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INSTITUTE FOR ROAD SAFETY RESEARCH SWOV
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The Institute

The Institute for Road Safety Research SWOV was founded in 1962. Its object is, on the basis of scientific research, to supply the authorities with data for measures aiming at promoting road safety. The information obtained from this scientific research is disseminated by SWOV, either as individual publications, or as articles in periodicals or via other communication media.
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Introduction

In the last years researchers and policy makers try to approach the problems of traffic safety by novel methods. Until recently the general trend was to establish statistical relationships between accidents and the characteristics of road users, vehicles, roads and environment. Such approach involves that measures are mostly taken after accidents have happened. Thereafter, as a rule, it takes quite a long time before policy makers can actually start with elaborating corresponding measures. This is certainly true in times of economic recession: prior to spending much money on certain measures, it has to be carefully studied whether other measures would not prove to be of greater social benefit. Due to all these factors the traffic-safety policy always lags behind novel developments. In the worst case measures concerning traffic safety seem to have the effect like closing the stable doors after the horse was stolen. For past accidents do not always predict reliably future occurrences, since circumstances in traffic are continuously changing.

Future-oriented policy

In order to establish a more future-oriented policy knowledge must be available of critical traffic situations, which may lead to accidents. The behaviour of the road user plays an important role in the development of critical combinations of circumstances. It has to be investigated how traffic behaviour arises and how it is to be influenced by external means. In case critical combinations of circumstances can be perceived at an early stage, it will be possible to implement measures before a great number of accidents have happened. Under such conditions traffic-safety policy could be focused more intensively on the prevention of accidents instead of mitigating them. Thus, we should not wait until a sufficient number of accidents occurred in order to be able to analyse them statistically.

Co-operation between experts

The outlined approach to traffic-safety problems requires a close co-operation between experts of various scientific disciplines. Up till now the main factors of the traffic system (man, his vehicle, the road and the environment) have been studied too much separately and independently from another. Not enough attention is given to the interactions between these factors, which urgently require an interdisciplinary approach to the problems.
Nowadays, planners indicate the places where roads have to be constructed, traffic engineering experts make designs and establish road structures, road building experts determine how the roads have to be built and with which materials, vehicle engineering experts design the vehicles and determine their functions, behaviourists and legal experts study the regulation for the use of vehicles and transport means. However, the knowledge of these experts in special areas is not integrated sufficiently if at all. Such monodisciplinary way of thinking manifests itself, for example, in a statement like: 'Traffic can be made safer only if the mentality of road users improves'. People who make such statements do not take into consideration the fact that the traffic behaviour of road users depends to a great extent on their surrounding. Wide, straight lined, asphalt-covered roads evoke highspeed driving because such roads stimulate the impression of comfort, surveyability and safety. On places with much slow traffic and frequent pedestrian crossings, such impression may be deceptive and dangerous. Signs indicating a speed limit of 50 km/hr set up at the entrance to residential areas are not very effective on this type of roads.

Long-term planning

We must not be under the illusion that the necessary co-operation between experts can be realised from one day to the other. The separating walls between the various scientific disciplines are much too high and strong to be broken down with one blow. In addition, the theory for such integrated approach to traffic-safety problems is still in its infancy. However, in order to be able to combat traffic unsafety drastically in the future, it is necessary to stimulate vigorously the recently started developments.

E Asmussen
Director Institute for Road Safety
Research SWOV.

Characteristics to be registered

In order to describe and explain the development of traffic safety in The Netherlands on a national level, a philosophy of the accident process has to be established. On the basis of such philosophy and depending on the related problems, it is possible to select indicators of traffic safety.
In general, at present accidents are regarded as multicausal chance phenomena. This means that anybody participating in traffic is exposed to the chance of being involved in an accident, occurring as a consequence of a critical coïncidence of circumstances and or events.
The possibility of accidents is not excluded completely by eliminating one of the factors causing an accident. It is necessary that we reveal the relationship between the combination of circumstances and the chance of accidents.
The relevant characteristics of the accident, which we know from the theory, have to be registered. These characteristics refer to the traffic, the implicated person(s), the vehicles, the road and general conditions. The most risky combinations of circumstances can be discovered by, sometimes rather complicated, analysis techniques. The mode of accident registration in The Netherlands and many other countries as well is actually based on this philosophy. However, the number of characteristics collected is a much too small basis for the policy makers to draw up corresponding measures.
From the social point of view traffic safety encompasses all consequences of traffic accidents, including injuries, material damage and indirect consequences, like the fear of going in the street.
Such indirect consequences in terms of 'subjective unsafety' and 'traffic livability', received more and more attention in the last years. However, there is still considerable confusion concerning these issues and there is still no generally accepted operationalisation available.
As regards the direct consequences of accidents, there is experience of many years in using the relevant data. Since data, as for example the number of traffic accidents or casualties, as a rule, do not provide sufficient information for a meaningful interpretation, the data have to be related to relevant data of exposure. There are still some misunderstandings on the concept 'exposure' and the application of exposure data', caused by giving this term three different meanings.
In the first place, the term 'exposure' indicated a neutral measure of normalisation or correction: the number of inhabitants, surface area or length of the road net. The first global step in an

analysis should be to relate accident figures to such a normalisation measure. The obtained quotient would permit global comparisons between areas.
According to another interpretation, the term 'exposure' indicates the share of participation in traffic, expressed as vehicle or traveler kilometres. By establishing a relationship between such a 'production measure' and accident data, we can find out to what extent differences of changes in traffic safety can be explained by differences or changes in the traffic or transport performance.
Finally, 'exposure' also indicates to be 'exposed' to a risk. In this sense, exposure relates to situations with inherent potential of accidents, for example the number of pedestrian crossings or the number of vehicles passing through a crossing. Such date are being used in detailed analyses.

Data bank

In order to describe and explain developments in traffic safety, a large amount of different data has to be collected.
A satisfactory functioning of the registration and processing system of traffic accidents also implies that it should be adapted to meet the extremely diversified demands of potential users.
According to SWOV this needs a central data bank, built up from a basis registration system and a number of subregistration systems.
The data bank has to
- be as complete as possible, containing a maximum number of accidents with a minimum of data per accident;
- comprise reliable data;
- comprise uniformly collected basic data.

Depending on the requirements of the users, the central data bank can be complemented with data banks of a more specified character. Such specified data banks are indispensable for scientific theory forming.
It seems that several countries outstripped The Netherlands in data collecting. In Great Britain accident and casualty rates are collected according to various road categories and modes of traffic participation. All passing vehicles are counted on 120-180 stationary counting posts. In addition, once in five years visual counting is carried out in one day on 15,000 mobile counting posts. In this way the British hope to get a representative image of traffic, distributed over time and various locations. Based on the obtained results, traffic is evaluated on special road sectors and crossings, in certain areas and networks of areas.

