Specific safety measures for emergency lanes and shoulders of motorways

A proposal for motorways' authorities in the framework of the European research project SAFESTAR, Workpackage 1.1

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TNO	*Human Factors Research Institute; Soesterberg, NL*
RD	*Road Directorate; Copenhagen, DK*
VTI	*Swedish Road and Transport Research Institute; Linköping, S*
VTT	*Technical Research Centre of Finland; Espoo, FIN*
LNEC	*Laboratório Nacional de Engenharia Civil; Lisbon, P*
NTUA	*National Technical University of Athens; Athens, GR*
CETE	*Centre d'Etudes Techniques de l'Equipement Normandie Centre; Grand-Quévilly, F*
RC	*Transport Research Centre; Brno, CZ*

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Summary

This workpackage is one of seven workpackages of the European SAFESTAR project, launched by DG VII. Directing on safety standards and recommendations for the Trans-European Roadway Network (TERN), the workpackage considered safety measures on emergency lanes (stopping strips), which are inherent facilities of the TERN-motorways.

Giving space for emergency stops and making the carriageway of a motorway safer, the emergency lane contains its own additional elements of accident risk. Multiple-vehicle accidents, (when at least one of the involved vehicles was entering, on, or leaving the emergency lane of the motorway), are seldom, but extremely serious. This workpackage activity consists of the following four tasks:

- a survey of existing views and policies on the subject emergency lanes and shoulders of motorways;
- surveys of relevant research results, including in-depth analyses of road accidents and behavioural studies of road users;
- an actual risk estimation of accidents on emergency lanes of motorways in EU-countries;
- a formulation of recommendations.

The survey of international national standards on emergency lanes has shown a lot of differences between basic norms and standards in the EU-countries. The data, guidelines, norms and differences between European countries are collected by means of data requests and interviews with specialists from most EU-countries:

- basic geometric standards of emergency lanes, and the actual percentage of motorways equipped with emergency lanes;
- spacing of emergency phones along motorways;
- operational rules on the use of emergency lanes;
- the spacing of rest areas with parking facilities;
- the spacing of service and accommodation areas.

There are also some deviating practices found in different countries when segments of the emergency lane are used for other purposes than usual, such as:

- an additional lane during the rush-hours;
- a separated lane for public buses;
- an additional lane when the opposite direction of the road is under reconstruction.

These measures are relatively new and there is no evidence pro or contra because of the lack of accident data. Further monitoring of such deviating practices in EU-countries is recommended.

Risk figures were estimated for accidents on emergency lanes in the EU by using IRTAD- and CARE-databases, and available in-depths studies in the UK and the Netherlands, The accuracy of the estimation is limited by the lack of in-depth studies in EU-countries. In order to retrieve the needed multiple-vehicle accidents the databases have to proceed rather sophisticated data manipulations taking into account the initial and final

position and manoeuvres of the vehicles that are involved in accidents. Only few European countries have this facilities.
Totally, about 65,000 injury accidents (causing 3,500 deaths) happen each year on approximately 40,500 kilometres of motorways in 15 EU-countries. An estimation of multiple-vehicle accidents on emergency lanes of these motorways showed at least about 1,000 of such accidents and about 300 road deaths each year on motorways in EU-countries. The severity of such accidents is more than five times higher than average.

On Dutch motorways the presence of obstacles on emergency lanes has been investigated by field observations and behavioural studies. Using the databases of the Royal Dutch Touringclub ANWB and field observations, the density of broken down cars per road kilometre were obtained. The frequency of breakdowns strongly depends the time of day. For instance at 6 am, there is about one broken down car every 70 kilometre and at 9 pm, there is about one broken down car every 33 kilometre on the emergency lane. In total every 12,4 kilometre there are obstacles found on the emergency lanes: mostly work zones, stopped cars, and very seldom pedestrians).

For a more accurate and deep estimation of multiple-vehicle accidents on emergency lanes, a sample inventory study on motorways of EU-countries should be launched. The Dutch technics for in-depth accident analysis can be recommended, also for the continuation and extension of this research in other EU-countries.

Contents

Foreword

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1. Introduction

At the conference EURONCAP (European New Car Assessment Programme) in Berkshire, United Kingdom 1 July 1997, Mr Neil Kinnock (Member of the European Commission responsible for Transport and Trans-European Networks) gave some important characters of the road safety problem.

In the fifteen Member States during the last few years:
- *about 45,000 people are killed and 1.6 million are injured every year in road traffic accidents.*
- *some estimates put economic costs of road accidents as high as £100 billion each year*
- *only taking account of the costs of medical treatment, emergency services, damage to property, and lost economic output, the bill for road accident deaths and injuries amounts to about £36 billion across the European Union each year.*

Road infrastructure is a significant part of the road transport system. The level of road safety is to a large extent determined by the features and the layout of the infrastructure. In other words, proper road design is crucial to prevent human errors in traffic, and fewer human errors will result in fewer accidents. It has been estimated that engineering improvements on roads have been the main factors behind the reduction in casualties on the roads of the EU-countries in recent years.

At the end of 1996 in the framework of the Road Transport Development Programme (see official document TRC/VII/014.re3/96), the EU's DG VII has announced task 7/2/13:
Development of safety standards for highway design and redesign on all classes of road, including tunnels and bridges, taking account of the proposals for technical standards made in the TERN-report.

This task has to be realized on the basis of results of the SAFESTAR project launched by DG VII, which is a research study focusing on traffic safety for what is known as the Trans-European Road Network (TERN).

Among the seven topics of SAFESTAR, the emergency lanes and shoulders along motorways are considered as one of the important spear points. Emergency lanes (stopping strips) and safety devices are inherent facilities of the TERN-motorways.

The suddenly stop of a car on a motorway because of a breakdown or other urgent circumstances can be very dangerous. Giving space for emergency stops and making the carriageway of motorways safer, the emergency lane contains its own additional elements of accident risk. The multiple-vehicles accidents (at least two road users involved), when at least one of involved vehicles was either entering, on, or leaving the emergency lane of the motorway, are seldom, but extremely serious.

When an accident has happened on a motorway, the presence and quality of passive safety devices (barriers), the design of the shoulder or verge, and an

obstacle-free space behind the verge, play an important part in reducing the impact of such an accident.

DG VII proposed two fields of activities and therefore two workpackages (WP) concerning shoulders/verges on emergency lanes on motorways:
- WP1.1 specific safety measures for emergency lanes and shoulders on motorways;
- WP1.2 criteria for safety devices on motorways and express roads.

Workpackage 1.1 deals with preventing multiple and single-vehicle accidents on emergency lanes by specific safety measures against all kinds of inappropriate use of emergency lanes.

Workpackage 1.2 concerns the standards on passive safety devices on motorways and also on express ways to reduce the impact of accidents. Workpackage 1.2 will be reported in 'Criteria for roadside safety of motorways and express roads; A proposal for road authorities in the framework of the European research project SAFESTAR, Workpackage 1.2'.

In this report, only Workpackage 1.1. is presented.

2. SAFESTAR in the framework of the EU's Programmes

The Directorate General Transport of the European Commission (DG VII) consists of the following Directorates:

A International relations and Trans-European transport network and infrastructures;
B Inland transport;
C Air transport;
D Maritime transport;
E Development of transport policy and research and development.

The mission of DG VII is to work with national, regional, and local authorities, business and non-governmental organisations of the European transport system for better economic and environmental development in the European Union. Three of the five Directorates of DG VII are concerned about the safe and effective development of a main road network in the member countries.

DG VII's main areas of work are set out in a White Paper on the Common Transport Policy and the Common Transport Policy action plan (1995-2000). These plans cover the following matters about road safety on major motorways:
- environmental, safety, and social standards for transport;
- supporting research and technical development in transport.

The Trans-European Road Network (TERN) was established in 1993 by the Council of Ministers' of Transport Decision of 29 October 1993.
The basic conditions on motorways in a framework of TERN are the regulations of Vienna Conventions on Road Traffic Signs and Markings (*Appendix I*).

SAFESTAR is part of the European Transport Research and Technical Development Programme within the Fourth Framework Programme of DG VII, task 7/2/13:
Development of safety standards for highway design and redesign on all classes of road, including tunnels and bridges, taking account of the proposals for technical standards made in the TERN-report.

The issues of SAFESTAR are also important and will be taken into consideration in the framework of two other European programmes managed by DG VII:
- the Trans-European Transport Network;
- Road Safety Strategy Programme (published April 1997).

3. Objectives of this study

Workpackage 1.1: Specific safety measures for emergency lanes and shoulders of motorways, has been worked out by SWOV. There are no other partners involved in this part of SAFESTAR.

As background objectives, SWOV used the following starting points of the SAFESTAR project as whole:

Proper road design is crucial to prevent human errors in traffic, and fewer human errors will result in fewer accidents. To prevent human errors in traffic, three safety principles have to be applied in a systematic and consistent manner (Wegman, 1997):

- *functional use* of the road network by preventing unintended use of roads;
- *homogenous use* by preventing large differences in vehicle speed, mass and direction;
- *predictable use*, thus preventing uncertainties amongst road users, by enhancing the predictability of the road's course and the behaviour of other road users.

It is to be expected that proper road design, according to these safety principles, could reduce considerably the number of accidents and accident rates. Among the objectives of the SAFESTAR project, the central place is an approach of a structurally safe traffic system. In order to achieve structurally safe changes, the design of the road should be optimally adapted to human capabilities and limitations.

Also, due to improved design solutions in recent years, the number of fatal accidents has decreased considerably in most European countries. To further enhance road safety in Europe, continued improvement of road design standards is required.

3.1. A workpackage activity plan

The study aims to provide an (in-depth) analysis of accidents related to the use of emergency lanes in different European countries and subsequently produce an accident typology. This typology will then be used to derive possible countermeasures to prevent these accidents. The nature of this task is an explorative one. The results could be used as a starting point for a discussion with road authorities in the TERN framework.

3.2. Target groups

The target groups are supranational bodies and national authorities in EU-countries which are responsible for the safety of road infrastructures, or working on it.

3.3. Terms of reference

Accident statistics of several European countries indicate that a sizeable proportion of accidents on motorways are related to emergency lanes. The

cause of these accidents seems to be the inappropriate use of the emergency lane and the nearside lane. For instance, vehicles avoiding ruts in the road surface by partially driving on the emergency lane.

