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SafeMAP – Feasibility assessment of a digital map for road safety applications

Definition of SafeMAP database

Final Report
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1 Starting point and objective of the research

1.1 Situation in the states of the EU

In the past few decades the number of motor vehicles in the countries of the EU has risen continuously. The number of vehicles in use has more than tripled from 62.5 million to 205.8 million between 1970 and 2001. The number increases every year by more than 3 million (COMMISSION OF THE EUROPEAN COMMUNITIES, 2003b).

Several predictions assume a further increase in traffic demand. For the 15 current member states of the EU the demand for passenger and goods transportation is estimated to increase by 24 and 38% respectively. Most of this growth is expected to be taken up by the road traffic, which will cause major impact, including also an additional number of traffic accidents with fatalities, injuries and property damage.

Among other measures, the continuous improvement of passive safety of motor vehicles contributed to the improvement of traffic safety. Thus, the number of fatalities in Germany fell by 38% between 1991 and 2001, the number of serious injuries by 28%. The number of slight injuries rose by 7% in the same period (BMVBW, 2002).

In the member states of the EU, fatalities have been reduced from 56,027 in 1991 to 39,684 in 2001, which is a reduction by 29% (COMMISSION OF THE EUROPEAN COMMUNITIES, 2003a). Fig. 1 shows this trend.

In spite of these improvements, 40,749 people lost their lives in traffic accidents in the states of the EU in the year 2000 (IRTAD, 2003). It is estimated that accidents cause costs of 160 billion € or 2% of the GDP in Europe (COMMISSION OF THE EUROPEAN COMMUNITIES, 2003b).

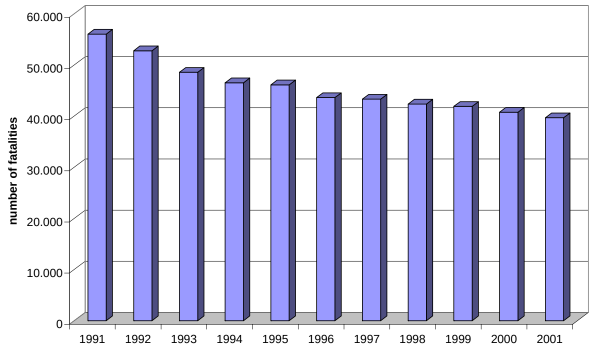


Fig. 1: Number of accident fatalities between 1991 and 2001 in the EU

1.2 Development of safety systems by using new technologies

The European Commission aims at reducing the road fatalities by half between 2000 and 2010. In this context, it was concluded that a further development of the “conventional” safety measures like safety belts, ABS, Airbags, ESP does not provide the potential for a major improvement of traffic safety. A decisive improvement of traffic safety can only be achieved by the development and introduction of advanced and active safety systems. A promising approach is the use of Information and Communications Technologies for the development of intelligent in-vehicle and telematics-systems (COMMISSION OF THE EUROPEAN COMMUNITIES, 2001).

The eSafety working group, which was established by the European Commission in 2002, concluded in their report that intelligent in-vehicle safety systems have a great potential to improve traffic safety. Vehicle Safety Systems based on Information and Communications Technologies provide interesting solutions for the interaction between driver, vehicle and road (COMMISSION OF THE EUROPEAN COMMUNITIES, 2002).

The idea is to develop in-vehicle safety systems that are based on Information and Communications Technologies to provide solutions for assisting the driver in the seconds before the potential crash. In this phase, an accident can still be avoided by the driver or at least the accident severity can be significantly reduced. Such systems can operate in different ways, e.g.:

- autonomously on-board the vehicle
- by vehicle-to-vehicle communication
- by vehicle-to-infrastructure communication.

A number of intelligent vehicle safety systems is identified by the eSafety Working Group (COMMISSION OF THE EUROPEAN COMMUNITIES, 2002). Some of them are still in the phase of research and technological development, while others are already introduced to the market. Each of these systems has the potential to prevent a specific group of accidents. Examples are

- safe speed (Speed Alert)
- lane support
- safe following (**A**daptive **C**ruise **C**ontrol)
- improved vision
- driver monitoring
- intersection safety systems.

1.3 Aim of the SafeMAP project

The so-called “SafeMAP” is a high quality digital map containing road data as well as safety related data. With the capability of vehicles with navigation systems to identify its current position within a road network, the system is able to inform the driver on safety issues related to the road section ahead.

The main goal of the overall analysis within the SafeMAP project is to assess the feasibility and the socio-economic effectiveness of a dedicated digital map for road safety applications. This map will be the basis for an in-vehicle safety system that can assist the driver while driving through a section with a comparably high risk of getting into an accident. Using intelligent information technologies this system could be able to analyse the current situation and to decide whether this situation is dangerous or not. Only in the case of a certain risk a warning will be given to the driver.

It should be noted that in this stage of the research it is not the goal to develop the SafeMAP up to readiness for marketing but to develop an approach for this application, to test it and to assess the feasibility and the potential benefit of this tool.

Besides the assessment of the effectiveness of this digital map technical specifications for realisation and permanent updating of this database are to be developed. Also juridical questions are to be examined.

In the end, a recommendation will be given to all institutions that would be involved in realisation and launch of such a system (authorities as well as the industries). Therefore, all participants (car manufacturers, telecommunication industry, road traffic authorities and legislation) have to find coordinated measures to provide greatest possible safety to the user of the system.

In this context the applications that will be described in this report are completely independent from the safety related assessment of the road network that will be conducted by the European Road Assessment Programme (EuroRAP). Thereby each road section is to be combined with its specific risk to get into a serious accident using defined thresholds of the fatal and serious accident rate per billion vehicle kilometres. On the basis of this estimation a road map showing the specific risk (high, medium-high, medium, medium-low,

low) is to be created. Each driver can inform about the safety risk of his chosen route before starting his journey.

SafeMAP follows a completely different approach: With this application a driver will be warned by the system if his specific risk of getting into an accident is comparably high at this road section according to his driving style and considering also the external conditions.

1.4 Organisation of the Project

The work within the SafeMAP project is organised in several work packages (WP). For the first project year the different WP's can be described as follows:

- WP 1: Definition of the SafeMAP database content
- WP 2: Feasibility of map data provision
- WP 3: Feasibility and evaluation of vehicle application.

The present report describes the analyses undertaken within the first year of WP 1. Tasks of this work package are

- to analyse the structures of existing road and accident databases
- to identify critical road sections with a potential high risk considering the interaction between the course of the road and the specific driving situation
- to define safety related data for the SafeMAP application
- to prepare and to provide data for selected network segments
- to identify typical road stretches that accidents frequently happen on
- to deliver a draft assessment of potential road safety benefit.

With these analyses WP 1 provides input to WP 2 and WP 3.

The main goal of the overall analyses in the first year is to assess the feasibility of the SafeMAP concept. The project will further continue in a second year if the studies come to the conclusion that there will be a noticeable benefit by developing such an application.

In the second year a demonstrator will be built by WP 3 and test runs will be conducted. By the results of the test runs the potential benefit of the SafeMAP application in terms of traffic safety will be finally assessed.

1.5 Concept of the SafeMAP application

The safety related data that has to be added to a digital map can be defined in different ways (see also chapter 1.6). For instance, the following approaches of safety applications are imaginable:

- information about the legal speed limit
- calculation of a safe speed in curves using road surface data and geometric parameters
- identification of dangerous road sections considering bad configurations of geometric parameters.

To realise those applications several road parameters have to be available. Otherwise they have to be measured for the whole road network.

This present report follows a completely different approach. The idea is to analyse accident information of a road section in detail and to identify critical circumstances that contributed to the accident (such as weather, pavement, lighting condition).

For the accidents on a specific road section a detailed scenario as a combination of accident circumstances can be created that fits all accidents best.

If the current driving situation matches the combination of accident circumstances on this section to a particular degree, the risk of getting into an accident is comparably high. In this situation the driver should be warned by the system. He can then slow down and pay special attention while driving through this section.

This approach allows for the circumstance that accidents happens because of a multitude of reasons where road geometry, road surface, weather conditions and speed are only a few of them. If a driver would be well informed about any characteristics concerning the road section he could adjust his driving style to drive safely through this section. Nevertheless, accidents happens at road sections, where the sum of characteristics is not perfectly fitting each other. Those points can either be identified by collecting lots of parameters which is expensive and time-consuming. The more promising approach seems to identify critical sections and specific circumstances by analysing accident data that is already available.

Following this approach safety related data contains information about traffic accidents. For each road section, the accident data for a specific time period is attached to the map.

It is obvious that there may be also other approaches to provide more safety to road users. Finally there will be a digital map with additional safety related information that can be used for in-vehicle applications in different ways. It is then up to the car manufacturers (WP 3) to choose an adequate and promising approach that can be realised.

1.6 Overview of projects related to SafeMAP

1.6.1 Inter-vehicle Hazard Warning - IVHW

The system is able to give a warning of a danger to a driver by using vehicle-to-vehicle communication. It can identity different hazard types that a car is involved in. Possible hazards are:

- traffic congestion
- vehicular breakdown
- traffic accident.

If a car approaches the point of a hazard, the driver gets acoustical and optical warnings allowing him to slow down and pay special attention to the road section ahead.

The threshold for an early or late warning is defined by two different parameters: the minimum distance to the point of the hazard and the expected time period until arrival at this point. According to the evaluation of field tests in Germany, the minimum distance between a car and the hazard point is 400 m for an early warning and 300 m for a late warning. These values correspond with an expected time period of 20 sec for an early warning and 10 sec for a late warning (HAUMANN et al., 2002).

So far, the system would warn every driver in a defined area around the hazard. There is no information used about the specific road a car travelled on. Using the capability of a navigation system in a car to localise its own position within the road network the system could be able to only give a warning if the car is really approaching the site of the hazard and not in the case the car is driving past the hazard point on a parallel road.

The car industry obviously follows this approach to assist the driver in critical situations. Several car manufacturers (Audi, BMW, Daimler-Chrysler, Fiat, Renault, Volkswagen) have founded the so-called “Car 2 Car Communication Consortium”. The main goal of this organisation is to develop and establish an open European industry standard for car-to-car communication systems based on wireless LAN components and to guarantee European-wide inter-vehicle operability. On the basis of the results the development of active safety applications will be enabled. A first basic concept and a first prototype should be finalised by the mid of 2005, specifications as input for standardisation are planned to be defined by the end of 2006 (www.car-2-car.org).

1.6.2 INVENT

INVENT (Intelligent traffic and user-friendly technology) is a German research initiative with the goal of developing and investigating solutions for safer and more efficient traffic. A total of 23 companies is involved in the project, including automobile manufacturers, IT companies, logistics service providers, software developers and research institutes. The cooperation is organized into three projects focusing on safety, traffic management and logistics.

One of the component projects deals with Anticipatory Active Safety (VAS), concentrating on assistance systems to support a variety of lane changing and turning manoeuvres. Besides radar, sensors and image processing, digital maps and GPS will provide a basis for all assistance systems as these are key elements for the identification of the current traffic condition, other vehicles and obstacles, infrastructure and road signs.

The 4-year INVENT program will be completed in 2005. First results of some component projects are already published (www.invent-online.de).

1.6.3 PReVENT Integrated Project

This project is part of the eSafety initiative of the European Commission, which aims at the implementation of Information and Communications Technologies for safe and intelligent vehicles. The project started at the beginning of 2004 and has a duration of 4 years. The key focus is to develop a system that alerts drivers and – if there is no reaction from the driver – assists and intervenes accordingly if possible.

The PReVENT project consists of 4 vertical application-oriented areas with 8 related subprojects. Table 1 provides an overview of the four research areas with a short description of every subproject.

Three additional horizontal subprojects provide a link between the separate (vertical) application-oriented subprojects and deal with overall issues that are relevant to all PReVENT activities:

- RESPONSE 3
- ProFusion
- MAPS&ADAS.

The task of the RESPONSE 3 subproject is the elaboration of a non-technical “Code of Practice” for the development and testing of Advanced Driver Assistance Systems (ADAS) and a common impact assessment.

ProFusion (Project for Robust and Optimised perception by sensor data FUSION) deals with the identification of main challenges for sensors and sensor data fusion.

Fields of research	Subproject
Safe speed and safe following	**SASPENCE** Development and evaluation of an innovative system able to perform the Safe Speed and Safe Distance concept
	Wireless Local Danger Warning Development of a system for on-board hazard detection, in-car warning management and decentralised warning distribution by communication between moving vehicles on a road network
Lateral support and driver monitoring	**SAFELANE** Development of a lane keeping support system that operates safely and reliably in a wide range of even difficult road and driving situations
	LATERAL SAFE Lateral support and driver diagnostics. The project develops a driver assistance for coping with safety critical lateral situations based on a multi-sensor platform
Intersection safety	**InterSafe** Improvement of Safety in Intersections based on sensor systems and communications. Development of an intersection safety system by use of two full-scale dynamic driving simulators
Vulnerable road users and collision mitigation	**APALACI** Advanced Pre-crash And Longitudinal Collision mitigation: Development of advanced pre-crash and collision mitigation applications including the development of systems with pedestrian classification ability
	COMPOSE Collision Mitigation and Protection of Road Users: Development and evaluation of collision mitigation and vulnerable road user protection systems for trucks and cars
	UseRCams Use of Active Range Cameras: Specification, application, evaluation and customisation of an active 3D range camera for obstacle recognition, localisation and classification

Table 1: Research fields and related subprojects of PReVENT Integrated Project

The standard for an interface to access map and positioning data from various vehicle applications and methods for gathering, providing and maintaining safety content-enhanced map databases are to be defined by the MAPS&ADAS subproject.

The work on the PReVENT project will be done by 51 partners from industry, public authorities, universities and public/private organisations.

1.6.4 MEDAS

MEDAS (**M**ap **E**ngine for **D**river **A**ssistance **S**ystems) is a software-based application that extracts information and attributes out of a digital map in a defined area around a given position. Information provided by MEDAS includes the roadway curvature, the lane width, nearby intersections and even speed limits. The system enables other applications to integrate this data into driver assistance systems (www.navigon.com).

MEDAS was developed by NAVIGON, a German firm that is also involved in the EU project ActMAP (Actual and Dynamic Map) and the industry forum ADASIS (Advanced Driver Assistance Systems Interface Specification).

2 Structures of databases in Germany

2.1 Accident characteristics

During the acquisition of accident data by police officers in Germany detailed circumstances of every single accident are filled in a standardised form. Data of all accidents are to be collected by the Statistical Offices of the Federal States and finally by the Federal Statistical Office.

To get detailed information about an accident, the following criteria are included in the form:

- date, time
- location (type of road, name of the road, mileage, driving direction)
- number of involved road users
- number of fatalities, seriously injured persons, slightly injured persons, damage costs
- is anybody under the influence of alcohol
- accident category (“Unfallkategorie”)
- accident type (“Unfalltyp”)
- accident kind (“Unfallart”)
- accident cause
- characteristics at accident location (e.g. intersection, upgrade, curve)
- specifics at accident location
- lighting conditions, road conditions, pavement
- details of how the accident occurred
- information about involved road users (e.g. age, sex, means of transportation used).

Accident parameters like accident type, accident kind and accident cause are very important for accident analysis.

In Germany, the data acquisition by the Statistical Offices is supposed to include the following accidents:

- accidents with fatalities or injuries
- accidents with severe property damage, i.e. if at least one vehicle is not ready to start
- accidents, where at least one of the involved road users is under the influence of alcohol.

Accidents with minor property damage are usually not documented by the Statistical Offices in Germany.

2.2 Road characteristics

The road network in Germany is classified in different ways. The first is the classification by the ownership of the road:

- motorway (“Autobahn”)
- federal highway (“Bundesstraße”)
- state highway (“Landesstraße”)
- county road (“Kreisstraße”)
- city and community street (“Gemeindestraße”).

Additionally, the road network is classified by

- nodes (“Netzknoten”)
- roadway sections (“Straßenabschnitte”).

Every section is defined by 2 nodes. A roadway section can further be divided into single elements that are defined by guidelines for route planning. In

Germany, there are three different types of horizontal elements:

- straight line
- circular curve
- transition curve.

Usually there is a transition curve between a straight line and a circular curve. The shape of a single element is defined by parameters like length and radius.

These characteristics should be included in road databases. In Germany the road construction office of each State is responsible for collecting and updating its road data.

2.3 Status quo of databases in Germany

2.3.1 Survey

The project team conducted an survey to collect information about road and accident databases in Germany. A questionnaire was sent to the Statistical Offices and to the road construction offices of the Federal States in November 2003. Additionally, a cover letter with an explanation of the project was included.

To get the same information from every responsible authority a standardised form was created. The following questions about the data were included in the form for the Statistical Offices:

- Are you keeping an electronic accident database?
- Are all accidents to be collected?
- How is the accident type coded?
- Does the data include any geocoding information?
- If so, which type of coordinate system do you use?
- Is there a central responsible office for the whole data of the State?
- Do you use a standardised data set?

Finally, there was a question whether the office would make data available for this project.