In The Netherlands, the governmental authorities should see to it that a kind of 'thermometer' is developed indicating modifications, trends in traffic safety. Such 'thermometer' should be read out periodically and the level established should be published in basic figures as it is done with redundancy figures. Such figures should be made available for authorities on a lower level too. In the frame of their condition-providing function, governmental authorities should support certain measures and actions of lower authorities.

Developments of traffic safety

The reduction of the number of traffic fatalities which could be observed during the past years, continued also in 1981. In 1980, 1997 persons died in the traffic in The Netherlands, while in 1981 the corresponding number was 1807. This trend can be expected to continue in 1982 as well.

In 1981, in addition to the usual data, comparisons were provided between the number of traffic fatalities per 100 000 inhabitants (the so-called mortality figures) for several years with long intervals therebetween. Furthermore, calculations were made to establish the risk of fatal injuries for various groups of road users in relation to the distance covered. These analyses were carried out by means of data obtained from the investigation into 'Travel behaviour', carried out by the (Dutch) Central Bureau of Statistics.
In the 'CBS' investigation it was not possible to collect travel data concerning young people under 15 years. In order to include the up to 14 years age group in the traffic risk analysis, SWOV made an evaluation of travelers kilometers concerned on the basis of a sample survey in 1976.

In 1960/61 the number of fatalities per 100.000 inhabitants in The Netherlands was 60% higher than in 1950/51. This percentage was again by 42% higher in 1970/71 than in 1960/61. In 1978/79 traffic mortality was reduced by 40% with regard to 1970/71. A decrease of traffic mortality could be observed for all categories of road users with the exception of motor cyclists. The greatest reduction was found for moped riders, a result of the compulsoty use of crash helmets and of the decreased use of mopeds.
The lowest number of fatalities per distance covered was found in the age groups between 25 en 44 years, while the death rate was the highest for the 65+ age group, seven times higher than for the 25-44 years old. In the age groups of 0-14 years and 15-24 years the risk is twice resp. three and a half times higher than for the 25-44 age groups.
In slow traffic more fatalities happen per travel kilometer than in the category of car passengers.
The higher death rate of the 65+ category can be ascribed to the greater risk of their being involved in an accident, mainly as cyclists or pedestrians. On the other hand, the high death rate of aged people is also the result of their higher risk of dying in consequence of the injuries suffered in an accident.
The high death rate in the age categories of 15-24 years is only caused by the higher chance of being involved in an accident, mainly as driver of a passenger car of a moped rider.

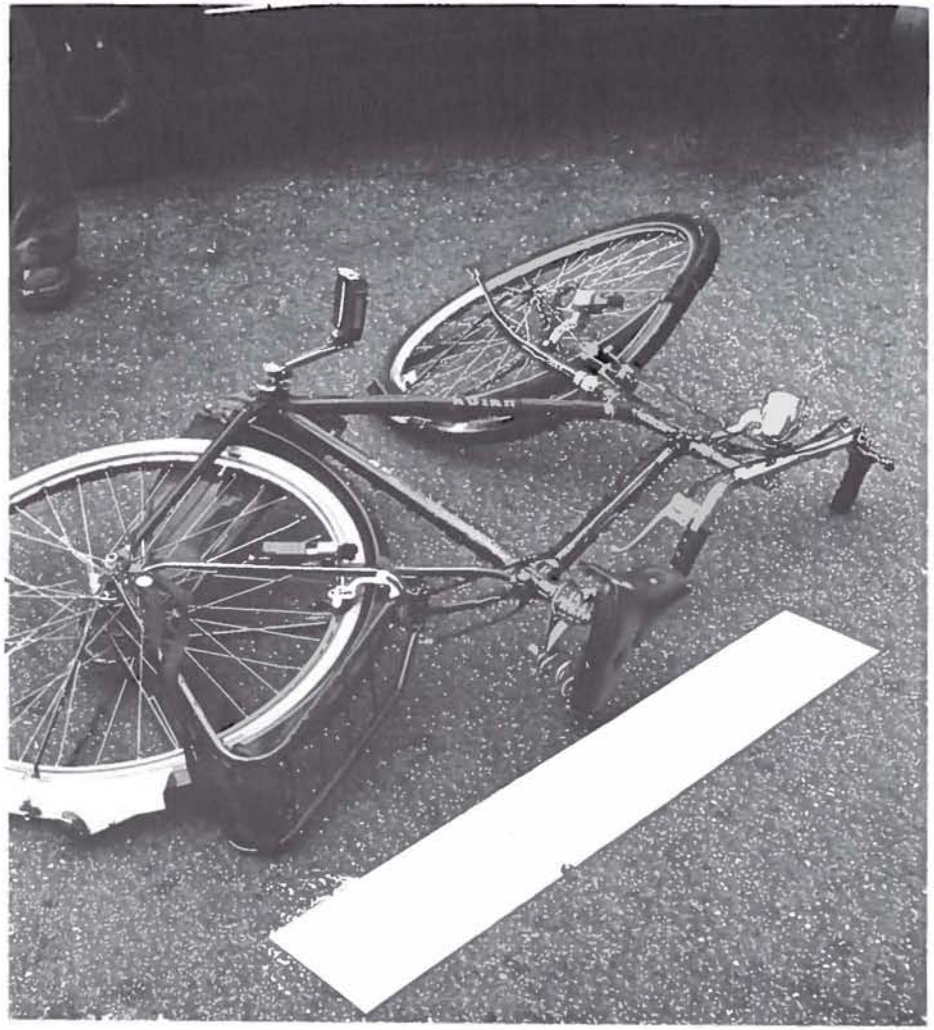
Accident analysis for Amsterdam

Under a contract with the municipality of Amsterdam, SWOV carried out in this city an accident analysis in co-operation with he Secretariats of Traffic and Transport and of Information on Administration. This study has essentially a descriptive character and concerns exclusively traffic safety within built-up areas. The results of this analysis are intended to indicate the problem areas for the traffic-safety policy of Amsterdam. In addition, this analysis can also be regarded as a preparation for more specific investigations, which may be undertaken at a later period. (In the meantime SWOV already started a more thorough investigation in co-operation with the authorities concerned into the accidents of cyclists in Amsterdam.)
It is for the first time that a municipality wishes to obtain a large scale analysis of traffic accidents over its entire territory. In order to categorise the traffic-safety problems of Amsterdam, we used a hierarchical classification. This, in turn, raised the following questions:
1. Which spatial and demographic trends affect the volume and character of traffic safety and to what extent (for example population density, population structure, building density, etc.)?
2. Which trends in the traffic and transport pattern affect the volume and

character of traffic safety and to what extent (for example modes of traffic participation, travel distance, choice of route, etc.)?
3. Which changes in the traffic infrastructure affect the volume and character of traffic safety and to what extent (for example separation of various traffic modes, integration, etc.)?
In order to clear up these problems, it has to be known, which kind of autonomous developments (for example increased driving experience) affect the volume and character of traffic safety and to what extent.