In most cases, the number of single-vehicle crashes with safety barriers and obstacles is known.
The impact of multiple-vehicle accidents on emergency lanes has not yet been studied properly. The extent and impact of these accidents should be estimated.

This workpackage activity consists of the following four tasks:
- a survey of existing views and policies (*Chapter 4*);
- a survey of relevant research results, including in-depth analyses of road accidents and behavioural studies of road users (*Chapter 5*);
- an actual risk estimation of accidents on emergency lanes of motorways in EU-countries (*Chapter 6*);
- conclusions and recommendations (*Chapter 7*).

Hypothesis
The practice of improper use of emergency lanes is different in each country. The improvement of legal regulations could avoid some hazardous practices. Road design countermeasures that take the typical behavioural tendencies into account could decrease safety hazards, caused by inappropriate use of emergency lanes.

Theoretical basis
Large proportions of road accidents are still blamed on shortcomings in road design. An interaction of some road design factors and some typical behavioural tendencies could be hazardous. For instance, adequate road countermeasures and design solutions could reduce the improper use of emergency lanes.

4. Survey of existing views and policies

4.1. International agreements and definitions

The main common document on Road Traffic for the European Union is The Convention on Road Traffic (Convention of Vienna, 1968). The main relevant definitions are used accordingly. Not all European countries are members of the Convention but all of them take the Convention into consideration as far as possible (*Appendix 1*).

In the framework of the European E-roads' network, the E-road network was established in 1975 by the European Agreement on Main international Traffic Arteries (AGR - Accord Européen sur les Grandes Routes de Traffic International) signed at Geneva on 15 November 1975 (*Appendix 2*).

Further developments of motorway standards are coordinated by the Motorway Working Group (MWG). This group was created in 1990 within the Infrastructure Committee of the Directorate General for Transport. EFTA countries have been invited to join the MWG and further contacts with Central and Eastern European Countries (CEEC's) have been developed within ad-hoc meetings.

The MWG includes different actions and activities. Seven Motorway Action Groups have been launched with the following themes:

NEMO 1 - monitoring of the execution of the network outline and its extension to the Community partners;
NEMO 2 - analysis of road mobility on TERN;
START - standardization of inter-urban road typology;
MAGIC - management of traffic;
AIRE - integration of TERN into the environment;
SPREAD - contribution of TERN towards territorial and economic development in the Community;
FINER - financing of TERN.

These themes are parts of a common task to design the Community guidelines for the development of the trans-European transport network. The trans European transport network comprises transport infrastructure, traffic management systems, and positioning and navigation systems.

In a Motorway Working Group Report on the TERN Master plan, the Motorways development in the most EU countries is represented (*Appendix 3*).
The recommendations of the START action of the Motorway Action Group 'Road Typology in the TERN' are relevant for this SAFESTAR project (*Appendix 4*).

The three above-mentioned international agreements contain a few recommendations concerning emergency lanes and hard shoulders of motorways (width of hard shoulders/emergency lanes and a few operational regulations). These recommendations do not have a mandatory status.

4.2. International standards

ISO/CEN

The international standardization in the field of road traffic and road safety has not yet been developed to road vehicle standardization. Two main organisations are collecting all the existing standards in these fields:

- ISO (International Organisation for Standardization) and
- CEN (European Committee for Standardization).

Both organisations have agreed to maintain a common base of relevant European standards (agreement ISO/CEN). All the standardization activities are to be registered by CEN (Comité Européen de Normalisation).

Among 214 technical committees of ISO the following five committees are concerned about *road traffic and/or road safety*:

TC 22 / SC 13	Ergonomics applicable to road vehicles;
TC 22 / SC 12	Restraint systems;
TC 204	Transport information and control systems;
TC 22	Road vehicles;
TC 43 / SC	Noise.

Only the five following ISO standards are concerned with *roads*:

ISO/TR 8349:1986	Road vehicles; Measurement of road surface friction;
ISO 8608:1995	Mechanical vibration; Road surface profiles; Reporting of measured data;
ISO/DIS 11819-1	Acoustics; Method for measuring the influence of road surfaces on traffic noise Part 1: Statistical pass-by method;
ISO/TR 14825:1996	Geographic Data Files (GDF);
ISO/TR 14904:1997	Road transport and traffic telematics; Automatic fee collection (AFC); Interface specification for clearing between operators.

There are hundreds of standards concerning *road vehicles* but there are no ISO or CEN standards available concerning *motorways*.

A common conclusion could be drawn from this fact. It means a relative low (recommended but not mandatory) status of the present international norms and standards concerning motorways.
This is an explanation of the big variety in road design characteristics in different countries. Since the direction of the development of road characteristics on TERN-roads is proclaimed towards uniformity, the measure of such uniformity could be established only by the defining of common international norms and standards.

4.3. International and European databases on road accidents and exposure

In order to estimate the accident risk on motorways and emergency lanes of motorways, international databases, taking into consideration the available data, have been studied. The three necessary demands for accident data are as follows:

1. the total numbers of accidents and casualties on motorways;
2. the above-mentioned data on certain types of accidents, when at least one of the involved vehicles was on, entering, or leaving the emergency lane (hard shoulder) of motorways;
3. accident data should be available for at least for 3-4 years, otherwise, the accident frequencies are too low for any conclusions;

And, at least the following exposure data is necessary to be able to estimate properly the relevant accident risk:

4. total length of motorways;
5. percentage of motorway length with emergency lanes (hard shoulders);
6. AADT on motorways.

The main available databases were consulted in order to find available data for the fifteen member countries of the EU.

IRTAD

The IRTAD database maintained by BASt makes it possible to answer most of the above questions (*Appendix 5*)
The IRTAD-data presented in *Appendix 5* are available for an extensive period (for most of the European countries since 1970).
Two very important questions unfortunately could not be answered by the IRTAD database.

- data of accidents, when at least one of the involved vehicles was entering or leaving the emergency lane (hard shoulder) of motorways;
- the percentage of motorway length foreseen with emergency lanes (hard shoulders).

Motorway Databank Europe-95 of IRF

IRF's Motorway Databank Europe-95 is a computer database of the motorway network data collected for all European countries during the three-year-period of 1992-1994. The Motorway Databank contains main road safety data per road section, featured in a Geographic Information System. The data available from this databank does not add additional information to the IRTAD data.

CARE Database

The current development of the Community database (June 1997) on road accidents (CARE) presents, according to ETSC, a great potential for a comprehensive data source for EU road safety policy.
The CARE database comprises annual national accident data files in their *original form*. They are supplied by all 15 member states without harmonization of individual variables. The Commission's and Member States' aim in the pilot project is to provide a framework of *transformation rules* in CARE to achieve database comparability.
The CARE database will produce the structure of data for accident analysis including:

- exposure data: vehicle kilometres, vehicle fleet, passenger kilometres, population, and road network characteristics.
- results of in-depth studies on accident and injury causation (see STAIRS), information on road safety measures, relevant national legislation, enforcement levels etc.

Until further notice the CARE database is not operational.

STAIRS
This is the EU Fourth Framework research project developing a harmonised procedure for in-depth investigation of crashes. The purpose is to provide new research facilities for improved car crashworthiness and safety regulations.

The first results were reported to the FERSI road safety Conference in Lisbon in September 1997, and the final report was published in 1998.

Availability of accident data (summary)
A short summary on the availability of relevant accident information could be made:

- there are no ready-made data on accidents on hard shoulders available in any European database at the moment;
- one could expect in the near future that the relevant accident data will be available in the European database CARE (within two or three years).

In order to achieve the necessary accident data, the main national road safety research centres were asked to deliver the data on multiple and single-vehicle accidents on emergency lanes of motorways (Questionnaire in *Appendix 6*).

There are no recent ready-made available data on multiple-vehicle accidents on emergency lanes of motorways. To get such data is only possible by performing an expensive in-depth research. It is not possible to realize this research in all countries (the budget needed is about 10-20 working days in each of the 15 countries) within the limited budget of SAFESTAR.
But it is strongly recommended to check the national databases in order to achieve, in the near future, the availability of these data in the framework of cooperation within CARE.

In this research, an estimation of volume and risk of multiple-vehicle accidents on emergency lanes of motorways in EU-countries is made in *Chapter 5*.
The obtained data on single-vehicle accidents on shoulders of motorways are used and discussed in Workpackage 1.2 and not in this report.

4.4. International operational regulations and recommendations

Motorway Lighting
The CIE (International Commission On Illumination) has developed some operational regulations for motorways. The most relevant CIE requirements are presented in Publication CIE 23-1973: International Recommendations for Motorway Lighting (see the short summary in *Appendix 7*).

Other relevant recommendations on motorways lighting developed by CIE and PIARC (Permanent International Association for Road Congresses) are:

- Visual aspects of road markings (joint technical report CIE/PIARC), 1988
- A guide for the design of road traffic lights (1988) -CIE.

From interviews with specialists from different countries, a conclusion could be drawn that motorway lighting is an effective preventive measure.

The minimal conditions on motorway lighting of TERN-roads is important at such locations as around motorways entries.

Automobile Daytime Running Lights (DRL)
The Automobile Daytime Running Lights (DRL) seems to be an efficient measure to reduce road accidents on motorways. Also, collisions involving vehicles standing on, entering or leaving hard shoulders (emergency lanes) on motorways could be reduced by implementing DRL (see a short summary of publication CIE 104-1993 Automobile Daytime Running Lights (DRL) ISBN 3 900 734 43 7 in *Appendix 7*)

4.5 National Standards and Guidelines concerning motorways design in EU-countries

In the framework of the international project 'Safety effects of road design standards' (1993-1994) the SWOV report 'Road design standards of medians, shoulders and verges' has been published (Schoon, 1994). This report contain a comprehensive survey of existing standards in the following countries:

Austria	Iceland	Portugal
Denmark	Ireland	Spain
Finland	Italy	Sweden
France	Netherlands	Switzerland
Germany	Norway	United Kingdom

The important safety aspects are discussed in relation with the design of the shoulders and verges. According to Schoon (1994), three basic designs of hard shoulders containing *obstacle zones* should be distinguished:
- an obstacle free zone near the hard shoulder;
- a zone with single obstacles;
- a full protected zone (when a hazardous area such as water, slopes, walls etc. is situated near the road).