The whole questionnaire is shown in Appendix A.

A similar standardised form was developed to collect information about road data from the road construction offices. Experience with prior projects related to accident data taught that sometimes road construction offices keep accident data as well as road data. So the form included questions about both data sets. The same questions about accident data as in the form for the Statistical Offices were used. Additionally, the following questions about road data were included:

- Are you keeping an electronic road database?
- Does the data include any geocoding information?
- If so, which type of coordinate system do you use?
- Is there a central responsible office for the whole data of the state?
- Do you use a standardised data set?
- Do you use a specific software to display the information graphically?

Finally, there was also the question about the availability of the data.

The questionnaire is also shown in Appendix A.

The last questionnaire was returned in February 2004. Altogether there were answers of all 16 Statistical Offices and 12 road construction offices.

2.3.2 Accident databases

As described before, the Statistical Offices of the Federal States collect accident data from the police and provide the complete data to the Federal Statistical Office. So the Statistical Offices typically use the same type of data set. Therefore, the Federal Statistical Office provides a standardised data set with a length of 340 characters (“UM004X”). It contains relevant information about the accident, involved road users, injured persons and fatalities.

The road construction offices often use a different data set if they are keeping an accident database. The so-called EUDAS-data set (“Erweiterter Unfalldatensatz” = enhanced accident data set) has a length of 550 characters. Therefore, it is possible to save more detailed information with this data set.

The collection of accident data at the Statistical Offices and the road authorities is carried out parallel and independently. Both authorities should keep the same data, except accidents with minor property damage. Data on these accidents are not collected by the Statistical Offices at all but are partly collected by the road authorities.

Table 2 provides an overview of the structures of accident databases administrated by the Statistical Offices of the Federal States as it was specified during the survey.

As expected, the road construction offices in Germany often collect accident data as well as road data. An overview of accident databases administrated by these authorities is given in Table 3.

The exact accident location as the most important information for SafeMAP application is not given by co-ordinates (Gauss-Krueger, GPS, etc.) in the data sets of the Statistical Offices in Germany.

In fact, the location is normally given by

- class of street
- number of street
- notation of adjacent nodes A and B of the road section
- distance of the accident location to the node A (distance on the road).

With this information the accident location can automatically be transformed to Gauss-Krueger co-ordinates with the help of the software package UNFAS (“Unfallauswertesystem” = accident analysis tool). The algorithm works with the structure of accident databases used by the road authorities in each Federal State except of Bavaria. The tool is used by German authorities (e.g. road construction offices). The use by non-public institutions is not destined.

The road construction offices often use this software package to add geocoding information to their data sets. Provided that they keep an accident database, the geocoding information is already included in the data sets (see Table 3).

To describe the conflict that led to an accident the so-called accident type (=”Unfalltyp”) is a very important attribute. Accidents can be classified by a catalogue of 7 one-digit basic types. Additionally, the basic types can be further divided into the three-digit accident types, which provide more detailed information about how the accident occurred. For more details see a German guideline (FGSV, 2003) or the overview in Appendix B.

Normally in the German Federal States the accident type is coded one-digit with the exception of Rhineland-Palatinate. In this State the administrations use the catalogue of three-digit accident types.

Name of State	Responsible authority	Limitation	Coding of accident type	Geocoding of data sets	Coordinate system	Standard of data set
Baden-Württemberg	Statistisches Landesamt Baden-Württemberg, Stuttgart	accident category 1-4, 6	one-digit	partly (by nodes)	WGS 84 (GPS starting 2005)	UM004X
Bayern	Bayerisches Landesamt für Statistik und Datenverabeitung, München		one-digit	no		
Berlin	Statistisches Landesamt Berlin, Berlin	no database				
Brandenburg	Landesbetrieb für Datenverarbeitung und Statistik, Frankfurt/Oder	accident category 1-4, 6	one-digit	no		GENESIS Datenquader
Bremen	Statistisches Landesamt Bremen, Bremen	no database				
Hamburg	Statistisches Landesamt, Hamburg	no database				
Hessen	Hessisches Statistisches Landesamt, Wiesbaden	no database				
Mecklenburg-Vorpommern	Statistisches Landesamt Mecklenburg-Vorpommern, Schwerin	accident category 1-4, 6	one-digit	no		yes
Niedersachsen	Niedersächsisches Landesamt für Statistik, Hannover	no database				
Nordrhein-Westfalen	Landesamt für Datenverarbeitung und Statistik Nordrhein-Westfalen, Düsseldorf		one-digit	no		
Rheinland-Pfalz	Statistisches Landesamt Rheinland-Pfalz, Bad Ems	no database				
Saarland	Statistisches Landesamt des Saarlandes, Saarbrücken	no database				

Table 2a: Structures of accident databases by the Statistical Offices of the Federal States in Germany

Name of State	Responsible authority	Limitation	Coding of accident type	Geocoding of data sets	Coordinate system	Standard of data set
Sachsen	Statistisches Landesamt des Freistaates Sachsen, Kamenz	accident 5 only numerical	one-digit	no		yes
Sachsen-Anhalt	Statistisches Landesamt Sachsen-Anhalt, Halle	accident category 1-4, 6	one-digit	no		
Schleswig-Holstein	Statistisches Landesamt Schleswig-Holstein, Kiel	no database				
Thüringen	Thüringer Landesamt für Statistik, Erfurt	accident category 1-4, 6	one-digit	no		

Table 2b: Structures of accident databases by the Statistical Offices of the Federal States in Germany

Name of State	Responsible authority	Limitation	Coding of accident type	Geocoding of data sets	Coordinate system	Standard of data set
Baden-Württemberg	no answer					
Bayern	Autobahndirektion Südbayern, München	all accident categories	one-digit	yes	Gauss-Krüger, mileage	EUDAS
Berlin	Statistisches Landesamt Berlin, Berlin	no database				
Brandenburg	no answer					
Bremen	Polizei Bremen, Verkehrsabteilung[1]		one-digit	no		
Hamburg	Freie und Hansestadt Hamburg, Hamburg	no database				
Hessen	Hess. Landesamt für Straßen- und Verkehrswesen, Wiesbaden	accident category 1-4, 6	one-digit	yes	Gauss-Krüger	EUDAS

1 – Questionnaire was forwarded by the Statistical Office

Table 3a: Structures of accident databases by the road construction offices of the Federal States in Germany

Name of State	Responsible authority	Limitation	Coding of accident type	Geocoding of data sets	Coordinate system	Standard of data set
Mecklenburg-Vorpommern	Landesamt für Straßenbau und Verkehr, Rostock	no database				
Niedersachsen	Landesamt für Straßenbau, Hannover	no database				
Nordrhein-Westfalen	Straßen NRW			yes		EUDAS
Rheinland-Pflalz	Landesbetrieb Straßen und Verkehr, Koblenz	all categories (since 1/02),	three-digit	yes	Gauss-Krüger	EUDAS 95
Saarland	Landesbetrieb für Straßenbau, Neunkirchen	no database				
Sachsen	LISt Ges. für Straßenwesen und ingenieurtechnische Dienstleistungen, Rochlitz	A, B, S, K-Straßen	one-digit	node-system (partly flawed)	node-system	EUDAS
Sachsen-Anhalt	no answer					
Schleswig-Holstein	Landesamt für Straßenbau und Verkehr, Kiel	no database				
Thüringen	no answer					

Table 3b: Structures of accident databases by the road construction offices of the Federal States in Germany

Name of State	Responsible authority	Elements	Geocoding of data sets	Coordinate system	Standard of data set	Software
Baden-Württemberg	no answer					
Bayern	Autobahndirektion Südbayern, München	nodes, other	yes, all elements	Gauss-Krüger	ASB 92	TT-SIB (MapINFO)
Berlin	Statistisches Landesamt Berlin, Berlin	no database				
Brandenburg	no answer					

Table 4a: Structures of road databases by the road construction offices of the Federal States in Germany

Name of State	Responsible authority	Elements	Geocoding of data sets	Coordinate system	Standard of data set	Software
Bremen	Amt für Straßen und Verkehr, Bremen	nodes, road sections	only nodes	Gauss-Krüger	OKSTRA 1007	TT-SIB, MapINFO
Hamburg	Freie und Hansestadt Hamburg, Hamburg	nodes, road elements in ground plot	yes, all elements	Gauss-Krüger	yes, partly	Megatel VISOR
Hessen	Hess. Landesamt für Straßen- und Verkehrs-wesen, Wiesbaden	nodes, road elements in ground plot	yes, all elements	Gauss-Krüger	ASB 98	VIS, SIB-View, NW-SIB
Mecklenburg-Vorpommern	Landesamt für Straßen-bau und Verkehr, Rostock	nodes, road sections	partly	Gauss-Krüger	ASB 92	MapINFO
Niedersach-sen	Niedersächsisches Landesamt für Straßen-bau, Hannover	nodes, section geometry	yes, all elements	Gauss-Krüger	no	NW-SIB
Nordrhein-Westfalen	Straßen NRW		yes		NW-SIB	MapINFO, UNFAS
Rheinland-Pflalz	Landesbetrieb Straßen und Verkehr, Koblenz	nodes, road elements	yes, all elements	Gauss-Krüger	No	TT-SIB, MapINFO
Saarland	Landesbetrieb für Straßenbau, Neun-kirchen	road ele-ments in ground plot, other	yes, all elements	Gauss-Krüger	TT-SIB	MapINFO
Sachsen	LISt Gesellschaft für Straßenwesen und ingenieurtechnische Dienstleistungen, Rochlitz	nodes, road elements in ground plot	yes	conversa-tion to Gauss-Krüger possible	no	MapINFO
Sachsen-Anhalt	no answer					
Schleswig-Holstein	Landesamt für Straßen-bau und Verkehr, Kiel	road ele-ments in ground plot	yes	Gauss-Krüger	TT-SIB	TT-SIB, MapINFO
Thüringen	no answer					

Table 4b: Structures of road databases by the road construction offices of the Federal States in Germany

2.3.3 Road databases

Additionally to the accident data, the road construction offices basically collect data about the road network in the respective Federal State. Table 4 provides an overview about road data administrated by these authorities.

2.3.4 Results of the survey

The tables show the different structures and qualities of both accident and road databases in the Federal States in Germany.

The Statistical Offices of seven Federal States reported that they have no accident databases at all. It should be noted that in Germany it is intended to keep an accident database at a Statistical Office in every Federal State. In fact, during prior projects some of these offices provided accident data. The project team assumes that either the questionnaire was misunderstood or the authorities did not want their data to be used in this analysis.

Using the information given during the survey as well as experiences from other projects, it can be concluded for the accident databases of the Statistical Offices that

- only accidents of category 1-4 and 6 are included
- the accident type is coded one-digit (except of Rhineland-Palatinate)
- no geocoding is included (maybe planned in the future)
- the accident location is given by nodes and mileage.

From the 12 road authorities that have returned the questionnaire just 6 offices stated that they keep an accident database. The structures differ between the states. Altogether the accident databases have the following characteristics:

- accidents of category 1-4 and 6 is standard, sometimes also category 5 is included
- the accident type is coded one-digit (except of Rhineland-Palatinate)
- even geocoding is not yet included the offices started to generate co-ordinates.

Out of the 12 offices that returned the questionnaire, one authority stated that they keep no road database at all. In the other 11 States a database including different elements is available. The results can be summarised as follows:

- road database include elements like nodes and road sections
- only characteristics in the ground plot are included
- there is full or partial geocoding in Gauss-Krueger co-ordinates in every database
- there is no uniform standard of data set or software used.

A road database should be available in every Federal State in Germany. Currently it seems that there are efforts to standardise road databases in Germany and to include more relevant information to manage the road network more efficiently (development of OKSTRA or TT-SIB / NW-SIB).

2.4 Definition of the test area for SafeMAP application

2.4.1 Requirements for the test area

To find a suitable test area, attention should be paid to the following points:

- databases in the area should be of standard type to get results comparable to most of the Federal States
- data sets (accident data as well as road data) have to be available at the responsible authorities in the respective State
- if possible, geocoding information should be included in the road and accident data.

2.4.2 Selection of a test area

The selection of a test area had to be executed as soon as possible to make the relevant data available for this study. In fact, first considerations to choose a test area were made in December 2003.

At that time, a test area for developing and studying a SafeMAP application could only be chosen from those Federal States that had already returned the questionnaire. Initially the choice of an area for the test application was limited to the following Federal States:

- Bavaria
- Hesse
- North Rhine-Westphalia
- Rhineland-Palatinate.

For the other Federal States, either the data is insufficient or no information about structures in databases was available. At a closer look, the road database in North Rhine-Westphalia is very well developed, but accident data are not available easily. The road construction office of Hesse administrates a road database as well as an accident database, but accident data are not available for the project. In case the Hessian Statistical Office would provide accident data for this analysis they could add the geocoding information afterwards. Unfortunately the Hessian Statistical Office stated that they do not collect accident data at all.

So finally a test area could be chosen in the Federal States of Bavaria and Rhineland-Palatinate. Responsible authorities are the road construction offices in these States, which have both accident and road data available.

In Bavaria, the Autobahndirektion Südbayern in Munich administrates databases that represent a kind of standard for several Federal States (as far as known). For their road database they use the software package TT-SIB, which is also compatible to NW-SIB (used in North Rhine-Westphalia, Hesse and Lower Saxony). The accident database is based on the EUDAS-data set (see chapter 2.3.2) with an additional geocoding information (according to the information given in the questionnaire). The accident type is coded one-digit as it is done in 15 Federal States in Germany.

Rhineland-Palatinate is the only State in Germany that uses the three-digit accident type for all accidents. So the accident data sets provide more detailed information about the circumstances leading to an accident. The Landesbetrieb Straßen und Verkehr in Koblenz administrates an accident database based also on the EUDAS-data set (see chapter 2.3.2) with additional geocoding information. Accident and road data are available for classified roads from motorways up to country roads. The same applies for data in Bavaria.

For SafeMAP application finally 2 test areas were chosen. The first region is represented by an area around Regensburg in Bavaria, where databases are kind of standard in comparison to all Federal States. The district of Ahrweiler in Rhineland-Palatinate was selected as a second test area. Databases of this region are highly developed and provide an optimal standard as a basis for an application like SafeMAP.

2.4.3 First test area in Bavaria

For the first test area the adjacent administrative districts Cham, Neumarkt i.d. Opf., Schwandorf and the rural district of Regensburg were chosen. This region is located in the southeast of Germany about 100 km north of Munich. The area has a size of about 5,722 km².

Road and accident data were provided by the the responsible road construction office "Autobahndirektion Südbayern". Road data with the following specifications was provided for the road network of the pertaining area:

- data for nodes with geocoding information
- data for road sections as a drawn continuous irregular line with geocoding of the center of gravity
- the notation of the adjacent nodes, the length of the section and the mileage of every road section from start node and end node is given
- data is available for classified roads (motorways, federal highways, state highways, county roads)
- data represents the current status (February 2004)
- only road sections outside of built-up areas were selected.

The same authority provided data on accidents for the selected area with the following specifications:

- accidents on roads outside of built-up areas
- on classified roads (motorways, federal highways, state highways, county roads)
- for the period from January 2002 to December 2003
- accident types 1, 6, 7 are pre-selected.

Contrary to the expectation (and the statements in the questionnaire) no geocoding information was included in the data sets. The accident location is given by:

- class of street
- number of street
- block of appropriate road section
- mileage of accident location.

The notation of the adjacent nodes is not included. This is different to the accident data from other Federal States in Germany. In the databases of the Statistical Offices in particular, this information is usually given (see chapter 2.3.2). Therefore, it is not quite easy to assign the particular accident to the respective road section without geocoding of the accident data sets.

Because of the differences in the structures of accident data of Bavaria compared to other Federal States, it is not possible to add geocoding information to the accident data automatically with the help of UNFAS-software package (see chapter 2.3.2). Other methods had been found to handle this step of work.

It should be noted that these irregularities in the database structures were unknown before the choice of the test areas. By the study of the answers in the questionnaire it was supposed that the structure of the Bavarian accident database is comparable to the other states. Also during several phone calls with the responsible person at the Autobahndirektion Südbayern no other information was given.

For the accident data only the one-digit accident type is available. To select the relevant data sets for SafeMAP application according to accident types (see chapter 3.1.7), the three-digit accident type has to be added beforehand. This can only be done with the accident forms including a description of the sequence of the accident.

The Autobahndirektion Südbayern provided road data on 3,284 km of the road network and data on 3,945 accidents.

Because geocoding of accident data sets is essential for this study and an automatically geocoding was not possible, this step was done for every data set by hand. Based on the road data provided by the road construction office and the information on the accident location given in the data sets (see above), the co-ordinates of the accident location were determined using the MapINFO software package. For that purpose, the appropriate section was identified and the distance from one node to the accident location was measured in the digital map. This point was marked by a flag. Co-ordinates were generated by MapINFO using the geocoding information of the road data.

Geocoding was not possible for 318 data sets because of missing information or a clash of different information given in accident and road data sets (like a mileage that did not fit the road section).

