Safety and accident reduction
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1. **Introduction**

1.1 **Definition**

**Safety** can be defined as: freedom from injury or risk. It relates to the safety experienced in the transport process (absence of conflicts and accidents in traffic).

Thus, **traffic safety** implies that all journeys / trips made to a specific location are made without any accidents or unsafe feelings.

**Accidents** are defined as: unexpected adverse event. May be a fall, crash, collision, explosion. A distinction is made between:

- **Road accident** (or traffic accident): definition used for statistics in most countries: collision occurring on a public road and involving at least one moving vehicle. Road accidents include damage-only accidents and injury-producing accidents

- **Accident causation**: set of events involving different elements of the road traffic and transport system (the road environment, the vehicles, the road users) and leading to collisions

- **Accident data**: formalised set of information on injury-road accidents

- **Accident factor** (or contributory factor): any element of the traffic and transport system (i.e. related to the road and its environment, vehicles, traffic or transport organisation, road users, or to interactions between these) that has been identified as taking part in an accident process in such a way that the accident would not have occurred if this element had been different or missing.

It would not be fair to compare the safety/risk of different transport modes on the basis of travel kilometres because the kilometres of different modes are made on different road types with different safety facilities. The differences in risk relate to different exposure conditions:

- If only these roads are considered which are also used by cyclists and pedestrians, the risk for car driving is higher compared to walking and cycling;

- Young drivers have a higher share of trips during weekend nights. Their risk in the daytime only is much lower;

- Some road users tend to avoid situations when the risk of accidents is highest, e.g. motorcyclists ride more in good weather, elderly people tend to avoid road use during peak hours and at night;

- The fatality rate for cyclists is known to vary in inverse proportion to the amount of cycling per occupant. In countries where people cycle a lot, cyclists have a lower fatality rate. Also the risk for pedestrians and cyclists at crossings decreases with increasing numbers of pedestrians and cyclists.
Factors of influence for high risk are:

- **Protection**: the vulnerability of the body is important in comparing the risks of modes. The mass and speed of motor vehicles is not compatible with non-motorised transport;
- **Vehicle characteristics**: high risk of motorised two-wheelers;
- **Priority in planning and design**: planners and designers are much more aware of the comfort and efficiency needs of car drivers than of the needs of two-wheeler riders and pedestrians;
- **Relation to exposure**: when fewer people choose to walk or cycle, planning for them is given less priority and problems are not resolved. Moreover, a low proportion of a mode in traffic affects expectations and results in worse anticipation by other road users;
- **Lack of communication**: basic factor in accidents, as drivers may be surprised by unexpected actions or misunderstand each other’s intentions; communication is especially difficult when speeds are high, when the physical environment is not designed to help drivers focus their attention on pedestrians, or when there are visibility problems;
- **Age**: elderly people run more risks of being killed or severely injured due to the vulnerability of their bodies, whereas children and youngsters have a much higher risk of being involved in accidents because of lack of skills and inexperience;
- **Risk seeking**: sensation seeking applies to about 30% of the car-driving population. (PROMISING Final Report, 2001)

### 1.2 Objectives and skills

The students should gain the following skills and knowledge:

- have a system’s (integrated) overview of the traffic safety field
- get a European perspective on an issue which is usually national
- be up to date with current policies, techniques and methods
- be aware of best practices concerning traffic safety work

### 1.3 Challenges

Accident data in different European countries indicate that traffic safety still is a major problem, asking for effective solutions.

A great number of road safety measures were developed in the 20th century. The development took off during the 1960s. Mass motorisation and the annually increasing number of fatalities made the need for road safety policies acute. The exchange of expertise and experience with measures provide a rich basis for future policies. Measures that have proved their value in some countries may be implemented in others. But, the applicability of experiences and expertise has its limitations. Generally speaking, in the past road safety policies did not take into account the mobility needs of different modes of transport and took the growth of car traffic for granted.
Nowadays, many countries in Europe are developing policies that also regard cycling and walking as modes of transport. Design requirements for efficient transport will have to be developed in an appropriate manner for walking and cycling.

A second limitation relates to the road safety policy itself. Many measures that were developed have been successful, but do not suffice to create the conditions for a safe road system. Road users should also be able to see immediately from their traffic environment, what kind of behaviour is appropriate, and their behaviour should be technically guided in this direction. The risk of serious injuries should be minimised by a fine-tuning of the road design to the limited human capacities. New road safety concepts have been developed to realise this. Spatial and transport planning together may for example create a good basis for traffic calming solutions in built-up areas. The trend for speed reduction is also not only being stimulated from a road safety perspective. Integration of road safety policies with policies regarding transport, traffic management, environmental pollution, urban quality of life, and other social matters are therefore a prerequisite. (PROMISING Final Report, 2001).

1.4 Link with EU policies
The new White Paper *European transport policy for 2010: time to decide* states: “The European Union must, over the next 10 years, pursue the ambitious goal of reducing the number of deaths on the road by half; this by way of integrated action taking account of human and technical factors and designed to make the trans-European network as safer network (…) Though responsibility for taking measures to halve the number of road deaths by 2010 will fall chiefly to the national and local authorities, the European Union too needs to contribute to this objective, not just through the exchange of good practice, but also through action at two levels:

- Harmonisation of penalties, and
- Promotion of new technologies to improve road safety.”
(White Paper 2001)

“Improving road safety is one of the key issues within the Common Transport Policy, and four main research areas have been identified:

- Road infrastructure design and redesign
- Vehicle design (to prevent accidents and to reduce injuries of vehicle passengers as well as vulnerable road users)
- Traffic signing and control
- Driver behaviour (e.g. appropriate speed, no alcohol and drugs, wearing seat belts).

Several factors to improve safety have been identified, including harmonising road accident information, statistics and databases. Creating safety standards for road and junction design, and improved vehicle passive safety through research in vehicle design and crash testing are important factors together with the creation of vehicle speed control standards. Individual and collective driver behaviour may be changed through publicity campaigns on new traffic laws and regulations together with better enforcement of the rules on speed, alcohol, drugs and wearing seat belts.” (Transport RTD Programme, ROAD Transport, EXTRA-project, EC)
2. Understanding Traffic Safety

This book summarises a number of traffic safety measures and approaches that have come out of European research projects. An integrated approach is needed to address the traffic safety problem. All measures and methods described in this book should therefore be interpreted and considered in relation to each other, even though they are split up here into the three classical E’s – Engineering, Enforcement and Education – for reasons of clarity. Under ‘Engineering’ technical standards regarding vehicles and environment will be classified. The second area of ‘Education’ contains measures on behavioural aspects. The last ‘E’, for ‘Enforcement’, consists of legal and alternative enforcement measures. Not all aspects will be treated equally, which is due to the amount of relevant results available from European projects. It by no means reflects the importance that should be attached to these different issues. This book does not aim to be a full overview course on traffic safety, but rather presents key information on current topics in European road safety research. Recommendations for further and more in-depth reading are included in chapter 7.

2.1 Defining the problem

The price paid for mobility in Europe is still far too high. In 2000 over 40 000 people were killed and more than 1.7 million injured in road accidents in the European Union. The age group most affected, is the 14-25 year olds, for whom road accidents are the prime cause of death. The directly measurable costs of road accidents is around 45 billion euros. Indirect costs (including physical and psychological damage suffered by the victims and their relatives) are three to four times higher. The annual figure is put at 160 billion euros. (White Paper. European Transport Policy for 2010: time to decide, 2001).

Next to the actual figures, there is also a considerable feeling of traffic unsafety among the people, which is not only based on accidents but also on the idea one regularly has of just having escaped an accident. Fighting objective and subjective unsafety remains an important societal priority.

Each traffic safety problem can be described on the basis of three principal risk dimensions, referring to the three most important phases in each accident (before, during and after):

- First dimension: size of the activity which can result in accidents: the exposition; can be measured in terms of the number of travels, the travel distance and the travel time

- Second dimension: the risk (possibility of a traffic accident) one takes when carrying out the activity

- Third dimension: the consequence of an accident (casualty, fatally injured, seriously injured, slightly injured, material damage)

(OECD 1997)
A traffic accident usually is a direct result of the failure of one or more of three mutually influencing elements:

- The intrinsic safety of the vehicle
- The intrinsic safety of the road and its environment
- The desired behaviour of the road user

Especially the interactions between these factors plays an important role. Traffic safety measures should aim to break through the concurrence of circumstances leading to an accident in a concrete situation. If one of these influencing factors can be changed, there is a good chance that the accident will not take place. In other words, less accidents means a safer behaviour of the road user, safer vehicles and safer traffic infrastructure; for example through improved education, better driver skills or more experience of the road users; better road design causing less conflicts for the road users; safer vehicles with increased visibility or better brakes, etc. Studies show that especially the combination and integration of these elements is important. The safe operation of the interfaces between these elements is as important as the intrinsic safety of the road user, vehicle and environment as such.

Traffic safety measures should:

- Prevent the occurrence of incidents and avoid that an incident becomes an accident;
- If an accident does take place, limit physical and material damage;
- Prevent that the cause damage and injuries are extended and make sure they are repaired in a professional way.

In judging the acceptability or non-acceptability of risks, a number of factors have to be taken into account:

- The extent to which one can control the risk with which one is confronted; e.g. public transport users and airplane passengers accept a lower risk than independent traffic participants such as motorcyclists and car drivers;
- The extent to which one is protected and the other unprotected; e.g. the risk that pedestrians and cyclists run is considered to be less acceptable than the risk of car drivers;
- The avoidability of the risk: situations in which the risk could have been easily avoided, e.g. risk as a consequence of aggression, excessive alcohol user, speeding, are less accepted than situations in which the risk could not so easily have been avoided;
- The fatality of the risk: one accident with 100 casualties seems more important than 100 accidents with one casualty;
- The importance that is attached to a travel: a car driver who left late for an important appointment, takes more risks than someone leaving for a leisure trip. (Design Mobility Plan Flanders, 2001)
Motorised versus non-motorised modes

Safety policies have been developed more or less independently of transport policies. Especially for pedestrians and cyclists, many safety measures were restrictive in the past. Priority has been given to smooth car traffic. Pedestrians and cyclists have had to give up space and freedom and still are vulnerable when they share the road with motor traffic.

Although the opportunities and benefits of non-motorised transport receive an increasing amount of interest, the balance in planning and design between motorised and non-motorised transport is far from being realised. To consider walking and cycling as a means of transport requires a change of thinking on the political level. If the safety and mobility of all groups are to be enhanced in an integrated way, a better balance in mobility and safety for all modes of transport must be created. The design of road facilities should be directed towards the safety and mobility needs of walking and cycling. These needs concern a coherent network, direct routes to destinations, safety, comfort, easy task performance and attractiveness. In order to make the recommended safety measures for walking and cycling work, these transport modes need to be recognised as transport alternatives in their own right.

Long-term planning is also needed if real progress is to be made in the field of road safety. New concepts provide the framework that long-term planning requires (cf. Chapter 7). These concepts stop defining road fatalities as a negative, but largely accepted side effect of the road transport system. Rather, road fatalities can and should be avoided, and the probability of accidents can be reduced drastically by means of the infrastructure design. Where accidents still do occur, the process which determines the severity of these accidents should be influenced in such a manner that the possibility of serious injury is virtually eliminated.

The main consequences for road planning and design are:

- Motorised traffic with a flow or distribution function must be segregated from non-motorised transport;
- A network of main traffic routes must be created for pedestrians and cyclists;
- A fair balance between motorised and non-motorised traffic for priority facilities at crossings should be achieved;
- The maximum speed of motorised traffic should be limited on roads where it mixes with non-motorised traffic.

(PROMISING Final Report, 2001)

A number of infrastructure levels have to be considered when designing facilities that allow safe interaction between motorised traffic, cyclists and pedestrians, as well as between cyclists and pedestrians. Ideally, these facilities at the same time promote cycling and walking and encourage their use. (ADONIS Final Report, 1998)

Basic needs for travelling and trip optimisation

When it comes to travelling, no matter with which mode, a planner should take into account that a trip has to be quick, safe and comfortable. Quick can be expressed in terms of speed, time and trip length; safe is a general term for the road safety experienced in the transport process (conflicts and accidents in traffic) and the social safety (security) in the urban environment; and comfortable relates to both the vehicle and the road environment.
The three modes under consideration – car driving, cycling and walking – can each optimise these three basic needs:

- **Car drivers** will use speed for getting somewhere in a quick way. Their safety is supported by a safety belt, a ‘stiff compartment’ and the mass of the car. Their comfort relates to both the car construction and the road surface;

- **Cyclists** will try to make the trip as quick as possible by choosing the shortest route and by reducing waiting times. The safety of the trip can be optimised by avoiding crossing situations with heavy traffic, by crossing at locations where vehicle speeds are low, and by using the ‘force of the crowd’. Many cyclists crossing at the same time will force the car drivers to stop even if drivers formally have right of way. The use of a cycle helmet, which is common in some countries, also contributes to increase safety. The comfort of a cycle trip can be optimised by choosing routes with a smooth surface and by avoiding windy, open road sections;

- **Pedestrians** use more or less the same strategy as cyclists. With regard to comfort, the presence of a footpath is likely to be most important. Next comes quality of the road surface.

### Two Approaches to Road User Demands

Pedestrians and cyclists can only have a safe, quick and comfortable trip if certain requirements concerning the walking and cycling itself and concerning the interactions between cyclists or pedestrians and other road users are fulfilled:

- **Cycling and walking as an activity**: when it comes to priorities, most cyclists give priority to quickness and comfort instead of safety. A cyclist on his way to work wants to be there as quickly as possible without much ado about safety facilities. Quickness and comfort are also essential for pedestrians, although relaxation, freedom and health are even more important to them. *Facilities for cyclists and pedestrians should be designed with this in mind. A facility which road users do not consider really functional or relaxing to use will hardly be accepted or used.* (ADONIS behavioural study);

- **Interactions between road users**: interactions between cyclists or pedestrians and other road users are inevitable in an urban area. Facilities aimed at minimising this sort of interactions, which often lead to accidents, are usually designed for reasons of safety. Quickness and comfort of cyclists and pedestrians should however be kept in mind. Often designers give priority to other road users, e.g. traffic signals meant to increase safety lead to long waiting times; streets with one-way traffic result in detours; bent-out cycle tracks with priority rules in favour of other road users. *It is however important to consider possible interactions, because they influence the quickness, safety and comfort of cycling and walking to a large extent.*
2.2 Why do accidents occur?

The qualitative analysis of cyclist and pedestrian accident factors in the European project ADONIS shows that various factors may result in an accident (ADONIS Final Report, 1998):

- Inattention, including lack of perceiving the other party as a hazard and lack of being aware of the other party at all;
- Not obeying the rules, including ignoring red lights, driving too fast, not observing duty to give way, cycling without lamps;
- Misjudgement, including the inability to correctly interpret the other party’s intentions;
- Poor visibility, firstly because one of the parties was hidden by other cars or in the blind angle, secondly because a dazzling sun or rainy weather made it difficult to see.

Impacts of speed on accidents

Early studies on the relationship between speed and accident involvement showed that vehicles travelling more slowly than the average speed for a road, as well as vehicles travelling faster, have an above-average risk of accident involvement, but that the severity of accidents increases more than proportionally to speed. This is consistent with subsequent findings showing that on roads of a given type, injury accident rate, severe injury (including fatal) accident rate and fatal accident rate increase roughly as the $2^{nd}$, $3^{rd}$ and $4^{th}$ powers of the mean traffic speed.

![Figure 1: Effects of mean speed on the number of accidents according to the Swedish model in case where the initial mean speed is 80 km/h (Andersson & Nilsson 1997 in Master, Final Report, 1998)]
Accident rates and the variance of speed are positively correlated. There is no logical connection however, between speed variation and accident causation. Moreover, speed variation does not affect the consequences given that an accident occurs. An increase in the absolute speed on the other hand logically increases accident risk because it decreases the time the driver has in critical situations for observation, decision-making and evasive manoeuvres. Increase in absolute speed, unlike increase in speed variation, almost always increases the forces affecting in the crash. Consequently, increase in speed increases the damage to the vehicles and the severity of injuries to the occupants. Furthermore, in pedestrian accidents the fatality risk of the pedestrian increases rapidly with the impact speed of the car, e.g. by a factor of 2.5 when impact speed increases from 40 to 50 km/h. (MASTER Final Report, 1998)

Cross-sectional log-linear statistical modelling offers the prospect of cross-national models that could estimate the effects of choice of speeds upon accident frequencies on particular categories of roads in a range of member states. Development of a tool to contribute to the appraisal of effects of different levels of speed on different types of road requires a full-scale programme of development of cross-national models for each relevant category or road – notably motorways, main rural roads and main urban roads.

Factors affecting speed choice
The theory of planned behaviour is frequently used in traffic psychology. Models built on this theory indicate that driving behaviour is largely determined by intentions, which in turn are determined by attitudes, subjective norms, and perceived behaviour control. Still, speed behaviour is not only driven by motivation, but also by external feedback factors as perceived by the drivers, such as road design elements (cf. 2.2) and the behaviour of other road users in their surroundings. The figure below gives an overview of the factors that influence drivers’ speed behaviour.

Figure 2: The effect of impact speed on fatality risk in pedestrian accidents (Pasanen 1991 in Master Final Report, 1998)
Drivers’ choice of speed is affected by the driving speed of fellow road users and by how people evaluate the opinions and reactions of significant others (family, friends, passengers, police, government). The relative importance of attitudes and social norms depends on the kind of road. People are not only subject to, but also exert social influences. Information campaigns can make use of this fact. People’s intentions and behaviours are also affected by the control people think they have over their behaviour. People not only have the feeling that it is difficult to control driving speed behaviour, they also overestimate their own ability to control the consequences of speed.

A familiar factor in speed behaviour is that of sensation-seeking. The need to be in control in difficult situations is probably a primary factor in driving at higher speeds; the need for danger plays a smaller role. A second possibility is aggression, which probably leads to all kinds of dangerous behaviour, including driving at high speeds.

The MASTER project interviewed 1200 road users in 6 European countries about acceptability of speed levels and measures to limit speed. The findings indicate a clear dissatisfaction with current levels of speed, among drivers themselves as well as among vulnerable road users, and in terms of the quality of urban life as well as road safety. There is a readiness, at least in principle, to see speeds reduced. This indicates that, notwithstanding current choices of speed by drivers, the climate for speed management policies for moderating speed may well be favourable.

The interviews show that traffic safety implications are aspects that all road users consider to be important, when they are asked about the importance of speed limits and of road users’ compliance. However, car drivers connect dangerous situations with the presence of other car drivers and not so much with their own behaviour. Still, mostly in connection with being in a hurry or not wanting to disturb the traffic flow, car drivers agree that they contribute to speed problems. Arguments in selling speed management measures should be related to this aspect and combined with the perspective that car drivers are well aware that inappropriate speeds cause serious problems for pedestrians and residents. The persons to be addressed, should also be reminded with facts that speeding occurs frequently and everywhere, that it is not a marginal problem. The results also show that for communicating with the public one should focus on the advantages of lower speeds and what they can contribute to the quality of life for residents. Since car drivers in their role as residents would benefit from a better speed management as well, the usefulness of traffic safety measures for residents should be made more transparent.
Another way of increasing the acceptance of traffic safety measures is to communicate that even when better-adapted speeds are felt restrictive by drivers from their point of view, they help to improve the situation of others. (MASTER, Final Report, 1998)

Vulnerable road users

Most of the road users interviewed in Amsterdam and Copenhagen for ADONIS’ accident analysis are of the general opinion that cyclists behave badly. They are not very concerned about safety and take too many chances. Also pedestrians take too many chances when crossing, which was especially pointed out in Barcelona. In Copenhagen, pedestrians walking on the cycle path or waiting there for the bus seems to be a problem, both for themselves and for passing cyclists. However, more than half of the cyclists and pedestrians have changed their behaviour after they had an accident. Changes include: wait longer before crossing, cross at safe places, cyclists take safe routes, try to prevent misjudgement of the other party’s manoeuvre by establishing eye contact.