A frequent presence of obstacles or a hazardous area near the road demands the implementation of safety barriers.
When the obstacles are less frequently present, the expensive continous safety barriers could give place to separate protection devices and impact attenuators.

Only a few characteristics of shoulders and verges are available in national standards. These are the following cross section dimensions of the roads which are noted in the report of Schoon (1994):
- median width;
- lane width;
- width of the paved inner shoulder;
- width of the paved outer shoulder (emergency lane);
- width of the verge (unpaved).

The matter of safey barrier implementation and other safety devices is the subject of another work package of SAFESTAR project (WP1.2). This report is mostly dedicated to multiple-vehicle accidents on emergency lanes of motorways.

In order to obtain all the data concerning the emergency lanes 'up to safety barriers', the relevant norms and practices were collected by means of correspondence with colleaguse from European countries.

The relevant available national norms and practices in EU-countries were collected and are presented in three tables in *Appendix 8*:

- Table B8a. Standards, guidelines concerning motorways design;
- Table B8b. Main road design characteristics;
- Table B8c. Traffic regulations about the use of emergency lanes of motorways.

A following common conclusion could be drawn from the above-mentioned survey of national standards presented in the three tables.

Despite the present international agreements on motorways (*Paragraph 4.1*), the national standards and practice in European countries are different. The recent typology of TERN-motorways (*Appendix 4*) demands a harmonization of these norms on significant parts of European motorways included in TERN.

The regular periodic check and monitoring of achievements in this harmonization will be recommended. A randomized inventory journey-observations of a couple of hundreds kilometres per country could be proposed in order to produce a periodic report to the body concerned (MWG).

5. Survey of relevant research results

5.1. Methodology of modelling of road design impact on road safety

The Dutch advisory bureau Goudappel Coffeng BV (1988) has studied models predicting road accidents on hard shoulders: Glennon (1974); Cleveland & Kitamura (1978), Hall & Mulinazzi (1978), Knoflacher & Gatterer (1981), Labadie & Barbaresso (1982).
The two last models gave an appropriate description of empirical data used. Both models give scores to individual objects on hard shoulders. The variables of the models are:

- sideways distance between obstacle and passing traffic;
- damage-index of obstacles.

The second group of variables concerns road geometry at the location of an obstacle such as a slope angle, a bend or curve etc. The traffic volume and average speed were used for defining the exposure. The higher the score, the higher the risk for the severity of the result of the confrontation with such an object. Nevertheless, the possibilities to use these models for the Dutch situation are considered problematic.

The modern approach to the modelling of road design impact on safety is presented in various works of Maycock.
In the research of Maycock & Summersgill (1994), specially dedicated to the evaluation of road standards, a comprehensive approach is presented. The approach takes into consideration two major problems of correct estimation:

- random fluctuations of accident figures and rates;
- corrections needed for systematic changes over time.

The Generalized Linear Modelling (GLM) methodology as a convenient way of analysing data, is discussed. Concerning in-depth accident and conflict studies, it is pointed out that obviously so-called behavioural studies are actually 'an attempt to classify the events and contributory factors which have led up to a specific outcome - the accident'.

The further development of the GLM methodology is realised in modern statistical techniques such as the Weighted Loglinear Analysis and particularly the Weighted Poisson Model (GENMOD procedure of SAS). If sufficient empirical material is available, one could estimate the influence of different road design variables on the overall ratio of accidents/exposure. The 'contrasts' between different values of a variable (for instance A: the width of the emergency lane is 2 m; B: the width of the emergency lane is 2.5 m). Then the model compares two samples of quotients (accident frequency / traffic volume) selected by the above-mentioned values of this variable. This simplified explanation makes it obvious that the model could only be realized if arrays of data are available. Just 'one figure' per country is not enough to make a statistically correct comparison of design solutions and their impact on road safety.
Another principal consideration is the necessity of observation planning. To compare different road design solutions in different countries, one should take into account the necessity of additional data collection, possibly using

random sampling, and the inevitable conversion of data from different countries to one compatible common format.

5.2. Research of the Working Group on Accidents on Hard Shoulders, (GB,1982)

The working group on accidents on hard shoulders (WGAHS) began its study in 1980 and finished it in 1982. This study had the following terms of reference: "to study the frequency, causation, and possible means of reduction of accidents involving vehicles using motorway hard shoulders". It was shown that the severity of these accidents is three times higher than the severity of other accidents on motorways.

This research resulted in three types of approaches to accident reduction on hard shoulders: engineering, legislation, and measures aimed at modifying road user behaviour.

Engineering
Cable detection of hard shoulder occupancy. Such devices could be used in warning systems of the police and approaching drivers.
(Advanced) road marking, surface maintenance, such as texturing of a rumble strip type.

These possible solutions cannot be implemented overall or on a large extent of emergency lanes because of financial limitations. A standard for such implementations based on a minimum level of traffic flow could be recommended.

Accordingly to WGAHS the 'clustered hard shoulders accidents' form an important problem for the further research. They recommend 'working out of an in-depth technique for localising accident groupings on hard shoulders'.

Legislative measures and enforcement
WGAHS has considered and discussed possible amendments to the Motorway regulations. In some cases they have decided to support a possible amendment (marked with '+'), in other cases they voted against recommending this (marked with '-').

(-) Make it an offence to fail to notify the police when a vehicle has stopped on the hard shoulder, either immediately or after a given lapse of time.
Voted against, because it could lead to drivers remaining on the hard shoulder, and thus exposing themselves to danger, for longer than was necessary.

(-) Rendering obligatory immediate removal of stationary vehicles from hard shoulders.
WGAHS suggested that such obligatory actions could result in more delay in traffic than stationary vehicle themselves.

(-) Defining 'emergency' in the Motorway Regulations, and thus clarifying for drivers the circumstances (of which many appear genuinely unsure) in which the hard shoulder may legitimately be used.

(-) Elimination of Regulation, which legitimize amateur help.

(+) Use of four-way hazard flashers by vehicles stopped on hard shoulders.

(-) Compulsory use of a reflective red warning triangle.
In some European countries, carriage and use of these triangles is compulsory. WGAHS decided against such regulation in the United Kingdom. Placement of the triangle in accordance with the Highway Code recommendation, 50-150 yards (1 yard = 0.9144 m) behind the vehicle, entails extra risk for the driver in walking back down the hard shoulder.

Influencing Driver Behaviour

(+) Fixing notices on emergency telephone boxes, explaining their functions, and possibly specifying the information the police will need.

(+) Revising the leaflet on motorway use to indicate the circumstances in which hard shoulders should and should not be used, and again, explaining the functions of the telephones.
Any revised leaflet should also draw attention to the particular risks involved in being on a hard shoulder and of effecting re-entry to the carriageway, and also advise how to minimize these risks.

Summary of conclusions and recommendations of WGAHS

Though the accident rate on motorways is lower than on any other class of road, accidents on them tend - partly because they are frequently severer than accidents on all-purpose roads - to evoke great public concern. This is particularly so with accidents involving vehicles on hard shoulders which, besides having a high death to injury ratio, occur in the area, justly seen by drivers in trouble, as affording refuge.

There is no engineering countermeasure suitable for application over the whole network which could be expected to prevent all such accidents and, the countermeasures most likely to have some effect would generally fall far short of cost-effectiveness.

Some important data obtained in this research are used in *Chapter 6* for comparison with recent research results of SWOV (1997) in the framework of WP 1.1 of SAFESTAR.

5.3. SWOV Research (1987)

The most relevant issue for this project is the earlier research of SWOV carried out by Mathijssen (1987).
The key data collected in this research (from 1987) are used as a reference basis for this research of SWOV (in 1997) in the framework of the SAFESTAR project. Comparison of these data is reproduced in *Chapter 6*.

That project is the first Dutch in-depth research of road accidents on the emergency lanes of motorways. This activity was caused by awareness of society about fatal accidents on motorways when cars parked there because of a breakdown, were involved. Especially the death of a couple of breakdown service officers made the beginning of the research definite.

The research of Mathijssen consisted of three main parts:

Literature study
The literature study, which showed that of the relevant issues almost none were present. There were no available data found for the required estimation of the road accidents risk, caused by vehicles situated on emergency lanes (hard shoulders) of the motorways. The following two parts of research were maintained in order to obtain an estimation of the risk of such accidents.

Collecting of data on relevant accidents
Multiple accidents
The essence of accident analyse is the following selection criteria:
- multiple motorway accidents: at least two (or more) road users involved in an injury accident on motorway emergency lanes;
- at least one of the involved vehicles (road users) was on, leaving, or entering the emergency lane (hard shoulder).

Comparing this selection criterium of earlier Britain research (accidents when at least one of the involved vehicles was on, entering, or leaving the hard shoulder), one can conclude that almost the same kind of collisions are considered by these two independent researches, with the exception of vehicle-pedestrian collisions.
The most important data from SWOV-research is presented in *Table 5.1.*

Type of accident	Number of accidents	Fatally injured		Hospitalized	
		Number	Ratio [1]	Number	Ratio [2]
Multiple accidents on emergency lanes	177	38	21.5	101	57.1
Other injury accidents	6188	364	5.9	2604	42.1
Total	6365	402	6.3	2705	42.5
[1] deaths per 100 injury accidents			[2] hospitalized persons per 100 accidents		

Table 5.1 *Injury accidents on motorways, the Netherlands 1979-1982.*

Note that the severity ratio 'deaths per 100 injury accidents' on emergency lanes is 3.6 times higher than for other injury accidents.

As risk increasing factors of those 177 multiple accidents, the following conditions were found (*Table 5.2.*):

Road and traffic conditions	Frequency	Percentage of accidents
Darkness, no lighting	42	24.6%
At work zones	11	6.4%
Secondary accident (place of primary accident)	10	5.8%
Straight sections of road	163	95%

Table 5.2. *Risk increasing factors of multiple accidents*

Describing	Frequency	Percentage of accidents
Driving too much on the right side of the carriageway	67	37.9%
Careless crossing over by pedestrians	30	16.9%
Skidding of the vehicle	25	14.1%
Lost power on the driving-wheel	13	7.3%
Wrong merging from emergency lane	11	6.2%

Table 5.3. *The behavioural 'causes' of multiple accidents*

Single-vehicle accidents
Almost 100% of single-vehicle accidents on emergency lanes are collisions with safety barriers and obstacles. These accidents have a less serious impact than multiple accidents (*Table 5.4.*). A more detailed analysis of these accidents will be done in Workpackage 1.2.