2.4.4 Test area in Rhineland-Palatinate

The administrative district of Ahrweiler was chosen as a second test area. The region is located in the western part of Germany about 50 km south of Cologne. The area has a size of about 787 km².

The responsible road construction office (Landesbetrieb Straßen und Verkehr) provided road and accident data for this area. The road data had the following specification:

- nodes with geocoding information
- data for road sections between 2 nodes with notation of the adjacent nodes and length of the section
- partly data for single road elements with exact location at the road section and geometric parameters
- data is available for classified roads
- data represents the current status (February 2004)
- only road sections outside of built-up areas were selected.

The accident data had the following specification:

- accidents on roads outside of built-up areas
- on classified roads
- for the period from January 2002 to November 2003
- accident types 1, 6, 7 were pre-selected
- accident type is coded three-digit
- geocoding information in Gauss-Krueger co-ordinates is included.

Since the three-digit accident type and the geocoding is already included, no more work on this database or further information is needed to start the analysis.

Road data on 751 km and accident data on 3,160 accidents were provided by the road authority. In comparison to the Bavarian data, the road network has only one fourth of length. But because there is a great number of accidents with minor property damage, the whole number of accidents is comparable between both areas (see also Fig. 2).

3 Definition of database filters

3.1 Choice of relevant accident data sets

3.1.1 General procedure to create an appropriate accident database

For the SafeMAP application only relevant data should be added to the digital map. A safety system like SafeMAP can not include all imaginable accident situations, but should rather concentrate on specific situations that will be defined in this chapter.

It is also not necessary to include the whole set of accident attributes that is available in the databases of the authorities because only some of them will be needed to give safety related information to the driver. This matter will also be studied here.

3.1.2 Choice by road type

In Germany the acquisition of an accident by the police is not constrained by the type of road that the accident happened on. So in Germany accidents on all types of road are included in the accident databases.

Road databases on the other hand only include data for classified roads. In several Federal States the road database is in the phase of construction. Therefore, road types like county roads are not yet included in all road databases.

For the SafeMAP test areas data on the following roads will be examined:

- class 1: motorways
- class 2: federal highways
- class 3: state highways
- class 4: county roads

Road data on county roads is not available for all of the appropriate roads in the test areas.

3.1.3 Choice by construction zones

If an accident happened on a road section with a construction zone, it will be marked in the accident forms. In the block “specifics at accident location” an accident within a construction zone is supposed to be coded (specifics = 6). In the case this is marked in the accident form (and later in the accident data set), the construction zone was regarded as a determining factor for the accident.

A construction zone is in most cases a temporary event while accident data will be collected for at least one year. At the time the accident data will be used by an in-car system, the construction zone is probably no longer in place and the road will be opened for traffic without any restriction. So the construction zone as a determining factor for the accident will no longer exist.

Therefore, those accidents will not be taken into account.

3.1.4 Choice by type of vehicles

30 different types of traffic participation are defined in Germany to code the type of vehicle in the accident data sets. For every type a key number is specified. For the whole list see Appendix B. In a first step a SafeMAP application will be set up for passenger cars, busses and trucks. Therefore, accidents with bicycles, motorbikes, trains, pedestrians and special vehicles are not included in the analysis.

The choice by type of vehicle will be based on the first involved road user in the accident data sets because this generally indicates the responsible party for the accident. The following types of vehicles will be taken into account:

- passenger cars, also with trailer (key number 21)
- busses (omnibusses, coaches, public-transit busses, school busses; 31-35)
- delivery and freight trucks (without or with trailer) and fuelling vehicles (41-48)
- semitrailer trucks (without or with semi-trailer), tractors, special trucks (51-59).

3.1.5 Choice by influence of alcohol and drugs

Accidents that happened because of the influence of alcohol are explicitly marked in the accident form and in the data set.

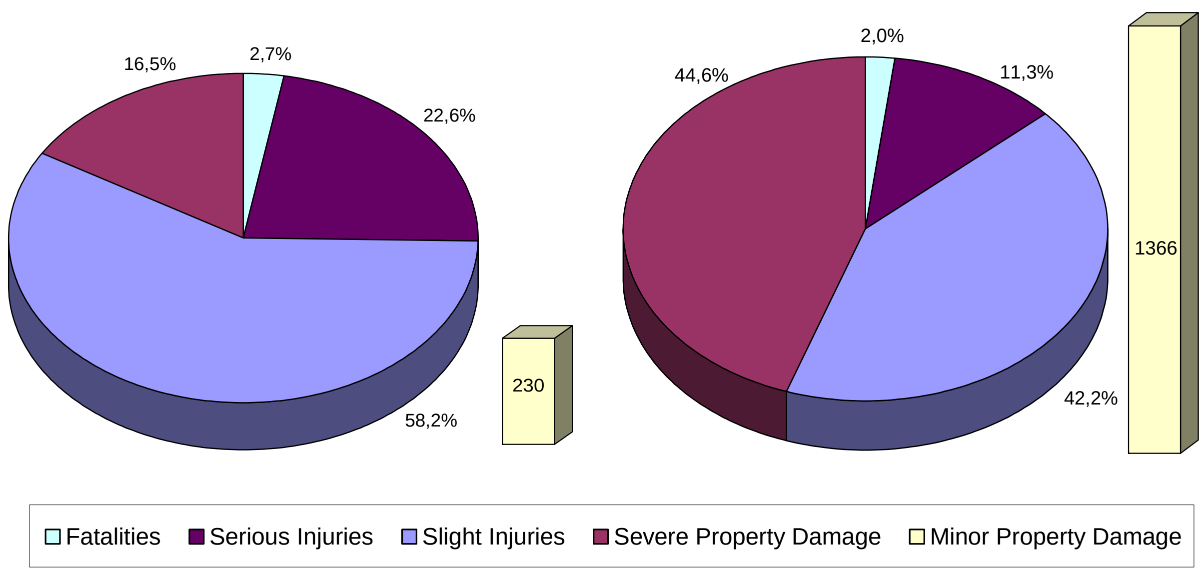
As alcohol affects the ability of drivers to react in critical situations, accidents caused by drunk drivers can not be compared to accident caused by drivers that are not under the influence of alcohol. Thus, all accidents caused by a drunken driver will be disregarded from further analyses.

The influence of drugs is also indicated in the accident data, these accidents can be identified by the accident cause 02 (see list of accident causes in Appendix B). The effect of drugs on the capabilities of a driver are comparable to the effects of alcohol. Therefore, accidents caused under the influence of drugs will not be taken into account.

3.1.6 Choice by accident severity

In Germany the accident severity is described by the accident category (see Appendix B). Accidents with minor property damage (i.e. all vehicles remain fully functional) are not included in the accident databases of the Statistical Offices. In the accident databases for the test areas (provided from road authorities) these accidents are partly included.

The distribution of the accidents to the different accident categories for the test areas in Bavaria and Rhineland Palatinate is shown in Fig. 2. The number of accidents within the categories differ for



Note: Accidents with minor property damage (Cat. 5) are partly included in the databases in both areas, whereas the Rhineland-Palatinate database includes data on more of these accidents than the Bavarian database. Therefore the number of these accidents are shown separately.

Fig. 2: Distribution of accident severity in test area data sets for Bavaria (left) and Rhineland Palatinate (right)

the two areas (for accidents with minor property damage in particular) because the number of accidents of Cat. 5 in the database is not identical to the number of accidents of this kind that actually occurred. Obviously, the database of Rhineland Palatinate contains more of these accidents than the Bavarian database.

At the time an accident occurs the consequences are not clearly determined. If, for example, a vehicle runs off the road because of excessive speed, the consequences depend on the type of vehicle, number of car users, terrain and planting beside the street and so on. The circumstances leading to an accident however could be comparable. Due to this relation no choice by accident severity should be made.

3.1.7 Choice by accident type

It is quite clear that an application like SafeMAP can not warn a driver of every possible situation leading to an accident. A SafeMAP system can not give a specific warning in situations where a driver does not pay attention to the rules of right of way and causes an accident or where a driver damages a parked vehicle while parking his own car. Therefore, from the catalogue of all possible scenarios leading to an accident only a few have the potential to create a warning. The choice is based on the catalogue of three-digit accident types in Germany. For more details on the classification of accident types see Appendix B or the appropriate guideline (FGSV, 2003).

To investigate the feasibility of the SafeMAP application four different accident scenarios were chosen.

1. Driving accidents (three-digit accident types 101-199)

This category combines all accidents that are caused by a driver’s loss of control over the vehicle. Often the reason is excessive speed or a speed level that is not appropriate for the routing of the street, weather conditions or lighting conditions. The driver looses control over his car, the car starts skidding and perhaps runs off the road.

Usually, accidents of this type are also called single-vehicle accidents, even though there could be more than one involved road user. To avoid misunderstanding, the term “driving accidents” is used in this analysis.

The guideline defines different situations for driving accidents as shown in Fig. 3. For SafeMAP application all these accident types are relevant.

2. Rear end accidents (601-629)

These three-digit accident types belong to the accidents in longitudinal traffic (basic type 6). These accidents are caused by a conflict between road users that move in the same or opposite direction. These accidents occur for example at congested roadway sections where drivers are not able to identify the congestion ahead due to bad conditions or a complex routing of the street. SafeMAP can support the driver at dangerous roadway sections where congestion often occurs (e.g. on upgrades, intersections, railway crossings, approaches to traffic signals, etc.).

The characteristics of these accidents are shown in Fig. 4.

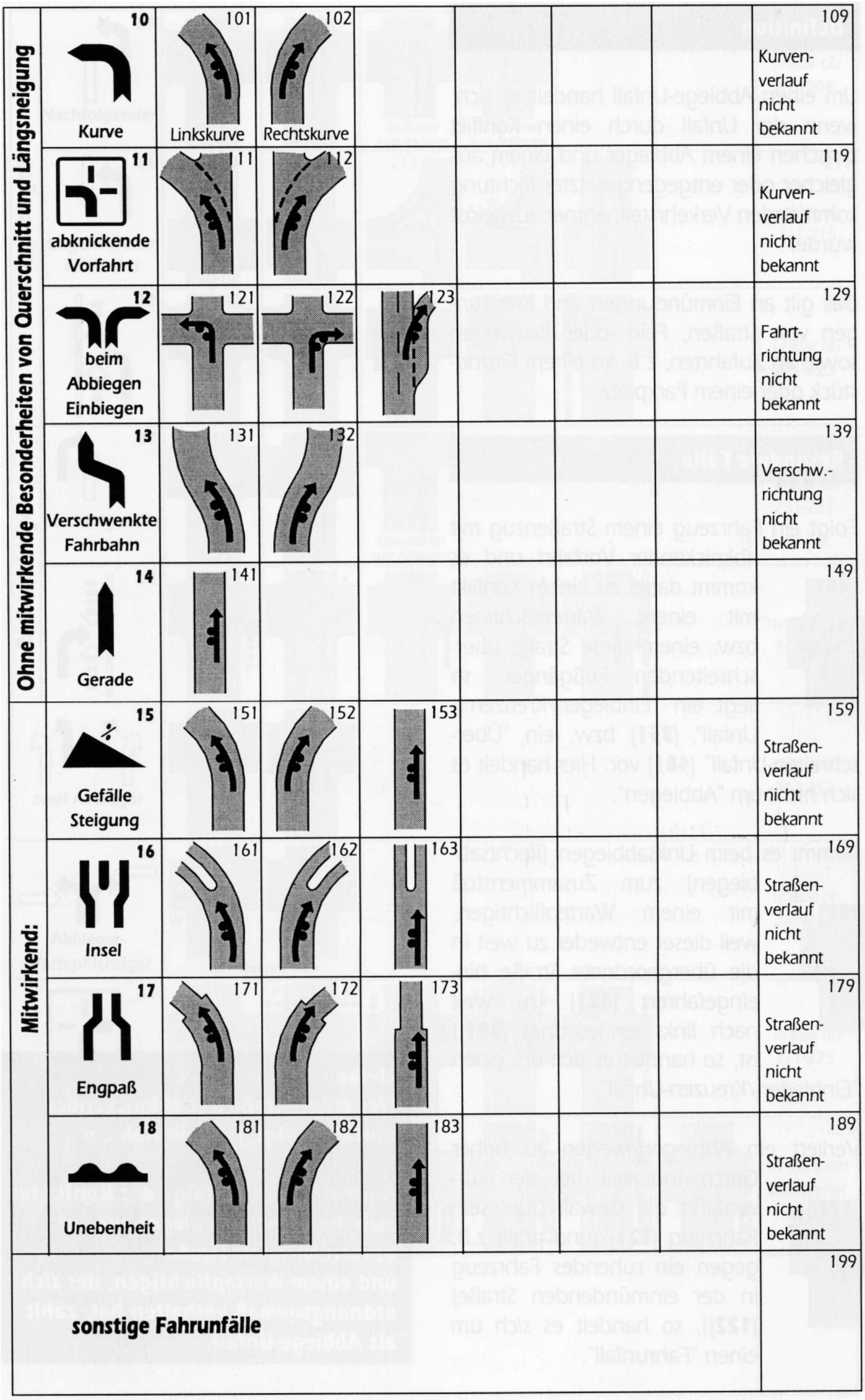


Fig. 3: Driving accidents of type 101 to 199 as defined by FGSV (2003)

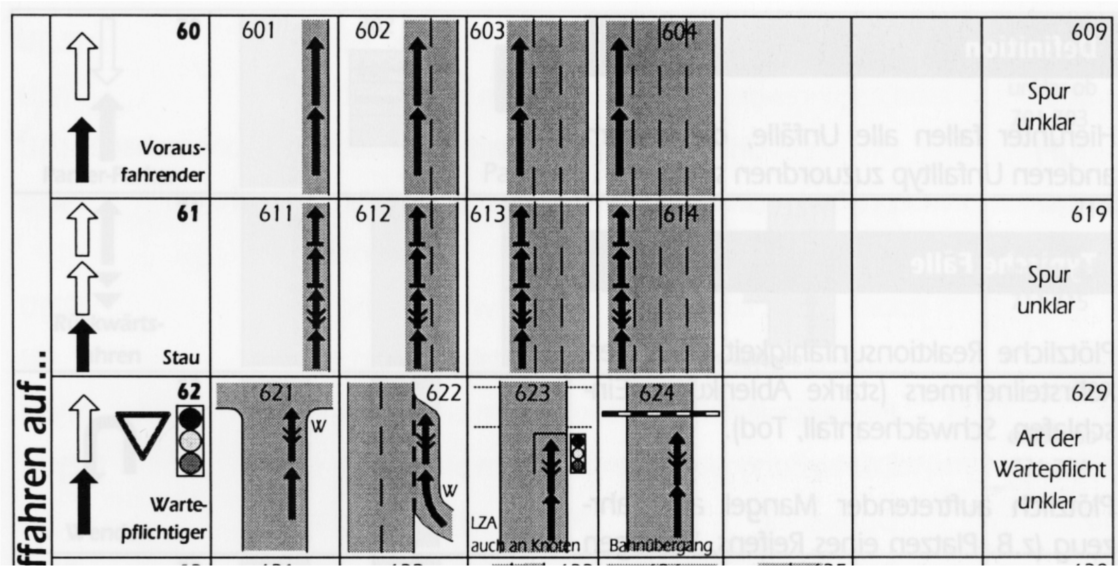


Fig. 4: Rear end accidents of type 601 to 629 as defined by FGSV (2003)

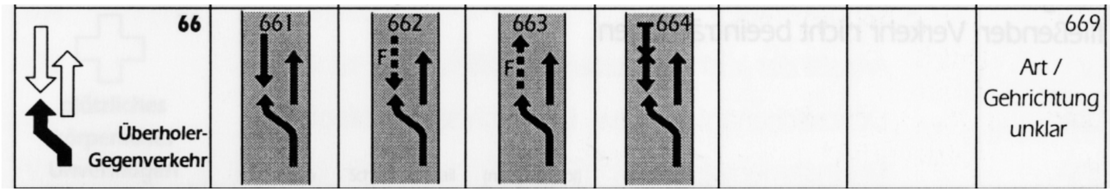


Fig. 5: Accidents while overtaking of types 661 to 669 as defined by FGSV (2003)

3. Accidents while overtaking (661-669)

These three-digit accidents types also belong to the accidents in longitudinal traffic (basic type 6).

In these situations a driver starts overtaking assuming that there is no oncoming traffic. Because of bad weather or lighting conditions or a complex routing he overlooks a car in the oncoming traffic. The accident may also be caused by a misjudgement of distance or speed. A SafeMAP application can warn the driver in those situations at critical road sections.

Fig. 5 describes these situations by pictograms.

4. Wildlife accidents (751)

Accidents of this type belong to the so-called other accidents (type 7). These accidents can not be assigned to types 1 to 6. Typical accidents of type 7 are accidents while reversing or during a U-turn manoeuvre or accidents in combination with obstacles or animals on the road. It is differentiated between game animals (does, wild pigs; type 751), unattended pets (dogs, cats; 752) and attended pets (753). For SafeMAP application type 751 is the relevant type. Wildlife accidents usually happen on typical sections in the road network depending on the surrounding area. The application can detect those road sections in the accident reanalysis (see also chapter 4.2).