To change cyclists and pedestrians so that they adopt a safer behaviour requires not only clear and unambiguous road design and markings, but also information and education. This was mentioned by many of the accident-involved interviewees, and they could suggest a number of measures that in their opinion could increase safety, for instance by:

- Implementing safe routes for cyclists and pedestrians and establishing more safe places to cross the street;
- Reducing the conflicts with cyclists and pedestrians; interviewees find that car drivers behave badly: they drive too fast, do not stop for cyclists and pedestrians. There is a need for more speed reducing facilities to make walking more attractive in cities with low/medium level of walking and there is a need for more speed surveillance and enforcement of speed limits to make cycling more attractive in cities with low level of cycling;
- Increasing visibility; the accident analysis shows that road users had an inadequate perception of other travellers, were not sufficiently aware of other traffic and were therefore unable to make avoiding actions in time. This indicates that it is important to improve the visibility of the different road users, especially when talking about non-segregated road networks. Parking bans and more enforcement of illegal parking should eliminate visibility problems, often caused by parked cars. Measures to improve visibility could contain changing the rules for parking along roads, such as more space between parked cars so that pedestrians, crossing between them, can easily be seen; more distance between parked cars and intersections and/or zebra crossings;
- Introducing campaigns with the aim of informing pedestrians and cyclists of the need for assessing other road users more carefully.

(ADONIS Final report, 1998)
Lack of obeying the traffic rules will often lead to conflicts or result in accidents, but often conflicts are caused by road users’ misjudgement of each other. It is therefore important to teach road users to understand the importance of obeying the law. In order to avoid walking against red, travel time for pedestrians must be reduced as much as possible, i.e. allow longer or more green phases for pedestrians. To avoid cycling against red, light signals should focus on reducing waiting time for cyclists in signalised crossings. Time is crucial for cyclists, which means that it is an essential feature of promoting cycling to give priority to cyclists in as many ways as possible. In addition, this should stimulate cyclists to obey the rules and prevent them from adopting bad habits or a risky behaviour, which eventually may result in accidents. (ADONIS Final report, 1998)

Efforts aimed at increasing awareness among road users are important in order to increase safety. Examples of measures that increase the awareness in crossings between car drivers and cyclists are measures dealing with new types of design in crossings, or campaigns. In short, to increase awareness among road users the following measures should be taken:

- Increase awareness in intersections and other locations where road users cross each other;
- Inform about physical measures;
- Improve and increase traffic education.

Another important issue to reduce accident occurrence is to ensure that road users understand measures and rules. Although respondents who took part in the accident analysis did not score safety as determining for their choice of a transport mode, safety conditions for pedestrians and cyclists in general should be improved, before promoting a switch over from driving to walking and cycling. It should be recalled that motorised vehicles are involved in a large number of cyclist and pedestrian accidents and that they especially influence the risk of severe accidents for both groups of road users. (ADONIS Final Report, 1998)

2.3 Integrated approach

As mentioned before, an integrated approach is of prior importance when addressing traffic safety problems. Optimal results in tackling these problems can only be obtained through a careful mix, containing engineering, education and enforcement measures. The next paragraphs are examples of integrated European policies that have been implemented in several EU-member states.

Road Safety Audit

‘Road Safety Audits (RSA) are utilized to identify potential safety problems and concentrate on safety measures to overcome these problems. This technique is used to detect possible safety hazards, in the various stages of a scheme, before a new road is open to traffic’ (Safestar, Final Report, 1998). RSA can help to prevent accidents or reduce the severity of accidents.

RSA have been in use since the early 80’s. In the UK, the use of RSA is compulsory for all trunk roads and is also issued on a voluntary basis in other road schemes. The main objective is to ensure that highway schemes operate as safely as possible, i.e. to minimise the number and severity of accidents. RSA want to make sure that ‘mistakes’ are not built into new schemes.
Other aims of RSA are:

- To minimise accident risk on the network adjacent to new schemes;
- To emphasise safe design practice and increase the awareness of everyone involved in planning, design, construction and maintenance of roads;
- To highlight the importance of taking into consideration the needs of all types of users;
- To reduce the whole-life cost of the schemes, by minimising the need of future corrections.

(Safestar, Final Report, 1998)

**Urban Safety Management (USM)**

**Introduction**

Urban Safety Management (USM) is a method to reduce road accident casualties in a town or city by bringing together a variety of approaches and people to deal with the accident problem in a strategic way. It is an area-wide approach that integrates different disciplines, such as traffic management, enforcement, education, public transport, etc. By bringing these different disciplines and safety approaches together, a wider range of possible solutions is created (Dumas Research Report, 1998).

USM was developed to provide solutions for the ‘scattered accidents’. These are the accidents that do not occur on specific sites but are more randomly scattered through the urban area. They cannot be solved by specific local actions but need this area-wide approach.

Safety management can be defined as a ‘structured approach to accident prevention and casualty reduction on urban roads’ (IHT, 1990). An urban area is then treated as a series of local area safety schemes. Each of these schemes considers issues under two headings: local safety strategy and other policies influencing safety.

<table>
<thead>
<tr>
<th>Safety strategy</th>
<th>Other policies influencing safety</th>
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<tbody>
<tr>
<td>Measures for pedestrians and cyclists</td>
<td>Road construction and maintenance</td>
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<td>Measures at high risk sites</td>
<td>Public transport</td>
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<td>Enforcement</td>
<td>Environment</td>
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<td>Education, training and publicity</td>
<td>Land use</td>
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<td>Health, welfare and education services</td>
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*Table 1: Safety Management*
This is shown schematically in the figure below:

![Safety Management Diagram](image)

**Framework for USM**

The Dumas project developed a framework for Urban Safety Management. Prerequisites for USM are:

- The safety problem has to be analysed and shared objectives must be agreed and publicised. Technical knowledge and expertise from different areas is necessary;

- There is inter-dependency between safety, mobility and the environment with safety benefits achieved by a variety of actions (not just safety measures);

- People must co-operate towards common goals. Support of local politicians and public is vital;

- Communication and implementation must be managed as an integrated programme;

- Area-wide treatments are necessary to deal with scattered accidents;

- Funding is critical in achieving success (Dumas Research Report, 1998).

The framework provides a ‘how to’ guide to engineers or managers wanting to implement an urban safety management scheme. The framework only applies when problems have been analysed and issues to be addressed in the USM scheme identified. It provides all questions that need to be answered to obtain a successful action plan. This framework is only a guideline and needs specific adaptations for different countries and cities.
The preliminaries

<table>
<thead>
<tr>
<th>1.1. Are you sure?</th>
<th>If not, stop here</th>
</tr>
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</table>

1.2. Have you got sufficient support? Support is needed from:
- Politicians – local and central Government
- The public – local residents are most important
- Technical staff in the local authorities
- Transport operators
- Network operators
- Police

1.3. Have you got finance? If not, give up now and seek funds.

1.4. Are there legal barriers? Check out before starting the project.

Starting the project

| 2.1. Set up structures | Management structures
Communication channels |
|------------------------|-------------------------|

2.2. Launch Have a big press announcement to get the project launched.

2.3. Set objectives Have clear high-level objectives for the project. For example casualty reductions of X% by year Y.

Running the USM project

| 3.1. Analysis phase | • What are the safety and mobility problems?
• Where do the accidents occur? To whom? At what time of day? Etc.
• Understand the problems in the town/ city – safety, environmental and mobility.
• Listen to everyone’s complaints. |
|---------------------|--------------------------------------------------------------------|

3.2. Strategy phase • Give the high-level objective and the problems, how do we go about fixing the problems to achieve the objective?
• Break the town/ city down into sub-areas and produce a safety strategy for each.
• Check these strategies with everyone – get commitments.

3.3. Planning Stage • Plan to tackle the problems in order, usually starting with the biggest.
• Use as many approaches as possible to deal with problems.
• Check the consequences of solutions proposed.
• Have timescales that are reasonable, with some contingency
• Check these solutions with everyone to get support
### 3.4. Design stage
- For the solutions proposed, design measures.
- Make designs acceptable to as many people as possible.
- Check costs do not exceed finance limits.
- Check resources are available to design and implement each measure proposed.
- Check designs are supported by everyone.

### 3.5. Implementation stage
- Implement measures in stages, starting with a ‘quick fix’ to a large problem – you need a success to start with.
- An individual initiative might follow these stages:
  - Consultation
  - Detail design – involve as many as possible
  - Implementation
  - Flow/speed changes – getting used to it.
  - Assessment

Note: the full benefits may not be realised until all the measures are in place.

### 3.6. Assessment stage
- Measures accidents, casualties and flows, etc. Check against objectives – where objectives not achieved, reconsider and possibly introduce additional measures.
- Make sure everybody knows about successes and failures during the project with regular press releases and announcements.
- Report back on achievement of objectives.

Getting support of local politicians for a safety programme is one of the most important requisites for success. Implementing measures will not always be popular, so it is vital that safety remains a high priority with the decision makers. Getting local support can be a lot easier if there is support for safety from the central government (Dumas Research Report, 1998). It is unlikely though to get political support without first achieving public interest and support for the reduction of scattered accidents. Awareness raising on environmental effects and safety benefits is necessary to influence public opinion.

As stated clearly in the framework, lack of finance is often a stumbling block to planning and implementation of a USM scheme. Most countries have 3 ways of funding a USM project: resources from (1) central government, (2) local government or (3) other sources such as local firms, developers, insurance companies, etc.

Urban areas form a complex and dynamic system in which various factors inter-relate. Special attention should be paid to those elements that influence the management process at urban level, i.e. the institutional framework (national, regional and local), the legislative framework, and rules and regulations for technical projects and countermeasures.
DUMAS distinguishes 4 aspects related to safety management in urban environments that need to be assessed:

- **Exogenic factors**: economic changes (disparity of transport costs, pressure of car manufacturers, etc.) and social changes (number of retired persons, more women working, etc.)

- **Urban development**: urban planning codes (strategic plans, master plans, etc.) and transport policies (circulation planning, parking policies, etc.).

- **Management policies**: traffic, transport, energy, environment, etc.

- **Malfunctions**: environmental qualities (pollution, noise) and urban hazards (insecurity, congestion, delinquency, etc.).
  
  (Dumas Research Report, 1998)

**Starting a USM project**

One of the most important features of successful USM is to get everyone involved and committed from the start (Dumas Research Report, 1998).

To set up the management structure, all the diverse skills concerning USM (cf. also ‘introduction’) have to be brought together. Depending on the country the management structure may vary, but the main project team should consist of all ‘major players’ such as the mayor, chief executive, senior officials, etc. This team will be responsible for identifying the accident reduction targets and the strategy of the USM project. For example, in its simplest form, a casualty reduction target might be to bring casualties within the urban areas down to 100 per year by year, with subcategories for fatal, serious and light. There may then also be figures for vulnerable road users, where the reductions might be proportionally greater than for car occupants (Dumas Research Report, 1998).

In a later stage it will be possible for the management structure to consist of different subteams, each dealing with specific elements of the strategy. As mentioned before, the USM approach is area wide and multidisciplinary. The following fields are the most important:

- **Safety**: introduce features to help vulnerable road users and reduce speeds;

- **Traffic control**: improve junctions, manage flows with traffic signals;

- **Police and enforcement**: reduce speeds, improve driving behaviour;

- **Public transport**: manage flows by improving the PT service;

- **Education**: influence behaviour through publicity and safe routes to school.

- **Network management**: use traffic management techniques, such as road closures and mini roundabouts to manage flows;

- **Health**: improve attention to reduce accident severity;

- **Planning**: ensure new traffic generators.
The USM process should directly involve the elected representatives of the city, possibly as part of a ‘forum’ which allows all other interested parties to include their views. (Dumas Research Report, 1998).

After the management structure has been set up and the overall objectives have been defined, the project team and sub-teams will apply the USM principles through the analysis, strategy/targets, design, implementation and assessment phases (see framework). During each phase of the implementation it will be important to assess and monitor the changes by recording before and after speeds and flows on critical and/or representative links.

Conclusion
Urban Safety Management has been around for over 10 years but up till now the number of implemented schemes is virtually zero. The reasons for this might be that USM is complex, political and costly. It is therefore the non-technical factors that have usually been the stumbling blocks. The DUMAS framework should help to overcome these problems.

Accident and Injury Registration
A single European-wide crash injury registration system and database would be of exceptional benefit and value to the legislation process at EU level. A direct data driven approach would allow identification of any safety problem at an early stage, and facilitate a quick and accurate evaluation of any new or remedial measures, including legislation, that may have been implemented (Stairs, Final report, 1999).

Accident and casualty databases are an indispensable tool to allow for objective assessment of the transport safety problem, identification of priority areas for action and resource and for monitoring the effectiveness of countermeasures. As stated in the Stairs project, such accident databases are needed at EU level to describe the current state of transport safety across the European Union, to help define target levels of safety for each of the transport modes and to adopt a data-led systems approach in defining strategies. The process of creating a range of common data sources necessary for the development and monitoring of the Common Transport Policy began in 1993. Progress has been achieved, especially for road transport, but for other modes basic kinds of data are lacking on an EU-level.

Recognising the benefits of a European road accident database, the Council of Ministers approved in November 1993, the creation of a Community database on road traffic accidents in Europe; the so called CARE database. The CARE database is part way towards providing a system that will enable basic counts of fatalities and reported casualties of severities as well as provide basic details of the reported crashes. The Stairs project researched the need and possibilities for an in-depth crash injury database to set the safety priorities in vehicle design and to provide feedback on regulation effectiveness. The CARE database comprises statistical information of reported road accidents in the European Union resulting in injury or death. It also contains annual national sets of accident data in their original form supplied by all the 15 Member States, without harmonisation of individual variables. Each Member State is responsible for the quality of its data and is requested to validate its data after inclusion in the CARE database. In this way, it can be ensured that the information from the CARE database corresponds to the information extracted from the national database. (ETSC, Brussels 2001).

Within accident and injury registration systems in general, a distinction is made between primary and secondary safety objectives. Primary safety looks at methods that try to prevent a crash from happening, while secondary safety looks at methods that prevent injuries after a crash has occurred.

The European STAIRS project investigated different ways of collecting data. Detailed accident studies were classified into 3 categories: ‘retrospective studies’, ‘on the scene, on time studies’ and ‘hospital based studies’.

Safety and Accident Reduction
PORTAL Written Material
www.eu-portal.net
Retrospective Studies

The first category are the so-called ‘retrospective’ studies. They normally have a secondary safety objective i.e. understand how people got hurt or killed in road accidents (STAIRS, final report, 1999). This data collection method requires the inspection of vehicles involved in the crash and not necessarily the crash scene itself. It is obvious that this type of data collection applies only to stable data or to data collected by others and conveyed to the data collection team later on, as is the case with medical data. This type of data is applied mainly to vehicles, such as general characteristics or deformations, as well as to information on the scene and circumstances of the accident.

A first and obvious advantage of retrospective studies is that of costs. This type of study can be carried out during normal office hours. Moreover, the organisation of the latter allows a certain degree of freedom in timing, which also contributes to the reduction in costs. With retrospective studies, the notification of a crash could be slightly delayed, but a system where the researcher is informed immediately costs more in terms of manpower and technology than one where the reporting is more casual. Therefore, the choice of the crashes on which it is possible to carry out such a study, restricts costs by limiting the rejection rate of the files. This rejection is generally due to the absence of values for data considered as obligatory or to a crash classification error. The quality of the data collected is generally improved by a team which does not work ‘under the stress of an emergency setting’.

A clear disadvantage of this collection method is the noting down of volatile information. In fact, with time, it becomes difficult to note down certain data, e.g. the more time passes, the lesser the chances are of having clear traces, which can be easily attributed to the vehicle studied. The problem comes up in a more general manner for data that need to be taken down almost instantaneously. When these data are collected through the use of services of other people intervening, the risk is high that the quality or the reliability of information – due to lack of specific training – is lost.

On the scene, on time studies

The name of this data collection system suggests the principle directly. It is a question of rushing to the scene of the accident as quickly as possible after it occurs, ideally before the vehicles involved have been removed. It seems clear that the speed of the data collection team is essential to the quality of the data collected. This is the most sensitive aspect of ‘on the scene on time’ investigations.

It is obvious that this method, as opposed to the retrospective method, makes it possible to note down volatile data. This method clearly permits a wider range of study than retrospective data collection since it covers both primary and secondary safety aspects of a crash. Another interesting point is that data collection may be carried out almost entirely by the staff of the data collection team. It is therefore easier to control the quality of the data collected.

The major disadvantage is the cost. In fact, operating in real time on the scene of the crash generally requires round the clock intervention every day. The second disadvantage is the setting up of the notification system. In some case studies problems occurred due to the fact that collaboration from emergency services is required but not easy to obtain.
Hospital based

This type of data collection concerns a systematic register type collection with the basic entry being the individual victims of a traffic accident. This type of collection functions for a given population which must be clearly defined. A register should be systematic and exhaustive. This obviously requires the active collaboration of the different medical departments involved.

One of the main advantages of this method is the fact that the data collection staff is also hospital staff. Intensive training is therefore not required for this task. It is thus possible to have a large number of correspondents in a large number of hospital departments. This immediately implies a second advantage: the number of cases dealt with annually may be very significant. With this system it is also noted that exhaustivity is a realistic objective.