Type of accident	Number of accidents	Fatal injured		Hospitalized	
		Number	Ratio [1]	Number	Ratio [2]
Single vehicle accidents on emergency lanes	2111	143	6.8	947	44.9
Other injury accidents	4254	259	6.1	1758	41.3
Total	6365	402	6.3	2705	42.5
[1] deaths per 100 injury accidents *			[2] hospitalized persons per 100 accidents		

Table 5.4. *Injury accidents on motorways, the Netherlands 1979-1982*

Behaviour study and recommendations on accidents prevention
The purpose of this part of research was to estimate the presence of vehicles or other subjects on emergency lanes (hard shoulders). The main attention was paid to reasons and behavioural explanations of use of this emergency part of the motorway.

The common exposure is 'the frequency of a car staying on emergency lanes per kilometre of motorway (a random sample of 3,750 kilometre observations) (*Table 3.5.*).

Road / traffic conditions	Frequency	Per 1000 km
Break down vehicles and service	57	15.20
Work zones related	61	16.27
Others	37	9 87
Total	155	41.33

Table 3 5. *The frequency of a car staying on emergency lanes of motorways*

There are more detailed exposures available from the research concerning 'behavioural' reasons for being on the emergency lanes. But because of the too small relevant accident frequencies, it is not possible to get sufficient risk evaluations even for the above presented distribution. Only the total

exposition of 41 33 vehicles per 1,000 kilometre road could be used in indicating risk estimations comparing other time periods.

Data is also available on crossing the marking strip between the emergency lane and the carriageway (*Table 3.6.*)

Vehicle category	Percent of driving behind of the marking strip			
	Carriage lane width 3 5 m		Carriage lane width 3.25 m	
	Dry surface	Wet	Dry surface	Wet
Passenger cars	0.1%	-	0.1%	0.7%
Vans and trucks	1.3%	-	2.9%	7.4%

Table 3.6. *Observation results of partial driving on the emergency lanes (Oldenburg, 1985)*

According to Mathijssen (1987) only 3% of the vehicles situated on emergency lanes had placed the mandatory warning triangle. The following reasons for this very low percentage are given by Mathijssen:
- insufficient knowledge of traffic rules;
- absence of the emergency triangle in the car;
- trouble to get out the car and to place the triangle;
- fear of being run over while placing the triangle;
- doubt about efficiency of the triangle as a warning device and
- doubt about the necessity to warn other road users.

About 20% of the vehicles, staying on the emergency lanes, are less than one metre away from the marking strip.

Efficient measures could be realized in the following directions:
- instead of the triangle, introduce a new effective (and attractive to use) warning device;
- establish a norm of 3.00 m width of emergency lane;
- widening of emergency lanes where necessary;
- prevent crossing of the marking strip (for instance using rumple strips);
- information campaigns for road users.

The behaviour observations have shown that drivers cross the right marking strip and drive apparently on the emergency lane from 0.1% to 7.6% of the total driving time on motorways.

To reduce the danger of collision with the vehicles standing on the emergency lanes, a recommendation is given to consider the possible norm of a minimal 3 50 m width of the carriage lane.
Another recommendation is the extension of lighting on motorways, especially on sections where emergency lanes or carriage lanes are narrow.
Another less expensive solution is to introduce vertical profiled reflecting rumble strips for marking the border between a carriageway and the emergency lane.

5.4. Special use of emergency lanes

Work zones
The 4th Framework Programme of DG VII started in 1997 an Advanced Research on Road Work zone Safety Standards in Europe (ARROWS). ARROWS concerns the whole range measures of applicable work zone safety measures (current and innovative). The work zones use emergency lanes of motorways. The relevant measures on the prevention of road accidents in the work zones are also important for common standards and regulations for emergency lanes.
The recommendations of ARROWS and SAFESTAR concerning the use of and the safety measures on emergency lanes and hard shoulders should be coordinated.

Emergency lane as an additional lane during rush hours
In order to obtain a better usage of the existing infrastructure, the Dutch Ministry of Transport is testing the possibilities to use the emergency lane as an additional lane during rush-hours. TNO has optimized the design of an experimental stretch (Theeuwes et al, 1995)

Buses on emergency lanes
During rush-hours, the connecting time of the public buses is not guaranteed. Delays because of congestions are very annoying for passengers. Sometimes a couple of hundred metres of fully crowded motorway (expressway) delays a bus for an half an hour. The idea of the use of emergency lanes for buses in such cases is not new. Recently experiments were carried out in the Netherlands.
The use of emergency lanes as additional lanes during the rush-hours was experimented within the Netherlands in the beginning of 1990 on three different locations (two sections of the motorway A2, and a connecting section between the motorways A1 and A6 through a viaduct).
The evaluation of these experiments was carried out by SWOV and Bureau Goudappel Coffeng B.V. in 1991 (van Minnen & Dommerholt, 1991).
It was found out that
- the use of small parts of emergency lanes for buses does not increase the road accident risk when properly designed, prepared, and organized;
- it is relevant to work out the proper design of such locations using electronic warning boards.

The preliminary recommendations to be learnt from these experiments are that:
- the speed of buses should be reduced;
- the additional reserve breakdown parking places should be made along experimental sections of emergency lanes;
- there is no data to estimate the impact on road safety of these experiments measured in terms of road accidents;
- according to subjective estimations of bus drivers, passengers, and other involved drivers, the safety was reduced on the experimental locations.

To make definitive recommendations more tests are needed.

6. Actual risk estimations

Only multiple-vehicle accidents on emergency lanes (hard shoulders) of motorways are taken into consideration. Workpackage 1.2 of this project deals with single-vehicle accidents, which for almost 100 % are collisions with safety barriers or obstacles.

In order to estimate the risk of multiple-vehicle accidents on emergency lanes, the available data on motorway accidents was collected for 1995.
At first the IRTAD data was collected (*Table 6.1*).

Country	Length		Deaths	Injury Accidents	Deaths per 100 accidents	Percent of all in EU countries		Injury accidents per km
	abs	%				Deaths	Injury Accidents	
Austria	1,589	3.93%	169	2,287	7.4	4.9%	3.6%	1.44
Belgium	1,666	4.12%	208	3,809	5.5	6.0%	5.9%	2.29
Denmark	786	1.94%	34	265	12.8	1.0%	0.4%	0.34
Finland	388	0.96%	14	130	10.8	0.4%	0.2%	0.34
France	8,030	19.85%	516	5,897	8.8	14.8%	9.2%	0.73
Germany	11,143	27.55%	978	25,513	3.8	28.1%	39.8%	2.29
Greece [1]	280	0.69%	*24*	*445*	5.4	0.7%	0.7%	1.59
Ireland	24	0.06%	5	14	35.7	0.1%	0.0%	0.58
Italy	6,397	15.82%	745	10,860	6.9	21.4%	17.0%	1.70
Luxembourg	122	0.30%	8	120	6.7	0.2%	0.2%	0.98
Netherlands	2,167	5.36%	133	2,719	**4.9**	3.8%	4.2%	**1.25**
Portugal	687	1.70%	99	1,100	9.0	2.8%	1.7%	1.60
Spain	2,728	6.75%	359	2,522	14.2	10.3%	3.9%	0.92
Sweden	1,157	2.86%	31	851	3.6	0.9%	1.3%	0.74
United Kingdom	3,281	8.11%	159	7,522	2.1	4.6%	11.7%	2.29
Total	40,445	100.00%	3,482	64,054	**5.4**	100.0%	100.0%	**1.58**

[1] There are no accident data on motorway accidents in Greece. Using the share of Greece in road length (0.7%) the number of accidents and deaths are estimated for Greece's motorways (respectively 445 and 24).

Table 6.1. *Accident on motorways in EU-countries*

6.1. Accident information

The IRTAD data contains no data concerning multiple-vehicle accidents on emergency lanes. To get lacking data, a literature study was carried out. The relevant research data was found only for two countries: GB (1982) and the Netherlands (1987). In order to acquire this data, a questionnaire was sent round. Unfortunately, this questionnaire did not obtain all the data requested. On the other hand this lack of data corresponds to the absence of publications.
It is also understandable, because it is a rather sophisticated task to register and retrieve such multiple accidents. Such a task can be performed only if the following conditions are fulfilled:
Road accident data must be stored in a relational database containing at least the following layers of information:

- common information on accidents (including type accidents, time, date etc.);

- identification of a road category at the road section or junction where accidents happened (to be able to select accidents on motorways);
- information on the road users involved and on other objects including:
  - certain location;
  - moving;
  - direction of moving;
  - contribution to the accident causes;
  - role in the chain of events before the crash.

The top level of solution in such a statistic database is SAS, used by most modern accident analysis organisations in the world. Not all the EU's countries have these facilities. Even the presence of these facilities does not mean a simple automatic solution of accidents retrieval. Such a data retrieval (as presented in *Table 6.2.*) is still a 'made to measure' work procedure.
To calculate frequencies presented in the row 'Two or more vehicle accidents on emergency lanes' only accidents are selected when:
- no less than two road users were involved;
- at least one of the involved vehicles was on, entering, or leaving the emergency lane (hard shoulder) of the motorway.

