads vehicles are allowed to drive on (for example mopeds not being allowed on the bicycle track within the urban area), or what safety clothing is compulsory, such as a helmet on a quad or a seat belt in a one-seat car with moped engine.

EuroNCAP

In order to overcome the disadvantage of slow legislation, a number of parties decided to establish EuroNCAP (European New Car Assessment Programme), a European test programme for the safety of new vehicles. The results are presented to consumers in order to influence their buying behaviour. Participants are the European Commission, several national governments (including the Netherlands), and consumer organisations.
To date, EuroNCAP only assesses the crash-worthiness of vehicles. The tests are performed by a limited number of accredited test houses in Europe, including TNO. Possibilities are being explored to see whether the programme can be expanded to include active safety.

MOT test

The MOT test was introduced mainly because of safety considerations, but in recent years, testing for environmental aspects has become more important.
The test is held every two years for cars that are more than four years old (the test is held yearly for cars running on diesel or gas because these generally have a considerably higher mileage). The vehicle is checked on a number of safety and environmental aspects. The system exists throughout Europe, but the set-up is sometimes different.

Specific measures and programmes
Sometimes the national government can take a specific measure to enforce or promote a safety improvement, for example to anticipate on future European legislation. The exceptional legislation introduced in 2003 for systems improving the field of vision of lorries is a good example. This regulation is particularly intended to tackle the problems regarding the blind spot.

Research programmes
The majority of measures in the field of vehicle safety are based on extensive research. This research is done by both the industry and (independent) research institutes. In the Netherlands, TNO carries out structural research into vehicle safety, both as part of their own expertise development programme and under the authority of government institutions and the industry. The Ministry of Transport, Public Works and Water Management commissions research to support their policy development and to work out technical requirements.
A lot of research takes place within the Framework programmes of the European Union in which vehicle safety plays an important role. Dutch institutions like TNO and SWOV participate in these programmes, which are often partly financed by the Ministry of Transport, Public Works and Water Management.

Public Relations campaigns
The Ministry of Transport, Public Works and Water Management and Dutch traffic safety association (VVN) regularly organise public relations campaigns to stimulate the use of safety features, such as seat belts, child restraint seats and crash helmets.
Recently, the European Commission started a campaign to encourage the use of ESC (Electronic Stability Control) [8.11].

8.4 Summary

Vehicle safety is the collection of measures taken to improve the safety of vehicles. This involves both the vehicle itself and safety features and systems inside the vehicle, such as seat belts and airbags. Vehicle safety is divided into two categories: primary safety, the prevention of accidents, and secondary safety, the prevention of injury from collisions. Integrated safety is the combination of primary and secondary safety, mainly focused on safety systems that function with the assistance of Information and Communication Technology (ICT).
Vehicle safety is related to the driver and the infrastructure in various ways.
Safety measures are often based on accident analyses.

Various parties affect (the improvement of) vehicle safety: authorities, the industry, consumer and interest groups, car fleet managers, transport companies, research and test institutions, and insurance companies.
Vehicle safety must contribute substantially to achieving the ambitious government targets regarding a reduction in the number of traffic fatalities and injuries. Tools to achieve this are legislation, test programmes (EuroNCAP star system), the MOT test, and research and public relation campaigns.

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9 Road safety education

Learning objectives for students:

- to know what road safety education is;
- to be able to indicate and motivate the key educational measures for road safety;
- to know in which situations and for what problems education can be useful.

Road safety education is the second of the three Es – ‘Education’.

9 Road safety education

9.1 Introduction

Traffic participation demands specific knowledge and skills that people do not possess as a matter of course. This is especially true of inexperienced people who are participating in traffic for the first time, such as children learning to cycle or learner drivers.
In addition, experienced drivers are sometimes faced with changing circumstances that render their knowledge and experience inadequate. This is why education is necessary for people of all ages, irrespective of their chosen mode of transport. This chapter discusses the way in which road users of all ages and using all modes of transport can prepare themselves for their role in traffic.

9.2 What is road safety education?

Road safety education is the collective name for all more or less structured (formal) activities that are carried out in order to convey to people the knowledge, skills and motivations that are the conditions for safe and efficient traffic participation. Although road safety education is often considered to be part of educational activities at school, instruction (extra-curricular training focusing on specific traffic roles) and information (messages that are disseminated on a large scale without personal contact) must also be gathered under the same heading. In the ideal scenario, these forms of formal learning connect seamlessly with informal learning, which is to say that people learn spontaneously by gaining experience and observing the experiences of others. Informal learning in the form of independent traffic participation provides substantially more learning moments than any form of formal learning, which is why it is important to understand that formal road safety education will only provide a modest contribution to the learning process as a whole [9.6].

When developing educational measures for different target groups, it is important to consider what form of education is the most adequate, with attention focusing on reaching the target group (drivers, for example, can be more easily reached through information than through training courses). Consideration must also be paid to the aspects (knowledge, attitude, skills) that are the most critical for the safety of the target group concerned. These aspects determine the most desirable form of education. If the primary problem within a particular group involves attitude and risk assessment, there is little point in offering them a skills course.

In this chapter, education also includes information and instruction. When discussing the different target groups and/or behavioural themes, an indication will be given of which forms of education are the most appropriate.

The key role of road safety education is to increase road safety through reducing the number of fatalities and injuries resulting from accidents. However, other objectives are also conceivable and these have become increasingly important in recent years. Some road safety education programmes, for example, focus on involving parents and residents more in road safety in the area around schools. In recent years, programmes have been introduced that focus on the environment and traffic flow. Campaigns such as 'Het nieuwe rijden' [Ecodriving] and 'Rij schoner, rij 80 in z'n 5' [Help the Environment, Drive 80 in 5th Gear] are examples of programmes that intend to teach a particular driving style that has less of an impact on the environment. Recent campaigns focusing on the use of extra lanes during rush hour are aimed at encouraging a driving style that promotes traffic flow.

9.3 What people can and cannot learn

Different psychological theories have attempted to explain and predict how people learn. The theories originate in different areas of psychology, including educational psychology and development psychology. Educational theories can provide clues for the development of road safety education programmes, while development theories provide insight into the various phases of development of people. This section discusses key learning and development theories.

It should be noted that a large number of other psychological theories take development and learning into consideration and that a great deal of interesting research is currently being conducted. A recent study in the field of neuropsychology, for example, showed that the cognitive development of adolescents is only fully complete around the age of 25 and not at 17 or 18 as previously thought. This is especially true with regard to the suppression of impulses [9.3]. Interesting results come from the field of social psychology. Elliott and Armitage [9.2] demonstrated that programmes aimed at behavioural change (in this case, speed) are effective if people make a plan in advance. This forces them to think about how often they will manifest certain behavioural traits and how they will go about performing them. This strategy has had a clear impact on the reduction of the number of self-reported speeding violations.

More information on child development and age-related aspects of road safety education can be found in 'The effectiveness of road safety education' [9.1].

9.3.1 Learning theories

Two schools of thought can be distinguished within the learning theories field. The first focuses on behaviour and association and comprises behavioural theories that focus on taught behaviour, such as theories concerning classical and operant conditioning in addition to theories on associative learning. The second focuses on thought processes and comprises information processing and cognitive theories.

Classical and operant conditioning

In principle, classical conditioning links a neutral sensory stimulus with a series of responses. This form of learning was first demonstrated by the Russian researcher Pavlov, who discovered that a dog not only started to salivate when it was given food, but also at the moment it heard a signal that indicated the food was being brought. The dog had learned to associate the signal with food and displayed the accompanying response. Commercial slots and information campaigns use this principle by linking a stimulus (showing a product or measure) to a positive experience such as a particular image with a positive atmosphere. After repetitively linking the image to the brand/product, seeing the brand or product is enough to create an association with the image.

Operant conditioning uses the same principle as classical conditioning: a neutral stimulus can summon a response. However, operant conditioning also involves new responses, while classical conditioning comprises responses that are linked to a stimulus. Operant conditioning prompts the creation of new behaviour or the adaptation of existing behaviour by creating links to their positive or negative consequences. Wearing a seat belt in the car, for example, is behaviour that can be improved by means of a reward. Other areas have also experienced positive impacts as a result of providing such incentives, although it must relate to specific behaviour: a reward for wearing a seat belt does not mean that people will adhere better to the speed limit. In addition, people will cease to behave in a particular manner if the reward is withdrawn. Traffic enforcement can be seen as a form of operant conditioning: negative consequences are linked to undesirable behaviour. Traffic enforcement and rewards in road safety policy will be discussed in more detail in chapter 10.

Information processing theories and cognitive theories

Information processing theories are based on the principles by which a machine functions (the functional components and their organisation) and could in fact be the same as those by means of which living organisms such as human beings function. Anderson's theory [9.13] is an information processing theory that states that in the process of acquiring skills, a distinction must be made between declarative and procedural knowledge. Declarative knowledge comprises facts and data. Behaviour is based on these facts. Procedural knowledge comprises information concerning chains of events in the form of a cause/effect theory: if I do this, then that happens. Procedural knowledge is far less susceptible to mistakes than declarative knowledge, because it appeals less to the main memory.

Behaviourists are primarily concerned with (strengthened) reactions and responses, and information processing theories are more concerned with a hierarchical organisation of tasks and a person's deliberate actions. This is why rewards and/or punishments occupy a less prominent position in these theories.

Cognitive psychology deals with cognition: the acquisition of knowledge about the world and the use of that knowledge in making decisions and performing actions. Cognitive psychologists try to understand how knowledge is organised and how learning works. In terms of road safety education, this approach has primarily contributed to the analysis of traffic behaviour and its division into various levels such as operational or control level (operating the vehicle), manoeuvre level (preventing conflicts on the road) and strategic level (navigation and choice of route) and the division of the execution of tasks into skill-based, rule-based and knowledge-based (see section 1.2.2). These divisions form the basis for the development of learning strategies that focus, for example, on the acquisition of specific cognitive skills such as danger recognition or situation awareness.

Social learning

The social learning theory uses principles that stem from both behaviourist theories (behavioural modification; learning by doing) and cognitive psychology, striking a balanced medium between these two approaches to human learning. The theory was developed by Bandura [9.14] and assumes that people learn by observing and imitating others, even without immediate confirmation or reward. The principles of operant conditioning can also be found in social learning: people can display certain behaviour because they see that others are rewarded for doing so. The four elements of social learning are:

1 attention (a person must observe a particular stimulus);
2 retention (the stimulus is given a name or image so that people can remember it and know what the response is in the cognitive sense);
3 skills (learning the (sequence of) actions);
4 motivation and reinforcement (strengthening and fine-tuning the skills).

The combination of techniques that characterises this approach lends itself perfectly to the development of (elements of) road safety education programmes.

9.3.2 Development theories

One of the most important theories in terms of development psychology is that of Piaget, who defined four stages of a child's development. Although the stages can differ in terms of duration by several months for each individual child, they are generally fixed, also in terms of order. The four stages distinguished by Piaget are:

- the sensorimotor stage (0 to 2 years): discovery of perception, development of locomotor system;
- the pre-operational stage (2 to 6 years): discovery of connections and their own place in the world;
- the concrete operational stage (6 to 11 years): discovery of other perspectives, can think figuratively;
- the formal operational stage (11 years and older): logical and conceptual (abstract) thinking, thinking in three dimensions.

It was previously thought that it was impossible to begin road safety education at an early age. The most recent insights, however, indicate that it is possible to provide certain forms of training from the age of 5 [9.1].

Another important theory in development psychology is that of Vygotsky. While Piaget focused primarily on cognition, Vygotsky focused more on action. The key theme in his theory is the term 'zone of proximal development', which means that children with a certain level of development and particular skills can achieve more if they are helped by someone who is more developed than if they attempt to perform a task alone. Both Piaget and Vygotsky see the social context as essential for the development of the child.

9.4 Formulating learning objectives for road safety education programmes

The principles and processes that can play a role in learning have been highlighted above. These theoretical insights must be taken into account when developing learning methods, also in terms of road safety education. This section, which is largely based on the 'Learning objectives document for permanent road safety education' [9.5], will broadly outline how a learning method can be developed. It should be noted that a great many materials and methods have already been developed, especially with regard to primary school pupils, inexperienced drivers and the elderly. The Toolkit for permanent road safety education presents an overview of the substantial number of educational methods (information projects, training courses, videos) available. This section, therefore, is particularly relevant to those who want to develop methods and programmes for road safety education. Sections 9.5 and 9.6 highlight what can be done for different target groups and behavioural themes, what the pitfalls are and how the target groups can be reached.

9.4.1 General principles

Learning objectives describe the knowledge, skills and attitude that a course has to convey to a student. There are six basic principles for the development of learning objectives for road safety education programmes:

1. the target group;
2. the context in which traffic participation by the target group occurs;
3. the subjects and the capabilities that are important for the safe and responsible traffic participation of the target group;
4. continuity in road safety education (the permanent character of road safety education);
5. a framework for the assessment of new and existing road safety education activities;
6. possibilities for supplements or modifications on account of progressive developments.

The six basic principles are discussed in more detail below.

Basic principle 1: Target group

In the development of any programme, it must be clear in advance for which target group the programme is being made. The programme must appeal to the target group and connect with the target group's environment . Only when the target group has been defined can the next step be contemplated: how to reach the target group (for example young moped drivers or elderly motorists)?

Basic principle 2: Context-dependent traffic behaviour

A key principle in the development of learning objectives for target groups is that traffic behaviour depends on the context. It is important to know about the target group: what are the personal characteristics, ambitions and competences that influence traffic participation by members of this group? Aspects that have a more immediate relationship with traffic participation can also be relevant. The choice and planning of particular journeys by a target group influence the choice of educational measures for this group. One example is that young motorists often travel at night in the weekend, while older drivers avoid travelling at night. On a more concrete level, it is important to know the situations and circumstances that the target group is confronted with in traffic and what this requires of the execution of the task.

Basic principle 3: Overview of relevant subjects and capabilities

In order to make the correct choices and decisions and to then transform these into the correct actions in the traffic context described, a road user must possess the requisite capabilities or behavioural repertoire. In general, a distinction can be made between:

- knowledge and skills;
- understanding and control of factors that increase risk;
- self-evaluation, calibration and motivation (attitude) with regard to risks.

Knowledge and skills

- This relates to knowledge of destination, options for and methods of travelling (including essential characteristics of vehicle and road), routes, hazardous and risk-enhancing circumstances, tools to increase road safety, behavioural norms (formal and informal codes of conduct), rules to act in a manner that increases safety, prevents accidents and limits damage, and the modes of behaviour of the person and others (particularly their limits).
- In this sense, skills mean the control of body and vehicle, observational skills, motor skills, communicative skills, learning from feedback, compensating for non-optimal or reduced perception, understanding and actions.

Understanding and control of factors that increase risk

- Understanding conditional aspects such as being sufficiently equipped or rested, not driving under the influence of alcohol or psychoactive substances, etc.
- Understanding the relationships between conditional aspects, knowledge elements and the consequences for behaviour, understanding varied and complex situations, understanding risks.
- Risk management, good perception (situation awareness), correct and timely danger recognition, correct and timely reaction.

Self-evaluation, calibration and motivation

- Self-evaluation with respect to personal skills: be aware of the strong and weak points, insight into the dangers of overestimating oneself.
- Calibration: a realistic assessment of individual skills, attuning behaviour to individual possibilities, calculating the balance in which every relevant element of the traffic context is considered.
- Motivation (attitude) with regard to safety: not wishing to use traffic participation for purposes other than an efficient and proper journey (and not, therefore, as a game, acting out or flight).

Of course, the concrete interpretation of the desired capabilities or behavioural repertoire is largely dependent on the specific target group.

Basic principle 4: Monitoring continuity in road safety education

In terms of road safety education, it is important to develop suitable activities and measures for all ages. Continuity implies that no target groups are excluded and everyone, young and old, can be reached. Continuity in road safety education can be achieved by using the same method to develop and test educational programmes for each target group. A method that is often used is the GDE matrix, which will be discussed in the next section.

Basic principle 5: Assessment framework

When the characteristics of a target group are clear, and when it is clear what the members of the target group know and are capable of, it is important to determine the extent to which existing programmes suffice. Are they focused on the objectives of the target group? Are any key learning objectives missing?

Basic principle 6: Flexibility

It must be possible to add learning objectives or adapt them to include progressive insights.

9.4.2 From general basic principles to a concrete approach

The 'Learning objectives document for permanent road safety education' [9.5] is based on the GDE matrix (Goals for Driver Education), which can be used to move from general basic principle to concrete learning objectives. The matrix provides an overview of the relevant subjects and skills (basic principle 3) and juxtaposes them with different levels of task performance to introduce a certain system and order into the collection of learning objectives for each target group.

The basic structure of this GDE matrix is shown in figure 9.1, which presents the learning objectives of children aged 4 to 12 as an example [9.4]. Learning objectives can be placed in each cell in the matrix. In this way, the learning objective 'The child knows which personal characteristics influence traffic behaviour' can be placed in the cell to the extreme upper left,

Figure 9.1. Model with 'Goals for Driver Education', the GDE matrix, completed for children aged 4 to 12

	Knowledge and skills	Understanding and control of factors that increase risk	Self-evaluation, calibration and motivation
IV. Personal characteristics, ambitions and competences (General level)	The child knows which personal characteristics influence traffic behaviour (character, physical characteristics)	The child knows which high-risk tendencies are dangerous in traffic and knows how to take them into account (behaviour at play, acting tough)	The child is aware of its own risk high-risk tendencies and adapts its traffic behaviour accordingly (peer pressure, exploring boundaries)
III. Considerations and decisions in the traffic context (Strategic level)	The child knows which general factors play a role in choosing and planning traffic participation and is capable of planning a route (choice of route, departure time, cycling in pairs or groups)	The child knows which risk factors play a role in choosing and planning traffic participation and knows how to take this into account (no cycle path, transfer to public transport)	The child is aware of the risk factors with regard to choosing and planning traffic participation and is prepared to take this into account (time, quickest or shortest route)
II. Management of traffic situations (Tactical level)	The child understands informal arrangements and rules and knows what they mean (which play areas, school routes)	The child can recognise dangerous situations and circumstances on their route and knows how to deal with them (bicycle defects, cycling in pairs or groups)	The child recognises its own high-risk behaviour and is prepared to behave in a traffic-safe manner (visibility, ignoring traffic regulations)
I. Performance of concrete tasks (Operational level)	The child knows what is key to traffic safety and is capable of applying the basic skills (crossing, cycling, other users)	The child knows the risks of crossing, cycling and travelling as a passenger and knows how to deal with them (weather conditions, other road users)	The child is aware of its strong and weak points with regard to concrete tasks and is prepared to adapt its behaviour accordingly (uncertainty, adapt to group norms)

which can be detailed as follows:
The child can provide an adequate description of the personal factors and circumstances that can influence traffic behaviour:

- *character traits (for example adventurous, risk-avoiding versus risk-seeking);*
- *norms/rules of parents/school, friends;*
- *physical characteristics (for example height).*

In this way, learning objectives for each target group can be described in each cell in the matrix. The 'Learning objectives document for permanent road safety education' [9.5] elaborates this for every target group, so consult this publication for a complete overview of learning objectives.

9.5 The content of road safety education: target group approach

The previous section explained how learning objectives are formulated and tested. This section will discuss the actual contents of education. What are the characteristics of the target group? How can the target group be reached? What are the key learning objectives for this group? What learning methods can be used? The target groups in this section are defined by the concept of permanent road safety education, which is discussed in more detail in section 9.7.

9.5.1 (Parents of) children aged between 0 and 4

Characteristics of target group

In 2006, there were five traffic fatalities in the target group comprising children aged between 0 and 4, with a further 66 requiring hospitalisation as a result of an accident.

The independent role of children of this age is minute. In so far as they do participate in traffic, however, they use public space only in the immediate vicinity of their home, such as the pavement in front of their house. Parents, carers and older children must always be around. In terms of independent traffic situations outside their immediate surroundings, children between 0 and 4 play no role on account of the fact that they do not yet possess the skills necessary to perceive and assess situations effectively. What does play a role, however, particularly for parents, is the mode of transport: how do parents ensure that their children are transported safely by bicycle or car? Parents can also start to teach the rules for playing safely and crossing the road safely.

Reaching the target group

In essence, the target group of children aged 0-4 can only be reached through the parents. One possibility is to approach the parents with programmes via day care centres and play-groups, although this will only reach a limited proportion of parents. Another way is to distribute leaflets or brochures via midwifery practices and health centres.

Learning objectives

Only two learning objectives are relevant to the children themselves:

- Children at the upper end of this age group know which basic principles apply to safe participation in traffic (rules concerning crossing the road and playing outside) and can apply these principles in practice.
- Children at the upper end of this age group can estimate which traffic situations are still too difficult and can summon the help of an adult. The adult then functions as a role model.

The other learning objectives are aimed at parents. Several key learning objectives for the parents of children aged between 0 and 4 are:

- Parents recognise risks to their child and themselves when supervising their child in traffic, they know what their strong and weak points are and display a willingness to adapt their behaviour.
- Parents can describe the most important basic rules (in the context of their function as a role model) and the key traffic signs, and can explain to their child why they must adhere to the rules.

Educational tools
There are various educational tools, including information leaflets aimed primarily at the safe transportation of children and several projects that are linked to day care centres (JongLeren) and school (Piramide). JongLeren focuses primarily on parents, Piramide on both parents and children (age 3 and up).

9.5.2 Children aged between 4 and 12

Characteristics of the target group
In 2006, there were 16 traffic fatalities in the target group comprising children aged between 4 and 12, with a further 327 requiring hospitalisation as a result of an accident.

Children aged between 4 and 12 start using public space more and more independently, also as road users. Initially, they remain in their immediate surroundings. The (undesirable) trend is that in recent decades the range of action of children extends at an increasingly later age: children nowadays go to school independently at age 9, while in the 1970s, this was at age 6. Because informal learning through independent traffic participation (see section 9.2) provides by far the most learning moments, a sufficiently safe environment in which this is possible provides one of the best forms of road safety education. Expansion of the range of action with increasing levels of difficulty in terms of traffic participation will still be conducted under supervision for this target group, which is why the learning objectives are still aimed at both parents and children.

Reaching the target group
This group can be reached through linking educational programmes to primary schools.

Learning objectives
Learning objectives for children aged between 4 and 12 are aimed at both parents and children. Several important learning objectives for children are:

- Knowledge and skills with regard to playing and crossing the road safely.
- Knowledge of the risks related to complex situations and circumstances (cycling in pairs and ignoring traffic regulations).

Several key learning objectives for parents are:

- Knowledge of the risks related to, for example, the (in)visibility of the child, behaviour in terms of dropping children off and picking them up, interaction with other road users.
- Awareness of the child's level of development and tendencies towards taking risks.

Educational tools
A number of programmes have been developed for the target group comprising children aged between 4 and 12, which can be subdivided into the following:

- Traffic methodology.
- Skills training.
- Safe school-home routes, dangerous locations.
- Knowledge and application of traffic rules.
- Products aimed at parents/carers.

- Projects that create conditions such as the primary education teacher training module on traffic.
- Every year, the Dutch traffic safety association organises a national traffic exam, which is taken by 95% of primary school pupils. A practical exam, which has a less structured support range, is taken by 60%.

There are also support structures in place that enable schools to access road safety education in a more structured manner. Examples include the Road safety label and road safety education project for primary schools.

9.5.3 Young people aged between 12 and 16

Characteristics of the target group
In 2006, there were 25 traffic fatalities in the target group comprising youngsters aged between 12 and 16, with a further 419 requiring hospitalisation as a result of an accident.

This group is characterised by large-scale changes, both in terms of the young people themselves and in terms of their choices, considerations and mobility behaviour. Physical and hormonal changes can be accompanied by severe emotions. The hormonal changes in boys often lead to an increased need for excitement and acting tough in front of their peers. Young people in this age group are usually more than capable of assessing the consequences of their actions. They are capable of behaving responsibly and can be held accountable for their behaviour. At the same time, the motivation to adhere to the rules decreases, while conformity to the actions of their peers increases. The circumstances in which they find themselves are also subject to significant change, such as a new route to school, a new mode of transport, other destinations (shops, places of entertainment) and being introduced to alcohol and drugs.

Reaching the target group
This group can best be reached via secondary schools.

Learning objectives
The learning objectives at this stage are primarily aimed at the youngsters themselves. Several key learning objectives are:
- Knowledge of tendencies that are risky: sheep mentality/peer pressure; need for excitement, sensation, competition, the need to impress, belong, et cetera; non-conformist behaviour (general tendency to want to break the rules; anti-authority).
- Knowledge of risks related to: characteristics of routes; being in a hurry; use of alcohol/drugs/medicines; reduced concentration due to performing two tasks at once (using mobile phone, et cetera); cycling in groups; circumstances (weather, light/dark, et cetera).

Educational tools
A number of programmes have been developed for this target group on such subjects as:
- road safety education packages;
- school-home route;
- use of alcohol/drugs;
- moped-related projects;
- consequences of involvement in an accident.

There are also umbrella projects for this group including the Road safety label for Secondary Education and support structures such as the Road safety education project for secondary schools.

9.5.4 Novice drivers

Characteristics of the target group

In 2006, there were 136 traffic fatalities in the target group comprising people aged between 16 and 25, with a further 2,348 requiring hospitalisation as a result of an accident.

This group comprises novice moped riders and drivers. While at this stage of their lives both groups have completed their physical development, they are still developing in terms of their cognitive capacities [9.3]. The development of awareness and impulse control in particular is not completed until around the age of 25, which is one way of explaining the lack of ability to assess risks. The combination of this phase in a young adult's life, in which everything is changing, and a new mode of transport that travels faster means that they are exposed to greater risks. Specific causes of accidents involving young moped riders must be looked for in adolescence as well as insufficient ability to convert knowledge of traffic rules into safe traffic behaviour. In addition, driving at high speeds is less safe for young moped riders than for older, more experienced riders. Not wearing a helmet also plays a significant role [9.10]. For young motorists, an important cause of accidents is that they are often exposed to dangerous situations, such as driving late at night in the weekend. Another key characteristic of young motorists is that they tend to overestimate their own capabilities and underestimate the complexity of the traffic situation [9.11].

Reaching the target group

This group is difficult to reach. From 16 onwards, young people can no longer be approached via the standard channels, school or education, because a large proportion of young adults have already entered the workforce. However, despite this, certain educational programmes, specific to mopeds, are provided via schools. Another possibility is via driving schools, which is the perfect way of reaching learners. However, novice moped riders do not often take lessons because there is not yet a practical moped exam (although this is expected to change). A final way of reaching this group is through mass media information campaigns.

Learning objectives
Several relevant learning objectives for this target group include:
- Knowledge of risks caused by mistakes in assessing the situation, driving too fast, reacting aggressively, insufficient space between the rider/driver and other road users (including vehicle spacing).
- Skills related to the perception and selection of relevant information (danger recognition), anticipation of eventualities, communication with other road users.
- Knowledge and skills in terms of the unmanageability of emergency situations, dealing with the vehicle's limitations.

Educational tools
Educational tools for this group can be divided into programmes for novice moped riders and novice motorists.

Examples of projects for the former group include:
- information projects at school;
- skills training.

Examples of projects for the latter group include:
- phased driving lessons;
- second phase driving lessons.

9.5.5 Drivers in possession of a driving licence

Characteristics of the target group
In 2006, there were 304 traffic fatalities in the target group comprising people aged between 25 and 60, with a further 4,315 requiring hospitalisation as a result of an accident.

People in this group are generally in a more stable phase of their lives, with usually more security in terms of a joint household or family situation. People often have more responsibility at work and are more accustomed to interacting in traffic on an independent level. The basic skills are largely automatic to the majority of this group (see section 1.2.2). However, some behaviour may have been acquired incorrectly. In this group, motorists travelling on business are more likely to violate traffic rules and underestimate the accompanying risks than people who are travelling for other reasons. Speeding and driving under the influence are risks most commonly taken by people in this target group (most frequently by those between the ages of 35 and 50).

Reaching the target group
This group is also difficult to reach with educational material. Only large-scale mass media campaigns have a certain guaranteed reach. Using lease companies to disseminate information is also an option, given that they already endeavour to communicate with their drivers, albeit primarily for reasons of economical driving.

Learning objectives
Several important learning objectives for this group are:
- Awareness of the overly automatic execution of tasks, the unmanageability of emergency situations, and dealing with the vehicle's limitations.
- Knowledge of risks related to being in a hurry, pressures of work, fatigue, reduced concentration, mood (aggression, et cetera).
- Knowledge of the risks related to the performance of dual tasks (mobile phone, navigation system, et cetera).

Educational tools
A large number of road safety education programmes are available to this group, which are specially designed for motorists, motor-cyclists, ambulance drivers and taxi drivers. In addition, in-house road safety programmes have been implemented for businesses and transport companies. Such programmes fall under the heading 'Safety Culture'.

9.5.6 Elderly road users

Characteristics of the target group
In 2006, there were 244 traffic fatalities in the target group comprising the over 60s, with a further 1,560 requiring hospitalisation as a result of an accident.

People aged 60 and over are retiring from work. As a result, they have more free time and the opportunity to travel whenever they please. This is also when age-related physical ailments first start to manifest themselves. Deteriorating sight, deteriorating muscular and articular flexibility and reduced ability to quickly process information are typical problems with which the elderly can be confronted. Moreover, the elderly need to be aware of the consequences that illness and medicines can have on driving behaviour. It is also vital that older road users are aware of the fact that their driving performance could deteriorate in terms of vehicular control and management. In some cases, elderly people switch from riding a bicycle to light mopeds or single-seat cars with moped engines, which means that they have to contend with travelling at increased speeds.

Learning objectives
Several relevant learning objectives for older road users are:

- Know how to optimise and compensate for functional limitations and display this ability (transition to automatic car, mirror on bicycle).
- Be up to date with changes in traffic signs and rules.

Educational tools
The educational tools for this group can be divided into four categories:

- Programmes for elderly drivers;
- Programmes for older cyclists;
- Programmes for users of three-wheeled mobility scooters;
- General programmes for safe and responsible mobility.

9.6 Road safety education contents: an approach based on behavioural themes

In addition to target groups, road safety education can also be aimed at behavioural themes. This approach is key to the 'Advancing Sustainable Safety' programme, which succeeds Sustainable Safety [9.6]. Specific themes are identified that constitute a problem for road safety. The themes need not be linked to an age group or mode of transport, given that problems often encompass different groups and modes of transport. 'Advancing Sustainable Safety' identifies five behavioural themes that meet the following two criteria: they constitute a problem for road safety and they can be influenced by means of education. Because this approach does not target specific groups, there are no learning objectives.

The five themes are:

1 insufficient understanding of the problem of road unsafety, which means that measures (in the context of Sustainable Safety) are not necessarily taken for granted;
2 no or insufficient use of strategic safety considerations when making traffic-related choices (choice of vehicle/route);
3 wilful traffic violations;
4 undesirable or improper habitual behaviour;
5 insufficiently equipped novice drivers.

These themes are briefly explained below.

Understanding and accepting the problem
Although, in general, people attach great importance to road safety, support for some road safety measures is limited. This can be attributed to the social-dilemma problem: a collective interest (for example a better environment) that conflicts with an individual interest (for example arriving at your destination earlier and driving quickly in order to do so). It may also be attributed to an insufficiently clear link between measure and safety, which road safety education can help to clarify.

Strategic safety choices
This theme concerns the notion that some modes of transport, times, routes or manoeuvres are safer than others and that people can therefore make safe choices before they participate in traffic. The following basic principles, partially taken from the older Sustainable Safety concept, are key:

- do not make unnecessary use of the system (which is to say: drive as few kilometres as possible);
- do not make unnecessarily dangerous use of the system (the safest vehicle on the safest roads);
- know your limitations (task proficiency) and do not overstep them.

Education can help road users gain insight into the function and workings of the traffic system as well as their own capabilities.

Wilful traffic violations
Two types of wilful violation are distinguished in 'Advancing Sustainable Safety', namely:

- socially accepted violations (such as exceeding the speed limit by a small amount);
- socially unacceptable violations (such as driving under the influence).

Education is easier with regard to the last category than it is with regard to the first because it can be linked to the social norms that people already have. When people fail to see the value of a particular law or regulation, it becomes more difficult.

In such cases, education must emphasise the importance of collective participation in traffic, the importance of rules and the connection with road safety.

Undesirable or improper habitual behaviour
Although routines and automatisms are essential when executing traffic tasks, they also have a downside. Automatic behaviour is largely inflexible, it can lead to dangerous mistakes on account of lack of feedback and little attention to the driving task. Education can help by:

- contributing to the proper development of automated manoeuvres and habitual behaviour;
- periodically testing developing habitual behaviour;
- teaching people to recognise the importance of strategic choices.

Insufficiently equipped novice drivers
Inexperienced road users lack the experience to execute the task at an automated, skill-based level. It takes a considerable amount of time (or kilometres) before their accident risk decreases substantially. Yet this awareness is underdeveloped in novice drivers, who have the tendency to make the task too difficult (by driving too close to the car in front or by driving too fast, for example) for the ability that they posses at that moment.
Education, therefore, must be aimed at this harmonisation process of task complexity and individual ability. Emphasis must not only be placed on how to participate in traffic in certain circumstances, but also on the decision to take part in a particular traffic situation in the first place.

9.7 The organisation of road safety education in the Netherlands

The Regional and Provincial consultative bodies for road safety (RCBRs and PCBRs) play a key role with regard to the guidance and co-ordination of road safety education programmes. In the past, there was little cohesion between the different activities in the field of road safety education. In 1998, the RCBRs and PCBRs took the first steps towards creating a collective vision on Permanent road safety education (PRSE). The National road safety education consultative committee contributed to enhanced unity concerning ideas about how to tackle road safety education. In recent decades, road safety education in the Netherlands was primarily approached from the permanent road safety education perspective, which focuses on target groups based on age and modes of transport. An important aspect of the PRSE approach is that education anticipates the moments when things change with regard to the human role in traffic, which in turn renders existing knowledge and skills inadequate. Examples are a child that cycles to school for the first time or an elderly motorist that first encounters an age-related physical ailment. Another important basic principle of permanent road safety education is that it builds on issues that were offered in earlier phases and that laid the foundations for the following phases.

The national government provides little guidance, with control lying firmly in the hands of the provinces, urban districts or urban regions (JCA+ regions; previously known as Framework Act areas).
When implementing road safety education, municipal councils can play a crucial role on account of their contacts with schools, driving schools and local offices of the Dutch traffic safety association.

This decentralised structure means that there are regional and local differences in how road safety education is tackled, which programmes are supported, where the emphasis lies in terms of target groups, et cetera.

Although trade associations ensure strong co-ordination in terms of driving instruction, there are also significant differences between driving schools due to the fact that, unlike many other countries, there is no obligatory curriculum for driving lessons in the Netherlands. This is due to the freedom of education laid down in the constitution, which also governs driving schools. The driving test dictates driving education: people must pass the test before being allowed to drive on the roads, but the exact content of the driving lessons is up to the individual driving school.

9.8 The effectiveness of road safety education

Road safety education can serve various purposes: reducing road unsafety by influencing behaviour, elevating road safety on the agendas of policy makers, or involving parents and residents. When evaluating road safety education programmes, it is important to bear in mind the primary aim of the programme: effectiveness in terms of behavioural changes and victim reduction or process/agenda setting.

Effectiveness
Little is known about the effectiveness of road safety education, given that it is rarely implemented in isolation but rather in combination with other measures. This makes it difficult to see potential effects.
The 'Study into the effects of road safety education' project was the first large-scale systematic study into the effects of road safety education in which this problem was removed by means of the research design.
In total, the study comprised eleven projects, in which two groups were distinguished: an experimental group that completed the education programme and a control group that did not. Both groups received pre-measurements in the form of a questionnaire, which contained questions regarding their knowledge of, attitude towards and behaviour in traffic. The experimental group then started the programme. Approximately a month after the programme was finished, both the experimental and the control group filled in their post-measurements. The study highlighted that approximately 50% of the education projects had an effect on the knowledge, attitude and behaviour of the target group.

Programme and process
A successful programme is more than an effective programme in terms of knowledge, attitude and behaviour. Many programmes also aim to involve parents and residents, for example, or to place road safety in a particular neighbourhood or town on the agenda.
A programme's success must be determined

in a process evaluation, which could, for example, ask the following questions:

- What actors are involved in the project?
- How satisfied are the various actors with the project?
- What do the receivers think about the project?
- How many people, schools or municipal councils are participating in the project?
- Is the project receiving any media coverage?

9.9 Road safety education in a wider perspective: opportunities and threats

As indicated earlier, it is difficult to determine the effectiveness of road safety education as an independent measure. The effect is difficult to measure in terms of behaviour and accidents, which is why the use of approximate indications such as self-reported behaviour is necessary. Sometimes programmes are structured in such a way that they are bound to have demonstrably little impact or are even counterproductive. Shock campaigns, for example, are a popular means of drawing attention to road safety and all manner of health issues. While this can be useful, it is so only if this information is combined with attainable and effective behavioural strategies. If this is not the case, such campaigns can result in people ignoring the message or seeing the problem as less serious than it actually is [9.12]. Other problems with road safety education can be that the target group is not reached, that the wrong group is reached or that the contents of the programme are not aligned with other statements.

‘Advancing Sustainable Safety’ [9.6] includes three aspects that road safety education must take into consideration. Firstly, road safety education is only useful if it refers to problems relating to knowledge, attitude or skills. Design faults, an inherently illogical traffic system or the complexity of the traffic task cannot be solved through education, which is why it is argued that the traffic task should be linked to the possibilities of the road user. This is a prerequisite that must be met before even considering how education can support or guide road users in their task.

Secondly, there are personal differences between people, in terms of both making mistakes in the traffic task and conscious behaviour. These differences cannot be solved through education: a four-year-old, for example, is not yet capable of crossing the road unaccompanied. While an education programme cannot influence character traits regarding, for example, whether people are quickly angered in traffic or not, it can help to deal with these limitations. The parents of a four-year-old can learn that their child should not enter the traffic unaccompanied. A quick-tempered person can learn to look for safer expressions of emotion. In Belgium, there are experimental behavioural training courses, the introduction of which is also currently being considered in the Netherlands.

A third aspect involves wilful traffic violations. In general, these are difficult to counteract through education on account of the fact that this sort of behaviour involves engrained behavioural routines. They are also often more or less related to firm character traits. Despite this, attempts have been made to influence traffic behaviour through education, such as the introduction of the Educational Measure on Alcohol. The Educational Measure on Behaviour that is under development will allow persistent offenders to choose between paying to take a course or losing their licence. These educational measures have a strong repressive character and can be effective as a result.

These limitations do not mean that investing in road safety education is a futile exercise. On the contrary, road safety education in combination with other measures that influence traffic behaviour can be particularly useful. Traffic fines administered by the Central Fine Collection Agency will soon include an information leaflet that explains the effects of speeding. In this way, education and enforcement are combined.
National and regional road safety campaigns also consist in many cases of a combination of mass media information and traffic enforcement activities with regard to the spearhead concerned. This combination of enforcement and communication, and the role and function of communication will be discussed in more detail in chapter 10 on Traffic Enforcement.

9.10 Summary

This chapter discussed the role that education can play in road safety. Road safety education is the collective name for all more of less formal activities that are used to teach people the knowledge, skills and motivations required for safe and efficient traffic participation.
A discussion of the key theories in the field of learning and development was followed by an explanation of road safety education programmes. It is important to know which

learning objective is central to each education programme so that this can also be tested.
The GDE matrix presents the learning objectives for each target group. The target group approach was discussed in terms of the content of road safety education programmes. The specific characteristics, key problem areas and the accessibility of each target group were discussed. Moreover, several important learning objectives and educational tools were presented. After this, the focus turned to a behavioural theme-based approach, which centres on particular clusters of behavioural problems that lead to a road unsafety rather than on target groups subdivided by age or mode of transport.
The organisation of road safety education in the Netherlands was discussed next, before the chapter ended with a discussion of the effectiveness of and the opportunities and threats for road safety education. It is useful to combine road safety education with other measures that influence behaviour.

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10 Traffic enforcement

Learning objectives for students:

- to know what traffic enforcement is;
- to understand how traffic enforcement works and on which basic principles it is based;
- to know the role and effect of enforcement communication;
- to understand traffic enforcement policy in the Netherlands;
- to know how traffic enforcement is organised in the Netherlands and which organisations are responsible for what;
- to be able to explain when and how traffic enforcement can be introduced as an effective measure and when it cannot.

Traffic enforcement is the third of the three Es – 'Enforcement'.

10 Traffic enforcement

10.1 Introduction

This chapter discusses traffic enforcement: the police surveillance of whether road users comply with traffic rules and all related matters. A relatively large amount of attention is paid to the conditions that must be satisfied for traffic enforcement to be effective, such as good communication. This chapter describes traffic enforcement in the Netherlands and how this can be further optimised.

10.2 What is traffic enforcement?

10.2.1 Description and aim of traffic enforcement

Traffic enforcement is the police supervision of road users' compliance with traffic laws and the punishment for non-compliance. The most common method of enforcement, as discussed in this chapter, is control and punishment. Traffic enforcement can also be interpreted in a wider sense. In the context of influencing road user behaviour, the punishment of undesirable behaviour can be complemented by rewarding desirable behaviour. While this is sometimes a more favourable option, it is better to apply a combination of both.

The aim of traffic enforcement is to prevent traffic violations by means of controls and sanctions. In most cases, 'violation' means 'unsafe behaviour'. The ultimate aim of traffic enforcement in the context of this book is the promotion of road safety. Traffic enforcement can also be a tool to combat violations that negatively impact liveability or the environment.

10.2.2 Background of traffic enforcement: intrinsic and extrinsic motivation, subjective probability of detection

To fully understand how traffic enforcement works, it is necessary to understand the psychological concepts of intrinsic and extrinsic motivation.

- Intrinsic motivation means motivation that comes from inside the performer, without an obvious reward or other incentive. In general, intrinsic motivation depends on the person and the activity in question: someone finds it useful or enjoyable to do something and derives a sense of satisfaction from it.
  In terms of road user behaviour, this means that someone wants to wear a seat belt, does not want to drink drive or speed, et cetera. In more general terms, a person knows and understands the usefulness of the rules and will therefore in all probability comply with them. In fact, the question is whether a rule is always necessary for such people to display such behaviour. However, for other people, the rules are needed and it will be necessary to check whether they are being followed or not. This involves extrinsic motivation.
- Extrinsic motivation is motivation that comes from outside the performer and will almost always involve a reward or punishment. In terms of traffic enforcement, this means (the chance of) punishment for violating the rules. Put differently, it refers to the feeling that road users have about being caught violating a traffic rule. This is known as the subjective probability of detection.
  It centres on the feelings of the individual and relates to the actual, statistical chance that a person will be caught for violating a traffic rule.

The subjective probability of detection is predominantly the result of:

- the objective probability of detection;
- the conspicuousness of police controls;
- the publicity/communication surrounding those controls.

In order to strengthen intrinsic motivation, road users are informed about the rules and the reason behind them. In most cases, this involves clarifying what risks both the road user concerned and others run if the rules are not followed. Information on how the rules can best be followed can help to cement intrinsic motivation.
Traffic enforcement, thus extrinsic motivation, then serves to show that it is a serious matter.

10.3 Statutory and organisational aspects of traffic enforcement

This section will discuss the statutory framework and the organisation of traffic enforcement, including:

- the 1994 Road Traffic Act (WVW);
- the 1990 Traffic Rules and Signs Regulations (RVV 1990);
- the Traffic Regulations (Administrative Enforcement) Act (WAHV).

The parties involved are:

- Chief Public Prosecutor;
- Public Prosecutor (OM);
- Traffic Law Enforcement Bureau of the Prosecution Service (BVOM);
- Central Processing Unit of the Prosecution Service (CVOM);
- Central Fine Collection Agency (CJIB);
- Basic police duties (BPD);
- Regional traffic enforcement teams (RTHTs).

10.3.1 Statutory

Road traffic rules and regulations

In a constitutional state such as the Netherlands, traffic regulations must be established by law in order for them to be enforced. The most important legislation in this respect is the Road Traffic Act (WVW), which stipulates, among other things, which vehicles and people are permitted to participate in traffic. This also includes the rules with which road users must comply.
The WVW is made up of five regulations:

- the 1990 Traffic Rules and Signs Regulations (RVV 1990): rules for the road user.
- Driving Licence Regulations: who is permitted to participate in motorised traffic.
- Vehicle Registration Regulations: registration of motorised vehicles.
- Motor Vehicle Regulations: vehicle requirements, thus: what vehicles are allowed on the roads.
- Administrative Provisions (Road Traffic) Decree. The BABW contains the rules to which the road authorities must comply when placing road signs giving an order or prohibition signs.