Fig. 6 shows the appropriate pictogram

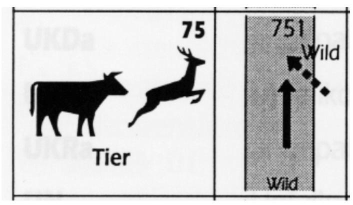


Fig. 6: Wildlife accidents of type 751 as defined by FGSV (2003)

3.1.8 Choice by other attributes in cases the three-digit accident type is not available

As described in chapter 2.3.2, the three-digit accident type is only available for accident data sets from Rhineland-Palatinate (see also Table 2 and Table 3). The relevant accident data sets for SafeMAP application were chosen in chapter 3.1.7 by using the three-digit accident types. In cases only the one-digit accident type is available (e.g. the Bavarian accident data), this choice has to be made either by adding the three-digit accident type (accident forms from police stations have to be collected to acquire the three-digit type from accident descriptions) or by combining the accident type and other accident attributes by logical correlation.

To get very reliable results for the three-digit accident type, this attribute should be acquired by using the descriptions in the accident forms. But in consideration of the functionality of SafeMAP, this application has to work using only data that is available in the existing databases. Therefore, it has been decided to adopt the accident data as it stands and to find relations between the one-digit accident type and other attributes. Those interrelations have to be investigated before the definition of relevant accident attributes in order to avoid deleting a criterion needed.

Initially the correlation will be defined by logical considerations. The Rhineland-Palatinate accident database will then be used to prove these interrelations. If the results are satisfying and reliable at a certain level for this database, the choice of relevant data sets by these attributes will be assigned to the Bavarian accident database.

1. Driving accidents (type 101 to 199)

All accidents of basic type 1 were chosen for accident analysis and no further choice by the three-digit accident type will be made here. The cause of these accidents is often excessive speed or a speed level that does not fit the actual road or weather conditions. This cause is not dependent on a certain situation.

No further attributes are needed to choose the relevant accidents from a database that includes only the one-digit accident type.

2. Rear end accidents (601-629)

In combination with rear end accidents the accident kind 1 (“crash with vehicle that starts up, stops or parks”) or kind 2 (“crash with vehicle that drives ahead or waits”) should be marked. The cause of such accidents is often excessive speed (accident cause 13), insufficient safety distance (14), intense breaking of the vehicle ahead (15) or other causes (49). If the three-digit accident type is not available, these accidents can possibly be detected by a combination of these attributes.

In Table 5 the numbers of suitable accidents detecting in the Rhineland-Palatinate database by a combination of these attribute are listed.

There is a total number of 279 accidents. Two possibilities were analysed. Also the number of falsely estimated accidents (accidents that are assumed to be rear end accidents but in fact are not) were identified.

The second possibility is the preferred one because it is more reliable than the first one. Only 19 accidents (7%) can not be detected with this combination and only 6 accidents (2% of rear end accidents) were falsely assumed to be rear end accidents.

Accident situations	number	percentage
Rear end accidents (601-629), first possibility		
total number	279	100%
estimated by a combination of basic type = 6 and accident kind = 1-2	271	97%
missing accidents	8	3%
falsely estimated (type is not 601-629)	26	
Rear end accidents (601-629), second possibility		
total number	279	100%
estimated by a combination of basic type = 6, accident kind = 1-2 and accident cause = 13-15, 49	260	93%
missing accidents	19	7%
falsely estimated (type is not 601-629)	6	
Accidents while overtaking (661-669), first possibility		
total number	24	100%
estimated by a combination of basic type = 6 and accident cause = 17-19	21	88%
missing accidents	3	12%
falsely estimated (type is not 661-669)	7	
Accidents while overtaking (661-669), second possibility		
total number	24	100%
estimated by a combination of basic type = 6 and accident cause = 17-19, 22	23	96%
missing accidents	1	4%
falsely estimated (type is not 661-669)	28	
Wildlife accidents (751)		
total number	855	100%
estimated by a combination of basic type = 7 and general cause = 86	844	99%
missing accidents	11	1%
falsely estimated (type is not 751)	3	

Table 5: number of detected accident using combinations of attributes in cases the three-digit accident type is not available for Rhineland-Palatinate accident database

3. Accidents while overtaking (661-669)

Accidents while overtaking can potentially be detected by a combination of basic type 6 and accident cause 17 (“overtaking in spite of oncoming traffic”), 18 (“overtaking in spite of unclear traffic conditions”) or 19 (“overtaking in spite of bad visibility conditions”). Maybe the accident cause 22 (“other mistake while overtaking, e.g. insufficient lateral distance”) should also be taken into account.

This relation was analysed by using the Rhineland-Palatinate accident data. There is a total number of 24 accidents while overtaking. With the first possibility 21 accidents (88%) can be detected, but also 7 accidents are falsely estimated. With the second possibility 23 accidents (96%) can be found, but 28 accidents are falsely assumed to be accidents while overtaking (see Table 5). Also other combinations of attributes (using the accident kind) were analysed, but these proved to be not viable.

It has been decided to use accidents while overtaking only in case the three-digit accident type is available. Using data including only the one-digit type, it is not possible to reliably estimate these accidents from the database. Furthermore, these accidents represent only approximately 1% of all relevant accident situations for SafeMAP application (in the Rhineland-Palatinate accident database).

4. Wildlife accidents (751)

In the Bavarian accident database those accidents are marked by an extra attribute, but this is not the case in other Federal States. So this attribute can not be used for the selection of these accidents.

In general, wildlife accidents should be marked with the general cause 86 (“game animal on the road”). For other accidents of basic type 7, the cause 86 should not be marked. Thus, this criterion is very reliable to detect these accidents.

For the accident data of Rhineland-Palatinate there is a total of 855 wildlife accidents. Using this attribute 844 of these accidents or 99% can be detected (see Table 5). Only 3 accidents were falsely assumed to be accidents of type 751. They are registered in the data with other accident types. Because of the marked accident types, these accidents are also expected to be wildlife accidents.

This comparison shows that nearly all of these accidents can be detected by using the basic type 7 and the general cause 86.

It has been shown that relevant accidents can partly be chosen from the database by using logical interrelations between 2 or 3 attributes in cases the three-digit accident type is not available. In the stadium of a feasibility study, this approach also is helpful to define requirements for future databases. The quality of this choice using combinations of attributes strongly depends on the quality of accident data. Accident forms are differently filled in by police officers. In order to get reliable data, these forms have to be filled in correctly and completely. Only in this case it is possible to reliably chose relevant accidents by using these interrelations.

3.2 Final filtered databases

3.2.1 Amount of accident data sets in the test areas

In consideration of these criteria (chapter 3.1.2 to 3.1.7), the accident database from Rhineland-Palatinate can be reduced from 3,160 to 1,774 accidents. These numbers already include the pre-selection of accidents based on the criteria given in Chapter 2.4.4.

The Bavarian database decreases from 3,944 to 1,628 relevant accidents after the geocoding process (see chapter 3.4.3) and the application of the combinations described in chapter 3.1.8.

3.2.2 Distribution of accident situations

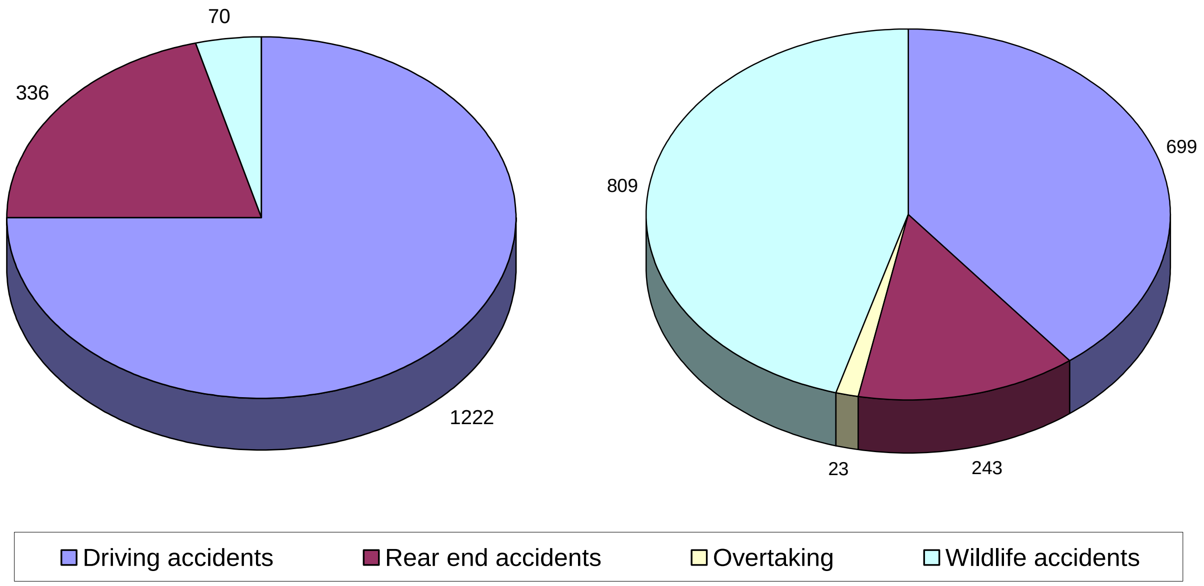
In chapter 3.1.7 four accident situations from the whole list of accident types were defined that are relevant situations for the SafeMAP application. Fig. 7 shows the number of accidents for each of the situations in the final filtered databases of the test areas.

The Diagrams show the different distribution among the four situations. About 75% of the accidents in the Bavarian database are driving accidents (accident situation 1). In Rhineland-Palatinate these accidents represent only 39% of the relevant accident data.

Rear end accidents (situation 2) have a share of 21% in the Bavarian accidents while in Rhineland-Palatinate only 14% are accidents of this situation.

Because the reliable identification of accidents while overtaking (situation 3) is not possible if the three-digit accident type is not available, those accidents are not included in the Bavarian database. In the database of Rhineland-Palatinate only 1.3% of the relevant accidents are of this situation.

The numbers of wildlife accidents (situation 4) show a wide difference between the two test areas. In Bavaria only 4% are wildlife accidents while in Rhineland-Palatinate 46% of all accidents in the database are of this situation. The different amount of wildlife accidents perhaps corresponds with the different distribution of the accident categories (accident severity) in the test areas (see chapter 3.1.6). In Rhineland-Palatinate 99% of wildlife accidents are of category 5 with only minor property damage. Because in the Bavarian database there are less accidents with minor property damage also the amount of wildlife accidents are less than in Rhineland-Palatinate.



Note: A reliable identification of accidents while overtaking (situation 3) is only possible if the three-digit accident type is available. Therefore accident situation 3 is not regarded for the Bavarian test area.

Fig. 7: Distribution of accident situations in test area data sets of Bavaria (left) and Rhineland-Palatinate (right)

3.2.3 Distribution of types of vehicles

As described in chapter 3.1.3 only accidents with certain types of vehicles are included in the filtered accident database. For accidents with more than one involved road user the type of vehicle of the first involved person is taken. This road user is normally responsible for the accident. Other persons or road users are just blamelessly involved in the accident.

The diagrams in Fig. 8 show the numbers of accidents separately for the chosen types of vehicles for the accident databases of the two test areas.

In the filtered databases of the test areas 90% (Bavaria) and 93% (Rhineland-Palatinate) respectively are accidents with passenger cars (key number 21 according to list of traffic participation; see Appendix B). Accidents with busses (31-35) have a stake of less than 1% in both areas. Delivery and freight trucks (41-48) are involved in 7% of Bavarian accidents and in 5% of the chosen accidents in Rhineland-Palatinate. Only a small part of the accidents (3% in Bavarian test area and 2% in the test area in Rhineland-Palatinate) are accidents that were caused by a driver of an semitrailer truck (51-59).

3.2.4 Distribution of road types

In the databases of the test areas accidents on 4 types of roads are included (see chapter 3.1.2). In Fig. 9 the distribution of accidents to the certain road types in the test areas is shown.

In Bavaria the most accidents happened on motorways. To compare the numbers of accidents in the two test areas also the length of the road network and the different accident categories (see chapter 3.1.6) have to be taken into account. Compared to Rhineland-Palatinate the length of motorways is about thrice as large in the Bavarian test area. The whole considered road network is four times larger in Bavaria than in Rhineland-Palatinate (see also Table 6).

For the different road types the density of accidents that happened on these roads varies due to different traffic volumes. Therefore, there is a varying risk to get involved into an accident on a

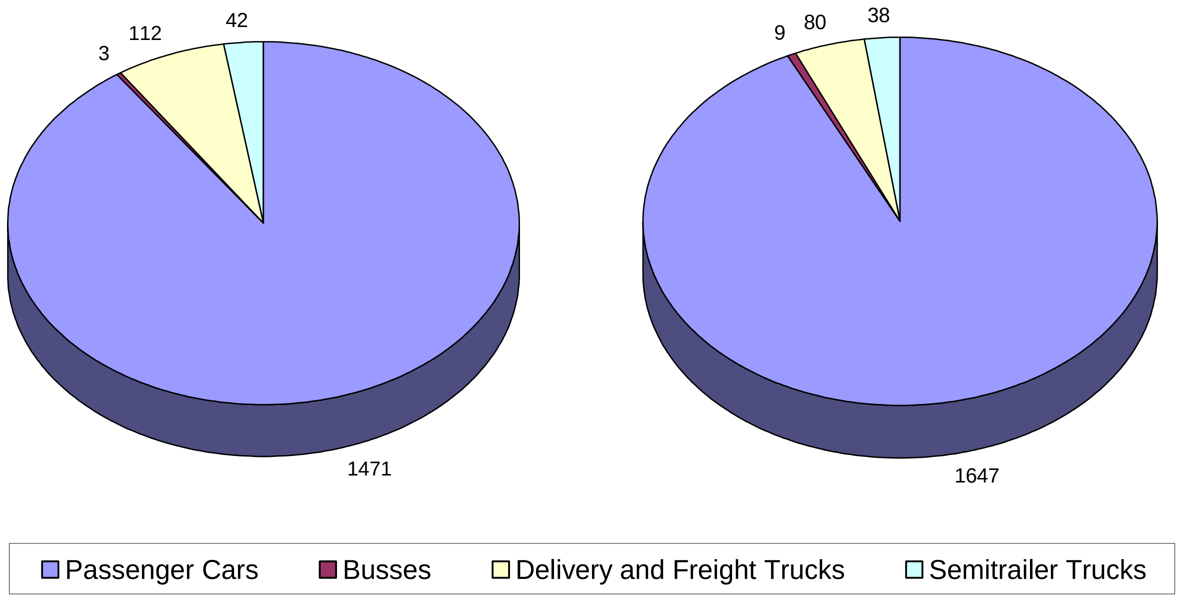


Fig. 8: Distribution of types of vehicles in test area data sets of Bavaria (left) and Rhineland-Palatinate (right)

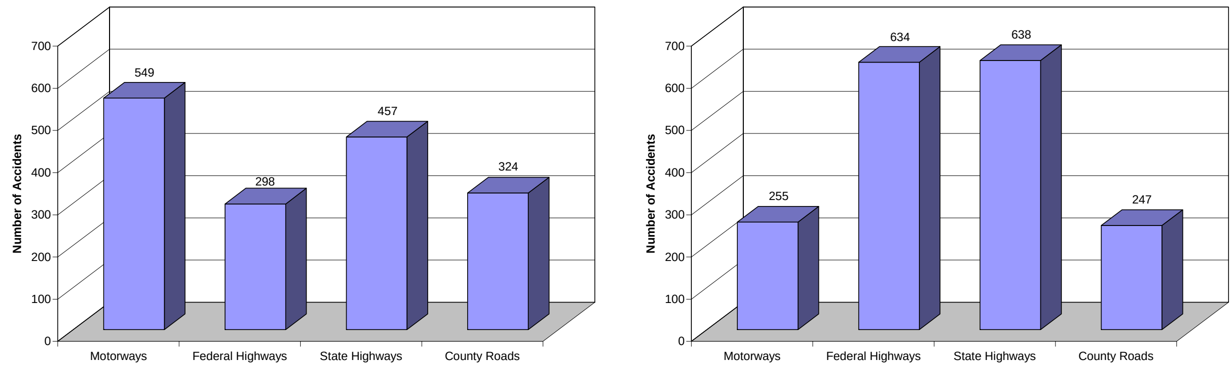


Fig. 9: Number of accidents on certain road types in test area data sets of Bavaria (left) and Rhineland-Palatinate (right)

certain road type. In Table 6 the number of accidents, the length of the considered road network divided by type and the density of accidents is given.

As the different numbers in the table show, the density of accidents in Rhineland-Palatinate is higher than in Bavaria due to the huge number of accidents with minor property damage (Cat. 5; see chapter 3.1.6). Density on motorways is the highest compared to the other road types in both test areas. Due to fast travelling on motorways, those accidents often cause injuries or fatalities and those accidents should be recorded by police officers without exceptions.