The main disadvantage is insufficient information. In fact, it is generally easy to know the type of road user involved (car to car, pedestrian to car, etc.), but on the other hand more difficult to know from reliable sources, whether the seat belt was fastened or whether there was an air bag present. As for the deformations and the characteristics of vehicles, one cannot obtain this information from purely hospital date collection. The second disadvantage is in direct conflict with the main advantage: the hospital staff is not necessarily available for an additional task and this may therefore lead to a dysfunction of the system. Finally, and this depends on the local legislation, the medical registers are often closely regulated and this can complicate the setting up of the system. (Stairs, Final Report, 1999)

Select a data collection system

The choice for one of these systems should be based on: the objective of the study and therefore the data that you wish to gather; the means that you can bring to bear, on a human level as well as on a financial one; and the local organisation of the emergency services.
The following table sums up the different possibilities:

<table>
<thead>
<tr>
<th></th>
<th>RETROSPECTIVE</th>
<th>ON THE SPOT</th>
<th>HOSPITAL BASED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secondary Safety</td>
<td>Yes</td>
<td>Yes</td>
<td>Little data on vehicles</td>
</tr>
<tr>
<td>Primary Safety</td>
<td>Partially possible</td>
<td>Yes</td>
<td>Needs specific studies</td>
</tr>
<tr>
<td>Accident cause</td>
<td>Not suitable</td>
<td>Possible</td>
<td>Needs specific studies</td>
</tr>
<tr>
<td>Injury details</td>
<td>Independent</td>
<td>Independent</td>
<td>Yes</td>
</tr>
<tr>
<td>Cost by cause</td>
<td>Low cost/case</td>
<td>High cost/case</td>
<td>Very low cost/case</td>
</tr>
<tr>
<td>Manpower</td>
<td>Reference level</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Specific team (gathering)</td>
<td>“Universal specialist” (except for medical data)</td>
<td>Several specialists</td>
<td>Except for specific studies</td>
</tr>
<tr>
<td>Notification system</td>
<td>Relatively easy</td>
<td>Difficult</td>
<td>Not relevant</td>
</tr>
<tr>
<td>Special agreement (except for involved people)</td>
<td>Police reports Hospital data</td>
<td>Police (access to the scene) Hospital Emergency services</td>
<td>Hospital (public and private) Emergency services</td>
</tr>
<tr>
<td>Statistical sampling</td>
<td>Easy, movable</td>
<td>More difficult, more often fixed</td>
<td>Possible exhaustivity</td>
</tr>
</tbody>
</table>

*table 2: Categories of accident studies*

**In-depth accident data base**

As already stated before, a European-wide injury registration system and accident database would be an exceptional help to identify safety problems in an early stage and facilitate a quick and accurate evaluation of any new or remedial measures, including legislation, that may have been implemented. When designing such a database, the following steps should be considered:

- Can we identify the types of questions/estimations required?
- What is the population of interest?
- What is the required precision on any estimate?
- Are resources limited – what are the realistic limits?
- What is the optional sampling approach?
- What is the best data collection approach?
- What will be the constraints on the answers that can be provided?
- What is the acceptable delay in obtaining an answer?
- Practical restriction
If estimates are to be made on a Pan-European basis then certain conditions will have to be met. The first is the acceptability of the national estimates, which in turn require the acceptability of regional estimates. Almost certainly there would be some under-reporting of accidents where the damage and injury may be minor. The importance of this depends upon the answers being sought and in some instances it may be desirable to conduct special surveys to try and determine the level of under-reporting.

Any constraints, which apply at a regional or national level, will also apply on a Pan-European level. Moreover, countries may use different sampling schemes, and to combine will require extra efforts. Once details of all European in-depth databases are known, it is desirable to determine the population(s) in common, and hence the questions that can be estimated from data across Europe. Generally speaking, methodology is available to calculate estimations for parameters of interest resulting from complex sampling surveys, according to three important characteristics: weight, stratification and sampling weights. The broader the available data, the broader the questions that can be addressed. This suggests that it may be better to broaden the data and scope of in-depth databases, but not at the expense of sample sizes.

There is still a long way to go before there is a European-wide harmonised in-depth accident and injury databases. There are still some barriers to overcome with regard to the way in which data are (not) collected in different Member States; with respect to ethical questions, privacy and confidentiality of data; regarding the costs involved in data acquisition, data analysis and information provision; in relation to the differences in importance that various people attach to road safety in general across the European Union; and with respect to the willingness to harmonise all efforts. (Stairs, Final Report, 1999).

### 2.4 Engineering

#### Road Safety Audit

**Procedure of RSA**

To undertake a RSA some key factors should be taken into consideration. The efficiency of the safety audit may relate to the organisation and the selection of the audit team (see further). Support and commitment from senior management is another key factor. The actual procedure to undertake a RSA consists of three major steps:

- Collection of information, such as detailed plans, design standards, traffic volumes, pedestrian counts and accident records;
- Systematic and detailed check of the design: overlay the details from one plan on to another, site visits, examination of physical elements. Each element should be checked individually. Once the audit team has predicted the type of accident problem that is likely to be associated with an aspect of the design, a solution should be suggested. For this the use of checklists is recommended;
- The findings of the audit are presented in a formal report. A precise description of the possible problems identified is required, giving reasons for the anticipated conditions. The report should include some recommendations on how to solve the possible problems.

It is recommended to monitor the RSA. Feedback to the designer should lead to more awareness of the safety implications of his design. Safety advice from the auditing team to the design team may conflict with the independence. For that reason the use of checklists is also highly recommended. Practitioners should not rely solely on them and are encouraged to expand them.
Nevertheless, the purpose of the checklists is to make sure that nothing is overlooked. Although RSA’s mainly refer to new designs, they can also be applied to existing roads as a complementary tool together with an analysis based on accident data. (Safestar, Final Report, 1998).

Different countries working with RSA use different definitions. Still, they are more or less the same. Key elements from the different definitions are that RSA’s are independent, formal procedures meant to assess possible safety problems before implementing new designs. The table below shows the different stages used by the different countries. (Safestar, 1998).

<table>
<thead>
<tr>
<th>United Kingdom</th>
<th>Denmark</th>
<th>Norway</th>
<th>Australia</th>
<th>New Zealand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Feasibility</td>
<td>Planning</td>
<td>Feasibility</td>
<td>Feasibility</td>
</tr>
<tr>
<td>2</td>
<td>Preliminary</td>
<td>Preliminary</td>
<td>Draft design</td>
<td>Project</td>
</tr>
<tr>
<td></td>
<td>design</td>
<td>design</td>
<td></td>
<td>assessment</td>
</tr>
<tr>
<td>3</td>
<td>Prior opening</td>
<td>Detailed design</td>
<td>Construction</td>
<td>Detailed design</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>work</td>
<td>Final design</td>
</tr>
<tr>
<td>4</td>
<td>Post opening</td>
<td>Opening</td>
<td>Pre opening</td>
<td>Pre opening</td>
</tr>
<tr>
<td>5</td>
<td>Maintenance /</td>
<td>Monitoring</td>
<td>Post opening</td>
<td>Existing road</td>
</tr>
<tr>
<td></td>
<td>monitoring</td>
<td>(existing road)</td>
<td>road marking /</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>maintenance</td>
<td></td>
</tr>
</tbody>
</table>

*table 3: Different stages used by different countries (Safestar, 1998)*

Points of attention with respect to the audit team are:

- The team should include specialised safety engineers with experience in accident investigation and analysis;
- To make sure that the procedure is as objective as possible, the auditors should be independent of the design team;
- All road users and their needs should be taken into account: pedestrians (especially children), bus drivers and passengers, cyclists as well as motorists, especially for urban schemes. In order to achieve this, the auditors should take the role of all users and try to predict/visualise, as precisely as possible, the way different users will perceive the scheme (‘drive, ride, walk’ concept);
- Consultation with experts outside the AT (such as traffic signals engineers, the police) may be necessary.

The site visit should take place both in daylight and at night. An RSA should be carried out at the beginning of the design process so that ‘errors’ are avoided in a later stage. Attention should be paid to monitoring and feedback to the audit team when accidents occur after opening of the road. The RSA should be formally organised and its outcomes documented. It should be clear what has to be audited, which tasks there are and who is responsible for those tasks.
Safestar drew some general conclusions on RSA:

- Some European countries have developed a national RSA system. Many people involved see RSA as a promising way to improve safety;

- RSA pilot projects point out that design inaccuracies can be discovered in new road designs and RSA evaluations already carried out in some countries were very positive; RSA seems to work;

- The introduction of a RSA system can either be bottom-up or top-down. A bottom-up approach can lead to a vast, enthusiastic participation, whereas a top-down approach leads to a more explicit introduction.

Although design solutions for safety can be identified using a RSA, the precise effects are yet still unknown. It is clear though, that quality is added to a national road system by using a RSA system. (Safestar, Final Report, 1998).

**Environmental design and redesign**

**I. Modifications to the road environment**

Vision is one of the primary means for drivers to acquire information from the traffic environment to enable them to drive safely. Driver behaviour is traditionally classified into a three-level hierarchy: macroperformance (navigation), situational performance (guidance) and microperformance (control). Navigation comprises behaviours related to trip planning and preparation and route planning; guidance concerns ‘subtasks associated with response to road and traffic situations’; and the control level includes vehicle control tasks such as steering and speed control (Gadget, WP 2 report, 1999).

Driver expectations are based on different levels of this hierarchical model. Both planned and unplanned information from the road environment are important sources of drivers’ expectations, which govern their behaviour. It is therefore important that the parts of the traffic system which can be controlled, are designed to suit the ‘driver information needs’ in conjunction with the three-level model (Gadget, WP2 report, 1999). A violation in the expectation of the performance of a particular subtask may also affect performances of subtasks in the lower hierarchy. A consistent and predictable road environment is not only favourable for the drivers’ expectations but also for the mental load of the driver, an important intervening variable between the road environment and driver behaviour.

The three-level hierarchical model of driver behaviour also helps to understand the behavioural mechanisms behind risk compensation. For example, drivers may be reluctant to drive in darkness on unlit roads and therefore choose other modes of travel.

All this implies that a consistent geometric design of road environment is an important factor in avoiding driver errors and thus accidents. A clear road classification that drivers are generally able to recognise will help drivers getting the appropriate input needed to drive safely.

Roadside information can keep drivers in a good psychophysical condition. A medium complexity of road environment helps to maintain an appropriate level of activation and thus can counteract boredom and fatigue. When this roadside information matches the visual functions of people, it will help them to perceive the relevant input and to distinguish it from irrelevant, distracting information. In fact, the more the road layout meets the expectations of the driver, the better the chance to avoid wrong assessment of input (Gadget, WP2 report, 1999).
II. Safety Standards for design and redesign

The features and layout of the road transport system infrastructure thus determine, to a large extent, the level of road safety. Improving the engineering of roads has been one of the main factors behind the reduction in casualties on the roads of EU countries in recent years. Standards in road design and redesign play a vital role in this respect.

Designing and redesigning roads requires different kinds of skills, such as traffic engineering techniques and psychological insight in driver behaviour. Behind the design or redesign of a road lies a certain ‘philosophy’. Examples of such philosophies are the *sustainably safe transport and traffic system* and the *relation design*.

A. A sustainably safe traffic and transport system

The Dutch sustainably safe traffic and transport system (STTS) concept has far-reaching ambitions. Because these aims go beyond merely following an existing trend of fewer casualties per year, a STTS with structurally low accident figures has to be met.

STTS gives a new meaning to the old man – vehicle – road model:

- road infrastructure should be adapted to human capabilities and shortcomings;
- vehicles should simplify the driving task and offer protection;
- road users should be well informed and, where necessary, controlled.

Designing principles within STTS aim at connecting the three angles of the 'golden triangle' FUNCTION – DESIGN – USE. Three design principles have been established:

- A functionally planned road network: each link fits well into the whole system and actual route choice is in accordance with planned route choice;
- A homogeneous use of the road: road users should only be confronted with small differences in speed and mass;
- A recognisable road environment that stimulates the right expectations: predictability of traffic situations.

Each traffic and transport system is meant to interconnect areas, distribute traffic within an area and give access to 'individual' destinations. The road classification in STTS network differs from traditional road classification systems. The latter accept that each road can have different functions at the same time. In STTS each road only gets one function:

1. Interconnective roads are only meant to interconnect areas;
2. Distributors are only meant to distribute traffic within an area;
3. Access roads are only meant to give access to individual destinations.
The design of the road network should meet certain requirements in order to fulfil the starting points and principles of STTS. The *functional requirements* can be regarded as the basic criteria for dividing the roads of the network into various categories. Twelve functional requirements apply to all road categories in the entire urban and rural road network:

- largest possible areas with traffic calming (both in rural and in urban area);
- a maximal part of the journey using relatively safe roads and routes;
- journeys as short as possible;
- the quickest and shortest routes coincide;
- avoid the necessity to search for directions/destinations;
- easily recognisable road classes;
- limit and make uniform the number of possible types of design;
- avoid encountering of oncoming traffic;
- separate types of traffic;
- reduce speed at potential points of conflict;
- avoid obstacles near the carriageway.
Next to functional requirements, operational requirements also have to be met. These concern the most important characteristics of the cross-section, the alignment, and the types of traffic allowed to use the road and their position on the cross-section. Crow (1997) has collected the operational requirements for five different road categories in STTS (Safestar, Final Report, 1998).

<table>
<thead>
<tr>
<th>Type of area</th>
<th>Rural area</th>
<th>Urban area</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Road class</strong></td>
<td>Interconnect-ing Road</td>
<td>Access Road</td>
</tr>
<tr>
<td><strong>Abbreviation</strong></td>
<td>IR</td>
<td>D</td>
</tr>
<tr>
<td><strong>Speed limit (km/h)</strong></td>
<td>120/100</td>
<td>80</td>
</tr>
<tr>
<td><strong>Marking (longitudinal)</strong></td>
<td>Fully</td>
<td>Fully but different from IR</td>
</tr>
<tr>
<td><strong>Physical separation of directions (number of lanes in one direction)</strong></td>
<td>Yes (1 or more)</td>
<td>Yes (1 or more)</td>
</tr>
<tr>
<td><strong>Type of physical separation</strong></td>
<td>Barrier</td>
<td>Difficult to cross</td>
</tr>
<tr>
<td><strong>Emergency facility</strong></td>
<td>Lane</td>
<td>Shoulder or lay-by</td>
</tr>
<tr>
<td><strong>Pavement, surface, irregularity</strong></td>
<td>Minor</td>
<td>Minor</td>
</tr>
<tr>
<td><strong>Accesses</strong></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Crossing (mid-block / between junctions)</strong></td>
<td>Grade separated</td>
<td>Grade separated</td>
</tr>
<tr>
<td><strong>Parking</strong></td>
<td>No</td>
<td>Parking lane</td>
</tr>
<tr>
<td><strong>Public transport: stops</strong></td>
<td>No</td>
<td>Turnout</td>
</tr>
<tr>
<td><strong>Obstacle-free zone</strong></td>
<td>Large</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Cyclists on the carriageway</strong></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Mopeds on the carriageway</strong></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Slow moving motorized vehicles (e.g. agricultural vehicles)</strong></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Speed reducing facilities (e.g. humps)</strong></td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td>To be decided</td>
<td></td>
</tr>
</tbody>
</table>

*table 4: Operational requirements for five different road categories in STTS. Crow (1997)*
A set of the foregoing operational requirements should ensure predictability of the traffic situation. The mechanism that ensures the right predictability consists of two steps: at first the road users must be able to recognise the road class by the following four elements: marking; separations of directions; pavement, irregularity of the surface; obstacle-free zone. Secondly, through information and experience, the road user knows which possible traffic situations belong to the present road class.

B. Relation design
Relation design is another philosophy that can be followed when (re)designing roads. Lamm & Smith (1994) define ‘relation design’ as follows:

“… no more single design elements with minimum or maximum limiting values are put together more or less arbitrarily, rather, design element sequences are formed in which the design elements following one another are subject to specific relations or relation ranges.”

This approach should result in a longitudinal profile, which offers the car driver a consistent chain of tangents and curves. The consistency is focused on the sight distances and design speeds of the successive design elements. (Safestar, final report, 1998)

The definition of design speed is thus the subject of discussion. While some countries define design speed as the maximum speed at which car drivers can use the road safely and comfortably, other countries accept that drivers mostly drive faster than the design speed. Each of the approaches demands a specific procedure to reach a satisfactory relation design.

C. SAFESTAR approach
The SAFESTAR project used a combination of the above-mentioned philosophies to set standards for (re)designing roads.

A. Alignment
Different studies indicate that accident rates can be 1.5 to 4 times higher in curves than on tangents. The narrower the curve, the higher the accident rates are. Hence, the location and design of curves as well as the design consistency between curves is of importance to increase traffic safety. This does not imply however, that curves should be avoided altogether. The use of straight sections longer than 5 km is generally discouraged because it might make drivers drowsy and less alert.

Since the early days of motorised traffic, signs have been used to warn drivers when they are approaching a substandard curve. To increase safe and comfortable use of substandard curves, advisory speed signs, curve warning signs, background markings and markings on the road give an indication of the desirable speed. Research from current practice in several EU-member states shows that there is no clear relation between the actual ‘danger category’ of a substandard curve and the applied signing and marking of that curve.

Safe and efficient traffic behaviour is greatly influenced by the geometrical features of the road. A review of accident-spot maps show that accidents in rural areas tend to cluster on curves, particularly very sharp ones. Serious safety problems occur in situations where large differences exist between the operating speed on the upstream horizontal alignment (the approach speed) and the design speed of the substandard curve. Two main approaches can be distinguished to solve this problem:

- Make the design speed of the curve similar to the approach speed.
- Use marking and signing of curves to provide the driver with the information needed for correct and timely estimation of the design speed.
Several national signing and marking guidelines in Europe have been developed. Each basic signing and marking concept consists of one or more of the five following elements: delineators, centre lines and edge lines; advance warning; advisory speed signs and chevron signs. (Safestar, Final Report, 1998)

The Safestar project identified a number of measures that can be added to the basic signing and marking of curves where special road safety problems occur.

**Poor visibility of the curve**

- **Vegetation:** vegetation on the inner side of a curve makes the curve less visible and should be reduced. Vegetation such as shrubs and small trees on the outer side of the curve, will on the other hand improve the visibility and give good guidance through the curve, especially during daytime;

- **Pavement marking:** in some cases painted signs on the road surface can improve the alertness of drivers.

**Poor readability of curve**

- **Vegetation:** vegetation on the inner side of a curve makes the curve less visible and should be reduced. Vegetation, such as shrubs and small trees on the outer side of the curve, improves perception of the direction and sharpness of the curve in daylight.

*High speeds*

- **Perceptual illusions:** special road markings may help the driver to choose the most adequate speed at places where the accident risk is often underestimated;

- **Electronic speed sign:** electronic advisory speed signs which show the curve design speed, and flash when a vehicle exceeds this speed, can help estimating the correct speed;

- **Improved road surface:** a rough road surface, which increases the noise level in the vehicle, or a surface in a different colour can also cause drivers to choose a lower speed;

- **Pavement marking:** in some cases painted signs on the road surface can improve attention;

- **Humps:** the use of speed humps in the approach can effectively reduce speeds in the curve;

- **Carriageway width:** reduced carriageway width on the approach and on the curve itself can reduce speed;

*High frequency of run-off-the road accidents:*

- **Hard shoulder:** improvement of the verge e.g. by making a paved hard shoulder, can reduce run-off-the-road accidents;

- **Safety barriers:** safety barriers do not reduce the number of run-off-the-road accidents, but can reduce the severity of these accidents;

- **Road surface:** improvement of the friction of the road surface can reduce the number of run-off-the-road accidents.
High frequency of head-on collisions

- **Ghost island**: a central hatched island increases the distance between opposing vehicles and thus reduces the risk of head-on collisions. Double continuous lines can give comparable results;

- **Hard shoulder**: a possible cause for head-on collisions is the overcompensation after running off the road. These accident types can be reduced by the presence of a hard shoulder.

B. Cross-section

**Emergency lanes and shoulders**

Accident statistics of several European countries indicate that a sizeable proportion of accidents on motorways is related to emergency lanes. The cause of these accidents seems to be inappropriate use of the emergency lanes and the nearside lane. In order to prevent improper use and to reduce the number of stopped cars, the typical facilities spacing is recommended by the Motorway Working Group of the EC: rest areas with parking and toilets (every 20 km), service areas (every 50 to 100 km), and service and accommodation areas (every 200 km). Also the presence of emergency calling posts is recommended.

The Safestar project concludes that despite present international agreements on motorways, national standards and practices in European countries are still different. The recent typology of Trans-European Road Network-motorways demands a harmonisation of these standards on significant parts of European motorways included in TERN.