Type of accident	Total number of injury accidents	Fatal accidents		Serious accidents		Total number of injury accidents	
		Number	Ratio[1]	Number	Ratio[2]	Per billion vehicle km	Per 100 km of road
Two or more vehicle accidents on emergency lanes	230	37	16.1	90	39.1	4.0	4.6
Other injury accidents	7,889	308	3.9	2,118	26,7	137.8	157.4
Total	8,119	345	4.2	2,208	27.2	141.8	162.0
[1] fatal accidents per 100 injury accidents				[2] serious accidents per 100 injury accidents			

Table 6.2. *Injury accidents and accident rates on motorways in GB 1979-1980 (exposure data from IRTAD database, 1996; Accident data - Report DOT GB (1982))*

Type of accident	Number of accidents	Fatal injured		Hospitalized		Number of accidents	
		Number	Ratio [1]	Number	Ratio [2]	Per billion vehicle km	Per 100 km of road
Two or more vehicle accidents on emergency lanes	177	38	21 5	101	57 1	2.2	2.5
Other injury accidents	6,188	364	5 9	2,604	42 1	76.9	87
Total	6,365	402	6.3	2,705	42 5	79.1	89.4
[1] deaths per 100 injury accidents				[2] hospitalized persons per 100 accidents			

Table 6.3. *Injury accidents and accident rates on motorways in the Netherlands, 1979-1982 (Exposure data from IRTAD database; Accident data - this SWOV research (SAS query on Dutch National Road Accident database) and shadowed area: Mathijssen, SWOV,1987*

Type of accident	Number of accidents	Fatal injured		Hospitalized		Number of accidents	
		Number	Ratio [1]	Number	Ratio [2]	Per billion vehicle km	Per 100 km of road
Two or more vehicle accidents on emergency lanes	151	40	26.5	94	64.6	1 0	1.7
Other injury accidents	9,660	415	4.3	3,060	31.7	61.9	111.9
Total	9,985	497	5	3,270	32.7	64.9	115.6
[1] deaths per 100 injury accidents				[2] hospitalized persons per 100 accidents			

Table 6.4. *Injury accidents and accident rates on motorways in the Netherlands, 1992-1995. (Exposure data from IRTAD database; Accident data - this SWOV research (SAS query on Dutch National Road Accident database)*

Comparing the accident risk in the Netherlands of multiple-vehicle accidents on emergency lanes of motorways in 1979-1982 with 1992-1995 one can note some reduction of the share of such accidents: from 2.8% to 1.5% of all accidents on motorways and some reduction of mortality in such accidents, from 9,5% to 8,1% deaths of all casualties. Using these Dutch ratio's we can obtain an indicative estimation of these accidents and deaths in EU-countries each year (*Table 6.5.*).

	Share of multiple accidents on emergency lanes		Total on motorways EU	Multiple accidents on emergency lanes, estimated for 1995 (using NL's ratio)
	1979-1982	1992-1995		
Injury accidents	2.8%	1.5%	64.054	967
Deaths	9.5%	8.1%	3,482	280

Table 6.5. *Estimation of the share of multiple-vehicle accidents on emergency lanes of motorways in EU-countries*

Such accidents during the last years had a share of about 1.5% of all injury accidents on Dutch motorways. At the same time about 8.5% of all deaths on the motorways occurred in these accidents! The situation has improved since the beginning of 1980 when these figures were respectively about 2.8% and 9.5%.

If we assume that the average proportion of such accidents in EU-countries is not higher than in the Netherlands, then we can conclude that at least 1,000 (rounded up from 967) of such accidents occur and respectively about 300 (rounded up from 280) people die each year on motorways in EU-countries.

If we take into consideration the fact that the Dutch accident rates are better than average in Europe (*Figures 6.1. and 6.2.*), we can conclude that the reality is worse than these estimations. We can only use these estimations as indicative minimum values.

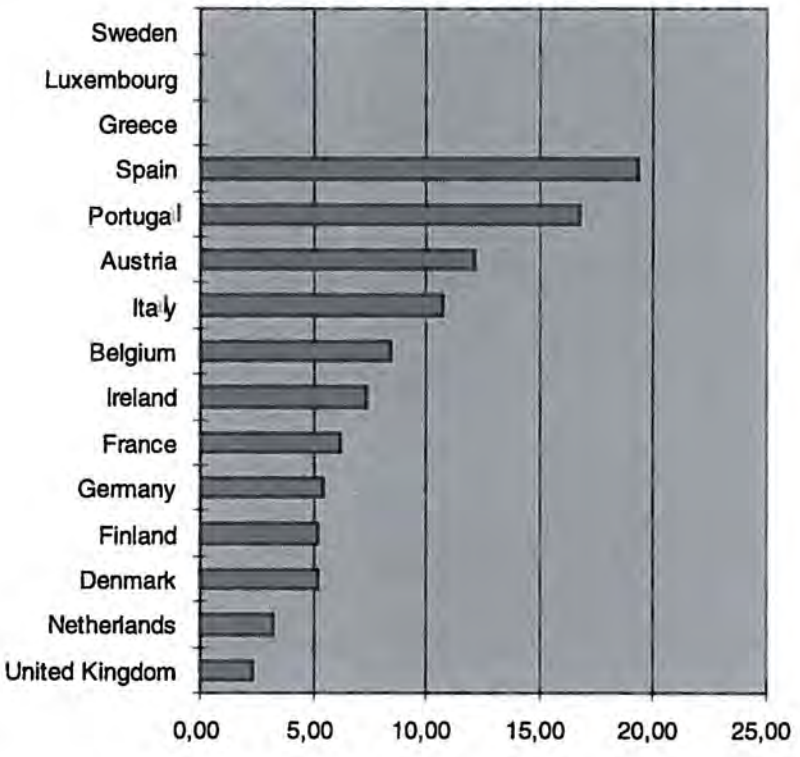

Figure 6.1. *Fatalities per billion vehicle kilometres on motorways in EU-countries. No data for Sweden, Luxemburg and Greece (IRTAD, 1995).*

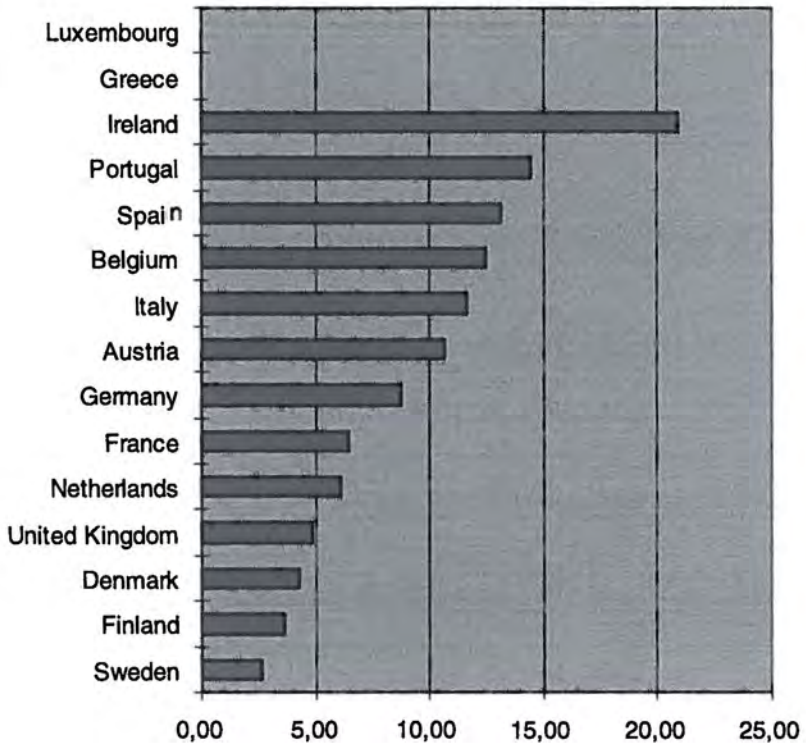

Figure 6.2. *Fatalities per 100 kilometres on motorways in EU-countries. No data for Luxemburg and Greece (IRTAD, 1995).*

	Share of accidents/ Share of length	Share of deaths/ Share of length
Austria	1.24	0.91
Belgium	1.45	1.44
Denmark	0.50	0.21
Finland	0.42	0.21
France	0.75	0.46
Germany	1.02	1.45
Greece (unknown)	**1.00**	**1.00**
Ireland	2.42	0.37
Italy	1.35	1.07
Luxembourg	0.76	0.62
Netherlands	0.71	0.79
Portugal	1.67	1.01
Spain	1.53	0.58
Sweden	0.31	0.46
United Kingdom	0.56	1.45
Ratio's standard deviation	0.57	0.43
Ratio's margins (±) n=15	0.0092	0.0070

Table 6.6. *Relative safety on motorways in European countries*

6.2. Empirical behavioural study

6.2.1. *ANWB database*

By courtesy of the Royal Dutch Touringclub ANWB, the frequency of breakdowns on the motorways has been obtained *(Figures 6.3 -6.5.)*. These data presented all 274,812 help actions managed by the technical service of ANWB (Wegenwacht) in 1996 on Dutch motorways. The average waiting time on the motorway was 32 minutes and the average repair time was 23 minutes. Taking into account the time to call technical service by using the alarm phone as about 5 minutes, we get very rough estimation of 60 minutes of an average stay of a broken down car on the motorway (plus 23 minutes accompanied by the service car).

These data give the possibility to calculate how long cars are staying on the emergency lanes because of the break down. This varies by time of day, day of the week, and month. For instance 185 cars were helped between 1 and 2 pm on Monday 12th May 1996. It also means that approximately the same number of broken down cars were during that period on the emergency lanes. Also about 70 service cars were there during the same period.

The total length of carriageways (i e. both directions) of motorways in the Netherlands is 4,334 kilometres. Under the above-mentioned conditions, one had to drive an average of about 24 kilometre to pass one broken down car and about 62 kilometre to pass one service car. The time of day explains well the variation of breakdowns. At 6 am, one drives an average of about 70 kilometre to meet one broken down car and about 182 kilometre to meet one service car (see distributions below). At 9 pm, one drives an average of about 33 kilometre to pass a breakdown car on the emergency lane.

6.2.2. *Field observations*

Combined with other activities, SWOV measured the estimated driving distance needed to pass a broken down car on the emergency lane of a motorway. The random sample observations, during four days in May 1997, have shown that one drives an average of about 39 kilometre to meet one broken down car on the emergency lane or on the hard shoulder of the motorway. Also many obstacles at the road repair areas are noted (every 20.4 kilometre of the route). In total, obstacles are found every 12,4 kilometre on the emergency lanes. The road repair areas should rather be taken into consideration differently from other obstacles. The speed should be slowed down. Drivers have to be warned by special mobile installations. The nature of possible conflicts at road repair areas and when passing a broken down car are different. This difference will be considered in greater detail in the ARROWS project.