Road Type	Length of road network [km]	Number of accidents [-]	Density of accidents [acc./km]
*Test area in **Bavaria***			
Motorways	153.1	549	3.59
Federal highways	436.1	298	0.68
State highways	1,167.9	457	0.39
County roads	1,526.4	324	0.21
Total	**3,283.6**	**1,628**	**0.50**
*Test area in **Rhineland-Palatinate***			
Motorways	59.0	255	4.32
Federal highways	170.2	634	3.73
State highways	280.5	638	2.27
County roads	241.2	247	1.02
Total	**750.9**	**1,774**	**2.36**

Table 6: Accident and road data of the test areas divided by road type

On all road types there are 0.50 accidents per kilometre in Bavaria and 2.36 accidents per kilometre in Rhineland-Palatinate on average. If accidents with minor property damage would be left out of the analysis, the numbers would decline to 0.43 accidents per kilometre for Bavarian data and 0.54 accidents per kilometre for the test area in Rhineland-Palatinate respectively, which means that accident databases from both test areas are nearly comparable.

3.3 Choice of relevant accident attributes

3.3.1 Available attributes from databases

The standardised accident databases in Germany include a lot of information on every single accident that can be used for accident analysis. To provide an overview over criteria that are available from those databases, a list of attributes based on the EUDAS data set is given in Table 7. Altogether the EUDAS data set contains 115 records or 550 characters. Records for internal purposes are not listed. If necessary, a short description is given.

3.3.2 Estimation of expected usefulness of accident attributes

In this section a choice of relevant attributes as given by the accident databases (EUDAS data set; see Table 7) will be made. This means each attribute will be examined in regard to the expected usefulness for the re-analysis of accident data and for a comparison of accident attributes and in-car data. It must be pointed out that the SafeMAP application has to work in cars with all types of sensors integrated as well as in cars without these sensors. For example, to estimate the lighting conditions in a car typically the light sensor will be used. If a car does not have this sensor integrated, the lighting conditions can be assessed by using information about the headlights (switched on or switched off) or maybe by using the actual time. The information from the light sensor is very reliable. Headlights can also be switched on during the day. So the conclusion from switched on headlights to darkness is not accurate in every situation. The conclusion from actual time to lighting conditions is not quite easy because the change of daylight and darkness depends on the season and the location.

These kind of considerations have to be applied to all available attributes of the accident data sets, as follows:

<u>administrative district</u>
The knowledge of the administrative district is not needed. The accident location will later be given by the co-ordinates.

<u>date, day of week, time</u>
The year is not relevant for the in-car system. Only for the database update this information is necessary (see chapter 6.2). The month is essential due to wildlife accidents that are normally concentrated to certain periods of the year. It is also important to estimate lighting conditions (in connection with the time) in case a light sensor is not available.

The exact day is not of further interest. However, the day of week and the time should be used to identify periods with heavy traffic in connection with rear-end accidents. The time is required to estimate accidents that happened due to lighting conditions or due to heavy traffic (in particular relevant to rear-end accidents)

<u>number of involved road users</u>
Provided no weighting of accidents by this number will be made, this attribute will not be needed.

EUDAS record no.	Attribute	Details
3	district	administrative district
5	date	day, month, year
6	day of week	Monday, Tuesday,...
7	time	hour, minute
8	number of involved road users	
9-11	number of fatalities, seriously injured, slightly injured persons	
12	accident kind	kinds 0-9 due to kind of collision (see Appendix B)
13	characteristics at accident location	e.g. intersection, upgrade, curve
14	specifics at accident location	e.g. complex routing, pedestrian crossing, construction site, roundabout
15	traffic lights	in use / out of service
16	speed limit	speed limit according to road signs
17	lighting conditions	daylight / twilight / darkness
19	road conditions	dry / wet / glazed frost or snow / slippery
21	general causes	causes of the accident 70-89 due to road or weather conditions or obstacles on the road (see Appendix B)
22	location	inside or outside of built-up areas
23	accident category	categories 1-6 due to accident severity (see Appendix B)
24	accident type	types 1-7 (one-digit) or 101-799 (three-digit) due to kind of conflict (see Appendix B)
25	class of street	motorways / federal highways / state highways / county roads
26	number of street	
28	mileage	
29	driving direction	
32-36	accident location	road section from node to node, mileage
37	collision with obstacle	obstacle 0-5 due to type of obstacle besides the road

Table 7a: Attributes included in the EUDAS accident data set

EUDAS record no.	Attribute	Details
50	damage costs	
51	alcohol	marked if at least one involved road user was under the influence of alcohol
52	hit-and-run	
53	aquaplaning	
55-69	involved road user 01	details on the first involved road user who is generally the causer of the accident
55	driver's age	
56	driver's sex	
57	accident causes	accident causes 01-69 due to driver's mistakes (see Appendix B)
58	means of transportation used	type of vehicle or pedestrian
59	licence plate number	code for administrative district
60	knowledge of location	coded 1-2 due to driver's knowledge of the area
61	foreign driver	
62	code for citizenship	
63	type of injuries	killed / seriously injured / slightly injured
64	number of passengers	
65-67	number of killed, seriously injured, slightly injured passen-gers	
68-69	further details to vehicle	overall weight of vehicle, trailer, registration date of vehicle, age of driving licence
70-84	involved road user 02	details on the second involved road user comparable to record numbers 55-69
85-99	involved road user 03	details on the third involved road user comparable to record num-bers 55-69

Table 7b: Attributes included in the EUDAS accident data set

number of fatalities, seriously injured, slightly injured persons

These numbers are not relevant for the accident analysis. Only if accidents will be weighted by the accident severity, i.e. if the minimum threshold to create a specific warning will depend on accident severity, these numbers might be useful.

accident kind

This attribute is not of interest to the accident analysis because it describes the kind of collision between the involved road users. It provides no information about any cause of the accident.

characteristics / specifics at accident location

In the application addressed here accidents at a specific location or a specific road section will be analysed together. The characteristics and specifics at the accident location arises therefore from the pertaining location. The attributes given in the accident data sets will not be taken into account.

traffic lights

A warning based on this attribute could only be given if definite information about the status of the oncoming traffic light is available (not all traffic lights are operated around the clock). This would require a communication between the on-street system and the vehicle.

At the current state it is proposed to remove this attribute from the data set, as the expected benefit is rather low compared the complexity and costs of such a system.

speed limit

This information is useful to identity excessive speed and to give a specific warning. If accidents happened due to excessive speed with exceeding the given speed limit (accident cause 12; see Appendix B), a warning should be created if a driver exceeds the given speed limit.

lighting conditions

This attribute will be used to create a specific warning. Accidents often happen due to darkness because a driver misjudges a curve or the routing of the street. During daylight those accidents will probably not happen. In this case the warning should only be given during dark conditions.

The lighting conditions of the actual situation can be estimated from a light sensor (if installed in the car), the headlights or the actual time (see above considerations).

road conditions

The relevance of this attribute is comparable to the lighting conditions. Accidents may happen because of a wet or slippery surface of the road or glazed frost at certain road sections. During dry conditions those accidents are not likely to happen at these sections. A specific warning should be created depending on road conditions.

The information about wet conditions can be estimated from the rain sensor in the car. This information is, similar to the lighting conditions from the light sensor, very reliable. If this sensor is not installed, the estimation can be based on the status of the wipers (switched on or switched off). Normally the wipers are only active if they are needed to clean the windscreen from rain or spray.

The determination of glazed frost or snow requires at least an onboard temperature sensor, an estimation based only on the actual month and time would not be sufficient. However, exact information about the actual road conditions can only be derived from data provided by an additional ABS- or ESP-sensor.

Slippery roads often occur during autumn due to foliage or mud (from agriculture vehicles) on the road. So a specific warning should depend on the appropriate months.

general cause

In connection with details on road conditions the information on general causes can be useful to identify slippery road conditions. Therefore, this attribute should be taken into account.

location

The location inside or outside of built-up areas is not needed. Currently only accidents outside of built-up areas are included in the analysis. The exact accident location will later be given by coordinates.

<u>accident category</u>

In chapter 3.1.6 it was established to take all categories of accidents into account. This attribute is therefore not relevant for the analysis. It is imaginable to weight the accidents by this attribute.

<u>accident type</u>

By this attribute the four types of accidents that are relevant for SafeMAP application are defined. It is further required to create specific scenarios at a location where several accidents happened.

<u>class of street, number of street, mileage, driving direction, accident location</u>

The accident location will be finally given by co-ordinates. These attributes are needed to identity the accident location and to determine the co-ordinates in case they are not given in the data set. With the availability of the co-ordinates all attributes describing the accident location are unnecessary except for the driving direction. This attribute is required to give a specific warning in case the driving direction of the car concurs with the direction of previous accidents at the respective location.

<u>collisions with obstacle</u>

It is not of interest for the application whether a car crashes into an obstacle (and if so what type of obstacle is being hit) after running off the road. Therefore, this attribute is not required for further analysis.

<u>damage costs</u>

This attribute will not be needed for a SafeMAP application.

<u>alcohol</u>

Accidents under the influence of alcohol will be not taken into account (see chapter 3.1.5). Thus, this criterion is not needed.

<u>hit-and-run</u>

This attribute is not needed for accident analysis.

<u>aquaplaning</u>

In combination with the attribute related to road conditions this criterion would be useful to identify accidents caused by wet surface of the road. The German Federal States have different regulations on how to incorporate this attribute in the accident forms. In the accident data of the test areas this attribute is not included.

<u>driver’s age</u>

With the age of the driver given by this attribute it is possible to estimate the experience of the driver. But this estimate is not very reliable because it is unknown at what age the driver actually got his licence. This attribute might be useful to create a specific warning. Otherwise it is not clear how to determine the age of the actual driver. Furthermore the question is whether an old driver should not get a warning if accidents only happened to young drivers. If this will be implemented, other attributes should be weighted stronger than the age of the driver.

<u>driver’s sex</u>

If accidents at a specific location happened to male drivers only, should a female driver not be warned at this location? If a specific warning will be created based on this attribute, other criteria like road and lighting conditions should overrule the sex of the driver. However, it is not quite clear how to determine the driver’s sex in the actual situation (equivalent to driver’s age).

<u>accident causes</u>

The accident causes due to driver mistakes describe the mistake the driver made in the driving situation leading to the accident. The given causes can help in a general accident analysis to take actions to affect driver’s behaviour. For an application like SafeMAP it makes no sense to evaluate mistakes of the driver because there is no chance to compare the causes given by the accident data with the actual driving situation except for one situation: accident cause no. 12 codes “excessive speed with exceeding the given speed limit”. In these cases, the speed limit of this road section is included in the data. If accidents happen due to this cause, a specific warning can be given to a driver who is exceeding this speed limit. A driver who follows the given speed limit will not be warned in this situation.

<u>means of transportation used</u>
The accident database was filtered by this attribute prior to the analysis. A distinction between accidents with passenger cars, trucks and busses will be made to create a specific warning for the appropriate type of vehicle.

But there has to be a differentiation based on the types of accidents identified in chapter 3.1.7. Wildlife accidents are not dependant on the type of vehicle. Also rear-end accidents or accidents while overtaking are independent of the type of vehicle. Driving accidents in contrast depend to a certain degree on the vehicle, its centre of gravity and its driveability. Accordingly, this attribute is of decisive importance to create a specific warning.

The type of vehicle is in connection to SafeMAP application a fixed variable in every vehicle. The whole system is permanently integrated in the car. So there might be the possibility to create specific accident databases for every type of vehicle that is considered in this analysis.

<u>licence plate number</u>
This attribute will not be taken into account.

<u>knowledge of location, foreign driver, code for citizenship</u>
These attributes will not be needed. Normally the probability of an accident with a driver who is familiar with the road section is likely higher than the probability of an accident with a driver who does not know the area. The first reason is that drivers who live in the area drive more frequently along those sections than other drivers. Secondly, a driver who knows the region feels more safely on the road and drives faster than others. Therefore, more accidents with local drivers happen.

On the other hand the question is whether a driver should not be warned by the system based on his good or bad knowledge of the location. Furthermore, this attribute is hard to assess from the driver in the actual situation.

<u>type of injuries, number of killed, seriously injured, slightly injured passengers</u>
This attribute will not be needed. If accidents will be weighted by accident severity, attributes like accident category or number of fatalities/injuries of all involved should be used.

<u>number of passengers</u>
This attribute will have no impact on the accident analysis.

<u>further details</u>
These attributes are poorly marked in the accident data. On the other hand they are not very helpful for accident analysis or to create a specific warning. Therefore, they will not be taken into account.

3.4 List of relevant attributes

Based on the considerations regarding the choice of accidents (chapter 3.1) and the expected usefulness of accident attributes (chapter 3.3), the relevant criteria will be defined in this chapter.

First of all, a list of attributes that are needed to choose the relevant data sets for SafeMAP application was established. This list is given in Table 8.

Group of attributes	attribute	to use for
accident data	road type	choice of relevant accidents
	type of vehicle	
	specifics = 6 (construction zone)	deleting data sets
	accident cause = 01, 02 (alcohol, drugs)	
	(accident severity)	weighting accidents
	three-digit accident type	direct choice of relevant accidents (4 situations of accidents)
	one-digit accident type	indirect choice of relevant accidents (3 situations of accidents)
	accident kind = 1, 2	
	accident cause = 13, 14, 15, 49	
	general cause = 86	

Table 8: Relevant attributes for choice of relevant accident data sets for SafeMAP application

Group of attributes	attribute	to use for / to compare with in-car data
location	XY-co-ordinates	define actual position, driving direction
	road number, section from node to node	
	driving direction, mileage	
accident data	accident type (3 or 4 situations of accidents)	creating a specific warning
	lighting conditions, road conditions	actual conditions
	time	actual time, lighting conditions
	month	creating a specific warning
	day of week	estimating periods with heavy traffic
	general cause	actual road conditions
	speed limit	actual speed
vehicle and driver	type of vehicle	creating a specific warning
	driver’s age	
	accident cause (excessive speed)	

Table 9: Relevant attributes for accident re-analysis and to create a specific warning in SafeMAP application

A second list of attributes that are needed to re-analyse accident data in connection with data on the actual situation and to generate a specific warning relating to the current driving situation was determined. These attributes are listed in Table 9.

For each test area one accident database was prepared using the regularities established in this chapter. The filtering process includes the choice of relevant data sets as well as the choice of relevant accident attributes. Finally reduced databases with only relevant information are available. For the accidents of the test area in Rhineland-Palatinate 23 attributes are includes in the tables whereas the tables for the Bavarian test area includes 27 attributes. The difference results from additional attributes to define the accident location (data for nodes of the appropriate road section).

Both databases were provided to the partners in June 2004. The attributes used in these databases are listed and described in Appendix B.

4 Detailed accident analysis

4.1 Driving accidents, rear end accidents and accidents while overtaking (sit. 1-3)

4.1.1 Proposed algorithm to create a specific warning

After choosing the relevant accidents and relevant attributes, the final list of accident data should be added to the digital map. This could be either one table (layer) for the whole area of Germany or the data could be divided according to the Federal States or counties.

Afterwards it is the task of the in-car SafeMAP system to create a warning or not depending on the circumstances of the accidents in the past and the current driving situation. As an algorithm to create the warning, the project team proposed the accident – road element matrix. This tool should be implemented into the in-car system.

The system has to select all accidents from the database that happened on the appropriate road within a horizon of maybe 300-400 meters (proposed distance for a warning, see chapter 1.6.1). The data of these accidents should be filled in the matrix. This has to be done for accidents of situations 1-3. Wildlife accidents (sit. 4) have to be considered separately because these accidents are not dependent on attributes like driving direction or the type of vehicle. The choice whether to give a warning of wildlife activity will be considered separately in chapter 4.2.

To fill out the matrix it is further necessary to distinguish between

- the type of vehicle and
- the driving direction.

It is obvious that the risk of an accident of situation 1-3 is not compulsory the same for both directions. Also, different types of vehicles perhaps have a different risk to get into a driving accident.

4.1.2 The accident – road element matrix

The accident – road element matrix is a tool to identify similarities between accident attributes and the current situation. The matrix contains each accident attribute in its columns and rows. In the rows it is differentiated between the possible characteristics (see also Table 12).

At the beginning each cell of the matrix has a value of zero. For each corresponding characteristic of the accident attributes the appropriate value of the matrix increases by 1. At the end of this stage the value of each characteristic gives the number of accidents. The sum of the values in each cell is the basic value of the matrix.

The next step is the comparison with the current situation. For each attribute all rows with characteristics that do not match the current situation will be deleted. For each attribute only one single line with a characteristic will remain in the matrix. The sum of the remaining values is the final value of the matrix.

To decide whether to give a warning or not a threshold value has to be defined. This can be done either by a minimum final value or a minimum percentage of the basic value.

The matrix contains the accident attributes given in Table 9. Not all of these attributes can be included with the same weighting. Attributes with high importance for creating a warning are:

- lighting conditions
- road conditions
- excessive speed.