RVV 1990 contains the traffic regulations with which road users must comply in the Dutch traffic system, and describes the package of signs (road signs, road markings). Road signs are used to indicate what specific rules apply where. In order to obtain a driving licence, people are tested on their knowledge of traffic regulations and road signs by means of a theoretical exam. The WVW distinguishes between traffic offences and traffic violations, and stipulates the punishments for traffic offences and several more serious violations. Punishments for less serious violations are contained in the Traffic Regulations (Administrative Enforcement) Act (WAHV).

The Traffic Regulations (Administrative Enforcement) Act (WAHV).

The WAHV is better known as the 'Mulder Act' after the chairman of the committee that developed it. The WAHV came about to enable the administrative-law processing of traffic violations contained in the WVW.

Before the WAHV came into effect in 1993, traffic offenders were considered suspects under criminal law. The increasing number of traffic violations, however, led to an overburdening of the criminal justice system. The WAHV provides a highly automated system in which those road users responsible for a traffic violation can be given an administrative sanction. If there is uncertainty about who is responsible, this sanction is imposed on the registered owner of the vehicle.

Police officers and special investigating officers (SIOs)

The establishment of statutory rules is not sufficient to guarantee compliance with the rules; enforcement and sanctions are also required. However, this is not straightforward and must also be permitted by law. Section 9 of the WVW describes who is authorised to investigate and what their jurisdiction is. In general terms, two categories of individuals are authorised to conduct traffic investigations:

- normal police officers;
- special investigating officers (SIOs).

The difference between the two categories is that police personnel have completed a full police training programme and are authorised to issue fines for every offence and violation, while SIOs have a limited (investigatory) authority. Police personnel are authorised to issue fines for every conceivable violation.

A SIO only has the authority to set up and read out the equipment for automated speed checks.

Sanctions, CJIB, CVOM

Violating a traffic rule is, therefore, a traffic offence or violation as described in the WVW or WAHV. Whether a violation is committed is determined by a police officer or SIO, with or without the help of equipment.

Traffic offences and serious violations are dealt with under criminal law. Anyone who significantly exceeds the legal blood alcohol limit or exceeds the speed limit by more than 50 km/h must appear in court. The exact sanction is stipulated in the WVW.

Less serious traffic violations are administratively dealt with under the WAHV, which also gives the sanctions or punishments for such violations. This means, for example, that a person who has exceeded the speed limit by up to 30 km/h over the allowed limit will receive a payment slip in the post.

Sanctions issued by the police and SIOs for lesser violations are processed at the Central fine collection agency (CJIB), which sends the payment slips and receives the fines. A new system for fine rates was introduced in the Netherlands on 1 January 2006, focusing on the principle that the more dangerous the violation, the higher the fine. The rate system was further tightened on 1 April 2008. If the party in question disagrees with the fine imposed, it is possible to appeal against the sanction with the public prosecutor, the subdistrict court and, in certain cases, the district court in Leeuwarden. Failure to act on time will result in the party concerned forfeiting their right to appeal. Approximately 2.3 million fines were issued for traffic violations in the period around 1990. In 2006 that number had risen to almost 10 million for the spearheads of traffic enforcement policy only (red light running, not wearing a seat belt or crash helmet,

exceeding the speed limit or driving under the influence).
It appears that 97% of people pay their fines on time, with only 3% appealing against the sanction. Since 2005, all 'Mulder' appeal cases (approximately 360,000 a year) are handled by the Central processing unit of the prosecution service (CVOM) in Utrecht. This high level of payment may be the result of the collection measures the CJIB has at its disposal. In addition to increasing the fine, in the most extreme cases, the party in question can also be faced with sequestration of goods, income or property. Other measures that can be taken to compel offenders to pay their fines include confiscating their driving licence, impounding their vehicle and even imprisonment.
The high level of automation of the WAHV procedure in the settlement of traffic fines has a number of disadvantages. Firstly, the offender is not addressed in person by an authority, but merely receives a payment slip from an administrative body. The question is whether this has any corrective impact on the offender.
A second disadvantage is that the offender often fails to see the connection between the violation and the payment slip because this usually arrives several weeks after the violation was committed. There is no immediate feedback on the undesirable behaviour (see the section on behavioural learning in chapter 9) and chances are that the corrective aim of the sanction is not achieved. Speeders, in particular, often consider paying their fine as a form of taxation.

10.3.2 Organisational

The organisational basis of traffic enforcement is formed by the authority relationships in the Netherlands, which are divided into districts and police regions. Within the police force, a distinction is made between regular police duties and specialist traffic tasks.

Criminal and public order

To begin with, a distinction in can be made between criminal order and public order:

- criminal order
  Ultimate responsibility for criminal order lies with the Chief Public Prosecutor as head of the Public Prosecutor in a district. The Public Prosecutor is authorised to press charges and issue summons to appear in court.
- public order
  The government is responsible for public order. Final responsibility for public order within a municipality lies with the mayor.

Tripartite consultation
In principle, police deployment is discussed as part of tripartite consultations between the police force chief, the chief prosecutor and the police force manager.

Districts and police regions
In terms of the Public Prosecutor, the Netherlands is divided into nineteen districts. There are a further 25 police regions and a national police agency (KLPD). Therefore, some districts comprise more than one police region, each of which has a regional force with its own police force chief and organisation.

Traffic enforcement is an activity for which the enforcing parties are responsible, that is the Public Prosecutor and the police.
For enforcement activities to be optimally effective, consultation between the parties and the government is desirable. This is why traffic enforcement is on the agenda of various tripartite consultations.

Traffic enforcement by the police: two cornerstones
Traffic enforcement is currently dealt with by two police bodies:
- regional traffic enforcement teams (RTETs);
- traffic enforcement as part of basic police duties (BPD).

RTETs have more traffic enforcement tasks than the BPD, and they operate according to a plan. Traffic enforcement as part of basic police work is less planned and determined more by incidents that present themselves.
Specialist traffic police operate alongside the BPD and RTETs, and other enforcement activities are carried out as well. The KLPD undertake all traffic tasks, all police forces have a team that investigates traffic accidents and some have a traffic service with an enforcement function in addition to the RTETs.

RTETs and BVOM
The regional traffic enforcement teams (RTET) comprise approximately 28 fte's whose only task is traffic enforcement. Every police region launched an RTET between 1999 and 2003, the resources for which are made available by the Prosecution service's traffic law enforcement bureau (BVOM). Regular funds for regional police forces are provided by the ministry of the Interior and Kingdom Relations. In terms of traffic enforcement, the RTETs focus fully on helmet use, seat belts, red light running, alcohol and speed, the five spearheads chosen in order to optimise the chances of improving road safety through enforcement.

Agreements are made between the BVOM, the regional Public Prosecutor and the regional police force regarding how the RTETs will divide their efforts over the various spearheads. Depending on the situation in a region, agreements are reached concerning:
- the total number of hours the team spends on monitoring each spearhead;
- the accompanying expected return in the number of tickets issued.

The hours and the number of tickets are agreed on the basis of historical figures and the percentage of offenders and is directed as much as possible at the specific safety problems in the relevant police region. The combination of hours and tickets constitutes the obligation that the region concerned has to produce results for the period covered by the agreement.

The various enforcement activities within the RTETs are monitored and co-ordinated by a steering group comprising the RTET management team, a representative of the regional Public Prosecutor, a representative of the BVOM, a representative of the principal road authorities in the region, occasionally a representative of (former) RCBRs/PCBRs and representatives from the Dutch traffic safety association. The steering group convenes every six to eight weeks to monitor, co-ordinate and manage the enforcement activities. During such meetings, the RTET executive management team (team leader and co-ordinator) can discuss enforcement within a particular region on a broader platform. The regional Public Prosecutor can fulfil both a guiding and an authoritative role in the meetings.

In the agreements, approximately half of the enforcement hours have been allocated to speed. The choice of locations is largely determined by an accident analysis on a regional level, with emphasis on roads that have seen the most accidents and where offender percentages are highest. The number of locations is limited, however, on account of the fact that there has to be a sufficiently high level of enforcement at each of the locations. If the level of enforcement is too low, the performance of the teams will fail to impress and insufficient behavioural changes among road users will be brought about. In terms of the remaining spearheads, the locations to be monitored are determined by the location where the offences take place, irrespective of whether it is seen as a risk location.

The latest traffic enforcement task of the RTETs is enforcement aimed at reducing subjective road unsafety. Since 2005, most RTETs have included teams that work in areas where residents have lodged complaints about road safety. After an analysis of the complaints, an estimate of the perception of road safety can be made in addition to a study of potential violations in order to begin enforcement at a particular location. A settling-in period (in which the teams reveal their presence) is followed by a period of intensive enforcement, after which the total monitoring process is reduced to maintenance level, which is the level necessary to ensure that the preventive effects of enforcement continue. After a certain period of time, follow-up measurements are taken which are aimed at both the perception of road safety and violations. It is then determined whether the enforcement efforts have yielded results or whether a follow-up procedure is required.

Traffic monitoring in BPD

Traffic monitoring is just one of the many activities in basic police work, and there will always be competition between the various tasks that need to be carried out. Even within the officially traffic-related tasks carried out by the police, traffic enforcement is only one of many, including accident assistance and advice regarding taking traffic measures.

One consequence of this competition is that traffic monitoring as part of BPD is spread thin and the scope has decreased [10.8]. The nature of the work within BPD, including traffic monitoring, is reactive or, in the words of the police themselves, customer-oriented. This means that in the course of their everyday surveillance duties, the police may be confronted with deviant road user behaviour and called upon to respond. However, this customer-oriented approach does not mean that normal police officers do not have a traffic task – certain traffic related task agreements have been made. In contrast to the RTETs, these primarily relate to the number of tickets to be written rather than the hours of deployment.

Traffic monitoring within BPD principally runs along two lines:

- Emergency assistance
  In terms of emergency assistance, almost half (47%) of the activities are traffic-related. These are not restricted to checks but also include assistance and maintaining public order. A ticket is issued in twenty percent of trafficrelated activities that include emergency assistance.
- Area-specific work
  In area-specific work, more than a quarter (27%) of the work is traffic-related, which is almost half that of emergency assistance (47%).

In three per cent of cases relating to traffic duties, area-specific work results in a ticket being issued. Research [10.16] has shown that repressive action in area-specific work is far less frequent than emergency assistance (3% versus 20%). The same study also showed that in 85% of area-specific work and emergency assistance, trafficrelated duties are performed on the initiative of the police. The customer-oriented attitude means that when police officers in BPD respond to incidences that present themselves, they do so diligently. The extent to which this is the case varies with the level of urbanisation: in terms of both emergency assistance and area-specific work, the police receive more reports from citizens in smaller communities than in larger communities, also with regard to traffic.

Communication

Communication regarding traffic enforcement is provided from both RTETs and BPD, with each regional team having a dedicated spokesperson. This person regularly works in close collaboration with the BPD information department so that communication regarding the various forms of traffic enforcement in a police force can be closely co-ordinated.
The police spokespersons work primarily with representatives of the Dutch traffic safety association and of the provincial and regional bodies for road safety.

The future: administrative enforcement?

Traffic enforcement powers are currently vested almost completely in the police. The question of granting specific traffic enforcement powers to other organisations in the future has been the subject of debate for many years. Because the police do not always appear to have (or to allocate) the capacity to satisfy the safety demand, the road authorities (municipal and provincial) have expressed an interest in also having enforcement powers.
With the establishment of the National traffic and transport plan (NVVP) in 2001, the possibility of such a form of administrative traffic enforcement was considered, in which municipal councils would be granted far-reaching powers

Table 10.1. Framework for the establishment of communication activities

General					
who (sender)	what is said (message)	to whom (target group)	through which channel	with what aim	and with what effect
Examples					
	says	*to*	*by means of*	*with the aim of*	*with the effect*
Road Safety in the Netherlands	speeding is dangerous	drivers	television commercials	imparting knowledge about the dangers of speeding	- more knowledge of speed, - less positive attitude towards high speeds, - slower driving (behaviour)
Police	we monitor speed limits	drivers	website, road signs	increasing the subjective probability of detection, imparting knowledge about the cost of speeding	- more knowledge of speed, - less positive attitude towards high speeds - slower driving (behaviour)

to monitor traffic violations, including speeding. In the end, the Ministry of Justice and the Ministry of Transport, Public Works and Water Management together decided that there were too many drawbacks to granting municipal councils such far-reaching powers. A key point of attention was that it could harm the classic separation of legislative, executive and supervisory powers, in that granting traffic enforcement powers to road authorities could result in an undesirable conflict of interests on account of the fact that traffic enforcement can also involve financial returns. In 2004, preparations were made for two almost parallel bills 'Bestuurlijke boete kleine ergernissen' ('Administrative fines – minor irritations') and 'Bestuurlijke boete voor fout parkeren en stilstaan' ('Administrative fines – illegal parking and stopping'). These bills were intended to empower municipal councils to enforce several minor traffic violations. However, certain minor violations such as cycling without lights or speeding in a residential area were not covered by these bills and remain a matter for the police.

10.4 Enforcement communication

10.4.1 What is communication?

Enforcement communication is an essential element of traffic enforcement. Communication is a slightly broader term than information and assumes that the 'informed' (the target group of the communication) also respond. Communication is the transfer of information from a sender to a receiver. While the aim of communication is the alteration of knowledge, attitude and/or behaviour, it is ultimately, of course, aimed at behaviour. Communication is an element of Education (the 3Es) and Persuasion (the 3Ps) as explained in the introduction to part 2 of this manual. Generally speaking, communication activities revolve around answering the following question: 'Who says What to Whom through Which channel with What aim and What effect?'

Naturally, this must be elaborated for each communication expression.

In theory, communication is two-way: the sender must try to find out what the target group thinks and wants. This means more than merely evaluating information activities (aimed at influencing behaviour). It should include finding out in advance the opinions, knowledge and motives of the target group before the sender begins communicating. After all, it is important to know first why people do not wear a seat belt before informing them that their motives for not doing so are flawed.

10.4.2 The function of communication in enforcement

Communication concerning (un)desirable behaviour

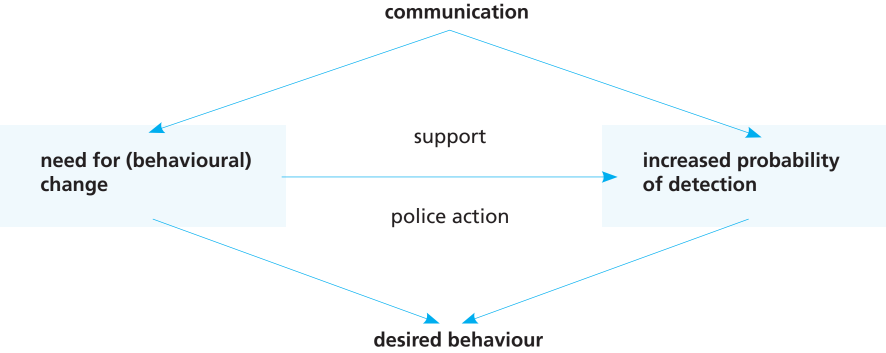
It must be made clear why speeding, drink driving, not wearing a crash helmet, et cetera, are dangerous and therefore undesirable, and/or what road users should do and how. In some cases, the need for desirable behaviour is obvious, such as drink driving. One problem is that many people underestimate things, such as the effects of speeding. In addition, there are various other less rational but no less essential motives for undesirable behaviour such as people thinking that wearing a helmet is uncool. The necessary communication therefore differs for every spearhead or behavioural aspect.

Communication concerning traffic enforcement: subjective probability of detection and its consequences

People are not so much impressed by the actual probability of detection for a violation, but they are when it relates to the instinctive chance that this will happen if they speed or drink drive. Increasing the subjective probability of detection is achieved in various ways, including a traffic enforcement strategy (for example random rather than selective alcohol checks), as well as by means of communication. If there are regular media reports of traffic checks where ten speeding offenders or five motorists driving under the influence have been caught, this will make an extra impression and increase the credibility of the reports announcing the checks.

In addition to the probability of detection, communication also needs to focus on the consequences. The fact that many people are caught is one thing, but this will make an even bigger impression if the consequences are known, such as people having lost their licences or their cars, having to pay a large fine, follow an obligatory and expensive course, et cetera: risk = chance × consequence. The greater the risk is made out to be by emphasising the chances and the consequences, the more effective the communication.

Figure 10.1. The road from communication to desired behaviour



Enforcement communication step by step; support
Elements in traffic enforcement communication include:

- focus on intrinsic motivation (existence and reasons for the rule, reasons for traffic enforcement);
- announcing that checks will be carried out, why they will be carried out, how many will take place and what the punishments and possible rewards are (increase subjective probability of detection: focus on extrinsic motivation);
- strengthen public support for surveillance (as a result of intrinsic motivation: seat belts are important, therefore, it is good that the police monitor it);
- strengthen basis of support/(intrinsic) motivation among the police.

Communication should therefore:
1 substantiate the desired behaviour;
2 increase the preventive effect of the legal consequences of undesirable behaviour;
3 encourage social control: a child or partner that points out the driver's (un)desirable behaviour.

The first has a positive additional influence on the second. Once it is made clear how undesirable it is to exceed the speed limit or drive under the influence, it is also clear that it is important that the police monitor this. In more contemporary terms, police checks provide a much-needed basis of social support. However soft that might sound, it is extremely important. Once people accept that the police are monitoring certain forms of behaviour, this provides an extra impetus for people to behave in the desired manner. If people do not accept this, this results in uncertain and irritable, and in the worst cases, recalcitrant behaviour: 'we'll just drive at high speeds when the police can't see us'. The longstanding debate concerning the usefulness of automated speed checks and the fining of marginal violations illustrates this. To clarify: this is not about the legitimacy of that debate and the accompanying arguments, but rather about the fact that the debate exists at all. That is bad for support for the checks and bad, therefore, for compliance with the behavioural rules. It is evident that communication can and must be used to straighten out a number of issues. And clear support for traffic enforcement is important for the motivation of the police officers involved. Drink driving is universally condemned. The officers concerned with alcohol checks regularly hear: 'It's good that you do this.' A police officer also wants to hear once in a while that they are doing something worthwhile, which will give them extra motivation to carry out their work.

10.4.3 Points of attention with regard to communication

Below are several general remarks concerning communication in the context of road safety and traffic enforcement in particular.

Striking the right note

Advertising agencies are extremely inventive in creating catchy slogans and attractive visualisations. The impact of an advertising campaign, however, is not a guarantee that the message will hit home and leave a lasting impression. Moreover, it must be understood that communication in the context of road safety is (or rather: should be) very different from mainstream commercial advertising. This is because road user behaviour differs from purchasing behaviour in a number of ways. Purchasing behaviour usually involves choosing a particular brand (macaroni, television, washing powder). A shift in purchasing behaviour therefore constitutes a minor shift in behaviour. Changes in road user behaviour include stopping certain forms of behaviour (speeding, driving under the influence) and/or the start of other forms of behaviour (wearing a seat belt or crash helmet). The persistency of the undesirable road user behaviour is mostly far greater than in terms of consumer behaviour. In principle, there is little resistance on the part of the consumer to the purchase of another brand of washing powder, but it is almost impossible to stop motorists in a hurry from speeding.

In addition, road user behaviour is a habit, which means that it is established on account of the fact that it is successful. A change in road user behaviour is therefore far more difficult to realise than in purchasing behaviour, which is why it is far from easy to utilise the same advertising techniques for purchasing behaviour and road user behaviour.

Safety and/or probability of detection: chance x consequence

Of course, it would be better if everyone behaved safely because it is safer to do so – because they are intrinsically motivated. Unfortunately, the fact is that, for a number of reasons, people do not generally think that they will be involved in an accident. In terms of motive, avoiding a fine is a significant factor in behaving safely. This means that whatever the case may be, the (subjective) probability of detection must be emphasised, in addition to which safety information can also be given. However, it is definitely worthwhile focusing on intrinsic motivation. On the whole, communication can be based on the following points:

- Consequences of undesirable behaviour without an accident ensuing: (chance of) being fined, costs, social disapproval, et cetera. This can also be formulated as disappointing benefits of undesirable behaviour (speeding is a waste of time, not wearing a crash helmet is uncool).
- Consequences of undesirable behaviour in the short term: an accident and the resultant pain, damage, delay, costs, punishment, social disapproval.
- Consequences of undesirable behaviour in the long term: an accident and resultant pain, invalidity, but especially the knowledge that you are responsible, for example, for the death of a child.
- Attractiveness of desired behaviour: safety, relaxed driving, social approval, et cetera.

In this way, the benefits of undesirable behaviour are instinctively reduced and the benefits of desired behaviour are strengthened: pushing and pulling through persuasion. Once the parties in question begin to become convinced of the desirability of particular behaviour, it is important to then facilitate such behaviour. For example, how do you extract yourself from the social pressure of drinking and driving? By agreeing in advance who will drive on a particular evening, by appointing a designated driver.

10.4.4 Connection between traffic enforcement and communication

Communication increases the effects of traffic enforcement, particularly if the communication is aimed at increasing the subjective probability of detection. This means that communication is essential. However, communication regarding traffic enforcement is pointless if the enforcement (or police check) is not perceptible in some form or another. Communicating on non-existent checks would be the end of traffic enforcement because it is too transparent and people will no longer believe in communication on checks that are being carried out.

10.4.5 Relationship between spearheads: consider the hierarchy

In principle, it is possible to communicate about (the traffic enforcement concerning) various spearheads simultaneously. However, this entails the risk that the message will become diluted. Traffic enforcement of extremely dangerous behaviour must not suffer as a result of traffic enforcement of relatively less important behaviour. If a motorist passes a breathalyser test (= significant reduction of the chances of an accident) and the police officer in question complimented him on that, it would be foolish to then issue the motorist with a ticket for not wearing a seat belt (= merely limiting the consequences of a potential accident). However, if the officer says in a friendly manner: ‘And perhaps you could put your seat belt on as well?’, the motorist will leave satisfied. Because of this positive approach, the probability that this motorist will wear a seat belt in the future is greater than if he had been given a ticket.

10.4.6 The sender: who is communicating?

The first thing to consider is what the message will be. However the sender does have an influence on the impact of the message. Clear agreements must be made (internal communication), while the involvement of the police is a matter of course. However, communication is more than just a dialogue between ‘the’ police to ‘the’ road user. It also takes place between individual officers and individual road users. A key element in communication is fairness. The person who is stopped must always have the feeling that they are being treated fairly.

It is obvious that the police must dedicate themselves to the actual surveillance. It is also obvious that the police officer involved must explain why the violation was dangerous. In the event that communication only takes place by issuing leaflets, it is similarly obvious that, pragmatically speaking, this should be done by volunteers rather than police officers.

It has already been stated that it is primarily the duty of the RTET and BPD spokespersons to design the communication, working in close collaboration with representatives from the Dutch traffic safety association and the Regional/Provincial traffic safety bodies.

10.4.7 Intermediaries

Intermediaries in communication

The sender need not address the receiver directly; intermediaries may also be involved. The most obvious intermediaries are the media, for insance through commercials and adverts. However, free publicity is equally important, which means that the media place information that they receive via press releases and press conferences. It is important, therefore, that the media receive information that is:

- relevant;
- attractive enough to pass on.

The latter point sometimes means that the message is conveyed more forcefully than is customary.

When providing the media with information about surveillance or accidents, they should also be given additional, useful information such as 'the victim was not wearing a seat belt'. Those offenders who have been caught displaying extreme behaviour are just the kind of 'fodder' that the media loves.

Other intermediaries include teachers, driving instructors, garage owners, petrol station owners, moped shop proprietors, employers and celebrities. They can either pass on the message directly or literally act as an intermediary for leaflets and suchlike. The same is true for family members and other passengers in particular. If your twelve-year-old son says that you should wear your seat belt ...

Intermediaries in terms of behaviour

In addition to intermediaries in communication, there are also intermediaries that influence behavioural decision-making in other ways, such as hosts/hostesses and catering personnel with regard to drink driving. Car salesmen can also act as intermediaries by offering free equipment that warns motorists if they forget to fasten their seat belts, for instance. Similarly, employers can play an important role by emphasising the importance of arriving at work safely rather than on time. A motorist's immediate surroundings also play a role and vice-versa. If parents always put on their seat belts, children will not know any better than to do the same.

10.4.8 The target group

The message must be geared to the target group in terms of:

- the tone;
- the content of the message (to a certain extent);
- the arguments that must be used;
- the communication channel.

Young moped drivers could be informed by means of a radio commercial that wearing a helmet is cool. This argument, this choice of words and this channel will probably be less appealing to people over 65.

10.4.9 When is communication necessary?

A distinction can be made between momentary information, background information and feedback.

- Background information is often issued at an early stage, explaining in detail the reasons why seat belts should be worn, even while driving next to water, why driving under the influence is dangerous and reprehensible, et cetera.
- Momentary information is given at the moment (and often at the location) that the relevant decision must be made. This information is very limited because there is no time or place for background information.

- Feedback is given after the checks have taken place. It explains the results and the consequences for the individual offenders.

The trick is to the ensure an optimal combination of background information, momentary information and feedback.
Posters of seat belts at the exit from a petrol station or a leaflet about alcohol behind the windscreen wiper in the car park of a restaurant or bar (momentary information) is an ideal way of creating a link to a commercial with background information that the people involved may have seen on television the evening before. Information on police surveillance that people may have seen should preferably be reported in the local media within several days.

10.4.10 Do's and don'ts

A number of practical tips.

1 Road users should preferably receive their fine within two weeks of committing a traffic violation. The effectiveness of punishments and rewards is greatest if they follow the action immediately. This means that ideally, all traffic offenders should be stopped, but, in reality, this is not always feasible. However, the maximum term between the offence and receiving the fine in the post remains two weeks.

2 Communication must be considered in the early stages of planning traffic enforcement. The requirements are:
   - that the communication is clear;
   - that the communication is interesting;
   - that the communication does not reveal the exact time and place where the checks will be held.

3 Monitoring is required so that the safety effects of traffic enforcement become publicly known.

4 Communication works both ways. It is important that it is clear where people can go for extra information or to lodge a complaint regarding a fine they believe to have been wrongfully issued. This address must be stated in all communiqués.

10.5 Setting up effective traffic enforcement

10.5.1 Getting started with traffic enforcement

General principles

Whatever the road user behaviour, the key principle of effective police enforcement is increasing the subjective probability of detection. This can be achieved by means of:

- publicity surrounding surveillance;
- conspicuous nature of the checks;
- an unpredictable pattern in terms of where and when random checks will take place;
- selective checks at times and locations where the chances of catching offenders are greatest;
- checks that are difficult to avoid;
- continue surveillance over a prolonged period.

Checks that focus on the violation of traffic rules primarily affect the extrinsic motivation of road users to comply with those rules. After all, such checks come with the threat of punishment, which in itself is an extra incentive.

The intrinsic motivation of road users to comply with the rules should preferably be improved as well. The police can contribute to this by:

- providing a good example in traffic themselves;
- informing the public clearly about the importance of traffic rules and the usefulness of traffic controls;
- paying attention to the complaints or comments of road users;
- having contact with road users designed to persuade, warn and promote involvement;
- supporting and collaborating in the (information) activities of other parties in the field of road safety;
- issuing warnings and alternative punishments (for example repairing a broken bicycle light) rather than fines, particularly with regard to young offenders.

The introduction to chapter 5, which discusses the PCOSE approach (problem, cause, objective, solution and evaluation), stated that there is an inclination to tackle actual or alleged problems off the bat. The demand for police checks is particularly prevalent on roads and in neighbourhoods where speed limits are exceeded. However, even speed-related problems require a systematic approach.

A clearer image of the problem and the causes can be gained by measuring behaviour in traffic and analysing accident data. Accidents can be studied in terms of road type (inside or outside the built-up area), age of victims, mode of transport/conflict type (car, bicycle, moped, et cetera, with car, bicycle, moped, et cetera, or single-vehicle accidents), season/quarter, day and time (weekdays, weeknights, weekend days, weekend nights). Complaints lodged by residents or road users regarding road safety can also provide data for problem analysis and the search for the causes. It is important, however, that the complaints are ordered in terms of their severity, location and time. The most serious complaints must be more closely objectified using observations or measurements taken at the location.

Objectives should be formulated first of all to reach agreement on the result, but also to monitor along the way whether the intended objective will be achieved or whether any adjustments are necessary.

Whatever the case may be, the solution in terms of enforcement, whether combined with communication or otherwise, must be linked to potential engineering measures. It is also important to have established the type of behaviour that causes the problem (rational or customary), so that the strategy can be developed accordingly. The questions to be answered include, for example: should the enforcement/information be preventive or repressive, aimed at knowledge, attitude or behaviour, should the focus be on offenders or observers (and therefore at punishments or rewards), should the approach be integrated or focused on a specific group, location or behaviour?

If the solution to the problem (also) lies in enforcement, an enforcement plan has to be formulated that comprises the following elements:

- a clear description of the objectives of the checks;
- the choice of target groups to which extra attention will be paid;
- the messages and information channels including internal information to implementing personnel;

- clear agreements with other collaborative partners such as the Public Prosecutor and municipal councils;
- additional measures on or along the road to support enforcement, such as improved visibility of signs and markings;
- the choice of locations and times for traffic controls;
- the consideration between high-visibility of checks and more unexpected checks;
- the organisation of checks in accordance with operational guidelines;
- the well-planned construction and dismantlement of checks over time;
- the evaluation of the implementation of agreements and the effects of checks.

In terms of evaluation, a distinction must be made between process evaluation and product or effect evaluation. Process evaluation analyses the way in which the effect is created. Effect evaluation analyses whether the intended effect (fewer speeding offenders, for example) has been achieved. Process and effect evaluation can each be divided into four successive phases, see table 10.2.

When carrying out an evaluation, it is important to pay attention to the following points. The way in which surveillance is performed on-site is crucial for the success of traffic enforcement. It is very important for successful completion that the personnel carrying out the evaluation are motivated. It is also possible to benefit from the knowledge of or the collaboration with specific intermediary organisations. The motivation of the police officers can be strengthened by allowing them to develop the various elements of the overall plan themselves. In practice, the general principles on which enforcement should be based (increased probability of detection, unpredictable checks, random stops, alternation between high-profile and inconspicuous check) should offer sufficient room for manoeuvre in terms of planning the surveillance.

For specific groups of road users, collaboration with intermediaries is key. The police have potential access to a large proportion of youngsters through schools. It is advisable that the police invest time in these types of informal contact with the target group. Given the disproportionately high risk associated with riding

Table 10.2. Phases in the process and effect evaluation

Phase	Process evaluation
1	Was the original plan correct?
2	Did the implementation conform with the plan/agreements?
3	Was the target group reached to a sufficient degree?
4	What do the target group think?
	Effect evaluation
1	What is the effect on knowledge and/or attitude of the target group?
2	What is the effect on the road user behaviour of the target group?
3	What is the effect on the number of accidents/victims amongst the target group?
4	What benefits does the increase in road safety within the target group have for society?

Table 10.3. Checklist for setting up road safety activities

Phase	Things to be done; decision criteria
Problem exploration	• Collect all data (accidents, behaviour, complaints, checks, local research) • Itemise data according to relevant characteristics • Present data visually
Determine causes	• Examine all information in mutual connection where possible; visualise, work with colours/symbols • Study locations, possible behavioural motives, offenders and their partners (school, work, parents) • Distinguish between primary causes and secondary causes; distinguish between short and long term; distinguish between links early and late in the chain
Objectives ('SMART')	• Specific: changes in behaviour • Measurable: premeasurements and follow-up measurements • Achievable and action-oriented: motivation of officers responsible for performing the checks is of decisive importance • Realistic: as based on available capacity • Time-bound: interim results after several weeks or months, final result after six or twelve months
Solutions	Questions: 1 Which 'Es' (integrated approach) and particularly: would an infrastructure approach be better? 2 Feasibility? 3 Effectivity? 4 Risk? 5 Link to other activities/objectives? 6 Support from public and partners? Implementation: involve the parties concerned in the objectives and plan, enforcement plan, interim information and motivation, and on-site supervision in advance
Evaluation	• Process evaluation and adjustment, where necessary (also interim) • Effect valuation and adjustment, where necessary (also interim)

a moped, for example, it is important that the police create time and capacity to tackle this problem.

The evaluation of traffic enforcement activities also shows what a certain activity has yielded. In this respect, an increase in traffic enforcement does not automatically lead to a proportional improvement in road user behaviour: process evaluation concerns the way in which the effect is achieved and is subject to the law of diminishing returns.

Table 10.3 contains a checklist of elements that should always be taken into account when developing road safety activities.

10.5.2 Five national spearheads

The five national spearheads related to intensive surveillance are helmet use, seat belts, red light running, alcohol and speed. This section systematically discusses the ways in which traffic enforcement of these spearheads can be designed. The following aspects will be featured in the tables: the problem and its connection to road safety, target group and motives, points of attention for surveillance and points of attention for communication.

Helmet
Registration plates have been compulsory for mopeds since 1 January 2007. This new legislation enables the police to issue fines based on registration as well as making it easier to distinguish between mopeds and light mopeds, which is necessary to know whether the rider is required to wear a helmet or not.

Table 10.4. Basic information concerning helmet surveillance

Helmet	
Problem and connection to road safety	• Moped riders must wear an approved, well-fitting and properly fastened helmet. • Correctly wearing a helmet reduces the chance of motorcyclists or moped riders suffering fatal injuries in accidents by 50%. • The percentage of riders who wear a helmet fluctuates between 91% and 94%. • In 2006, 88% of drivers wore a chin strap and 89% wore their helmet properly across their forehead.
Target group and motives	• Primarily 16-19-year old moped riders. Light moped riders are not required to wear a helmet. Motorcyclists wear them as a matter of course, as do older moped riders. • Motives for not wearing a helmet include: uncomfortable (12%) and hair becomes dirty/greasy (3%). • Primary motives for wearing a helmet include: compulsory (74%), dangerous (68%), chance of being fined (37%) and habit (36%).
Points of attention for surveillance	• Start with a peak period for surveillance of three to four weeks, followed by continual maintenance levels of checks. • Initial emphasis on stops, warnings and issuing tickets (repressive approach), followed by clearly visible preventive surveillance. • Honest and fair performance. Therefore, not selective in terms of certain groups of offenders, no distinction between age or ethnic background, not restricted to schools, no stops for minor offences. • Claim time for regular enforcement as a follow-up measure. In large cities in particular, district bureaus differ in terms of available capacity. • Preferably integrated moped checks with emphasis on the use and condition of helmets, checks for the possession and legality of driving licences, and test rig trials. • Mobile moped controls in a larger area is possible if they are carried out by five or six officers, one or two motorcycle police officers and three or four controllers, and with the transportation of the test rig in a police van.

Table 10.4. Basic information concerning helmet surveillance (continued)

	• When using motorcycles, it is recommended that extra protection be introduced given that moped riders have rammed motorcyclists on a number of occasions. • In cases of insufficient manpower, monitor a number of locations first so that sufficient officers can be deployed for each location. Experience determines how many officers are required for each. • Surveillance locations based on: - volume of moped traffic; - location of school routes - on-site road user behaviour; - police must also be able to operate inconspicuously. • Locations with mass crossings and right-of-way are less suitable. • The fact that mopeds now have registration plates makes it possible to issue fines for not wearing a helmet based on the registration. However, little is known about this.
Points of attention for communication	• Make it clear during stops why not or incorrectly wearing a helmet is dangerous. • Avoid merely reprimanding moped riders; this will increase the chance that the safety message will not be accepted. • Tone of the information concerning helmet use and riding mopeds must be positive ('It is enjoyable and exciting, but you should also realise what is and isn't acceptable'). • Provide information in advance concerning extra checks at or via schools. • Send a letter to the parents of underage moped riders who have received a fine for riding a tuned-up moped. This keeps parents up to date and they can then ensure that the moped is returned to its original state. • Use the information to also highlight the dangers of riding a moped in general and what can be done about it.

[10.36]

Seat belt

Seat belt checks are often carried out by one officer observing and one officer stopping motorists or by officers driving alongside motorists to observe seat belt use. Observing seat belt use from the road side or from a motorbike is far from foolproof, which is why experience is the best way to eradicate any mistakes.

Tabel 10.5. Basisinformatie gordelcontroles

Seat belts

Problem and connection to road safety	• Since 1 April 1992, it has been compulsory for all passengers in the vehicle to wear a seat belt. • Seat belts reduce the chance of a fatal injury by 40% in the front and 30% in the back. • In 1995-2002, intensified enforcement led to a 23% increase in seat belt use in those police regions where the surveillance was part of a regional plan. Throughout the Netherlands, increased seat belt use as a result of intensified surveillance in combination with education has resulted in a 3% reduction in traffic fatalities. • In 2006, seat belt use was 94% in the front and 73% in the back.
Target group and motives	• Target groups for surveillance and communication include motorists, passengers (including children), motorists transporting children. • Key motives for wearing a seat belt include: safety (mentioned by 76% of motorists and 78% of passengers in 2005), habitual (61% and 61%, respectively) and the fact that it is compulsory (60% and 61%, respectively). The risk of being fined was a less prevalent motive (32% and 32%, respectively). • Motives and causes for not wearing a seat belt include: 'I forgot' (11% of motorists, 12% of passengers in the front, 22% of passengers in the back) and uncomfortable (6% of motorists, 5% of passengers in the front, 16% of passengers in the back). • Seat belts are worn more often by women, the elderly, people with a higher level of education, married people, people living together, private motorists (compared to motorists on business) and motorists who primarily use their cars to commute.
Points of attention for surveillance	• Surveillance over a period of two or three months. • A clearly agreed and supported booking policy (what to do when four people in one car fail to wear seat belts, for example) can contribute to improving the motivation of the officers concerned. • Attention should also be paid to seat belt use in the maintenance period that follows (through secondary checks). • As many variations are possible. • Initially limited to warnings and leaflets. • Regular counts of seat belt use at different locations within and outside the built-up area in order to formulate or adjust the surveillance plan. • Police officers must set an example by wearing their seat belts at all times.
Points of attention for communication	• Attention to the subjective probability of detection • The significance of wearing a seat belt, especially within the built-up area where most accidents occur, also at lower speeds (30-50 km/h). • Not only do people not wearing a seat belt run an increased risk themselves, they also pose a threat to other passengers. • Explanation of the rules to small children using clear illustrations or photos. • The chances of people emerging unscathed from a car submerged in water or on fire is greater if they are wearing a seat belt.

[10.33]

Red light running

In general, people tend to comply with the rules better if it is clear why they exist. This applies, for example, to speed limits as well as traffic lights. If waiting at a red light takes too long while there is no crossing traffic, this makes the usefulness of the light unclear and makes it tempting to run a red light. It is important, therefore, to check whether the sequencing is set up optimally before carrying out intensive controls using cameras.

Table 10.6. Basic information concerning red light running surveillance

Red light running

Problem and connection to road safety	• In 2005, red light running was the primary cause in 6% of accidents in which a fatality occurred and in slightly less than 4% which involved a hospitalisation. Accidents as a result of red light running are therefore relatively serious.
Target group and motives	• Target groups: motorists, cyclists and pedestrians. • Little is known about motives. (Prevented) gains in time will play a key role.
Points of attention for surveillance	• Red light cameras lead to a 25-30% reduction in injurious accidents. • Cameras must be clearly visible so that motorists can see them from a distance and do not brake suddenly. • Place camera on those (arms of) junctions where the most/most dangerous red light offences (can) take place. • When stopping offenders, work with one officer who observes the offence and another who stops the offender. • Advance warning signs can also be used during 'manual' surveillance. If there are more or less permanent advance warning signs, regular (daily) checks should be performed to guarantee the credibility of the signs.
Points of attention for communication	• Dangers of red light running for self and others. • The poor example of red light running. • High speed/haste as determinants of red light running. • Increased checks and level of fines. • In principle, amber light means 'stop' rather than 'continue'; continuing to drive is only allowed in certain situations.

[10.29]

Alcohol

In contrast to many other checks, systematic alcohol checks demand that more officers are deployed, which is important, particularly in terms of transporting offenders to the police station and processing them quickly and efficiently. Therefore, the demands placed on good planning and preparation are more significant with systematic alcohol checks than with other checks.

Table 10.7. Basic information concerning alcohol surveillance

Alcohol	
Problem and connection to road safety	• In the Netherlands, approximately 25% of all serious accidents are the result of alcohol use. • Alcohol diminishes the ability to concentrate, to observe (the ability to differentiate between objects and their background, narrowing of the field of vision), to estimate distances, reaction speed and self-assessment. • Blood alcohol level of 0.5 (0.5 grams of alcohol for every litre of blood) increases the chances of being involved in an accident by 150%. A level of 1 increases this chance by 400%, a level of 1.8% by 1700%. • In 2006, the percentage of alcohol-related offences was 3% on weekend nights. • The percentage of male and female offenders in 2006 was 3.5% and 1.8%, respectively. • Heavy drinkers with a Blood Alcohol Concentration of more than 1.3% are responsible for a disproportionate number of alcohol-related accidents.
Target group and motives	• It is especially difficult to influence the category of ‘flagrant’ alcohol offenders. Alcolocks appear to be an effective means of preventing re-offending within this group. • For novice drivers (in possession of a driving licence for less than five years), the blood alcohol limit is 0.2; due to lack of experience , the chances of young people with blood alcohol levels between 0.2 and 0.5 being involved in an accident is greater than for older drivers with levels between 0.5 and 0.8. • 25% of all serious alcohol-related accidents are caused by men between 18 and 24 years old, while this group only constitutes 5% of the Dutch population. • Key motives for drink driving include: the need to get home and no other transport is available (43%), unsociable not to drink (16%) and underestimating the effect of alcohol on driving behaviour (13%).
Points of attention for surveillance	• Emphasis on enforcement during the periods when the problem of drink driving is most acute: midnight – 6 a.m. and Friday, Saturday and Sunday afternoon/evening (between 4 p.m. and 10 p.m.). • Stopping and breathalysing road users at random. • Carry out controls in the early evening (4 p.m. to 10 p.m.) in small teams (three to four officers) on roads with a heavy volume of traffic (give off a signal that drink driving checks will be carried out that evening).

Table 10.7. Basic information concerning alcohol surveillance (continued)

	• One motorcycle policeman for each check to intercept motorists who try to stop, turn round or avoid the check. • Planned checks in weekend nights and other periods with large numbers of offenders by relatively large teams of five to seven officers who change location every 30 minutes or so. Small teams of three are often incapacitated for an hour or more after catching an offender due to procedural issues. • Transport the offenders to the station and have them processed by people who are not members of the surveillance team. • Continuity of surveillance throughout the year. • Reduce work stress related to drink driving checks by: - working with other police forces or groups; - using trainee groups (make sure they are authorised); - using reservists (make sure they are authorised); - combining alcohol checks with other traffic checks. • Systematic alcohol check at accidents. This may result in a general preventive effect as long as the public are well informed. Also required for the registration of alcohol-related accidents.
Points of attention for communication	• Road users can be stopped at any hour of the day or night. • Regularly provide the media with the results of alcohol checks. • Announce long periods of intensive surveillance in the media. • Do not announce exact days, with the exception of large-scale events where increased alcohol consumption can be expected. • Alcohol also influences response capacity in small amounts. • Alcohol can have an extra impact on motorists who are tired or inexperienced. • Social disapproval of alcohol use in traffic. • Extreme increase in risk as a result of the combination of alcohol and drugs • Getting caught could result in loss of licence. • Specific to young road users: alcohol use in traffic is not tough or cool, drunken youths are less attractive to girls, the consequences of an accident could result in lifelong disability. • Rectifying a popular misconception: driving skills increase after a drink, beer contains less alcohol than wine or gin, it is possible to reduce the effects of alcohol by eating something or drinking coffee. Use social surroundings (hosts/hostesses, family, friends) as intermediaries in communication.

[10.31, 10.32]

Speed

Before speed checks are implemented, two issues must be taken in to consideration:

1 The first question that needs to be answered is whether many people exceed the speed limit on the road in question. If this is the case, attention should be paid to whether the existing speed regime is suitable for the road. The introduction of a higher speed limit could be a solution. If this is not possible, it is important to check whether the physical nature of the road and its surroundings makes speeding too attractive. If this is the case, radical infrastructure measures are necessary to change the roadscape.