It is recommended that achievements in this harmonisation will be periodically monitored. It is also advisable to gather information from the European countries about the experience with special use of emergency lanes.

At hazardous locations with a higher risk, some additional safety measures can be taken:

- rumble strips for marking the border between a carriageway and the emergency lane;
- widening of emergency lanes;
- information campaigns for road users about typical hazardous locations;
- application of lighting on motorways, especially on sections where emergency lanes or carriageway lanes are narrow.

**Express roads**

Express roads are roads, which are between the well-known and well-defined motorways on the one hand, and ordinary single carriageway rural roads on the other. The EC Motorway Working Group describes the general characteristics of express roads and recommends that they should:

- have no urban sections;
- have no private access;
- do not permit parking and stopping on the carriageway;
• do not permit slow moving vehicles, bicycles, pedestrians or animals;

• have a minimum lane width of 3.5 m;

• have edge lines and central markings;

• have a head clearance of 4.5 m;

• provide emergency calling points;

• provide service areas at a maximum distance of 100 km, directly accessible from the road and with 24 hours refuelling possibilities;

• have an average daily traffic for single carriageway express roads of 5000 vehicles per day, for dual carriageway express roads of 10,000/15,000 vehicles per day.

From detailed accident analyses it becomes clear that express roads have a bad safety record when compared to roads with a full motorway design. The most frequent accident types on express roads are, as on motorways, run-off-the-road accidents. Although from a safety point of view it would be better not to build any more express roads, it is clear that the decision on what type of road will be built is mainly based on (expected) traffic volume and financial resources. Safety arguments do not seem to play an important role in the decision making process. Analysis of the decisions to build express roads shows that in the future, express roads will play an important role. Replacing existing express road sections by the more expensive motorway sections or planning for motorways rather than express roads does not seem to be a realistic strategy. (Safestar, Final Report, 1998)

It is therefore important to improve their safety. To this end, the SAFESTAR project has defined uniform, safety based design guidelines:

• A lane width of 3.5 m for single and dual carriageway express roads;

• The presence of shoulders contributes significantly to the traffic safety;

• A shoulder width of 3.0 to 3.5 m is recommended;

• The separation of opposing traffic with a median strongly improves traffic safety;

• Slopes and obstacles in the median should be avoided (or protected);

• Climbing lanes must be recommended on upgrade sections on single carriageway express roads.

Rural roads

Although the risk of an injury accident per kilometre driven is higher on urban roads, the risk of a fatal accident is considerably higher on rural roads. The two most dominant accident types of serious accidents are head-on collisions and run-off-the-road accidents. Both accident types indicate the important role of the cross-section design and cross-sectional measures in the safety of rural roads.
Run-off-the-road accidents: several studies on major causes of run-off-the-road accidents show that they can be divided according the driver’s condition. This is shown in the figure below.

![figure 5: Major causes in run-off-the-road accidents (Safestar, 1998)](image)

Head-on collisions: a study of accident causes of fatal head-on collisions mentions a cause for about 50% of the accidents. Often mentioned causes were high speeds, overtaking manoeuvres and wheels on the verge or soft shoulder. The following figure illustrates the major causes in head-on collisions.

![figure 6: Major causes in head-on collisions](image)

The following dimensions for cross-section design are recommended (Safestor, Final Report, 1998):

- Lane width on two-lane rural roads should preferably be about 3.5 m;
- The presence of shoulders has positive safety effects;
- The width of shoulders should be between 1.3 m and 1.5 m, resulting in a total pavement width of approximately 10 m;
- Side slopes steeper than 5:1 are not recommended because of a significant higher severity of accidents with vehicles that run of the road;
- Values for obstacle free recovery zones should vary between 3 m and 15 m.
C. Safety devices

To protect occupants of vehicles that leave the road from serious injuries, safe roadside and medians are important. Free zones, safety barriers and impact attenuators are effective to realise this. The standards that are being developed ensure the effectiveness of these devices, but say nothing about the road characteristics and circumstances in which they should be applied. SAFESTAR made some proposals for standards and strategies in EU-countries:

Motorways: shoulders

There are safety reasons for favouring wide obstacle free zones. A minimum width of 9 m is recommended. This distance is not chosen in advance as an absolutely safe width. Slopes may be a part of an obstacle free zone if vehicular manoeuvres are possible. This is the case with a gradient of at least 5:1 for high slopes (> 5 m) and 6:1 for lower slopes (<2 m). Only fixed roadside objects can be located within an obstacle free zone if their support poles are flexible. If solidarity rigid obstacles cannot be relocated, protecting them with a crash cushion is the solution.

Motorways: medians

In terms of safety, obstacle-free zones for off-the-road vehicles in the median have to be at least 20 m. The level of containment of the safety barrier depends on the circumstances of the cross-section, the traffic volume, the proportion of heavy traffic and so on. If a decision is made for a low containment level, steel barriers are in favour if only the installation costs are calculated. It depends on the local circumstances which type of barrier is to be preferred.

Express roads: dual carriageways

If express roads have dual carriageways, it is necessary for road safety that a safety barrier is built in the median. There is not much difference between safety barriers for motorways and for dual carriageways, although the containment level is probably lower because of the lower design speeds of the road. Obstacle-free zones are preferred for the shoulders, the width of these zones should be about 6 m.

Express roads: single carriageways

Roads of this type with a high traffic volume preferably have some kind of physical separation of carriageways on the road axis. The shoulders are obstacle-free zones with a width of at least 6 m. Safety barriers such as those used on motorways do not fit this type of road because there is the danger of reflections, and therefore the chance of a frontal collision. Special constructions are needed, which will keep a car on the roadside during a collision. If there are high risk zones (viaducts, watercourses, ravines) standard safety barriers must be placed. (Safestar, final report, 1998)

D. Tunnels

Road tunnels have been used to cross obstacles like mountains, rivers, canals and major navigable waterways. More recently tunnels are applied in densely populated areas. Another development favouring tunnels are the increased demand for environmental protection from traffic. The tendency is to build more complicated infrastructure with high capacity under the ground. Research on
the development of tunnels shows that decisions depend on the costs. Therefore the problem is how one determines that a solution is to be economical. In the ideal situation, a tunnel in a motorway should have no effect on the level of service and road safety. In reality however, this is not the case. For the motorway in the open, detailed design guidelines are developed, where tunnel designs depend largely on the local situation. Hence there is a need to quantify the effect of tunnel design parameters on traffic safety. (Safestar, Final Report, 1998). Up till now only significant simulation studies have been possible to compare design of tunnels with design of open roads.

E. Junctions and interchanges

Though junctions and interchanges constitute a very small part of the express road network, a substantial part of the accidents happen there. Studies in Portugal (Cardoso & Costa, 1998 in Safestar final report, 1998) showed that on dual carriageway express roads 11% of the accidents were located at junctions. The majority of junction accidents, both at dual and single carriageway express roads are lateral collisions and as such the express roads are comparable to ordinary roads (see table below).

<table>
<thead>
<tr>
<th>COLLISION</th>
<th>HIT PEDESTRIANS</th>
<th>RUN OFF THE ROAD</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frontal</td>
<td>Rear end</td>
<td>Lateral</td>
</tr>
<tr>
<td>2x2 Motorway</td>
<td>5</td>
<td>23</td>
<td>16</td>
</tr>
<tr>
<td>2x2 Express road</td>
<td>19</td>
<td>12</td>
<td>32</td>
</tr>
<tr>
<td>2x2 Ordinary road</td>
<td>7</td>
<td>8</td>
<td>56</td>
</tr>
<tr>
<td>2x1 Express road</td>
<td>16</td>
<td>12</td>
<td>49</td>
</tr>
<tr>
<td>2x1 Ordinary road</td>
<td>24</td>
<td>11</td>
<td>46</td>
</tr>
</tbody>
</table>

*table 5: Accidents at junctions (Safestar final report, 1998)*

Given the high accident risk at junctions, in combination with the function of express roads, the number of interchanges should be limited.

The Sustainably Safe Traffic and Transport System defines three design principles which should also be applied to the design of (major) urban junctions. Elaborating on these principles when classifying the road network, has an important drawback for the selection of the type of junctions:

- Each road class should have a limited number of different types of junctions;
- A road class should only be connected to another road class according to the table 6
table 6: Operational requirements for connecting road classes (by a certain type of junction, Safestar, 1998)

<table>
<thead>
<tr>
<th>Interconnective road</th>
<th>Distributor</th>
<th>Access road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade separated</td>
<td>At-grade, priority regulation, speed reduction</td>
<td>At-grade, priority regulation, speed reduction</td>
</tr>
<tr>
<td>Distributor</td>
<td>Grade separated</td>
<td>n.a.</td>
</tr>
<tr>
<td>Access road</td>
<td>n.a.</td>
<td>At-grade, priority regulation, speed reduction</td>
</tr>
</tbody>
</table>

Speed reduction near and at junctions play an important role in meeting the second design principle. Speed reduction can be attained by physical measures and partly by signalisation. Generally four-arm junctions are not recommended. Roundabouts are superior to both three- and four arm junctions with respect to the number of accidents.

The predictability of traffic situations is a combination of expectation (what could happen) and observation (what can be seen). The road environment should trigger the right expectations, therefore a uniform layout is considered to be helpful. Especially facilities for cyclists and pedestrians have a great variety in design and layout. Some of these facilities have been evaluated thoroughly by BASt, (German company, partner in Safestar) in 1992. In the following figure they give an overview of the most common facilities at junctions.

Facilities 20 and 21 had the lowest numbers of accidents per junction. The highest numbers of accidents were found at type 22, 23 and 24 (BASt, 1992 in Safestar Final Report, 1998). Three different types of facilities for cyclists (defined by BASt, 1992) have been compared with each other. For two indicators, the number of accidents per junction and the number of accidents per million bicycle kilometres, it appeared that type 50 had the lowest numbers, and type 52 the highest. Regarding facilities for cyclists, facilities 30 and 31 have lower accident rates than facilities 32, 33 and 34 (Bast 1992 in Safestar Final Report, 1998).
III. Road design and speed

Speed perception also depends on cues in the visual environment, thus a proper design of the road environment may bring drivers’ speed choice and expectancy more in line with what is considered to be appropriate in the given circumstances. Then drivers have the idea that speeding is not appropriate, and they do not feel they are forced to decrease their speed but show the appropriate speed behaviour rather voluntarily. Below you find an overview of current speed reducing measures (MASTER Final Report, 1998):

- Urban areas:
  - Speed humps and traffic calming zones, esp. in residential areas;
  - Road surface treatments;
  ⇒ negative effects: decreased driving comfort at low speeds, abrupt braking patterns, increased noise levels;
  - Converting traditional junctions into roundabouts.

- Rural single-carriageway roads:
  - Transverse road markings or transversely placed rumble strips: if the distance between transverse markings or rumble strips decreases while approaching the dangerous location, this usually leads to a reduction in speed, since this creates an illusion of acceleration;
  - Longitudinally placed rumble strips that reduce comfort when taken with high speeds require more accurate lane keeping, which is decreasing driving speed;
  - Advisory speed signs as a warning for a dangerous location will only lead to speed reductions if drivers understand the reason for the warning.

- Urban and rural roads:
  - Decreasing visibility distances: increase uncertainty, need to slow down in order to achieve better anticipation; can be achieved through the amount of curvature, rising and falling gradients, buildings and overgrowth;
  - Disadvantage: decrease safety when drivers do not reduce speed; advisable to combine with e.g. road markings or transverse rumble strips to warn drivers to slow down.

- Motorways:
  - Concept of design speed: speed drivers can maintain comfortably under favourable traffic and weather conditions; drivers have a high level of acceptance about this and behave accordingly;
  - Substandard situations need explicit warning;
Variable Message Signs are more and more used to regulate and guide traffic on motorways with dynamic speed limit signs, e.g. dependant on visibility conditions, a fog warning is given together with an appropriate speed limit.

Most road design adaptations lead to the best speed-reducing effects if they are combined with other adaptations in road design. By providing drivers with the idea of an increased risk for high speeds, driving speeds can be reduced on all kinds of roads. Ideally, drivers’ perceived (subjective) risk should reflect correctly the actual (objective) risks, or even overestimate them. Reducing road width asks for accurate steering behaviour and increases the perceived risk of running off the road or hitting other vehicles. Placing obstacles along the side of the road works much in the same way. The problem with these measures is that they also increase the actual risk of running off the lane and colliding with an oncoming vehicles or an obstacle for those drivers who do not reduce their speed as intended. Ideally, only the perceived risk of high speed driving should be increased. One way to achieve this could be the reduction of lane width without reducing pavement width.

Currently the largest reductions in driving speed are realised with speed-reducing measures that physically restrict driving at high speeds such as speed humps and chicanes. Roundabouts have primarily a positive safety effect.

**Effects of cognitive road classification on driving speeds**

Physical measures only force road users to reduce speed, but do not let them choose this voluntarily. Therefore, a better solution is to design roads that are self-explaining. By designing a road that provides a speed image, which is in accordance with the actual speed limit, drivers are persuaded to choose appropriate driving speeds more or less automatically. The Self-Explaining Roads (SER) concept advocates a traffic environment that elicits safe behaviour simply by its design. Therefore, it is important that the function and use of roads match the way people subjectively categorise these roads. At present, subjective road categories do not seem to correspond with the official road categories.

According to the SER concepts, road users classify road scenes into categories. Each type of road has its prototypical representation, so individual roads do not have to be stored (and remembered) separately. Prototypical representations of road scenes develop through experience and constitute the basis for categorising road environments. As soon as an unknown road is encountered, existing schemes and their typical characteristics are used to categorise this road as a member of a subjective category. In order to obtain Self Explaining Roads, it is important that the design of the infrastructure is adjusted to the way the road environment is categorised in the heads of its users. Successful categorisation may lead to a timely anticipation of possible events. Inadequate categorisation induces wrong expectations that may lead to human errors in perception and judgement on appropriate speed choice and consequently in an increased accident risk (MASTER Final Report, 1998)

**Conclusion**

Road category and driving environment apparently influence drivers’ speed choice. It is therefore important that road design gives a correct impression of the road category to drivers, and thus enhances their chances for appropriate choice of speed. In practice, road categories are defined by a set of characteristics on several dimensions such as lane width, road surface, delineation, and elements along the road. Due to local circumstances, some of the predefined characteristics cannot always be applied in a given traffic situation. Providing redundant information does not help the individual road user, since he only makes use of a few of the available characteristics for individual road classification. Correct classification by road users is
only possible if the few dimensions that are used by these road users always provide consistent and correct information on the type of road. It appears to be best to identify those dimensions in such a way that differences between categories are learnt most easily. Only specific dimensions such as lane width and the presence of bicycle lanes seem to affect drivers’ speed choice directly. (MASTER Final Report, 1998)

IV. Road design and non-motorised modes

Pedestrians form the second largest group of road casualties (after car occupants). They account for approximately 15 % of the road fatalities in the European Union. Age groups of over 55 and below 12 are the most subject to pedestrian casualties. Compared to most other road accident types, the severity of pedestrian accidents is high. This is due to the vulnerability of pedestrians vis-à-vis the vehicles. Pedestrians have the highest ratio of deaths to injuries of all categories of people injured by motor vehicles; about twice as high as for motorcyclists, and over four times higher than for motor vehicle occupants. In most countries, accidents involving pedestrians (apart from those resulting in fatal injuries) tend to be underreported. Statistics thus provide an optimistic view of the pedestrian safety problem. (PROMISING Final Report, 2001)

The Dutch have the largest figure for bicycle use per inhabitant in Europe: on average more than 1000 bicycle kilometres per inhabitant per year and a modal share of 28 %. Denmark is second with 960 bicycle kilometres per inhabitant per year and a share of 18 %. The average of kilometres/year/person in the EU is 200. Austria, Belgium, Finland, Germany, Ireland, Italy and Sweden range between 100 and 400, whereas France, Greece, Luxembourg, Portugal, Spain, and the UK are below 100.

The number of cyclists killed per cycled kilometre is very much influenced by the total number of cycled kilometres. The accident risk based on the amount of cycling is lowest in Denmark and the Netherlands (respectively 15.9 and 17.6 fatalities per billion km). The risk is particularly high in France and Great Britain (67.7 and 52.5), where the amount of cycling is low. It has been proven that the risk decreases as exposure increases. An increase in cycling is thus not automatically linked with a linear increase in road casualties. As is the case with pedestrians, non-fatal injuries to cyclists are very much underreported. (PROMISING Final Report, 2001)

Measures for the enhancement of safety and mobility

Two measures are of primordial importance with regard to pedestrian safety:

- **Area-wide speed reduction or traffic calming schemes**: aimed at reducing vehicle speeds and thus at allowing for a safer mingling of pedestrians with motor traffic. The most widespread scheme is the 30 km/h zone;

- **The provision of an integrated walking network**: usually centred around a downtown pedestrian zone; serves to remove and/or reduce conflicts between pedestrians and vehicles and to provide or improve crossing points.
Both measures contribute to the achievement of a more readable traffic environment. They are commonly proposed in current traffic planning and engineering practice as part of packages for urban areas. The actions can be seen as backbones of a balanced and comprehensive approach for improving pedestrian safety. (PROMISING Final Report, 2001)

The demands made on the design of roads and their environment, and on traffic planning and management by pedestrians’ movement patterns are summarised in the following table.
(PROMISING Final Report, 2001)

<table>
<thead>
<tr>
<th>Activities performed on the pedestrian network</th>
<th>Needs common to all pedestrians</th>
<th>Special needs of the more vulnerable pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparation of trips</td>
<td>Planning</td>
<td>Planning</td>
</tr>
<tr>
<td></td>
<td>-information on weather conditions, shopping times, road works</td>
<td>-information on existence or absence of relevant facilities</td>
</tr>
<tr>
<td></td>
<td>-precautionary measures</td>
<td></td>
</tr>
<tr>
<td>Performing trips</td>
<td>Planning</td>
<td>Planning</td>
</tr>
<tr>
<td></td>
<td>-appropriate walking network enabling pedestrians to reach all their destinations</td>
<td>-avoidance of steep gradients that may not be usable by elderly or disabled pedestrians</td>
</tr>
<tr>
<td></td>
<td>-shortest possible routes between two destinations, except in areas mainly devoted to leisure, commerce, culture</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-possible choice between alternative routes for different purpose trips (leisure - work)</td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>Planning</td>
<td>Planning</td>
</tr>
<tr>
<td></td>
<td>-continuity of routes (avoid abrupt changes in the way they are planned and amount of attention required from pedestrians)</td>
<td>-rest areas (places to sit) along the walking network to enable elderly or disabled pedestrians to walk longer distances</td>
</tr>
<tr>
<td></td>
<td>-adequate location of crossing (zebras, traffic light crossings, underpasses or bridges) in order to satisfy the two requirements: shortest route, continuity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-reduction of friction between motor or bicycle traffic and pedestrians wherever possible (segregated or separated pedestrian routes, or speed reduction)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-shelters from bad weather or for waiting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-adequate capacity of pedestrian walking facilities in relation to pedestrian flows</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-smooth and non-slippery surfacing for comfortable walking</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-elimination of all obstacles likely to obstruct pedestrian routes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-specific direction signing for pedestrians, particularly on the links of the network segregated from motor traffic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-reduction of vehicle speed on links of the network with mixed traffic (residential, commercial or historical streets)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-adequate lighting</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>Design</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-clearance of snow, ice or dead leaves from pedestrian walking facilities as soon as needed</td>
<td>-adequate width to accommodate wheelchairs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-avoidance of steep gradients and steps</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-tactile guidance for blind pedestrians</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-severe reduction of vehicle speed on links where children are likely to run onto the road (around schools, sports grounds…)</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-clearance of snow, ice or dead leaves from pedestrian walking facilities as soon as needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-repair of holes, damaged surfacing as soon as needed</td>
<td></td>
</tr>
<tr>
<td>Crossing</td>
<td>Planning</td>
<td>Design</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>--------</td>
</tr>
</tbody>
</table>
| - adequate location of crossings  
- adequate timing for crossing  
- reduced waiting time for pedestrians (through traffic management measures)  
- reduced physical effort (few underpasses or pedestrian bridges)  
- possibility of crossing all along links with particular specifications (commercial streets, leisure areas): traffic management  
- adequate mutual visibility of pedestrians and drivers on the approaches to the crossing (planning of parking facilities) | no underpasses or footbridges for elderly pedestrians, wheelchair users or partially disabled people |
| - planning of areas free of vehicles where people can stop, sit, talk, etc. near the main pedestrian destinations  
- adequate integration of meeting points in pedestrian routes (continuity)  
- adequate design of meeting points for attractiveness & comfort of social activities | - signals perceptible by blind people, indicating that they are approaching a crossing as well as the period when they can cross safely  
- denivellation between pavement or footpath and carriageway must be such that wheelchair users can cross it  
- sufficient crossing time for slow pedestrians (elderly, partly disabled people)  
- adequate visibility/detectability of children for drivers (in particular removal of parked cars near crossing) |
| Playing / Exercising | Planning | Design |
| - provision of play areas in residential areas, and/or mixed-traffic streets with very low speeds  
- reduced traffic flows on residential streets | - design of residential streets ensuring very low speeds of vehicles | - good visibility of young children for drivers, esp. on residential streets and near schools |
| Social interaction / Rest / Waiting | Planning | Design |
| - planning of areas free of vehicles where people can stop, sit, talk, etc. near the main pedestrian destinations | - adequate integration of meeting points in pedestrian routes (continuity)  
- adequate design of meeting points for attractiveness & comfort of social activities | - access to meeting points must be easy for elderly or disabled pedestrians |

*table 7: Planning principles for pedestrians (PROMISING Final Report, 2001)*
The same basic planning principles that apply for pedestrians apply for cyclists. It is very important to avoid restrictive measures since they are incompatible with a sustainable approach promoting maximum use of cycling as mode of transport. (PROMISING Final Report, 2001)

**Spatial proximity**

Long travel distances restrict the usability of the bicycle. Therefore land use planning should be based on proximity.