The most striking trends in Amsterdam in the period 1975-1978, emerging from the accident analysis are the following:
- the increase of the number of registered accidents involving material damage only, by 7% per year;
- the reduction of the number of traffic casualties above 40 years, by 6% per year (most remarkably in the age group of 40-44 years);
- the reduction of casualties among the moped riders, by about 10% per year.

As regards casualties with serious injuries, the following categories were overrepresented: pedestrians, the age groups between 16 and 24 years and men.
The overrepresentation of age groups among those, who suffered serious in-



juries was also investigated according to the mode of participating in traffic.
The following results were obtained:
– for passenger cars, the age groups of 20-54 years,
– for lorries, the age groups of 25-44 years,
– for motorcycles, the age groups of 18-29 years,
– for mopeds, the age groups of 16-19 years,
– for cyclists, the age groups of 11-15 years and of 55-75 years,
– for pedestrians, the age groups of 0-10 years and those over 44.

The largest number of traffic casualties can be found among cyclists, moped riders and pedestrians, getting into conflicting situations with the high-speed traffic.
Collisions involving road users and cars in high-speed traffic caused considerably less casualties.

In a paper presented at a regional study meeting 'Traffic livability in cities and villages', in Beilen, Mr.F.C.M.Wegman, Eng., introduced a relatively novel problem area: that of 'traffic livability'. This concept has been first mentioned by the Interdepartmental Working group 'Traffic safety in residential areas' in order to establish a relationship between traffic and livability.

Since everybody has his own special interests, problems seem nearly inevitable if, once outside of the house door, public spaces have to be given their appropriate functions. In addition to differences between people, there are functional conflicts within the individual person as well. Sometimes we drive a car, sometimes we walk or ride on a bike. Or, we just want to be outdoors and have a friendly chat with our neighbour. Due to such controversial interests and functional conflicts, certain choices have to be made in the structuring of public spaces.
A friendly quiet stay somewhere outdoors is in conflict with many speeding cars, stench, noise, the feeling of unsafety. The Working group 'Traffic livability in cities and villages' dealt thoroughly with these problems. However, the most important recommendation of this Working group was that all municipalities must clearly and unambigously determine, where local traffic and where through-going motorised traffic must be given priority. A basic starting point in this connection is that each house (dwelling) and school (for children under the age of 16) must be safely accessible from an area and of sufficient size to be able to walk and play therein.

Accidents in residential areas

We have to accept that accidents in the surrounding of the dwelling and the school and in the first place, serious accidents, often make a deeper impression on the people living in the neighbourhood; quite often acquainted persons are involved, elder people and children pass through the place of the accident nearly every day. Such accidents are remembered, even after many years.
Another characteristic of accidents in residential areas is that, as a rule, they happen all over the area and not on some restricted place alone. Thus, measures have to cover the entire area.
Some local investigations yielded the following data:
– about 30% of registered accidents occurred on not-throughgoing traffic roads, thus in residential areas;
– most investigations came to the conclusion that biking or running children and older people are involved in accidents more often in residential streets

than in other streets; probably because these groups use most intensively the residential streets;
- accidents involving children whild on their way to school make up about 20% of all accidents involving children;
- accidents involving children while on a rule, in the proximity of the place where they live, 2/3 of the accidents happening within some hundred metres from their house with not much traffic in the street;
- not much is known about accidents involving aged people in residential areas;
- 70% of fatalities and casualties concern pedestrians in streets of slow traffic, a major part of these people being run over by motorised traffic.

The feeling of unsafety

There are special issues in residential areas, which cannot be interpreted by traffic accidents alone. The authorities are quite often confronted with feelings, opinions of the inhabitants (or a group of inhabitants). Sometimes such feelings, opinions, refer to a special place of the district or to a special group of road users on such a special place. Sometimes feelings and opinions are indications of a general uneasiness.
One of the problems we are confronted with is the prudent handling of the complaints of the inhabitants: how to relate complaints and accidents. Because it is in no way impossible that an abated feeling of unsafety will increase the risk of accidents. This (unconscious) adjustment of behaviour can rightly be indicated by the words: 'It seems to be safe here, thus I can be less careful'.
From various investigations into the possibilities of reducing accidents in residential areas the following conclusions could be drawn:
- Strict differentiation of streets according to their traffic function leads to safer residential areas;
- Distribution of traffic into a residential area with multiple access from a ring road is safer than central distribution.
- Full segregation of motorised traffic from pedestrians, cyclists, leads undoubtedly to less accidents. In some countries recommendations are made for the integration of various traffic modes ('woonerven' (residential yards), shopping centres). In this respect no investigation results are as yet available;
- Cul-de-sac streets are safer than loop streets, the latter being safer than traditional.

All of the publications indicate that it is desirable to exclude through-going traffic from residential districts and to concentrate such traffic on roads outside of the residential area. Should this be impracticable, through-going traffic has to be directed to streets within the residential area, which are specially indicated for this purpose and thereafter all streets in the area can be given a form which automatically evokes the required, adequate traffic behaviour.

The traffic risk of old people

In 1978 the Interdepartmental Steering Group for the 'Policy concerning old people' decided to set up a work group to deal with the traffic safety of old people. SWOV took part in this group and carried out an accident investigation. Most of the analyses performed by SWOV refer to the years 1974-1977.