2 If the road does not invite speeding, but it occurs nonetheless, measures such as minor infrastructure changes, traffic enforcement and information are required. When combining traffic enforcement and information, the extent to which each is emphasised must be taken into consideration. If, for example, it turns out that many motorists are unfamiliar with the location and are speeding unknowingly, emphasis should be placed on information. If this proves unhelpful, or if the motorists know full well that the speed limit is 80 km/h on the road concerned, more time must be spent on traffic enforcement.

Table 10.8. Basic information concerning speed surveillance

Speed

Problem and connection to road safety	• Excessive speed is (partly) responsible for approximately 30% of traffic accidents. • Higher speeds mean greater chance of an accident due to reduced time to observe and react; longer braking distance. • Higher speed means higher impact speed which means more serious injury. • For instance, if speeds were reduced by 1 km/h on a 50 km/h road, this would result in an estimated 8% reduction in fatal accidents and 4% in injurious accidents. A similar reduction on an 80 km/h road would result in a 5% reduction in fatal accidents and 2.5% in injurious accidents.
Target group and motives	• Offenders are often young, highly educated males, married or living together and driving a considerable number of business kilometres in a company or lease car. • Primary motives include: adjusting speed to other traffic and being in a hurry. • Motives for adhering to the speed limit include: safety, mandatory, avoid fine. • All motorists want to drive faster than they find safe – for others – and overestimate their own driving ability.
Points of attention for surveillance	• First look to see if the speed regime on the road concerned is logical and whether infrastructure measures are not a more obvious solution than enforcement. • Speeding cameras are a practical solution for large volumes of traffic and for a high percentage of systematic offenders at specific dangerous locations. • Visible and less visible checks at changing locations are the most suitable at the more differentiated danger points on the road (network).

Table 10.8. Basic information concerning speed surveillance (continued)

	• Mobile surveillance with stops should be principally used to track the most serious offenders, but is less effective in terms of its general impact on speed. • Section control is the most suitable for reducing speeds on controlled sections of road. • Video surveillance is the ideal way of checking several spearheads at the same time as well as checking deviant behaviour. The aim is to pay more attention to the more serious offenders and to confront them with their dangerous behaviour. • The level of surveillance is dependent on the number of offenders.		
Points of attention for communication	Not speeding	**Emphasise advantages** • Smaller chance of an accident; • Lower costs; • Environmentally friendly; • Better overview; • More time to react.	**Mitigate disadvantages** • Travelling times are minimally increased.
	Speeding	**Emphasise disadvantages** • Chance of an accident is much higher; • Higher costs; • Bad for the environment; • Chance of being fined; • Undesirable in the vicinity of schools, small children and cyclists.	**Mitigate advantages** • Minimal gain in time; • Uncool.

[10.35]

Finally, the following issues should also be considered: using publicity and the policy regarding the issuing of tickets.

Smart use of publicity
Speed checks must be unpredictable in terms of time and location so that motorists cannot intentionally avoid them. This is why the exact time and place of the checks must not be announced in advance. However, carefully considered announcements can lead to prevention and announcements made through sources such as www.flitsservice.nl lead to confirmation of the announced checks. Such publicity must be used smartly.

Booking policy
Booking policy determines the limit after which fines are issued. Equipment used by the police to measure speed is set up in such a way that it flashes if vehicles exceed the speed by more than 7 km on roads with 50 km/h and 80 km/h speed limits. This limit is 8 km/h on 100 km/h and 120 km/h roads. While this is the measured speed, a correction will be made for equipment deviation. This correction amounts to three kilometres (3% at speeds exceeding 100 km/h). The ticket issued by the Central fine collection agency states both the measured speed and the corrected speed.

In several sections of society, and particularly among enforcing officers themselves, there is a desire to enforce higher tolerance levels on roads where the relationship between speed and road unsafety appears to be less clearly present, especially if people have the idea that speed checks on these roads are more about enforcing standards (validating a rule) than they are about safety. A booking policy that provides more room for variation contributes to the improved motivation of officers and wider support for the speed checks. Ideally, this would lead to improved customisation, but the dangers of employing a certain level of arbitrariness are lying in wait if clear guidelines are not introduced at the same time concerning the application of speed checks.

10.5.3 Other undesirable road user behaviour

In addition to the five national spearheads for intensive traffic surveillance, there are many other types of violation that cannot be ignored by the police due to the danger they pose and the severity of their consequences, such as tailgating on the motorway, mobile phone use behind the wheel, cycling without lights, and, of course, various forms of aggressive driving. Depending on the frequency and dangerousness of these offences, the police could draw up a local hierarchy of the level of danger and deploy any remaining enforcement capacity on this basis. Given that these offences are not structural spearheads, they usually require less police capacity, which is why any real improvements in behaviour are often difficult to realise. Controls carried out on these offences are useful nonetheless because they serve to further reduce such behaviour and to combat blurring of moral standards.

In terms of their approach to such behaviour, the police follow two strategies:

- zooming in on one type of behaviour (in the same way as the other spearheads) and focusing surveillance specifically on that behaviour (for example camera detection of tailgating on motorways);
- monitoring behaviour at changing locations and stopping road users after they commit an offence (this approach often demands that enforcing officers have more training/ expertise).

High-profile and active police intervention has an impact on (traffic) behaviour and on the faith citizens have in the police. This is also an important argument within the police organisation itself.

10.6 The quality of traffic enforcement

The previous sections discussed the individual building blocks required for traffic enforcement in the Netherlands. It is the mutual coherence of these aspects that determines the quality of traffic enforcement. The term quality indicates how successful traffic enforcement has been in promoting compliance with traffic rules.

10.6.1 The traffic enforcement chain: coherence and strategy

The previous sections showed that traffic enforcement is not a stand-alone measure. It can only occur and lead to the desired effects if:

- the aims are clear;
- it is embedded in a legislative framework;
- there is collaboration between the various parties concerned;
- the various activities are geared to one another.

With regard to this last point, the cohesion between traffic enforcement communication and traffic enforcement itself is vital. This section discusses the traffic enforcement chain in order to explain the relationship between these four aspects. The intended effect of traffic enforcement is described using a model, which focuses on the fear of punishment as a key mechanism for determining behaviour. In practice, traffic enforcement consists of both rewards and punishments as active mechanisms for influencing behaviour. This is discussed further in section 10.6.2.

Figure 10.2 shows the traffic enforcement chain. The term chain indicates that all elements are inter-linked and interdependent. For example, an increase in the objective probability of detection is partly dependent on the way in which the police organise their tasks and the legislation that makes it possible to fine motorists on the basis of their registration plates.

According to this model, traffic enforcement is rooted in legislation, because it would be impossible without statutory regulations.

There must also be a traffic enforcement policy and/or programme. Enforcement must have a goal, there must be a task. A policy provides an aim and a direction to the efforts, so that traffic enforcement activities can be practically oriented. Section 10.3 discusses the organisation of traffic enforcement in more detail.

When enforcing officers start work, this creates a certain level of traffic enforcement pressure, called the objective probability of detection: the statistical, objective chance that an offender will actually be fined.

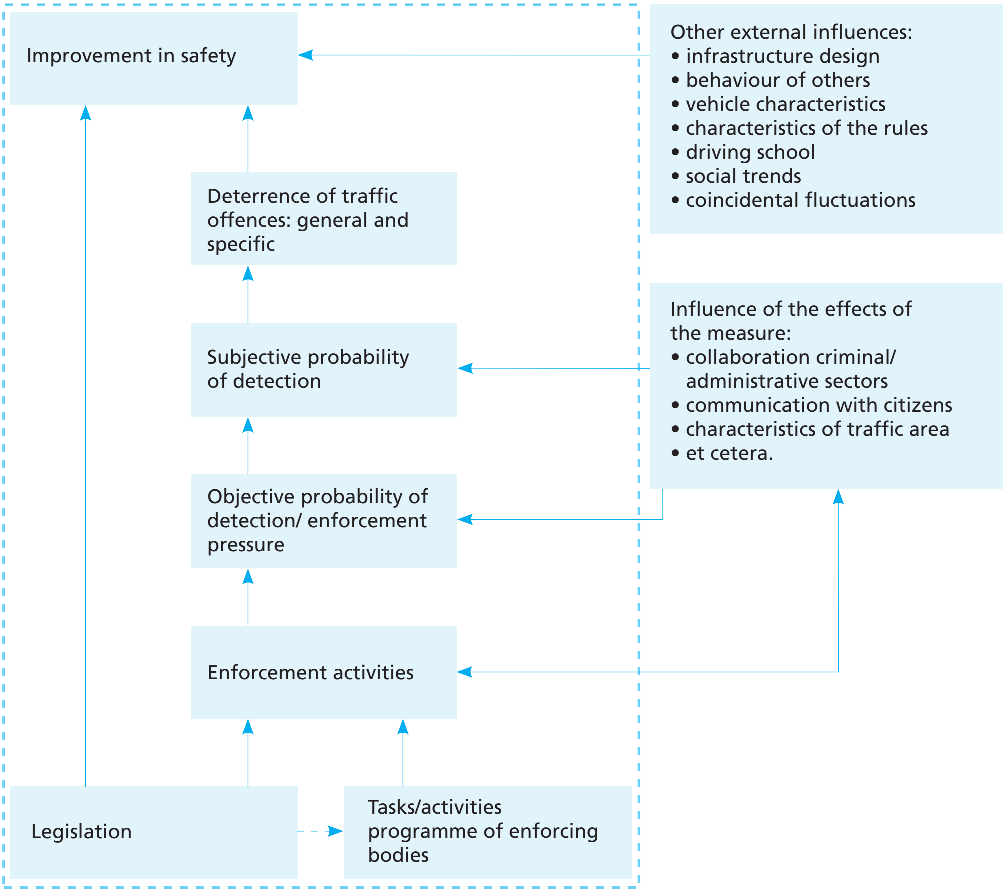
Offenders themselves do not generally have a clear image of the objective probability of detection, which is a good thing. By being shrewd in terms of the visibility of checks and the communication of the checks in the media, the enforcer creates the instinctive feeling among road users that their risk of being caught is greater than the objective probability of detection actually is. This feeling that there is a reasonable chance of being fined for committing an offence is known as the subjective probability of detection (see also sections 10.2 and 10.5).

If road users deem the chance of being fined for committing an offence to be significant enough and decide as a result to comply with the rules, this is seen as the preventive impact of traffic enforcement. Therefore, the activities that occur in the context of traffic enforcement (and the accompanying communication) have a deterring effect.

General deterrence can be described as the impact of the threat of legal punishment on the public at large. Drivers adjust their behaviour without ever actually being punished. Specific deterrence can be seen as the impact of legal punishment on those who have been apprehended.
To make the intended safety effects of traffic enforcement as great as possible, it is necessary to aspire to as high a level of general deterrence as possible. Ultimately, within the framework of this model, this amounts to using the threat of punishment to dissuade the largest proportion of the population from committing traffic offences if it is evident that intrinsic motivation is lacking. On the one hand, this can be interpreted as a matter of efficiency: how can maximum effect be achieved through the deployment of minimum police capacity? On the other hand, it is also a must: it is only when the majority follow the rules that the intended gains in safety can be achieved.

Fortunately, the subjective probability of detection is not the only reason why people follow the rules. Most people are naturally (intrinsically)

Figure 10.2. Schematic representation of the expected mechanism of police enforcement (within the dotted box), including the influence of external factors (outside the dotted box) [10.5, 10.9]



motivated to behave according to the rules. Another reason for complying with the rules is that people want to do so because they are law-abiding. For such groups, traffic enforcement has the primary function of keeping them on side and specific deterrence has the function of showing them that people who do not follow the rules will be punished. This confirms that their choice of conforming to the rules is a good one and that this choice is supported by the government.

Specific deterrence, therefore, serves two purposes within the contours of the model: to punish offenders and let them see that this is not to be taken lightly, and to show non-offenders that they have made the right choice. To achieve the latter aim as optimally as possible, it is important that the fines issued to (serious) offenders are widely communicated.

The general deterrence effects of traffic enforcement are generally increased if:
- the subjective probability of detection is increased;
- the definitive nature of the punishment is increased (objective probability of detection);
- the punishment is issued more rapidly after an offence is committed.

Rewarding desirable behaviour is a recurring theme throughout a person's life:

- 'Well done, John', says John's mother when he ties his shoelaces for the first time. John likes the idea of doing it himself again the next time.
- 'Well done, John', says the driving instructor when John successfully completes a difficult manoeuvre. John decides to work on this manoeuvre so that he can perform it even better.
- 'Well done, John', says the boss when he rewards John with an end-of-year bonus for having been particularly industrious. John is determined to work even harder next year.
- 'Well done, Mr. John', says the police officer when John passes a breathalyser test. John thinks that drink driving is all the more reprehensible.
- 'Well done, Mr. John', says his car insurance company, giving him a no-claims discount after a claim-free year. John is determined to continue to drive claim-free.

The latter factor relates to specific deterrence. The impact of the general deterrence effects is also dependent, therefore, on the design of specific deterrence, which is why there is a link between general and specific deterrence. Although traffic enforcement should emphasise general deterrence, this should not be done at the expense of specific deterrence. The deterring nature of police intervention has more effect on large sections of the population if there is an increased chance that an offence is dealt with specifically and quickly. The trick to achieving an effective traffic enforcement programme is to find the optimum balance between both forms of deterrence.

The chain highlights the need for far-reaching collaboration and co-ordination in traffic enforcement, involving many different parties. Their challenge is to boost the efficiency of traffic enforcement programmes through collaboration and a focused approach.

10.6.2 Punishments and rewards

In addition to instruction, training and modelling (social learning), one of the educational instruments employed is the punishment of undesirable behaviour and the rewarding of desirable behaviour. Rewards are used expressly to teach people something and bring about a sustained change in their behaviour. In terms of learning psychology, rewarding desirable behaviour is the logical continuance of punishing undesirable behaviour. Previously, the government did not reward desirable behaviour, but this has now changed. Rewards accentuate the difference between undesirable and desirable behaviour. It is also a method of enticing people towards behaving in a desirable manner. As an educational instrument, therefore, rewarding desirable behaviour is not so much a token as a tool that is solidly embedded in psychological theories and mechanisms.

Rewarding desirable behaviour works in a number of other interrelated ways:

- rewards accentuate the difference in perception of undesirable and desirable behaviour;
- rewarding desirable behaviour gives such behaviour a positive connotation;
- this prompts a mechanism in which people convince themselves of the desirability of this safe behaviour;
- ultimately, rewards can provide the incentive required to behave in a desirable manner, not just for the moment, but for the long term.

Rewarding desired behaviour is always good for extra publicity as well, which, in turn, is always good for a campaign. In addition, a person receiving a reward achieves a certain status. While not lasting forever, rewards, like punishments, do have an effect for several months. Rewarding desirable behaviour is, therefore, an excellent component of a package of measures that consists largely of information and (often) traffic enforcement.

Pros and cons

Rewarding desirable (traffic) behaviour in the context of a road safety campaign is always good for a lively discussion, particularly among politicians during election campaigns who are far from experts on the subject. The following are a number of arguments and counter arguments:

- Normal behaviour should not be rewarded. It is not about normal versus abnormal, but desirable versus undesirable. It is irrelevant whether it is normal or otherwise, as long as people behave more safely.
- People should not be paid for behaving in a desirable manner. And this is not what happens: desirable behaviour is given a positive connotation, a positive image rather than a monetary reward. Payments are proven to be unsuccessful because they merely prompt people to change their behaviour because of the money and not the conviction that it is the best thing to do. This, thus, becomes a business transaction with no educational effect rather than a more or less sustainable behavioural influence.
- Thieves are not rewarded for refraining from thieving. This stance is based on the misconception that people would be paid for behaving in a desirable manner, 'the deal'. Moreover, thieves deliberately go out to obtain the greatest possible advantage. This is a very different form of undesirable behaviour to not wearing a seat belt. In terms of traffic offences, rewards are primarily aimed at people in the middle group between those who are honest and those who are persistent offenders. For them, a gentle shove in the right direction is often enough.
- Offenders must be punished rather than non-offenders rewarded. In fact, both should be done because this ensures the best results. After all, this explicitly separates good and bad. It has also been stated in the literature that rewards are more effective than punishments, which is fine but to reiterate: in relation to offences, a combination of punishments and rewards provides the best effect. The same applies in most educational situations where students are not always equally motivated.
- Rewards are unethical; people are not dogs! While the latter is true, why should similar principles not be used in human upbringing? Moreover, if rewards are unethical, punishments must be unethical too.
- It is truly unethical not to use an effective, simple way to make traffic safer.

Rewards include:

- a small gift;
- the chance of a larger gift (for instance, a lottery giving you the chance to win a DVD player);
- a compliment.

The reward should not be too large because this will prompt people to alter their behaviour based on the gift rather than on their own conviction. It must not constitute a transaction or deal. It is all about the psychological process of a person's own conviction, as in that case the behavioural change is more likely to last. A reward can relate to the behaviour in question, but this is not necessarily the case.

The time between behaviour and reward must be kept to a minimum otherwise the link is lost; the positive association fails to materialise. On-the-spot rewards are as effective as on-the-spot fines. A trial was conducted in which drivers were observed by means of a black box and only rewarded at a later stage for not tailgating or speeding. The time between the (desirable) behaviour and the reward was significant, which is possibly one of the reasons why after receiving their rewards via this 'Belonitor' [10.10], the participants promptly lapsed into their old, flawed habits again.

Rewarding desirable behaviour in the context of a campaign must be maintained for several weeks in order to generate a sufficient familiarity and to provide sufficient numbers of people with the opportunity to show the desirable behaviour and be rewarded for it. This familiarity, of course, requires publicity (education, persuasion).

For many years, social scientists have contended that rewards are as effective as punishments with regard to achieving behavioural change. This is also the case in terms of rewarding road user behaviour [10.6, 10.7]. One problem when evaluating reward programmes is that it is often difficult to gain factual data concerning the behaviour of individual road users over longer periods of time. This is why current reward activities remain limited to behaviour that is easy to assess, such as wearing seat belts.

10.6.3 Measuring quality

Traffic enforcement is subject to three quality criteria [10.24]:

- effectiveness (behavioural effects);
- efficiency (yield per unit of effort);
- credibility (public acceptance).

These three criteria can be established by means of a periodically repeated comparative study. The number of fines issued as a result of police surveillance is not representative of its quality. The behavioural and road safety effect of police surveillance does not relate one-on-one to the number of fines. However, in the event of an initial intensification of police surveillance, the number of fines will also initially increase, but if a surveillance project extends over a longer period of time, the number of fines will stabilise or decrease, and the quality of the surveillance must be derived from other indicators.

10.6.4 Effectiveness of police surveillance

The effectiveness of police surveillance is, therefore, a key quality component. This section discusses the most important findings with regard to the effectiveness of police surveillance.

Drink driving

In the period 1999-2006, the number of alcohol-related fatalities fell from 210 in 1998 to 100 in 2006. In addition, the percentage of alcohol-related traffic fatalities compared to the total number of traffic fatalities also fell from 18% in 1999 to 12% in 2006. The percentage of offenders fell from 4.2% in 1999 to 3% in 2006. Apart from a minor increase in 2006 (3%) in comparison to 2005 (2.8%), there has been systematic decrease in the percentage of offenders since 2001. It is highly probable that intensified police surveillance in the period 1999-2006 contributed substantially to this positive development in drink driving reductions. However, this has made it increasingly difficult for police checks to achieve further improvements [10.31].

Seat belt use

The Institute for Road Safety Research estimates that intensified seat belt checks between 1995 and 2002 led to a 23% increase in seat belt use by drivers and passengers in those police regions where the intensification of surveillance was included in a regional plan. The number of traffic fatalities between 1994 and 1995 and 2000 and 2001 decreased more sharply (4 to 5%) in regions with a regional plan than in regions without one. Throughout the Netherlands, increased seat belt use as a result of increased checks in combination with information campaigns was estimated to have resulted in a 3% drop in traffic fatalities in this period, or approximately thirty deaths a year. Since 2002, seat belt use in the front has increased from 88% to 94% and in the back from 52% to 73%. The Centre for Transport and Navigation (previously the Transport Research Centre) estimated that this improvement for the period 2003 - 2006 resulted in forty fewer fatalities

Table 10.9. Overview of the effects on safety of different forms of speed checks

Road type	Method of speed check	Relative reduction in accidents	Country and year
Within the built-up area	Fixed speed cameras	minus 28%, all accidents	Worldwide general study, 2004
Outside built-up areas	Fixed speed cameras	minus 18%, all accidents	Worldwide general study, 2004
Within the built-up area	Fixed speed cameras	minus 22%, personal injury accidents	Great Britain, 2005
Within the built-up area	Mobile speed cameras	minus 22%, personal injury accidents	Great Britain, 2005
Outside built-up areas	Mobile speed cameras	minus 33%, personal injury accidents	Great Britain, 2005
Outside built-up areas	Mobile speed cameras	minus 15%, personal injury accidents	Great Britain, 2005
Outside built-up areas	Fixed speed cameras	minus 20%, personal injury accidents	Norway, 1997
Outside built-up areas	Mobile hidden speed cameras	minus 21%, personal injury accidents involving a motor vehicles	The Netherlands, 2006
Motorway	Mobile speed cameras	minus 25%, accidents during the day that involve unsafe speeds	Canada, 2000
Motorway	Hidden speed cameras	minus 11%, all accidents (extra effect over and above visible cameras)	New Zealand, 2001
Motorway	Random controls and stops (all offences)	minus 58% serious personal injury accidents	Australia, 1988

[10.35, w10.4]

and 300 fewer hospitalisations. To a large extent, the improvement is probably the combined result of seat belt checks and national and local information campaigns. In addition, seat belt use is probably better as a result of increased attention to the issue in schools and driving schools and due to the growth of cars with a seat belt reminder system (a light or sound signal if the driver and/or front passenger fail to wear their seat belts) [10.33].

The use of moped helmets
In 1996, helmet use was 98%, but this dropped to 92% in 1999. Since then, this percentage has constantly hovered at 92-93%. Intensified police checks since 1999 have helped to prevent any further decrease in helmet use, but they have also failed to bring about an improvement [10.36].

Red light running
An analysis of eight international studies concluded that red light cameras led to 25-30% fewer personal injury accidents at intersections. The collective impact of red light cameras and other red light checks on the safety at intersections in the Netherlands has yet to be charted. An evaluation study in the city of Amersfoort has shown that the effects on safety were comparable to those in international reviews, thus a decrease of 20% in the number of personal injury accidents [10.29].

Speed checks
Various speed check methods have been studied worldwide. Table 10.9 shows an overview of results of reasonably successful studies conducted in different countries. The results show that positive results have been recorded in different countries with different methods of monitoring speed, ranging from a 15% to an almost 60% reduction in (serious) accidents [10.35].

There is also some knowledge concerning the behavioural effects of speed checks after they have ended (what is known as the time halo effect) or after road users have passed the control point (the distance halo effect).
It has been estimated that when road users see the police actively checking speeds, the effect on speed is halved 900 metres downstream of the enforcement site. The effect that stopping motorists has on speed diminishes somewhere between 2.5 and 8 km beyond the enforcement site. At locations where speed cameras are clearly visible, the (greatest) effect is often limited to 500 metres before and after the camera. It has been further estimated that the police would have to be present at a location six days a week before a (small) time halo effect is achieved.

Several other conclusions:
1 The effects of speed checks on road safety, expressed in the reduction of the accident percentage, often relate to specific road sections or locations where the speed check was carried out. In other words, road safety is improved at those locations where extra checks were carried out. It is possible, therefore, that road safety increases at places where the police conduct extra checks while this appears to remain constant or decrease at places where no controls are carried out.
2 Most studies concern prolonged high-level police surveillance. The successes are, therefore, a question of tenacity and perseverance.
3 Internationally positive results are not generally comparable to those in the Netherlands. Other countries have other roads, other speed limits, other fines, et cetera. The risk presented at the outset of a surveillance procedure is also often different in other countries than in the Netherlands.
4 The safer the roads become, the more difficult it is for police surveillance to achieve the positive results that they have made in the past, thereby showing that previous results are not a guarantee for success in the future.

10.6.5 Improving quality
The ambition would be to continually improve traffic enforcement. The road to improvement has three paths: collaboration, learning from experience and the application of new technology.

Improved quality through collaboration
Police surveillance is one link in the total traffic enforcement chain. This means that the effectiveness of police surveillance cannot be seen as separate from the way in which the police collaborate with other parties involved in the chain. Collaborating with various parties such as public relations officers, schools, researchers, intermediary organisations and municipal organisations often makes it possible to create a better and smarter surveillance project. Better knowledge of the target group to be reached through traffic enforcement leads to a smarter use of people and resources.

Improved quality through learning from experience
Learning from experience also leads to better quality traffic enforcement. It is useful to employ a framework such as the Table of Eleven [10.15], which is a list of points regarding the quality of traffic enforcement and the enforceability of the rules. The Table of Eleven can be used for systematic benchmarking.

The regional traffic enforcement teams acquire significant knowledge from behavioural measurements. Traffic enforcement in the regional teams is organised in accordance with a systematic method [10.14].

This method is characterised by the fact that it monitors intervention and effect. The Information system enforcement act registration system registers what the teams do. Perception research and measurements of the behavioural effects (speed with test loops, studies into drink driving, helmet use and safety devices) are used to evaluate whether changes in behaviour are going in the desired direction.
If the intervention fails to bring about the desired effect, adjustments are made to how capacity is divided (in so far as this is possible within the appointed framework).
On the basis of scientific knowledge and practical experiences, the Public Prosecutor bureau for traffic enforcement has since drawn up profiles for alcohol and helmet checks as well as speed checks with a laser gun.

Lessons can also be learned from the evaluation of concrete traffic enforcement projects, such as the project set up to evaluate the effects of speed controls in the Appelstraat in The Hague (speed limit of 30 km/h), which found that the percentage of offenders exceeding the speed limit had decreased significantly (premeasurement: > 50%; final measurement < 10%). However, it was surprising that despite this reduction, more people felt that the street was still unsafe after the follow-up measurement than during the premeasurement [10.13], while the fact that people felt unsafe was the reason that the project was introduced in the first place. The objective improvement in the situation (lower speeds) was insufficient to reduce these feelings. The lesson here is that in addition to speed the total image of traffic in the street (traffic volume, parked cars, lorries/buses) is extremely important for people's feelings of safety. While speed checks can be very useful, they are certainly not the only solution to improve the unsafe image of traffic.

Improved quality through new technology
Traffic enforcement prompts road users to behave in a safer manner through providing them with an extra incentive. This incentive is increasingly incorporated in technology. An increasing number of companies within the automobile industry want to incorporate safety systems into their newest models, such as systems that warn the driver or intervene in

Table 10.10. New technological developments and implications for traffic enforcement

System	Development	Perspective for traffic enforcement
Automatic number plate recognition	Speed and red light cameras (and general security cameras in public spaces) are increasingly used to record car registration plates and compare them to a database of vehicle-related offences/ crimes (uninsured, stolen cars, et cetera).	At multiple locations and particularly border crossings, checking vehicle number plates against data in various national and international databases where offences/crimes are recorded will become a standard practice.
Detecting offences within the car	There are a number of vehicular-technological solutions for deliberate or unintentional offences or mistakes (for example mistakes as a result of fatigue, alcohol use, no seat belt, tailgating, poor night-time vision, red light running) such as Intelligent Speed Assistance (ISA), alcolock, seat belt lock, and black box speeding registration. European research projects are formulating standards for such technological solutions in conjunction with the industry.	These solutions will primarily be introduced through commercial marketing. By 2020, police enforcement of countless offences can be assumed by vehicle systems that warn the driver or actively intervene in the event of a potential offence (for example reduce speed, refuse to start; register and save an offence in a databox in the car or send it to a data centre).
Controls on drug use in traffic	The chances of drivers who take various types of drugs sustaining an injury is 25 times higher than that of sober drivers. A mixture of alcohol and drugs increases this level to 35 times. This makes those road users who use alcohol and drugs a key high-risk group requiring extra attention from the police.	Efficient control of drug use is currently limited due to a lack of legal limits and relevant detection equipment. Saliva and sweat tests, which can be easily conducted on the roadside, have improved significantly in recent years. European study results that include potential recommendations for legislation and checks will be published soon.
Customised punishment	Technology can be used to enforce punishments tailored to the offence. Alcohol offenders, for example, can be provided with an electronic alcolock. For people who drive aggressively, an ISA or black box in the vehicle (at the offender's expense) is an option.	Police surveillance will remain necessary to check whether offenders are evading their alternative punishment.

the event that drivers fail to wear their seat belt or drive too fast, if the car is unstable, or if there is a threat of a collision with another vehicle, et cetera. Consumer demand for these 'safe' cars is expected to increase. Electronic vehicle systems that inform road users about the choice of the correct speed and warn or even intervene in the event of possible speeding offences have the advantage that they are operational at all times in all locations. This is in sharp contrast to physical policing, which is often limited to particular times and places. However, irrespective of the effectiveness of new safety systems, the final responsibility regarding road user behaviour still rests with the driver, who must continue to take responsibility and check the warnings/signals provided by the system.

Despite future developments in vehicular technology, the police will continue to occupy a key position in traffic enforcement. In the future, the police will be primarily required to acquire experience with the shrewd application of new digital surveillance techniques and combining these techniques with stopping motorists and human contact [10.11].

Table 10.10 provides an overview of several of the key technological developments and possible implications for traffic enforcement.

10.7 Summary

This chapter discussed traffic enforcement, the third of the three Es. Traffic enforcement entails police surveillance of compliance with traffic rules, the punishment of non-compliance ('pushing') and possible rewarding of compliance ('pulling'). This manual deals primarily with violations that are deemed to be dangerous for the driver and/or others. The (threat of) punishment for a violation is an example of extrinsic motivation: the motivation that is not directly linked to what someone actually wants to do because it is good for them (this is intrinsic motivation), but that comes from an external source.
An important external motivator is the subjective probability of detection: the chance that someone thinks they have of being caught for committing an offence. Enforcement and information will be of no use, let alone be sustainable, if the infrastructure prompts undesirable behaviour.
In this sense, there is a certain hierarchy in the three Es.

This chapter also discussed the statutory and organisational aspects of traffic enforcement. Key legislation comprises the 1994 Road Traffic Act (WVW) and the Traffic Regulations (Administrative Enforcement) Act (WAHV). The WVW is made up of in five regulations, including the 1990 Traffic Rules and Signs Regulations.

Communication is extremely important in terms of traffic enforcement and should increase intrinsic and extrinsic motivation. Intermediaries play a key role in terms of communication.

The five national traffic enforcement spearheads are helmet, seat belt, red light running, alcohol and speed, and it is important to follow the PCOSE approach when establishing traffic enforcement activities geared to these spearheads.

The various traffic enforcement components in the Netherlands are linked in a single chain. These links must be properly co-ordinated for enforcement activities to be effective. Policy is required to provide an aim and purpose to the activities. Traffic enforcement will only be successful if both specific and general deterrence are realised.

The criteria for the quality of traffic enforcement are effectiveness (behavioural effects), efficiency (yield per unit of effort) and credibility (public acceptance). The quality of traffic enforcement can be improved through collaboration, learning from experience and the application of new technologies. In time, more self-enforcing vehicle systems will be introduced that provide warnings prior to offences, register offences or even intervene before an offence occurs. However, this will not mean that traffic enforcement and one-on-one contact with road users will no longer be required.

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Part 3 - Dangerous behaviour, dangerous groups and what can be done about them

In this part of the 'Road safety manual' the different perspectives on road safety, the problems and different measures regarding road safety are all linked together in the form of integrated approaches towards road safety. The dynamics surrounding road safety are highlighted: everything is interconnected.

Creating a good design for 'new' situations at the onset is an attractive and often viable option. The most obvious course of action is choosing a design according to Sustainable Safety in connection with the spatial and urban planning visions. This is the ideal situation.
In practice, however, things are often not that straightforward. An unsafe situation has frequently evolved from a convergence of circumstances and come about gradually. Most of the time, there is no such thing as starting from a clean slate. Adjusting a road design afterwards is often a difficult and sometimes thankless task. Likewise, habitual behaviour is harder to influence than behaviour shown by people who are still open-minded in a situation that is new to them. Furthermore, not all determining factors are completely controllable; there are many other factors that influence behaviour. To add insult to injury, a 'perfect' new layout might well be financially unattainable.

The chapters of part 3

11 Risk-enhancing behaviour in traffic;
12 Specific groups of road users;
13 Practical examples

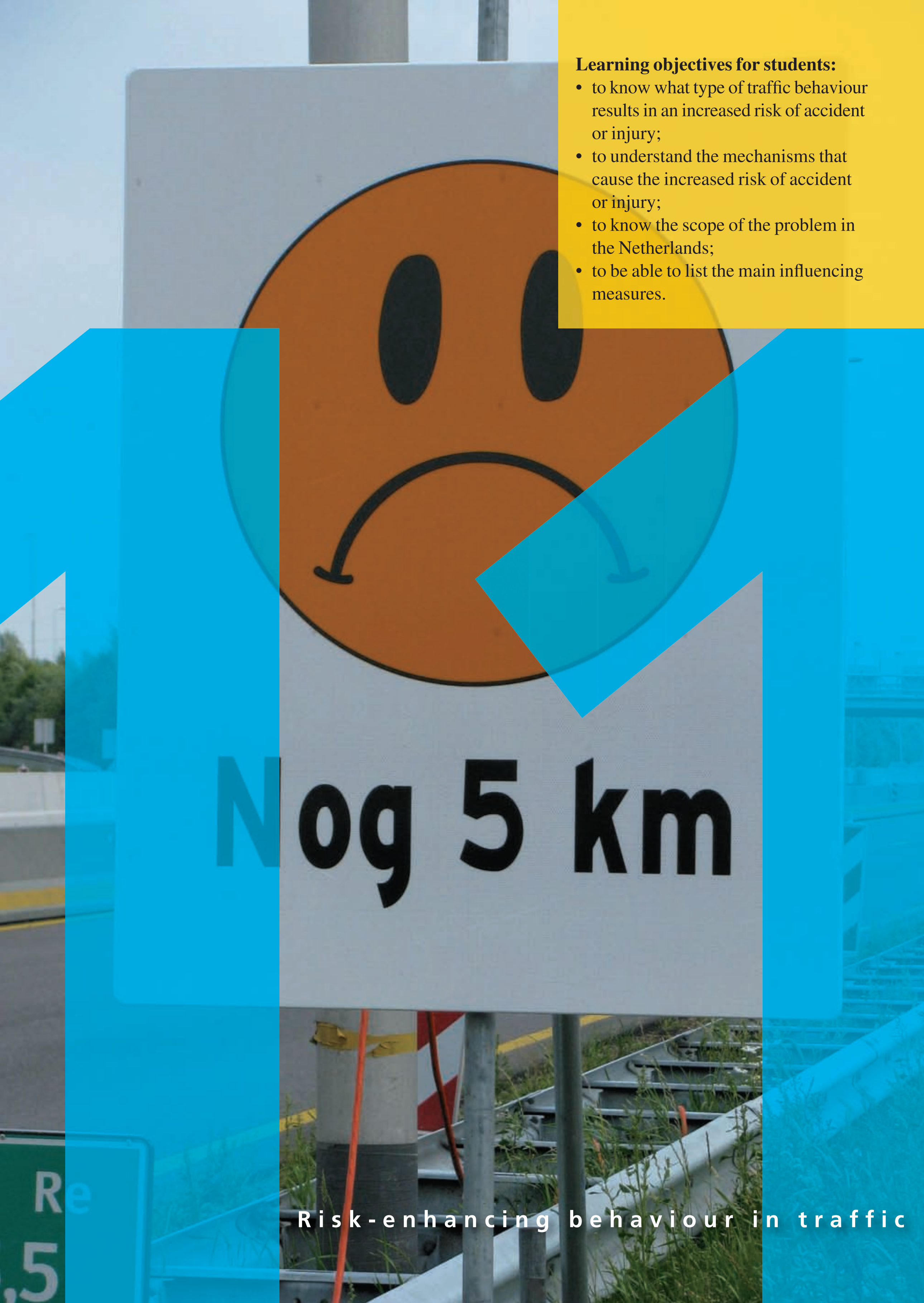
Chapter 11 'Risk-enhancing behaviour in traffic' discusses behaviour that leads to an increased risk of accidents. The legal context for every type of behaviour is indicated, as is the behaviour itself, the kind of risk associated with that behaviour, and the measures that can be taken.

Chapter 12 'Specific groups of road users' deals with the different kinds of road user groups with a high accident risk. Each group's share in the total number of casualties is indicated, as well as the type of measures that can be taken.

Chapter 13 'Practical examples' discusses a number of cases that give an impression of the day-to-day practice of road safety, showing above all the enormous diversity of the road safety expert's sphere of action .

Learning objectives for students:

- to know what type of traffic behaviour results in an increased risk of accident or injury;
- to understand the mechanisms that cause the increased risk of accident or injury;
- to know the scope of the problem in the Netherlands;
- to be able to list the main influencing measures.



Risk-enhancing behaviour in traffic

11 Risk-enhancing behaviour in traffic

11.1 Introduction

This chapter discusses traffic behaviour that involves an increased accident risk. Although there is always a certain chance that an accident will occur, some forms of behaviour significantly increase that risk.
Drink driving probably is the most well-known form of such behaviour. Other causes of increased risk are the use of certain drugs and medicines, driving while tired, and being distracted, for example, while using a mobile phone.
In general, this 'behaviour' affects the capacity and motivation of performing the traffic task safely and, in turn, may lead to specific high-risk behaviour, such as speeding, red light running, aggression in traffic, tailgating and failure to wear a seat belt or crash helmet. Incidentally, these types of behaviour can also occur without a specific cause.

The information in this chapter mainly relates to motorised traffic. This is not to say that dangerous behaviour does not occur among or is not risky for pedestrians, cyclists and moped riders. Pedestrians who are drunk, cyclists making a mobile call and speeding moped riders also run an increased risk of being involved in an accident. However, there is hardly any reliable data on the extent to which this behaviour occurs or the risk it entails. This is why this chapter focuses on motorists. [w11.1]

11.2 Alcohol

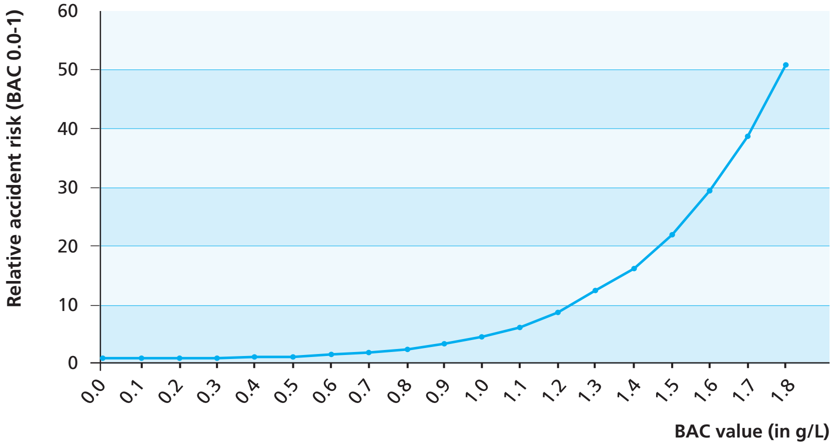
11.2.1 Statutory framework

In 1974, a statutory limit for alcohol in traffic was introduced: a Blood Alcohol Concentration (BAC) of 0.5 g/l. Since 2006, the limit for novice drivers is 0.2 g/l. Drink driving is an offence that cannot be handled under administrative law or by means of a police proposal for an out-of-court settlement. It is up to the public prosecutor's office to decide whether the offender will receive a proposal for an out-of-court settlement or has to appear in court.
In the event of BAC values between 1.3 and 1.8 g/l (or between 0.8 and 1.8 g/l for novice drivers) or for repeat offenders, the CBR (Dutch driving test organisation), on behalf of the Minister for Transport, Public Works and Water Management, can order participation in the Educational Measure on Alcohol (EMA) in a separate administrative law procedure.
In the event of BACs over 1.8 g/l, the CBR, on behalf of the Minister, orders a medical-psychiatric examination of the driver's driving aptitude. If that examination shows that the driver is fit to drive, participation in the EMA is required after all. If the driver proves to be unfit to drive, the driving licence is revoked. This is the case in approximately 90% of all examinations.

11.2.2 Drink driving in the Netherlands

Alcohol use in traffic has been assessed for a long time; in recent decades even as much as annually. All alcohol checks are performed on weekend nights. In 2006, the percentage of drink drivers on weekend nights totalled 3.0% [11.4], which evens out to an average of less than 1% of all days and times of the week [11.33]. In the late 1970s and early 1980s, 12% of motorists would drive while having consumed too much alcohol on weekend nights. In the 1990s, this fell to 4 to 5%, and this drop continued by about a third between 2000 and 2006.
However, this latter drop only concerned minor offenders, while the share of heavy drinkers (BAC > 1.3 g/l) appears to have

Figure 11.1. Relative accident risk with increasing blood alcohol concentrations (BAC); the risk at a BAC of 0.0 g/l (1 g/l equals 1 g/l) is set at 1 [11.7]



remained largely the same. Despite representing only about a quarter of alcohol offenders, the category of heavy drinkers does cause approximately three-quarters of all severe alcohol-related accidents.

It is estimated that some 25% of all traffic fatalities are the result of drink driving. An exact percentage cannot be given, because there is no standard procedure in the Netherlands to test drivers involved in an accident for alcohol consumption. In the case of motorists who have died in an accident, this is even the exception rather than the rule. This means that the estimated number of police-registered alcohol-related accidents is too low. Young men (aged 18 to 24) are strongly overrepresented in alcohol-related accidents: while comprising a mere 5% of the Dutch population, they constitute almost 25% of the group sustaining severe or fatal injuries due to alcohol-related accidents.

A European study of the opinions of motorists on road safety has shown that Dutch motorists say they are very much opposed to drink driving, and very much in favour of increased monitoring and more severe penalties. In this respect, Dutch motorists are not very different from motorists in other European countries [11.21].

11.2.3 Alcohol-related accidents and the risks related to alcohol consumption

The risk-enhancing effect of alcohol has been the subject of many a study. These studies show, without exception, that the accident risk increases progressively with the blood alcohol concentration. Figure 11.1 shows the results of recent research. The risk for sober driving has been set at 1. The accident risk rises from BAC 0.5 g/l and increases sharply from 0.8 g/l. At a BAC 1.0 g/l, the risk is over five times as high, at BAC 1.5 g/l over twenty times as high, and at BAC 1.8 g/l over fifty times as high. In young people, the effect of alcohol on the accident risk is apparent at even lower levels,

Table 11.1. Measuring alcohol concentration

	Experienced drivers	Inexperienced drivers
Blood alcohol concentration	0.5 g/l	0.2 g/l
Breath alcohol content	220 µg/l	88 µg/l

Alcohol is measured in two ways; the blood alcohol concentration is the best known among the public at large. Breath alcohol content is a measure used by the police. Blood alcohol content and breath alcohol content are related. Above are the limits for both.

because they are both novice drivers and inexperienced drinkers. This is why the statutory limit for novice drivers (usually young people) has been lowered to 0.2 g/l.

Alcohol negatively impacts a large number of key aspects of the driving task, with very small quantities of alcohol far below the statutory limit of 0.5 g/l often being sufficient to prompt deterioration in driving skills:

- the capacity to drive in a straight line diminishes;
- it is more difficult to maintain a constant distance to the car in front and respond to its changes in speed;
- reaction times increase;
- it becomes more difficult to divide attention between the driving task and other tasks, such as talking to a passenger;
- visual information is increasingly sought in the central field of vision to the detriment of information from the peripheral field of vision (tunnel vision).

11.2.4 Measures

Information campaigns

Information campaigns have always paid a lot of attention to drink driving, from the famous 'Glaasje op, laat je rijden' campaign to the 'Bob' designated driver campaign ('Bob jij of Bob ik?') that was introduced a number of years ago. This campaign, which was launched in Belgium and then copied in the Netherlands, has since conquered a large part of Europe. These two campaigns have in common that they, more or less explicitly, offer an alternative to drink driving: arrange in advance who is the designated driver and will not drink. Campaigns are almost always accompanied by enforcement measures.