**Planning for cycling as a mode of transport**

Because cycling is suitable for travel over relatively greater distances than walking, it is necessary to distinguish a flow and an access function. As is the case with motorised traffic, a network for the flow function is required. However, this network cannot follow the network for through-motor traffic easily, since the mesh of the routes of the cycling network is smaller. Provisions for cycling should therefore not simply be seen as additional features of the traffic structure for motor traffic. Rather, they require a network of their own.

A hierarchy of roads was developed according to function, design and behaviour for all modes of transport. It was based on the requirements of coherence of the network, directness, safety, comfort and attractiveness on the one hand and on the new concepts for road safety in the Dutch sustainable traffic system and the Swedish Zero Vision on the other hand.

The hierarchy was developed only for built-up areas and comprises 5 types:

- through-traffic route with a speed limit of 70 km/h and only grade-separated crossings;
- main street or urban arterial road with speed limit of 50 km/h and, in some areas, 30 km/h;
- residential street with a speed limit of 30 km/h;
- walking-speed street;
- car-free areas for pedestrians and cyclists.
<table>
<thead>
<tr>
<th>Through-traffic route</th>
<th>Main street</th>
<th>Residential street</th>
<th>Walking street</th>
</tr>
</thead>
<tbody>
<tr>
<td>Function</td>
<td>for longer car journeys through built-up areas passing through residential area(s)</td>
<td>used by motor vehicles &amp; cyclists travelling from one neighbourhood to another nearby, or to through-traffic road</td>
<td>priority to local inhabitants</td>
</tr>
<tr>
<td></td>
<td>priority to efficient transport by car at steady moderate speeds</td>
<td>car parking can be permitted</td>
<td>attractive, pleasant space, suitable for children, elderly &amp; disabled persons</td>
</tr>
<tr>
<td></td>
<td></td>
<td>only local traffic with origin / destination in neighbourhood</td>
<td>some have through-traffic function for cyclists</td>
</tr>
<tr>
<td>Design</td>
<td>alignment often of high standard and as far away from buildings as possible</td>
<td>one lane in each direction</td>
<td>communal outdoor space share by everyone living in the street</td>
</tr>
<tr>
<td></td>
<td>often two or more car traffic lanes per direction</td>
<td>wide cycle tracks &amp; ped. Pavements crossings for cyclists &amp; ped. at intersections</td>
<td>attractive, pleasant space for meetings, play and recreation</td>
</tr>
<tr>
<td></td>
<td>grade separated crossings for cyclists &amp; pedestr.</td>
<td>cycle tracks natural link in bicycle network, at least 2 metres wide per direction</td>
<td></td>
</tr>
<tr>
<td>Behaviour</td>
<td>max. 70 km/h at intersections max. 50km/h if any risk of side impact collision</td>
<td>max. 50 km/h 30 km/h at intersections</td>
<td>entire street is intended for everybody</td>
</tr>
<tr>
<td></td>
<td></td>
<td>normal for a pedestr./cyclist to cross anywhere or at crossings</td>
<td>not divided into separate lanes for different types of traffic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>main cycle route/street can cut across resid. Area</td>
<td></td>
</tr>
<tr>
<td>Walking and cycling</td>
<td>frequent grade-separated crossings to prevent barrier effect for cyclists &amp; pedestrians</td>
<td>important to construct cycle tracks along these streets to promote cycling, for safety reasons, and to enable road users to perceive intuitively that they are on a main street</td>
<td>pedestrians and cyclists always have right of way</td>
</tr>
<tr>
<td></td>
<td>limit number of routes to prevent built-up areas being cut up in separate parts</td>
<td></td>
<td>max. speed for motor vehicles does not exceed walking speeds, 5-10 km/h</td>
</tr>
</tbody>
</table>

*table 8: Hierarchy of roads in build-up areas*
Crossing facilities
The safety of bicycle facilities is often reduced drastically by a lack of proper solutions at crossings. Feelings of mutual respect can be promoted by right-of-way regulations, speed reduction measures (e.g. raised bicycle crossings, humps, refuges in crossings, mini roundabouts) and improved visibility (e.g. truncated cycle tracks, advanced stop lines at signalised intersections, parking regulations).

Regulations
Regulations may be an important contribution to enhancement of the protection of cyclists and to enhance their right to make efficient and comfortable use of the road. Regulations can enhance cycling policies for three reasons:

- to set standards for safe behaviour of cyclists and road users who potentially put cyclists at risk;
- to give a legal status to standards for a good combination of safety and mobility aims regarding cyclists;
- to formulate the legal responsibilities in case of accidents.

Two main principles for highway codes and guidelines may be taken as a general approach:
- the waiting time for pedestrians and cyclists at crossings should be minimised, the pedestrians and cyclists being provided with the same rights as motor traffic;
- in urban areas, walking and cycling should receive first priority, except on some roads with a traffic flow function for cars only.

To ensure first priority for cyclists and pedestrians, technical measures are needed, supported by rules. Possibilities are:

- advanced stopping lines at crossings with traffic lights, to enable cyclists to wait in front of motor traffic and to continue first;
- leading phase for cyclists and pedestrians;
- traffic lights that provide a green phase to cyclists and pedestrians twice during each cycle;
- detectors that provide cyclists and pedestrians with green light as soon as they arrive at a crossing;
- providing cyclists with the right to turn right when motor traffic has to wait for a red light. (PROMISING, Final Report, 2001)
Criteria for design of technical facilities

Before implementing cyclist and pedestrian facilities, layouts that optimise efficient cycling and walking and at the same time minimise hazards between road users have to be considered and chosen. For both demands criteria have been set up, indicating at which level in the road infrastructure actions or measures should be taken. The different infrastructure levels are:

- **The network** as a whole, comprising all footpaths and cycle paths or tracks;
- **Routes** as chains of road sections and junctions, connecting important parts of the urban area with each other;
- **Road sections** as the links between the nodes (junctions) in the network;
- **Junctions** comprising accesses to and exits from routes, mostly located at crossroads, but in some cases part of a road section, e.g. because of discontinuity in the cross-section.

Cycling or walking as an activity

Four criteria have been set up, dealing with the longitudinal and cross-sectional continuity of the movements:

- **Possible and necessary manoeuvres** can be limited by the width of the facility (e.g. walking with two people next to each other can be impossible on a narrow footpath), by the type of facility (e.g. overtaking at a narrow cycle lane is possible by using the carriageway), and by traffic conditions (e.g. turning left at a busy junction can be difficult);
- **Continuity in the cross-section** relates to the layout (e.g. a cycle track which is ended at a certain point in a road section) and to the actual condition of a facility (e.g. the road surface is in a bad condition);
- **Predictability** facilitates a road user in his cycling or walking task. The road and road environment can help the road user to recognise the sort of circumstances he will be facing. This will prevent unexpected interactions or situations;
- **Continuity from one route or road section to another** support the road users’ way through the road network (e.g. the continuity of a route at a junction can be indicated by signposts, by the continuity of the layout of the cross-sections, by a coloured road surface or by the arrangement of elements and buildings in the road environment).

These four criteria can play an important role in making cycling and walking more attractive. The criteria meet to a great extent the recommendations of both the behavioural study and the accident analysis that were carried out by the ADONIS project.
Interactions between cyclists or pedestrians versus other road users

Four criteria have been identified, relating to the amount and characteristics of the movements of both interacting road users:

- **Same direction or crossing** is aiming at the most suitable angle at which road users should interact. An angle of $90^\circ$ gives much more opportunities to observe another road user than a smaller angle. Pedestrians mostly cross at an angle of $90^\circ$, but in countries where it is legal, cyclists will often cross at much smaller angles, especially when they turn left (direct left turn);

- **Differences in mass and speed** should be small in order to prevent conflicts and accidents;

- **Frequency of interactions** has a direct relation with the number of conflicts and accidents;

- **Priority regulation** determines the nature of the interactions. That is why the priority regulation at a certain location should be clear to all road users.

These four criteria are essential for countermeasures regarding the sort of accidents described in the ADONIS accident analysis (cf. 2.2.1). These criteria have a direct impact on the manoeuvring or guidance level of the driving task (cf. before)

The following table indicates at which infrastructure levels relations between cycling and walking exist as an activity and the four criteria concerning continuity, and secondly at which infrastructure levels relations exist between road users’ interactions and the four criteria concerning minimising accidents. The choices that need to be made concerning the structure and layout of the road network and the routes, determine to a great extent how the traffic system will function at the street level (road sections and accesses/exits). Trips on foot and by bicycle can only be quick, safe and comfortable if the right choices are taken at the higher levels of the network and routes. The nature of the choices is discussed below, using criteria from the table.

<table>
<thead>
<tr>
<th>Demand</th>
<th>Criterion</th>
<th>Network</th>
<th>Route</th>
<th>Road section</th>
<th>Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycling or walking as an activity</td>
<td>Possible/necessary manoeuvre</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Continuity in the cross-section</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Predictability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Continuity between the infrastructure levels</td>
<td>+</td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Interactions between cyclists or pedestrians and other road users</td>
<td>Same direction or crossing</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Difference in speed and mass</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Frequency</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Priority regulation</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

*table 9: Vital demands and criteria related to each of the infrastructure levels (Adonis)*
Design criteria related to cycling and walking as an activity

Before deciding upon measures to be taken, consider the present state of a city in order to be sure to select facilities that will meet cyclists’ and pedestrians’ demands for longitudinal and cross-selectional continuity.

Network level (first column of table)

Continuity of each route between the infrastructure levels has to be assured at the road network level. The route system should be a type of network, which interconnects all important areas with each other (radial or grid network). Each route should have a minimal level of quality (regarding the layout of the cross-section, the type of facilities, and the road environment) from the beginning to the end. There should be a clear difference between a road section, which is part of a route, and another section, which is not a part of any route. Signposting can facilitate this difference.

Route level (second column of table)

In most cases possible/necessary manoeuvres play a role at the lower levels (road sections, accesses/exits). But on the route level one has to take care of the longitudinal continuity of the route. The quality of the different parts of the route should not vary too much. The possible and necessary manoeuvres have to be more or less the same at all parts of a route.

Continuity in the cross-section is an important feature for showing the continuity of a route to the road users. A continuous cross-section also prevents cyclists and pedestrians from making unnecessary and illogical manoeuvres and crossings.

Predictability is important for creating realistic expectations about the traffic conditions. This criterion can be fulfilled by using roadside elements in a systematic way and by applying the continuity in intersections.

Road section level (third column of table)

Possible/necessary manoeuvres of cyclists and pedestrians when moving along a road section very much depend on obstacles blocking their way. Especially cyclists who try to avoid an obstacle tend to make a sudden move to the left, which can easily result in an accident. Lanes, paths and tracks for cyclists and pedestrians should be free from obstacles and vehicles.

Junction level (fourth column of table)

Possible/necessary manoeuvres of cyclists and pedestrians must be clear to all road users. Marking of the road space for these groups underlines their spatial position.

Continuity between the infrastructure levels: every access/exit is part of a chain of road sections (route). How the route continues must be clear from the roadside elements, from the sign posting system, from the road design and all other functional elements.

Design criteria related to interactions between road users

Consider in the same way which measures will meet cyclists’ and pedestrians’ demands in their city concerning the prevention of conflicts and accidents.
Network level (cf. again first column of table)

**Same direction or crossing:** at this level one can influence the position and orientation of the most important flows (all modes). Interactions between major flows of pedestrians and cyclists on the one hand and major flows of motor vehicles on the other can be manipulated in such a way that the angle of crossing is 90°. For instance, the bicycle flows can be concentrated on radial routes while the major flows of motor vehicles are directed to a network of ‘concentric circles’.

**Difference in speed and mass:** the speed of motor vehicles is dominating the differences in speed and mass when it comes to an accident with a pedestrian or a cyclist. There are several ways of influencing the speed of cars at the network level: (1) areas with a small amount of traffic and low speeds (traffic calming), (2) a network of arteries with an interconnected light signal system that stimulates driving at a relatively low speed and (3) engineering measures to prevent high speeds at junctions and all other exits from walking and cycling facilities.

**Frequency** of interactions between cars and pedestrians/cyclists can be lowered by constructing level crossings and by diverting major car flows to a limited number of arteries.

Route level (cf. again second column of table)

**Same direction or crossing:** to prevent interactions between cars and cyclists or pedestrians at angles smaller than 90°, a cycling or walking route should not be parallel to a major car flow unless possible crossings are regulated. Left turning cyclists should make indirect left turns.

**Difference in speed and mass** can be attained by lowering speeds of motor vehicles. This can be done by an interconnected traffic signal system that stimulates driving at a relatively low speed. Traffic engineering measures at crossings are an alternative.

**Frequency** of interactions can be reduced by separating cars from other types of road users. Common facilities are cycle tracks/paths, footpaths and out-of-level facilities like tunnels, bridges and viaducts. Separation can also be achieved ‘in time’ by traffic signals.

**Priority regulation** on this level aims at a logical and systematic application of the priority rules. So all junctions of a certain route should be regulated in the same way for all cyclists and pedestrians following that route.

Road section level (cf. again third column of table)

**Priority regulation** must express the importance of a route. So the route should get priority at junctions.

Junction level (cf. again fourth column of table)

**Same direction or crossing:** position and orientation of most of the flows are given at this level. Car speeds should be lower than 30km/h at location where cyclists and pedestrians interact with car drivers at angles smaller than 90°.

**Difference in speed** should be restricted at accesses/exits, e.g. by raised junctions or relevant traffic calming measures.

**Frequency** of interactions at a certain access/exit has been determined at the higher levels. High volumes of motor vehicles will frustrate a quick crossing, unless (partial) level crossings or a traffic signal system, which benefits cyclists and pedestrians, will be introduced.

**Priority regulation:** high volumes of cyclists and pedestrians are a good reason to change the priority regulation in favour of these groups.
Costs, benefits and effective measures

The political debate demands more and more results from cost-benefit analyses, because the costs of measures are often tremendous. Measures that reduce motor traffic, either by raising the direct costs or by slowing traffic down, will often fail a cost-benefit test because the methodology is biased in favour of kilometres travelled. In this sense, cost-benefit analyses can hardly be said to be neutral with regard to long-term policy objectives. Reduced cost and increased demand always count as a benefit in cost-benefit analyses, whereas a reduction in demand counts as a loss of benefit. Policies that aim to reduce travel demand are very difficult to justify by means of cost-benefit analyses. Yet, it may be precisely such policies that are needed in order to promote a sustainable transport system.

In the PROMISING project the calculations were made of single measures only, as it is very difficult to get good data on the exposure and risk of injury of different modes and, related to this, of the effects of measures on travel efficiency and safety. Only those measures of which the effects are well-known, and only situations in which policy requirements and objectives are clearly articulated and widely supported were assessed for their cost-benefit ratio, since monetary values had to be assigned to the effects. These considerations limited the selection of measures for the analysis. Cost-benefit analyses were made of the following measures for improving the safety and mobility of vulnerable and inexperienced road users: roundabouts; road lighting; integrated area wide urban speed reduction schemes; environmentally adapted through-roads; upgrading pedestrian crossings; parking regulations; front, side and rear underrun guard rails on trucks; local bicycle policy to encourage mode switching from car driving; bicycle lanes; bicycle paths; advanced stop lines for cycles at junctions; mandatory wearing of bicycle helmets; improving bicycle conspicuity; daytime running lights on cars; daytime running lights on mopeds and motorcycles; mandatory wearing of helmets for moped and motorcycle riders; design changes on motorcycles; graduated licensing – lowered age limit for driver training; licence on probation – lowered BAC-limit for novice drivers; disco buses.