These analyses prove that people over 65 are exposed to a greater risk of being involved in traffic accidents than all other age groups together. Their higher fatality risk is partly the consequence of the fact that more of them are involved with accidents and that more of them pass away on account of the injuries suffered than the younger ones.
In absolute terms, most of the older road users lose their live while walking in the street or biking: 787 and 940 fatalities, resp. in the period 1974-1977. The major part of younger road users suffer lethal injuries while driving a passenger car or a lorry or by riding on a motorcycle or a moped.
The accident data broken down according to various circumstances reveal that in the older people versus younger people relationship:
- more of the older ones become casualties on working days than during weekends and more of them between the rush hours between 9 and 16 hours than between 7 and 9 and 16 and 18 hours and yet again more in the evening rush hour than in the morning;
- more of the older ones become involved in accidents during day time than during twilight and in darkness;
- more of the older ones die at a later period than directly at the place of the accident;
- more of the older ones become involved in accidents on road crossings than on streight roads or in bends;
- more of the older people (when biking or driving a moped) become involved in accidents in dry weather than in rain, snow or fog;
- more of the older people, when walking in the street or driving a car, become involved in accidents within the built-up areas than outside of them;
- more of the older pedestrians become involved in accidents in larger places than in smaller ones, while as regards cyclists it is the other way around;
- more of the older pedestrians become involved in accidents on crossing the street on a marked pedestrian crossing place than in any other manoeuvre and, when cycling, more on crossing over a crossing place than in any other manoeuvre;
- more of the older moped drivers become involved in unilateral accidents than in collisions with a stationary object, a parked car, an animal; more casualties occur by collisions with a passenger car than with a lorry;
- more of the older pedestrians become involved in a collision with a moped than with any other kind of vehicle.

Some of the aforementioned differences (as regards older and younger people) can be explained quite simply.
For a more thorough investigation of these issues the following hypotheses can be recommended:
- older people are more in the street during daylight than the younger ones;
- older people use their bike or moped more in dry weather than the younger ones;
- older people cannot cope with traffic situations on crossings as well as the younger ones;
- older people use more pedestrians' crossing than the younger ones and encounter more problems there than the younger ones.

There is every reason to give priority to measures directed to improving the traffic safety of older people.
In this connection the vulnerability of older people riding on a moped or walking in the street has to be considered in the first place.
Although traffic accidents are not the most important causes of death of older people, the risk of their participation in traffic in relation to the time spent in the street is much higher than the risk of activities in the private sphere.

Cycling in twilight and in darkness

The risk of fatal accident for a cyclist in the dark is four times higher than in daylight. It is evident that this is caused to some extent by the reduced visibility during the night. Consequently, this problem is related to the public lighting system.
At first we shall discuss the rear light of the bicycle. In order to ensure a satisfactory visibility under various conditions, a considerably higher light intensity should be actually prescribed than currently applied for bicycle rear lights. This must be considered in connection with the limited electrical capacity of the bicycle, most of which to be utilised for the front light.
A red reflector is used as an auxiliary system, which can ensure a reasonable visibility. However, a reflector (or actually only a small speck of light) is not sufficient to perceive and recognize a bicycle in dense traffic. The road users must know what this light indicates: the presence of a person, of a cyclist; the exact place of the cyclists on the road, his riding speed and the direction in which he rides. All these factors can be summed up as 'recognizability'.
The most evident mode of promoting the recognizability of a cyclist is to emphasize his footwork on the pedals. In the first place, this can be done by providing the pedals with retroflectors for which satisfactory inspection rules and quality demands have to be set up.

Furthermore, it would be advisable to distribute the weak electrical capacity of the bicycle power supply in a more appropriate manner. The general idea about bicycle lamps is that they primarily have to illuminate the path on which the cyclist rides, while its visibility for other road users seems to be of secondary importance only. Such an idea, however, has to be challenged from the point of view of traffic safety. The number of fatalities associated with weak front lights is inconsiderable, whereas the number of fatalities associated with insufficient signaling is rather high.
It may be that having a light beam as headlamp is effective in preventing accidents of less serious character and that such light beams contribute to the comfort of the rider, but an improvement of signaling at the rear of the bicycle is important as well.
Reflectors cannot provide satisfactory solutions. Active lighting and reflectors are two different signal systems, each with its own function, although they may supplement each other to some extent. In case one is satisfied with a lower light intensity of the front beam, an adequate all-round signalisation can be ensured, even with the electric capacity which is available at present. In any case the electric system of bicycles needs to be improved.
A considerable part of cyclists involved in accidents lost their life on account of side collisions. For this reason, the recognizability of the bicycle from various directions has to be improved by the application of additional reflectors, not only on the rear, for example on the mud guard (flap), but especially at the sides of the bicycle, on the tyres or between the spokes.
The application of a white frontal reflector should be taken into consideration as well, e.g. like in the USA. Such additional measures are always useful, since the headlamp is often out of order or it is wrongly directed or not switched on at all.

The application of a red reflector

The expectation that red reflectors will be fitted to nearly all bicycles 1 – 1½ years after the implementation of the compulsory use of them, proved right with regard to the common bicycles. This fact emerged from a SWOV inquiry. 94% of common bicycles was provided with a red reflector, while only a small percentage of race bicycles had one. However, on account of the small share of such bicycles in the total amount of bicycles in The Netherlands, this is not important.

Speed limits

It is a remarkable fact that in The Netherlands discussions over traffic safety mostly concern motorways or residential areas. Remarkable because only a small part of all traffic fatalities and casualties occur on these types of roads.
For this reason, speeds or more accurately speed limits on such roads are in the focus of interest. There is a fundamental difference between the points of departure for influencing speed on motorways and in residential areas. As regards residential areas it is assumed that influencing speed behaviour in residential areas alone by adjustment of traffic rules will not be enough. Physical speed restricting measures have to be implemented, which can be, if necessary, be supported by legislation. As regards motorways, however, it is regarded as sufficient to announce statutory regulations: maximum speeds or recommended speeds. In the period of the energy crisis in 1973/1974 a speed limit of 100 km/hr was set up, while motorways in general are designed for a speed of 120 km/hr. It is really not surprising that road users now exceed the legal maximum speed on a large scale, although at the beginning the social acceptance of this measure was more satisfactory than at present.

Outside of built-up areas

The relationship between speed and safety as two aspects:
- the driving speeds
- the variation of speed distribution

Higher speeds lead to higher collision speeds, which in general will cause more damage in accidents. Thus, it can be expected that the risk of accidents will rise with increasing speed. In the period between 1974 and 1978 (the years for which the latest data were at our disposal) there was a drastic increase of speeding on the Dutch motorways.
In these years the average speed of passenger cars went up from 90 to 105 km/hr (speed limit 100 km/hr) and that of lorries from 75 to 85 km/hr (speed limit 80 km/hr).
About 50 – 70% of the passenger car drivers and 50 – 85% of the lorry drivers exceed the legal limits on measuring points.