Enforcement

Intensive enforcement has probably been the cause of a decrease in drink driving in recent decades. This enforcement only really got under way with the introduction of electronic breathalysers in 1984. In addition, between 1987 and 1989, breath analysis replaced blood tests as legal proof, which hugely improved the efficiency of alcohol monitoring and, with it, the objective probability of detection. Together with the many information campaigns and media coverage, this also contributed to an increase in the subjective probability of detection.
The establishment of regional traffic enforcement teams in 2000 resulted in a further enforcement of alcohol monitoring in traffic. As in most European countries, alcohol screening in the Netherlands is random, which means that any motorists can be asked to take a breathalyser test, even without indication of alcohol consumption. If there is an indication of alcohol consumption, testing becomes selective. This type of testing is still performed in the United Kingdom, Germany and the United States.

Educational Measure on Alcohol and Traffic

The Educational Measure on Alcohol and Traffic (EMA) has been in existence since 1996. It is a three-day compulsory remedial course for motorists found driving with a relatively high

BAC or for repeated drink driving. Initially, the EMA was compulsory for BACs between 1.3 and 2.1 g/l, but in 2000 the upper limit was lowered to 1.8 g/l. In the event of a higher BAC, offenders are first subjected to a medical-psychiatric examination to study their fitness to drive. In 2002, the legal limit for novice drivers (motorists who have had a licence for less than five years) was lowered to 0.8 g/l. While a study into the effectiveness of the EMA did show increased knowledge about drink driving, it did not indicate an effect on repeat offences [11.36].

Alcolock

An alcolock is an alcohol tester in cars linked to the ignition that serves as an ignition interlock. Only when the driver has passed an alcohol test can the car be started. Various provisions and regular inspection make fraud difficult. Studies in Canada have shown that 65 to 90% of serious offenders who took part in an alcolock programme were less likely to repeat the offence than drivers with a licence suspension [11.5]. In the Netherlands, plans to introduce alcolocks for serious and repeat offenders are at an advanced stage.

Licence suspension

In the current situation, the court can order a driving ban for a certain period for serious and repeat offenders. Moreover, their driving licence may be revoked by the Minister for Transport, Public Works and Water Management (which, in practice, is the CBR) if they are found to be unfit to drive in a medical-psychiatric examination. However, this measure has limited impact because many of them simply continue to drive, given that the chance of being caught is slight. Research in the United States and Canada has shown that people whose driving licence has been suspended are two to three times more likely to repeat the offence than motorists with an alcolock following a similar offence [11.5]. Based on these findings, imposing an alcolock is preferred to licence suspension [11.55-11.57, w11.1].

11.3 Drugs and medicines

11.3.1 Statutory framework

There are no statutory limits in the Netherlands (yet) for the use of medicines and drugs that influence the ability to drive. Motorists can be prosecuted, however, on the basis of section 8, subsection 1 of the 1994 Road Traffic Act:
'It is forbidden to drive a vehicle or be in charge of a vehicle while under the influence of a substance the use of which the driver knows or should reasonably know to affect – whether or not in combination with the use of a different substance – the ability to drive to the extent that he cannot be considered capable of properly driving the vehicle'.
Limits are set to be introduced in the relatively short term, in conjunction with means of detecting drug and medicine use in traffic that are easy to apply and reliable. Large-scale research conducted at a European level is to provide insight into the tolerance levels for drugs and medicines, from which realistic, risk-related limits comparable to the 0.5 g/l limit for alcohol can then be derived.

11.3.2 Detection of drugs and medicines

It is not easy to quickly and reliably detect drugs and medicines in traffic and the police do not yet have a practicable set of tools. Blood tests are costly and difficult to apply in the field. Most drugs can be detected in the blood up to approximately 24 hours after use, but others, such as heroin, are undetectable in the blood after 1 to 2 hours, but still affect the ability to drive. Urine tests are difficult to perform, prone to fraud, they violate the integrity of the human body and they are likely to produce many false-positive readings, particularly for cannabis, because traces remain detectable in the urine for several days, even though they no longer affect behaviour.

Having undergone rapid developments in recent years, saliva tests are a good alternative. They can be quite easily performed in the field, are not as susceptible to fraud as urine tests and yield fewer false-positive results. Saliva samples have a detection time similar to blood samples and can, therefore, be used to determine recent drug use. A drawback is that some drugs, such as cannabis and ecstasy, decrease saliva production, rendering it difficult to obtain samples that are sufficient for testing. Sweat tests have also been developed further in recent years. While they are less of an invasion of privacy than saliva tests, it is more difficult to prove recent drug use with sweat tests.

The sensitivity of saliva and sweat tests to some drugs still leaves something to be desired, but the question is whether that drawback is outweighed by the advantages referred to. In the event of suspicion of drug use, the police can order a blood test and, in exceptional cases, a urine test, to furnish (additional) proof. This is already the case.

11.3.3 Drugs and medicines in traffic in the Netherlands

Drug use among motorists has increased enormously during the past two decades. Research conducted in hospitals in Rotterdam in the mid-1980s showed that some 5% of injured motorists had used drugs [11.52], while in a recent study conducted in and around Tilburg, almost 20% of injured motorists were found to be positive [11.33]. Like alcohol, drugs are more often used during weekend nights than during the rest of the week: in the Tilburg police district, 10% of motorists were found to have used drugs during weekend nights, compared to 7.5% during week nights.

The drug most frequently used in traffic is cannabis. Mathijssen and Housing [11.33] found traces of cannabis in the urine of almost 5% of the motorists tested. However, not all motorists found to be positive were actually under the influence because cannabis, while detectable over a long period, only affects the ability to drive for a maximum of 12 hours after use. Other drugs found in traffic were ecstasy, cocaine and heroin. A small number of drivers use a combination of alcohol and drugs. Their BAC level is generally very high and their drug use is rarely limited to a single substance. Approximately 0.1% of drivers in and around Tilburg were found to be under the influence of such a combination.

11.3.4 The risk of drugs and medicines

Research into the risk-enhancing effect of drugs and medicines is more recent than research into the risk of alcohol consumption. Most research has been conducted into the effect of cannabis use on the accident risk of drivers, but the research results are not conclusive. Some studies show that risk increases, others say it does not, arguing that the use of cannabis does not necessarily have to result in an increased risk because users seem to be aware of their decreased ability to drive and will drive more carefully.

Drugs that affect the ability to drive are, in particular, benzodiazepines (sleeping pills, sedatives, anti-anxiety medication) and codeine. Called psychoactive substances, these medicines often have a numbing effect, which negatively impacts a driver's reaction time. Alcohol consumption can increase this effect. Elderly drivers may even use different types of medication at the same time. The effects of this multi-medication depend on the exact combination of medicines and the patient's condition.

The study in and around Tilburg looked at the risk of alcohol, drugs and medicines by comparing the use of these substances in traffic with their use by drivers who had been involved in a serious accident [11.33]. The study showed in particular that drivers who had used a drug other than heroin or a psychoactive substance, but no alcohol, did not run a demonstrably higher accident risk. However, the accident risk does increase strongly with combined use of drugs, psychoactive substances and/or alcohol. The greatest risk increase involves drivers who combine drug use with a BAC above 1.3 g/l.

11.3.5 Measures

At the moment, enforcement is only possible on the basis of section 8, subsection 1 of the Road Traffic Act, although the establishment of a legal limit for drug use is receiving increasing support. The introduction of such a limit and the resultant enforcement activities will, of course, have to be accompanied by large-scale information campaigns.

Legislation on the use of medicines that affect the ability to drive is ambiguous. In principle, the doctor prescribing the medication is under the obligation to inform the patient of the potential effects on the ability to drive. In practice, however, patients have to rely on the information in the patient information leaflet, which is often of a very general nature. In the 1970s, the yellow sticker and red sticker were introduced in the Netherlands, with the yellow sticker stating that 'this medication can affect the ability to drive' and the red sticker 'Do not drive a vehicle when taking this medication'. The doctor was supposed to indicate whether a sticker would have to be used and if so which, but this hardly ever happened in practice, so that chemists more or less automatically applied a yellow sticker. These days, the information is sometimes printed on the label. The red sticker has completely disappeared. Wegman and Aarts [11.53] posit that it is important that the pharmaceutical industry, doctors and chemists should themselves be better informed of the risks and the circumstances under which these occur, enabling them to give patients more specific information [11.33, 11.56, 11.57].

11.4 Fatigue

11.4.1 Statutory framework

As fatigue is difficult to measure, there is no such thing as a legal limit and it is very difficult to fine someone for being too tired to be on the road. However, legislation related to fatigue is in place for professional lorry drivers: the Working Hours Act and driving and resting times. This legislation is largely formulated at European level. As these stipulate minimum requirements, national laws may deviate by imposing stricter requirements, but not less strict ones.

11.4.2 Fatigue in traffic

What exactly is fatigue? Fatigue cannot be unequivocally defined and is usually given a physical (e.g. hard and prolonged physical labour) and neurobiological (biologically determined sleep-wake rhythms) significance. It also has a mental/psychological significance: not having the energy to do anything, a subjectively felt reluctance to continue with a task.

Fatigue can have many causes [11.43] and a lot of people drive when they are tired.

1 *Time-on-task.* Traditionally, fatigue was directly and exclusively related to the time spent on a certain task (time-on-task) and this is still considered one of the main factors. However, research in recent years has revealed other factors that are equally important.

2 *Amount of sleep.* A lack of sleep may be chronic or acute. Chronic sleep deprivation is the result of a lack of sleep over a longer period of time. Acute sleep deprivation also results from a lack of sleep, but does not occur all the time: it exists after only one night of sleeping poorly or not long enough.

3 *Quality of sleep.* The quality of sleep is also a key factor in causing fatigue. It is affected by sleep disorders – e.g. sleep apnoea (temporary interruption of breathing while sleeping) and narcolepsy (the pathological tendency to fall asleep suddenly) – but also by chronic diseases and/or medication, as well as external factors such as a noisy or uncomfortable sleeping environment.

4 *Biorhythm*. Yet another form of fatigue is related to the daily sleeping cycle, or biorhythm. This means that people need sleep more at certain times of the 24-hour cycle than at others. People need sleep most early in the morning (between midnight and 6 a.m.) and, slightly less and less deeply, about 12 hours later (between 2 and 4 p.m.).

5 *Stress*. Stress in this context is defined as a situation in which the requirements for the task exceed the available capacity, either because the task is too difficult or the available capacity (temporarily) too small. If stress continues for too long, it manifests itself in feeling tired. Age, physical condition, the use of alcohol, drugs and/or medicines, external factors such as temperature, noise, vibrations, but also task routine are all factors that have an indirect effect. Boredom, for example when driving alone on a monotonous road for a long time, is also an indirectly influencing factor. In themselves, they do not cause fatigue, but they do cause the consequences, such as a decrease in alertness, to manifest themselves.

Given the many different causes of fatigue, the conclusion seems justified that everyone is very tired at one point or another. Questionnaire and interview research have shown that this regularly affects approximately 30% of the population. It is estimated that about 10% of the population suffers a serious form of insomnia, and approximately 3% have a sleep disorder, among which sleep apnoea is by far the most common. As a result, fatigue while driving is a frequent phenomenon, different studies have shown. Some 25% of (professional) drivers indicate they have fallen asleep behind the wheel at one time or other; about half say they sometimes drive while very tired or have almost fallen asleep [11.43].

11.4.3 The risk of driving while tired

Fatigue leads to a deterioration in alertness, slower reaction times, memory problems, poorer psychomotor co-ordination and less efficient information processing. Fatigue also affects moods to the extent that the motivation to perform a task decreases, communication and interaction with the environment deteriorate, and irritation and aggressiveness towards other people and events increase. In other words, fatigue leads to decreased capability and willingness to act [11.58, 11.59].

All issues referred to above are important for the accurate and safe performance of the driving task. It can be expected, then, that fatigue will also result in a deterioration in driving task performance, and this has been confirmed in various studies [11.43]. First of all, tired people have difficulty driving a straight line, more frequently cross or threaten to cross the edge line, and their steering corrections are more abrupt and pronounced. It was also found that they react less accurately to speed changes of the car in front. This goes to show that fatigue as a cause of accidents does not necessarily mean that the driver actually fell asleep behind the wheel.

The question of to what extent fatigue is a co-factor in causing accidents is difficult to answer. As indicated above, it is difficult to objectively determine the level of fatigue. Based on police reports, the incidence of sleep-related accidents is estimated at 1 to 4% of all registered traffic accidents. In the Netherlands, the police register approximately 1% of all accidents as being primarily caused by (the combination of) sleep/illness. This is probably a severe underestimation of the problem. Police in most countries are not (yet) alert to fatigue as a cause of accidents. Moreover, healthy people are not inclined to admit that they were very tired or fell asleep at the time of the accident. In addition, the accident itself usually takes away all manifestations of fatigue.

Questionnaire surveys and detailed accident analyses have led to very different conclusions about the role of fatigue in traffic accidents. Estimations of the percentage of sleep-related accidents based on these approaches vary greatly, but at 10 to 25% are considerably higher than the figures that may be concluded from police registrations. Higher percentages were found mainly in studies of accidents involving lorries and/or fatal accidents. These estimates all concern countries other than the Netherlands; there is no general estimate for the Netherlands. However, based on a study of a hundred lorry accident dossiers, it was found that 18% was related to the driver falling asleep behind the wheel. This percentage is in line with findings in other countries.

Most fatigue-related accidents occur on motorways and trunk roads late in the evening and early in the morning, while the weather and other conditions are good, and people have been driving for a prolonged period.

Fatigue usually results in people veering off the road or crashing head-on with oncoming traffic. The consequences are mostly severe: drivers fail to brake or brake too late, so that the crash speed is very high. There are several groups of drivers that are relatively frequently involved in fatigue-related accidents [11.35]:

- the under-25s;
- people with sleep disorders;
- people driving at night;
- long-distance drivers;
- professional drivers;
- shift workers.

A limited number of studies have looked at whether fatigue results in an increased chance of being involved in an accident, showing that people with a sleep disorder and people with an acute lack of sleep in particular have a considerably increased (3 to 8 times as high) chance of being involved in an injurious accident.

11.4.4 Potential measures

Measures to prevent fatigue-related accidents are limited, particularly for non-professional drivers. Driving fatigue countermeasures for this group centre mostly on information on causes, effects, symptoms of fatigue and advice on how the effects of fatigue can be limited, even if only for a short while. This may raise awareness of the role of fatigue in road safety, which is a conditional but in itself insufficient step toward behavioural change.

There are more options for professional drivers. First of all, this group can be reached by means of legislative measures (driving and rest hours). Enforcement of that legislation is, of course, crucial. Moreover, professional drivers can also be reached via transport companies. Many companies, particularly in Australia and the US, have Fatigue Management Programmes, which are aimed at employers (in respect of drawing up drivers' schedules) as well as the drivers themselves. An important part of these programmes for both groups is information about fatigue. Fatigue is also part of the Safety Culture principle, which is encouraged in the Netherlands as well. However, given the increasing (international) competition in the transport industry, fatigue countermeasures are not very popular, because they often result in increased costs.

In terms of infrastructure measures, longitudinal rumble strips are one way of alerting drivers by means of an audio-tactile signal that they are threatening to leave the road. Experiments with Lane Departure Warning Systems are technologically more advanced but serve the same purpose. Roadside safety constructions and obstacle-free zones are of key importance in limiting the effects of the typical fatigue-related accident: veering off the road.

Numerous devices are on the market that claim they are capable of warning drivers when they start getting tired, but these are not very practical. Multi-year European research (SAVE project, AWAKE project) shows that even a combination of measures (for example speed of eyelid closing, duration of eyelid being closed, the degree to which a driver starts to swerve towards the lines, how often steering corrections are being made) is not sufficient to predict when someone is too tired. The problem with these devices is that there is a risk of them issuing warnings too often (false alarms), for example in situations in which the driver is not tired. There are systems that give a loud beep when the driver starts to doze off. But this systems warns at too late a stage, does not take into account the fact that some people fall asleep without their head lolling forward, and also warns when the driver's head moves in a specific manner, as when looking down. It appears difficult, therefore, to find a reliable set of objective measures that can be assessed while driving.

A subjective measure for fatigue is not suitable either. While drivers generally do sense when they are getting tired, very few of them actually stop driving as a result. This is demonstrated by the large number of fatigue-related accidents that occur. Moreover, drivers are not always aware of the fact that they are tired. Some studies have shown, for example, that sometimes drivers' brainwaves are briefly in sleeping mode (microsleep) while the drivers themselves say they are not tired [11.43, 11.60, 11.61].

11.5 Distraction due to mobile phone use while driving

11.5.1 Statutory framework

Since 2002, it is illegal to hold a mobile phone when driving a motor vehicle, disabled vehicle and moped. Having a mobile phone conversation and even dialling is permitted as long as it is done hands-free. The reason for this legislation is that mobile phone use while driving draws attention away from traffic. This section will explain that this applies equally to hand-held and hands-free calling. The reason that hands-free phone use is still permitted is that it is difficult for the police to detect and enforce the law.

11.5.2 The frequency of using mobile phones while driving

Over 14 million people in the Netherlands have a mobile phone. However, there is no objective data on mobile phone use in traffic in the Netherlands. Foreign research indicates that 3 to 5% of all kilometres are travelled while on the phone [11.11]. Assuming a similar situation for the Netherlands, this means three billion kilometres a year in the best-case scenario of only 3%.

When asked whether they ever use their mobile phone behind the wheel, a large majority of drivers say they never do. Almost a quarter admits to phoning hands-free or hand-held. This was the situation in 2005. Compared to four years earlier, in 2001, when both hand-held and hands-free calling were still permitted, there has been a considerable decrease, particularly in the use of hands-free phones (table 11.2).

Table 11.2. User-reported use of hand-held and hands-free telephones while driving, in the Netherlands, in 2001 [11.17], 2003 [11.23] and 2005 [11.2]

Frequency	Hand-held (%)			Hands-free (%)		
	2001	2003	2005	2001	2003	2005
Often	4	1	2	43	14	14
Sometimes	36	22	24	48	23	26
Never	60	77	75	9	63	60

11.5.3 The risk of phoning while driving

Many studies have demonstrated that mobile phone use while driving has a negative effect on driving behaviour [11.11]:

- Slower reactions and more missed information. Using the phone results in considerably slower reactions to traffic signals and increases the chance of missing them altogether.
- Braking later but harder. The brake reaction time is longer when a driver is making a phone call, with the reaction delay varying from 0.3 to 0.7 seconds. When drivers on the phone do brake, they brake harder (stopping more quickly), but all in all the distance to the other vehicle, stop line or intersection is still shorter.
- Deteriorated traffic awareness. The three elements of situational awareness (perception, understanding and prediction) clearly diminish because the phone call monopolises the attention.
- Riskier decisions. When they are making a telephone call, drivers tend to accept shorter distances to the car in front and are less likely to correctly adjust their speed to potentially dangerous road conditions such as slipperiness.

Mobile phone use while driving is a typical example of distraction, of an activity that decreases attention to the driving task. The driver is involved in things that have nothing to do with the driving task. Changing a CD, listening to the radio, having a conversation with a passenger or eating may also distract the driver's attention, yet experts agree that these activities have fewer consequences than making a phone call. The main difference is that all the other activities are self-regulating, as it were: drivers are aware if and when a situation requires their complete attention, and passengers are aware of the situation and understand it if the conversation falls silent for a bit. People on the other end of the phone, however, may not even know that the other person is behind the wheel.

Recent research in the US studied the scope of the problem of distraction [11.10]. In this study, 100 cars were equipped with all kinds of measuring devices and cameras. For a period of 1 year, all kinds of data on these cars and their drivers were recorded, allowing the researchers to exactly establish the events preceding the 69 actual accidents and 761 near-accidents that had occurred. In almost 80% of all accidents and 65% of all near-accidents, the driver was not looking toward the looming conflict and was not paying (enough) attention to the traffic task. In 24% of these cases, the driver was doing things other than the driving task, as referred to above. In 19% of the cases, the driver was doing things related to the driving task but that were not relevant to the emergence of the conflict (e.g. operating the windscreen wipers). Other reasons were fatigue (frequent blinking) and lack of concentration (looking away or staring without specific reasons).

Going back to the specific case of mobile phone use while driving: motorists will drive more slowly when they are making a phone call. This may be a form of compensation for the extra mental pressure of calling. By driving more slowly, they try to simplify the driving task so that they can pay more attention to the telephone call. It is not entirely clear whether this is a conscious or subconscious process.

A substantial amount of research has been done into the difference between hand-held and hands-free calling. A large majority of these studies concludes that hands-free does not offer a significant advantage over hand-held calling. Although hand-held phones make the driving task more difficult because they involve actually holding the phone, the most negative feature of mobile phones is the same for both methods, namely that they draw attention away from the driving task to the phone call.

It is difficult to establish the degree to which such behavioural effects also lead to an increased chance of being involved in an accident, because it is often not clear whether the driver was making a phone call just before the accident happened. Drivers tend not to report this, for various reasons. Estimates range from a factor of 2 to a factor of 9 for a higher accident risk for drivers who are using their mobile compared to drivers who are not. Despite this relationship, there does not need to be a causal link between the use of mobile phones and accidents, since motorists who use a mobile phone also display other types of high-risk behaviour, such as failure to wear a seat belt, drink driving and exceeding the speed limit.

11.5.4 Measures

Enforcement

In addition to the statutory ban on hand-held phone calls, it is key that this legislation is enforced. The (subjective) probability of detection must be sufficient to be effective. This is difficult to realise for mobile phone use, because the police must detect it at the moment of use and then have the opportunity to stop the motorist in question. The number of fines for mobile phone use while driving has clearly increased in the period from 2002 (when the ban was introduced) to 2006, from almost 3,000 to about 10,000 a month. Whether this is related to increased enforcement or the fact that mobile phone use behind the wheel has increased is not clear from these statistics.

Information
Information about legislation and enforcement as well as on their underlying motivations can contribute to the awareness that mobile phone use while driving is not advisable. While various studies show that drivers are generally aware of the dangers of mobile phone use and the need to limit this, many still think that hands-free calling in traffic is not that dangerous. This area, then, offers scope for further information [11.11, 11.62].

11.6 Aggression

11.6.1 Statutory framework

Aggression in traffic is a collective name for a wide diversity of behaviour, such as hooting, giving someone the finger, tailgating, forcing others off the road, followed by a flood of abuse, threats with a baseball bat or physical violence. There is a line between what is ill-mannered (but not an offence) and a violent offence, but this is a thin line that is difficult to define. Aggressive incidents that have no further visible consequences are rarely reported to the police. Incidents involving injury or damage are more often reported and are grouped under the heading 'traffic violence.'
Incidentally, if violence occurs after the parties involved have left their vehicle, any victims are not considered traffic victims. Such situations are more often referred to as 'public violence between strangers resulting from a traffic situation'. In terms of the Road Traffic Act, aggressive traffic behaviour can be directly dealt with under section 5: 'Road users are to refrain from behaving in such a manner that they cause or could cause danger on the road or hinder or could hinder other traffic'.

11.6.2 Aggression in traffic

Aggression in traffic is a subject receiving increasing public and political attention. But what is aggression and how big is the problem of aggression in traffic?

Aggression in traffic is closely related to the subject of emotions. Traffic appears to be associated with events that result in emotions which, in turn, affect behaviour in traffic [11.34]. Usually, four basic emotions are distinguished:
- anger;
- happiness;
- fear;
- sadness.

All other emotions are derived from these primary emotions. In traffic, anger and happiness are the most common emotions, with happiness being much more frequent than anger: once per two journeys compared to once per five journeys, respectively [11.32]. Happiness generally has a positive effect on road safety, while anger more often leads to riskier behaviour and is also at the root of aggressive traffic behaviour.

Aggressive traffic behaviour means that road users behave in such a way as to deliberately do damage or threaten to do damage to other road users. In this context, damage is used in the broad sense of the word, including not only material damage or physical injury, but also damage in the sense that a road user's objectives are being thwarted by the aggressor, such as safety and traffic flow [11.30]. There are two forms of aggression:

Affective or reactive aggression: retaliating
Someone who has the feeling of being deliberately treated unfairly by others will seek revenge or satisfaction. This is a characteristic of affective and hostile aggression and can take many different forms: obscene gestures, name calling, hitting the car, overtaking, tailgating, cutting someone up. In serious cases, people may be threatened by dangerous manoeuvres or forced to stop, which may result in casualties.

Instrumental aggression: intended to achieve a goal
Instrumental aggression is not a result of anger or seeking revenge, but is a form of aggression driven mostly by self-interest and that completely disregards the interests of others. In terms of its manifestations, instrumental aggression is more diverse than affective aggression. Driving too fast to get somewhere quickly or just for fun can, for example, be considered a form of instrumental aggression. Little is known about the causes of instrumental aggression. Any form of harmful behaviour or behaviour that oversteps moral standards can be a form of instrumental aggression, depending on whether it was deliberate or not. Moreover, others may consider behaviour that is not deliberately harmful or transgressing moral standards as deliberate and, therefore, aggressive.

There is little reliable information on the prevalence of aggression in traffic. Most minor incidents of aggression are not reported to the police and, consequently, not registered. Traffic violence offences are not systematically registered either, particularly not at national level. There is, however, data from several police regions. Based on the available data, a rough estimate of the national situation was made several years ago, which resulted in a figure of 4,000 to 5,000 reports of incidents of violence against strangers in traffic on an annual basis [11.49].

Aggression of road users against road workers was the subject of a recent study [11.22], which investigated the incidence and triggers of aggression against road workers. A questionnaire survey supplemented with group discussions and interviews shows that road workers mostly work inside the built-up area and that most aggressive behaviour (shouting, threats, obscene gestures, et cetera.) also takes place there. Outside the built-up area and on motorways, road workers often perceive road users to be exceeding the speed limit deliberately, while road users say they are hardly ever frustrated by road works and rarely deliberately drive too fast to express their frustration over road works.

11.6.3 The risk of aggression in traffic

It is not known how many fatalities result from aggression in traffic or to what extent aggressive behaviour in traffic increases the risk of road use. Data is available for some forms of aggression, such as tailgating or extreme speed offences, but lacking for others. However, many forms of aggression can be said to have a direct effect on the safety of the traffic flow.

11.6.4 Measures

There are three tracks along which aggression in traffic can be reduced [11.30]:

- awareness (education, information, driver training);
- system adjustments (infrastructure, telematics);
- enforcement (stopping a person, Educational Measure on Aggression).

Awareness

The possibilities of decreasing aggressive behaviour in traffic and the resultant irritation can mainly be found in raising awareness. Explicit attention should be paid to driver training, including, for example, a remedial course for aggressive traffic offenders, such as already exists in Belgium. In such training, driving a car is considered a social skill that requires emotion management and empathy. However, the effects of such training are not yet known. General public information campaigns could indicate the importance of 'social leniency' by pointing out [11.53]:

- the fact that not all behaviour that is experienced as aggressive is actually aggressive: it could just be 'stupid';
- the importance of empathy, both in terms of a driver's own anger and the 'stupidity' of others;
- the danger of escalation of a situation when you respond aggressively to the (alleged) aggression of others;
- the fact that tolerating mistakes or even aggression of others is a sign of strength and competence you can be proud of.

System adjustments

Anger and frustration among road users can be reduced at the source by making adjustments to the traffic system. This could include a better harmonisation of traffic control systems, preventing unnecessary delays, informing drivers about delays. The use of telematics could also contribute to this, by homogenising road users' behaviour by means of intelligent speed reducers or intelligent cruise control.

Enforcement
In recent years, the police have paid a lot of attention to traffic behaviour that contributes to or results from aggression, focusing on 'aggression' as a problem area. More than is currently the case, the police should focus its enforcement activities more on specific 'aggressive' behaviour that is known to be related to road unsafety. The subjective probability of detection of such behaviour should be increased by means of information campaigns, such as the recent keep-your-distance campaign, which informed road users of the right distance to the car in front and what fines they would risk for failing to adhere to this.

Measures to counter aggression near road works should focus on improving the provision of information, the attitude and behaviour of road users, the image of road workers and road works and the reporting and registration of incidents of aggression [11.22] [11.30, 11.34, 11.63].

11.7 Speed

11.7.1 Statutory framework
Initially, speed is regulated by means of speed limits. This phenomenon was not introduced in the Netherlands until 1957, when the speed limit for roads inside the built-up area was set at 50 km/h. Only in 1974 were speed limits introduced for roads outside the built-up area: 100 km/h on motorways and 80 km/h on all other roads. In 1988, the general speed limit for motorways was raised to 120 km/h. The general speed limits are laid down in the Road Traffic Act:
- 120 km/h for motorways;
- 100 km/h for trunk roads;
- 80 km/h for other roads outside the built-up area;
- 50 km/h for roads inside the built-up area.

Under the terms of the Administrative Provisions (Road Traffic) Decree ('BABW'), specific deviations are allowed. These are specified by the Minister for Transport, Public Works and Water Management in the BABW Implementation Regulations (Article 2.4, paragraph 2) and include optional speed limits of 30 or 70 km/h inside the built-up area, 60 km/h outside the built-up area and 100 or 80 km/h on motorways. The road authorities determine what limit applies where by means of a traffic decree.
The same section of the BABW Implementation Regulations also states the following: 'The maximum speed to be imposed must concur with the local roadscape. This means that where necessary circumstances will be adjusted such that the intended speed reasonably follows from the nature and layout of the road and the road environment.'

The maximum speed for lorries is 80 km/h; for buses 100 km/h. Cars with caravans and trailers are currently bound to a maximum speed of 80 km/h, but this is set to be increased to 90 km/h.

11.7.2 Speed and speed choice
Exceeding the speed limits is very common. Typically, over 50% of all drivers travel faster than the speed limit. There are different reasons why drivers exceed the limit; these are related to the driver's motives or attitudes, characteristics of the road and characteristics of the vehicle.

As all cars have a speedometer, driving speed and speeding offences are, in fact, a deliberate choice. Drivers often choose their driving speed deliberately. Reasons to adhere to the limit include safety and avoiding a ticket; reasons for driving too fast include being in a hurry, enjoying driving at high speeds or adjusting to other traffic.

Driving speed and speeding offences can also be the result of a subconscious process in which the subjective perception of speed plays a key role. Drivers who underestimate their own speed may pose a risk, for example when leaving the motorway after having driven at high speed for a long time and then entering the built-up area.

The characteristics of the road and the road environment also clearly affect the choice of speed. Everyone knows examples of roads on which the speed limit is not as expected, that encourage speeding, as it were. Characteristics of the road or road environment that (help) determine speed choice are related to the cross section (for example road width, presence or absence of a cycle lane), alignment (for example number of bends) and the direct road environment (for example buildings or vegetation along the road). Drivers tend to underestimate their speed on open roads with little vegetation or few buildings, because speed perception is largely determined by information from the peripheral (lateral) field of vision rather than by information from the central field of vision. The lack of vertical elements in the peripheral field of vision, such as trees and buildings, means drivers think they are driving more slowly than they actually are.

Finally, there are several vehicle characteristics that unconsciously result in higher speeds than desired. The noise and vibration levels of cars have decreased considerably in recent years, and these are two elements that provide feedback on speed. SUVs (Sports Utility Vehicle) and other four-wheel drive cars are also very popular these days. Because of their height above the road, the perception of speed is distorted: drivers think they are going more slowly than they are. In a driving simulator without speedometer, test subjects would, on average, drive 7 km/h faster when driving in a high SUV as compared to driving in a lower sports car. Two thirds of the subjects were not aware of this, and some even thought they were going slower when driving in the SUV [11.42].

11.7.3 The relation between speed and accidents

Speed is one of the most important risk factors of traffic. Estimates are that in around 30% of fatal accidents, speed is an essential contributory factor.
The following factors play a significant role:

- at higher speeds, it is more difficult to process information and react in time, preventing an imminent accident;
- at higher speeds, the braking distance is longer, which makes it more difficult to prevent a collision;
- higher speeds result in higher impact speeds, resulting in more serious injury.

In short: higher speeds result in greater accident risk and severity. Over the years, substantial research has been done into the exact relationship between speed and accidents [11.1].

Speed and severity of injury
The higher the impact speed, the more severe the consequences in terms of material damage and injury. This is a law of physics related to the amount of energy released when two objects collide and that is then converted into heat or material distortion. Added to that is the fact that humans are physically very vulnerable compared to the enormous forces released in a crash. While, in recent decades, vehicles have become better equipped (crumple zones, airbags, seat belts) to absorb the energy released on impact and, consequently, protect the driver and passengers, the impact velocity still determines the outcome of an accident to a large degree. At an impact velocity of 80 km/h, the chance of a fatal outcome is about twenty times higher than at 30 km/h [11.25].

The effect of speed is even greater with collisions between motor vehicles and cyclists or pedestrians, who, after all, have no crumple zone or airbag. Laboratory crash tests have shown that the chances of survival of a pedestrian being hit by a car diminish dramatically the faster the car is travelling: at 30 km/h 'only' 5% of the pedestrians die, at 50 km/h this is 45% and at 65 km/h as much as 85% [11.14].

Speed and chance of accident
The relationship between speed and safety also has to do with the chance of an accident. The faster a car goes, the higher the chance of being involved in an accident. This is a non-linear relationship and can best be described using a power function: the chance of an accident increases more with an increase in speed if speeds are higher, and vice versa.

This suggests that an increase in speed has more effect on motorways, for example, than on roads inside the built-up area. But this is not true. Both the extent of the risk and the extent of the risk increase at higher speeds depend strongly on the type of road [11.1]. Broadly speaking, motorways have the lowest accident risk and the accident risk there increases less sharply at increasing speeds than it does on lower-order roads. This is related to the complexity of the road and the road environment combined with human limitations to process large amounts of information, particularly if this has to be done in a short time. And driving on motorways is considerably less complex than driving on roads inside the built-up area with all their intersections and different types of road users.

The effect of changes in speed
Moreover, an increase or decrease in speed (v) has greater impact on severe accidents than on minor ones, a fact that Nilsson already calculated in the early 1980s, based on the laws of kinetics [11.38]. Later empirical studies [11.12, 11.39] confirm that this applies to different types of road. Nilsson stated that the number of accidents is proportional to v^2 (speed squared), while the number of severe injuries increases by v^3. According to Nilsson, the number of traffic fatalities is proportional to v^4. A slight change in speed therefore has a large effect on the change in the number of fatalities and a smaller effect on less severe accidents.

The effect of a change in speed on road safety also depends on speed itself. This is illustrated in table 11.3 based on a fictitious number of traffic fatalities. Roads with a 50 km/h speed limit are compared to 100 km/h roads. It is based on an initial number of 100 fatalities and Nilsson's model, which says that the number of fatalities is proportional to speed to the power of four.

It appears, then, that a decrease of 1 km/h on 50 km/h roads results in a larger relative decrease than on 100 km/h roads, which is quite logical, because on roads with a sufficiently low speed limit, there are almost no traffic fatalities. The lower the speed, the greater the relative savings in the number of fatalities. A speed change from 32 km/h to 30 km/h that reduces the number of fatalities from 2 to 1 is a 100% improvement. Preventing the last fatality would be an infinite improvement. The table shows that a speed decrease per km/h is more effective in terms of road safety on roads with a lower speed limit than on roads with a higher speed limit. The reason is that 1 km/h is a relatively greater change on a 50 km/h road than on a 100 km/h road.

Table 11.3. Expected effect of a change in speed of 1 km/h on the number of traffic fatalities. Accidents with a varying degree of severity at different initial speeds.

50 km/h			**100 km/h**		
Number of fatalities at 50 km/h	Number of fatalities at 1 km/h less	Relative change	Number of fatalities at 100 km/h	Number of fatalities at 1 km/h less	Relative change
100	92	– 8%	100	96	– 4%

Figure 11.2. Required distance for an emergency stop on a wet road at various speeds, with a reaction time of 1 second

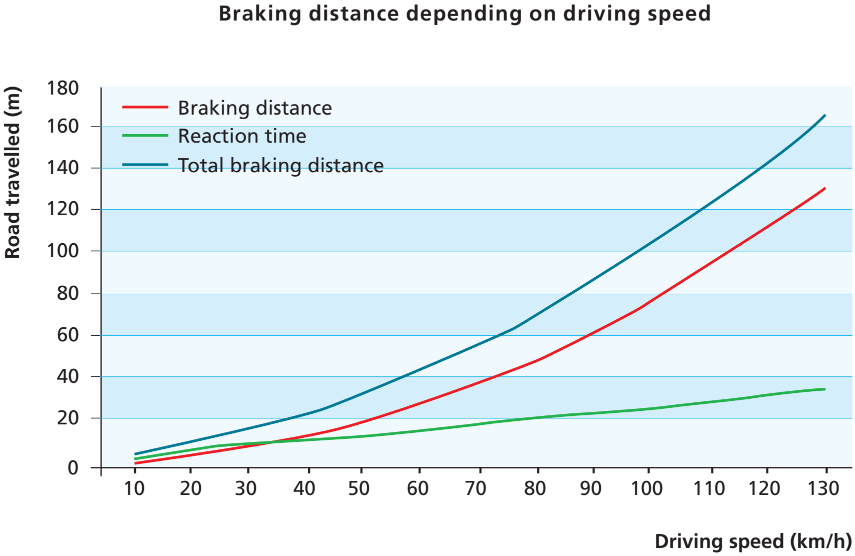
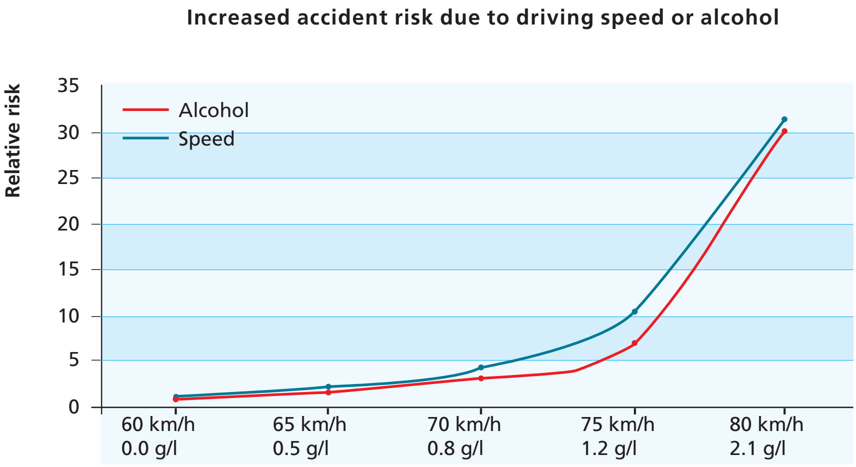


Figure 11.3. Accident risk at different speeds and different BACs [11.28]



Relationship between braking distance and speed
Figure 11.2 illustrates reaction time (the time between observing the object and pressing the brake pedal), the braking distance and the total braking distance or stopping distance as a function of the driving speed, in which a constant braking deceleration of 5 m/s is assumed for an emergency stop on a wet road surface. In the case of an emergency stop at 80 km/h, the total braking distance is approximately 70 m, at 120 km/h this has doubled to over 140 m. More favourable results are obtained on a dry road surface, of course, but the disproportionally longer braking distance at higher speeds remains.

Speed and alcohol compared
Australian research has compared the chance of accidents as a result of speed with that of alcohol [11.28]. It focused on through roads inside the built-up area with a 60 km/h speed limit. The results showed that drivers exceeding this speed limit by 5 km/h have twice as much chance of being involved in an injurious accident as drivers who adhere to the limit. The chance of an accident is four times higher when the speed limit is exceeded by 10 km/h and as much as ten times higher at 15 km/h above the limit. The increase in risk resulting from exceeding the speed limit on the roads studied was approximately the same as the increase in risk on similar roads resulting from a blood alcohol concentration (BAC) of 0.5 g/l, 0.8 g/l and 1.2 g/l, respectively (figure 11.3).

The effect of speed differences
Differences in speed between vehicles also affect accident risk. Roads with a larger speed variance (large differences between vehicle speeds within a 24-hour period) appear to be less safe than roads with a smaller speed variance. Several studies have looked at the speed of vehicles involved in an accident compared to the speed of other traffic. This was done for the first time in the US in the 1950s en 60s.
All studies, including that of Solomon [11.45], yielded a U curve: both drivers going faster and drivers going slower than average on that particular road had an increased chance of being involved in an accident. However, more recent studies using modern measurement equipment and a more accurate research method yielded a different conclusion [11.27], namely that cars going faster than average had a higher accident risk, while cars going slower did not run a higher risk.

11.7.4 Speed control measures
Wegman and Aarts [11.53] have formulated the following step-by-step approach to speed control with a view to road safety considerations.

Safe and credible speed limits
First of all, speed limits must indicate a safe speed, reflecting the function of the road and the composition of traffic. If, for example, motorised vehicles mix with pedestrians, cyclists and moped riders, the speed must be low. The possibility or impossibility of certain conflicts, such as a transverse or frontal conflict, also affect safe speeds.
Speed limits must also be credible, reflecting the characteristics of the road and the road environment. A 60 km/h road should not look like a 80 km/h road. The idea is that if a limit is not credible, drivers tend to choose their own speed at will. Moreover, if there are many situations with limits that are not credible, this will affect the reliability of the limit system as a whole.

Current speed limits in the Netherlands are mostly fixed and rigid and fail to take into account prevailing circumstances, which largely determine safe speed. Dynamic limits do take actual circumstances such as the weather and the traffic situation and are, therefore, more credible than rigid limits. Dynamic limits have been introduced in the Netherlands to some extent: on motorways with Matrix Signal Indicators, speed limits are adjusted to cater for such circumstances as the formation of traffic jams, extreme traffic volumes or road works. An expansion of the dynamic limit system is scheduled, but for the time being on the main road network only.

Information about speed limits
Moreover, drivers must be aware of the local speed limit at all times. Any semblance of ambiguity must be avoided, but this is often not the case. At the moment, information about the local limit is usually given by means of traffic signs; in future, drivers will increasingly be supported by means of in-vehicle systems, such as navigation systems.

Infrastructure measures
Road design and infrastructure must support the speed limit. Physical speed reduction measures can be used to reduce speed at locations where this essential, for instance near schools, pedestrian or bicycle crossings, and intersections, in order to force drivers to adjust their speed.

Police enforcement
When all these measures have been implemented adequately, it can be assumed that most unconscious violations of the speed limit have been eliminated. However, as long as drivers can choose their own speed, there will always be drivers who regularly and deliberately exceed the speed limit. For these intentional violators enforcement remains a necessary instrument. As long as the aforementioned measures are insufficient, speed control depends on police enforcement aimed at prevention and repression.

Education and information
Education and information provide support and are essential preconditions for the above measures. Road users must be aware that speed control is a serious issue and understand the speed limit system, why countermeasures are taken, et cetera.
The possibilities of directly influencing speed behaviour through education and information are limited. A course is being developed in the Netherlands for speed violators and other traffic offenders that is comparable to the Educational Measure on Alcohol and Traffic (EMA) for alcohol-related offences. This Educational Measure on Behaviour (EMB) is due for completion in the second half of 2008.

Intelligent Speed Assistant – ISA
ISA provides the vehicle with information on the speed limit in the area, to which the vehicle responds. ISA is, in fact, the collective name for different systems. There are systems that only give information on the applicable speed limit, but there are also systems that warn drivers when they exceed the limit through a visual or audio signal or by upward pressure on the accelerator pedal. Other systems automatically limit speed when the limit is exceeded.
The ISA system can work with static speed limits, either alone or in combination with location-dependent (recommended) limits. Dynamic limits will be used on an increasing scale. Much is expected from ISA in terms of safety gains, especially from the intervening systems [w11.1, w11.2, 11.64-11.66].

11.8 Red light running

11.8.1 Statutory framework
According to Article 68 of the Netherlands 1990 Road Traffic and Traffic Signals Regulations (RVV 1990), three-colour traffic signals have the following meaning:
- green light: continue;
- amber light: stop; drivers who are so near the traffic lights that stopping is reasonably impossible: continue;
- red light: stop.

Clearance times allow for drivers running the amber light at the very last minute (regardless of whether or not they could have stopped).
In terms of road safety, only red light running is important.

11.8.2 Red light running
Red light running is a very frequent traffic offence among cyclists, moped riders and pedestrians. It is less so among motorists, but cars often run red lights too. The percentages vary considerably and depend on the situation the traffic signal is intended to control.
An older study of red light running by motorists in Amsterdam mentions figures between 1 and 9% [11.40], while data from the Central fine collection agency (CJIB) indicate that some 350,000 road users were fined for red light running in 2006.