Attributes with minor importance are:

- month
- day of week
- time
- driver's age.

Excessive speed is likely to be the attribute with the highest risk to get into an accident. This is also been shown by the official accident statistics in Germany (STATISTISCHES BUNDESAMT, 2003). This attribute should therefore get the highest weight in the matrix.

Driving accidents in particular are likely dependent on road conditions (maybe in connection with excessive speed) and lighting conditions. Often a driver does not realise the critical points of a road section because of darkness or bad weather.

The season of the year itself (expressed by the month) is of minor importance to the causes of an accident. Typical weather or road conditions for each season are included in the attribute for road conditions (wet or glazed frost).

The risk of an accident is only in some cases strongly dependent on the day of week and the time. Maybe there is a congestion on a specific day of the week at a specific time on a road section (because of rush hour at Friday or shopping traffic at Saturday) and a driver gets into a rear end accident. The risk of such a collision is only high on the specific days.

The age of the driver is practically not important because typical accidents of specific age groups are mainly related to the times of travelling and not to the age of the driver itself. Only young drivers with little experience of driving have a higher risk to get into an accident. But there is also the problem whether an elderly driver should not be warned of the risk to get into an accident if there were only young drivers involved in accidents at this location in the past. Therefore, the age of the driver should be weighted very low.

Thus, it is proposed to weight the attributes as shown in the following table.

Attribute	Weighting
Excessive speed	1.3
Lighting conditions	1.0
Road conditions	1.0
Month (season)	0.2
Day of week	0.2
Time	0.2
Driver's age	0.1

Table 10: Proposed factors to weight each attribute in the accident – road element matrix

These factors arise from the study in chapter 3.3 and should be understood as a proposal in the stage of the SafeMAP feasibility study. In case some of the attributes can not be compared with the actual driving situation (because of missing sensors in the car), these factors can be adjusted.

4.1.3 Set-up of the matrix

Table 11 shows an example of accident data for the motorway A61 in the test area of Rhineland-Palatinate. The motorway has a speed limit of 130 km/h. All accidents happened within a distance of 200 meters. There were 9 driving accidents in this section, no rear end accidents and – as expected – no accidents while overtaking. Wildlife accidents are not considered in connection with the accident – road element matrix. These accidents and the algorithm to create a warning of wildlife activity will be examined separately in chapter 4.2.

ACC_NO	1	2	3	4	5	6	7	8	9
COORD_X	**87186	**87158	**87152	**87186	**87186	**87152	**87203	**87220	**87220
COORD_Y	**90569	**90494	**90476	**90569	**90569	**90476	**90616	**90662	**90662
COS	1	1	1	1	1	1	1	1	1
NOS	61	61	61	61	61	61	61	61	61
KM	*685	*765	*784	*685	*685	*784	*634	*585	*585
DIR_TR	2	2	1	2	1	1	2	1	1
ACC_SIT	1	1	1	1	1	1	1	1	1
LIGHT	2	0	0	2	0	0	1	1	2
ROAD1	1	1	1	1	1	1	0	1	0
ROAD2									
TIME	02:30	06:55	16:10	22:40	11:50	13:58	16:20	18:45	13:30
MONTH	7	4	5	11	11	11	12	9	11
DAY	We	Tu	Sa	Mo	Th	Th	Su	Mo	Tu
CAUSE1			75		73				
CAUSE2									
SPEED	130	130	130		130	130	130	130	
VEH	21	21	21	21	21	21	21	21	51
AGE	29	42	36	22	53	73	30	39	
SEX	2	1	1	2	1	1	1	1	
LICENSE									
EXC_SP	0	2	2	2	2	2	2	2	0

Table 11: Example of accident database of test area in Rhineland-Palatinate (see Appendix B for descriptions; Note: Data on accident location is partly disguised for reasons of privacy)

For this case study it is assumed that a person in a passenger car drives in direction 1 of this road section. From the table only the accident records 3, 5, 6 and 8 are relevant for this driving situation (accidents 1, 2, 4, and 7 are relevant for the other direction; accident 9 is caused by a truck).

Using these records, the matrix will be set-up as shown in Table 12 first without the factors given in Table 10. The matrix has a basic value of 28.

Each accident has a total value of 7 due to the number of attributes in the matrix. If the data of the accidents is filled in the matrix, the basic value is a multiple of 7 if all attributes are available.

Because of the proposed weighting of attributes the numbers in Table 12 have to be multiplied with the appropriate factors in Table 10. This step results in the values for the accident – road element matrix shown in Table 13.

Attribute	Characteristics	Lighting cond.	Road cond.	Time	Date	Date	Actual speed	Driver's age
Lighting conditions	Daylight	3						
	Twilight / darkness	1						
Road conditions	dry		0					
	wet		4					
	snow / ice		0					
Time	0-6 a.m.			0				
	6-12 a.m.			1				
	12-6 p.m.			2				
	6-12 p.m.			1				
Month	Mar-May				1			
	Jun-Aug				0			
	Sep-Nov				3			
	Dec-Feb				0			
Day of week	Weekday					3		
	Weekend					1		
Excessive Speed	no						0	
	break of speed limit						0	
	in other cases						4	
Driver's age	up to 25							0
	25-65							3
	over 65							1

Table 12: Set-up of Accident – Road element matrix for the example data in Table 11

The matrix has then a basic value of 16. Each accident has a total value of 4 if all attributes are available.

Usually the basic value of the matrix is a multiple of 4 using the proposed weighting factors. If some of the attributes are not included in the data sets, the matrix value for one accident is less than 4.

The second step is to delete all rows with characteristics that do not match the current situation. Therefore in this example 3 different scenarios will be defined to show the outcome of the algorithm for different conditions.

Scenario 1:

First scenario considered here is the following:

Attribute	Characteristics	Lighting cond.	Road cond.	Time	Date	Date	Actual speed	Driver's age
Lighting conditions	Daylight	3						
	Twilight / darkness	1						
Road conditions	dry		0					
	wet		4					
	snow / ice		0					
Time	0-6 a.m.			0				
	6-12 a.m.			0.2				
	12-6 p.m.			0.4				
	6-12 p.m.			0.2				
Month	Mar-May				0.2			
	Jun-Aug				0			
	Sep-Nov				0.6			
	Dec-Feb				0			
Day of week	Weekday					0.6		
	Weekend					0.2		
Excessive Speed	no						0	
	break of speed limit						0	
	in other cases						5.2	
Driver's age	up to 25							0
	25-65							0.3
	over 65							0.1

Table 13: Accident – Road element matrix for the example data in Table 11 considering also the weighting factors given in Table 10

- weekend in August, at 13.30 a.m.
- no rain
- driver's age: 35
- current speed: 140 km/h.

Not matching rows have to be deleted remaining:

- daylight
- dry conditions
- 12-6 p.m.
- Jun-Aug
- weekday
- excessive speed with break of speed limit
- age 25-65.

Attribute	Characteristics	Lighting cond.	Road cond.	Time	Date	Date	Actual speed	Driver's age
Lighting conditions	Daylight	3						
Road conditions	dry		0					
Time	6-12 a.m.			0.2				
Month	Jun-Aug				0			
Day of week	Weekend					0.2		
Excessive Speed	break of speed limit						0	
Driver's age	25-65							0.3

Table 14: Accident – Road element matrix for the example data in Table 11 – Scenario 1

Attribute	Characteristics	Lighting cond.	Road cond.	Time	Date	Date	Actual speed	Driver's age
Lighting conditions	Twilight / darkness	1						
Road conditions	wet		4					
Time	12-6 p.m.			0.4				
Month	Sep-Nov				0.6			
Day of week	Weekday					0.6		
Excessive Speed	in other cases						5.2	
Driver's age	25-65							0.3

Table 15: Accident – Road element matrix for the example data in Table 11 – Scenario 2

Attribute	Characteristics	Lighting cond.	Road cond.	Time	Date	Date	Actual speed	Driver's age
Lighting conditions	Daylight	3						
Road conditions	wet		4					
Time	6-12 a.m.			0.2				
Month	Mar-May				0.2			
Day of week	Weekday					0.6		
Excessive Speed	no						0	
Driver's age	25-65							0.3

Table 16: Accident – Road element matrix for the example data in Table 11 – Scenario 3

The final matrix after deleting the rows that are not relevant is given in Table 14. The final value of the matrix is 3.7. Relating to the basic value of 16 this means that the current driving situation matches the accident situation in the past to a degree of 23% (3.7 / 16 * 100%).

Scenario 2:

The results will be given for the following conditions:

- weekday in November, at 5.45 p.m.
- rain
- driver's age: 47
- current speed 125 km/h.

The appropriate matrix is shown in Table 15. For the given time darkness or even twilight is assumed. It is also assumed that the current speed of 125 km/h is not fitting the wet road conditions even though there is no break of speed limit. In consideration of these assumptions the final value of the matrix is 12.1, which is equal to a similarity of 76% with the accidents in the past (12.1 / 16 * 100%).

Scenario 3:

For the third scenario the following conditions will be considered:

- weekday in May, at 11 a.m.
- rain
- driver's age: 26
- current speed 110 km/h.

The final matrix for this scenario is given in Table 16. The final value of the matrix amounts to 8.3. That means the similarity of the current circumstances to the accident situations in the past is 52% (8.3 / 16 * 100%). In this case it is assumed that the speed level of 110 km/h is appropriate for the wet surface of the road.

4.1.4 Definition of a threshold value for the display of a warning

An important step is to define a threshold value for the decision whether to give a warning to the driver or not. For the definition of this threshold it has to be taken into account that a warning should be given only in situations with a high potential risk of an accident. At locations with only one single accident in the past a warning should only be given if the current situation completely matches the accident circumstances. Otherwise a minimum percentage of similarity has to be defined.

The following criteria are proposed as a threshold to generate a warning to the driver:

- a minimum percentage of the final value of the matrix of 50% based on the basic value and
- a minimum final value of the matrix of 4.

The first criterion is relevant for a warning in case the current situations matches the accident circumstances to a certain degree. In the stage of a feasibility study a percentage of 50% is proposed. This value can possibly be adjusted during a later stage of this project. The second criterion is chosen to avoid warnings in situations where only one single accident had happen at the appropriate road section and a certain (not complete) similarity of the current situation and the accidents is determined. This criterion means that a warning because of one single accident will only be given if the current circumstances completely match the situation of the accident. Both criteria have to be fulfilled in order to generate a warning, i.e. if there were at least two accidents in the past a minimum similarity of 50% is necessary.

In the following Table 17 the resulting final values for each considered scenario and the decision whether to give a warning or not are summarised.

	matrix basic value	matrix final value	percentage >50%	final value >4	warning
Scenario 1	16	3.7	-	-	no warning
Scenario 2		12.1	✓	✓	⚠
Scenario 3		8.3	✓	✓	⚠

Table 17: Summary of matrix values for the 3 scenarios and decision whether to give a warning or not

It is shown that a warning will be given for the scenarios 2 and 3. Scenario 1 will not generate a warning because the percentage of similarity is too low and the final value is lower than the allowed minimum value.

4.1.5 Estimation of current lighting conditions

In the accident data it is differentiated between daylight, twilight and darkness. The period of twilight is – especially during winter – a very short period. Because of the rapid change between the lighting conditions there are often inaccuracies in the data of the accident forms. Police officers have to assess the current conditions during their work at the accident location. In addition to the safety at the accident location and the first medical care of injured persons (which are the most important tasks), the police officers have to make notes according to the circumstances leading to this accident. Even if there is a short time spread between the accident itself and the arrival of the police at the accident location, the prior tasks take their time and condition may change during the work. Therefore, the specification of lighting conditions are not very accurate, especially at daytimes with a change of conditions.

It is proposed to combine twilight and darkness to a single specification for both conditions.

To estimate the lighting conditions of the current driving situation the output of a light sensor inside the vehicle can be used. In case a light sensor is not installed, the current lighting condition can be estimated by using the date, time and geographical position. With these information, an astronomic estimation of sunrise and sunset can be conducted. In Fig. 10 an example for this estimation is shown for Kassel (geographical position 51.32 N, 9.5 E).

This method to identify lighting conditions is only a rough estimation but can be used in the case, a light sensor is not available in the vehicle.

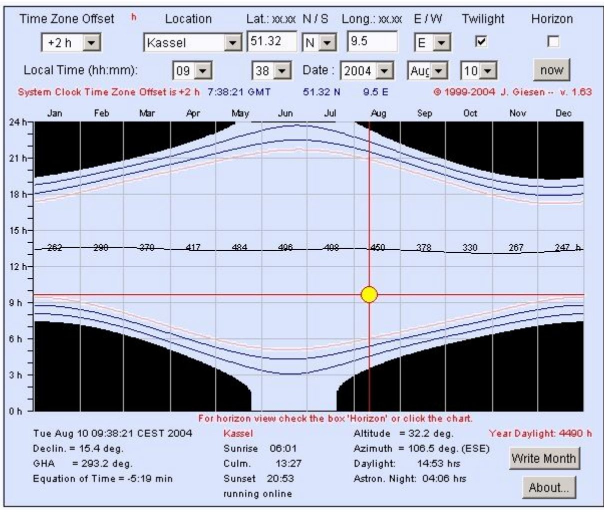


Fig. 10: Sunrise and sunset times for Kassel over the course of the year (source: http://www.jgiesen.de/daylight/index.htm, 16.8.2004)

It is proposed to consider the period between sunset and sunrise as darkness and the period between sunrise and sunset as daylight.

4.1.6 Consideration of excessive speed level

During the consideration of the 3 scenarios in chapter 4.1.3 a difficulty according to the attribute “excessive speed” appeared: In the accident data sets “excessive speed in other cases” is marked if a driver did not break the speed limit but did not adjust his speed to the (poor) road conditions. (see also considerations about accident causes in chapter 3.3.2) There is the question about a threshold to define whether a speed value is well adjusted to the conditions or not.

On the other hand the number of the characteristic “excessive speed with exceeding of speed limit” should be included in the number of “excessive speed in other cases” because exceeding the speed limit usually means a speed value that is not adjusted to the circumstances.

The reason for most accidents at wet conditions is the so-called aquaplaning. The causes for aquaplaning are mainly the speed, the tread depth of the tires and the thickness of the water film on the road, which depends on its part on the rain intensity, structure of the road surface and the length of the flow path.

In a paper of TRAPP (2002) the interrelation between these attributes were analysed and safe speeds were calculated for different conditions using meteorological formulas. For different values for the longitudinal slope and constant lateral slope of 2 - 2.5% he estimated safe speed values of 69 - 77 km/h. He stated that these results are too low and not very realistic. One reason for this underestimation is the presumption of a treadless tire in one of the formulas. The second reason is that the formulas were developed in the 1960s and 1970s based on tires engineered at that time. But the development of tires in the last 30 years lead to increasingly powerful tires with better tread and improved drainage capability. Further studies on this topic are necessary to improve the calculation methods.

According to test results from the TÜV AUTOMOTIVE GMBH (2004) the aquaplaning speed for currently available tires average between 85 and 100 km/h depending on the dimension of the tire. In this test the aquaplaning speed was measured in a basin with a water depth of 8 millimetres whereas in the study of TRAPP (2002) a thickness of the water film of around 1.5 millimetres was calculated. This comparison shows the enormous potential of modern tires.

In this stage of the study a safe speed during wet conditions will be defined to 110 km/h. This value can be redefined in a later stage using findings from more recent studies.

The current road conditions can be estimated in the car using a rain sensor or, if it is not installed, the signal from the wipers. Maybe it is also possible to use information from the ESP-system, which includes sensors to measure the steering angle, wheel speeds as well as yaw-rate and lateral acceleration sensors.

The consideration of this criteria in the in-car system should be a two-stage process. The first step is to compare the current speed of the vehicle with the speed limit at this road section coming from the accident data (if filled in the accident form) or directly from the digital map (in a future stage of advanced maps). If the driver exceeds this given speed limit a warning will be given.

This process can possibly be operated independently from the algorithm in the matrix. Then this part of SafeMAP will alert drivers exceeding the speed limit. The other possibility is to compare the current speed with the speed limit within the matrix algorithm in case that accidents happened because of braking the speed limit.

Second step is to compare the current speed with the defined safe speed for wet conditions in periods with rain or a wet road surface if accidents happened because of “excessive speed in other cases”. For winter conditions (snow or glazed frost) the safe speed must be examined separately.

Above all, a comparison of the current speed with the allowed speed limit is only possible if the speed limit is given in the accident data. Therefore this estimation will only work for road sections where accidents happened in the past due to an excessive speed level. It is not planned to use other data sources to collect information about legal speeds.

4.1.7 Consideration of different accident situations and conclusion

Basically a warning on accidents of situation 1-3 can be generated using the accident – road element matrix. Every accident situation probably leads to a specific warning. Therefore, it is imaginable to vary the amount of attributes or the proposed factors of importance according to the specific situation.

According to driving accidents the attributes day of week and time are in most cases not necessary. It makes no difference whether a driving accident happened on a weekday or a weekend. Also, the time is not relevant for the risk of a driving accident (besides the lighting conditions, which are considered separately).