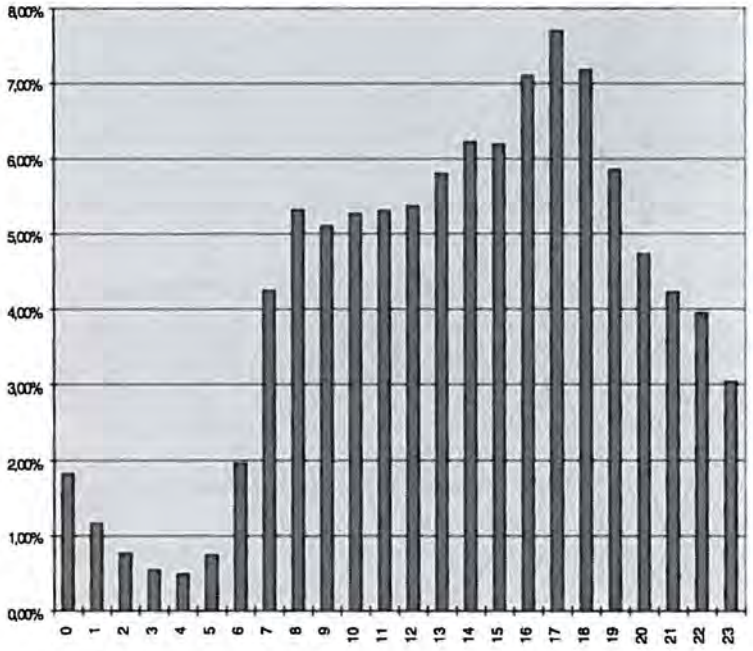

Figure 6.3 *Distribution of the service actions on the motorways in the Netherlands, 1996; distribution by time of day (ANWB)*

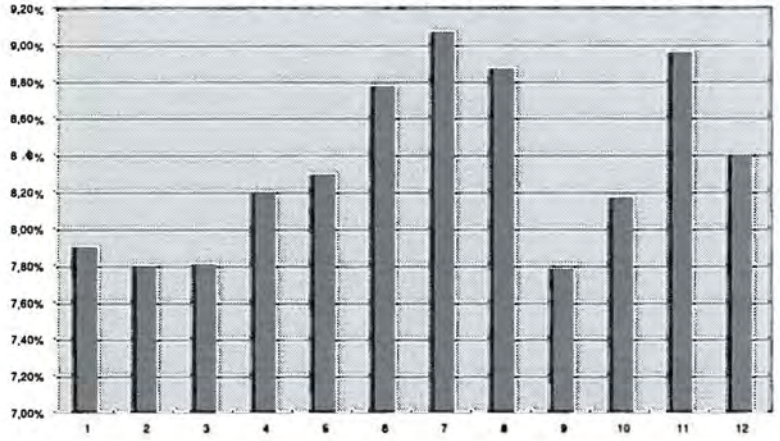

Figure 6.4. *Distribution of the service actions on the motorways in the Netherlands, 1996; distribution by month (ANWB)*

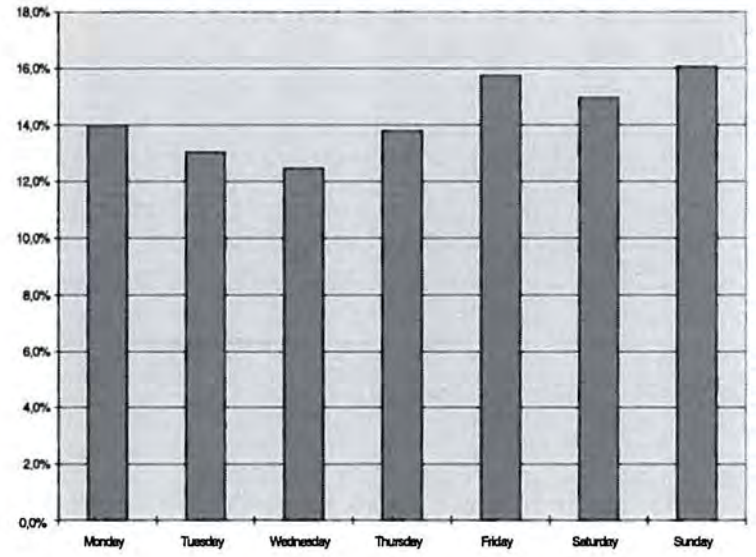

Figure 6.6. *Distribution of the service actions on the motorways in the Netherlands, 1996; distribution by day of the week (ANWB)*

7. Conclusions and recommendations

One third of all accidents on motorways are single-vehicle accidents. Almost 100% of single-vehicle accidents on emergency lanes (equipped with a safety barrier) are collisions with safety barriers, thus limiting emergency zones. These accidents have a less serious effect than multiple-vehicle accidents on emergency lanes. A more detailed analysis of single-vehicle accidents is not the subject of this report (it will be done in Workpackage 1.2 of the SAFESTAR project 'Criteria for safety devices on motorways').

The following three international documents contain the conditions on motorways in EU:
- The Convention on Road Traffic, Vienna, 8 November 1968;
- AGR - European Agreement on Main international Traffic Arteries (E-roads), Geneva, 15 November 1975;
- START-report of the Motorway Action Group 'Road Typology in the TERN', 1994.

The above-mentioned documents give recommendations for national standards of the EU-countries. There are no ISO or CEN standards concerning motorways. There are some additional documents such as the recommendations of the International Commission On Illumination, PIARC, and other organisations, which contain some relevant (but not mandatory) operational regulations for motorways.

The survey of national standards on emergency lanes of motorways has shown a lot of differences between the EU-countries. In order to harmonize the national standards, the START-report proposes minimum conditions on 'Road Typology in the TERN'.

Summarized, the following international recommendations on motorways emergency lanes and hard shoulders have already been made:
- a minimal width of traffic lanes on straight alignment is recommended (3.5 m);
- a minimal width of the hard shoulder (paved or stabilized) is recommended (3.75 m);
- the shoulders should normally include a continuous emergency stopping strip (of at least 3.00 m),

In order to prevent improper use of emergency lanes and to reduce the number of stopped cars, the typical facilities spacing is recommended by MWG:
- rest areas with parking and toilets (every 20 kilometre); service areas (every 50 to 100 kilometre); service and accommodation areas (every 200 kilometre).

Emergency calling posts are recommended as follows:
- they are to be placed every two kilometres in each direction and opposite of each other (in order to avoid the perceived possible need to cross the road);
- notices explaining their functions, fixed on emergency telephone boxes;

- make a European leaflet on motorway use to indicate the circumstances in which hard shoulders should, and should not, be used. Include instructions concerning emergency telephone use and explaining the functions of the telephones.

Additional to the above mentioned recommendations, the following conclusions and recommendation could be drawn as a result of this research.

1. There are no readily available data of accidents on hard shoulders in any European database at the moment.
   The present European databases do not contain data on multiple accidents on emergency lanes. Mostly, only the data of single crashes with safety barriers and obstacles is known. The impact of multiple accidents on emergency lanes has not yet been studied properly.
   To make these serious accidents measurable will be recommended in the framework of development of the European database CARE. It shall be strongly recommended to check the national databases in order to achieve, in near future, availability of these data in the framework of cooperation within CARE.

2. There is no in-depth research data available on these accidents in European countries. In order to obtain these data, a coordinated data gathering should be organized with a certain budget available per national research centre of each of the 15 EU countries. In the framework of this project the inventory measurements of road characteristics samples of TERN-motorways should also be carried out. Combining the whole accident data and inventory road and traffic data, the risk estimations should be carried out on the different types of roads and in different countries of TERN network.

3. From interviews with specialists in different countries, the conclusion can be drawn that motorway lighting is an effective preventive measure. The minimal conditions on motorway lighting of TERN-roads is important at such locations as around motorways entries.

4. The Automobile Daytime Running Lights (DRL) will be recommended on TERN-roads as a mandatory preventative measure at least as an experiment for at least 18 months.

5. In order to estimate the number and impact of multiple-vehicle accidents on emergency lanes of motorways in EU-countries, two in-depth researches in the Netherlands were used. Such accidents had, during the last years, a share of about 1.5% of all injury accidents on Dutch motorways. At the same time about 8.5% of all deaths on motorways occurred in these accidents!
   The severity of multiple-vehicle accidents on emergency lanes (hard shoulders) is three to four times higher than the severity of other accidents. This situation has changed since the beginning of 1980 when these figures were about 2.8% and 9.5% respectively.
   If we assume that the average proportion of such accidents in EU-countries is not higher than in the Netherlands, we can conclude that at least about 1,000 of such accidents happen, and about 300 people die each year on motorways in EU-countries. We can use these estimations

as indicative minimum values because the Dutch situation is better than average in EU-countries.

6. The presence of broken down cars as one of exposure components has been investigated. By courtesy of the Royal Dutch Touringclub ANWB, the frequency of breakdowns on the motorways was obtained. The time of day explains the variation of breakdowns well. At 6 am, there is about one broken down car every 70 kilometre and a service car every 182 kilometre on the emergency lane. At 9 pm, there is about one broken down car every 33 kilometre on the emergency lane.
The random sample observations, during four days in May 1997 have shown that there is about one broken down car every 39 kilometre on the emergency lane/hard shoulder of the motorway. In total obstacles are found on the emergency lanes every 12,4 kilometre (most of them are the work zones). The inventory of obstacles on emergency lanes in EU-countries could be recommended as an important component of exposure.

7. The next step will be the risk estimation based on an in-depth accident data inventory of road characteristics and exposure data. The regular risk estimation is very important in order to improve road safety by introducing new, common norms and guidelines, and by implementing urgent and/or additional measures based on clustering of hazardous locations.

8. There are some deviating practices known in different countries when segments of emergency lanes are used for other purposes than usual:
   - additional lanes during the rush-hours;
   - separated lanes for buses;
   - additional lanes when the opposite direction of the road is under reconstruction.

   These measures are relative new and there is no evidence pro of contra because of the lack of accident data.
   Gathering information on such deviating practices in EU-countries shall be recommended.

9. In order to realize the above mentioned recommendation, an inventory or monitoring project should be started under supervision of MWG.

10. On hazardous locations with higher risk, some additional measures can be taken:
    - rumble strips marking the emergency lanes;
    - widening of emergency lanes if necessary;
    - information campaigns for road users about typical hazardous locations;
    - another recommendation is the extension of lighting on motorways, especially on sections where emergency lanes or carriage lanes are narrow.