By far the most red light running offences by motorists occur in the early red light phase. This is probably related to a combination of high speed and with being in a hurry or alleged time savings (just making the light). Running a red light in a later phase is generally unintentional, for instance in response to the wrong traffic light, or unwittingly because of following the car in front. Distraction or lack of concentration due to the use of alcohol, fatigue or using the mobile phone while driving can also cause drivers to unintentionally run a red light in a late phase. Deliberately ignoring a red light in a late phase also occurs, but only in very exceptional cases.

Red light running offences by cyclists and moped riders and pedestrians cover almost the entire duration of the red light phase. These are usually deliberate decisions in order to avoid what the cyclist, moped rider or pedestrian considers to be overly long waiting times.

11.8.3 Accidents caused by red light running

In 2005, red light running was the main cause of 6.2% of all fatal accidents and 3.7% of accidents resulting in hospitalisation in the Netherlands [w11.3]. It can be concluded that red light running accidents are fatal relatively more frequently. The problem of red light running is greater in the Netherlands than in the United States, for example, where red light running is estimated to cause approximately 2% of all road accident fatalities every year (IIHS, 2000). This may be related to the fact that there are relatively more vulnerable road users in the Netherlands (pedestrians, cyclists, moped riders, motorcyclists), who come off worse in collisions with motorised vehicles.

11.8.4 Measures

To prevent red light running, traffic lights must be clearly visible in time, and waiting and clearance times must be properly adjusted. The 'Handboek verkeerslichtenregelingen' (Traffic light control handbook) 11.8] provides the guidelines for this. Further measures to counteract red light running can be found in infrastructure and enforcement.

Infrastructure

Roundabouts are effective replacements for intersections with traffic lights and, consequently, effective solutions to prevent accidents caused by red light running. Roundabouts have fewer points of potential conflict and should a conflict nevertheless arise, the collision angle and collision speed are such that physical injury is not as severe. Replacing a four-way intersection by a roundabout reduces the number of severe injuries by approximately 70% [11.9]. On intersections with traffic lights, the installation of a raised section just before the intersection can help reduce the number of red light running offences, on the one hand, and limit the consequences of such offences, on the other. Because of the raised intersection, motorists will lower their speed and therefore be more inclined to stop when the light is amber (just turned red). Even if they do not stop, any consequences will be less serious because of the lower driving speed. The province of Zuid-Holland has conducted a preliminary and follow-up study to measure the effect of raised intersections on 80 km/h roads on road safety [11.20]. The study shows that the number of accidents with victims on intersections with traffic lights decreased by 40 to 50%.

Enforcement

Enforcement of red light running offences by motorists is usually done by means of cameras, often combined with speed checks. About one third of all fines for red light running are based on camera evidence. Analysis of a number of different, mainly foreign, assessment studies [11.41] shows that the use of red light cameras brings about a reduction of between 40 and 60% in the number of offences and a reduction of between 25 and 30% in the number of injurious accidents. An assessment study in the city of Amersfoort shows a similar effect on road safety: a 20% decrease in the number of injurious accidents [11.51]. Enforcement of red light running offences by pedestrians, cyclists and moped riders has been intensified since 2005, mainly by means of pulling them over but, in the case of moped riders, also on the basis of the vehicle registration number [11.8, 11.67].

11.9 Keeping distance/tailgating

11.9.1 Statutory framework

Under Article 19 of the RVV1990, every driver must be able to stop his vehicle within the distance along which the road is surveyable and free. In practice, motorists are advised to keep two seconds headway, advice which is based on the reaction time of drivers under various circumstances. Drivers who tailgate keep extremely short distances of only a few metres to the car in front for a longer period of time. The police define tailgating as a headway time of much less than 1 second, say half a second. Their fines policy reflects this, as such short headway times constitute reckless driving that is subject to punishment.

11.9.2 Headway times

There is no data on exact headway times and the frequency of tailgating, but results from a test to reward safe behaviour do offer an indication [11.47]. In this test, 62 lease car drivers were given a device that registered driving speed and distances kept to the car in front. The drivers were given feedback on their behaviour; they could earn points for good behaviour that could be exchanged for a small gift. Headway times during the pre-measurement (when the equipment had been installed, but no feedback was given) provide an indication of the 'normal' behaviour of these drivers. As the drivers knew about the presence of the measuring equipment and were all driving a lease car, the data is probably not representative of Dutch drivers in general. On weekdays, almost half the number of kilometres travelled (distance up to 100 m) were driven with a headway time of less than 1.3 seconds, on weekend days this was approximately 35% of the kilometres travelled. Headway times on motorways tended to be shorter than on 80 km/h roads, where they were shorter than on 50 km/h roads. No incidents of extreme tailgating were found in this study.

However, tailgating is a very common phenomenon: in 2006 alone, over 1,400 motorists were fined for tailgating, 90% of whom were male. Moreover, tailgating is high in the top ten of driver irritations and is one of the manifestations of aggression in traffic (see section 11.6) used to 'punish' someone who, according to the tailgating motorist, did something wrong earlier (affective aggression) or because the person tailgating has the feeling that they are being held up by the car in front (instrumental aggression).

11.9.3 The dangers of tailgating

To drive safely behind the vehicle in front in a steady stream of traffic, motor vehicle drivers are advised to keep two seconds headway. The two-second rule is based on the reaction time of drivers. This is not the same for every driver, but varies from less than one second to about two seconds, depending on a number of factors. There are differences between individual drivers, and reaction time depends on a driver's alertness (which may also be influenced by fatigue or distraction, such as mobile phoning), the complexity of the traffic situation and expectations as to what is about to happen. Also important alongside reaction time is braking distance, which depends first of all on speed and maximum braking deceleration. Maximum braking deceleration in turn depends on vehicle mass, tyres and road surface.

If headway times are (too) short, chances are that a car is unable to stop in time if the car in front has to brake suddenly, resulting in a rear-end collision. Twenty per cent of all fatal accidents and 42% of injurious accidents on motorways are rear-end collisions (data for 2001-2006; BRON). The police record overly short headway times as the cause of 80% of these rear-end collisions.

11.9.4 Measures

Enforcement
The police check tailgating mainly through 'standard' surveillance or in unmarked video cars. On the main road network, the police also use the Video Control System. Fines depend on speed and headway times at that speed.

Advanced Cruise Control
A more modern way to maintain a fixed headway time is by using Advanced Cruise Control (ACC). This system can not only be set at a specific speed (cruise control) but can also control an adjustable headway time. Originally developed as a comfort system (cruise control) for use on long distances with more or less uninterrupted traffic flow, ACC also has the added value of automatically keeping sufficient headway times. Current ACC systems are not yet suitable for use in very busy traffic with varying driving speeds. That would require greater braking deceleration than the current systems offer.

Information
Tailgating is a regular subject of road safety information campaigns, sometimes as a separate theme ('Houd twee seconden afstand'– the two-second headway campaign), sometimes as a manifestation of aggressive and antisocial driving behaviour ('Rij met je hart', Drive with your heart). These campaigns are generally accompanied by intensified police monitoring of tailgating. [11.68]

11.10 Failure to use safety devices

11.10.1 Statutory framework

So far, this chapter has discussed behaviour that increases the chance of an accident. But when an accident actually does happen, there are all kinds of provisions that are intended to limit the physical consequences. Some of these, such as the crumple zone and the airbag, are automatic; others require an active decision and action on the part of the road user, such as use of the seat belt and child restraint seats and, for motorised two-wheeled vehicles, a crash helmet. The use of these safety devices is laid down by law.

Wearing seat belts in the front seat of cars, if present, has been mandatory in the Netherlands since 1975. The use of seat belts in the back seat was not made mandatory until 1992, the same year that seat belts in vans, lorries and buses (if present) became mandatory. At the moment, seat belts must be present in cars under Article l 5.2.47 of the Motor Vehicle Regulations (part of the 1994 Road Traffic Act), while compulsory seat belt usage for drivers and passengers is laid down in Article 59 of the 1990 Traffic Rules and Signs Regulations (RVV).

This article also stipulates the rules applicable to children. Until recently, children under the age of 12 and shorter than 1.50 m should use the safety devices approved for their weight class as much as possible, but these regulations were tightened up in 2006 based on European directives. The basic rule now says that children shorter than 1.35 m (a new standard) must sit in an approved child restraint seat or on a booster seat, both in the front and in the back of the car [w11.4].

The use of approved crash helmets has been compulsory for motorcyclists since 1972, and for moped riders since 1975. Both categories of helmet must meet the same (European) requirements in terms of shock absorption, penetration resistance, rigidity, protruding parts and surface friction, chin strap and the helmet's ability to stay on.

11.10.2 The use of safety devices

Periodical roadside measurements show that more drivers have started wearing seat belts in the Netherlands in recent decades. Outside the built-up area, this percentage rose from 78% in 1990 to 94% in 2006, inside the built-up area from 59% to 93%. This means that the traditional difference between inside and outside the built-up area has virtually disappeared. The percentage of passenger seat belt usage in the front seat is the same as for drivers, while this percentage has also increased sharply for back seat usage in recent years, hovering around 73% both inside and outside the built-up area, as shown in table 11.4.

Furthermore, measurements show that most children shorter than 1.35 m are transported in special child restraint seats. The number of children who are transported without any safety device whatsoever has decreased dramatically in recent years, from 25% in 2004 to 10% in 2006.

Crash helmet usage by motorcyclists has been at almost 100% ever since it was made mandatory by law in 1972.
Compulsory usage by moped riders introduced in 1972 initially resulted in general acceptance among this group. In 1984, usage totalled almost 100%, but by 1996 this had decreased to 98% for drivers and 86% for passengers.
In 2002, these figures totalled 91% and 74%,

Table 11.4. Percentage of seat belt wearers (inside and outside built-up areas) in the period 1990-2006, of drivers and back-seat passengers [11.3, 11.37]

Year	Drivers		Back-seat passengers	
	Outside the built-up area	Within the built-up area	Outside the built-up area	Within the built-up area
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
2006	94	93	73	73

respectively, and in 2006 91% and 80% [11.13]. Youngsters are less inclined to wear crash helmets than older people. Moreover, most moped riders fail to fasten their helmet properly, so that it is less effective. In 2005, 10% of moped riders had not fastened the chin strap and of those who did, there was too much play in 30% of the cases [11.46].

11.10.3 The effectiveness of safety devices

Safety devices are intended to reduce injuries in the event of an accident and they have proven to be effective. Table 11.5 provides an overview of the effects of seat belts and child safety devices in cars. Most research into the effect of seat belts dates back to the 1970s.

Table 11.5. Estimated decrease in the chance of injury as a result of the use of seat belts and child safety devices in cars in the Netherlands (seat belt statistics based on [11.15]; child safety on [11.44])

Type of injury	Seat belts front seat	Seat belts back seat	Child safety devices
Severe	25%	20%	30%
Fatal	40%	30%	50%

The only later study was conducted in the US in the late 1980s. This study [11.15] shows that seat belts in the front seat are more effective than seat belts in the back seat. This is related to the fact that back seats in themselves are much safer than front seats. The study also showed that seat belts are more effective in preventing fatal injury than severe injury, which has to do with the fact that fatal injury is largely the result of head and skull injury and internal chest injury – types of injury prevented by the use of seat belts. Moreover, the effect of seat belts also depends on the speed of impact. At extremely high impact speeds, the effect of seat belts ultimately decreases to 0, but at lower speeds, the effect is extremely high.

Child safety devices are even more effective than seat belts [11.4, 11.6]. These studies did not analyse the differences in effectiveness at different ages, types of safety device and place in the car.

Crash helmets have contributed considerably to reducing injury among motorcyclists and moped riders. In the early 1980s, Huijbers and Van Kampen [11.24] estimated that they reduced the chance of sustaining fatal injuries in an accident by 40% and the chance of a non-fatal severe accident by 30%. More recent studies confirm this positive effect. An Italian study among scooter riders [11.31] indicated that the risk of head trauma is three to four times smaller after the use of helmets was made mandatory. A World Health Organisation report states that the chance and severity of head injury is reduced by 72% when wearing a helmet. And a study conducted by Keng in Taiwan [11.26] shows that wearing a helmet reduces the chance of a fatal head injury by 40%.

It is sometimes assumed that the use of safety devices results in risk compensation, which means that people behave differently, take more risks, when they feel protected by a seat belt or crash helmet. This assumption has been cause for much debate in scientific circles for decades and no definitive conclusion has yet been reached. Some studies indicate a certain level of risk compensation, others do not. The estimated effects described in this section are based on research into actual accidents. If people do take more risks when they are wearing a seat belt or crash helmet, this has already been included in the estimated effects.

11.10.4 Measures

Although the use of safety devices in the Netherlands could be classified as fair to good, it is advisable nevertheless to strive for 100% usage. It has been calculated that if the final 7% of 'non-seat belt-wearing' drivers and front-seat passengers and the final 27% backseat passengers (see table 11.3) were to wear their seat belts, this would mean 15 fewer fatalities and at last 85 hospitalisations every year [11.48].

Enforcement

The use of seat belts and crash helmets comprises two of the five spearheads of regional enforcement plans that have been introduced in the different police regions since 1998. In the regions with a regional enforcement plan, the number of fatalities decreased by 21%, compared to 12% in the regions without such a plan. Although this sharp decrease was not significant, it could be concluded that half of the reduction resulted from increased seat belt use. The mandatory use of registration numbers for mopeds from 2006 has made it easier for police to distinguish between a moped (with compulsory helmet usage) and light moped (no compulsory helmet usage) and in turn facilitated enforcement.

Information

Even in the decades prior to regional enforcement plans, the use of seat belts and crash helmets already featured as a spearhead in national safety plans. Apart from enforcement activities, this also resulted in various information campaigns. The government campaign Goochem, featuring an armadillo that can be attached to seat belts, is aimed mainly at children and their parents and has been adopted in various European countries. The proper use of moped helmets has also been the subject of several national and regional information campaigns.

Seat belt reminders

Seat belt reminders were developed to encourage the use of seat belts A seat belt reminder is an in-vehicle device that alerts the driver or passenger that they are not wearing a seat belt while driving. The warning can be given visually by means of a light on the dashboard, acoustically by means of an audio signal, or by a combination of the two. Many cars already have such a fairly simple form of seat belt reminder, at least for the driver's seat. As regards passengers, the system will have to check whether the seat is in use first in order not to warn unnecessarily. Systems have already been developed that warn for all car seats. More intelligent systems measure driving speeds. At low speeds (below 10 to 15 km/h), the visual or audio alert is less insistent than at higher speeds, because it is assumed that lower speeds reflect such activities as a parking manoeuvre, for which wearing a seat belt is less essential. There are also systems with an acoustic signal whose duration and pitch depends on the time that has expired since turning on the ignition.

A Swedish study [11.29] found that 99% of people used their seat belts in cars with a fairly insistent form of seat belt reminder (a system with an audio signal that gets louder and lasts at least 90 seconds), compared to 93% in cars with a more 'friendly intermediate form' (a system using a lamp and no more than a slight audio signal) and 83% in cars without a seat belt reminder [11.3, 11.48, 11.69].

11.11 Summary

This chapter showed that some forms of behaviour significantly increase the chance of severe injury. It discussed the influence of alcohol, drugs and medicines, fatigue, mobile phone use while driving, aggression, speeding, red light running, tailgating and failure to use or incorrect use of safety devices.

The discussion of each of the separate subjects started with a brief outline of the statutory framework, followed by a description of the incidence of the behaviour in question, the extent to which it results in accidents and why and to what extent that behaviour increases the risk. Finally, existing and potential future countermeasures were discussed. The information related mostly to motorised traffic.

Some behaviour has been studied in much more detail than other behaviour, and not all subjects discussed in this chapter could be substantiated with sufficient hard figures. By far the most information is available on speed and alcohol, two subjects that have been considered to have had a major impact on road safety since the 1960s. Other subjects have only recently come under the spotlight, such as the effect of drugs and medicines. Research in that field is still on-going and knowledge about it is developing rapidly. Yet other subjects are considered to be so evidently negative for road safety that hardly any structural research has been conducted into the additional risk of such behaviour. This applies to aggression in traffic, red light running and tailgating, for example.

It is important to acknowledge that sometimes different subjects are highly interconnected. High speed and tailgating, for example, can be manifestations of aggression. A common feature of fatigue and mobile phone use in traffic is that drivers pay less attention to traffic and cannot react as quickly if something happens. And red light running may be the direct or indirect result of speeding.

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Specific groups of road users

Learning objectives for students:

- to know which groups of road users run the greatest risk of sustaining serious injury;
- to be able to name the characteristics that make road users vulnerable;
- to be able to name measures that can be taken to increase the safety of vulnerable road users;
- to know which groups of road users are involved in the most accidents and cause the most damage;
- to be able to explain how particular types of road user can cause more damage;
- to be able to name measures that can be taken to limit the severity of the injuries sustained.

The statistics on casualties and accidents presented in this chapter are based on data taken from the Centre for Transport and Navigation. Unless stated otherwise, the figures are average figures for the years 2002 to 2006 and are rounded up to the nearest five or ten. Figures referring to the number of kilometres travelled and the population size are taken from Statistics Netherlands.

12 Specific groups of road users

12.1 Introduction

This chapter will apply knowledge from earlier chapters to specific groups of road users, exploring for each group how their road safety can be improved. The road users discussed in this chapter are selected on the basis of the relatively significant role they play in road safety in the Netherlands. This role could be due to the fact that these road users have a relatively high chance of being involved in a traffic accident, the fact that they have a relatively high chance of sustaining fatal injuries as a result of an accident or the fact that the characteristics of the mode of transport they use increases the chance that another road user will sustain fatal injuries as the result of an accident. These three aspects are primarily related to the age of the road users and the mode of transport they use.

Age

There are a number of reasons why the age of road users can lead to an increase in the risk of their being involved in an accident. Age determines whether someone is permitted to use a particular mode of transport for the first time, for example, or whether they can drive longer distances (to secondary school, for instance) and is therefore an indication of the inexperience of road users. People with limited experience using a certain mode of transport generally have a greater chance of being involved in an accident. Examples include young children who fall off their bicycles or young motorists causing an accident because they are not able to properly assess complex traffic situations and react incorrectly as a result.
An individual's stage of life partly determines how they behave. This relates to behaviour in the broadest sense of the word. Young people (particularly young men), for example, are prone to taking greater risks and like to impress. Older people have this tendency to a much lesser extent. Their behaviour is determined far more by what they are capable of and how they can compensate for any shortcomings in their capabilities. In this respect, the elderly need more time to process and respond to information. They often try to compensate for this by anticipating what will come next. Both the high risk acceptance of young people and the limitations confronting the elderly can increase the chances of an accident.
Finally, age more or less determines the chances of someone surviving an accident. Older people are more physically vulnerable than younger people, which means that, proportionally speaking, their share in traffic fatalities is greater than their share in hospitalisations.

Mode of transport

A person's mode of transport also influences their chances of being involved in an accident or sustaining a serious injury. Some vehicles are more difficult to control than others. A prime example is the motorcycle, where balance is key to avoiding falls. In the event of a fall or collision, the seriousness of the injury depends on the protection provided by the vehicle and the clothing. Pedestrians and cyclists have very little in the way of protection. Moped riders and motorcyclists have a helmet to protect them against head injuries, while motorcyclists often wear protective clothing as well. Passengers in cars, lorries and buses have the best protection of all: a vehicle with a cage construction and crumple zone as well as other accessories such as seat belts and airbags, which reduce the chance of injury still further. The protection offered by the vehicle to those people inside it may, however, also constitute a danger to the other people involved in the collision. The weight of a vehicle has a significant influence on the seriousness of the injuries sustained by the other party. The heavier the vehicle, the more serious the injury sustained by the lighter party. A collision with a lorry, therefore, constitutes the most serious consequences for the other party. This subject is also discussed in chapter 8 on vehicle safety.

12.2 Children

12.2.1 Characteristics of this group

Children are particularly inexperienced, still developing the skills required to eventually participate in traffic in a responsible manner. For the youngest children, this entails developing the skills needed to play outside and walk to school safely. It relates, for example, to 'thinking that you can't simply chase after a ball that rolls onto the road', 'look to see if there is any traffic coming before crossing the road' and recognising those places where it is safe to cross and those places where it is not. Older children cycling to school unaccompanied by their parents are required to learn new things, such as how they can safely navigate through traffic with their classmates (see also chapter 9 on road safety education).

The key modes of transport employed by children are cycling and walking. When children travel somewhere, they do so on foot or by bicycle 60% of the time. Of course, younger children also play outside a lot. Older children cycle more often, particularly when they go to secondary school.

Pedestrians and cyclists are vulnerable because they participate in traffic largely unprotected. They often do not wear a helmet and have nothing to protect their bodies in the way that cars protect their passengers. Collisions with motorised traffic often lead to serious injury. This is discussed in more detail in the sections on pedestrians and cyclists below (see section 12.5 and 12.6).

12.2.2 Share in the total number of casualties

There are approximately 40 children aged between 0 and 14 killed in traffic accidents in the Netherlands every year, with a further 725 requiring hospitalisation, according to registration figures. The actual number of hospitalisations is significantly higher, given that estimates show that the police register less than 50% of injuries sustained by children requiring hospital treatment. The explanation for this is the relatively high number of accidents involving children, which are poorly registered. For that reason, this section will concentrate solely on the number of children who sustained fatal traffic injuries, which is done on the basis of mortality rates: the annual number of fatalities per 100,000 inhabitants. It appears that relatively few children die in traffic accidents compared with the average of all other age groups (see table 12.1). This is also the case when the number of youngsters killed in traffic is compared with the number of children in the population as a whole. Approximately 18% of the Dutch population is aged 14 or under, while the total number of fatalities in this age group is less than 5%. Of course, the scale of traffic participation must also be taken into consideration. Children travel shorter distances than the average road user, particularly as independent road users. Children aged 12 and under travel a substantial

Table 12.1. Mortality per age group for pedestrians and cyclists; number of traffic fatalities per 100,000 inhabitants

Age group	Mortality	
	Walking	Cycling
0-3 jaar	0,20	0,15
4-8 jaar	0,32	0,30
9-11 jaar	0,40	0,77
12-14 jaar	0,47	1,60
All ages (0-99 jaar)	0,50	1,04

proportion of the kilometres as passengers in the back seats of cars (more than 80%).

In recent years, the distribution of mobility of children over the different modes of transport has changed significantly. In the period 1994-2002, the number of kilometres travelled by children on foot and by bicycle decreased by 10% and 20%, respectively. By contrast, the number of kilometres travelled by car rose by 10%. This shows that parents are transporting their children by car more often, allowing them to participate in traffic on their own less frequently. The motives for this are probably the presumed road unsafety on the route and the distance, both of which were cited by parents as motives for taking their children to primary school by car [12.12].

Children killed in traffic accidents are primarily pedestrians, cyclists or passengers, with the highest mortality rate among cyclists aged between 10 and 14, which is the age at which children begin to travel independently more often, particularly from the age of 12 onwards. Of course, younger cycling casualties also include children travelling on the back of bicycles. Fatal accidents involving children almost always occur as a result of a collision with a motorised vehicle. For young pedestrians, these vehicles are mainly cars, and for young cyclists these are heavy vehicles such as delivery vans or lorries.

12.2.3 Measures that could improve child safety

The inexperience of children could be removed by allowing them to learn. It is important to realise in this respect that children learn in a domain-specific way, which means that children only put what they have learnt into practice in a place where they have also practised it, such as a regular crossing point on the way to school. The expansion of learning into new situations (crossing at another point) is slow, which results in more mistakes. This means that the child must be supervised by an adult in order to master these new situations. Children learn most from adults or people who mean a lot to them, including parents and teachers as well as heroes such as characters from Sesame Street or sportsmen and women. Children do not only learn from explicit messages such as ‘fasten your seat belt, it’s safe’, but from implicit messages as well, which are imparted by the way in which the ‘role model’ behaves. A parent who does not wear a seat belt, but expects their children to do so, sends an implicit message that wearing a seat belt is relatively unimportant.

Because accidents can never be entirely prevented, it is important that measures are in place that minimise the severity of the injury. This can be achieved by enforcing lower speed limits in areas where children play and cycle.

The current 30 km/h speed limit in residential areas is reasonably safe (5% chance of being fatally injured in a collision with a motorised vehicle). Currently, this speed limit is primarily enforced by means of infrastructure facilities such as physical speed-reduction measures. In the future, this will also be possible by means of automatic speed inhibitors in vehicles. In addition, more dedicated areas, like those in home zones, should be created where children can play carefree and traffic is only permitted to travel at walking pace. This enables children to gain experience in a safe environment. 30 km/h zones are safe as long as the pavements are wide enough.

The severity of injuries can also be limited by employing safety measures such as the compulsory use of child restraint seats and seat belts for children. Since 1 March 2006, every child under 1.35 m in the Netherlands must use an approved child restraint seat or a booster seat, both in the front and in the back seat. More and more children are wearing bicycle helmets when cycling, although this is confined to children of primary school age. Helmets are less popular with older children and adults. Furthermore, there are measures that are relevant to all pedestrians and cyclists. These will be discussed in sections 12.5 and 12.6 [12.3, 12.12, 12.21, 12.27, 12.32, 12.34].

12.3 Young people

12.3.1 Characteristics of this group

Young people aged between 16 and 24 have a relatively high chance of being involved in an accident, irrespective of which group of road users they belong to. This section discusses young motorists, section 12.7 focuses more closely on young moped riders.

Novice motorists aged 18-24 have a more than 4 times greater chance of sustaining a serious injury in an accident (fatal injury or hospital-isation) for every kilometre they travel than motorists aged between 30 and 59. While there are various reasons for this, they are primarily connected with lack of experience and age. Examples include:

- not yet mentally and physically mature;
- high risk acceptance;
- high exposure to dangerous situations: young people, particularly men, often drive under especially dangerous circumstances such as at night or in the weekend;
- lifestyle: trying new things, hanging out with friends and wanting to impress and outdo each other, conforming to group norms;
- more use of alcohol and drugs and more often fatigued;
- lack of routines and automatisms (lack of driving experience);
- overestimating personal skills in combination with underestimating the complexity of the traffic situation.

Figure 12.1. Accident risk for drivers in 2004-2006

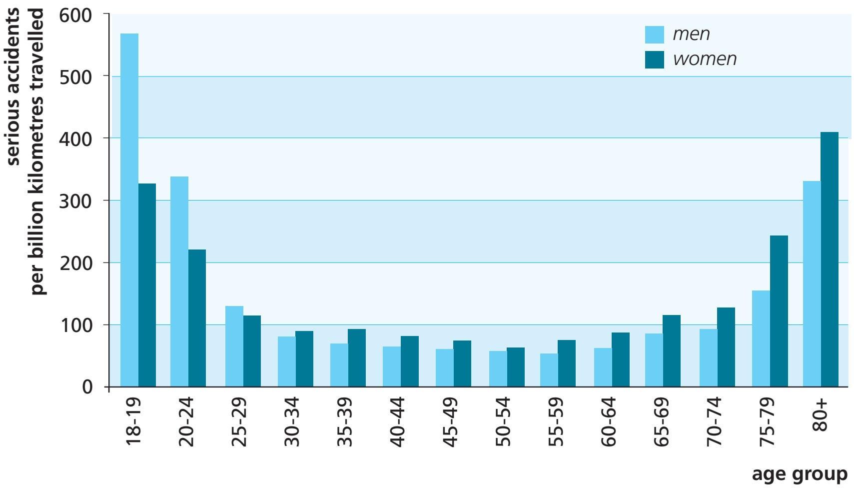
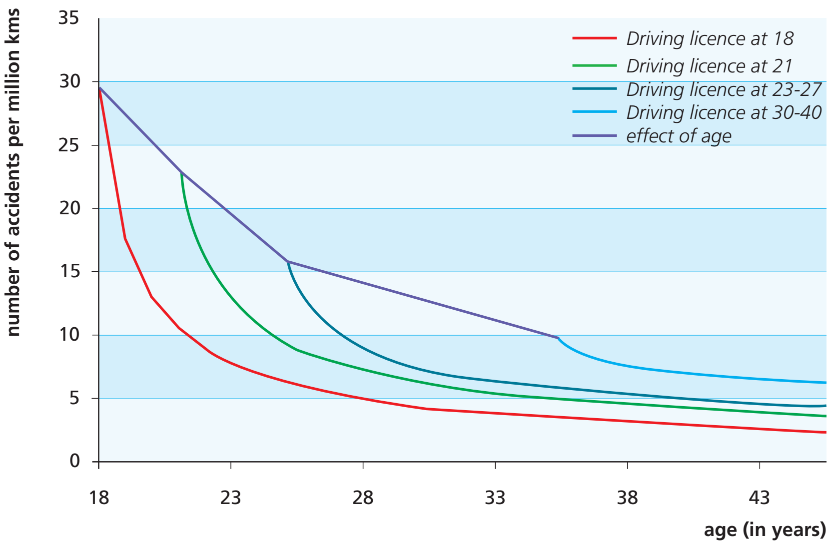


Figure 12.2. Decline in the accident risk of motorists who begin aged 18 and those who begin when they are older [12.39]



12.3.2 Share in the total number of casualties

Of all the cars that were involved in a serious traffic accident in 2005 (accidents that resulted in a fatality or hospitalisation), 20% were driven by motorists between the ages of 18 and 24. This is high, given that young motorists only make up 8% of the total number of motorists with a driving licence. In addition, men are almost three times as likely to be involved in a serious accident as women, including the drivers as well as their passengers or persons in the other vehicle. In 2005, there were 161 fatalities in accidents involving young drivers, 62 of which were drivers aged between 18 and 24 (50 men and 12 women). In addition, 632 young drivers sustained serious injuries (416 men, 212 women and 4 unknown). There were 38 fatalities among the passengers of motorists aged between 18 and 24, and 61 from the other party. Ages were non-specific in both cases.

Even when the statistics are corrected for the number of kilometres travelled by motorists, young drivers remain the group with the highest accident risk (see figure 12.1). Divided by gender, the accident risk for men and women is comparable for all age groups except 18 to 24. In the period 2004-2006, the accident risk for young men was almost twice as high as that of young women and more than 6 times higher than for 30-59-year old men. The risk of being fatally injured in a traffic accident is approximately 8.5 times higher for young male drivers than for more experienced male drivers (30-59 year). For young female drivers, this risk is 3.5 times higher.

Of course, driving experience and age generally go hand in hand. Figure 12.2 shows the course of accident risk in terms of experience and age. People who start driving at a later age have a lower initial risk than people who started driving at a young age, but ultimately cause more accidents.

Young drivers are involved in single-vehicle accidents comparatively often. Examples include vehicles that leave the road due to a steering error and overturn, or when a driver fails to see an object in time (for example a barrier) and collides with it. Of all the fatal accidents involving young male drivers, 52% are single-vehicle, versus 26% for experienced male drivers between the ages of 30 and 59. For young female drivers, these figures are 32% and 22% respectively.

12.3.3 Measures that could improve the safety of young motorists

Existing measures for young novice drivers are aimed at both driving lessons and the driving test as well as the period after they get their licence. In general, the effect of these existing measures on road safety is either unknown or could not be determined. One exception is the lowering of the statutory alcohol limit for novice drivers.

There are no known studies into the safety effects of the driving test itself. Such a study is also virtually impossible because every country within the EU has its own requirements regarding the driving test and there is, therefore, nothing to compare the safety in countries where tests have to be taken and countries where they do not. However, there are studies comparing countries with and without professional driving lessons, as well as different forms of such lessons. However, these studies have not been able to show that formal driving lessons in their current form have an effect on safety. This has been attributed to the fact that driving lessons in the Netherlands and abroad pay too little attention to attitudes, to the motives for safe traffic participation and to 'higher level skills' such as danger recognition (see also chapter 9 on road safety education). Moreover, there are too few lessons and too few practical situations to enable learner drivers to build up sufficient experience. Recently, the contents and structure of driving lessons were improved. Phased driving lessons (PDL) were introduced based on a schedule of manoeuvres that were to be carried out as part of the routine driving tasks. PDL was extensively tested in the province of Gelderland and has since been introduced nationwide. The results of the initial evaluation studies have so far proved to be cautiously positive [12.30].

Since 30 March 2002, drivers in the Netherlands are given a licence on probation first, which is linked to a fairly simple demerit points system that stipulates that three serious offences in the first five years could result in the forfeiture of the licence, while good behaviour during this same period will result in the issuing of a standard licence. The measure applies to all novice motorists: car drivers, lorry drivers, motorcyclists and moped riders. While the effect of this licence on probation has yet to be evaluated in the Netherlands, little or no effect is expected. This expectation is based on experiences with demerit points systems for novice drivers in Germany and the United Kingdom, where only Germany experienced a small but positive effect during the first year after the scheme was introduced [12.38]. This corresponds with the experience that points systems are effective shortly after introduction but not in the long term. No long-term effects could be determined for the points system for novice drivers used in Germany due to the reunification.

A substantial impact on safety can be expected from a longer, multi-phased learning process. A graduated driving licence system aims to enable novice drivers to gain experience in such a way that they constitute as little danger as possible to themselves and others. As their skills improve, novice drivers are then gradually permitted to gain experience in more dangerous situations. Moreover, attempts are made to increase the motivation to drive safely by only removing limitations once the driver has committed no traffic offences and/or been involved in an accident.

A multi-phased licence comprises three phases. The first phase is the apprentice phase, in which the motorists are only permitted to drive under the supervision of someone with a licence (this is not a driving lesson). The duration of the apprentice phase varies from six months to one year. The apprentice phase is followed by the interim phase, during which the pupil is permitted to drive independently but only in circumstances where the chance of being involved in an accident is minimal. This

phase is almost always subject to a total alcohol ban. There is also often a ban on driving in the dark and carrying passengers of a similar age. The interim phase is mostly concluded with the standard driving test, which, unlike the current test in the Netherlands, focuses more on testing the higher level skills and often contains a danger recognition test.
If successful, novice drivers move on to the third phase, which is similar to that of the licence on probation in the Netherlands, where the first years are subject to stricter rules (for instance for alcohol) or a demerit points system [12.26].

Before 1 January 2006, the statutory blood alcohol concentration limit (BAC) was 0.5 g/l. As of that date, this limit was lowered to 0.2 g/l for novice drivers. This adjusted blood alcohol limit applies to drivers who got their licence (on probation) on or after 30 March 2002 and applies for the first five years after the driving licence is issued. The Institute for Road Safety Research estimates that, provided the level of monitoring stays the same, this reduction for novice drivers could result in a 5% decrease in the total number of alcohol-related accidents in the Netherlands, equalling approximately twelve fewer fatalities and around one hundred fewer hospitalisations every year [12.16, 12.22, 12.39].

12.4 Elderly: road users aged 75 and over

12.4.1 Characteristics of this group

The elderly are more physically vulnerable than young adults, resulting in more serious injuries even if collision impact is the same. For instance, the chances of sustaining a fatal injury in a collision are three times greater for a 75-year-old than for an 18-year-old. This physical vulnerability is most serious for unprotected modes of travel, such as walking and cycling. While for older motorists this vulnerability is less prevalent, it still influences the severity of the injury.

Ageing increases the chance that a functional disorder (reduction in eyesight, slower reactions) and/or illness (dementia, eye disorders, stroke) will occur, which in turn increases the chance of an accident. Deteriorating motor skills also increase this chance. Generally, such deterioration comprises a reduction in movement, a decline in muscular strength, a diminishing of fine co-ordination and a particularly acute decrease in the ability to adapt to sudden changes in posture. This latter aspect is particularly important for cyclists and pedestrians, as well as for people who use public transport (walking and standing in moving buses and trains). There is little to suggest that the gradual deterioration of visual and cognitive functions affects road safety. Sensory, perceptual and cognitive disorders only lead to an increased accident risk in their most severe forms [12.2].
In general, the elderly need more time to prepare for and execute manoeuvres and it is more difficult for them to perform a variety of actions simultaneously. There are, however, profound differences within this group. After

all, ageing is a process that is far from uniform, which means that there can be substantial differences in the driving skills and physical and mental abilities of people of the same age, while some 85-year-olds may even be fitter than some 40-year-olds.

One third of journeys by the elderly are made on foot. No other age group is so dependent on walking to get from A to B. This is primarily because driving and cycling is increasingly difficult with age. While the elderly will try to continue to drive for as long as possible, cycling is often the first to go due to problems with balance or because traffic has become too busy and unpredictable [12.2]. Large numbers of elderly people do not have a driving licence, but this will change in the coming decades, with a particularly sharp increase in the number of older women with a licence [12.6]. Table 12.2 shows developments over the past twenty years.

There are currently approximately 1 million people over 75 in the Netherlands. This number is expected to rise to 2.2 million by 2040. Because this group is growing ever greater, it goes without saying that road safety policy should take their capabilities and limitations into account.

Table 12.2. Developments over the past 20 years (1985 versus 2006)

Index (1985 = 100)[1]	People aged 75 and over	
	Men	Women
Inhabitants	149	144
Driving licences	270	510
Kilometres travelled as motorist[1]	204	347
Serious injury[1]	119	190
Chance of serious injury[1]	58	55

1) Due to large fluctuations, three-year periods (1985-1987 vs 2004-2006) were used

Table 12.3. Risk of fatality according to age group and mode of transport: traffic fatalities per billion kilometres travelled, 2002-2006

	Walking	Cycling	Car	Total road use
30-49	14	5	2	3
65-74	27	33	4	8
75+	154	147	17	33
All ages	24	12	3	5

(Source: SWOV/DVS, CBS)

12.4.2 Share in the total number of casualties

Around 130 elderly people sustain fatal traffic injuries in the Netherlands every year and, according to police registrations, a further 600 are hospitalised. This means that elderly road users constitute a 15% and 6% share in the total number of fatalities and hospitalisations, respectively. While their share in the total number of hospitalisations is comparable with their share in the population, the number of fatalities is more than twice as high.

The number of traffic fatalities involving the elderly is high in relation to the total number of kilometres they travel. For people over 75, the chance of being involved in a fatal accident for every kilometre travelled is roughly six times higher than average (all ages). This risk is far less for people aged between 65 and 74 (see table 12.3).

The risk of sustaining a fatal injury is primarily prevalent for older cyclists, with the risk being twelve times higher for a person over 75 than that of the average cyclist. The differences are greater still when compared with the 30-49 age group.

12.4.3 Measures that could improve the safety of the elderly

Given the assumed increased prevalence of age-related functional disorders, it is important that elderly road users are given sufficient time to observe, decide and perform each driving task. It is also important that traffic situations are created so that they fit with the expectations that road users have on the basis of their experience. These conditions generally correspond with the principles of Sustainable Safety, which primarily benefits the safety of older road users. However, certain elements of Sustainable Safety could be even better co-ordinated towards elderly road users:

- new designs must connect to existing principles so that the elderly can use their experience and existing automatisms;
- it must be possible to perform complex tasks in phases (for example crossing the road in phases), thereby enabling the elderly to survey the situation again from a safe vantage point and determine when they will take the next step themselves;
- important characteristics of the infrastructure must be made prominently visible by means of good public lighting and well-maintained contrastive marking.

Concrete examples of infrastructure adjustments aimed at elderly road users are described in [12.2], such as advance warning for right-of-way signs, signs above each lane on the carriageway, single-lane roundabouts, greater sight distance and well-maintained contrastive marking. The common characteristic of these adjustments is that they give road users more time and information to judge the traffic situation and allow them to perform the traffic task step by step. The result is a reduction in the complexity of the task, which will cause elderly road users to make fewer mistakes. However, this will also benefit other road users, which is an additional argument in favour of implementing such measures.

It is also possible to customise measures to elderly motorists in the form of support that is tailored to their capabilities. Different technical adjustments are available, such as power steering and an automatic gearbox as well as adjustments that enable drivers to brake and accelerate using less force. These are systems that principally offer support to motor function disorders such as the deterioration of muscle strength. In addition, more advanced driving support systems are being developed that support older drivers with function disorders related to eyesight, attention and information processing. There are systems that warn about traffic that is simultaneously approaching an intersection, systems that help to enter and change lanes and systems that project the relevant road signs and warning signs on the road into the vehicle [12.8].

When accidents occur despite these measures, the consequences can be limited by means of protective measures, such as a bicycle helmet or side airbags in cars. These airbags provide extra protection against side-impact accidents such as left-turn accidents, which are relatively common among elderly drivers.

When the body deteriorates still further, adjustments to the road and the vehicle are not always enough to prevent someone from being unfit to drive. In such cases, it is important that there is an effective driving suitability test. People fail if they are unable to safely participate in traffic physically and/or mentally. The problem is that it is not clear which functional disorders lead to an increased accident risk and to what extent these disorders can be compensated for through help or training. However, it is important that the test does not lead to people who are capable of driving safely losing their licences. Table 12.3 shows that the risk of sustaining a fatal injury is far higher for elderly cyclists and pedestrians than for elderly motorists. In other words, the car is a safer mode of transport for them. In addition, the elderly often stop cycling earlier due to balance-related problems. Often, the inability to drive also means the surrender of a part of their social life.

12.5 Pedestrians

12.5.1 Characteristics of this group

Pedestrians have an increased risk of sustaining a fatal injury because of the severity of the injuries they generally sustain due to their lack of protection. A collision with a motor vehicle often results in serious injury or, depending on the speed at which the other party was driving, death. Accidents in which a pedestrian trips over a loose paving stone are not seen as traffic accidents, because these are defined as involving at least one moving vehicle.

Not only do pedestrians run a higher risk of sustaining a fatal injury because they are unprotected, they also have an increased risk because of the characteristics of the people who use this means of transport most often. Children under 11 and people over 75 are the two groups who walk the most, covering roughly one third of their journeys on foot. The previous sections already highlighted that children do not yet have the skills to perform traffic tasks safely and properly. The elderly are more physically fragile and often need more time to get into their stride, they walk more slowly than younger pedestrians, find it more difficult to differentiate between approaching vehicles in the confusion of traffic, find it difficult to estimate the speed of oncoming traffic and are less capable of avoiding a potential collision.

Skating and rollerblading

Under the terms of the Road Traffic Act, skaters and rollerbladers are equal to pedestrians. In practice, however, they tend to stick to the relatively smooth surface of the road rather than the pavement. Moreover, they seldom follow a training course. Basic skills such as braking and steering are not, therefore, a matter of course.

12.5.2 Share in the total number of casualties

Around 80 pedestrians sustain fatal traffic injuries in the Netherlands every year and, according to police registrations, a further 625 are hospitalised. Most of the fatalities are people over 75. This is also the case when the numbers are corrected for the size of this group in the population or the number of kilometres travelled. Most hospitalisations involve children under 11. If the number of casualties is set off against the number of kilometres travelled, people over 75 have the biggest chance of hospitalisation, followed by primary school children and secondary school pupils.

Crossing is the most dangerous manoeuvre for pedestrians, with 64% of all pedestrian fatalities resulting from an accident while crossing the road. Cars and lorries are the main causes of such accidents. Of the pedestrians who sustained fatal injuries as a result of an accident when crossing the street, 25% were using a zebra crossing or other type of pedestrian crossing.
Among the elderly, 75% of fatalities occurred when crossing the road, 38% of which on a pedestrian crossing [12.40]. Despite the fact that pedestrians might expect to be able to cross safely via a zebra crossing, in reality this is very often not the case.

12.5.3 Measures that could improve the safety of pedestrians

Given the connection between collision speed and the chances that an accident will have fatal consequences (see chapter 11 on risk-enhancing behaviour in traffic), every reduction in collision speed will substantially decrease those chances. Accidents with a collision speed under 30 km/h often end favourably (for more details on safe collision speeds, see chapter 1, Theory). One of the principles of Sustainable Safety is derived from this: in areas where pedestrians encounter motorised traffic, driving speeds must be lowered to a maximum of 30 km/h. As long as no measures can be taken in the field of Intelligent Speed Assistance (ISA), lower speeds will need to be primarily enforced through traffic engineering and infrastructure measures.

30 km/h zones
Many residential streets already have 30 km/h-zones within the context of Sustainable Safety, which does not mean, however, that everyone adheres to this speed limit. Physical measures such as speed bumps can help to enforce reduced speeds [12.24].

Pedestrian-friendly car front
A pedestrian-friendly car front is a construction without sharp or hard/rigid edges so that, in the event of an accident, a pedestrian sustains as little (serious) injury as possible. From 2012, all new cars must be equipped with a pedestrian-friendly front bumper, a regulation that also applies to all new car models introduced after 2005. An expansion to the pedestrian-friendly car front is the airbag that protects the pedestrian's head from impacting on the windscreen and the car's A-frame.