There were no changes in average speed on other roads outside of built-up areas. About 10 – 30% of passenger car drivers and 40 – 80% of lorry drivers exceed the limit on other (major) national highways (same limits as for motorways). On secondary roads, 40 – 75% of passenger car drivers, 20 – 50% of drivers of non-articulated lorries (speed limit for cars and lorries: 80 km/hr) and 80 – 100% of drivers of articulated lorries (speed limit 60 km/hr) drive above the limit. At present there is no effective mode of catching all of the offenders in The Netherlands.
On motorways a reduction in the variation of the speed distribution promotes the homogeneity in the traffic movement patterns: the manoeuvres will be more predictable, which will lead to less accidents. Such considerations have never been applied to non-motorways but most probably they are valid for the latter type of roads as well.

In case the speed limit for passenger cars on motorways will be increased, a part of the drivers will certainly drive at a higher speed. Under such conditions we can also expect an increasing variation of the speed distribution, particularly as the current speed limit for lorries is not changed. We can also expect that this will lead to more accidents. An increase of the speed limit on motorways will also increase the difference between the speeds on various road categories. A car driver moving from a motorway to another type of way will not be inclined to readjust his speed immediately. The Dutch Minister of Transport and Waterways used this negative effect as an argument for maintaining the existing speed limit. In addition, he was of the opinion that the public would not readily accept an increase of the speed limit.

Within built-up areas

The Committee '50 is too much' makes efforts for the modification of the present law, prescribing a generally valid maximum speed of 50 km/hr within built-up areas. Such speed is by all means much too high in residential areas. A car driver, driving at such a speed will quite often not be able to stop his car, when a child suddenly runs up on the road. In addition, at a lower speed, the collision speed will be lower as well thereby mitigating the seriousness of accidents.
When a pedestrian is run over by a car driven at a speed above 30 km/hr, his injuries will certainly endanger his life or even cause his death, it was found in Great Britain.
There are not many results available from fundamental investigations into the relationship between speed and accidents within built-up areas and more particularly within residential areas.
Speeding in residential areas not only may cause accidents but also evoke feelings of discomfort to the residents. The greatest troubles are not caused by average speeds of the motorised traffic but by some driver driving at very high speed.

In investigations into the modes of checking speeding in residential areas, the correct formulation of the aims is of great importance. The aim should not be

Traffic lights

the restriction of speeding on a limited number of places, but in all streets in an entire area. However, the formulation of concrete aims is still rather unusual at present. Measures have to be evaluated on the basis of the number of accidents, the nuisance caused by noise and the experiences of inhabitants and road users. Other aspects like the redirection of non-destinating traffic to other streets have to be studied as well.
The planning of physical speed restricting measures can be based on two theories:

- to make facilities which will physically inhibit driving over a certain speed limit;
- to design streets in a manner which make it evident that various activities in the street prevail over high-speed driving.

The first theory often involves inflexible and expensive solutions, while the second one involves uncertainties about the effects of the measures. This means that endeavours have to be made to intensify the motivation of car drivers for driving at a lower speed than that which they would prefer at a given moment.

In order to improve the traffic flow, traffic lights are installed frequently on road crossings. Sometimes the principal aim is the improvement of traffic safety on the crossing. SWOV carried out a literature study for establishing the contribution of traffic lights to traffic safety on crossings. The study proved that no general statements can be made over the effect of traffic lights on traffic safety. The effect depends a.o. on the composition of the traffic, the speed at which the cars are driven and the space available at the crossing.

Favourable effect possible in case of dense traffic

In addition to many differences there are also agreements as regards the established effects. It was found that traffic lights have a favourable effect on crossings of high traffic density. There are opinions that such effect is more favourable for car drivers than for cyclists and moped riders. This can be explained by the fact that traffic light regulations are designed and realised in the first place for accelerating the through-flow of traffic. Mainly the number of 'hook' accidents is reduced after the installation of traffic lights. On the contrary, cars turning to the left are relatively more frequently involved in accidents on traffic-light controlled crossings. For this reason it is advisable to provide a separate queue-up line for the left-turning traffic with separate traffic lights.

In the most favourable case the number of head-to-tail collisions will remain unchanged after the installation of traffic light. Should they happen then they will not be very serious. However, more accidents of this type will occur at the rate at which the traffic passes through the crossing. It could be expected that a uniform duration of the amber light would have a favourable effect on the development of head-to-tail collisions. Most probably less cars would drive through the red light phase, when the differences in the time of the amber light fase could be abolished. The literature study also proved that traffic safety as a rule is improved in case the traffic lights are functioning during the night as well. During that period the waiting times should be reduced by a suitable and preferably traffic-dependent programming. The separation of various traffic flows from one another as far as possible could also have a favourable effect on safety, provided that waiting times are not too long, because long waiting times tempt the drivers to drive earlier through the red light phase.

Standardisation

In the last years more and more traffic lights are installed at busy crossings in The Netherlands and abroad as well. In various countries recommendations have been made or directives issued traffic lights have to comply with. The most important point of departure was that the lights must be 'distinctly visible'. Thus, it is not surprising that there are differences in this respect between various countries. In the interest of industry and traffic the Commission International de l'Eclairage CIE made the first step towards standardisation by setting up a technical report, comprising requirements the traffic lights have to meet as for example:

- the colour of the lights;
- the intensity of light and its diffusion;
- the prevention of phantom effect (caused by light hitting the lamp glass and being reflected thereby creating the illusion that the light is burning);
- the mode of fitting symbols to the light;
- the mode of installation of traffic lights.

Some of these issues still need further investigations. SWOV made an important contribution to the realisation of the CIE-report.

The field of vision of lorry drivers

In the Department of Road Transport RDW the question came up, whether in the EEC directives concerning the rear-view mirror on vehicles sufficient attention is being given to the field of vision at the right side of lorries. According to an expert opinion, provided in 1976 by SWOV on the request of RDW, relatively numerous accidents occur involving lorries, cyclists and moped drivers or pedestrians being at the right side of the lorry. In conformity with current EEC regulations the zone at the right side of the lorry must not be 'seen' by the driver entirely. RDW again asked for an expert opinion comprising the most recent accident data and considerations.

SWOV started with establishing the 'invisible' zone in case:
– of a righthand rear-view mirror on the lorry in complete accordance with the EEC directives;
– the lorry driver can only see through the front windscreen and both side-doorwindows;
– there is no fellow-passenger in the car.
Under such assumptions the 'invisible' zones can be divided in two groups. There are zones with a limited sight upwards, mainly directly about the front part of the lorry. Road users being at the right side of the lorry, at the level of the driver's cab, are not seen by the driver. In addition, there are zones, which are completely beyond the field of vision of the driver: a considerable sector of the zone behind the lorry (a sector of importance in case of reversing) and a large zone at the right side of the lorry. This means that the lorry driver is unable to see for example some parts of a free bicycle lane.
The aforementioned considerations are based on the most unfavourable situations. In view of these difficulties, many lorries are provided with an auxiliary side window to influence sight conditions favourably. As regards fellow passengers, during the last years about 80% of drivers was alone in their cab, it was found.