In contrast, these attributes are important regarding rear end accidents because these accidents mainly happen in periods with heavy traffic. To identify these periods the day of week and the time are relevant and should therefore be weighted with factors of importance that differ from the ones for driving accidents.

Besides these minor deficiencies it is possible to generate a situational warning based an accidents using the accident – road element matrix. This approach can be further developed in the following stages of the study .

4.2 Wildlife accidents (sit. 4)

4.2.1 General

It is obvious that wildlife accidents are rather dependent on the characteristics of certain rural areas and the pattern of wildlife activity than on attributes such as the roadway geometry, the driving direction or even the driver’s age or sex.

The aim of the accident analysis is to identify parameters that describe the distribution of wildlife accidents in space and time and to investigate their potential use for the SafeMAP application.

4.2.2 Regional distribution

The number of wildlife accidents increases with the size of undeveloped areas and open space, while it declines with an increasing population density (SCHOENEBECK, 2004). Consequently, the majority of wildlife accidents occurs on rural roads outside of built-up areas.

Fig. 11 illustrates the regional distribution of wildlife accidents. Shown in the figure is the share of wildlife accidents among all accidents involving personal injury and severe property damage for all districts in Germany from 1995 through 2002. The two test areas are marked on the map. The test area in Rhineland-Palatinate (District of Ahrweiler) can be assigned to the highest category (share greater than 2.3%); the test area in Bavaria has a share of less than 1.5% (average category).

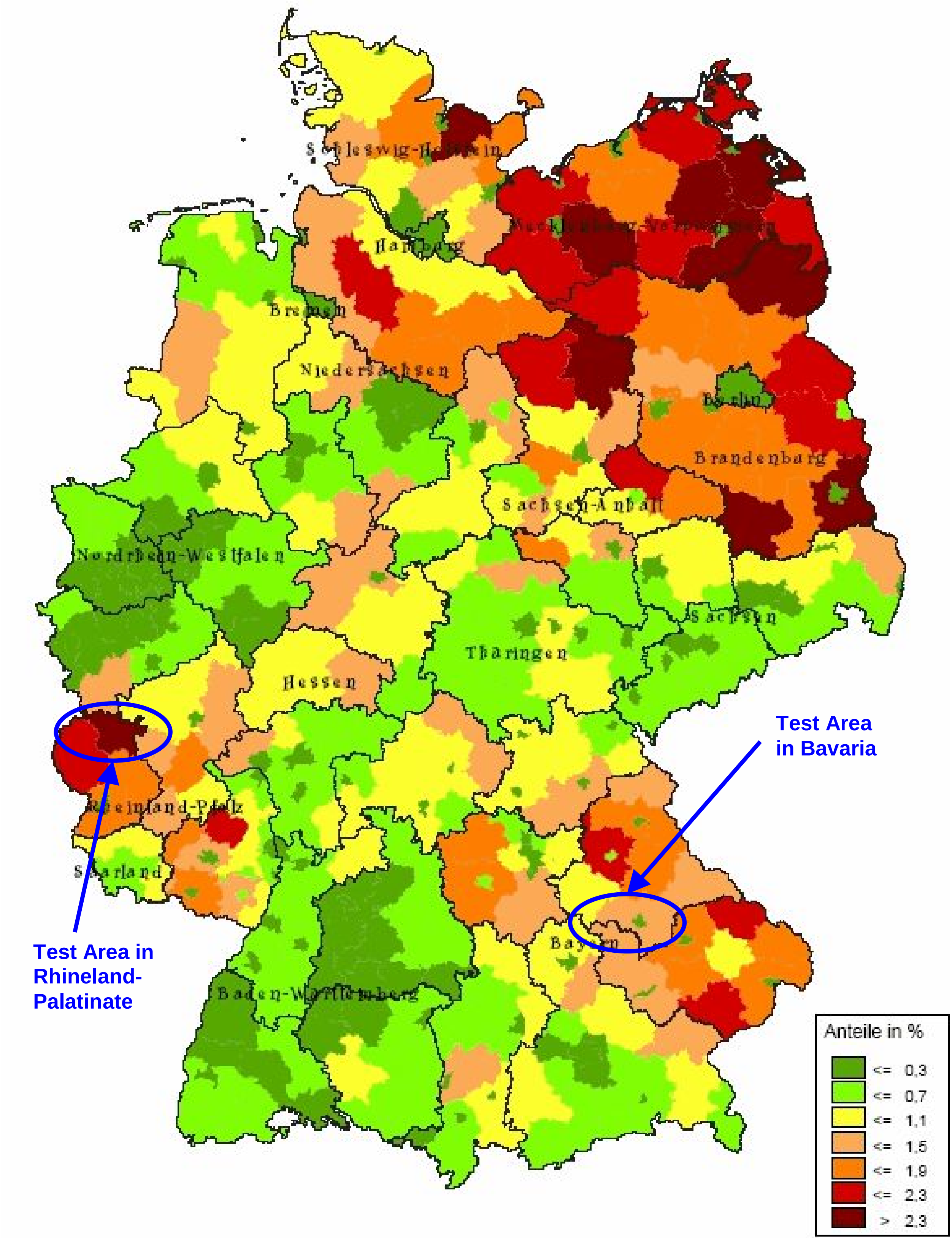


Fig. 11: Share of wildlife accidents among all accidents involving personal injury and severe property damage in Germany in %, 1995-2002 (source: SCHOENEBECK, 2004)

As can be seen, there are significant differences in the proportion and the appearance of wildlife accidents even in between neighbouring districts. In addition, the accidents are evidently not uniformly distributed within a district. Thus, it is not sufficient to asses to potential danger for wildlife accidents based on the category of the district.

Instead and similar to the other accident situations, the warning for wildlife accidents should be based on the precise location of previous accidents. However, wildlife accidents can not be aggregated to single points on the road network as wildlife activity is more related to certain stretches of the road network. This can be shown by an analysis of the test area in Rhineland-Palatinate.

For each single location with a wildlife accident the number of other wildlife accidents within a defined radius was determined using the co-ordinates given in the accident database. Fig. 12 summarises the results for three different radii: 100, 200 and 300 meter.

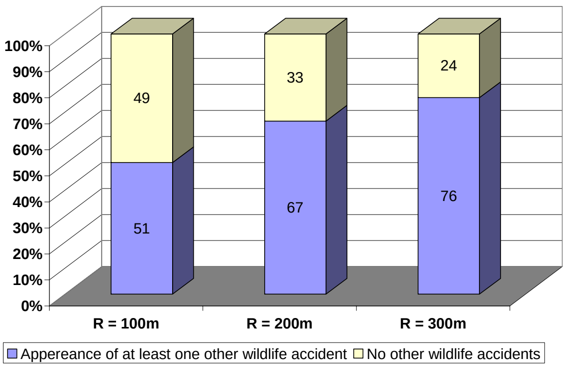


Fig. 12: Appearance of other wildlife accidents within a given radius for all wildlife accident locations (test area in Rhineland-Palatinate)

The analysis shows that for 51% of all 809 accidents there is at least one other wildlife accident within a range of 100 meter. For a radius of 200 meter, this percentage increases to 67%. Applying a radius of 300 meter, the respective number for at least one other accident is even higher (76%).

Fig. 13 also illustrates the accumulation of wildlife accidents.

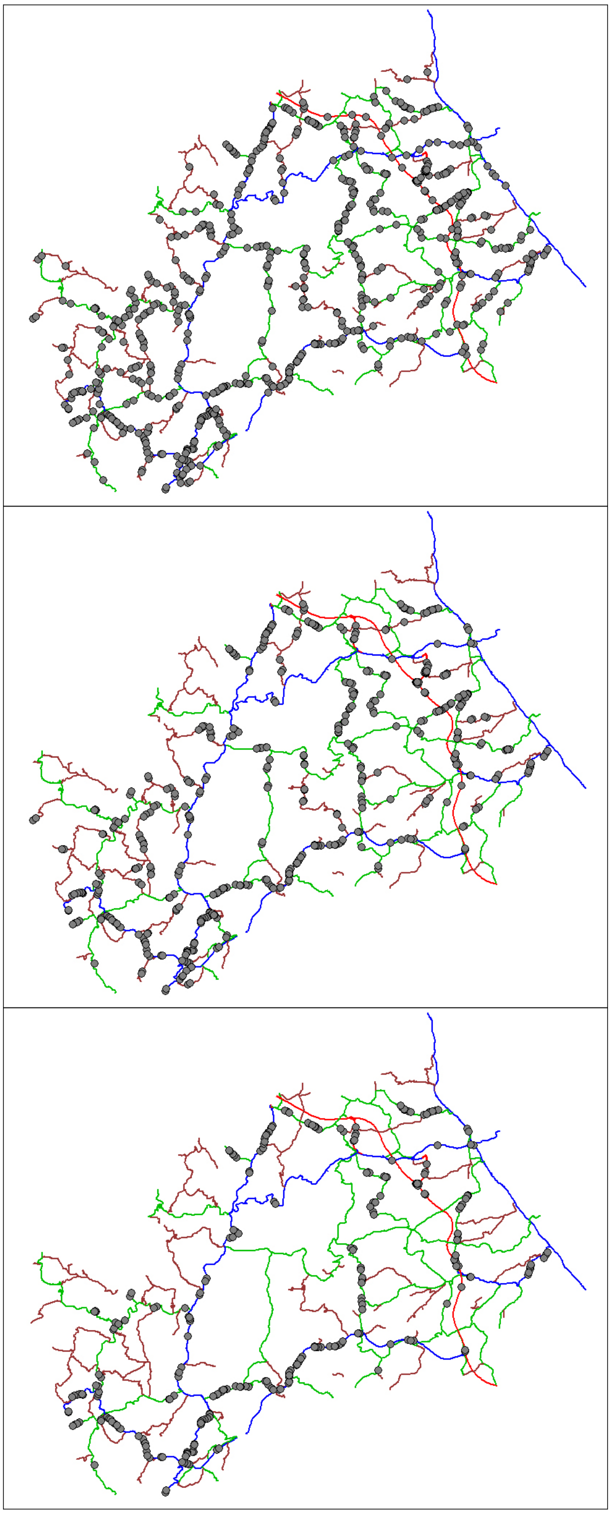


Fig. 13: Location of wildlife accidents with at least 0 (top), 1 (middle) or 2 (bottom) other wildlife accidents within a range of 300 m (test area in Rhineland-Palatinate)

The map on top shows the location of all wildlife accidents for the test area in Rhineland-Palatinate. The second map in the middle displays only those accidents that have at least one other wildlife accident within a range of 300 meter. Even though there are still 76% of all accidents shown on the map, the proportion of roadway sections with wildlife accidents is reduced significantly.

Shown on the bottom map are only accidents with at least two other wildlife accidents within a range of 300 meter. These add up to almost 50% of all wildlife accidents in the test area. This illustration clearly indicates the concentration of wildlife accidents and highlights roadway sections with a high risk of wildlife accidents.

In conclusion, the analysis confirms that the potential danger for this accident situation cannot be assigned to single points as there is in most cases an accumulation of wildlife accidents. This is due to the characteristics of this accident situation, which is predominantly dependent on the wildlife activity and the attributes of the surrounding area.

So rather than giving warnings for single points along the road, information about the potential danger of wildlife accidents should be provided by the SafeMAP application in form of an indicator that is based on the density of previous wildlife accidents on the respective road section.

This indicator should be zero unless a wildlife accident is detected within a range of 300-400 meters (proposed distance for a warning, see chapter 1.6.1) of the current position. If an accident is detected, the SafeMAP application should continuously estimate the density of wildlife accidents based on the examination of a longer road section, for instance for a range of 1,000 meter (the proposed distances for a warning and for the calculation of a density have to be reviewed and redefined at a later stage of this project). This density will then be used for weighting the current danger of a wildlife accident. The value of the indicator should increase with a rising density and decrease with a falling density accordingly. In case no more wildlife accident is detected within the given range, the indicator will be reset to zero.

It should be noted that the more information about the appearance of wildlife accidents is available, the more precise a warning can be. This means that each location of a wildlife accident is valuable for the SafeMAP application. Thus, all wildlife accidents that are reported to the police should be included in the accident database, even those accidents with only minor property damage (category 5). This is the case for the test area in Rhineland-Palatinate. The database for the test area in Bavaria contains only a limited number of category 5 accidents; the data from the Statistical Offices only include accidents with personal injuries or severe property damage. This leads to a significant smaller number of sample points. Consequently, there is only limited information about the location of wildlife accidents available, which reduces the potential to identify areas with a high degree of wildlife activity based only on the accident data.

4.2.3 Seasonal Distribution

SCHOENEBECK (2004) states in her study that the number of wildlife accidents increases during the warm months of the year. In Germany about 76% of all wildlife accidents occur between April and November. Two peaks can be observed, one in May and the other one in October.

A similar analysis was conducted for the two test areas in Bavaria and Rhineland-Palatinate. Fig. 14 summarises the outcome of this examination.

As can be seen, the data for Bavaria with the small sample of only 70 accidents shows peaks in March and October. The months April through November add up to a total of about 69%. So for this particular area, the data does not show a noticeable increase during the warm months. The data for the test area in Rhineland-Palatinate with more than 800 sample points reveals peaks in April and October. The period from April to November sums up to about 74% of all wildlife accidents, which is comparable to the results for Germany.

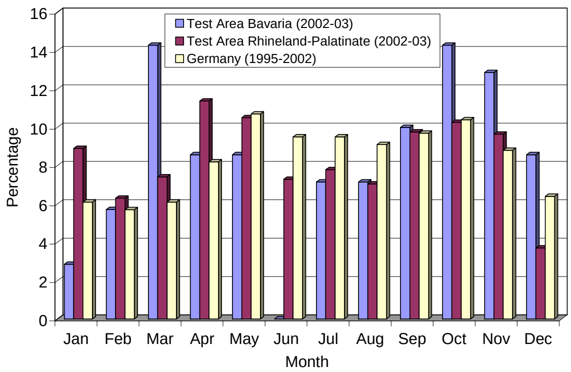


Fig. 14: Seasonal distribution of wildlife accidents

Even though the data in Fig. 14 illustrates the concentration of accidents during spring and autumn and the general increase during the warm months of the year, there is still a noteworthy number of accidents during the winter months that can not be disregarded. This can also be shown by an index analyses (Fig. 15). For this analysis the actual proportion for each month is divided by the average for all months.

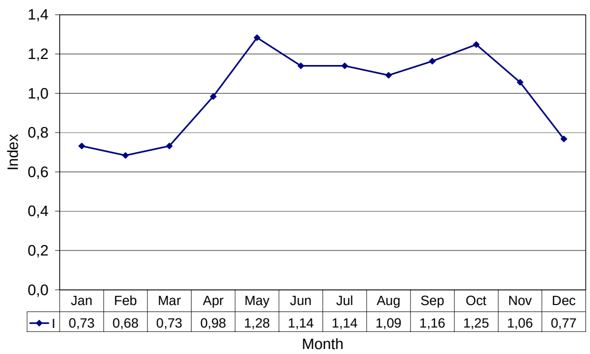


Fig. 15: Seasonal distribution of wildlife accidents (Index value, Germany, 1995-2002)

The figure shows that the two peak months (May and October) have an index value of 1.28 und 1.25 in comparison to a minimum index parameter of 0.68 for February. Based on these results it is proposed for the SafeMAP application to introduce this index value as a parameter for weighting the potential danger of a wildlife accident.

Thus, the indicator for a warning on a given roadway section with a certain number of accidents should be weighted by the index value for the respective month. For example, the factor for February would be 0.68, while a driving situation in May would be evaluated with a factor of 1.28, which is almost twice as high as the factor for February.

4.2.4 Analysis by day of the week

About 34% of all wildlife accidents in Germany occur on Saturdays or Sundays. However, the wildlife activity is not dependent on the day of the week. The higher number of accidents is only due to the increased nightly traffic demand on weekends, which consequently leads to more wildlife accidents on the road.

Nevertheless, the risk for each individual driver does not change as there is a consistent wildlife activity on the roads. Thus, the SafeMAP application should not differentiate between weekdays and weekends for this accident situation.

4.2.5 Analysis by time of day

Wildlife accidents predominantly occur during the evening and night time hours. The accident analysis for Germany reveals that the hours between 7 p.m. and 8 a.m. add up to about 77% for this type of accident. For the two test sites in Bavaria and Rhineland-Palatinate the corresponding numbers are 76% and 80%. Fig. 16 shows the distribution of all wildlife accidents by time of day for Germany and the two test areas.

As illustrated in the Fig. 16, all three curves follow the same basic pattern with a relatively low number of wildlife accidents during the daylight hours. The maximum values for accident numbers can be found in the period between 8 p.m. and midnight. More than 30% of all wildlife accidents happen during these four hours of the night. Another peak occurs during the early morning hours (between 5 and 8 a.m.), which can be explained by the high weekday traffic volumes during these hours.