Pedestrian crossings
Although pedestrian crossings should be the place where pedestrians can cross safely, this is not always the case. Extra measures are needed, therefore, to increase the safety of pedestrians while crossing, such as:
- clearly visible, recognisable and uniform crossings;
- raised crossings so that motorists approach at reduced speeds;
- smaller crossing distances by introducing a traffic island or widened areas in the pavements;
- more crossings with traffic lights;
- taking into account the slower walking paces of the elderly when sequencing the traffic lights;
- reducing traffic speed in areas where there are a lot of pedestrians or excluding motorised vehicles altogether.

Safe routes for children
'Kindlinten' are special corridors that guide children safely to schools, playgrounds and sports facilities. These child-friendly routes are predominantly found in busy neighbourhoods. Delft and Amsterdam were the first cities in the Netherlands to introduce 'kindlinten' (child ribbons) in 2006. The routes are playfully developed with recognisable markings and signs that guide children to their destination safely [12.13] [12.5, 12.9, 12.17, 12.31].

12.6 Cyclists

12.6.1 Characteristics of this group

Cyclists, like pedestrians, have a high risk of being involved in a fatal accident and also lack physical protection. Collisions with motor vehicles in particular lead to serious injury and should be avoided as much as possible. However, some cyclists sustain injuries because they have fallen while cycling or have collided with an obstacle. This can also result in serious injury, especially if the cyclist is older. Head injuries accounted for 30% of hospitalisations involving cyclists and 60% for cyclists who sustained fatal injuries. These injuries are largely skull fractures with brain damage. Older cyclists also suffer serious leg injuries relatively often, which is probably due to the fact that their bones are more brittle than a younger person's.

12.6.2 Share in the total number of casualties

Around 170 cyclists sustain fatal traffic injuries in the Netherlands every year and, according to police registrations, a further 2,160 are hospitalised. This means that cyclists make up approximately 20% of both fatalities and hospitalisations registered by the police.
Most fatalities involving cyclists are in the group over 60. When corrected for the number of inhabitants per age group, it appears that youngsters aged between 12 and 17 are also overrepresented in the number of fatalities involving cyclists and in the number of hospitalisations.
In terms of the number of seriously injured cyclists per kilometre cycled, only older cyclists stand out. The risk of a cyclist over 75 sustaining a fatal injury is twelve times higher than average, while the chance of hospitalisation for every billion kilometres travelled is five times higher than average.

Collisions between cyclists and cars are the most important cause of serious injury (fatalities or hospitalisations) among cyclists (55%). These collisions occur most often at intersections within the built-up area (58%) and at intersections outside the built-up area on 50 km/h roads (95%). There are few casualties within 30 km/h zones: of the total number of seriously injured cyclists, only 6% occurred within these zones, compared to 73% on 50 km/h roads. The manoeuvre that is most prevalent in accidents between cyclists and cars is when both vehicles cross without turning [12.24]. This makes crossing the most dangerous manoeuvre for cyclists too, especially on 50 km/h roads.

Encounters between cyclists and lorries that have serious consequences – representing 4% of the total number of seriously injured cyclists – are of a different nature. Almost one third of serious accidents involving lorries were the result of the cyclists being in the blind spot of a lorry turning right.

12.6.3 Measures that could improve the safety of cyclists

Two key infrastructure measures that could improve the safety of cyclists are the separation of bicycle traffic and motorised traffic by means of separate bicycle paths and the lowering of speeds of motorised traffic in situations in which cyclists and motorised traffic meet, such as at intersections and in residential areas.

Side shields on lorries prevent cyclists and other vulnerable road users from ending up under a lorry. Since 1 January 1995, new lorries, semi-trailers and trailers must have at least open side shields. More effective still are closed side shields, which extend lower (to the carriageway). Open side shields are estimated to have resulted in 25% fewer fatalities and injuries, while this percentage is 35% for closed side shields [12.14]. For collisions between cyclists and cars, it is important that car fronts have a safer design so that the consequences of accidents are less serious. The development of a pedestrian-friendly car bumper, which was discussed earlier in this chapter, is a step in the right direction. However, in collisions, cyclists often end up impacting the car in other places, prompting the need for additional requirements that will make the pedestrian-friendly car front bicycle-friendly as well.

Cyclists who travel at dusk or at night without adequate lighting are difficult for other road users to see (20% of bicycle casualties occur at dusk or in the dark). In 2006, 64% of all cyclists had a front and rear light [12.1]. However, not everyone used the correct lights: 8% of cyclists used a front and/or rear light that flashed, was the wrong colour or was not fitted to the bicycle. Young people (up to 25) use lights less often than other groups, with only 50% having an operational front and rear light.

Cyclists involved in an accident or falling off their bicycles run the risk of sustaining head injuries or brain damage. Young children are especially prone to falling without there being any collision with another road user. Wearing a bicycle helmet reduces the chance of serious injury [21.4, 12.9, 12.24, 12.33].

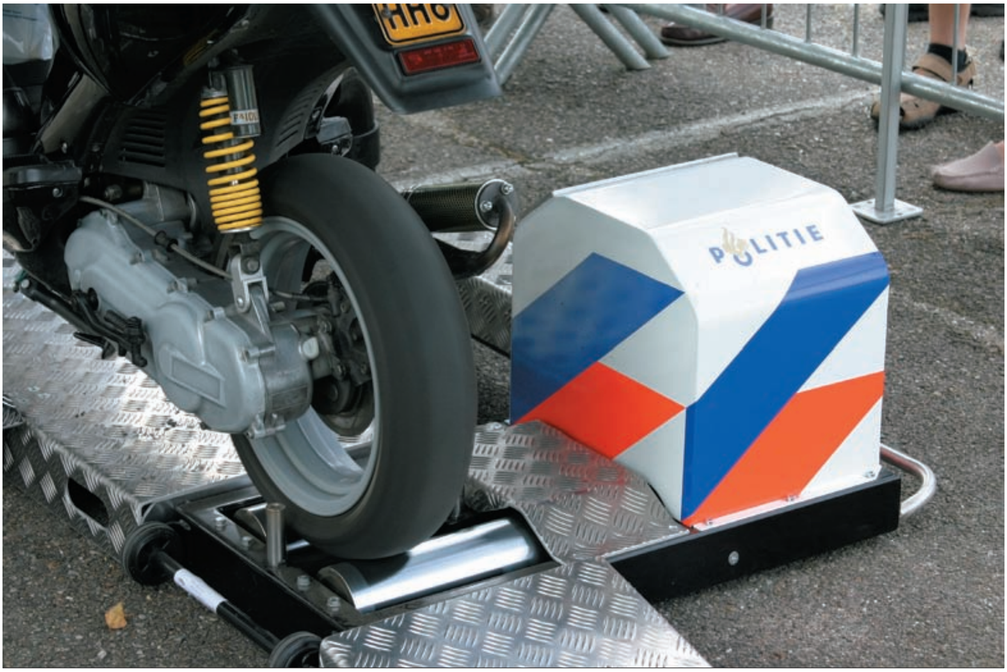
12.7 Powered two-wheelers

12.7.1 Characteristics of this group

Mopeds and motorised bicycles are balance-related vehicles and are, therefore, sensitive to disruption of that balance. They can accelerate faster than cars and provide no protection in the event of an accident or a fall. This is why their drivers have a significant chance of falling, going unnoticed by other vehicles and sustaining more serious injuries. Furthermore, mopeds are often tuned up so that they can go faster than the regular speed of 45 km/h. However, the characteristics of the predominantly young moped riders also play a key role in becoming involved in an accident, in that they often overestimate their own capabilities, have limited ability to convert knowledge into safe traffic behaviour, drive at excessive speeds and do not wear a helmet (see also section 12.3).

12.7.2 Share in the total number of casualties
Around 50 moped riders sustain fatal traffic injuries in the Netherlands every year and, according to police registrations, a further 1,400 are hospitalised. This means that moped riders make up a total of 6% and 14% in fatalities and hospitalisations, respectively. This is high given that less than 1% of all kilometres are travelled by moped. A substantial number of moped casualties are aged 16 or 17. Every year, this age group experiences approximately 15 fatalities and 585 hospitalisations, constituting 30% and 42% of moped casualties, respectively. The victims are primarily young males: 80% of the fatalities and 75% of the hospitalisations.

Annually, around 80 motorcyclists sustain fatal injuries, which is approximately 10% of the total number of traffic fatalities. According to police registrations, more than 700 motorcyclists are hospitalised every year, who, like moped riders, are predominantly male. A second similarity with moped riders is that the risks associated with motorcycling are very high. For every kilometre travelled, the chance of being involved in a fatal accident is almost 25 times higher than for car passengers, while the risk of hospitalisation is more than 20 times higher. Novice motorcyclists aged between 18 and 24 run the highest risk.



12.7.3 Measures that could improve the safety of powered two-wheelers

A combination of factors is the reason why young, predominantly male, moped riders are involved in moped accidents so often (see also section 12.3). Firstly, they are adolescents. During this phase in their lives, youngsters become psychologically, socially and economically independent. As a result, they experience uncertainty and push their boundaries. In traffic, this means that they are involved in accidents more often than normal due to a combination of uncertainty, overestimating their own capabilities, underestimating the risks and covering a large number of kilometres. This applies in particular to young men [12.35].
Secondly, youngsters are mostly insufficiently trained to translate their knowledge of traffic rules into safe traffic behaviour. A third factor is speed. Young moped riders admit more than any other group to exceeding the speed limits [12.10]. A key factor that contributes to serious injuries in an accident is not wearing a helmet. In the period 1999-2002, 8% of moped riders and 26% of passengers failed to wear a helmet. The nationwide introduction of the moped certificate (as of 1 June 1996) led to a sharp improvement in knowledge of and insight into traffic [12.36], but does not appear to have led to safer traffic behaviour [12.11].
On 1 October 2006, the certificate was replaced by a moped licence (category AM), which, like the certificate, requires that people successfully pass a theoretical exam. From mid-2008, youngsters also have to pass a practical exam in order to gain the licence.
In the same way as novice motorists, novice moped riders are also subject to more stringent rules (see section 12.3.3). Penalty points issued to moped riders (due to speeding or drink driving, for instance) are not waived and can then be added to any points they may incur should they later become motorists or motorcyclists. The total period in which offences are accumulated for people who gained their moped licences at age 16 or 17 is seven years.

In 1999, European directive 97/24/EC was introduced to prevent tuning up (light) mopeds. This guideline states that the vehicle's speed reduction facilities must be difficult to remove for unauthorised persons. Unfortunately, the guideline does not seem to be watertight in practice. Creating effective legislation is difficult because it must always be possible to remove certain parts in case of repairs. Yet the EU still intends to further hone the current regulations. Moped registration plates have been introduced recently as well, which also makes enforcement easier.

It is important for motorcyclists that other road users can see them. This can be stimulated in part by providing information to motorists and training them so that they are more prepared for the presence of motorcyclists. Furthermore, motorcyclists can also contribute by assuming a position on the road that enables other road users to see them. In addition, motorcyclists should always drive with their lights on. Some 10% currently fail to do so, particularly within the built-up area [12.37]. Motorcyclists can also ensure that they are visible by wearing reflective or fluorescent clothing, choosing a light-coloured helmet and having the front of the bike (especially the tank) emblazoned with bright colours and reflective material [12.19, 21.41].

The consequences of a crash can be limited by wearing protective clothing regardless of the weather conditions. Luckily, there are very few incidences of motorcyclists not wearing a helmet. Obstacle-free zones and non-aggressive road-side fixtures, such as motorcycle-friendly safety barriers, are also key to limiting the consequences of a motorcycle accident [12.15, 12.118, 21.29, 21.42, 12.43].

12.8 Lorries and delivery vans

12.8.1 Characteristics of this group

Lorries and delivery vans deserve attention in road safety policy for two reasons. Firstly, accidents involving these vehicles often lead to serious consequences for the other party. This is primarily due to the size of these vehicles. In general, the heavier the vehicle, the worse the consequences for those travelling in the lighter vehicle.
Secondly, accidents involving these types of vehicle are caused by other factors than those involving cars. Their high centre of gravity can cause lorries and delivery vans to topple over at high speeds or in sharp bends. Loads that are not properly secured can fall off and trailers and semi-trailers can jackknife. Furthermore, there is limited vision to the rear, which results in a larger blind spot. This plays a key role in accidents between lorries that are turning right and cyclists that are going straight ahead. Finally, accidents also occur due to loading and unloading in traffic, particularly in urban areas.

The behaviour of other road users can be unsafe as a result of their not taking the anomalous character of these vehicles into account. Many road users do not realise that they are in the lorry's blind spot or that a lorry can swerve out.

12.8.2 Share in the total number of accidents

Every year, delivery vans are involved in roughly 100 fatal accidents in the Netherlands, and lorries in a further 115. This means that they make up 12% and 14%, respectively, of the total number of fatalities (accidents with at least one fatality). The number of accidents involving delivery vans or lorries where someone required hospitalisation is 1,050 and 430, respectively. In comparison with the total number of hospitalisations, this constitutes approximately 12% and 5%, respectively.

Casualties in such accidents are almost always from the other party. Only 8% of fatalities resulting from a collision between a lorry and another road user were travelling in the lorry. The ratio of fatal accidents involving delivery vans is slightly different, however, with 72% being from the other party and 28% travelling in the van (22% driver, 6% passenger).

Most fatalities involving lorries are passengers in cars (46%), with cyclists making up the second largest group (25%). Passengers and cyclists sustaining fatal injuries in accidents involving delivery vans account for 34% and 29%, respectively.

12.8.3 Measures aimed at lorries and delivery vans

Blind spot mirrors and side shields on lorries can reduce the chances of an accident involving a cyclist and the consequences thereof. Since 1 January 2003, every lorry has been fitted with a blind spot mirror. The number of accidents involving cyclists going straight ahead and lorries turning right has decreased considerably as a result, but the problem of the blind spot has not been eradicated altogether [12.25]. Moreover, the effect appears to have been temporary given the subsequent rise in the number of accidents, which has fluctuated ever since. This fluctuation would appear to be the result of the publicity that was given to this subject.

Side shields on lorries prevent cyclists and other vulnerable road users from ending up under the lorry. Since 1 January 1995, new lorries, semi-trailers and trailers must have at least open side shields. Because of the lifespan of lorries, it will be years before the entire Dutch lorry fleet is equipped with such shields. In 2001, the level was approximately 60%. More effective still are closed side shields, which extend lower (to the carriageway). The effect of open side shields is estimated to have resulted in 25% fewer fatalities and injuries, while this percentage is 35% for closed side shields [12.14]. A unique aspect of delivery and haulage is that the participation of drivers in traffic is almost always work-related. This means that transport and shipping companies are co-responsible for road safety. This has resulted in the promotion of a safety culture within companies, which is said to be in place if every department within the company values the importance of safety and if safety is a consideration in all transactions and

decisions. In concrete terms, this is reflected in damage registration, sanctions/rewards, performance interviews, prevention meetings and driving proficiency tests.

Safe transport requires cargo to be neither too heavy nor too high so that it does not undermine the vehicle's characteristics by increasing braking distances or threatening to topple. Cargo must not land on the road surface and measures to this end include controls regarding overloading and incorrect loading as well as the application of systems to warn against toppling. However, reliable and affordable warning systems are currently unavailable [12.14, 12.23, 21.25, 12.28].

12.9 Summary

This chapter discussed how road safety can be improved for different groups of road users. The road users that were discussed all play a relatively significant role in road safety in the Netherlands. This role could be due to the fact that these road users have a relatively high chance of being involved in an accident, the fact that they have a relatively high chance of sustaining fatal injuries as a result of an accident, and the fact that the characteristics of the mode of transport they use increases the chance that another road user will sustain fatal injuries as the result of an accident. These three aspects are related to the age of the road users and the mode of transport they use.
The groups of road users were divided by:

- age: children, young people, the elderly;
- speed and mass of the vehicles or modes of transport: pedestrians, cyclists, motorised two-wheelers and lorries and delivery vans.

The characteristics of each group were discussed, as was their share in the total number of casualties and/or accidents in the Netherlands. In addition, the measures that could be taken to improve the safety of these road users or to restrict the negative influence on the safety of others was also discussed.

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To illustrate the previous chapters and the versatility of traffic engineering as a profession, this chapter describes a number of concrete road safety activities and projects.

13 Practical examples

13 Practical examples

13.1 Developing a road categorisation plan

This practical example provides more insight into the problems and preconditions in the planning process and gives a number of practical suggestions for the successful development of a categorisation plan.

Most road authorities in the Netherlands have attempted to formulate road categorisation plans in recent years. The formulation of development plans, revision of zoning plans, plans for new construction projects and suchlike often prompt a critical analysis of the role of road safety and the liveability of such plans.

The theory and guidelines of Sustainable Safety by themselves are far from sufficient to successfully realise a road categorisation plan. According to the principles of Sustainable Safety, for example, there are only two categories of roads in urban areas. As a result, road authorities feel more or less compelled to choose between the residential function (access roads) and the traffic function (distributor roads). In practice, however, this has merely resulted in the informal rise of grey roads. Old neighbourhood and district distributor roads, roads in industrial estates and outlying areas, passages, old arterial roads and mixed shopping streets provide many municipal councils with problems when they are (re)-developed: should they become access roads or distributor roads?

Although the theory behind road categorisation is sound, it can never be applied as such in practice. Ultimately, the uniformity of the roadscapes and their proper perception by road users are decisive.

Questions will always be raised, such as 'Is there enough space for separate bicycle facilities?', 'How can parking or crossing be solved safely?' In addition, while it often appears that accident statistics in residential areas offer little scope for analysis, there are real worries about (road) safety among non-motorised traffic and among residents and pressure groups.

Support

While residents and pressure groups are involved in the establishment of traffic measures, this is not always the case with regard to outlooks and/or planning. However, the input of interested parties (citizens, emergency services, schools and public transport companies) during the process is of critical importance for an effective 'customised plan'.
Furthermore, sufficient political support is also crucial. Politicians seldom appreciate what consequences a truly sustainable and safe urban development can have for spatial planning. Political compromises are unavoidable, also financially. It is important that funds be made available for (re)development, as well as for management and maintenance. When constructing speed humps, for example, it is not unusual to overlook maintenance costs, or to opt for a sober design.

The traffic engineer is both missionary and guard

In the planning process, the traffic engineer is both the missionary and the guard of the effective sustainable safety message. He acts as jack of all trades and unfortunately sometimes also as scapegoat. Knowledge of the files and good social skills such as flexibility and willingness to accept compromises are key competences for the traffic engineer. It is important to understand that compromises are not always the best option. Sometimes it is better to take no measures than half measures.

'Button' theory

The terms function, use and design are the foundations on which the Sustainable Safety theory for infrastructure is based. These are the three buttons that can be pressed, as it were, to influence road safety. A safe distributor road (= function), for instance, must not handle more than x number of vehicles (= use) and must satisfy a number of design requirements (= design).
By repeatedly discussing the result of pressing these buttons, the choices made can be clarified and the differences solved.

Example of a tree structure

When redeveloping a residential area with a clear tree structure, the allocation of 30 km/h zones is not generally a problem. The discussion usually concentrates on the crossability of the often busy primary access road. Adapting the function of this road is not always desirable. Based on the theory, traffic engineers can clearly explain that only two 'buttons' remain (use and design). Introducing measures to alter the function of the primary access road is often difficult because of the undesirable spatial interventions this requires, which hardly ever has any political support. The chance of support is greatest if a link can be created to another spatial plan, such as the revision of the zoning plan. In that case, it will also be properly embedded in legal terms. A decision not to alter the use gives the traffic engineer the chance to then use design as the remaining 'button'. Ultimately, a compromise must be found that accommodates all spatial problems, financial limitations and 'not in my backyard' problems.

Example of a grid structure

The 'button' approach is also effective in achieving an end result in a grid structure. The problem with these structures is that the differences in function, use and design are not significant enough to enable clear choices to be made. Sometimes, road sections do have a sort of natural function due to the distribution of amenities (houses, shops, schools, et cetera.) in the area. It is important to collect sufficient knowledge about this to create a basis on which to launch the discussion. Particularly in these areas, close collaboration with those involved is crucial, because their interests can differ substantially.
The analysis of use and design (wishes, facts) forms an effective start to the planning process. Collectively supported roadscapes are created on the basis of discussions concerning the way in which these two buttons interact (if this… then that…). The allocation of functions is then the final piece in the jigsaw.

It is clear that developing a road categorisation plan can be a difficult and unpredictable process. An approach focused on flexibility, customisation and compromise engenders the most support and is, therefore, the most promising option.

In summary

The following basic principles help to make the road categorisation planning process a success.

Support is the leitmotiv for the formulation of a plan

- Residents and pressure groups must be involved, because they are the users and have key information about the subjective road unsafety. Complaints must also be analysed.
- Conflicting interests must be dealt with pragmatically. Discussions must be based on objectively verifiable arguments.
- An integrated approach is key. A planning process that is linked to the revision of a zoning plan, for example, provides opportunities for effective co-ordination with other policy fields, leads to legal embedding and provides the parties with the opportunity to hold each other to the agreements that have been made.

In the planning process, the traffic engineer is both the missionary and the monitor of the effective sustainable safety message

- He can highlight the benefits: for example better crossability.
- A strategic position is important. The key sustainable safety theme must be maintained. The traffic engineer must clearly indicate which choices must be made in which phases of the process. The traffic engineer must make decisions and, from the beginning of the process, avoid longwinded discussions concerning technical details, such as the exact location and design of speed bumps.

The co-ordination of function, use and design of road infrastructure offers an effective starting point to the planning process

- The traffic engineer must show that co-ordination is necessary, for which the 'button' theory is a helpful tool.
- The traffic engineer must be flexible and avoid applying rigid rules.
- Attempts should be made to reach a compromise/most suitable solution.
- Names are less important than the layout/design of roads.
- Requirements for noise reduction and air purification must be included.

13.2 Zeeweg to Zandvoort

The facts

The Zeeweg between Haarlem and Bloemendaal aan Zee/Zandvoort is the oldest dual carriageway in the Netherlands. This now listed site was constructed during the unemployment relief works of the 1920s and 30s. The road was designed to bisect the Zuid-Kennemerland National Park and make it possible for vehicles to reach the Noordzeestrand.

The increase in motorised traffic and technical developments in particular meant that the Zeeweg quickly became a road with very high speed, especially at quiet moments. The result was obvious and by the mid-1990s, the road was notorious as the number one accident black spot due to a number of single-vehicle accidents with fatal consequences.

While the current traffic volume numbers approximately 7,000 vehicles a day, on hot summer days, that number can be as much as 2,200 an hour in both directions.

Basic situation
The road fails to comply with the design standards and many accidents occur as a result. The course of the road and the width of the pavement are laid down in spatial plans. Vertical elements and not official signs are not permitted.
The requirements of nature and of the area as a listed site provide little room for reconstruction of the road. The character of the road must not be tarnished and the flora and fauna must not be disturbed. Accessibility to Zandvoort, with its many catering establishments and, in particular, its circuit, must be guaranteed. The road was reconstructed shortly after the turn of the millennium.

Players
- the Municipal Councils of Bloemendaal and Zandvoort and the province;
- the manager of the Kennemerduinen in the Zuid-Kennemerland National Park (PWN water board);
- the Rijnland Water Authority;
- the emergency services (fire brigade, ambulance service and police);
- catering establishments in Zandvoort/ Bloemendaal;
- residents in apartments;
- campsite owners in the dunes along the boulevard;
- Zandvoort circuit;
- public transport services.

Process
The process involved the following phases:
- initial exploration of the possibilities within the framework of the spatial plans, the statutes of the water authority, the requirements relating to flora and fauna, and the outlooks formulated by the municipal councils;
- administrative intention to tackle the problem by means of collaboration;
- bring in a landscape architect to visualise how the modification blends into the area;
- initial sketch for the area outside the national park, including the municipal outlooks and a sketch of traffic engineering requirements within the national park;
- administrative approval of the further development of a plan of action;
- formulation of a draft plan and information meetings with all parties;
- processing the information arguments and creating a final design;
- administrative approval of the plan;
- tendering and implementation.

Results
The section of the Zeeweg between Haarlem and Bloemendaal aan Zee through the Zuid-Kennemerland National Park remains a dual carriageway, each of which has two narrow lanes. Each lane remains 6 m wide and no adjustments were made to the bends. Statutory official signs are still used and there are no vertical elements.
The boulevard in Zandvoort along the North Sea coast was reduced to two lanes with a parallel bus lane and separate parking spaces. The end of the Zeeweg in Bloemendaal aan Zee was adapted to include a roundabout. On the Haarlem side of the Zeeweg, a roundabout was constructed and the municipal council reduced the number of lanes to one in each direction with a

partition verge as a central reservation. This enables metering of the traffic flow onto the Zeeweg.

The listed Zeeweg is equipped with dynamic road surface lighting that is activated by approaching vehicles, while the bends are indicated with warning signs and curve reflector stuts and have a local recommended speed of 60 km/h. A 60 cm verge parallel to the road surface is reinforced with concrete mats. The partition verge is in places raised to an embankment.

These measures resulted in the reduction in the total number of accidents from 48 in 2000 to 20 in 2006, and a reduction in serious accidents from 7 to 2 a year. There have been no fatal accidents since 2000.

Conclusion

An ostensibly simple reconstruction of a road section can be a complex problem if the parties involved have conflicting interests and are not prepared to compromise. The phased and open approach with administrative support ultimately led to a solution that was acceptable to everyone and promoted road safety.
The limited space for farreaching measures on the Zeeweg led to an innovative approach (dynamic public lighting), which, in practice, results in a more than 90% energy saving in comparison to conventional public lighting.

13.3 Road safety audit: alterations to the Maaswijkweg and construction of a multi-lane roundabout in Spijkenisse

Basic situation

The Maaswijkweg is a distributor road within the built-up area with two carriageways, each of which has two lanes. Vehicles travel at high speeds. There are crossing and turning points at four locations along the road, which cause conflicts and are the reason for wanting to reduce them in number. Both sides of the road have separate bicycle and moped paths and one side has a footpath. The lack of a footpath on the other side has led to conflicts and accidents between pedestrians walking on the bicycle path and mopeds/bicycles. A new side-road is required to connect to a residential care complex. A three-way junction (without traffic lights) will be replaced by a multi-lane roundabout (with four branches). The multi-lane roundabout will be a turbo roundabout with several two-lane exits. In the previous design, the intended new connection road was categorised as an access road.

Consequences

The crossability of the Maaswijkweg in Spijkenisse will change due to the removal of a number of crossing and turning points. The construction of a multi-lane roundabout will make it more difficult for non-motorised traffic to cross the road.

Road safety audit

Spijkenisse Municipal Council had a road safety audit carried out in the preliminary design phase, when details in the proposed design were still missing. In this phase, the road safety audit primarily focused on consistency in the development of the categorisation, on cross section, alignment, junction type and design, and on provisions for non-motorised traffic.

Process/approach

A consultancy organisation had the audit conducted by two auditors. The firm met the client, Spijkenisse Municipal Council, on several occasions. The audit report was then drawn up and the client was asked to include the findings in the final design. But the audit had an advisory status and the client was at liberty to disregard the findings even though in setting a road safety audit, the client should provide written arguments as to whether and how they will include the findings.

Audit results

The key findings were:

- The new connecting road was categorised as an access road while the others on the roundabout were categorised as distributor roads. In reality, every branch of a roundabout should have the same categorisation. The recommendation was to move the transfer from distributor road to access road to a point further from the roundabout.
- Construction of the missing footpath is good for road safety.
- Removing several crossing and turning points will promote safety.
- The roundabout will result in fewer accidents than the three-way intersection in the previous situation.
- The proposed turbo roundabout is safer than a normal two-lane roundabout.
- The final design requires extra attention for marking and signs because road users must choose their lanes well before the roundabout.
- Problems can occur at two-lane exits between cars leaving the roundabout and slow crossing traffic. Vehicles in the outside lane of the roundabout can actually screen the non-motorised traffic from vehicles in the inside lane. This is particularly important because the design assumes that crossing traffic has the right of way.
- The distance between the crossing and the roundabout carriageway is too short to have cars wait without hindering traffic on the roundabout.
- Moped riders have not yet transferred to the carriageway.
- Bus stops are not sufficiently developed to assess their safety.

Conclusion

It is important during an audit to discuss the issues that are relevant to the phase concerned, in this case the preliminary design. Observations concerning markings or public lighting must be raised in the next phase. An audit is intended to discover design flaws. The auditor must not provide concrete advice about alternatives – that is the designer's job. However, the auditor can suggest (general) solutions to the designer.

13.4 Designs and design flaws

Most road users behave with the best of intentions and a good design makes it possible to encourage these well-intended road users to behave appropriately.

A poor design is not easily rectified, especially not with makeshift measures. A good design speaks for itself. In this view, the introduction of all sorts of traffic technology, road signs and warnings means conceding that a poor design has been made.

The picture below illustrates this. The handle invites pulling and makes pushing seem illogical: a poor design therefore. The push sign does nothing to rectify this. The door mercilessly punishes inattentiveness or haste.

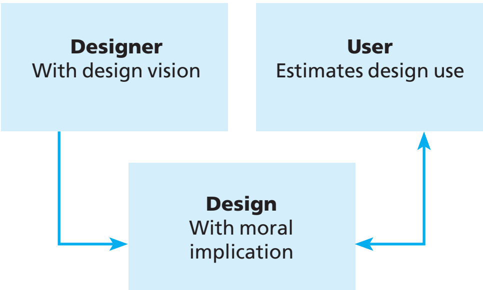
A designer's idea of an engineering structure often differs from that of a civil engineer.
A similar difference in the interpretation of the term design exists between urban planners and architects, who see a design as the result of a unique, creative, social process, and civil engineers, who are more likely to see a design as the practical result of a rational, technical, functional process.
When a design is successful, the civil engineer will be inclined to copy it in other situations, while urban planners and architects will be inclined to create new designs.

Views

There are various ways of looking at a design. The design of a public space may be subject to a number of different interests:

- aesthetic: whenever aesthetics predominate, life becomes more attractive but not necessarily more comfortable;
- functional: whenever functionality predominates, life becomes easier but also sometimes less attractive;
- beauty (relatively speaking): the strong and weak points in the design of one object in comparison to another similar object;
- trendy/contemporary versus timeless: with the aside that a modern design becomes naturally dated;
- financial considerations: whenever financial considerations predominate, a cheap design may ultimately prove to be more expensive.

There is also the question of the tension between creating and maintaining the design. Often, designs that were easy to make are not necessarily easy to maintain.



Seven design principles
The designer rarely if ever directly communicates with the user. In the best-case scenario, communication between the designer and the user goes through the design.
Every design holds a moral judgement about how public space should be used. This moral judgement is inherent to every design. Along the same lines is the question: 'What constitutes use and misuse of a design?'
The design can be used in an attempt to 'block' the use of public space – to completely control it. Use can also be left completely open, as is the case with Shared Space.

Designers must keep seven principles in mind if their designs are to be used effectively:

1 Users must be able to use their knowledge of the environment.
2 The design must be clear to the user (and should allow itself to be interpreted correctly by the user).
3 Simplify the structure that underlies the tasks and focus on the essential tasks in good time.
4 Cultivate the existing preconditions and limitations, irrespective of whether they are natural or artificial.
5 Make everything visible and tangible, especially during the step from action to evaluation.
6 Design for error. Making mistakes is often seen as something done by people who have insufficient training or motivation. However, in reality, everyone makes mistakes. In well-organised and complex situations, the most diligent and conscientious people are often the ones who make mistakes. Mistakes should, therefore, be considered as signs that the system needs to be improved and made as foolproof as possible. Mistakes must not be considered a question of guilt. In concrete terms, this means that the designer:
   - must understand what the cause of the mistake is and minimise it.
   - must ensure that actions can be reversed and undone and that irreversible actions are discouraged.
   - must ensure that users can easily discover what the mistake is and that they can easily correct it.
   - must change his attitude towards mistakes and try to see the user of the design as someone who is also trying to carry out a task on the basis of assumptions that are not always correct. The flawed actions of the user are therefore attempts to do something on the basis of the wrong assumptions or incomplete or misleading information that can be attributed to the system rather than the user. If someone makes a mistake, there is generally a good

reason for it. Therefore, rather than denying and punishing mistakes, designers should make it possible to make them!

7 If everything else fails, the correct actions of the user must be standardised and the users trained [13.1].

The creation and assessment of a good design demands experience. In addition to limited staff and insufficient design experience, time pressure can also be a cause of design flaws. Bringing in specialists and some form of quality assurance can prevent a significant number of mistakes in the design.

13.5 Tiel Station

Construction work on Passewaaij, a new residential area in Tiel, started in the late 1980s. This estate has been developed according to the 'Houten model' with eight neighbourhoods around a central area. These neighbourhoods are separated by a radial network of bicycle paths, while cars have separate access via the ring road, which is a distributor road. In addition to space for bicycles and cars, an important requirement for Passewaaij was a good connection with the public transport system. Passewaaij Station opened in 2007, creating a direct rail link to Utrecht and Arnhem.

Basic situation

The site is not immediately suited to building a railway station. In addition to the customary procedures of making a site ready for public transport provisions, a connection also has to be made to the surrounding area. There are no suitable crossing points for cyclists and pedestrians.

Due to the presence of green verges with waterways and a playground on the other side of the ring road, the crossing point must be also be suitable for children. Moreover, an old narrow road parallel to the railway line must become the access route to the car park. In addition, part of the bicycle route that comes from the outlying area and runs parallel to the railway line is missing and, according to the zoning plan, should link up with the old road. As a result of this missing section, cyclists sometimes cycle on the distributor road. This route has not been redeveloped because the

municipal council does not own the land. It goes without saying that no expensive infrastructure will be created if there is no call for it. But now was the time to fit the station development into the existing infrastructure. It was also the perfect moment to fit in all sorts of other smaller scale projects that had arisen over the years, such as the playground that was built in the area between the railway line and the ring road, and the crossings of the ring road. Another key point was the completion of the bicycle route along the railway line. Acquisition and possible expropriation of land is usually a drastic occurrence and is carried out only in the event of a problem or if the opportunity presents itself.

To date, the residential area did have an alternative route, albeit one with a detour.

The following objectives applied:

- Clarify that the development of the area is an integrated issue involving various disciplines. In addition to the customary traffic engineering, civil engineering and urban planning perspectives, residents, the play function and youth care also imposed requirements.
- Establish that a growing neighbourhood sometimes develops beyond its intended confines, but that there are always solutions for a liveable and (traffic) safe neighbourhood.
- Show that the construction of the station (primary aim) will provide opportunities to create a practical public transport space and to combine it with the play function and a safe crossing/connection point for cyclists and pedestrians.
- Confirm that the road safety prize awarded by the province of Gelderland in 1993 is still applicable and that Passewaaij is still ‘an example to other municipal councils’.

A project leader was appointed whose primary task was to build the station in collaboration with ProRail (the railway agency). For the spatial design, a flexible working party, the Public Space Consultative Body (PSCB), was set up within the council comprising representatives of the required disciplines from the council’s Urban Management Department. Experts in urban planning, play areas and applied art also served on the PSCB.

The basic principle from a traffic engineering perspective was the realisation of a small railway station with approximately 75 parking spaces, bicycle storage and kiss&ride provisions. Additional requirements were that the station had to be a pleasant, traffic safe location that fitted with the new residential area and that there was a road to the station that was suitable for everyone going to the station and the surrounding area. Furthermore, the large, attractive trees were to be maintained and water storage needed to be added.

Results
The station was eventually built. The bicycle parking facility was located between the access road and the railway line. The road to the bicycle parking facility and the car park was constructed as a narrow road with passing places. This prevented cars from being parked along the road, which could have caused passing problems. At the same time, this also meant that speeds had to be reduced, which was also beneficial to road safety.
The forecourt and the 75 parking spaces are on the same level. However, the car park is clearly marked so that it is obvious where cars should be parked and where they should drive. Space was used efficiently to ensure that a playing field and a water storage facility were also created.
The ambience of the forecourt matches the allure of the new residential area. The square was built using a yellow clinker. No bicycle path or footpath adjacent to the car park was constructed. The separation of traffic would be at the expense of the play area, which was already substantially smaller as a result of the car park. This is the reason that the forecourt was constructed in accordance with the principles of Shared Space, which means that everyone is forced to take everyone else into consideration. The station area was categorised as a 30 km/h zone.
A well-lit crossing point for cyclists and pedestrians was constructed over the ring road. There is also a bus stop. The crossing is continued with a line that guides the visually impaired to the station. A separate footpath for this group was never considered – they, too, share the space. The area is even designed so that it can be used for other activities when empty of cars.

In the end, a bicycle path was constructed parallel to the railway line without the need to expropriate any land. The path was built on ProRail land and equipped with a safety barrier between it and the railway.

Conclusion

- When developing this type of area, it is important to take the needs of everyone in the area into consideration. People should not be afraid of combining functions, but conditions should be created in which this can be done safely.
- The expert must also be an integral advisor. Synthesis is more important than compromise.
- The realisation of new projects offers the opportunity to improve the existing environment. Examples in this case include the linking of the crossing with the construction of the area in front of the station and the bus stop and the construction of the bicycle path parallel to the railway line.
- Essential consultation meetings can be used to draw attention to key side issues.

13.6 Goilberdingen, Culemborg

The Goilberdingen district in Culemborg was built in the late 1980s. To reduce the shortages in the operating budget at the outset of the project, then urban architect Joost Vahl opted for a simple plan.

Design of the residential area

An optimum amount of land available for allocation was created by having parking spaces on each plot and having a street width of only 5 m from garden to garden. A dense grid of continuous paths and streets runs from north to south and east to west. The wider lanes and avenues create defined areas. Roads and pavements are constructed on the same level and every intersection and back path has a speed hump or raised section. Back paths are marked with a lamppost and a fence. The entire area is subject to a 30 km/h speed limit.

The Luthulisingel cuts through the area. Along this street sheep have been introduced to keep the grass short. Their pasture is dissected by two roads, both of which have been equipped with cattle grids.

Culemborg Municipal Council: 'We tried to design an area that functions effectively in a number of ways: social, (traffic) safe, environmentally friendly, liveable. The entire area must radiate the fact that people reside there, live there and play there. We tried to strengthen that image in a number of details:
narrow streets, green boulevards, grazing sheep, limited number of cars parked on the streets. These signals were designed to influence how motorists behave. The speed humps are a side issue, extra insurance. The advantage of individual parking spaces is that you create a tranquil streetscape. However, they are not compulsory. While working reasonably well, they are not perfect. People still park on the street, even though this is less than in other districts. The boundary between the residential area and surrounding area is a soft one. The lines of the surrounding landscape extend into the estate and it is easy to walk or cycle into the neighbouring meadowlands without having to cross a busy road first. In terms of traffic, our basic idea was that we wanted to avoid a radical separation of traffic types. We tried to distribute traffic volume as much as possible rather than concentrate it on a set number of roads.'

It is both unique and normal that there was no attempt to create specific roads for traffic, even though the residential area has a general design with wider strips around the individual neighbourhoods and narrow continuous streets. The wider boulevards, avenues and bypasses, however, are created such that they form part of the residential environment. The streets have been designed in such a way that it is logical for people to be able to walk or cycle down the middle of the street. The use of the streets is not subject to any particular hierarchy.

Results

Culemborg Municipal Council: 'The area has proven to be very safe. Accidents are few and far between. However, research has shown that 40% of the residents in the estate do not think it is safe for children. Many people have the idea that a separate, raised pavement would be safer than having everything on one level: children could then play on the pavement while cars use the street. However, children do not stay on the pavement, while motorists more or less depend on this. This means that such a stringent separation ultimately leads to road unsafety. This is why we chose not to make a distinction between the pavement and the road. Motorists are then more aware that anything can happen and drive more carefully as a result.'

In principle, every road user can drive, cycle and walk everywhere. The layout of the area has been designed to be as friendly as possible. Everything points to the fact that people have to drive 'socially'. The dense network means that minor conflicts are possible everywhere and people must be aware at all times. It is neither safe nor unsafe. A dense network also means that the environment can be enjoyed because everything is immediately accessible.

Residents are mixed in their reactions to the traffic situation, especially with regard to children, but, ultimately, satisfaction prevails: 'At first glance, the traffic situation here appears to be somewhat chaotic and therefore unsafe. But people think twice before speeding, so it must work'.

Conclusion
The district has functioned for almost twenty years now and is generally experienced by residents as a pleasant place to live. This goes to show that there are principles other than Sustainable Safety that can solve problems, at least at the level of the residential area. Threatening factors for the future could be increased levels of parking if the individual parking space is too small to accommodate more than one car. If more cars are parked in the street, the area becomes more cluttered and therefore more unsafe.

The feeling that there is road unsafety on the streets can be reduced in part by officially labelling the area as a whole as a home zone with the accompanying lower speed limits (walking pace, that is maximum 15 km/h) and a ban on random parking.
Pavements are not suitable here and should not be constructed. However, a car-free area could be more explicitly created on wider roads by the careful placement of various street furniture, such as trees, bicycle stands and benches, so that people can walk along them unconcerned [13.2, 13.3].

13.7 Sustainable Safety in an area of cultural and historical value

Aim
The exclusive residential district in northwest Hilversum has unique architectural, scenic and cultural-historical qualities that must be retained and, where possible, strengthened. The quality of the area is especially found in the relationship between the buildings, the public space and the green areas. It is this relationship that gives the district its status. In terms of their design and history, the parks and villas have a clear cohesion. Retaining and, where possible, strengthening this cohesion was the primary aim in the vision developed for the area. The area was awarded conservation status in 2002 based on its scenic and cultural-historical qualities.

Basic situation

The public space in the area consists primarily of avenues. Squares and parks are only present in limited quantities. The carriageway on the avenues is generally narrow (between four and six metres) and laid in asphalt throughout. The intersections are largely spacious to very spacious in terms of design. The verges are wide and unpaved. While there are very few footpaths, informal paths sometimes wind along the verge.

The spatial outlook for the area states that the continuous character of the avenues is under pressure as a result of increased parking demands on the verges within the area and that the redevelopment of the avenues can signify an important improvement in quality for the area. Quality improvement is especially possible by restoring the visually dominant locations such as vistas, parks and intersections. The street profile must ensure that the public space of the road flows via the verges into the gardens, thus restoring its park-like character. The green appearance of the verges must be restored and strengthened, integrating entry roads and parking solutions.

There is a short cut through the district, but because both sides need to remain accessible, it is difficult to discourage the use of this route. The district has primary and secondary schools, day-care centres and schools for special-needs children, to which a large number of children are transported by minibus.

In its traffic circulation plan and road categorisation plan, the local authority opted for a system consisting of an inner ring, an outer ring and a number of radials from the inner to the outer ring (spider's web model). These main roads have the status of distributor roads; all other roads are classified as access roads.

There are few accidents despite motorists travelling at relatively high speeds in the neighbourhood, (V_{85} exceeds 50 km/h in multiple avenues). Any accidents that do occur happen primarily at intersections, particularly at the large intersections where motorists have a tendency to 'meander'. With the exception of a few intersections, the need for radical intervention on the grounds of road safety cannot be justified.

Preconditions

A number of preconditions have been formulated in order to turn a conservation area into a traffic-calm area. These preconditions, however, are difficult to combine with the basic principles of Sustainable Safety:

- Avenues and intersections must retain their character, road safety measures must be primarily sought in area-based solutions.
- Avenues must not be equipped with elements that disturb the visual balance such as speed bumps, axis variations or narrowing of the road.
- The amount of material for the verges must be reduced to those standard materials that fit the area.
- The green character of the verges must be restored, which means that cars must no longer be permitted to park on the verges.

Results

These preconditions have led to the following solutions:

- The entire area is a 30 km/h zone.
- While every connection from the area to the main road network is implemented as an exit construction, the area itself has no traffic-reducing measures.
- A zonal parking ban was established for the verges in the entire district. Speed on the avenues will be reduced by transferring parking to the carriageway.
- Green traffic islands have been introduced at a number of large intersections on the short-cut.
- In order to accommodate vehicles dropping off and collecting the children from a number of schools, special parking provisions have been introduced on the verge that minimise disruption to their green character.
- All wooden, metal, concrete and plastic posts, often erected by private parties to stop people parking on the verges, have been removed. The decision not to erect replacement alternative anti-parking measures is due to the fact that the council would first like to find out where the no-parking rule is being ignored. This is why a considerable sum has been set aside to take any necessary additional measures after the evaluation is complete.