A generalisation of the results leads to the following conclusions:

- Measures that reduce driving speed, especially in urban areas, will improve safety, and sometimes mobility, for pedestrians and cyclists. However, more kinds of benefits must be included in the analysis such as social safety, mobility opportunities for children, elderly and disabled people, as well as the city and residential climate;

- The benefits of facilities for pedestrians and cyclists exceed costs by a wide margin;

- Measures that improve conspicuity and visibility of road users are cost-beneficial;

- The implementation of measures regarding injury protection underrun guard rails and helmet wearing for motorised two wheelers;

- Graduated licensing and driver’s licence on probation, including a lower BAC limit of 0.01% are promising measures for inexperienced drivers.
When the results of the cost-benefit analyses are combined with the recommended measures from the PROMISING reports on pedestrians, cyclists, motorised two-wheelers and young car drivers, and when it is taken into consideration that only isolated measures could be included in the cost-benefit analysis, the following 10 measures can be said to be the most important:

- a separate network of direct routes for pedestrians and a separate network of direct routes for cyclists;
- transport alternatives for young drivers, such as disco buses;
- a categorisation of roads to separate flow traffic from distribution traffic and access traffic;
- area wide speed reduction apart from roads with a flow function for motorised traffic;
- implementation (and) development of infrastructural design standards for pedestrians, cyclists and motorised two-wheelers;
- priority rules and regulations for cyclists and pedestrians in urban areas and technical measures that support priority and stimulate perception and anticipation;
- review of traffic rules to consider privileges for motorised two-wheelers in relation to car drivers;
- a graduated or intermediate licensing system for young car drivers and motorised two-wheelers;
- education that focuses on a considerable and respectful attitude to other road users;
- injury protection by design of cars and heavy vehicles. (PROMISING Final Report, 2001)

V. Safety measures, standards and procedures for work zones

An international review of accident studies carried out by the ARROWS project revealed that work zones have, typically, higher accident rates in comparison with equivalent non-works sections. The safety problem of road work zones deserves special consideration, for the following main reasons:

- A work zone signifies a temporary change in the standards of the road facility travelled, most usually a deterioration, potentially leading to violation of driver expectancies;
- Road work zones occur relatively frequently, since an increasing proportion of highway projects consists of either improving or maintaining existing facilities;
- The accidents that occur at work zones may involve not only road users (drivers, cyclists, pedestrians), but also site personnel.
Studies on road user behaviour in work zones reveal that speeding, abrupt deceleration and inadequate distances from preceding vehicles occur frequently in road work zones. Such behaviour is reasonably characterised as high-risk behaviour and assumed to influence traffic safety negatively.

A road work zone is the part of a road facility influenced by works occurring on, near, or above it. Besides the area actually occupied by the road works, a road work zone also includes:

- The complete road section(s) where signs, markings and other roadwork-related traffic control are effective;
- The roadside area used for the physical placement of traffic control measures and other road equipment (such as protective devices);
- The buffer area(s) separating the work area from traffic.
Along each stream of traffic affected by the road works, the following areas can be identified:

- **Advance warning area**
- **Termination area**
- **Transition area**
- **Announcement**
- **Narrowing area**
- **Stabilizing area**
- **Buffer area**
- **Actual work area**
- **Run-off area**
- **Lateral buffer area**

*Figure 8: Different areas affecting traffic (Arrows, final report)*
Based on location and duration of road works three categories can be identified:

- **Long-term**: regularly operating for more than one day;
- **Short-term stationary**: staying in one place only in the daytime, at least half a day;
- **Short-term mobile**: travel either at a constant rate or by successive bounds.

A wide variety of devices and techniques can be used for reducing the probability and/or severity of traffic accidents at work zones. Four main categories of safety measures can be distinguished:

- **physical design**: provision of smooth transitions between the normal roadway and the work area, as well as of adequate space for separating the travelled way from the road works, e.g. lead-in taper and exit taper, longitudinal and lateral buffer width;
- **traffic control**: information, warning and/or regulations for road users helping them to make sound decisions regarding speed, lane choice and other parameters of their behaviour, e.g. traffic signs, traffic lights, traffic markings. Traffic control alterations are emphasised through special types of signs (e.g. routing panels, variable-message signs, or retro-reflective signs) or by supplementing markings with road reflectors;
- **road equipment**: 3 categories according to the function of the measures:
  - warning / information,
  - closure/guidance,
  - protection;
- **miscellaneous**: devices and techniques that do not fit in one of the former categories, e.g. protective clothing for road workers, traffic information on the radio.

In order to avoid or mitigate road work zone safety problems, the following main safety objectives have to be taken into account:

**Information, warning and guidance of road users**

Assist road users with relevant, reliable, correctly timed and updated information, warning and guidance, to ensure proper adaptation of their behaviour: inform them about traffic disruptions, restrictions and alternative routes; warn them about the work zone and unusual conditions or hazards; guide them to the path that must be followed.

To be effective in achieving the desired behaviour of road users, measures used to promote safety at road work zones should be accurate, properly spaced and timed, perceptible and readable, comprehensible, ensuring alertness and reasonable.

**Regulation and enforcement**

In almost all work zone cases, certain changes in driver behaviour are required for safety reasons. Since drivers may not automatically make these changes, corresponding restrictive regulations are necessary. Typically, these regulations concern **speed limits** and **prohibition of overtaking**. Important factors in determining appropriate speed limits are adjustment to reduced roadway standards, protection of road workers and queuing. Overtaking prohibitions are
necessary in cases where it is important that vehicles should stay in their lane, e.g. narrowing and/or transition areas of multi-lane roads, such as motorways – to avoid side-swipe accidents; contra flow areas without physical separation of the opposing traffic streams – to avoid head-on collisions.

Even if work zone speed limits are appropriately chosen, there is still the danger that a significant proportion of drivers will ignore them, or that other important traffic rules, such as overtaking prohibitions, will be disregarded. Police enforcement or enforcement via speed cameras can help then.

**Protection**

Adequate protection has to be provided, for road workers (safe working environment) – as well as for road users, especially the more vulnerable ones (avoidance of hazardous elements and conditions). Risks and hazards include:

- Different types of collisions, involving traffic participants, road workers and/or works vehicles;
- Obstacles within the work area, e.g. trucks, materials and construction machines;
- Other hazards within the work area, e.g. removed surface, holes for the renewal of cables;
- Emergency situations, e.g. disabled vehicles or dealing with run-off-road incidents.

Protection is applied by means of protective road equipment; provision and maintenance of roadside recovery areas/buffers; proper design of entering/exiting areas – where possible, using dedicated slip roads and parking spaces; provision of adequate space for pedestrian movement; appropriate storage of work vehicles, material, debris etc.; preventing obstruction of sight lines; warning clothing for road workers; safe design of works vehicles; and safe operation of work vehicles. Protection of road workers is of special importance. The road as a working place should be ranked equal to other working places. Exposure of workers to traffic should be avoided and physical protection from traffic should be provided. The workers should be visible to road users. The workers should also be protected from accidents involving work vehicles. Excessive work hours should be avoided.

**Road work zone implementation**

The actors involved in the implementation of a road work zone are:

- the client: the ordering body for the road work zone
- the designer;
- the contractor: company responsible for installing, operating, removing the road work zone;
- the site personnel: the workers employed by the contractor for carrying out the road works;
- the traffic police and/or other bodies responsible for road safety.
The implementation of a road work zone consists of five phases:

1. Planning, taking into account safety of road users and workers; traffic flow and road user inconvenience; efficient work zone scheduling and economical traffic operation; environmental impact and other quality requirements;
2. Design, consisting of data collection, road work zone design, check and approval;
3. Installation, consisting of instructions to workers, placement of safety measures and pre-opening check;
4. Operation, consisting of observance of safety provisions, check/audit, evaluation.
5. Removal, i.e. withdrawal of temporary safety measures and final check.

(ARROWS Practical Handbook, 1998)

The responsibilities of the actors involved in the different phases of the implementation procedure are summarised in the table below. The underlined text indicates the actor having the central role in each action.

<table>
<thead>
<tr>
<th>ACTORS</th>
<th>PHASES AND ACTIONS</th>
<th>Client (CL)</th>
<th>Designer (D)</th>
<th>Contractor (CR)</th>
<th>Site Manager (SM)</th>
<th>Safety Responsible (SR)</th>
<th>Site Personnel (SP)</th>
<th>Police and/or Other Bodies (P/OB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PHASE 1 - PLANNING</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action 1a – Planning</td>
<td>Plans work zone</td>
<td>Consults P/OB</td>
<td>Appoints D and CR</td>
<td>Appointed by CL (In some cases) appointed by CR</td>
<td>Appointed by CL (In some cases) appoints D</td>
<td>Consulted by CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>PHASE 2 - DESIGN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action 2a – Data Collection</td>
<td>Assists D in data collection</td>
<td>Collects data</td>
<td>Assists D in data collection</td>
<td>Assists D in data collection</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action 2b - Road Work Zone Design</td>
<td>Supervises D</td>
<td>Designs work zone</td>
<td>(In some cases) supervises D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action 2c - Check and Approval</td>
<td>Consults P/OB Approves design</td>
<td>Revises design, if required</td>
<td>(In some cases) checks and approves design</td>
<td></td>
<td></td>
<td></td>
<td>Checks design</td>
<td></td>
</tr>
</tbody>
</table>
**PHASE 3 - INSTALLATION**

<table>
<thead>
<tr>
<th>Action 3a – Instructions to Workers</th>
<th>Appoints SM</th>
<th>The SM appoints SR, who instructs workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action 3b - Placement of Safety Measures</td>
<td>Supervises CR Consulted by CR</td>
<td>Supervises SM/SR Consults D, CL, P/OB</td>
</tr>
<tr>
<td>Action 3c - Pre-opening check</td>
<td>Consults CR, P/OB Approves installation</td>
<td>May be consulted during check</td>
</tr>
</tbody>
</table>

**PHASE 4 - OPERATION**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Action 4b - Check / Audit</td>
<td>Consults CR, P/OB Approves operation</td>
<td>Conducts internal check</td>
<td>The SM/SR supervise corrections, if necessary</td>
</tr>
<tr>
<td>Action 4c – Evaluation</td>
<td>Cooperates with P/OB</td>
<td>Cooperates with P/OB</td>
<td>The SM ensures collection of data</td>
</tr>
</tbody>
</table>

**PHASE 5 - REMOVAL**

<table>
<thead>
<tr>
<th>Action 5a – Withdrawal of Temporary Safety Measures</th>
<th>Supervises CR</th>
<th>Supervises SM/SR</th>
<th>The SM/SR supervise SP, who remove temporary safety measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action 5b - Final Check</td>
<td>Consults P/OB Approves removal</td>
<td>Supervises SM/SR</td>
<td>The SM/SR supervise corrections, if necessary</td>
</tr>
</tbody>
</table>

*table 10: Recommended Process for Road Work Zone Implementation (ARROWS 1998)*

**Speed management**

The level of speed on a section of a road is the product of individual choices by the road users. For a driver and other occupants of the vehicle being driven, the most directly perceived consequence of choice of speed is travel time, which decreases as speed increases, though at a progressively diminishing rate. Operating costs increase with speed from the middle range of speed upwards, but this effect is less directly perceived by drivers than the saving in time. Although risk of accident increases with speed, there is a widespread tendency of drivers to...
discount their own risk of involvement in an accident. Noise and exhaust emissions increase with speed, at least from the middle range of speeds upwards, but are borne largely by people other than the driver and fellow-occupants of the vehicle. The consequence of all these effects of speed choice, and of their incidence, is that the speeds chosen by drivers have a strong tendency to be higher than would be optimal for society.

In reaching decisions about speed management, it is helpful for the decision makers to be fully informed about the effects that speed management policies and measures may have, both in aggregate and in their distribution over the affected people, helpful to their own decision-making, and in their task of consulting the affected people and assessing the acceptability to them of the envisaged policies and measures. It is to this help that the MASTER framework for assessing the effects of traffic speed has been developed and tested. (MASTER Final Report, 1998)

**Framework for assessing the impacts of speed**

For practical implementation of the framework Excel spreadsheets are available to assist in the calculations. They can be downloaded from the MASTER website at [www.vtt.fi/rte/projects/yki6/master/master.htm](http://www.vtt.fi/rte/projects/yki6/master/master.htm)

**Objectives**

The aim is to provide a tool for the overall assessment of the impacts of (changes in) speed. The framework combines the effects of a given (change of) speed into a systematic presentation.

**Structure**

The figure below shows the direct and indirect impacts of the speed of traffic that the framework is capable of handling. The causal links from (a) to (j) are relevant in all cases, whereas those from (k) to (m) are considered only at the level of transport networks.

*figure 9: A summary of the direct and indirect impacts of the speed of traffic (Kallberg & Toivanen in Master, Final Report, 1998)*
The framework consists of three distinct phases: (1) outlining, (2) measurement and (3) assessment. Each phase can be divided into a number of steps:

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Deciding on the measure or policy to be tested</td>
<td>D. Choosing the impact functions or models and gathering data</td>
<td>H. Summarising the net impacts</td>
</tr>
<tr>
<td>B. Deciding on link or network level assessment</td>
<td>E. Deciding on which impacts to monetise at what monetary value</td>
<td>I. Analysing the distributional effects</td>
</tr>
<tr>
<td>C. Establishing which impacts are relevant to the case concerned</td>
<td>F. Making the calculations</td>
<td>J. Making sensitivity tests with the key assumptions</td>
</tr>
<tr>
<td></td>
<td>G. Analysing the extent of non-quantifiable impacts</td>
<td>K. Analysing the acceptability of the policy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>L. Analysing the overall socio-economic feasibility of the policy</td>
</tr>
</tbody>
</table>

Table 11: Structure of the MASTER framework (MASTER Final report, 1998)

**Scope**

The framework can be used to assess any measure or policy ranging from moderating the speeds of the fastest few % of vehicles on one particular section of a road, to a policy for reducing the speeds on all kinds of roads throughout a region or country.

The MASTER framework allows the user to begin by specifying the measure or policy to be tested. The user then decides on a link or network level of assessment, and chooses the impacts that are included in the assessment. Possible impacts are:

- at the link level: accidents; exhaust emissions; noise; travel time; vehicle operating costs;
- additionally at the network level: rerouting; change of mode of travel; change of destination; land use transport interactions.

For the included impacts the user then:

- chooses the impact functions or models for the quantification of impacts, gathers the relevant data for the existing situation and makes corresponding estimates for the new situation with the measure or policy being considered in operation;
- decides which impacts to express in terms of money and at which monetary valuations;
- makes the calculations;
- analyses and describes the non-quantifiable effects.
The user is then ready to

- summarise the net impacts of the policy of measures;
- set out the distributional effects;
- make sensitivity tests with respect to key assumptions and input values;
- use the results to assist the process of consulting the affected people about its acceptability (in case the results are sufficiently favourable to the policy or measure for it to be worth investigating its acceptability);
- use the results together with the outcome of consultation with the affected people to assist in the decision whether to go ahead with the policy or measure.

**Limitations**

The limitations on the use of the framework lie largely in the ability of the user to specify impact functions and models, and assemble the range of data needed to implement these functions and models. These limitations become more severe as the required level of detail and precision of the calculations increase. The required level of accuracy that the user, the decision makers concerned and the affected people being consulted will find adequate, in turn depends on the context and the policy or measure being considered.

At the network level, the user of the framework will need to implement appropriate assignment, mode choice, destination choice or even land-use transport interaction models to estimate revised flows of traffic on all affected links before applying link-based models of the various impacts.

**Application of the framework**

The framework is adapted for application to every type of road from the residential access road to the multi-lane motorway. The differences between applications to different kinds of roads lie in the choice between link and network levels, deciding which impacts are relevant, and choosing appropriate functions and models for these impacts according to the type of road.

**Use of the outputs in decision-making**

The outputs of the framework can help the process of consultation with people who will be affected by a proposed speed management measure or policy, with a view to assess the acceptability of the proposed measure or policy. In consulting such people, it should be helpful to make available the results of a transparent procedure for assessing the likely impacts and their distribution.

Secondly, the outputs may be of help in the subsequent decision-taking itself. This should be assisted by being informed by the outputs of the framework, which will then be considered alongside the results of public consultation and any other relevant material or considerations which the decision-makers choose to take into account in exercising their judgement and political responsibilities.

**Current speed management measures and tools**

MASTER provides an overview of current speed management measures and tools, listing for each measure: 1) description, 2) impact on speeds, 3) other significant impacts, 4) cost-effectiveness, 5) other relevant information. The following measures are dealt with:
Informative and legal measures | Measures related to road design | Intervening measures
--- | --- | ---
• posted speed limits | • speed humps | • conventional speed enforcement
• variable speed limits | • road cavities (inverted humps) | • automated speed enforcement
• vehicle and driver type specific speed limits | • road narrowings and horizontal deflections | • adaptive cruise control
• penalty systems | • roundabouts | • in-vehicle variable speed limiters
• speed recommendation signs | • village gateways | •
in-vehicle information | • road markings | •
road-side feedback | • rumble strips and other road surface treatments | •
in-vehicle feedback | • visibility and visual guidance | •
stop regulation | • traffic calming | •
education and publicity campaigns | • environmentally adapted through roads | •

Advanced transport telematics

Recent technological advances have allowed the application of information technology and modern communications to transport issues, often named ATT or Advanced Transport Telematics. “Telematics is a combination of tele-communication and informatics and covers a wide range of systems, from complex and interrelated systems like traffic management on the one side, till simple stand-alone systems like reversing aids on the other. Telematics seems to be a subject, difficult to define with a fuzzy set of systems. Even if the definition is not precise and the effects of telematic systems are discussed controversially, there is no doubt about the market potential of telematics.” (Gadget, Telematics Report, 1999).

Active safety devices can be seen as a subset of telematics systems. The Gadget project investigated the effects of in-vehicle safety devices on different mechanisms of behaviour acquisition, regulation and modification. Examples of in-vehicle safety devices are:

- Distance keeping systems: regulation of a safety distance to a leading car. These systems are known under the name of Adaptive Cruise Control (ACC), Autonomous Intelligent Cruise Control (AICC) or Automatic Distance Regulation (ADR). The main difference between distance keeping and collision avoidance is the lacking ability of ACC-systems of reacting to stationary objects.;

- Collision warning and avoidance systems try to detect obstacles with the aid of cameras, microwave radar or laser radar.;

- Parking aids (PTS) are devised, related to collision warning devices but technically less sophisticated. They are constructed for the detection of static obstacles at low speeds;

- Alcohol control systems (ACS) help to prevent driving under the influence of alcohol. When a breath alcohol ignition interlock device is installed in the vehicle, the driver is required to provide a breath sample by blowing into the device before starting the engine;
• Driver alertness monitoring: monitoring of the driver’s state of drowsiness;
• Pedestrian monitoring systems are designed to detect pedestrians (or simple obstacles) close to the vehicle or in the path of it;
• Route information systems provide the driver with information concerning the route.

Conclusions on the effect of such systems are (Gadget, Telematics Report, 1999):
• The effects of in-vehicle safety devices (SDs) on different psychophysical conditions depend on the design and the functions of these SDs. Generally, they are expected to reduce stress, which means that they make driving easier and more comfortable. On the other hand unintended negative effects of an SD also have to be taken into account;
• The effect of SD on driver condition depends on its design and its function as well. Assuming that the driver is satisfied with the use of this system, positive emotional states will be expected, as well as subjective safety;
• In-vehicle safety devices are conceived to support the driver’s complex information processing providing them with relevant information or relieving him of certain actions;
• If an SD is used voluntarily and successfully, enhancement of subjective driving competence is expected;
• The acquisition of driving skills is dependent on feedback. These processes may be altered considerably by the introduction of SDs, by providing feedback in other qualities or with other thresholds;
• One might presume that using a perfectly functioning and accepted SD, safety is assessed much higher by the driver than without using this system;
• The effect of using an SD-equipped vehicle on the intention and motivation of the driver depends on his experiences with this vehicle. If they are in accordance with his expectations, reinforcement of existing motivations is presumed. If the experiences differ from expectations, disapproval can arise and with that the willingness to disconnect the system if possible.