8. References

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Appendices

1. The Convention on Road Traffic (Convention of Vienna, 1968) about motorways
2. European agreement on main international traffic arteries AGR : done at Geneva on 15 November 1975 (extract of conditions and regulations on emergency lanes of motorways)
3. Statistical data concerning the trans-European road network outline plan - Horizon 2002
4. START action of Motorway Working Group 'Standardisation of Typology on the Trans-European Road Network' about emergency lanes of motorways
5. Available exposure and accident data on European motorways in EU's Member States'
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10. Common Observations Data (behavioural study)

Appendix 1. The Convention on Road Traffic (Convention of Vienna, 1968) about motorways

From Article 1 (Definitions)
'Motorway' means a road specially designed and built for motor traffic, which does not serve properties bordering on it, and which:

- is provided, except at special points or temporarily, with separate carriageways for the two directions of traffic, separated from each other either by a dividing strip not intended for traffic or, exceptionally, by other means;
- does not cross level with any road, railway or tramway track, or footpath; and
- is specially signposted as a motorway.

From Article 17 (Slowing down)
No driver of a vehicle shall brake abruptly unless it is necessary to do so for safety reasons.
Every driver intending to slow down to an appreciable extent shall, except where his slowing down is in response to an imminent danger, first make sure that he can do so without danger or undue inconvenience to other drivers. He shall also, unless he has made sure that there is no vehicle following him or that any following vehicle is a long way behind, give clear and timely warning of his intention by making an appropriate signal with his arm. However, this provision shall not apply if warning of slowing down is given by the vehicle's stop lights, referred to in Annex 5, paragraph 31 , of this Convention.

From Article 25 (Motorways and similar roads)
On motorways and, if so provided in domestic legislation, on special approach roads to and exit roads from motorways:

- the use of the road shall be prohibited to pedestrians, animals, cycles, mopeds unless they are treated as motor cycles, and all vehicles other than motor vehicles and their trailers, and to motor vehicles or motor-vehicle trailers which are incapable, by virtue of their design, of attaining on a flat road a speed specified by domestic legislation;
- drivers shall be forbidden to have their vehicles standing or parked elsewhere than at marked parking sites; if a vehicle is compelled to stop, its driver shall endeavour to move it off the carriageway and also off the flush verge and, if he is unable to do so, immediately signal the presence of the vehicle at a distance so as to warn approaching drivers in time.

From Article 31 (Behaviour in case of accident)
Without prejudice to the provisions of domestic legislation concerning the obligation to assist the injured, every driver or other road user involved in a traffic accident shall:

- stop as soon as he can do so without causing an additional danger to traffic;
- endeavour to ensure traffic safety at the site of the accident and, if a person has been killed or seriously injured in the accident, to prevent, in so far as such action does not affect traffic safety, any change in conditions at the site, including the disappearance of traces which might be useful for determining responsibilities;

- if so requested by other persons involved in the accident, identify himself to them;
- if a person has been injured or killed in the accident, notify the police and remain on the scene of the accident or return to it and wait there until the arrival of the police, unless he has been authorized by the police to leave or has to assist the injured or to receive attention himself.

Appendix 2. European agreement on main international traffic arteries AGR

Done at Geneva on 15 November 1975 (extract of conditions and regulations on emergency lanes of motorways)

From Annex II. Conditions to which the main international traffic arteries should conform

Motorways
'Motorway' means a road specially designed and built for motor traffic, which does not serve properties bordering on it, and which
- is provided, except at special points or temporarily, with separate carriageways for the two directions of traffic, separated from each other either by a dividing strip not intended for traffic or, exceptionally, by other means;
- does not cross level with any road, railway or tramway track, or footpath; and
- is specially sign-posted as a motorway.

Shoulders and central reserve
The recommended minimum width of the shoulder shall be 3.25 m for all-purpose and express roads and 3.75 m for motorways.
The shoulders of motorways and express roads shall include on the right side of the carriageway a continuous stopping strip, paved or stabilized, with a minimum width of 2.50 m to permit stopping in a emergency.
In all cases, surfaced or stabilized lateral strips, 1 m width, shall be provided on the shoulder along the carriageway. For safety reasons, wider strips, free of obstacles, shall be provided along motorways and express roads.

Safety barriers
On motorways and express roads, safety barriers shall be provided in particular:
- on the central reserve
- on the shoulders

when fixed and rigid obstacles such as bridge abutments and piers, retaining walls, gantry supports, a continuous line of lamp posts etc. are situated less than 3 50 m from the edge of the carriageway.

Appendix 3. Statistical data concerning the trans-European road network outline plan - Horizon 2002

EU-member countries	Links in the framework of TERN (km)			Expected development of motorways in the framework of TERN (km), 1992-2002					
	existing in 1992	to be realized	total in 2002 (target)	existing in 1992, [1]	total in 2002 (target)	new to be realized		existing to be widened	
						abs.	%	abs.	%
Austria [2]				1532					
Belgium	1415	88		1650	1,738	88	0		
Denmark	510	356	866	704	1,060	356	1		
Finland [2]				249					
France	7700	4400	12100	7110	10,110	3000	0	582	0
Germany	10200	1533	11733	10955	12,488	1533	0	1220	0
Greece	850	2530	3380	280	810	530	2		
Ireland	30	1190	1220	24	395	371	15		
Italy	5800	2111	7911	6214	8,325	2111	0	805	0
Luxemburg	70	20		120	140	20	0		
Netherlands	1575	70	1645	2134	2,204	70	0	629	0
Portugal	320	1056	1376	519	1,379	860	2		
Spain	6100	3562	9662	2728	6,290	3562	1		
Sweden [2]				969					
UK	2720	1195	3915	3245	3,785	540	0	812	0

[1] IRTAD database used as additional source
[2] no data in TERN Report of 1993; these countries joined the EU later, in 1994

Appendix 4. START action of MWG 'Standardisation of Typology on the Trans-European Road Network' about emergency lanes of motorways

Rules of the motorway
Drivers shall be forbidden to have their vehicles standing or parked elsewhere than at marked parking sites; if a vehicle is compelled to stop, its driver shall endeavour to move it off the carriageway and also off the flush verge, and if he is unable to do so, immideately signal the presence of the vehicle at a distance so as to warn approaching drivers in time.

Shoulders
The shoulder can be taken to comprise a stabilised or paved section and a grass or gravel verge.
The recommended minimum width of shoulders should be 3.75 for motorways. On difficult sections of mountainous terrain and on sections crossing inensively urbanised areas, and also on sections equipped with acceleraion or deceleration lanes the width of shoulder can be reduced to 1.50.

The shoulder should normally include a continous stopping strip (emergency stopping strip) of at least 3.00 m, stabilised and paved so as to permit stopping.

Equipment
It is very important for the safety and convenience of the motorists on TERN that there are adequate facilities provided without leaving TERN, for all their personal and vehicular needs. These include the following minimum level of service (comment it is also important in order to make adequate use of emergency lanes)

Facility	*Typical spacing*
Rest area with parking and toilets	20 km
Service area with parking, toilets, catering, fuel, and telephone	50 to 100 km
Service area with parking, toilets, catering, fuel, telephone, tourist and travel information and accommodation	200 km

Availability
Fuel, toilets and telephone shhould be available for 24 hours in each day and throughout the year.
On motorways, the shoulders should normally include a continous stopping strip (emergency stopping strip) of at least 3.0 m.

Emergency calling posts
- spacing between emergency calling posts: every two kilometres in each direction and opposite each other (in order to avoid the preceived possible need for the very dangerous motorway crissing by users) or as close as possible to this rule. In addition they should be placed so that users should not have to cross slip toads to gain access.
- signing of the emergency calling post;
- guidance to the nearest emergency calling post;
- emergency call post operation indication.

Appendix 5. Available exposure and accident data on European motorways in EU's Member States

Country	Exposure		Deaths in road accidents		
	Length of motorways, km	Traffic - vehicle kilometres billions	Absolute	Per road length	Per billion vehicle kilometres
Austria	1.589	13,97	169	0,11	12,10
Belgium	1.666	24,66	208	0,12	8,43
Denmark	786	6,54	34	0,04	5,20
Finland	388	2,68	14	0,04	5,22
France	8.03	83,58	516	0,06	6,17
Germany	11.143	179,5	978	0,09	5,45
Greece	280				
Ireland	24	0,68	5	0,21	7,35
Italy	6.397	69,56	745	0,12	10,71
Luxembourg	122		8		
Netherlands	2.167	40,93	133	0,06	3,25
Portugal	687	5,91	99	0,14	16,75
Spain	2.728	18,6	359	0,13	19,30
Sweden	1.157		31	0,03	
United Kingdom	3.281	68,04	159	0,05	2,34
Czech Republic[1]	392	2,1	33	0,08	15,71
[1] The Czech Republic is not an EU Member State but does participate in the SAFESTAR project					

Source: IRTAD

Appendix 6. Questionnaire

Questionnaire: Emergency lanes of motorways

N.B. All these questions refer only to your country

I. Traffic regulations and standards on motorways (and express roads)

1. Do you have standards or documents defining a list of (emergency) situations, which are acceptable as a reason for stopping a car on emergency lanes (hard shoulders)

□ yes □ no

□ if yes please send the bookmarks

2. Please mark the situations of allowed stopping/driving on hard shoulders of motorways if applicable:

□ Police, fire brigade, or ambulance in action □ Road maintenance in operation
□ Breakdown of the vehicle
□ Actual shortage of fuel
□ Actual assistance in case of accident
□ Being at police disposal as a witness
□ Due to extremely bad weather conditions
□ Suddenly becoming unwell
□ Suddenly needing "to use the bathroom" (by old people and children)
□ Actual need to check the load
□ Break because of tiredness of driver
□ Pause for eating and drinking
□ Pause to look for the way on the map
□ Driving escorted by police
□ Driving public bus on the specially marked hard shoulder during traffic jam
□ Other situations:

_____

_____

3. Standardized width of emergency lane: _____ metres.

4. Frequency of emergency phones: _____ kilometres of motorway per emergency phone.

II. Presence of emergency lanes on motorways

1. Please make a rough estimation of the extent (in %) of the presence of emergency lanes on motorways (per carriageway).