Evaluation and adjustments

The measures were evaluated after a certain period of time. Several adjustments were made on the basis of this evaluation. The evaluation showed that the parking ban for the verges was reasonably effective. In those areas where this was not the case, low green fences were erected along the roadside. In a number of places, additional parking spaces were added to the verge. Moreover, a stopping ban for one side of the street was put in place in several narrower avenues because parking on both sides of the road was hindering the traffic flow.

At one of the largest intersections, the shrubbery on the central traffic island was removed and the entire intersection changed into two small T-junctions. The remaining space was arranged with shrubbery so that both T-junctions are now surrounded by greenery yet still clearly visible.

Parking on the carriageway did not lead to a significant reduction in speed. Partly on account of the extremely low accident statistics prior to the renovation, it is only possible to record whether the number of accidents in the neighbourhood was actually reduced over a longer period of time.

The minimal reduction in speed necessitated the construction of an elevated crossing at a school along the short cut.

13.8 Road safety on industrial estates

Problems

Industrial estates form a tricky part of the urban structure and demand customisation. Industrial estates vary significantly, from harbour areas to small-scale business parks with a mixed function. They are all generally subject to substantial amounts of heavy goods vehicles and delivery traffic and the infrastructure is often spaciously designed with large, straight road sections. Bicycle paths are not always present and when they are, they are not continuous on account of the large number of wide exit constructions.

A 30 km/h zone, which is reasonably self-enforcing, is, in reality, difficult to realise on an industrial estate, depending on the environment and how the estate has been designed. The application of all sorts of standard traffic engineering measures (such as those employed in residential areas) is barely possible, if at all. At best, adapted measures can be applied, particularly at intersections.

Possible solutions

A number of possibilities exist to tackle road safety on industrial estates.

Sustainable Safety design

There are developments that can be used to consider re-designing an industrial estate in accordance with the principles of Sustainable Safety: new developments, standard maintenance, large-scale maintenance or revitalisation. A reprofiling of the industrial estate (a transformation to other functions) can also be a good reason.

The steps that are then required are:

- inventory of the area's characteristics;
- inventory of the infrastructure use;
- formulation of ideals;
- categorisation of the road network;
- formulation of a package of measures to achieve a Sustainable Safety design.

Points of special attention are:

- For new industrial estates: the choice of location and the accompanying approach roads: these should be as short as possible and suitable for heavy goods vehicles. It goes without saying that they should be connected to the existing quality network for goods vehicles.
- The design. It is also possible to find logical starting points for road safety measures on industrial estates. The problem is that there are rarely any acceptable measures against speeding. A second problem is that heavy goods vehicles can also cause serious conflicts with other road users even when travelling slowly.
- Mixed functions. For example, entrepreneurs who have their houses on the industrial estate as well. This can result in conflicts between vulnerable road users and heavy goods vehicles. The combination of activity with heavy goods traffic on the one hand and activities that attract a lot of visitors on the other (such as wholesalers, hypermarkets, garden centres and do-it-yourself stores) also creates conflicts. In instances where this type of functional mixing is unavoidable, clever planning of the functions and the creation of separated routes (for heavy goods vehicles and for vulnerable road users) will help to prevent serious accidents, which is beneficial to both parties.

Safety Scan
The Safety Scan was developed by the Ministry of Transport, Public Works and Water Management in association with industry organisations for road transport and haulage. This simple analysis instrument on a cd-rom tells hauliers and drivers how they can reduce the risk of accidents and damage. The Safety Scan can be used by all entrepreneurs with lorries and/or delivery vans and can contribute to businesses implementing an active and deliberate road safety policy.

Based on questions regarding the organisation, the drivers and the vehicles, the scan provides feedback on an entrepreneur's safety policy, offering insight into the strengths and weaknesses of that policy. At the same time, the Safety Scan provides customised advice and practical improvement measures. While it is well-suited to the aim of making business culture more traffic safe, little is known about the practical experiences that businesses have had with the scan.

Involving all parties
If the industrial estate is subject to park management, this is an excellent initial point of contact for the municipal council to start working on road safety throughout the estate, otherwise each individual company would have to be approached and a representative working party would have to be set up for the estate. It should be noted that it is often the most demanding rather than the average company that is representative. Effective road safety policy requires more than a viaduct under which the average lorry can pass.
A quality network for goods vehicles can also be an effective means of stimulating the debate on road safety.

Conclusion
There are different ways to consider the improvement of road safety on industrial estates: in terms of infrastructure and environment and in terms of safety culture within the companies present. Customisation is a prerequisite, irrespective of the approach taken. In addition, the interests of the entrepreneur must be taken seriously and creating a good relationship is a must. The lack of any balance of power means that the concessions and compromises can be beneficial to this end [13.4].

13.9 Behavioural observations at bus lanes and intersections

Effective and reliable public transport is one of the methods to help solve the increasing urban traffic problem. However, the limited flow of motorised traffic makes it particularly difficult for bus drivers to keep to their time schedules, which is why more and more municipal councils are turning to bus lanes to solve the problem. In reality, the construction of bus lanes at intersections is sometimes problematic in terms of how other road users perceive the situation. CROW publication 224 'Guidelines for the construction of bus lanes' [13.5] provides guidelines that enable the creation of responsible solutions in difficult situations. A recently conducted behavioural observation study clearly illustrates the problems that sometimes arise when constructing bus lanes at intersections [13.6]. The findings of this study could contribute to the way in which new designs are made. A number of examples taken from this study are outlined below.

The first situation involves a large-scale intersection with traffic lights, which, in addition to a right-turn-off lane, two through lanes and a left-turn-off lane, also features a separate bus lane to give priority in the traffic light control system to buses turning right (see photo 13.1, the buslane is indicated with B). Traffic that wants to turn left from the side road (bottom of the picture) is confronted with a very wide carriageway with the possibility that motorists turn left too early and drive into the lane on which the approaching traffic is travelling. During a 22-month video observation period, this manoeuvre occurred 6 times. Widening the first carriageway with a bus lane can invite motorists turning left to drive into that lane; specific attention must be paid to this aspect during the design of such intersections.

Photo 13.1. Motorists can turn left too early and drive against oncoming traffic

The opposite is also possible, namely that a bus lane is seen as a second carriageway and invites motorists to drive onto it. Once this idea has taken root (rule-based behaviour, see chapter 1), it is very difficult to change the road user's mind about it. See photo 13.2. At an intersection with traffic lights, motorists are required to turn left before the blue sign with wide arrow (all drivers must follow the arrow on the sign). The sign is located in the expected place, but rather than pointing in the direction that motorists expect, the arrow is pointing left. The dual-direction bus lane beyond the sign looks like a second carriageway, however, and motorists would, normally speaking, turn left after the central reservation. This situation has regularly resulted in unwitting road users driving onto the bus lane. In addition, the arrow sign that left-turning motorists expect to see while waiting at traffic lights is located too far to the left (see photo 13.3).

Erroneous left-turn manoeuvres can be prevented by:
- making the bus lane more recognisable for crossing traffic (by having the text 'bus' painted on the intersection, for instance);
- placing the information that motorists have to turn left before the bus lane (that must look less like a normal carriageway) in a location where motorists will see it more easily.

Photo 13.2. Bus lane can be seen as a second carriageway

Photo 13.3. Arrow sign is too far to the left

The next situation from the behavioural observation study also features a complex and large-scale intersection with traffic lights (photo 13.4 at A) where motorists regularly find themselves on the combined tram and bus lane (bottom left). These are either right-turning motorists in the opposite direction or left-turning traffic from the right. A different colour road surface would help to differentiate the tram/bus lane from the other lanes.

Photo 13.4. Motorists can find themselves on combined tram and bus lanes

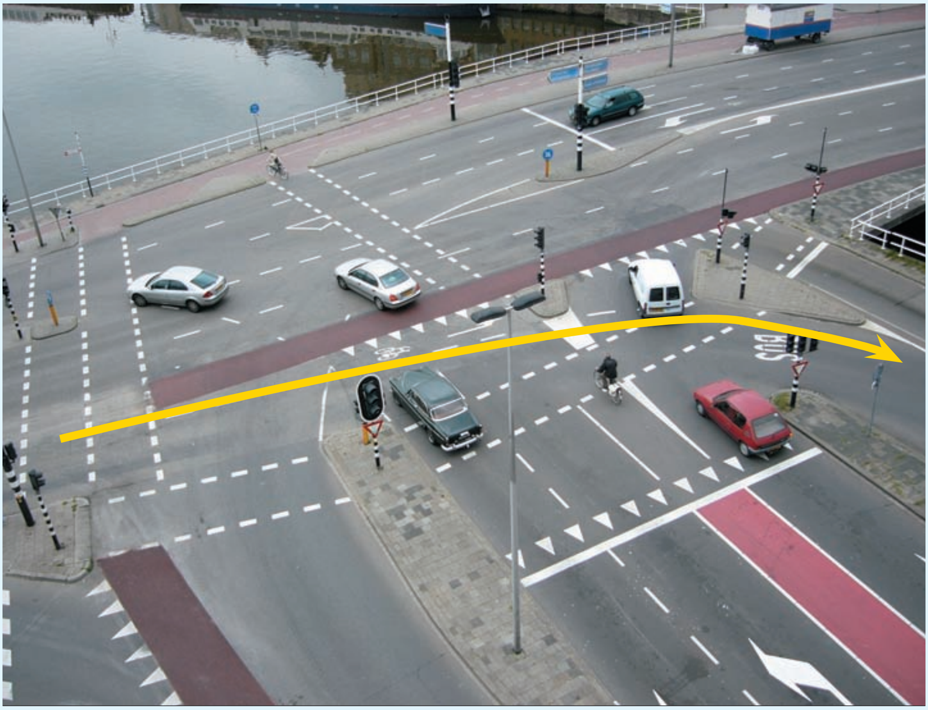


Photo 13.5. Bus lanes may be confusing to pedestrians

This third situation involves incorporating a bus lane on a T-junction with traffic lights (see the yellow line on the photo). The observation study showed that the design and marking of the bus lane that runs from left to right across the intersection (see also BUS on the road) may be confusing for pedestrians and cyclists. In combination with the relatively high speeds at which buses negotiate the intersection (40-50 km/h), this can result in serious conflicts. A different colour road surface would constitute an improvement in this case too.

13.10 Project to educate young motorists

Problem

Young people aged between 18 and 24 are involved in accidents more than any other group of motorists. Every year, approximately 2,700 drivers from this group are involved in accidents where someone is fatally injured or hospitalised. They are involved in more than 12% of serious accidents involving cars, while they only constitute 8% of motorists with driving licences.

Experience and age have a significant influence on accident involvement. A lack of risk detection and estimation are primarily the result of ‘experiential risk’. High risk acceptance stems primarily from overestimating capabilities, the need for excitement and to make an impression on their peers. This ‘age risk’ is most pronounced in younger, male motorists, who often go out in the weekend with their friends in the car, something that leads to various accidents and multiple fatalities every year. Alcohol is an added problem in this group because they are not as well conditioned to its effects.

Traditional solution

If a certain category of motorist is frequently involved in accidents, solutions are intuitively sought in better vehicle control. The reasoning goes that, if, for example, motorists in an emergency situation cannot stop in time, they have to learn to brake more effectively, which is why many road safety courses, including those for young people, focus on improving vehicle control.

However, such courses do not appear to yield any benefits. In fact, international research into anti-skid courses, for example, has shown that the skills someone is taught to deal with emergency situations often lead to more accidents [13.7]. This is explained in the inventory of learning objectives that was formulated by the KpVV (Traffic and Transport Knowledge Resource Centre) target groups [13.8]: ‘Many training courses heavily emphasise training technical skills. This type of training (also known as ‘skid training’) is often counter-productive in terms of road safety. It is more important to use road safety training to emphasise higher level skills (danger recognition, risk recognition and avoidance, et cetera), skills to avoid emergency situations (rather than providing training courses that give the illusion that such situations can be controlled) and to give the participants insight into the strengths and weaknesses of their own driving skills (and how to deal with them). It is important to choose a course where the emphasis is on higher level skills’. This clarifies what the most effective solution is: rather than teaching (extra) skills, concentrate on issues such as self-reflection, calibration and risk perception.

Effective solution

The best solution for young motorists, therefore, is a course aimed at inducing self-reflection and risk perception. The target group for such a course is made up of young motorists who have had their licences for approximately 6 months and the programme comprises:

- a short introduction in which the key theme of the programme is clarified (know your limitations, expect the unexpected).
- a road section on which participants are confronted with the lengthening of the braking zone on a wet surface at 50 km/h versus 30 km/h. This occurs by performing an emergency stop at this speed.
- a practice journey with three participants (drivers take turns) and their supervisor. Occasional stops are made and the driver is asked what was striking at that moment and why he dealt with the situation the way he did. The passengers are then asked for their assessment. The supervisor only gives his assessment at the end of the journey.
- a group discussion in which experiences with traffic and risks are exchanged. Alcohol and drugs are also discussed.

New skills are not taught. The instructors/supervisors take a very detached position: the course participants must convince each other because the peer group has more impact on the driver’s opinions and attitude than the ‘authority figure’.

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Parties involved
- (potential) course participants;
- their instructors/supervisors, who are given further training;
- the driving schools at which the (potential) participants are taught;
- local/regional governments;
- relevant ROV/province.

Funding
The funding of the organisation of the course and of the actual course itself (instructors, facilities) is split between the participants and subsidies from local and/or regional governments.

Communication
The course participants are approached at their home address through the driving school where they were taught. Governments and suchlike are approached through stands at road shows and by means of written material.

Co-ordination
Co-ordination (bringing together groups of participants and instructors, and organising the courses) is the responsibility of a (commercial) co-ordinator, who also takes care of recruitment and providing the instructors with further training.

Experiences
- The effects on accident involvement have yet to be studied. International studies have shown that while the results are not spectacular, they are reasonably favourable (in contrast to anti-skid courses, which have had an emphatically negative effect).
- Recruitment of participants demands substantial energy.
- Instructors/supervisors must be well supervised, particularly in the beginning, since they sometimes threaten to revert to their role as instructor: 'I will teach you to ...' rather than 'What did you think of ...'.
- Even the smallest impression that a new skill has been learned must be avoided. Several course participants said in the regular evaluations after emergency stops (which is only used to confront them with the increased braking distance at higher speed) that they had now learned to make an emergency stop, which, of course, completely defeats the purpose. The number of emergency stops per participant is, therefore, strictly limited to one for each speed.

13.11 Speed enforcement and communication on an 80 km/h road

This case is unique in that it involves a project that started twenty years ago and lasted five years. It features a number of interesting elements, but is primarily concerned with the criticism of contemporary, fully-automated speed enforcement that is both impersonal and anonymous. This results in financial sanctions rather than any feedback being provided concerning the undesirable behaviour: 'The fine is seen as nothing more than taxation, which does not lead to reform' [13.9].
The project took place on the N361 from Groningen to Lauwersoog via Winsum, which was then the S2. The 'S2 project' was fairly revolutionary: the police took a very high-profile position and paid significant attention to communication, including a letter to offenders.

Problems and objectives

The N361 is a provincial 80 km/h road. Almost every motorist on that road uses it several times a week or even a day. The road cuts through a number of built-up areas, which had experienced problems relating to both speeding and red light running at pedestrian crossings. This prompted the mayor of Winsum to form a project group in 1988 consisting of representatives of the municipalities of Adorp and Winsum (through which the N361 runs), the Province of Groningen (road authority), the Public prosecution service, the national police force and the Regional consultative body for road safety Groningen.

The project group set itself the task of improving the safety on the N361 through such measures as Focused traffic surveillance (FTS). That meant that the police focused on particular offences on certain roads; the type of offences that often lead to accidents on that road. As part of the FTS, the police also conducted systematic checks at different times and in different places along the road over an extended period of time, maximising the subjective probability of detection for the enforcement capacity provided.

The objectives of the project were set as follows: make users of the N361 aware of the road's problems and the Focused traffic surveillance project, as well as reduce speeds and the number of accidents on the road.

Project

The project was launched in October 1988 with enforcement as its primary component.

- Enforcement
  Focused traffic surveillance (focusing primarily on speed) on the N361 with emphasis on the section between Groningen and Winsum. Speed controls comprised marked radar controls at alternate locations and times, stopping as many vehicles as possible and overlapping motorcycle surveillance.
- Infrastructure measures
  Special stopping areas for offenders were introduced in five places. This was funded by the road authority and the two adjoining municipal councils. In a number of bends and at the T-junction near Ranum (intersection of the N363 and N361) trees and other shrubbery were planted to reduce the visibility through the bend. This led to improved visual guidance and the deterrence of dangerous overtaking manoeuvres.
- Information
  The project was given as much publicity as possible – a press conference at the outset, regular press releases on the results over the course of the project, and the road was lined with the Dutch traffic safety association poster 'Know your limit – 80'. Offenders who were stopped and fined received a letter from the police several days later, explaining that the offence for which they had been stopped on the N361 regularly leads to accidents and that this was why the police were being extra vigilant.

Results

Evaluations were continually carried out in the period between October and January. For each of these periods, an overview was made of police checks, speeds and accidents. The first time a fairly thorough process evaluation was conducted by means of a questionnaire that was handed out to motorists who were waiting at traffic lights in Adorp. The responses showed that the majority of road users had noticed the intensification of police checks and that they had driven slower as a consequence. The somewhat unconventional method of following up

Figure 13.1. Average speed on the N361 between 1988 and 1992

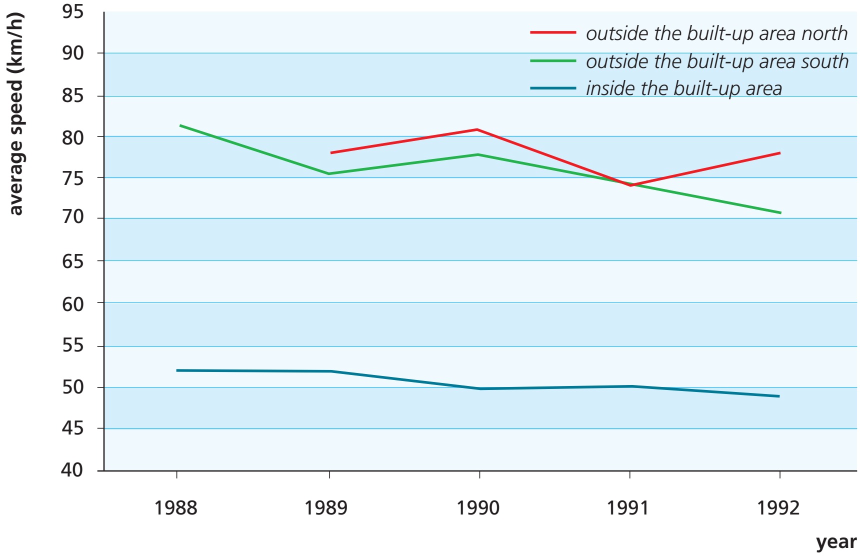
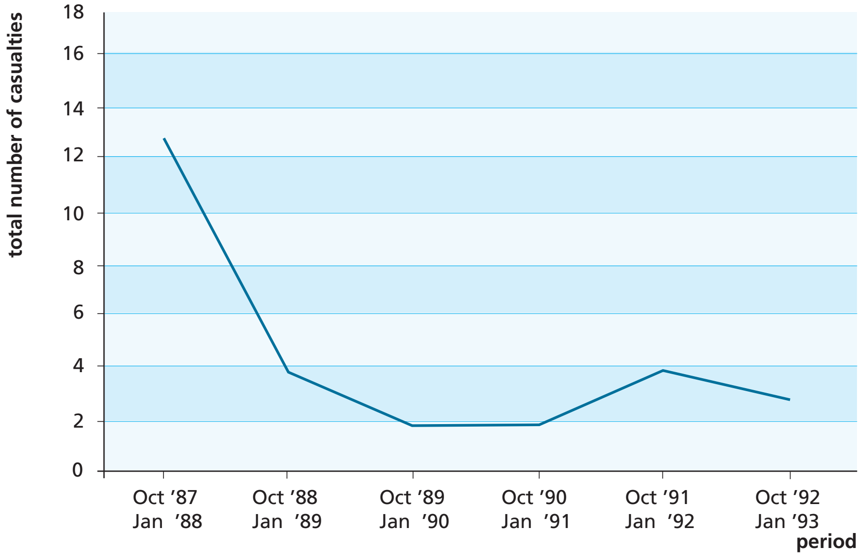


Figure 13.2. Total number of casualties in the evaluation period



a fine with a letter was seen as a success, in terms of both promoting the 'human face' of enforcement and stimulating safer traffic behaviour through the provision of information.

The frequency of police checks at the end of the project fell to an average of once a fortnight. The results in terms of speed and accidents are shown in figures 13.1 and 13.2 and table 13.1.

Table 13.1. Total number of accidents and casualties on the N361 during the project

	Oct. 87-Jan. 88	Oct. 88-Jan. 89	Oct. 89-Jan. 90	Oct. 90-Jan. 91	Oct. 91-Jan. 92	Oct. 92-Jan. 93
accidents within the built-up area	8	5	8	7	8	7
accidents outside the built-up area	14	11	9	8	10	11
total number of accidents	22	16	17	15	18	18
injuries	9	4	2	2	3	3
fatalities	4	0	0	0	1	0

After the project, far-reaching infrastructure measures were taken: within the framework of large-scale maintenance, the N361 was narrowed and the area boundaries visually improved.

Conclusion

The combination of enforcement and communication is an unconquerable duo, even if, in practice, communication could sometimes be intensified (by, for example, concentrating on the fines that offenders have to pay) as well as be more innovative. At the moment, it is sometimes too easy for regional enforcement projects to link up with the national 'The best way home' campaign (in which a spearhead such as speed has no place) [13.9, 13.10].

13.12 Section control system

Problem

Speed is a key risk factor in traffic. Higher speeds lead to an increased accident risk and more serious consequences in the event that an accident occurs, especially in more complex situations, such as within the built-up area or on distributor roads. Nevertheless, speed limits are frequently exceeded, with an average of 20% to 40% of all motorists doing so, regardless of the road type (figures from 2007).

In addition to road safety, speeding also has a direct, negative impact on the environment due to increased CO_2 emissions and noise pollution. One consequence of traffic accidents is that traffic jams build up, which then hinders traffic flow (also as a result of motorists slowing down to look at the accident). On very busy sections, such as the A2 and the A13, an accident almost always results in a traffic jam, making it difficult for the emergency services to reach the place where the accident occurred.

Solution

When influencing speeding behaviour, it is important that road design and traffic rules are logical and clear. Police surveillance is another means of influencing the speed at which motorists drive. Most road users will adhere to the speed limit if they consider the risk of being caught to be too high. This is the perceived probability of detection. However, a small group of motorists will always try to exceed the limit.

In recent years, tests have been carried out with a new enforcement system called section control, or average speed control. The Public prosecution service's bureau for traffic enforcement has allocated fourteen road sections for section control.

How it works

Section controls measure the average speeds over a longer distance. In principle, controls take place 24 hours a day, 7 days a week, meaning that there is a 100% probability of detection, which is in marked contrast to other enforcement instruments. Speed cameras, mobile radar controls and laser guns have the disadvantage that they only measure the speed at a single point. Because road users adapt their speed at the measuring point, these controls are easier to evade. Road users also think that it is fairer to be fined for an offence that was sustained over a longer distance than one that lasted a short time.

The section control on the Zeelandbrug has ensured that, in one year, the percentage of speeding offences has dropped from 20% to 1%.

Westerschelde tunnel

The Westerschelde tunnel links Zuid-Beveland with Zeeuws-Vlaanderen and has a speed limit of 100 km/h. The tunnel is 6.6 km long and sees daily traffic volumes of between 12,000 and 15,000 vehicles. Section control has been in operation here since December 2005.

The reason was that motorists regularly exceeded the tunnel's speed limit and extreme speeds in excess of 200 km/h were registered. High speeds in tunnels create life-threatening situations. In the event of an accident, traffic is brought to a complete standstill and emergency assistance is more difficult to provide due to the limited space. Since the tunnel was opened in 2003, ten accidents have occurred, resulting in one fatality and two serious injuries. After section control was introduced, this was reduced by 50% and any damage that did occur was mainly material. In 2007, only one accident occurred.

Due to the length of the tunnel, three gantries were placed: one above the tunnel entrance, another half-way through the tunnel and the final one at the exit. The system also continues to work even if maintenance or disaster causes only one tube to work.

Results

In 2005, only 54% of motorists adhered to the speed limit. The V_{90} was 120 km/h; 2.5% even exceeded 130 km/h. The average speed was 99.3 km/h. After section control was introduced, this picture changed dramatically. In 2006, 83% of motorists were sticking to the limit of 100 km/h, the V_{90} was 105 km/h and only 0.2% exceeded the maximum limit by 30 km/h or more. The average speed was now 94 km/h. 2007 saw the number of motorists exceeding the speed limit increase by 3% and the number of serious offences fall by 1%. In short: of all the enforcement instruments available, section control appears to be the most effective if you look at the probability of detection and the reduction in average speed.

Applicability of section control

For sections with a large number of exits or roads with an access function, the current system is far from foolproof and other enforcement instruments are used [13.11, 13.12, w13.1].

13.13 Reward project in the Gelderland-Midden police region

Project

In association with the Police academy, the Gelderland-Midden police region organised an enforcement project in the spring of 2007 in which, in addition to fines for offences, rewards were also handed out to motorists who behaved correctly. The aim of the project was to study whether the impact of enforcement could be improved through applying methods other than the classic enforcement methods. The project was part of a triple pilot scheme initiated by the Regional consultative body for road safety Gelderland. The approach focused on two areas of Arnhem, had motorists as the target group and concentrated on the spear-heads speed, drink driving and seat belt use.

The organisation

Over a period of eleven weeks, twelve checks were carried out on one or two spearheads. In the 260 man-hours that police spent on the project, more than 6,100 drivers were checked, 5,900 of whom drove correctly, with the other 235 receiving fines. Most offences involved speed (125). Apart from the specific themes of the project, almost forty other offences were recorded.

Of those who behaved correctly, every tenth driver had their registration number recorded and, within two weeks, they received a letter from the police explaining the reason for the letter and enclosing a lottery number, with which they could take part in a lottery and win one of fifteen prizes for correct traffic participation. At the end of the project, the police awarded the prizes during a well-attended meeting in the local sports centre.

communication

The project received attention in various media in the period before, during and after the controls. While the national and local media also reported on the project, the local newspapers followed the developments most closely. Radio and television were interested as well and the final awards ceremony was attended by the press.

Results

In order to record the project's impact, premeasurements and follow-up measurements needed to be taken. In the month prior to the project, four premeasurements were taken in the areas concerned and around 1,100 motorists were checked. Four months after the project ended, comparable measurements were taken in which more than 1,450 vehicles were checked. During the premeasurement phase, 84% of motorists complied with the speed limit; during the follow-up measurement, this percentage had risen to 93%.

A retrospective study showed that 45% of respondents were aware of the project. While the majority, particularly motorists up to the age of 55, were of the opinion that rewards were a good (or better) instrument to influence behaviour, a minority indicated that it had not prompted them to drive any more safely. Whether issuing rewards is the duty of the police is also debatable: the majority of young people felt this to be the case, while respondents over the age of 55 did not.

Conclusion

In general, it can be stated that enforcement is an instrument that stimulates compliance with the rules. The presence of police in a certain area has an impact and punishing offences serves to strengthen that effect. This project also showed that rewards, in combination with positive media attention, had a positive effect on compliance with traffic standards. Rewards in traffic also have a certain level of support, especially among relatively young road users. Although this project did not demonstrate the sustainability of the effect, it did show that rewards and punishments provide additional opportunities to realise sustainable compliance with legislation [13.3].

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Epilogue

Epilogue

E.1 A look into the future

Mobility in the year 2040 is clean, silent, smooth and safe. Far beyond the expectations of 2010, mobility in the first half of the 21st century has developed into a basic precondition for a dynamic and sustainable life. The renewed interest people have in encounters has led to an impulse to facilitate mobility.
Traffic has become cleaner because the internal combustion engine was finally done away with in 2028. The last petrol station along the A12 motorway is now in the Dutch National Mobility Museum. Fuel cells and batteries are the main energy sources for cars in 2040. The change in energy source for cars and their lower mass has led to more relaxed driving behaviour that is beneficial to road safety.
With hindsight, making built-in road environment scanners mandatory in 2012 has been an incredibly insightful idea. If vehicles are too close to each other, the system limits the driver's freedom of movement. The number of serious accidents has significantly decreased since then.
Traffic information providers in 2040 can predict travel time and travel cost, some even to an accuracy of 0.5 percent. Decisions to be at a certain place at a certain time are made consciously. Since the end of the 2020s, traffic information providers have further improved the traffic flow.
Demographic developments have led to an impulse to gear infrastructure to the information processing skills of the elderly. What is right for the elderly is right for all other road users. Since 2010, insurance companies have gradually turned their thoughts more intensively to the driving skills of motorists.
A different perception of risks, including their anticipation, has led to an unprecedented change in mobility culture.

A lot has changed. The three Sustainable Safety road categories have made way for continuous dynamic speed limits, everywhere and all the time. Traffic could proceed faster, but should often go slower. Depending on the spatial situation and the traffic engineering design, the appropriate speed limit for a certain type of transport is continuously calculated. In case of extreme weather conditions, speed limits are adapted accordingly.
The formula for these calculations is based on aspects such as mass, resilience, and collision-friendliness on the one hand, and on manoeuvrability, braking efficiency, active safety, and ITS on the other. If someone cannot drive fast safely, he will drive safely at a lower speed… and other road users will adjust their speed accordingly. Personal safety is just as important as the safety of others and vice versa.
Road users themselves can indicate their own physical resilience, and if things still go wrong: the elderly are less resilient than the young. It stands to reason that vehicles with an extremely pedestrian-friendly front are allowed to drive faster than vehicles for which only the passive safety of the vehicle's driver/passengers has been taken into account.

In 2040, the risks road users were forced to take at the beginning of the century are unimaginable. In particular, the fact that all kinds of safety measures were focused on drivers/passengers but that playing children were responsible for their own safety is a thing of the very distant past...

E.2 The Netherlands: one of the safest countries in terms of road safety

This 'Road safety manual' discusses today's world and the measures currently being used to guarantee road safety. At the time of writing, the Netherlands is one of the safest countries in the world. In the last decades, considerable effort has been put into gaining that position. That said, the Netherlands has to keep working hard to stay at the top.

It should be clear that in spite of being in the lead, the aforementioned situation of 2040 will not be easy to achieve. After all, there will be constant developments that change the traffic system, developments that are sometimes positive and sometimes negative. It is important to respond adequately to such developments. Moreover, possibilities for making roads safer have by no means been exhausted. Sometimes small changes are possible, and at other times big changes; some can be carried out quickly while others demand patience.

E.3 Developments, as tasks for road safety experts

Some matters, such as socio-economic developments, cannot be influenced. They determine the demand side of traffic and transport and determine or co-determine road safety. The following are a few social, socio-economic, and cultural developments that are relevant for road safety [E.1]:

- Because society has become more intense, sleeping problems and fatigue are increasing, which, in turn, increases the risk of accidents. Stress and similar factors can lead to more aggressive driving behaviour and recklessness and road unsafety (higher speeds, shorter vehicle spacing, overtaking on the right).
- In certain traffic situations, individual behaviour leads to accidents if a road user's own interest prevails over that of other road users. Because of the more informal interaction between people, they do not automatically comply with traffic legislation and there is less tolerance of authorities. Modern citizens can increasingly be characterised as inconsistent: they may complain about the 'stupendous amount of rules' imposed by the government, but also about the lack of enforcement of legislation by that same government.
- The increase in lorries and delivery vans leads to an increase in casualties because of the incompatibility of these vehicles compared to vehicles in lighter categories.
- Continued individualisation leads to preference for vehicles that are safer for the driver/passengers but less safe for other road users. All-terrain vehicles, such as SUVs, are a case in point.
- Parking problems are getting worse due to the rise in the number of cars per household because of the increase in double-income couples. Cars wrongly parked on street corners limit views, which can lead to unsafe situations for children on their way to school, in particular in residential streets and especially in older residential areas.
- Because of the ageing population, the number of car drivers aged 65 or over will rise dramatically between 2010 and 2030 and the number of casualties aged 75 or over will rise accordingly.
  Public transport with bad nationwide coverage encourages the elderly to continue driving long after the car stopped being safe. The use of special types of vehicles, such as

mobility scooters and single-seat cars with moped engines, will also increase.
- Children will increasingly grow up in a 'bring-by-car-culture'. They will learn less about how to travel independently and handle traffic, which means diminished skills in assessing traffic risks.

In the distant future, there will be new social, socio-economic and cultural developments all the time and it is up to the various authorities to anticipate them and respond with fitting measures.

E.4 Opportunities for a better infrastructure

In the short term, the infrastructure should be significantly improved; after all, a high level of road safety should be self-evident to the road authority. A comprehensive spatial design creates favourable preconditions for liveability and road safety. Furthermore, existing and missing links in the road system can be dealt with, either by making existing roads safer and improving junctions or by the inherently safe construction of new roads. Roads that turn out to have no significant traffic function can be given a new function that fits into the surrounding environment.

Much can be gained when designing residential areas. After 'quick' improvements to roads and streets, such as simpler designs of residential zones, future residential areas can take shape definitively and sustainably.
Traffic arteries and residential zones outside the built-up area derive their recognisability mainly from the implemented Essential Recognisability Characteristics, which represent the first step on the way to a safer road system. In the future, the following steps also need to be taken: reducing unwanted encounters between road users, improving verges, et cetera.

When developing new residential or business areas, road safety can be taken into account from the very start. By doing so, a minimum of traffic engineering will suffice in those areas and the means for achieving road safety can be implemented more effectively.

E.5 Opportunities for better vehicles

A different perspective on the future of road safety is that of technology. In the short term, vehicle technology can also contribute to solving problems with accessibility, liveability, and road safety. The large-scale introduction of ITS (Intelligent Transport Systems) in particular can play an important part. ITS is the umbrella term for Information and Communication Technology (ICT) in traffic and transportation. Furthermore, various driver assistance systems, usually referred to as ADAS (Advanced Driver Assistance Systems), can be applied more often. The manner in which these systems offer assistance varies significantly: from informing and warning to changing the speed, controlling and steering. These systems are being used in several pilot studies and tests to gain experience with their use.

ITS influences traffic flow, the environment, and most definitely also road safety. Important gains are being claimed in exploratory studies [E.2]. The estimated overall effect of ADAS is a decrease in the number of fatal accidents by 25-50%, depending on the extent to which the system is compulsory and the amount of vehicles equipped with ADAS.
The effect of Adaptive Cruise Control (ACC), which is already used in vehicles in the more up-scale market sector, is estimated at an 8% reduction of the number of accidents, if all vehicles were equipped with it.
Systems that help the driver keep the vehicle in lane (Lane Keeping Support, Lane Departure Warning Assistant) can prevent 24% of the single-vehicle accidents and 25-37% of the side collisions [E.2].

The elderly, in particular, will benefit from in-car driver assistance systems with emphasis on safely crossing junctions [E.3]. This is of additional significance given the expected increase in the number of elderly people as road users.

It can, of course, be expected that people will adapt their behaviour to new situations and take advantage of the opportunities such systems offer for activities that are not always related to road safety. In the past, road safety measures that were originally seen as positive were at least partly compensated by adapted behaviour of road users.

ITS is generally expected to constitute a large part of the intended improvement of road safety in the future (the next 20 years). The combination of intelligent in-car systems with roadside systems in the form of co-operative road-vehicle systems will yield the best results for road safety. This of course depends on the extent to which the implementation of those systems can count on the support of the population.

E.6 ...And opportunities for better people as well?

While people will always make mistakes, they are very capable of learning at the same time and are still in control of technology, even in complex situations. Nowadays, people grow up with motorised traffic and therefore are familiar with the dangers posed by traffic, which was certainly not the case in the 1970s, a time when the road unsafety reached its zenith.

Education and enforcement will develop in future years, becoming more efficient and effective. Education will be a more permanent fixture in people's lives. In terms of enforcement, much is still to be gained by automating simple tasks, such as speed enforcement, which will allow more leeway for enforcing more complex offences.

Even if people are taken as the measure of all things, even if everyone is taken into account, and even if the residential function in public spaces is optimally guaranteed, people and their behaviour will still be the weakest link in the traffic and transport system.
The fact that people make mistakes and will go on making mistakes in the future is the reason why the title of this section ends with a question mark.

E.7 Evolution and revolution

Interactions between people, vehicles and the surrounding environment will change in the longer term. The question is how such interactions will change and how fast they will take place.

It is apparent that much work still needs to be done to bring about significant changes in road safety, aside from whether or not the prognosis for 2040 will come true. This will sometimes entail continuous hard work, small steps taken everywhere and by everyone, forever perfecting things and evolving every day. Sometimes great efforts will bring about a revolution, a leap in the way people think. Sustainable Safety is such a revolution.
Evolution and revolution are both important for the end result: more safety and more freedom of movement.

Traffic will always be there (even if it is of a different kind), accidents will keep on happening, and road engineers will always have an inspiring job, based on two of the most fascinating confrontations imaginable:

- the confrontation between man and fellow man (and, not to forget, with themselves);
- the confrontation between man and technology.

Road safety is a field of expertise in which concrete results can be achieved with effort and enthusiasm. Better still, you can continually modify the objectives in that field. It is wonderful to be able to contribute to something like that.

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Questions and answers

Students can use the questions in this chapter to test their knowledge. No opinion questions have been included because they are more difficult to answer clearly. Any opinion questions can be dealt with during face-to-face education.

The questions section is followed by a list of answers.

Questions

Introduction

1 Why is there a preference in the Netherlands for a preventive approach to road unsafety rather than a curative approach?
2 What forms of safety are relevant to traffic, transport and mobility?
3 Name two key differences in safety between the various modes of road/water transport on the one hand and rail/aviation on the other.
4 Name an example where the interests of road safety and accessibility are the same and one where they are in conflict.

Part 1

1 Theory

1.1 The unacceptability of the traffic risk is determined socially and politically. Name three influential factors.
1.2 Name the three measures for risk often used in practice to analyse a road unsafety.
1.3 What is the difference between objective and subjective road unsafety?
1.4 What is shown in a Haddon matrix?
1.5 Name each phase of Asmussen's phase model and indicate what each phase involves.
1.6 Name the five principles of Sustainable Safety.
1.7 Explain the basic thought behind a Sustainable Safety traffic system: 'Man as the measure of things', and name two characteristics of the human scale.
1.8 Describe the cycle of human information processing.

2 Developments and trends

2.1 The number of (registered) traffic fatalities tripled between 1950 and 1972, after which there was a noticeable decline. Describe the key measures in road safety taken between 1973 and the present that brought about this drop.
2.2 Describe road safety performance in the Netherlands in comparison with other countries in terms of the total number of traffic fatalities for every 100,000 inhabitants.
2.3 Are 'rich' countries tackling road safety any more effectively than 'poor' countries? If so, how?
2.4 Name four key trends that will influence road safety in the Netherlands in the coming years.
2.5 Traffic accidents have consequences. Name four social consequences of traffic accidents and explain exactly what they involve.

2.6 Describe which of these two measures is more useful in terms of preventing traffic accidents:
- keeping the level of mobility constant;
- making airbags compulsory in all cars.

3 Policy

3.1 In the period between 2008 and 2020, road safety policy will be based on the three cornerstones that have made the policy so successful in recent years. Describe these three cornerstones.

3.2 Why is collaboration in the field of road safety so important?

3.3 Policy is largely developed according to a cyclical process. Name the four key phases in this policy cycle.

4 Data collection and data analysis

4.1 Research into road safety requires information that describes the actual situation. Name the three principal data groups.

4.2 Research into road safety requires information to explain or understand safety at a particular location. Name the four information types that are required.

4.3 Name the key source of information concerning accidents on the Dutch road network and indicate who administers it and how it is supplemented.

4.4 Ideally, accident registration should contain every accident that occurs on the public road network, but in reality, this is not the case. Name two causes for the incomplete nature of this registration.

4.5 Exposure to traffic can be expressed in different ways using statistics. Name the four types of data that provide the best indication of exposure to traffic.

4.6 How is a conflict defined in the DOCTOR method? What constitutes a critical traffic situation?

4.7 Describe the difference between a nominal measurement level and an ordinal measurement level and provide an example for each.

4.8 When is a random sample representative?

5 Practical research

5.1 Applied practical research studies a (safety) problem for which a solution is required. Often, a particular problem is tackled by looking for a solution without knowing what the cause of the problem is. Which approach prevents this situation from arising?

5.2 Describe the key steps when going through the analysis process of the AVOC method.

5.3 Name the key difference between a road safety audit and a road safety inspection.

5.4 Name two methods used to understand the concept of subjective road unsafety.

Part 2

Introduction: Making traffic safer

1 Describe the 3 Es of behavioural influence and indicate the importance of the cohesion between them.

2 Describe the relationship between the 3 Es and the 3 Ps. Also explain what the 3 Ps stand for.

6 Spatial planning and the road environment

6.1 Roughly outline the six phases in the decentralised planning process.

6.2 Given current design methodology for new housing estates, three general structures/archetypes can be distinguished. Describe these structures and name a disadvantage of each.

6.3 Describe the Sustainable Safety road categories.

6.4 There are various ways to create a project group and, with it, the formal co-operation between spatial disciplines and traffic. Name three recommendations for formal co-operation between these disciplines.

6.5 The binding factor between the spatial and traffic engineering disciplines are the end users (residents). If new plans are being developed for an existing estate, different forms of resident participation are possible. What are they?

6.6 What are the advantages of resident participation in the planning process?

7 Infrastructure

7.1 Name five of the twelve functional requirements (the attribution of functions to roads and their design) that road networks designed in accordance with the principles of Sustainable Safety must meet.

7.2 Road infrastructure must meet statutory provisions and regulations. Name the key provisions and regulations.

7.3 Why is categorisation of the road network so important within Sustainable Safety?

7.4 Make a table in which the Sustainable Safety road categories are functionally divided into road sections and intersections.

7.5 Essential recognisability characteristics have been formulated to recognise the difference between the various road categories. Which two recognisability characteristics are dominant in the differentiation of the road categories?

7.6 Describe the road types distinguished for each road category and state the road division per type.

7.7 What are ‘grey roads’? And why are they a problem for road authorities within current 30 or 60 km/h zones?

7.8 In the road network, an intersection constitutes discontinuity and, therefore, a potential hazard. There are five general design requirements for intersections at grade. What are they?

7.9 A road authority is considering the placement of a traffic light control system (VRI) at a priority intersection. What must the road authority take into consideration?

7.10 Infrastructure-related traffic measures are preferred to traffic signs. Explain why some infrastructure-related measures, such as a physical measure that limits accessibility to the road, also require traffic signs.

8 Vehicle safety

8.1 What is the difference between active and passive vehicle safety?

8.2 Name two new technological developments in the field of vehicle technology.

8.3 Name six parties that influence developments in vehicle technology.

8.4 Who ensures legislation for vehicle authorisation and who is responsible for implementing it?

9 Road safety education

9.1 What is meant by road safety education?

9.2 What does informal learning mean in road safety education?
Why is it so important?

9.3 The key aim of road safety education is to increase road safety. However, other aims are also possible, which have become ever more important in recent years. Name two aims of road safety education as included in a road safety education programme.

9.4 Name at least four basic principles for the development of learning objectives for road safety education programmes.

9.5 Name the four levels of the GDE matrix. At what level is the choice of an older motorist to leave after the morning rush hour? At what level is the choice to overtake? Which level is most important in terms of road safety?

9.6 Name the six target groups that can be distinguished within road safety education.

9.7 Name the five behavioural themes of ‘Advancing Sustainable Safety’. Are these themes in conflict with the target groups distinguished for road safety education?

10 Traffic enforcement

10.1 What is the difference between intrinsic and extrinsic motivation?

10.2 Explain why the introduction of the Traffic Regulations (Administrative Enforcement) Act (the Mulder Act) in 1993 made it possible to tackle the overburdening of the criminal justice system.