The European Commission has financed several research projects on telematics and in-vehicle safety devices. Examples are:
• ADVICE – Advanced Vehicle Classification and Enforcement: development of automatic classification system and enforcement with video’s, developing European guidelines for specifications.
• CARPLUS – Integration of Carpooling among the Union Cities: promotion of carpooling, integration of carpooling data base in telematics, real-time information, etc.
• COSMOS – Congestion Management Strategies and Methods in Urban Sites: Urban traffic congestion, development of strategical plans for integrated traffic enforcement in congested areas.
• IN-RESPONSE – Incident Response with On-line Innovative Sensing: quick and reliable incident detection and response, development of integrated detection and response-strategies for changing traffic situations.

• SITE – Improving Urban Transport in Medium Sized Cities: testing of new technological solutions to improve liveability in the city.

• TELSCAN – Telematic Standards and Co-ordination of ATT Systems in Relation to Elderly and Disabled travelers: research to involve elderly and disabled travelers in new telematic approach.

• AGORA – Innovative IST platforms and services to support a democratic regional / urban planning process: development of on-line information system

• INVETE – Intelligent In-Vehicle terminal for multimodal flexible collective transport services: development and validation of modular multi-applicable intelligent IVT to improve quality and reliability of transport services for the citizen.

• PROTECTOR – Preventive safety for unprotected road user: defining sensor- and communication systems, development and validation to improve safety of vulnerable road users and reduce the number of fatalities.

**ATT for speed management**

Tools based on ATT offer flexibility and give broad possibilities to manage speed also in varying conditions like adverse road and weather conditions, in place and time related critical conditions, in critical interactive situations with other road users.

ATT systems for speed management can be divided in three categories (MASTER Final Report, 1998):

1. Informative/warning systems aiming to influence drivers’ speed choice, but leaving the decision up to them; e.g. variable speed limit signs at the roadside, speed feedback signs at the roadside, informative in-vehicle devices, in-vehicle feedback on speed errors:

2. Recording systems registering speed; e.g. automatic speed surveillance by speed cameras, in-vehicle speed recorder

3. Intervening tools setting the limit in the vehicle and thus taking away the possibility for the driver to exceed the pre-set limit; e.g. adaptive cruise-control, fixed speed limiters, variable speed limiters.

**2.5 Education**

**Education and training**

Research proves that road fatalities are the main cause of death in the EU in the age group 15 to 24. Compared to other causes of death, such as cancer and cardiovascular disease, road crashes produce a much higher average number of potential years of life lost (Gadget, Education & training report, 1999).

To improve the health situation in this age group traffic education and especially driver education is important. The Gadget project developed a theoretical framework with the main criteria for increased safety through a change in behaviour. Besides safety as the main quality
criterion, measures were also judged as to their efficiency, as well as their impact on the environment and social equality. This led to a grid of questions that had to be answered for all measures. The training curriculum should cover driver behaviour on four hierarchical levels, starting with the acquisition of the necessary basic vehicle manoeuvring automatism to the progress of the mastery of traffic situations.

Recommendations for best practice from the Gadget project are:

- Graduated licensing systems can be recommended because in several cases evaluations have shown a reduction in accident involvement in those countries where the licensing age is below 18 years and where safety problems are especially serious;
- There is also some evidence in Europe (Germany, Austria) that probationary license systems offer some safety benefits;
- It makes sense to increase ‘protected experience’;
- No system covers the whole evaluation grid, which indicates that there is considerable potential for developing overall systems;
- If the social and psychological context as well as behavioural self-analysis methods are covered in the training programme, many of the well-known accident-related factors associated with young novice drivers may be dealt with;
- A combination of the ideas contained in a graduated system and an educational content aimed at the upper right corner of the grid would seem promising in safety terms;
- Social equality problems cannot be significantly improved by systems based mainly on private instruction. Selection effects may cause problems.

(Gadget, Education & training report, 1999).

At this point no country has a good permanent system for monitoring the results of driver training. Whenever a new element is incorporated in driver training, evaluation studies have to start from zero and resources are lost. Driver training must also respond to changes in basic social and economic conditions. For example, better perception of environmental problems reflects a change in a societal value system. This would present new requirement and opportunities – also for driver training. In addition trends in other safety measures need to be monitored and discussed in terms of their consequences for driver training (Gadget, Education & training report, 1999).

Safety Campaigns

A large international sample of evaluated campaigns were evaluated in terms of the effect the campaigns had on accidents as a function of certain variables and suggested policy guidelines for future road safety campaigns.

The main objectives of the GADGET project on “evaluated road safety campaigns” were:

- to collect a large international sample of campaigns that have been evaluated;
- to provide an accurate description of this sample using a detailed coding scheme and focusing on the design of the evaluation;
- to evaluate the effect the campaigns have on accidents as a function of certain variables.
The precise points of interest of GADGET were the ‘evaluated road safety campaigns’ from 17 European countries (within and outside the EEC) and 5 non-European countries (Australia, Canada, Japan, New Zealand and the United States). Out of 22 countries reviewed, GADGET collected 265 evaluated road safety campaigns from 18 countries. The documents on evaluated road safety campaigns were deliberately heterogeneous in order to reduce a selection bias of best reports. The evaluation reports gave only limited information about the design of the specific campaigns. Only 11,7% reported development based on an explicit theoretical framework. 36,6% of the evaluation reports specified that the campaign message had any explicit basis, mainly from previous campaigns. A lot of information was lacking on how and why the campaigns were developed.

In the GADGET sample, 41 different themes were involved, alone or in combination with other themes. The most common themes were alcohol (35,1%), seat-belt use (30,6%), speeding (26,8%), accidents (15,5%) and driving carefully (10,2%). The distribution of the themes was not uniform across countries:

- alcohol was most often found in Australia (17/33), the Netherlands (16/43) and Belgium (12/36),
- seat-belt use was most often found in the United-States (21/38), Canada (15/34) and the Netherlands (11/43),
- speeding was most often found in the Netherlands (16/43).

Themes such as accidents and driving carefully which were frequent themes rarely appeared alone in campaigns; they were in the majority of cases associated with other themes in the campaigns.

Three quarters of the evaluated campaigns were aimed at all drivers and were carried out on a national scale, then on a provincial scale, local scale and in cities. Few of them combined different scales.

**Main results**

One of the main results was that greater significant results were found for small scale campaigns on local scale and in cities, compared to results from provincial and national campaigns. Reductions in accidents were also achieved through the combination of a campaign with:

- enforcement alone (reduction of the number of accidents by 7,1%)
- enforcement and legislation (reduction of 16,8%)
- reward (reduction of the number of accidents by 20,2%).
Large effects from campaigns on traffic safety were found from a small sample of well-designed and well-evaluated campaigns. These large effects strongly reflect the data available from Australian evaluations that are associated with very special long-term campaigns (changes in legislation, high public support, intensive use of highly professional and emotional TV commercials, intensive enforcement levels, sustained campaign efforts over long periods, a very professional and autonomous traffic police division). Such campaigns are hardly typical of the average campaigns in Europe and in the United States. Also, of course large effects depend on the baseline level, if the baseline level of accidents is high we can expect large effects.

Analysis of the sample of campaigns shows that road safety campaigns could help to significantly reduce the frequency of accidents especially when they are combined with other actions. Some recommendations to policy makers and communications practitioners are:

- Do not spend taxation on campaigns that do not include a detailed report of the rationale and detailed results of the campaign;
- Do not spend taxation if a campaign presents no or a weak evaluation method;
- Co-operation between policy makers, safety researchers and communication must be encouraged, leading to better evaluation of future campaigns;
- Process-orientated and effectiveness-orientated research on road safety campaigns must be supported.

Safety campaigns mostly target impaired driving, trying to increase awareness of the importance of the psychophysiological condition for driving. Although it is not confirmed that a campaign alone can really reduce the number of drivers using drugs, drinking alcohol or driving when tired. It can be assumed that safety campaigns have long-term rather than short-term effects on impaired driving. Still, campaigns play an important role in a set of measures to overcome this problem. Unfavourable side effects may occur when campaigns do not consider specific groups and conditions. Also speed and aggression have been targeted by safety campaigns. Even if there may not be direct effect in the short term, at least in the long-term effects on beliefs can be assumed. Combinations with legal measures and enforcement, and the use of pre-tested concepts to avoid unfavourable side effects are recommended.

Safety campaigns address social norms and especially the norms on driving. They can provide adequate knowledge on manoeuvring and mastery of traffic situations, initiate reflection on driving, goals and context of driving and as said before, they can address the issues of impaired driving and driving under certain affective conditions. If messages are correct and campaigns are made in a professional way, potential side effects (reactance, comparative optimism, illusory self assessment) can be overcome.

Safety campaigns need not be restricted to the promotion of norms, they can also inform on dangers and how they occur. Detailed knowledge about risk determining factors helps drivers to come to appropriate interpretations of experience gained in traffic. This information on dangers may however lead to an adverse effect: it can make a driver overestimate his own driving skills and his feeling of control over driving-related decisions.

(Gadget, Safety campaigns report, 1999).
2.6 Enforcement

Legal measures
Enforcement of traffic laws is intended to influence the behaviour of road users in such a way that their risk of becoming involved in a traffic accident decreases. Traffic law enforcement can be regarded as the actual work of monitoring violations of traffic laws, apprehending offenders and securing evidence needed for prosecution.

These law enforcement activities can in turn be viewed as an essential part of a broader concept of traffic management. Besides activities directly related to enforcement, this concept of traffic management also covers traffic surveillance activities of a more general nature, such as registration, licence issues, administration, advice, information and education. Obviously these concepts are closely interrelated. Enforcement can only be effective if it operates in a supportive environment of laws, regulations, a sensitive penal system and co-operation bodies. (Escape, Traffic Law Enforcement by non-police bodies, March 2000).

The ETSC report (1999) mentions that improved and intensified traffic enforcement seems to remain the strongest and most suitable measure to increase road safety, especially on a short term (the period 2000-2010).

Alternative enforcement
To ensure a minimum level of safety for the users of a potentially hazardous traffic system, continuous police surveillance efforts seem to be indispensable. However, police resources are scarce and within police organisations, traffic law enforcement tends to have low priority. As a result, in several European countries a tendency can be noted to transfer some of the police responsibilities and competences in the area of traffic law enforcement to other, non-police based organisations.

The effectiveness of a traffic law enforcement system cannot be seen in isolation from developments within the police force itself, or from the way in which the police work together with other parties involved in the traffic law enforcement and traffic management chain.

The way in which national systems of traffic law enforcement and traffic management develop over years is to a large extent determined by the joint outcomes of public and political decision-making. A major task of the police is to assure security and safety in the public domain. The public road network and the way road users are using that network is a significant part of that domain. One would expect that an equally considerable part of police resources is allocated to police activities related to traffic management. However, in most European countries it is commonly agreed upon that police resources are scarce. Moreover, in general, traffic enforcement activities do not have the highest priority or status in police forces that have a general policing task. (Escape, Alternative Enforcement, 2000)

Enforcement of traffic laws carried out by institutions other than the police can be called "non-police based" enforcement. Some parts of the enforcement system, such as detection, registration and imposition of a penalty for violating a traffic law or regulation, are no longer the exclusive right of the police in several countries.

Non-police based enforcement may appear in several forms with different bodies involved. Enforcement activities can for instance be fully government-controlled, performed by a completely privatised, commercial organisation or by a public-private conjunction. Besides the different types of organisations that can be involved and the differences in the administrative and cooperative structures employed, the diversity stretches out to different types of traffic behaviour as well. The non-police based enforcement task may for instance be focused on a
specific target group (e.g. heavy trucks, freight traffic, etc.) or on specific (mass) behaviours (e.g. parking, speeding, etc.). The term non-police based enforcement may easily suggest that the police are no longer involved in the enforcement process, which does not necessarily have to be the case. The police organisation may still have an advising, supervising or other important role in the whole process of enforcement.

Non-police based enforcement forces us to consider the field of traffic law enforcement as an arena in which different parties with varying motives may be present. Considering that different agencies can be involved in separate tasks and phases of the enforcement process, or even simultaneously on one and the same level, some questions come to mind:

- Do the quality criteria of different departments or agencies conflict?
- When each part of the process is performed or monitored by an agency with an autonomous internal agenda, how can it be ensured that the quality control of the production process includes road safety concerns?
- How do criteria other than road safety enter into the decision making process?
- How are the activities of different agencies coordinated? And does this coordination ensure that the activities maximally benefit road safety?
- How are the respective responsibilities of the agencies operating on the same level of the productions process (e.g. the monitoring and detection of offenders) described? Does this description facilitate or hinder effective cooperation?

From a theoretical point of view it is tempting to see the traffic law enforcement process as a production process. The links in this production process could be described as: monitoring, detection, identification, administrative processing, prosecution, jurisdiction and fine-collection or imposition of (alternative) sanctions. In many European countries, other parties than the police handle several stages of this process. The courts’ officers or special administrative agencies, for instance, usually handle the last mentioned activities. Historically, there has always been a trend that those parts in the process and those problem areas in traffic which require a high degree of specialised knowledge or a standardised, routine and repetitive care, are handled by specialised, relatively autonomous agencies or departments, either public or private.

The next table presents a number of characteristics that can be used to describe whether a traffic enforcement task is eligible for a high degree of specialisation. Taking this categorisation of enforcement task characteristics as a starting point, speed enforcement could under certain conditions be considered as an activity that is eligible to be conducted by non-police bodies. Depending on the way in which the enforcement is carried out (e.g. traditional surveillance vs. automatic photo-radar on fixed camera locations) the activity could be described in terms of degree of standardisation and specialisation.
Typically the (traffic) police are best suited for offering traffic enforcement services on the middle ground between highly standardised, repetitive tasks and very specialised enforcement tasks. In general it can be expected that the police will remain an organisation that performs a multitude of tasks, in particular those involving a mix of routine and specialisation and those in which sensitive contact is rather large. The main asset of the (traffic) police in this respect is probably their capability to engage in multi-tasking.

From the findings of the Escape project, it can be concluded that the integration of other bodies in enforcement can be a meaningful step to optimise traffic enforcement and traffic management activities and, at last to improve traffic safety. Taking the limitations of administrative and fiscal enforcement into account, a second conclusion is that although local authorities can meaningfully supplement enforcement by the police, they cannot entirely replace it. A part of enforcement activities will have to rely on personal contact, where the authority of the police officer is necessary.

Road safety effects alone are not a sufficient criterion to evaluate the changes that are brought about by non-police based enforcement arrangements.

In a situation of transition between traditional police enforcement and non-police based enforcement the credibility of the enforcement itself should be safeguarded. On the long term, the acceptance and credibility of enforcement related activities are essential aspects of the sustainability of the behavioural effects. (Escape, Traffic Law Enforcement by non-police bodies, March 2000)

**Effects of Enforcement on Speed**

The purpose of speed enforcement is to keep actual driving speeds within the legal limits. Enforcement measures can be effective only when the probability of getting caught, as perceived by the driver, is relatively high. Speed enforcement at specific problem locations or on specific routes can significantly decrease speeds.
The impact of enforcement on actual speeds depends on several factors, for example actual speed level compared to speed limit, intensity of enforcement (risk of getting caught), penalty system, and publicity.

The effects of traditional speed enforcement where police officers measure speeds by radar and stop speeders for ticketing are typically limited in time and space. Furthermore, such enforcement is rather resource-intensive and not necessarily very cost-effective.

Speed cameras have proved to be effective and economic in many cases but can also be resource consuming if the law requires that the speeding driver must be identified from the photo. Modern technology offers several relatively cheap and effective means for speed enforcement, provided that the driver does not have to be identified, but instead the owner of the vehicle can be held responsible. An example of such solutions is an electronic identification device in the vehicle that could be used also for other purposes, such as for collection of road tolls and parking fees. At the moment such systems probably lack public support.

A number of recommendations for effective speed enforcement can be given on the basis of literature research:

- Explicitly and quantitatively formulated government policy objectives regarding speed and accident reduction are needed;
- Because of higher efficiency of speed camera enforcement compared to traditional speed enforcement where speeders are stopped, the first type of enforcement is recommended;
- It is recommended that the car owner is made primarily responsible for offences committed with a car;
- A point demerit system might enhance the efficiency and effectiveness of the enforcement endeavour;
- For enforcement to be accepted by the public, it is of importance that the objective is primarily prevention and accident reduction, and not punishment or financial gain;
- Enforcement should always be preceded and combined with publicity to inform the public about the danger of speeding, the enforcement method, and the effects achieved. This will prevent overloading the processing of speeding tickets at the start of the campaign. Publicity should be aimed at target groups;
- Fore warning of speed enforcement is functional where the enforced location or route is selected, based on a safety and speed problem;
- On a road network, enforcement is recommended to be randomised in space and time (unpredictable). No fore-warning should be given except through publicity. A sign informing drivers that their speed has been checked can be given down stream of the speed check;
- Use of new electronic technologies, such as automatic registering, reading, and identification of speeding cars, will increase the efficiency and effectiveness of the enforcement process. A high subjective and objective frequency of speed checks can thus be reached.

(MASTER Final Report, 1998)
3. National Differences/Local Adaptations

Despite differences in levels of vehicle use, climate, etc. the same key road safety problems are encountered in all Member States, differing only in extent. Numbers of 1997 indicate a seven fold difference in the risk of fatal injury between the highest and lowest rates across the EU. Since the late 1980s, several countries in Europe have recognised the importance of strategic road safety plans with numerical targets as a tool to increase the political priority and resources given to casualty reduction. The five countries with the lowest fatal casualty rates have all had targeted programmes since the 1980s, some even since the 1970s. The main casualty reduction strategies used in these programmes relate to:

- Managing road users’ exposure to risk;
- Preventing accidents by influencing human behaviour through a variety of means;
- Reducing injury in the event of a crash;
- Reducing the consequences of injury.

(Road Safety in Europe. A Shared Responsibility, 1997)

If all the Member States were to achieve the same results as for example the UK and Sweden, the number of people killed in traffic per year would be cut by 20 000. In 1998 the ratio between the number of persons killed in road accidents in Sweden and Portugal, two countries with comparable population figures, was 1 to 4.5, between the UK and France 1 to 2.5. (White Paper. European Transport Policy for 2010: time to decide, 2001).

Any policy development is of course strictly related to the specifications of the road safety problems of a particular country, region or city. The general applicability of a measure’s effects must always be tested in the context of actual mobility and safety patterns, the integration with various other relevant policy areas, the political environment, policy organisation and procedures. (PROMING Final Report, 2001)

The PROMISING project highlights some characteristics and points at differences in Europe, so that the context of mobility and safety patterns can be better understood. Cf. PROMISING Final Report, 2001, p. 43-47).
4. Examples and Best Practices

4.1 New policies and strategies for road safety

The Netherlands and Sweden make use of innovative safety strategies, which are important frameworks for the development of measures. Both concepts set targets for road safety in the future. Target setting has been in use for many years by different European countries. It has many advantages, such as directing policies, organisations and experts towards concrete aims.

‘Sustainable safety concept’ in the Netherlands

Starting point of the ‘sustainable safety concept’ is that man is basically the reference standard. The concept aims to drastically reduce the probability of accidents in advance, by means of infrastructural design. Where accidents do occur, the process that determines the severity of these accidents should be influenced in such a way that the possibility of serious injury is virtually eliminated.

Thus, a sustainably safe traffic system has:

- A structure that is adapted to the limitations of human capacity through proper design, and in which streets and roads have a neatly appointed function, as a results of which improper use is prevented;
- Vehicles fitted with ways to simplify the driver’s tasks and constructed to protect the vulnerable human being as effectively as possible;
- A road user who is adequately educated, informed and, where necessary, guided and restricted.