Presence of emergency lanes per carriageway, share of total length of the road in %	
Roadside	
In the median (if emergency lane ≥ 1,5 m)	

2. Total length of motorways _____ km

3. Average daily traffic (or a histogram of ADT) on motorways _____ 1000 vehicles

III. Research reports (cross the □ if available)

Please send us a copy of recent research reports concerning:
□ accidents and safety measures on emergency lanes on motorways
□ use of emergency phones and technical and medical assistance on the motorways

Questionnaire: Emergency lanes of motorways

IV. Accident data

If available, please insert data:

Year: _____ (most recent)	Number of injury accidents	Fatalities	Injuries	
			Serious*	Others
1. All injury accidents on **MOTORWAYS**				
1.1. Accidents on motorways with a collision related to the emergency lane (where vehicles were entering, on, or leaving emergency lane), total				
1.1.1. Single-vehicle accidents				
1.1.2. Multi-vehicle accidents				

*) hospitalization, if you use a different definition, please put your definition here:

V. Personal data

(of the person who has filled in this form):

Name: _____

Organization: _____

Post address: _____

Tel.: _____ Telefax: _____

E-mail: _____

Remarks:

Please send this form and required documents (if existing in English, otherwise in native language) to:

SWOV Institute for Road Safety Research
Dr. L.G. Braimaister
P.O. Box 170
2260 AD Leidschendam
The Netherlands

tel: +31 70 3209323
telefax: +31 70 3201261
E-mail: braimaister@swov.nl

Appendix 7. International recommendation of CIE on motorways (summaries)

Publication CIE 23-1973: International Recommendations for Motorways
This CIE recommendation describes the fundamental principles which govern the lighting of motorways also with regard to the road safety purposes. The recommendations are published, taking into consideration comments that were received from CIE member countries.
Motorway lighting differs from country to country; possibilities and usages vary. Nonetheless, there are certain principles and techniques which are generally applicable.
These general rules are described, in accordance with recent research and experience, in order to enable countries to issue or revise their own codes. The only methods of providing adequate lighting which are included in this report are those which are firmly established and give satisfactory results within acceptable economic limitations.

The use of these methods is not considered mandatory, and research into new standards and methods is encouraged. Therefore, the report does not constitute a code. It is hoped, however, that it may serve as a basis for the drafting of national codes, so that in the not too distant future the codes of different countries will be more uniform and, thus, more compatible with the growing volume of international traffic.

Publication CIE 104-1993 Automobile Daytime Running Lights (DRL) ISBN 3 900 734 43 7)
Lack of vehicle conspicuity is a large road safety problem judging both from accident statistics around the world, from accident-in-depth studies, and from road user explanations of collisions. One way to increase vehicle conspicuity, also in daytime conditions is to equip the front of the vehicles with lights. Accident statistics from Finland, Sweden, Norway, and USA, where comparisons of vehicles with and without DRL have been carried out support the concept. The reduction of the daytime collisions due to DRL is estimated to be approximately 10 percent.

Several countries have legislation for motorcycles to drive with the low beam turned on also during daytime. Some countries have legislation requiring low beam or special DRL for all vehicles during daytime (Finland, Sweden, Norway, Denmark). Canada has corresponding legislation for all new vehicles. The Economic Commission for Europe has produced a regulation for DRL. USA and some other countries do not require but allow DRL. The European Community has lately shown some interest in DRL as a road safety measure. However, except for the standard low beam as a DRL, the lighting specifications of DRL in most of these legislations, standards and regulations differ from each other.
Finally, the report analyses what kind of lighting specifications should be required. For automobiles the recommendations for special DRL are two white lights, each with a central intensity of 400-1200 cd and with a specified light distribution.

Appendix 8. National standards

Country	Standards, guidelines concerning motorway design	Comments
Austria		
Belgium	AGR, Wet houdende goedkeuring van de Europese Overeenkomst inzake internationale hoofdverkeerswegen en van de Bijlagen, opgemaakt te Genève op 15 november 1975, 15 maart 1985, Belgisch Staatsblad, 19 november 1985 Normen voor de Wegen en Autosnelwegen, Ministerie van Openbare Werken, Bestuur de Wegen, 1985 Caractéristiques routiéres et autoruotiéres, Circulaire n. A/WA/205/91-02685, Ministerie Wallon de l'Equipement et des Transports, Décembre 1991	The road design standards for motorways are those given in annex II of the AGR-treaty which Belgium has signed and ratified.
Denmark	4.30.01 Traffic engineering, Road and pathtypes, Catalogue of types for new roads and paths in rural areas, The Road Directorate, The Technical Committee on Road Standards, May 1981	Road standards are not mandatory and only give recommendations.
Finland		
France	Instruction sur les conditions techniques d'amenagement de autoroutes de liason (ICTAAL), SRTRA, Bagneux 1985 Instruction sur les conditions techniques d'aménagement de routes nationales (ICTARN), SETRA, Bagneux 1970 (mod.1975)	Compulsory norms for linking motorways (routes)
Germany	Richtlijnen für Außerortstraßen (RAS), Forschungsgesellschaft für Straßen- und Verkehrswesen, Arbeitsgruppe Straßenentwurf, Köln (Raümliche Linienführung, Vermessung, Querscnitt)	Guidelines for rural roads. Compulsory norms for linking motorways
Greece	no national standards	The German Guidelines (RAS) and American manuals such as of AASHTO Design Policy are used.
Ireland	Geometric Design Guidelines RT180, An Foras Forbartha (The National Institute for Physical Planning and Construction	No mandatory recommendations
Italy	Norme sulle caratterisiche geometriche delle strade extraurbane, Consiglio Nazionale delle Ricerche C.N.R., Bolletino Ufficiale (Norme techniche) del C.N.R., Anno XIV, pt IV, no. 78 luglio 1980	The standards for rural roads (strade extraurbane) apply to all rural roads to be constructed. Deviations from standards have to be justified.
Luxemburg	no national standards	French and German standards are used
Netherlands	Richtlijnen voor het ontwerpen van autosnelwegen (ROA) Hoofdstuck I, Basiscriteria, 1992 Hoofdstuk VII, Diversen, 1992 Richtlijnen Bebakening en Markering van Wegen, DVK, Rijkswaterstaat 1991	The guidelines for rural motorways are mandatory.
Portugal	Normas de Projecto, Ministério das Obras Públicas, Transportes e Comunicações, JAE, 1977	Mandatory standards on National Road Network. No deviations from standards are allowed.

Country	Standards, guidelines concerning motorway design	Comments
Spain	Normativa vigente en proyectos de la Dirrreccion de Carreteras, Ministerio de Obras Públicas y Transportes, 1993	An overvieuw of existing norms and standards in Spain
Sweden		
United Kingdom	Highway Link Design, TD 9/93, The Department of Transportation, 1993 'Highway Safety Guidelines: accident reduction and prevention. International edition' , Institution of Highways and Transportation, 1990	TD is a mandatory standard.

Table B8a. *Standards, guidelines concerning motorway design*

	Standardized width of emergency lane, m	Extent of motorways per one emergency phone, km	Presence of emergency lanes on motorways at roadside
Austria			
Belgium	2.5	2	95%
Denmark	2.5	2	80%
Finland	2.75 (paved)+ 0.25 (unpaved)	Not used	
France	2.5-3.0	2	90%
Germany	2.5	2	87%
Greece	2-.,5	-	100%
Luxembourg	2.5	2	100%
Netherlands	3	2	98%
Portugal	3.5	2	100%
Sweden	2.75	Not used	85%
United Kingdom	3.3	1.5	98%
Switzerland	2.5	max 2,5	90%
Czech Republic	2.5	2	100%

Table B8b. *Main road design characteristics*

	A	B	Dk	SF	F	D	Gr	L	NL	P	E	S	UK	Cz
Police, fire brigade, or ambulance in action		+	+	+	+	+	+	+	+	+		+	+	+
Road maintenance in operation		+	+	+	+	+	+	+	+	+		+	+	+
Breakdown of the vehicle		+	+	+	+	+	+	+	+	+		+	+	+
Actual shortage of fuel		+	+	+	+			+	+	+		+	+	
Actual assistance in case of accident		+	+	+	+	+	+	+	+	+				+
Being at police disposal as a witness		+	+	+				+	+				+	
Due to extremely bad weather conditions		+	+	+		+	+	+	+	+		+		
Suddenly becoming unwell		+	+	+	+	+	+	+	+	+		+	+	+
Actual need to check the load		+				+	+		+			+		+
Driving escorted by police		+		+					+				+	
Driving public bus on the specially marked hard shoulder during traffic jam				+					+					
When special traffic sign is open due to high traffic volume						+								

Table B8c. *Traffic regulations about the use of emergency lanes of motorways*

A = Austria
B = Belgium
Dk = Denmark
SF = Finland
F = France
D = Germany
Gr = Greece
L = Luxemburg
NL = Netherlands
P = Portugal
E = Spain
S = Sweden
UK = United Kingdom
Cz = Czech Republic

Appendix 9. Results of data retrival in the Dutch National Accident Database

1. All injury accidents in the Netherlands 1992-95

		Injured		
Accidents	Deaths	Total	Not admitted to hospital	In-patients
165301	5170	195740	149101	46639

2. All injury accidents on arterial roads, outside the built-up area 1992-95

		Injured		
N	Deaths	Injured	Not admitted to hospital	In-patients
13476	853	18649	13671	4978

3. All injury accidents on motorways, 1992-95

		Injured		
N	Deaths	Injured	Not admitted to hospitaln	In-patients
9985	497	13796	10526	3270

4. All injury accidents on motorways, when two or more road users colliding in the hard shoulder, 1992-95

		Injured		
N	Deaths	Injured	Not admitted to hospital	In-patients
ALL 151	40	253	159	94

Appendix 10. Common observations data (behavioural study)

Date	12 May 1997	26 May 1997	27 May 1997	29 May 1997	Total
A-road	4, 9, 2, 6, 7, 16, 20, 13	12, 50, 1, 35, 1, 28, 27	7, 6, 1, 4	12, 50, 28, N37, 15, 16, 13	
Total lengths, km	436	366	233	537	1572
Vehicle type					
Motor cycle	-	-	-	-	-
Passenger car/van	15	33	11	16	75
Truck/bus	9	8	-	2	19
Others	6	19	3	5	33
					127
Location					
Emergency lane	17	36	14	18	85
Shoulder behind emergency lane	11	20	-	4	35
Half	2	4	-	1	7
					127
Reason of stopping					
Break down	15	13	6	11	45
Work zone	13	47	8	9	77
Others	2*	-	-	3**	5
					127

* 2 persons using emergency phone
** driving aside a traffic jam.

Frequency of observations: one observation per 12,4 km,
where: one break down per 34,9 km
one maintenance area per 20,4 km
one other per 314,4 km

Observations were made by Mr. W.H.M. van de Pol (SWOV).