10.3 What is discussed during a tripartite consultation and what parties are involved?

10.4 Name three functional reasons why enforcement is communicated.

10.5 What are the five spearheads in traffic enforcement?

10.6 Explain why rewards must not be too substantial.

Part 3

11 Risk-enhancing behaviour in traffic

11.1 Explain why the blood alcohol concentration (BAC) was reduced to 0.2 g/l for novice drivers.

11.2 Name at least seven forms of risk-enhancing behaviour.

11.3 Explain why some forms of risk-enhancing behaviour are difficult to enforce.

12 Specific groups of road users

12.1 The age of road users can lead to an increased chance of involvement in a traffic accident for a number of reasons. Name three aspects that are related to this.

12.2 In recent years, the distribution in the mobility of children over the different modes of transport has changed significantly. Describe the distribution for the period 1994-2002 and the period after 2002.

12.3 Name two measures that are aimed at minimising the severity of injuries to children.

12.4 Name five causes for the fact that novice motorists (18-24 years old) have a more than four times greater chance of being involved in a serious traffic accident (with at least one fatality or hospitalisation) for every kilometre travelled than motorists aged between 30 and 59.

12.5 Name two reasons why lorries and delivery vans deserve attention in road safety policy.

Answers

Introduction

1 Prevention is better than cure. For ethical reasons, the preventive approach (that is the prevention of unsafe situations) is preferable to the curative approach (that is tackling a problem that appeared unsafe after the fact).
See also section I.4.1.

2 Road safety, external safety and social safety.
See also section I.4.2.

3 Example:
- Roads and waterways have grown historically. Road traffic was never designed with road safety as a criterion in the way that air traffic and railways were.
- For roads and waterways, individual freedom is a precondition; road safety must also be weighed up against other interests.
- For roads and waterways, personal requirements and educational requirements are less important than for air traffic and railways.
See also section I.4.3.

4 Accidents contribute to congestion and, in this sense, the interests of road safety and accessibility are equal. An example of a situation where there is a conflict of interests is the '2 seconds distance' rule on the motorway, which is good from a road safety perspective, but which would seriously undermine the capacity of the motorway and thus the accessibility if people adhered to it.
See also section I.4.3.

Part 1

1 Theory

1.1 The following six factors are of influence:
- the voluntary nature of participating in traffic;
- the catastrophic or chronic nature of the risk;
- the degree to which people can control the risk themselves;
- the degree of protection;
- the degree of familiarity with the risk;
- the assessment of the avoidability of risks.

See also section 1.1.1.

1.2 Three measures for risk often used in practice are:
- accident frequency: number of accidents per vehicle kilometre travelled;
- injury frequency: number of accidents with personal injury per vehicle kilometre travelled;
- accident density: number of accidents with personal injury per kilometre of road.

See also section 1.1.1.

1.3 An objective road unsafety is actually unsafe, while a subjective road unsafety is instinctive and therefore a question of perception.
See also section 1.1.2.

1.4 The Haddon matrix plots the system elements human factor, vehicle and road on the vertical axis and the crash phases precrash, crash and post-crash on the horizontal axis. By filling in the matrix for a certain accident, the factors that have contributed to that accident can be classified. The Haddon matrix shows that an accident never has just a single cause, but is always the result of a confluence of circumstances.
See also section 1.1.3.

1.5

Transport phase	*transport concept*
→ Traffic Phase	*traffic situation*
→ Encounter phase/conflict	*incident situation*
→ Crash phase	*accident situation*
→ Injury and damage phase	*injury situation*
→ Treatment and convalescence phase	*recovery situation*

See also section 1.1.3.

1.6 The five principles of Sustainable Safety are:
- Functionality of roads;
- Homogeneity of mass and/or speeds and direction;
- Predictability of road course and road user behaviour by a recognisable road design;
- Forgivingness of the environment and of road users;
- Road user's state of awareness.

See also section 1.1.4.

1.7 Sustainable Safety seeks to prevent (serious) crashes and, where this is not possible, eliminate the risk of serious injury wherever possible. In order to achieve the objectives of Sustainable Safety, man is taken as the measure of all things. After all, people are the linchpin in traffic and, moreover, a key cause of the road unsafety. The human scale is defined by two characteristics:
- people are physically vulnerable and therefore susceptible to injury;
- however well educated and motivated, people make mistakes and do not always follow the rules; as a result, people are a key cause of accidents. Sustainable Safety is aimed at reducing the chance of errors and traffic violations or dealing with their consequences by means of a road safety system that is designed on a human scale and by bridging the gaps therein.

See also section 1.1.4.

1.8 The cycle of human information processing comprises perception, assessment, decision and action.
See also sections 1.2.2 and 1.2.3.

2 Developments and trends

2.1 The various explanatory factors can be subdivided into three groups:

1 traffic planning measures;
2 road safety measures;
3 external factors.

Between 1973 and 1985, several of these traffic planning measures were taken, such as bundling traffic flows, target group lanes, separation of slow and fast-moving traffic. After 1985, relatively few fundamental planning measures were taken, save in the last few years: temporary overtaking bans for lorries and target group lanes. All these traffic planning measures resulted in a significant increase in road safety. The most important large-scale road safety measures that were taken in the 1970s were:

- the introduction of speed limits on all roads;
- the introduction of a maximum alcohol blood concentration;
- the compulsory use of helmets for moped riders;
- the compulsory use of seat belts for both driver and passenger;
- significant improvement in the crashworthiness of vehicles.

In the 1980s, the most concrete measures focused on police enforcement and included:

- the introduction of breath analysis as evidence for alcohol use;
- the possibility of issuing fines based on registration numbers;
- introduction of the Traffic Regulations (Administrative Enforcement) Act ('Mulder Act');
- the formulation of the spearhead policy, which focused on the most high-risk groups of road users.

Sustainable Safety was introduced in the late 1990s. By signing the Sustainable Safety Start-Up Programme, road authorities were obligated to implement the first series of measures towards the realisation of a Sustainable Safety system. The programme primarily focused on:

- distinguishing between traffic arteries and traffic-calmed areas;
- expansion of 30 km/h zones;
- expansion of 60 km/h zones outside the built-up area;
- right-of-way on traffic arteries;
- uniform right-of-way on roundabouts;
- mopeds on the carriageway;
- right-of-way for slow-moving traffic from the right.

There are several external factors that are not directly concerned with traffic but have an influence on road safety nonetheless. These factors – age, possession of a driving licence and collective learning – can explain long-term developments. See also sections 2.2.2 and 2.2.3.

2.2 The Netherlands is leading the field in terms of road safety. Road safety is one of the traffic engineering fields in which objectives are being achieved and even improved.
See also section 2.4.

2.3 Exposure in developed countries is higher than in developing countries due to the fact that there are more kilometres travelled in developed countries. The reason that safety is better in these countries is related to the accident ratio and the severity ratio: both the risk of an accident and the risk of being seriously injured in one are smaller, despite higher exposure. The consequence of the differences between developed and developing countries is that the latter require different types of measures with regard to road safety (and efficacy) than developed countries. See also section 2.4.

2.4 The trends are: ageing, increased passenger and goods transport, multicultural society, internationalisation, developments in technology and the changing relationship between citizens and government.
See also section 2.5.

2.5 The social costs of road unsafety are: medical costs, loss of production, immaterial costs, material costs, handling costs and congestion costs as a result of accidents.
- Medical costs are the result of the treatment of casualties, for example hospital costs, rehabilitation costs, medical costs and the costs of adjustments made for the disabled.
- The costs resulting from the loss of production stem from the temporary or permanent incapacity to work of those injured and killed in traffic accidents.
- Immaterial damage or 'human loss' relates to the loss of quality of life for casualties and their next-of-kin. These are 'costs' in the form of grief, pain, sorrow and the loss of enjoyment of life.
- Material costs are the result of damage to goods such as vehicles, freight, roads and road furniture.
- Handling costs are the result of dealing with accidents and the resultant damage caused to organisations such as the fire brigade, police, the judicial service and insurance companies.
- Congestion costs are the result of the time lost due to traffic congestion caused by an accident.
  See also section 2.3.

2.6 Keeping mobility at a constant level is the best measure. This targets the source and prevents an increase in the number of accidents. The second measure is only applicable after the accident has occurred and is standard for all new cars. Keeping mobility at a constant level means an annual decrease in the number of accidents.

3 Policy

3.1 The three cornerstones are: co-operation, an integrated approach and Sustainable Safety. Co-operation is sought not only within the world of road safety but outside it as well, with associations being formed with the education sector and, in terms of enforcement, with the police, judiciary and Public Prosecutor, including the collaboration within the local triumvirate (mayor, police and Public Prosecution Service). Countless social organisations also play a role in the implementation of policy.
See also section 3.2.1.

3.2 Co-operation between the various parties (or actors) is vital for road safety because policy and its implementation must be co-ordinated. Because road safety is a facet policy (road safety must be anchored in other policy fields), the activities must be co-ordinated so that the benefits can be optimised. Measures in terms of infrastructure, environment, education and enforcement can strengthen one another when they are used in conjunction.
See also section 3.2.

3.3 The policy cycle comprises preparation, decision-making, implementation, evaluation and monitoring.
See also section 3.4.

4 Data collection and data analysis

4.1 Irrespective of the type of research to be conducted, information is needed that describes the actual situation. In terms of road safety, this information usually comprises three principal data groups:
- number of accidents or casualties;
- exposure data or, in other words, the level of exposure to traffic (for example distance travelled in kilometres);
- risk data (for example accidents per billion vehicle kilometres).

See section 4.2.1.

4.2 In order to explain or understand road safety in any given location, more information is required, including:
- the way in which the traffic situation is organised (road design, road environment);
- which road users use this traffic situation (age, gender, experience);
- which vehicles are used (type and accessories);
- how the road users behave (speed, behaviour in terms of overtaking, behaviour in terms of right-of-way, use of crash helmets, et cetera).

See section 4.2.1.

4.3 By far the most important source of data concerning accidents on the Dutch road network is the Dutch Registered Accidents Database (BRON), which was created by the Ministry of Transport, Public Works and Water Management on the basis of registration forms supplied by the police. These registration forms provide concise information about the key characteristics of the accident and the road users involved.
See section 4.2.2.

4.4 The incomplete nature of registration is largely due to the fact that:
- the police are not always informed and, therefore, not always aware that an accident took place.
- the police do not always register and inform the Ministry about reported accidents.

See section 4.2.2.

4.5 Exposure to traffic can be expressed in different ways using statistics, based on either road users, vehicles, or means necessary for a vehicle to drive. The outcome varies and not every statistic gives an equally accurate image of the exposure. In practice, the choice of type of exposure data is often determined by the availability of statistics for the area, the roads or the type of road user to be analysed. While the types of data below can all be used as exposure statistics, the top four provide the best indication of exposure to traffic:
- kilometres travelled: the total number of kilometres travelled by individuals (as passengers or drivers);
- vehicle kilometres: the total number of kilometres travelled by vehicles;
- volume of traffic: the total number of vehicles that pass a certain place during a certain time;
- journeys: the total number of journeys made by people;
- vehicle numbers: the total number of vehicles in use;
- total number of residents in the region concerned;
- fuel consumption (can be linked to vehicle numbers).

The measure of exposure always provides a simplified representation of reality. The conversion of safety statistics in proportion to resident numbers, vehicle numbers, kilometres travelled provides information that is coloured from a particular perspective. The choice for a certain measure of exposure is therefore linked to the question that must be answered.
See also section 4.2.2.

4.6 The DOCTOR method defines a conflict as a critical traffic situation in which two (or more) road users approach each other in time and space to such an extent that there is a risk of collision and a real chance of physical injury or material damage if their direction and speed remain unchanged. Critical traffic situations are those in which the space available to manoeuvre

(to avoid one another) is smaller than the space that is necessary under normal circumstances.
See also section 4.2.3.

4.7 Variables that are measured at a nominal level are also called categorical variables. Measurements that relate to these variables consist solely of the division of research objects into different categories. One example of a categorical variable is the mode of transport with one of the following values: lorry, car, motorcycle, moped, bicycle, etc. When the data from a questionnaire are entered into a database, each category of this variable is given a number (for example lorry = 1, car = 2, motorcycle = 3), but these numbers do not have any significance. For example, it is impossible to say that a lorry (= 1) is smaller than a motorcycle (= 3), or that the difference between a motorcycle and a car (3 – 2 = 1) is the same as the difference between a car and a lorry (2 – 1 = 1). Nominal variables do not allow for the calculation of mean values.
An ordinal measurement level is created if the above-mentioned modes of transport are classified according to weight (0-100 kg, 100-500 kg, 500-1,500 kg; 1,500-5,000 kg; > 5,000 kg) and each class is given a number (1 to 5). The successive classes have a meaningful order. It is then possible to say that vehicles in class 1 are lighter than those in class 2 and that vehicles in class 5 are heavier than those in class 4. However, it is not true to say that the weight difference between vehicles in classes 1 and 2 is as big as those in classes 3 and 4. Ordinal measurements do not allow for the calculation of mean values either.
See also section 4.3.1.

4.8 A sample is representative if the characteristics of the objects or persons in the sample correspond with the characteristics of the objects or persons in the population about which a conclusion is to be drawn. A sample of Dutch motorists, for example, is sufficiently representative if the age division within the sample is equal to that of the entire population of Dutch motorists, with the same applying to the percentage of men and women. It would be even better if the annual kilometres travelled by each motorist, the use of the road network and the division throughout the provinces also corresponded.
See also section 4.2.3.

5 Practical research

5.1 This situation can be prevented by using the 'PCOSE' approach: a systematic approach to the solution through five phases: problem, cause, objective, solution and evaluation.
See also section 5.1.

5.2 It is vitally important that the common characteristics in the analysis (dominant accident types, formulation and testing of hypotheses, establishing causes and determining measures) are maintained throughout the research. Using the worksheets from the High-risk location approach manual is strongly recommended because these common characteristics are incorporated into them already.
See also section 5.3.1.

5.3 A road safety audit is primarily focused on the different design phases (feasibility study, preliminary design, final design) and is conducted in practice immediately prior to the opening of the road. The road safety inspection is focused on existing situations, in which the road network is regularly and systematically checked visually for deficiencies.
See also sections 5.2.2 and 5.3.6.

5.4 It is possible to gain an understanding of the concept of subjective road unsafety:
- by consulting with the end users through a complaints procedure;
- by conducting specific subjective experiential research;
- by approaching future inhabitants and users of a particular area at an early stage in the planning process. This constitutes consultation, but with future residents/users.

See also section 5.4.

Part 2

Introduction: Making traffic safer

1 Three categories of tools can influence human behaviour:
- Engineering
  The technical approach, 'the engineer's work', through the design of vehicle, road and road environment.
- Education
  Education generally means 'teaching and training'. Road safety education is the catchall concept for road user education, traffic or driving lessons and traffic information.
- Enforcement
  Enforcement refers to the formulation, publication and imposing of rules by the legislator or the police.

One E is not enough

With regard to traffic enforcement in particular, employing a single E is not always effective. Changes in road user behaviour (e.g. driving slower) can only be expected with any degree of certainty from infrastructure measures, i.e. engineering. Traffic enforcement should be planned together with education: people should know in advance that they can get caught if they do not abide by the rules. The effect of Enforcement is enhanced dramatically by information/publicity about police surveillance. To be more specific:

- sometimes one E is a condition for successful application of another E. In order to enforce traffic rules, road users must first know them, which is why Education is necessary.
- Especially when it comes to speeding, desirable behaviour should, first and foremost, be made inviting or even be imposed by the design of the infrastructure, i.e. Engineering. Only after that has been achieved will enforcement make sense. If the infrastructure incites undesirable behaviour, traffic enforcement and information will be a waste of time.
- in many cases, the most effective way to influence behaviour lies in the combination of two or three Es.

  See Introduction, part 2: Making traffic safer.

2 There is a helpful trio for the application of the tools (the 3 Es): the 3 Ps: Push, Pull and Persuasion.

- Push: Trying to 'push' someone away from undesirable behaviour.
- Pull: Trying to 'pull' that road user towards the desirable behaviour at the same time (or at least co-ordinated in time), encouraging desirable behaviour by addressing safety advantages.
- Persuasion: Persuasion is about convincing, about communication aimed at changing road users' knowledge and attitude (and, in the end, behaviour).

The art of influencing traffic behaviour is finding the best combinations of the Es and the Ps.

See Introduction, part 2: Making traffic safer.

6 Spatial planning and the road environment

6.1 The various decentralised plans are formulated in more or less equivalent planning processes that consist of the following phases:

- Initiative (idea): in this phase, a qualitative investigation can be made into the positive and negative consequences for road safety.
- Definition (what): in this phase, the qualitative investigation into road safety can be quantified where possible or a road safety audit carried out.
- Design (how): in this phase of the planning process, the consequences for road safety are dealt with more concretely: a design can be adapted to the

expected safety bottlenecks. If a road safety audit was conducted during an earlier phase, an audit that focuses on the design can be an effective addition.

- Preparation (how to make the plan): road safety also demands attention during the realisation of the plan; consider, for instance, road unsafety due to construction traffic. Communication on road safety also demands time and attention.
- Realisation (carrying out the plan): in this phase, it is important to ensure that all intentions are actually realised. Unforeseen problems concerning road safety will crop up regularly, and improvisation is required to address these.
- Aftercare (maintenance): in this phase, monitoring road safety is key: immediately after realisation of a plan, it is important to be aware of complaints and, where necessary, make observations. In the long term, safety statistics can provide information on road safety levels.

See also section 6.3.3.

6.2 Given current design methodology, three general structures can be distinguished:

- a main road with small autonomous neighbourhoods emanating from it
  The disadvantages are that the main road will handle a substantial amount of traffic, much of which will exceed speed limits. The main road will be difficult to cross because of the tendency to overdimension this traffic artery on account of the Noise Abatement Act. In this way, the main road often forms a barrier between the neighbourhoods, while a significant amount of space is wasted and the green zones are difficult to manage and maintain. The system necessitates a double infrastructure for cars and bicycles (double surfacing, double public lighting).
- a post-modern estate with circles and squares, avenues and lanes
  The disadvantage of this structure is that it is difficult to fit into the existing surroundings. The access system looks like a ring road system and is difficult to change or expand. The oblique and winding forms, circles and ellipses are no guarantee for beauty, practicability or conviviality. There is a relatively large amount of remaining space that is difficult to model.
- a grid of streets, avenues, boulevards and paths
  The disadvantage of this system is that cars have unrestricted access.

See also section 6.5.9.

6.3 The following categories can be distinguished:
- through roads: motorways and trunk roads; traffic arteries on which traffic flow is key on both the road sections and at intersections.
- distributor roads: connection between residential areas and through roads; traffic flow is key on the road sections and interaction with the surrounding area is key at intersections.
- access roads: roads with a residential function within connected areas where the traffic function is of secondary importance. This category connects more than just home zones, with 30 km/h zones also being included. Interaction is key on both the road sections and at intersections.

See section 6.4.1.

6.4 The following recommendations are given for effective formal co-operation:
- Create optimal preconditions for co-operation:
  - appoint an independent project leader/process manager;
  - organise the project group horizontally;
  - do not start with the development of a plan before the ambitions, preconditions, plans and decision-making moments are clear.
- Timely agreements on the integration of spatial disciplines, traffic planning and traffic engineering:
  - careful choice of project leader;
  - interdisciplinary composition of team;
  - interdisciplinary working method.

  The project leader and the project group are together responsible for content integration.
  - Use concepts to gain insight into the other's area of expertise:
  - joint approach to the design process;
  - joint terminology and language.
- Maintain short lines between the project group and the steering group.

See also section 6.9.2.

6.5 If there are residents, it is useful to invest in participation. There are different forms of participation, including:
- (public) enquiry: citizens can choose from different alternatives;
- initial involvement/participation: helping to think about solutions to problems;
- open planning processes: helping to think about identifying problems.

See also section 6.10.

6.6 The advantage of participation is that citizens:

- know the area better; it is useful to benefit from their knowledge.
- get an insight into the considerations made by planners, which contributes to a better relationship between administration and resident and to support from within the community.
- are more inclined to invest as a result.
- feel committed to the plans that they helped to create.

Participation is often a time-consuming investment that is subsequently recouped, producing plans with a long life. It is considerably easier to revise plans before they have been carried out.
In addition to participation in large-scale plans, small experiments are also useful. In this way, urban designers and traffic engineers can retain close links with residents in a new housing estate after the estate has been completed.
See section 6.10.

7 Infrastructure

7.1 Functional requirements are partly concerned with attributing functions to roads (the categorisation of roads) and partly with their infrastructure. The twelve functional requirements are:

1 Construction of the largest possible residential areas. Areas in which the majority of daily journeys take place must be safe. Barrier effects as a result of high traffic volumes or speeds above 30 km/h are undesirable in residential areas. The size of a residential area depends on the possibilities of accessing the area.

2 Maximum part of the journey on relatively safe roads. In principle, every road in the Sustainable Safety concept is equally safe, but in practice this is not always the case.

3 Make journeys as short (direct) as possible. The more kilometres the road user travels, the greater the chance of being involved in an accident. This applies, in principle, to all road users.

4 Combine the shortest and the safest routes. Road users are inclined to choose the quickest route to their destination. This is why the shortest route must also be the safest route when constructing the road network.

5 Avoid situations in which road users have to search to find their way. This requires a clear road network with easily recognisable road categories and effective signposting.

6 Make road categories identifiable. This requirement has two aims: the first is to distinguish the quickest route in the network from the less quick routes. The second is to achieve optimum uniformity in terms of traffic behaviour within each road category.

7 Limit the number of traffic situations and give them a uniform design. Repeatedly confronting the road user with uniform traffic situations increases the predictability of the situation. It can also be expected that the learning process of less experienced road users will be quicker as a result. This requirement is predominantly applicable to through roads and distributor roads. On access roads, however, a recognisable and consistent 'chaos' is also a form of recognisability and uniformity.
8 Avoid conflicts with oncoming traffic. High-speed head-on collisions must be avoided. This requirement is applicable to through roads as well as road sections on distributor roads where traffic travels at relatively high speeds.
9 Avoid conflicts with crossing traffic. The chance of conflicts with crossing traffic on through roads must be excluded because of the significant chance of (serious) accidents. For distributor roads, this chance must be reduced by enforcing low speeds for motorised traffic.
10 Separate different types of vehicle. An essential principle is that the different types of vehicle must be separated as much as possible when the vulnerability of some road users is at issue. In addition to this vulnerability, differences in speed and mass are the key arguments for this separation.
11 Reduce speed at potential conflict locations. Where traffic separation is undesirable or impossible, driving speeds must be reduced substantially.
12 Avoid obstacles at the side of the road. This requirement leads to the elimination, relocation or screening of obstacles on the road side and becomes more urgent when speeds are higher.

There are also other functional design requirements that concern, for example, the view, dimensioning of curves, skid resistance, etc. In this respect, no special requirements are laid down in the Sustainable Safety concept in relation to the current situation.
See also section 7.2.

7.2 The most important statutory provisions and regulations are included in the 1994 Road Traffic Act and the 2003 Buildings Decree. The Road Traffic Act includes such regulations as the Administrative Provisions (Road Traffic) Decree and the 1990 Road Traffic and Traffic Signals Regulations.
See also section 7.2.

7.3 The road user's driving task is made easier by a recognisable and continuous roadscape and predictable traffic situations. One means of achieving this is to divide the entire road network into road categories. The way in which each category's function, form and use are geared to one another is decisive for road safety and the quality of the service level.
See also section 7.3.1.

7.4 The division into residential space and traffic space on the one hand and traffic function on the other leads to a division into 'flows' and 'exchanges'.

- Rather than intersections at grade, through roads have interchanges or grade-separated intersections.
  Due to their large-scale character, through roads cannot be included in the built-up area. Through roads, however, can intersect a built-up area, but they must be completely isolated from the surrounding environment.
- On access roads, the traffic function is of secondary importance to the residential function: interaction between the road and the surroundings is unrestricted. The administrator can expect disruptions everywhere, from the road section to the intersections.
- Distributor roads form an intermediate category: the road sections are there for through traffic and the intersections at grade are there for the exchange of traffic between different roads.

The following table provides a summary of this:

Road category	**Road section**	**Intersection, interchange or connection**
Through road	flow	flow
Distributor road	flow	exchange
Access road	exchange	exchange

See also section 7.3.1.

7.5 The two dominant recognisability characteristics in distinguishing road categories are the geometry of the edge markings and carriageway separation.
See also section 7.3.4.

7.6 Two types of roads are distinguished in the through roads category:

- national through roads (NSW), motorways with 2x2 or more lanes;
- regional through roads (RSW), trunk roads with a through function with one or perhaps two lanes in each direction.

The distributor road category outside the built-up area comprises two road types:
- road type I: 2x2 lanes with a central reservation;
- road type II: 1x2 lanes with carriageway separation or 2x1 lanes with a central reservation.

Two types of distributor road are distinguished within the built-up area:
- road type with 2x2 lanes, maximum speed limit 70 or 50 km/h;
- road type with 1x2 lanes, maximum speed limit 50 km/h.

Two types of road are distinguished for the access road outside the built-up area:
- access road type I: separation of cyclists (bicycle lanes or protected bicycle tracks), a carriageway with matted/hard shoulders, speed reducing measures and, possibly, priority intersections;
- access road type II: complete mix of traffic types, junctions without designated priorities and a lane with matted/hard shoulders, where necessary.

Inside the built-up area, access roads are, in principle, part of a continuous 30 km/h zone [7.11]. Although a variation in design characteristics is possible due to the physically enforced low speed limit, the essential recognisability characteristics must also be followed in order to clarify that it is an access road.
See also section 7.3.5.

7.7 In practice, situations often arise in which a road with an access function is desired for reasons of road safety and liveability, while the road design is based on the distributor function. This creates significant tension between the residential function and the traffic function. Such cases are often referred to as 'grey roads'. Grey roads within the current 30 and 60 km/h zones constitute a problem for road authorities. In order to balance the function, design and use of the road, an adjustment to the road profile is often the only option.
The additional costs of dealing with these roads must then be estimated when the budget is determined.
A simple approach to grey roads is not sufficient. If insufficient financial means are available in the short term, it is better to opt for a phased implementation of the restructuring than a half-baked solution.
See also section 7.3.6.

7.8 There are five types of intersection at grade:
- roundabouts on which traffic on the roundabout has right of way;
- priority intersections, at which right of way is determined by traffic signs;
- priority intersections that are equipped with a traffic light control system (VRI);
- intersections governed by the rule that cars from the right have right of way;
- exits.

See also section 7.4.

7.9 The placement of a traffic light control system at a priority intersection is only considered if:
- the waiting times of those with right of way on the main road and side road(s) are unacceptably long and other solutions such as the construction of a roundabout will not help;
- road safety leaves something to be desired, on the understanding that the introduction of traffic lights is expected to have a positive effect on road safety and other solutions such as the construction of a roundabout will not help;
- service level must be influenced for traffic management reasons.

See also section 7.4.3.

7.10 A physical traffic measure will not always make the corresponding signs superfluous. For example, with a physical measure that restricts accessibility, the limited access will always have to be clarified to road users with the help of a sign, otherwise the road authority runs the risk of being held liable in the event of an accident. A well-known example of this is when motorists drive into a bus sluice. See also section 7.13.

8 Vehicle safety

8.1 Active or primary safety focuses on the prevention of accidents (accident prevention) while secondary or passive safety focuses on the prevention or limitation of injuries caused by accidents. This not only involves the protection of the drivers/passengers, but also that of people outside the vehicle, often vulnerable road users.
See also section 8.1.

8.2
- *ADA*
  An important development is that of Advanced Driver Assistance systems, or ADA. These are smart systems that assist the driver with his driving task. These systems give information and advice and are able to intervene when necessary. Below are some examples.
- *ACC (Adaptive Cruise Control)*
  This is a system that combines cruise control (fixed speed control) with an automatic monitoring function of the vehicle's distance to the vehicles in front (using radar, for example). When the distance becomes too small,

a warning is given or the speed is automatically lowered. This, however, creates a dilemma when traffic volumes are high. Keeping a safe distance in those situations is punished by other traffic constantly merging in front.

- *LDWA (Lane Departure Warning Assistant)*
  This system ensures that the vehicle stays in position in the lane by detecting the road markings with cameras. If the vehicle threatens to cross a line, a warning signal is given or the vehicle is steered back to the correct position.
- *ISA (Intelligent Speed Adaptation)*
  Speed control is an important instrument for increasing road safety.
  The ISA system automatically compares the actual speed with the speed limit. If the speed limit is exceeded, the driver will receive a warning or the vehicle brakes automatically. The information about the speed limit comes from the navigation system or the infrastructure, for example from beacons along the road. ISA also offers the opportunity to intervene in the driving speed at a certain location or time, for example when school is out. Such systems are not generally accepted yet, but support is growing, partly due to the fact that the risk of a fine is lowered and insurance premiums may decrease. For that matter, evaluations in Sweden and England show that there is considerably more support for systems informing the driver about (exceeding) the speed limit than for systems that intervene autonomously.
- *eCall*
  This is a system in the vehicle that automatically transmits an emergency signal in case of a collision, warning emergency services and directing them to the right location.
- *Pre-crash sensing*
  Modern sensors are able to detect if a collision is unavoidable before the collision actually occurs. This allows for the safety features in the vehicle to activate earlier (for example the airbag), so that their protective function is improved.
- *Occupant monitoring*
  Systems are being developed that monitor certain physical characteristics of the driver, such as eye movement.
  These characteristics are automatically analysed and the system will give a warning signal when the driver appears to be tired or sleeping.
- *Alcolock*
  With this system, the vehicle can only be started after an alcohol test has been carried out and the result is negative up to a certain limit.

See also section 8.2.3.

8.3 Parties that have an influence on vehicle safety include: the industry, consumers, interest groups, car fleet managers, transport companies, government, research and test institutes, insurance companies and courts of justice.
See also section 8.3.1.

8.4 While the EU provides legislation for vehicle authorisation, its implementation is the responsibility of the Rijksdienst voor het Wegverkeer (Government Road Transport Agency).
See also section 8.3.2.

9 Road traffic education

9.1 Road safety education is the collective name for all more or less structured (formal) activities that are carried out in order to convey to people the knowledge, skills and motivations that are the conditions for safe and efficient traffic participation.
See also section 9.2.

9.2 Informal learning is when people learn spontaneously by gaining experience and observing the experiences of others. Informal learning in the form of independent traffic participation provides substantially more learning moments than any form of formal learning, which is why it is important to understand that formal road safety education will only provide a modest contribution to the learning process as a whole.
See also section 9.2.

9.3 The key role of road safety education is to increase road safety through reducing the number of fatalities and injuries resulting from accidents. However, other objectives are also conceivable and these have become increasingly important in recent years. Some road safety education programmes, for example, focus on involving parents and residents more in road safety in the area around schools. In recent years, programmes have been introduced that focus on the environment and traffic flow. Campaigns such as 'Het nieuwe rijden' [Ecodriving] and 'Rij schoner, rij 80 in z'n 5' [Help the Environment, Drive 80 in 5th Gear] are examples of programmes that intend to teach a particular driving style that has less of an impact on the environment. Recent campaigns focusing on the use of extra lanes during rush hour are aimed at encouraging a driving style that promotes traffic flow.
See section 9.2.

9.4 There are six basic principles for the development of learning objectives for road safety education programmes:
1 the target group;
2 the context in which traffic participation by the target group occurs;
3 the subjects and the capabilities that are important for the safe and responsible traffic participation of the target group;
4 continuity in road safety education (the permanent character of road safety education);
5 a framework for the assessment of new and existing road safety education activities;
6 possibilities for supplements or modifications on account of progressive developments.
See also section 9.4.1.

9.5 The four levels of the GDE matrix are:
1 operational level (implementing concrete tasks);
2 tactical level (managing traffic situations);
3 strategic level (considerations and decisions in the traffic context);
4 general personal level (personal characteristics, ambitions and competences).
If an elderly motorist avoids rush-hour traffic, this is done so on a strategic level. The choice to overtake is made on a tactical level. The most important level is the general personal level, at which self-reflection plays a role. Is the party in question sufficiently aware of their own knowledge, skills and limitations in relation to the actual traffic situation? It is also important whether they are willing and able to alter their behaviour accordingly. This also relates to one of the five principles of Sustainable Safety, the road user's state awareness. Traffic behaviour is the outcome of a complex psychological process. The processes at a higher level influence the way in which someone is able to make responsible and safe choices at a lower level.
See also section 9.4.2.

9.6 The six groups that are distinguished in road safety education are: (parents of) children aged between 0 and 4, children aged between 4 and 12, youngsters aged between 12 and 16, novice drivers, drivers who possess a driving licence, and the elderly.
See also section 9.5.

9.7 The five behavioural themes of the ‘Advancing Sustainable Safety’ programme are:

1 insufficient understanding of the problem of road unsafety, which means that measures (in the context of Sustainable Safety) are not always accepted;
2 no or insufficient use of strategic safety considerations when making traffic-related choices (choice of vehicle/route);
3 wilful traffic violations;
4 undesirable or improper habitual behaviour;
5 insufficiently equipped novice drivers.

These behavioural themes are not at loggerheads with target groups distinguished within road safety education. These themes are not linked to age or mode of transport: in fact, problems often transcend various groups or modes of transport. The behavioural themes satisfy the following criteria: they form a problem for road safety and can be influenced through education.
See also section 9.6.

10 Traffic enforcement

10.1 Intrinsic motivation means that someone is motivated to do something without an obvious reward or other incentive. In general, intrinsic motivation depends on the person and the activity in question: someone finds it useful or enjoyable to do something and derives a sense of satisfaction from it. Extrinsic motivation is the motivation that comes from outside. This external motivation almost always has the character of a reward or punishment.
See also section 10.2.2.

10.2 The WAHV (The Traffic Regulations (Administrative Enforcement) Act) is better known as the ‘Mulder Act’ after the chairman of the committee that developed it. The WAHV came about to enable the administrative-law processing of traffic violations contained in the Road Traffic Act.
Before the WAHV came into effect in 1993, traffic offenders were considered suspects under criminal law. The increasing number of traffic violations, however, led to an overburdening of the criminal justice system. The WAHV provides a highly automated system in which those road users responsible for a traffic violation can be given an administrative sanction. If there is uncertainty about who is responsible, this sanction is imposed on the holder of the registration.
See also section 10.3.1.

10.3 In principle, police deployment is discussed as part of tripartite consultations between the police superintendent, the chief public prosecutor and the police force manager (one of the mayors in the region). Different tripartite consultations take place throughout the country, which is due to the various administra-

tive levels (municipal, provincial, national) on the one hand, and the regional division of the Public Prosecution Service and the police on the other.
See also section 10.3.2.

10.4 Communication should therefore:
- substantiate the desired behaviour
- increase the preventive effect of the legal consequences of undesirable behaviour;
- encourage social control: a child or partner that points out the driver's (un)desirable behaviour.

See also section 10.4.2.

10.5 The five spearheads are: wearing a crash helmet, wearing a seat belt, red light running, alcohol and speeding.
See also section 10.5.2.

10.6 The reward should not be too large because this will prompt people to alter their behaviour based on the gift rather than on their own conviction. It must not constitute a transaction or deal. It is all about the psychological process of a person's own conviction, as in that case the behavioural change is more likely to last. A reward can relate to the behaviour in question, but this is not necessarily the case.
See also section 10.6.2.

Part 3

11 Risk-enhancing behaviour in traffic

11.1 In young people, the effect of alcohol on the accident risk is apparent at even lower levels, because they are both novice drivers and inexperienced drinkers. This is why the statutory limit for novice drivers (usually young people) has been lowered to 0.2 g/l.
See also section 11.2.3.

11.2 Alcohol use, use of drugs and medicines, driving while tired, distraction due to mobile phone use while driving, aggression in traffic, speed, red light running, headway times/tailgating and the non-use of safety devices. See chapter 11.

11.3 Several forms of risk-enhancing behaviour have a negative effect on enforcement because they are relatively difficult to demonstrate before they lead to serious consequences. This is true of fatigue and the use of medicines.
See also sections 11.3.1, 11.3.2, 11.4.1 and 11.4.2.

12 Specific groups of road users

12.1 Age determines whether someone is permitted to use a particular mode of transport for the first time, for example, or whether they can drive longer distances (to secondary school, for instance) and is therefore an indication of the inexperience of road users. People with limited experience using a certain mode of transport generally have a greater chance of being involved in an accident.
An individual's stage of life partly determines how they behave. This relates to behaviour in the broadest sense of the word.
Both the high risk acceptance of young people and the limitations confronting the elderly can increase the chances of an accident.
Finally, age more or less determines the chances of someone surviving an accident. Older people are more physically vulnerable than younger people, which means that, proportionally speaking, their share in traffic fatalities is greater than their share in hospitalisations.
See also section 12.1.

12.2 In recent years, the distribution of mobility of children over the different modes of transport has changed significantly. In the period 1994-2002, the number of kilometres travelled by children on foot and by bicycle decreased by 10% and 20%, respectively. By contrast, the number of kilometres travelled by car rose by 10%. This shows that parents are transporting their children by car more often, allowing them to participate in traffic on their own less frequently. The motives for this are probably the presumed road unsafety on the route and the distance, both of which were cited by parents as motives for taking their children to primary school by car.
See also section 12.2.2.

12.3 Because accidents can never be entirely prevented, it is important that measures are in place that minimise the severity of the injury. This can be achieved by enforcing lower speed limits in areas where children play and cycle. In addition, more special areas, like those in home zones, should be created where children can play carefree and traffic is only permitted to travel at walking pace. This enables children to gain experience in a safe environment.
30 km/h zones are safe as long as the pavements are wide enough.
The severity of injuries can also be limited by employing safety measures such as the compulsory use of child restraint seats and seat belts for children.
See also section 12.2.3.

12.4 The causes are primarily related to a lack of experience and age. Examples include:
- not yet mentally and physically mature;
- high risk acceptance;
- high exposure to dangerous situations: young people, particularly men, often drive under especially dangerous circumstances such as at night or in the weekend;
- lifestyle: trying new things, hanging out with friends and wanting to impress and outdo each other, conforming to group norms;
- more use of alcohol and drugs and more often fatigued;
- lack of routines and automatisms (lack of driving experience);
- overestimating personal skills in combination with underestimating the complexity of the traffic situation.

See section 12.3.1.

12.5 Firstly, accidents involving these vehicles often lead to serious consequences for the other party. This is primarily due to the size of these vehicles. In general, the heavier the vehicle, the worse the consequences for those travelling in the lighter vehicle. Secondly, accidents involving these types of vehicle are caused by other factors than those involving cars. Their high centre of gravity can cause lorries and delivery vans to topple over at high speeds or in sharp bends. Loads that are not properly secured can fall off and trailers and semi-trailers can jackknife. Furthermore, there is limited vision to the rear, which results in a larger blind spot. This plays a key role in accidents between lorries that are turning right and cyclists that are going straight ahead. Finally, accidents also occur due to loading and unloading in traffic, particularly in urban areas. See also section 12.8.1.

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KpVV – Traffic and Transport Knowledge Resource Centre

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Email:	info@kpvv.nl
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Ministry of Transport, Public Works and Water Management

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SWOV - Institute for Road Safety Research

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Website: www.tno.nl
Email: info-DenV@tno.nl
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VVN – Dutch traffic safety association
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Visitors' address: Huizermaatweg 600, 1276 LN Huizen
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Windesheim university of applied sciences
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NHTV – Breda university of applied sciences
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Websites

Advancing Sustainable Safety *www.doormetduurzaamveilig.nl*
Association of Dutch municipalities *www.vng.nl*
Association of provincial authorities *www.ipo.nl*
Breda university of applied sciences *www.nhtv.nl*
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Public prosecution service *www.om.nl*
Regional consultative body for road safety Fryslan *www.rof.nl*
Regional consultative body for road safety Gelderland *www.rovg.nl*
Regional consultative body for road safety Limburg *www.rovl.nl*
Regional consultative body for road safety Overijssel *www.rovo.nl*
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Regional consultative body for road safety Zeeland *www.rovz.nl*
Regional consultative body for road safety Zuid-Holland *www.rovzh.nl*
Statistics Netherlands *www.cbs.nl*
Sustainable Safety information desk *www.crow.nl/duurzaamveilig*
The Dutch safety board *www.onderzoeksraad.nl*
The public prosecution service's bureau for traffic enforcement *www.verkeershandhaving.nl*
The public prosecution service's central processing unit *www.om.nl/parket/cvom*
TLN *www.tln.nl*
Traffic and transport council Drenthe *www.vvbdrenthe.nl*
Traffic and transport council Flevoland *flevoland.nl/themas/verkeer_en_vervoer/vervoerberaad_flevoland*
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University of Twente *www.utwente.nl*
Windesheim university of applied sciences *www.windesheim.nl*
World road association *www.piarc.org/en*

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List of abbreviations

ABS	anti-lock brake system
ACC	automatic cruise control
ADA	advanced driver assistance
ADAS	advanced driver assistance system
ADBLC	automatic double barrier level crossing
AFTLCS	automatic flashing traffic light control system
AGEB	area approach
AHBLC	automatic half barrier level crossing
AKS	roll-over control system
AMvB	Governmental decree
APK	MOT test
AR	access road
ASPE	Approach to groups of specific accidents
AUTO	online table elaboration
AVOC	approach to high-risk locations
AVV	transport research centre, now the centre for transport & navigation
BABW	Administrative Provisions (Road Traffic) Decree
BAC	blood alcohol concentration
BARVW	supplementary road tunnel safety regulations decree
BDU	Broad goal-oriented grant
BG	basic data, previously known as the national road accident register
BLIK	blackspots on the map
BOA	special investigating officers
BPZ	basic police duties
BREVER	law of retention of travelling times and journeys
BRON	the Dutch registered accidents database
BVOM	bureau for traffic enforcement of the public prosecution service
CBR	Central office for motor vehicle driver testing
CBS	Statistics Netherlands
CJIB	Central fine collection agency
CROW	Information and technology platform for transport, infrastructure and public space
CVOM	The public prosecution service's central processing unit
DOCTOR	Dutch objective conflict technique for operation and research
DR	distributor road
DVS	Centre for transport & navigation, previously the transport research centre
EBD	electronic brake distribution
eCALL	system that automatically sends an emergency signal in the event of a collision
EHK	essential recognisability characteristics
EMA	educational measure on alcohol
EMG	educational measure on behaviour
ESC	electronic stability control
EU	European Union
EuroNCAP	collision testing programme
EuroRAP	test programme focused on road design
FUPS	front underrun protection system
GDE	goals for driver education
GGA	area-oriented approach
GGB	network management
HBO	higher professional education
ICT	information and communication technology
ISA	intelligent speed assistance
ITS	intelligent transport system
KLPD	National police services agency
KpVV	Knowledge platform for traffic and transport
LARGAS or LRGS	Drive slower, go faster
LDWA	lane departure warning assistant
LIS	injury surveillance system (from consumer safety institute)

LMR	National medical registration
LPG	liquid petrol gas
LZV	longer and heavier lorry combinations
MON	Ministry of transport, public works and water management's mobility study
MVO	daytime running lights
NHTV	Breda university of applied sciences
NNZ	not hospitalised
OBiN	injuries and physical activities in the Netherlands
OM	Public prosecution service
ov	public transport
OVG	national traffic survey
PET	post encroachment time, see also DOCTOR
PIARC	World road association
PCOSE	problem-cause-objective-solution-evaluation
POV	provincial consultative body for road safety
PROV	periodic regional road safety survey
PV	ticket
PVE	permanent road safety education
RARVW	Supplementary road tunnel safety regulations
RDW	government road transport agency
ROV	regional consultative body for road safety
RVHT	regional traffic police team
RVV	road traffic and traffic signals regulations
SEH	emergency assistance
SER	self-explaining roads
SMART	specific-measurable-achievable-realistic-t time-bound
SUV	sports utility vehicle
SWOV	Institute for road safety research
TERN	trans european road network
TR	through road
TTC	time to collision, see also DOCTOR
UGL	microgram per litre, measure for breath-alcohol concentration
UMS	material damage only
VINEX	Fourth memorandum on physical planning-plus
VN	United Nations
VOR	national road accident register, now basic data
VPL	traffic exposure per location
VPR	regional traffic exposure
VRI	traffic light control system, also traffic lights
VVI	Road safety inspection
VVN	Dutch traffic safety association
VVR	regional road safety explorer
WAHV	Traffic regulations (administrative enforcement) act (Mulder act)
WARVW	Tunnel safety regulations act
WGR+	framework act areas, also known as urban regions
WHO	World health organisation
WLO	Welfare, prosperity and quality of the living environment
WO	university education
WVW	road traffic act
ZHS	hospital casualties

Colophon

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