The lack of unhindered vision may have unfavourable effects in view of traffic safety. The amount of information, which has to be continuously absorbed by the driver in order to be able to drive correctly, needs an unobstructed view around the lorry. Harmful consequences are mainly caused by reversing, by manoeuvres to the right, (change of lane and turning to the right), futhermore by turning to the left, during which traffic approaching from the right cannot always be perceived.
When the lorry makes a turn to the right or to the left, the track of the vehicle is widened: the rear wheels 'cut' the corner. In case of articulated lorries such 'track widening' can increase to 5 metres. In case of turning to the right, even at an inconsiderable turning hook, there will be minimum sight in longitudinal direction of the road. Free bicycle lanes, parallel roads and footpaths will be completely hidden from the lorry driver.
Drivers of tractors with trailers and of articulated lorries are unable to see the rear part of the combination in sharp bends. Under such conditions road users can emerge unobserved from behind the lorry and pass along its right side. It should be assumed that the lorry driver will signal in time his intention to make a right turn. Road users, who are at that moment at the right side of the lorry can react to this signal by stopping in time. However, they must take into account the widening of the lorry's track as well.
Also in case of left hand turns of lorries situations may arise, where the lorry driver cannot see the traffic coming from the right, mainly if during turning he is compelled to braking or stopping the lorry.

Accident data

We have not enough data at our disposal to give a precise assessment of the number of accidents, which can be ascribed to the limited field of vision behind and beside the lorry. However, a limited accident analysis could be

carried out to establish the number of accidents and casualties in the period of 1975-1979, which most probably were caused by the lack of good sight at the right side of the lorry.
During the mentioned years 173 road users died due to collisions between right-turning motorised vehicles with three or more wheels and road users in the inner bend. This is 1.5% of the total number of fatalities in the said period.
In each case the victimized road user was in the inner bend. 151 persons out of 173 were involved in accidents with lorries, turning to the right. Such high share of lorries in accidents is rather remarkable in view of the great difference between the kilometres covered by lorries and passenger cars (1:10).
Half of the number of casualties, i.e. 40% were cyclists, 9% pedestrians and 2% moped riders. About half of the killed moped riders and 17% of the killed cyclists were riding on a bicycle lane. This difference is also remarkable in view of the relationship between the number of moped riders and cyclists using the bicycle lane and may be explained by the higher speed of the moped.
About 55% of victimized moped riders and 74% of the cyclists were killed by being run over, while all of the killed pedestrians were run over by a car. Also in this connection the differences can be explained by the speed differences between these three categories of road users. A lorry while making a turn to the right in a built-up area will certainly not drive at a high speed. Mainly the fast moped riders are not able to stop in time and consequently run up against the lorry. The slower cyclists and pedestrians have a chance to stop but, as a rule, they do not take into account the 'widening' of the track.
It can be assumed that the mass, dimensions and shape of the lorry have a damaging effect on these accidents. This observation is supported by the fact that accidents, involving passenger cars turning to the right, are of a less serious character.

Improvement of information provided for the driver

It is a fact that the current EEC requirements leave a considerable part of the desired field of vision outside of the drivers' perception. This means that the requirements must be amplified.
In this respect it has to be taken into consideration that various traffic situations require various actions from the drivers. In city traffic, where speed differences are rather small, it is usually sufficient that the lorry driver perceives other road users. On motorways he must also be able to evaluate the distance and speed of other vehicles.
At the present state of technique an expansion of the field of vision can only be achieved by means of mirrors. In view of perception aspects, the mirror must preferably be flat. However, flat mirrors provide no optimum solutions for each situation. Consequently, mirrors with a slight curvature are being used at present. A substantial expansion of the field of vision can be realised by using mirrors of greater curvature. However, with increasing curvature the problems of establishing distance and speed increase as well. For these reasons, a combination of flat and convex mirrors seems to be the best solution. The place of fitting, size and convexity of the mirror have to be determined on the basis of the vehicle's shape.

Other solutions

The improvement of the rear view mirror is only one of the solutions of the involved problems. Accident analyses indicate that the problem of limited sight is mainly in connection with lorries turning to the right, running over cyclists and moped riders within built-up areas under otherwise normal circumstances.
We offer the following solutions:
1. Reduction of the necessity that the driver must see the zones behind and beside his lorry. This can be achieved by entirely excluding the possibility that

slow traffic could move up beside the lorry while it is turning. Another measure would be a modification of the priority rules. Traffic driving straight ahead (slow traffic) now has priority over (lorry) traffic taking a bend. Accidents will continue to occur because participants in the slow traffic (wrongly) believe that they have priority over the lorry driver. Yet another possibility would be to prohibit lorry drivers from making a right turn on places, where slow traffic **could** pass along the right side of the lorry. Right turns should be permitted only where traffic lights or an appropriately outwardly bent free bicycle lane completely exclude the possibility of conflicts. A solution in connection with traffic lights would be to 'explode' the bicycle lanes. In this case the stop line for high-speed traffic does not coïncide with the stop line for slow traffic, but is marked some metres before it. In this way the slow traffic queues up **before** the high-speed traffic in the red light phase.

A last possibility would be reorganisation of delivery traffic in such a way that less lorries, delivery vans can enter into built-up areas, mainly in the hours when a great number of (mostly young) cyclists are expected to be in the street.

2. In case conflicts between lorries and slow traffic cannot be completely eliminated, measures must be taken that such conflicts do not lead to accidents. In this connection we consider following measures:

– Improvement of the lorry drivers' sight conditions. A driver sitting in the right-hand seat of the cab has a better sight to the righthand-rear part of the lorry. On the other hand, this may cause problems in overtaking manoeuvres, because the sight to the left and back is limited.

Auxiliary external rear-view mirrors, as the case may be, in combination with enlarged windows in the doors may promote backward sight. However, it has to be taken into consideration that the rearview mirror is a projecting element, which may also obstruct frontal sight.

– The reduction of the track widening of turning lorries. This can be achieved by providing the lorry with a rotating rear axis. Another measure could be to spread information about the track widening effect, mainly among young traffic users.

– As a last possibility we mention the improvement of the flashing lights, mainly on long vehicles.