The concept can be translated into some practically oriented safety principles:

- Prevent unintended use, i.e. use inappropriate to the function of a particular road or street;
- Prevent large discrepancies in speed, direction and mass at moderate and high speeds, i.e. reduce the possibility of serious conflicts in advance;
- Prevent uncertainty among road users, i.e. enhance the predictability of the course of the road or street and people’s behaviour on it.

It is estimated that with this new policy the number of fatal accidents will be reduced with 60-80 % within approximately 30 years. (PROMISING Final Report 2001)

‘Vision zero’ in Sweden

In 1997 Sweden adopted an ambitious plan for ‘zero deaths and zero serious injuries in road accidents’ for the country as a whole. The vision states that the system should be dimensioned in such a way that possible conflicts, or incidents which might cause injury, never cause a
politically pre-defined level of unacceptable loss of health to be exceeded. In achieving the ‘zero vision’ in reality, the intention is to create a situation in which exposure to violence is minimised. At the same time, the degree of violence has to be kept below the violence tolerance level of an optimally protected human being. So, in this approach too, man is in principle the reference standard. (PROMISING Final Report 2001). The programme addresses all areas in which local authorities and companies have a leading role to play. They have been asked, for example, to introduce safety criteria into their public contracts for vehicles and transport services in order to increase the supply of safe vehicles. Systematic improvement to the road network have been undertaken to reduce the severity of accidents, and incentives have been provided, in co-operation with the private sector, to reduce the demand for road transport and thus the exposure of road users to risk. (White Paper. European transport policy for 2010: time to decide, 2001).

4.2 Catalogue of best practice measures

ADONIS has compiled a catalogue of best practice measures to promote cycling and walking. Each description of a measure is accompanied by illustrations – photos, diagrams of a layout design, or other road elements – as well as illustrations of public information material. The advantages and disadvantages of the measures in terms of comfort, costs, road safety and social safety are described in as much detail as possible. Advantages and disadvantages, if any, for road users other than pedestrians and cyclists are also discussed. If possible a cost estimate is provided. Finally, contact persons are listed as sources for further information.

How to know which of the measures in the best practice catalogue are relevant for specific circumstances? You will have to find the answer by classifying some characteristics of the local transport system under consideration, i.e. current modal splits and the density of the existing facilities for cyclists and/or pedestrians. Another question is whether a measure will be (cost) effective. This is related to the firmness of a measure, which in turn is determined by the quality of the knowledge about the measure, preferably gained by accident evaluation studies or other types of research. Various types of selection can be used as well as several possible classification criteria. The systems of selection offered by ADONIS are based upon the vulnerability of different types of road users, on the nature of each measure (infrastructure or not), and on the possible negative or positive effects of a measure for other road users (e.g. a good measure for cyclists can be bad for pedestrians).

4.3 Gladsaxe: Application of the DUMAS framework

The municipality of Gladsaxe forms part of the continuous urban area in the metropolitan region of Denmark and is located about 10 km from the centre of Copenhagen. Gladsaxe has worked systematically with traffic safety programmes for many years and thereby gives examples on urban safety management schemes. Main focus has been put on the traffic strategies stated by the municipality and evaluations of a number of implemented safety programmes such as speed management programmes in residential areas. The activities in Gladsaxe were linked with the DUMAS framework for speed management programmes and illustrate how a local road authority can use the framework.
Activities at national level and local level in Denmark to help increase traffic safety are closely related and often go hand in hand. The following figure shows the most important milestones in a chronological order taken at national level and at level of the Municipality of Gladsaxe.

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<thead>
<tr>
<th>National level</th>
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<tr>
<td>New Road Safety Action Plan</td>
<td>Speed management plan implemented in Gladsaxe</td>
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<td>2000</td>
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<td>Revised Road Safety Action Plan</td>
<td>Speed management plan implemented in Maglegard</td>
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<td>Introduction Transport Ministry's &quot;Traffic Fund&quot;</td>
<td>Speed management plan implemented in Morkhoj</td>
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<td>Traffic 2005 'White paper on traffic and transport'</td>
<td>Speed Management Plan</td>
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<tr>
<td>Handbook in environment and traffic planning for local road authorities</td>
<td>Plan of action for transport and environment in Gladsaxe</td>
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<td>1994</td>
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<tr>
<td>Road Safety Action Plan</td>
<td>Survey of environmental pollution caused by traffic in Gladsaxe</td>
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In order to determine whether speeds could be reduced by several measures in built-up areas, such as humps or raised areas, the principle was tested in the Mørkhøj and Magledård district. For the demonstration in Magledård the Dumas Framework was introduced. For both areas one of the preconditions for obtaining subsidies was setting up a steering committee with participants from the Municipality of Gladsaxe, the Gladsaxe police and the Road Directorate. This steering committee had overall responsibility for implementation of the project. For the purpose of gaining more detailed information of the problems experienced in the test-areas, and to gather knowledge learnt from the project, a working group was set up.

**STEERING COMMITTEE**
- Municipality of Gladsaxe
- Danish Road Directorate
- Gladsaxe Police

**WORKING GROUP**
- HT (Bus Service Company)
- Danish Cyclist Association
- School boards
- House owners association
- Co-operative housing society
- Municipality of Gladsaxe
- Danish Road Directorate
- Gladsaxe Police
The steering committee prepared a project document which stated clear objectives to be reached. The overall objectives were defined as being:

- To improve perceived risk for road users
- To improve safety for vulnerable road users in particular
- To contribute to more attractive urban areas

The following targets were also established:

- 30% fewer injured from 1995 to 1997
- 20% lower average speed
- 5% more cyclists (only for the Morkhoj area)

A planning phase was worked out and citizens were involved in various steps of implementing the project. In both areas a 40 km/h zone was introduced together with speed reducing measures such as humps.

As best practice the following figure shows the location and numbering of speed measurements in Maglegårds. All the ‘before’ measurements were carried out in June 1998, and the ‘after’ measurements were conducted in September 1999. Few ‘after’ measurements were carried out in April 1999 and in April 2000 however.

![Figure 10: The location and numbering of speed measurements in Maglegårds](image)
General Conclusions

The Gladsaxe town study illustrates how a local road authority by use of long-term systematic work with traffic strategies and action plans – in close relation to the national strategies – and by use of public involvement can produce promising results on road safety.

The study also shows that a high level of information to the public and the politicians on successful projects can raise the awareness of traffic related problems and possible solutions, and can ensure sufficient resources to traffic safety programmes.

The implemented road safety programmes have resulted in a >40% reduction in the number of killed and injured on municipality roads in Gladsaxe in the period 1987 – 1998. In many ways the activities in Gladsaxe can be related to the DUMAS framework for Urban Safety Management. Even though the framework has not been followed exactly, most of the activities listed in the framework have been accomplished. The DUMAS framework gives a fairly good idea of how to get started working with urban safety management by a local road authority. (Dumas, note 75, 2001)

For more detailed information on the Gladsaxe project we recommend to read the DUMAS Town Study Report from the Danish Road Directorate.

4.4 Application MASTER framework for assessing speed impact

Extending the wintertime speed limit to semi-motorways in Finland

A major part of the trunk road network in Finland is subject to a lower speed limit during winter. The wintertime reduction is from 120 to 100 km/h on motorways and from 100 to 80 km/h on other roads. A policy test was carried out on extending the wintertime limit to the slightly over 200 km of semi-motorways. This case concerns the reduction of the speed limit on these roads from 100 km/h to 80 km/h for a period of five months. Only link-level impact are considered. Presently, the average speed is 97 km/h in the summer and 94 km/h in the winter. It was assumed that a speed limit of 80 km/h would lower the winter-time average speed to 88 km/h. This assumption was subject to sensitivity tests: average speeds of 90 and 85 km/h were...
used as the minimum and maximum speed changes, respectively. The average number of personal injury accidents on these roads is about 30 per winter, resulting in 6 deaths and 46 non-fatal injuries. Thus, the accidents on these roads are often very severe. Results of the monetary impacts of extending the speed limit and the distribution of the impacts are described in detail. (MASTER Final Report 1998). Results can be found in a paper of Sami Toivanen, ST-Arkki, Finland & Veli-Pekka Kallberg, VTT Building and Transport, Finland, which can be downloaded from http://www.vtt.fi/rte/projects/yki6/master/preslist.htm.
5. Recommendations for further reading

5.1 Road Safety Audits

SAFESTAR is a research study focusing on traffic safety for what is known as the "trans-European roadway network" that links the major European centres. The knowledge needed for being able to carry out an effective safety policy at the European level is insufficient in regard to various safety aspects of road infrastructures. SAFESTAR was established to fill in these gaps of knowledge, with special notice being given to the following seven topics:

- emergency lanes and shoulders along motorways;
- tunnels located on motorways;
- express roads;
- cross-sections of rural roads;
- curves in rural roads;
- major junctions on roads in urban areas and
- assessing the safety of road infrastructure during the planning and design stages (the performing of safety audits

More information on these topics can be found on following website: www.vtt.fi/rte/yki6/safestar/safestar/htm

5.2 Urban Safety Management

Information on accident investigation, speed management, safety for pedestrians and cyclists, safety consequences of traffic management and the link between safety frameworks and other initiatives can be found on the DUMAS website: www.trl.co.uk/dumas. Detailed information on town studies can be ordered with the different DUMAS partners that are listed on the website.

5.3 Accident reduction

Accident and injury registration

The STAIRS website provides interesting information on data collection and protocols for the processing of accident investigations: www.ice.co.uk/stairs. You can read more about the CARE database in the ETSC report on EU transport Accident, incident and casualty databases: current status and future needs. This report can be ordered a the head office of ETSC: Rue du Cornet 34, B-1040 Brussels, Belgium.
Accident factors

The ADONIS project carried out a qualitative analysis of cyclist and pedestrian accident factors. The final report summarises the results of this analysis. For more in-depth information we refer to the report *A qualitative analysis of cyclist and pedestrian factors* (1998), addressing methods used and results on accident characteristics, accident factors, impact of the accident, attitudes to rules, regulations and other road users, proposals for measures, and finally, conclusions and recommendations. The report can be ordered at: Danish Council of Road Safety Research, Inger Marie Bernhoft, imb@rft.dk, tel: +45 39 65 04 44.

ADONIS also looked into the behavioural factors affecting modal choice. In this respect it also investigated the influence of traffic safety in modal choice. Results are also summarised in the final report. More in-depth information is available in the report *Behavioural factors affecting modal choice* (1998), on methods used, results of travel survey and attitude study, and profiles of walkers, cyclists and drivers. The report can be ordered at: Swedish National Road and Transport Institute, Sonja Forward, sonja.forward@vti.se, tel: +46 13 20 40 00.

5.4 Road Design and Redesign

Workzones

The ARROWS handbook provides indicative checklists of do’s and don’ts which can be used either descriptively, i.e. to remind of what one should or should not do, or as an aid to check what has already been done. The indicative checklists, based on the safety principles and recommendations of the handbook, are meant as examples of items that could be included in a prescriptive checklist. They are not exhaustive. However, they can be used in real practice on a test basis and, subsequently, be further developed and adapted to specific situations and needs.

Four checklists were developed, each dealing with a specific topic or road work zone safety:

- Traffic and speed management
- Physical design
- Work zone operation
- Ask yourself checklist for workers

The handbook can be obtained in digital format from Langzaam Verkeer, elke.bossaert@langzaamverkeer.be.

Non-motorised modes

ADOR(IS) has developed a best practice catalogue of safe infrastructure measures favouring cycling and walking. All measures are included in the cd-rom which goes with the final report. The final report with cd-rom can be ordered at Danish Council of Road Safety Research, Inger Marie Bernhoft, imb@rft.dk, tel: +45 39 65 04 44.
5.5 Vulnerable road users

PROMISING looked into measures that reduce the risk of injury to vulnerable and young road users. The aims is to present measures within an implementation framework, with the main focus on technical, non-restrictive aspects. In order to determine the potential for problem reduction, analysis concerned: data and expertise on safety problems, task requirements, measures related to problems and tasks, effects of measures on safety and mobility and the costs of measures. The potential for problem reduction was specified for four categories of road users: pedestrians, cyclists, motorised two-wheelers and young car drivers. Available reports are: *Pedestrians, Cyclist, Motorised Two-Wheelers, Young Car Drivers, Cost-Benefits of Measures* and the summarising *Final Report*. They can be ordered from SWOV, Institute for Road Safety Research, info@swov.nl, tel: +31 70 3209323

5.6 Speed Management

All MASTER research reports on speed management can be downloaded from the MASTER website at [http://www.vtt.fi/rte/projects/yki6/master/master.htm](http://www.vtt.fi/rte/projects/yki6/master/master.htm). Reports deal with: the effects of road design on speed behaviour; speed behaviour before and after road modifications; the effect of enforcement on speed behaviour; present speed and speed management methods in Europe; effects of cognitive road classification on driving behaviour; acceptability of speeds and speed limits to drivers and pedestrians/cyclists; speed-accident relationships on different kinds of European roads; framework for assessing the impacts of speed in road transport; categorisation of road environments and driving speed, the effects of ATT (advanced transport telematics) and non-ATT systems and treatments on speed adaptation behaviour; evaluation of in-car speed limiters; and recommendations for speed management strategies and tools.

5.7 Education

**Education and training**

Information on results of GADGET research on education & training, and safety campaigns can be downloaded from the website: [http://kfv.or.at/gadget.htm](http://kfv.or.at/gadget.htm).

5.8 Enforcement

Information on enforcement needs on European roads will be available on the ESCAPE website, as well as more information on new concepts in automatic enforcement, on the assessment of different methods, etc. The final report from ESCAPE will be available from September 2001: [http://www.vtt.fi/rte/projects.escape.htm](http://www.vtt.fi/rte/projects.escape.htm).

Information on results of GADGET research on legal measures can be downloaded from the website: [http://kfv.or.at/gadget.htm](http://kfv.or.at/gadget.htm).
6. Exercises

6.1 Urban Safety Management
Apply the urban safety management framework to a specific city.

6.2 Road Environment
Evaluate the use of appropriate design criteria for different road categories at specific locations and suggest improvements taking into account the concept of ‘Self Explaining Roads’.

6.3 Safety for Work Zones
Identify the necessary safety measures for a specific workzone situation.

6.4 Pedestrian/cyclist measures
Evaluate the pedestrian and cyclist facilities of a specific city or location making use of the ADONIS criteria and suggest improvements on the basis of these criteria.

6.5 Speed management
Apply the MASTER framework for assessing the impact of speed.
7. Literature

The following reports and websites have been used to set up this written material:


http://www.ntua.gr/arrows/


DUMAS (2001) Town Study Report, Gladsaxe, Denmark. Note 75, Danish Road Directorate, Copenhagen, Denmark.


EC (2001), European transport policy for 2010: time to decide, European Commission


OECD (1990) Integrated traffic Safety management in urban areas, OECD Paris, France

OECD (1997), Road safety principles and models: review of descriptive, predictive, risk and accident consequence models, Paris, France


8. Glossary

**Accident**: Unexpected adverse event. May be a fall, crash, collision, explosion.

- **Road accident** (or traffic accident): definition used for statistics in most countries: collision occurring on a public road and involving at least one moving vehicle. Road accidents include damage-only accidents and injury-producing accidents
- **Accident causation**: set of events involving different elements of the road traffic and transport system (road environment, vehicles, road users) and leading to collisions
- **Accident data**: formalised set of information on injury-road accidents
- **Accident factor** (or contributory factor): any element of the traffic and transport system (i.e. related to the road and its environment, vehicles, traffic or transport organisation, road users, or to interactions between these) that has been identified as taking part in an accident process in such a way that the accident would not have occurred if this element had been different or missing.

**Efficiency**: Efficiency of a road safety measure: quality of a remedial measure that succeeds in significantly reducing the expected number of future accidents or casualties.

**Exposure**: to uncover or make somebody/something visible. Variable measuring the presence of traffic and/or other road users.

**Hazard**: an event, or thing, that can become dangerous. Anything that threatens the integrity or the existence of a person.

**Perception**: the process of becoming immediately aware of something

**Predictability**: facilitates a road user in his/her task. The road and the road environment can help the road user to recognise the sort of circumstances he/she will be facing. This will help to prevent unwanted interactions or situations.

**Road user**: any person moving on a public road

- **Cyclist**: road user travelling on a bicycle, defined as a non-motorised vehicle with at least two wheels and pedals or hand-cranks, designed to carry one or several persons and possibly also goods.
- **Driver**: road user driving a motor-powered vehicle or a non-motorised vehicle
- **Pedestrians**: road user walking on public roads or spaces subjected to traffic legislation.
- **Vulnerable road user**: road user belonging to a category most at risk in traffic and generating little risk to other road users. By extension: road users unprotected by an outside shield, i.e. pedestrians and two-wheelers.

**Safety**: freedom from injury or risk. Relates to the safety experienced in the transport process (absence of conflicts and accidents in traffic).

**Traffic calming**: areawide programme of self-enforcing measures aimed at reducing speeds of motorised vehicles, and at enhancing the quality of interaction between road users.

**Traffic conflict** (or near-accident): a traffic situation in which two road users approach each other in such directions and with such speeds as to produce a collision unless at least one of them performs an emergency evasive manoeuvre. More rarely, a traffic conflict may involve one road road user only, on a collision course with a fixed obstacle or an animal.

**Urban area**: built-up area, which limits are marked on the roads leading to or from them by specific signs. Speeds are usually limited in urban areas (to 50 km/h in most EU countries).
9. **Safety and Accident Reduction – The consortia of the projects**

ADONIS - Analysis and Development Of New Insight into Substitution of Short car trips by cycling and walking

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ARROWS – Advanced Research on Road Work Zone Safety Standards in Europe.

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## DUMAS – Developing Urban Management and Safety

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## ESCAPE - Enhanced Safety coming from Appropriate Police Enforcement

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### GADGET – Guarding Automobile Drivers through Guidance Education and Technology

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### MASTER – Managing Speeds of Traffic on European Roads

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<td>Factum Chaloupka Prashhl, Risser OHG</td>
<td>AT</td>
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<tr>
<td>Institute for Transport Sciences LTD</td>
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</table>
PROMISING – Promotion of Mobility and Safety of Vulnerable Road Users with regard to Mobility Integrated with Safety taking into account the inexperience of the different Groups

<table>
<thead>
<tr>
<th>Consortium:</th>
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<tbody>
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<tr>
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<td>Echte Nederlandse Fietsersbond</td>
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<td>I-CE Interface for Cycling Expertise</td>
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<td>BUNDESANSTALT Fsr STRASSENWESEN</td>
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<tr>
<td>Institut National De Recherche Sur Les Transports Et Leur Securite</td>
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<td>De Voetgangersvereniging</td>
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<td>National Technical University of Athens</td>
<td>GR</td>
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<td>Transport Research Foundation T/A Transport Research Laboratory</td>
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SAFESTAR – Safety Standards for Road Design and Redesign

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<td>Laboratorio National De Engenharia Civil</td>
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<td>Centre ‘d Etude Technique de ‘l Equipment Normandie-centre</td>
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<td>DK</td>
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STAIRS – Standardisation of Accident and Injury Registration Systems

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<td>Medical University of Hanover</td>
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