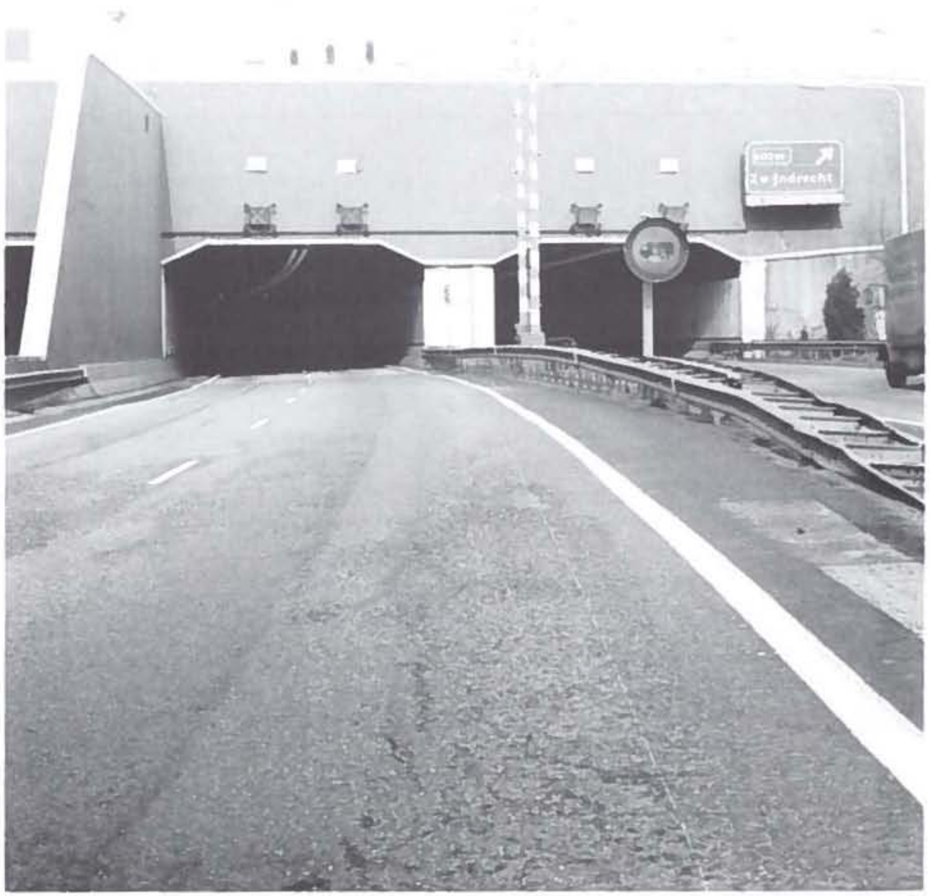
3. The third group of measures concerns the mitigation of the seriousness of accidents (if an accident cannot be avoided at all). In most cases the victim of an accident is run over by one of the wheels of the lorry. This could be avoided by providing the side of the lorry with a suitable 'screen'.

This review of possible measures proves that in addition to improving the rear-view mirrors, several other possibilities are available as well.

None of the proposed measures can be applied without suitable adjustments, because they all have advantages and drawbacks, which have to be revealed by further investigations.

Lighting of tunnel entries

The requirements concerning lighting installations in motortunnels are much more severe than for many other situations. Furthermore, necessary considerations on saving expenses and reducing energy consumption, changed views regarding driving comfort. This was the reason, why Rijkswaterstaat authorised SWOV to carry out an analysis of the related problems.
This analysis by SWOV is in the first place directed to establishing the conditions tunnel lighting has to fulfill in order to prevent that the special circumstances in tunnels cause serious problems. Obviously it is important that the tunnel should not be an obstruction for the traffic. The traffic flow near and in the tunnel must be at least as smooth as on the approach roads to the tunnel.



Background

The first special motortunnels were built in the twenties. Older tunnels were destined for slow traffic and consequently there were no serious visibility problems. Anyhow, we don't know much about the light systems in old tunnels. Motorised traffic, however, sets high requirements in view of lighting. At first the aim was to ensure an adequate light in the tunnel interior. But some attention was paid to the tunnel entrance as well: a so-called 'threshold lighting' over some tens of metres was installed. In some cases 'sun-screens' were provided at the tunnel entrance.

Generally applicable scientific research was not available but one could learn quite a lot from practice, which was supplemented by studies focused on special problems in specific tunnels. From these studies solutions were found which were applicable to these special cases only.
The first generation of tunnel entrance lighting was based on the assumption that the driver needs a certain period of time to adapt has eyes from broad daylight into the darkness of the tunnel. For this the change in the diameter of the eye pupil was thought to be of decisive importance. On the basis of this a transition period (adaptation time) of 5–10 seconds was established, which then, in turn, defined the lenght of a threshold zone (several tens of metres). The available knowledge about the eye's adaptation was not taken into account in the praxis of tunnel lighting. Neither was there any consideration for the fact that perception in the dark tunnel entrance is negatively affected by the contrasting brightness of the surrounding immediately around the entrance. This type of light systems like that installed in the Maastunnel in Rotterdam for example, turned out to be insufficient at very high traffic volumes. For this reason the tunnel near Velsen (in the fifties) was designed with a much longer threshold zone (about 150 m) and with a considerably higher light level. However, in designing the lighting system for this tunnel, no attention was paid to the fact that users of the tunnel are in motion: the light points do not form a continuous strip, whereby strong and irritating flickering effects are forming.

The mass-wise motorisation of traffic in most industrialised countries, reaching the peak in the sixties, had important consequences for tunnel lighting:
– the large number of tunnels built in these years requires a more scientifically oriented theory;
– due to the high speed and density of the traffic, the conditions of the entrance were much more emphasised as compared with the interior of the tunnel;
– due to the favourable economical situation in most countries, much attention was paid to the driving comfort.
This period is characterised by an intensive development of scientific investigations into the problems of tunnel lighting and resulted (in 1973) in international recommendations by the Commission Internationale de l'Eclairage CIE, followed by many national codes and standards.

The third generation

The necessity of reducing expenses and energy consumption led to an entirely new technique for the light system of tunnel entrances (third generation). In this connection, the application of daylight screens are considered important for the illumination of the first part of the tunnel. Such screens were already applied to the tunnels of the second generation; however, they had to be 'sunshine-tight'. The light-transmission of the screens was in the long run considerably reduced by soiling and corrosion. Recent investigations suggest that the required 'sunshine tightness' can be abandoned. Should this be true, it would be possible to construct screens of very high and constant light-transmission. It is expected that in the future light screens in tunnel entrances will replace artificial light to a far extent. Meanwhile in The Netherlands tests are being carried out with 'non-suntight' screens.

SWOV's problem analysis involves two essential questions:
1. What is the relationship between the demands of tunnel lighting and the visual conditions outside of (shortly before) the tunnel entrance?
2. What are the requirements the. lighting of the tunnel's first sector has to meet?

There are still two problems in connection with the former ones:
- In what way should the light system between the said first sector and the interior of the tunnel be carried out?
- which requirements have to be met by the interior lighting?

In order to solve these problems an investigation programme has to be established, taking into account the priorities of the various issues involved. For the time being we draw up an inventory of the problems, based on psychological, fysiological, traffic science and practical points of view.

Extending the validity of driving licences

The plans of the Dutch government to extend the validity of driving licences were analysed by SWOV with regard to possible effects of such extension on traffic safety.
With the exception of evident physical defects at present, it is not yet possible to indicate permanent human characteristics which would render a person specially prone to accidents. This is an important point of departure of the analysis. In this connection we have to make a marginal remark. From recent psychological studies indications emerged that certain mental and bodily factors may have an effect on the driving performance, mainly in situations where capacities and skills of the road users are specially involved, for example in dangerous overtaking manoeuvres and sudden emergency situations. However, at present, such findings cannot be brought into satisfactory relationship with driving skill requirements. For this reason, the SWOV report in question is only based on temporary factors and their combinations like stress, fatigue, drinking alcohol, hurry, illness, which may intensify the accident proneness.

SWOV investigated how many people do not get an extension of their driving licence for medical reasons or on whom certain restrictions have been imposed. It also has to be taken into account that applicants have to submit a fitness declaration themselves and consequently only voluntary declarations or a declaration forced by certain conditions are brought to the notice of the authorities concerned. Most people, however, are inclined to overestimate their driving skill (fitness).
It was assumed that in 1977 several thousand persons did not get an extension of their driving licence for heavy lorries and/or motorcycles, while keeping their qualification for passenger cars. Furthermore, several thousand persons got an extension with certain restrictions.
This means that they are authorised only to drive a car, provided with special facilities. According to the new law a part of these persons will have to undergo periodical medical examinations for testing their fitness. This regulation applies to disabled persons, who ask for financial aid from the authorities in order to be able to buy a special car, and to professional drivers.
The small group of people who are authorised to drive a car without any restriction according to the new law, while they would have been authorised to drive only under certain restrictions according to the old law, is not expected to cause any perceptible rise of traffic unsafety.
People older than 65 years will be tested every five years. The question arises, whether this is really necessary. Although

passenger car drivers above 65 seem to be more susceptible of being involved in accidents than the 25–45 years old, it is not yet cleared up whether the causes of this phenomenon are in any relationship with personal characteristics on the basis of which their driving licence could not have been extended.

In 1981, SWOV submitted recommendations to the Department of Road Transport RDW concerning the safety of different types of windscreens for cars and a novel type of safety belt buckle, which opens automatically after a collision.

Windscreen of laminated glass

Based on collision tests with dummies it had been established that a windscreen made of laminated glass causes less serious injuries in a collision than tempered glass. This can be explained by the better deformability of laminated glass, which eliminates the formation of loose, sharp glass particles flying around. A tempered windscreen consists of a single glass layer, which has been exposed to a special thermal treatment. On breaking, the entire screen becomes grainy and opaque. Laminated windscreens are made of several transparent strips, which are fitted together and at least ont of which consists of a plastic material. The fracture of the glass results in cracks but the screen remains essentially transparent. New cars are, as a rule, more and more frequently fitted with laminated glass windscreens, especially the high-priced cars. According to experts such windscreens are safer in collisions. However, a laminated glass windscreen is at least 100 guilders dearer than one of tempered glass.

In view of discussions over EEC directives, RDW asked about the effectiveness of laminated windscreens in practice. According to SWOV there is hardly any statistic difference between those two windscreens as regards the **outcome** of collisions. This statement is based on data emerging from an – as yet – unfinished accident investigation covering about 8000 passenger cars. However, it is quite probable that laminated glass windscreens have a favourable effect on the circumstances under which collisions **occur.** If the windscreen is fractured by a stone, the laminated glass, of which the windscreen is made, remains transparent. In addition, the plastic layer of the windscreen hinders the penetration of stones through the windscreen into the car. Since no reliable data are at our disposal concerning the number of windscreens breaking during driving, it is as yet impossible to establish differences (if any) as regards the role of the windscreen in accident risk. For the time being we have to be satisfied with a reasonable assumption.

Automatic release of the safety belt

Although nowadays not many people have doubts about the usefulness of safety belts, there are persons, in whom the safety belt evokes a kind of phoebia. Some people are afraid of not being able to escape from the car quickly enough after a collision. Some inventors and producers have taken these feelings of fright into consideration. For example, various types of belt knives are already put on the market. It is undeniable that such knives can be of great help for the rescue team in case the safety belt buckle is on a place, which is inaccessible from outside, i.e. between the (front) seats.

Another interesting solution is provided by an automatic safety belt releasing device, which releases the belt after a collision. An example is the so-called Lassche system, a Dutch invention, which is being produced in West Germany and which operates in the following way. Starting from collision speeds of 10-15 km/hr a time mechanism in the belt lock is set into operation by the forces acting on the belt. This time mechanism unlocks the belt in about eight seconds. Should a second or third collision occur in the meantime, the entire process is repeated. If after the eight-second period more than a given traction force acts on the belt lock, the

belt remains closed, until this force is suppressed. On account of this, a passenger still tied up by the belt after the collision, is prevented from falling from his seat. In all other cases the buckle is automatically released. In any case, the belt can be normally released with the normal release system. However, an international application of the Lassche system is not possible because according to prescriptions, the buckle should remain closed under any circumstances. In order to asses the possibilities of adjusting the international regulations accordingly, RDW asked for the expert opinion of SWOV concerning the advantages and drawbacks of this system.

According to SWOV the automatic system is mainly useful in case a car is set on fire or gets into water and the passengers are not able to unlock the belt because they are injured. Accident investigations prove that such situations do not occur frequently. Since the automatic system has no drawbacks with regard to existing belt systems, it can be recommended as an additional security measure for individual road users. And yet, there is some risk involved in the introduction of the automatic system. It might give rise to opinions that the existing systems are not satisfactory, which is most certainly not true. Accident data prove that there are hardly any buckles, which are defective or not working adequately after an accident. Since unlocking of the belt is simply a routine action, it can be assumed that this attitude will not change after a collision.