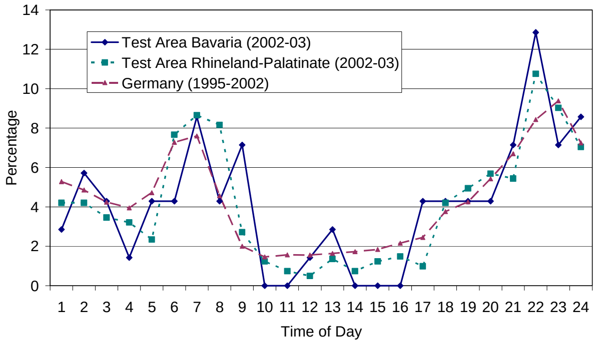


Fig. 16: Distribution of wildlife accidents – Time of Day

The correlation between the number of accidents and the time of day can be used to weight the potential danger during certain times of the day. Comparable to the index analysis for the seasonal distribution, the index value represents the ratio of the actual proportion and the average per hour. The results of the index analysis are shown in Fig. 17.

As it can be seen, the distribution of wildlife accidents strongly depends on the time of day. It seems as if the occurrence wildlife accidents depends on the deer behaviour as well as on the actual volume of traffic.

In her study, SCHOENEBECK (2004) noticed different wildlife accident frequencies according to the day of week. While accidents in general are most frequent on Fridays and Saturdays, wildlife accidents especially occur on Saturdays and Sundays. Since wildlife activity is not dependent on the day of the week, these findings show a correlation between the number of wildlife accidents and the actual volume of traffic. So the time series of daily traffic demand has a noticeable influence on the distribution of wildlife accidents by the time of day.

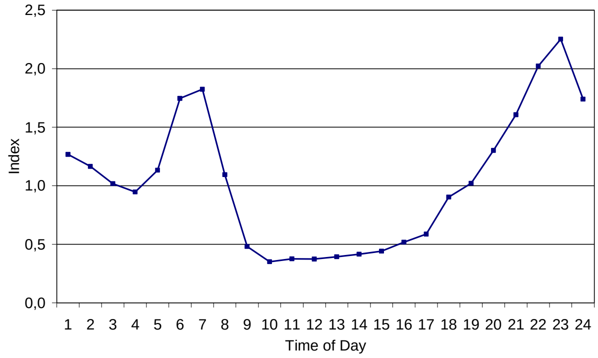


Fig. 17: Distribution of wildlife accidents – Time of Day (Index value, Germany, 1995-2002)

This index parameter would provide a simple approach for weighting the potential danger similar to the factor for the seasonal distribution. However, this index parameter is strongly correlated to the actual traffic volumes over the course of the day. For instance, the parameter implies that the risk for each individual driver doubles between 4 a.m. and 7 a.m., which is at least questionable. Thus, this parameter is not appropriate for the SafeMAP application.

4.2.6 Analysis by lighting conditions

Instead of a parameter for the time of day a factor for different lighting conditions should be applied here because the distribution of wildlife accidents by the time of day is mainly an effect of the lighting conditions. The data for Germany shows a strong correlation between the number of wildlife accidents and the lighting conditions. As it is indicated in Fig. 18, only 28% of all accidents occur during daylight, while accidents during twilight and darkness add up to about 72% (see Fig. 18).

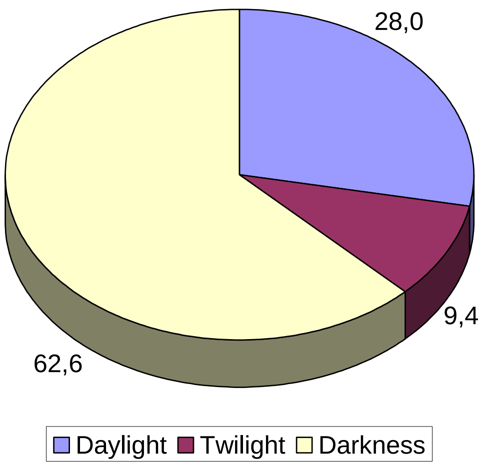


Fig. 18: Distribution of wildlife accidents – Lighting Conditions (Germany, 1995-2002)

The proportion of daylight hours over a year is greater than 50% all-around the world due to the eccentricity of the Earth's path. The actual percentage for each position can be calculated based on the respective latitude.

The average number of daylight hours per year for Kassel, which has a latitude of 51.32 N and is approximately located in the centre of Germany, is 4490. This is equivalent to a daylight percentage of 51.26% over a year. Consequently, twilight and darkness combine to an average of approximately 4270 hours or 48,74%. It is not recommended to differentiate between twilight and darkness because of the smooth transition between these two lighting conditions especially during the summer and the potential inaccuracy of the information given in the accident data.

Dividing the proportion of wildlife accidents during daylight by the average daylight percentage over a year leads to an index value of approximately 0.5. Accordingly, the index value for accidents during twilight and darkness is 1.5 (Fig. 19). These index values represent the potential danger of wildlife accidents under different lighting conditions.

It is proposed to use this factor for the evaluation of this accident situation in the SafeMAP application. For example, a driving situation on a given road should be evaluated with a factor of 0.5 during daylight and a factor of 1.5 during darkness, which indicates that the potential danger is approximately three times higher during darkness.

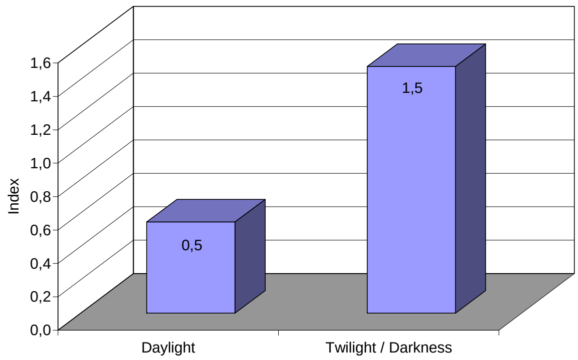


Fig. 19: Index for wildlife accidents based on lighting conditions

As it is described in chapter 4.2.5, the frequency of wildlife accidents during the time of day depends on the volume of traffic. There is the same correlation between wildlife accidents by lighting conditions and time series of daily traffic. For a detailed analysis of this relationship time series of daily traffic for each road section under consideration has to be examined in connection with the frequency of wildlife accidents on this section. Understandably this is not practicable for the whole road network of Germany.

At this stage of the analysis the project team proposes to abandon this detailed study. By analysing the frequency of wildlife accidents the risk of getting into such an accidents seems to be three times higher during darkness than during daylight. A complex investigation of this topic (using also time series of daily traffic volumes) will maybe result in different parameters for the effect of daylight and darkness, but can not be conducted here.

Assessment (Indicator)	Proposed warning signal inside the vehicle	
No or low risk		
Moderate risk		
High risk		
Extremely high risk		

Table 18: Proposed warning signals for different degrees of potential danger due to wildlife activity

This approach requires constant information on the current lighting conditions, which could be provided by a light sensor inside the vehicle. To verify the information given by the sensor or in case no light sensor is installed in the vehicle, the lighting condition can also be estimated based on the actual date and time and the current position of the vehicle (astronomic estimation of sunrise and sunset, see example for Kassel in Fig. 10).

4.2.7 Conclusion

Based on the results of the analysis, the evaluation of a driving situation and the assessment of the potential danger of a wildlife accident should be primarily based on one factor for the density of wildlife accidents on the road section ahead. It is furthermore proposed to introduce two other factors that incorporate the actual date and time (one factor for the seasonal distribution and one factor for the present lighting conditions). The required data for this approach is available at any time and does not rely on any other input (for example the age of the driver or the type of vehicle).

These three factors should be combined to one single indicator that represents an assessment of the current situation. Only if this indicator exceeds a certain threshold a warning will be given to the driver. The warning itself should not be given in form of a constant signal at a single location, as the density of accidents changes continuously. Instead, it is proposed to define further thresholds that represent a certain degree of potential danger. Table 18 illustrates the theoretical idea of this approach.

5 Costs and Benefits

5.1 General Procedure to estimate potential benefits

The German Federal Highway Research Institute (BASt) annually analyses the accidents that happen in Germany. As a result, they provide standardised costs caused by accidents depending on the accident severity and the type of road.

Accident costs measure economic damages caused by accidents. This includes costs for killed or injured persons (reduction or loss of earning capacity, medical or job-related rehabilitation) and property damages (costs of repair, costs for police, administration, insurance companies, case-law).

The latest accident costs are based on cost rates from the year 2000. They are provided in a paper by the FGSV (2003). This paper differentiates between global cost rates and adjusted cost rates. The easiest way to determine benefits of avoided accidents is to use global costs (including all costs in one sum) depending on accident categories and road categories. In Table 19 these cost rates are shown for roads outside of built-up areas.

Accident category	Motorways	Other roads
Accidents with fatalities or serious injuries	300,000	270,000
Accidents with slight injuries	31,000	18,000
Accidents with fatalities or injuries	*105,000*	*110,000*
Severe accidents with property damage	18,500	13,000
Other accidents with property damage	8,000	6,000
Accidents with property damage	*10,500*	*7,000*

Table 19: Global accident cost rates (in Euro) for accidents outside of built-up areas (prices valid for 2000) as given by FGSV (2003)

Accident type	Accident category	Motorways	Other roads
1: Driving accidents	Accidents with fatalities or serious injuries	305,000	280,000
	Accidents with slight injuries	30,500	17,500
	Accidents with fatalities or injuries	*125,000*	*135,000*
6: Accidents in longitudinal traffic	Accidents with fatalities or serious injuries	275,000	315,000
	Accidents with slight injuries	31,500	18,000
	Accidents with fatalities or injuries	*85,000*	*105,000*
7: Other accidents	Accidents with fatalities or serious injuries	340,000	220,000
	Accidents with slight injuries	30,500	17,000
	Accidents with fatalities or injuries	*130,000*	*90,000*

Table 20: Adjusted accident cost rates (in Euro) for accidents outside of built-up areas for the accident types considered in this study (prices valid for 2000) as given by FGSV (2003)

Adjusted cost rates consider specific numbers of casualties in each accident sample (e.g. separated by accident types). These adjusted cost rates are based on cost rates given separately for property damages and casualties. By the use of adjusted cost rates the global cost rates for accidents with fatalities or injuries changes accordingly. Cost rates for accidents with property damage only remain unchanged.

In consideration of these sums cost rates for different accident types are given in the paper. Table 20 shows these values for the accident types analysed in this study.

The FGSV-paper recommends the use of adjusted cost rates given for different accident types for analysing road safety of certain road sections. This is only possible for accidents with fatalities or injuries (cat. 1-3). For accidents with property damage only the global cost rates will be used to estimate accident costs.

The number of accidents in the test areas that are addressed by the SafeMAP application were determined in chapter 3.2.1. Potential benefits of avoiding these accidents will be estimated in the following section. The number of accidents in Germany that could be addressed with this application will be determined in chapter 5.3 using data from the Federal Statistical Office.

5.2 Potential benefits of avoiding accidents in the test areas

To determine the potential benefits of avoiding accidents in the test areas, the accidents have to be counted in the same way (according to accident severity and classes of street) as the cost rates are given (see chapter 5.1).

Table 21 and Table 22 show the numbers of accidents in the test areas by these categories. The numbers are based on accident data from 2

Accident Situation	Accident category	Motorways	Other roads
1: Driving accidents	Accidents with fatalities or serious injuries	40	244
	Accidents with slight injuries	129	378
	Severe accidents with property damage	113	108
	Other accidents with property damage	103	107
2: Rear end accidents	Accidents with fatalities or serious injuries	33	17
	Accidents with slight injuries	110	149
	Severe accidents with property damage	6	3
	Other accidents with property damage	11	7
4: Wildlife accidents	Accidents with fatalities or serious injuries	-	19
	Accidents with slight injuries	1	44
	Severe accidents with property damage	3	1
	Other accidents with property damage	-	2

Table 21: Number of accidents in Bavarian test area by accident categories (2002/2003)

Accident Situation	Accident category	Motorways	Other roads
1: Driving accidents	Accidents with fatalities or serious injuries	2	40
	Accidents with slight injuries	18	95
	Severe accidents with property damage	24	139
	Other accidents with property damage	71	310
2: Rear end accidents	Accidents with fatalities or serious injuries	4	3
	Accidents with slight injuries	16	26
	Severe accidents with property damage	8	6
	Other accidents with property damage	75	105
3: Accidents while overtaking	Accidents with fatalities or serious injuries	-	2
	Accidents with slight injuries	-	12
	Severe accidents with property damage	-	5
	Other accidents with property damage	-	4
4: Wildlife accidents	Accidents with fatalities or serious injuries	-	3
	Accidents with slight injuries	1	4
	Severe accidents with property damage	-	-
	Other accidents with property damage	36	765

Table 22: Number of accidents in test area of Rhineland-Palatinate by accident categories (2002/2003)

years (Bavaria Jan. 2002-Dec. 2003; Rhineland-Palatinate Jan. 2002-Nov. 2003).

These accident numbers could then be multiplied by the appropriate cost rates given in Table 19 and Table 20. The results of this step are given in Table 23 and Table 24.

According to these values the relevant accidents in Bavaria caused total costs in the amount of 121.9 million Euro within 2 years. Provided that there is no strong annual trend in accident numbers this is equal to costs for accidents that will be addressed by SafeMAP of 61.0 million Euro per year. In relation to the length of the road network in the Bavarian test area this corresponds with an accident cost density of 37,100 Euro/km/year.

Most of the accident costs were caused by driving accidents (accident situation 1). On motorways those accidents represent 59.8% of all costs, on other roads they represent even 85.5%. Costs for wildlife accidents (sit. 4) are relatively small (less than 1% on motorways and 5.5% on other roads). Costs of rear end accidents (sit. 2) have a ratio of 40.0% on motorways, but only 9.0% on other roads.

In the test area of Rhineland-Palatinate the chosen accidents caused costs of 29.7 million Euro within 2 years (23 months). This means accidents with costs of 15.5 million Euro per year will be addressed by SafeMAP in this area. In relation to the total length of the road network the accident cost density amounts to 20,700 Euro/km/year.

Accident Situation	Accident category	Motorways	Other roads
1: Driving accidents	Accidents with fatalities or serious injuries	12,200,000	68,320,000
	Accidents with slight injuries	3,934,500	6,615,000
	Severe accidents with property damage	2,090,500	1,404,000
	Other accidents with property damage	824,000	642,000
2: Rear end accidents	Accidents with fatalities or serious injuries	9,075,000	5,355,000
	Accidents with slight injuries	3,465,000	2,682,000
	Severe accidents with property damage	111,000	39,000
	Other accidents with property damage	88,000	42,000
4: Wildlife accidents	Accidents with fatalities or serious injuries	0	4,180,000
	Accidents with slight injuries	30,500	748,000
	Severe accidents with property damage	55,500	13,000
	Other accidents with property damage	0	12,000
Total		*31,874,000*	*90,052,000*

Table 23: Economic costs of accidents (in Euro) in Bavarian test area (2002/2003)

Accident Situation	Accident category	Motorways	Other roads
1: Driving accidents	Accidents with fatalities or serious injuries	610,000	11,200,000
	Accidents with slight injuries	549,000	1,662,500
	Severe accidents with property damage	444,000	1,807,000
	Other accidents with property damage	568,000	1,860,000
2: Rear end accidents	Accidents with fatalities or serious injuries	1,100,000	945,000
	Accidents with slight injuries	504,000	468,000
	Severe accidents with property damage	148,000	78,000
	Other accidents with property damage	600,000	630,000
3: Accidents while overtaking	Accidents with fatalities or serious injuries	0	630,000
	Accidents with slight injuries	0	216,000
	Severe accidents with property damage	0	65,000
	Other accidents with property damage	0	24,000

Table 24a: Economic costs of accidents (in Euro) in test area of Rhineland-Palatinate (2002/2003)

Accident Situation	Accident category	Motorways	Other roads
4: Wildlife accidents	Accidents with fatalities or serious injuries	0	660,000
	Accidents with slight injuries	30,500	68,000
	Severe accidents with property damage	0	0
	Other accidents with property damage	288,000	4,590,000
Total		*4,841,500*	*24,903,500*

Table 24b: Economic costs of accidents (in Euro) in test area of Rhineland-Palatinate (2002/2003)

On motorways in Rhineland-Palatinate costs of rear end accidents (sit. 2) have the highest ratio (48.6%). On other roads those accidents have a minor ratio of the total accident costs (8.5%). Main accident costs on other roads were caused by driving accidents (66.4%).

Wildlife accidents (sit. 4) are more frequent on other roads (21.4%) than on motorways (6.6%). Accidents while overtaking (sit. 3) obviously appear not on motorways and only in the test area of Rhinelnad-Palatinate (due to the choice of accidents in the case the three-digit accident type is not available; see chapter 3.1.8).

The distribution of accident costs according to the single accident situations is graphically shown in Fig. 20 for the Bavarian test area and in Fig. 21 for the test area in Rhineland-Palatinate.

Distributions of accident costs in both areas are quite similar according to the following facts:

- driving accidents have a high percentage on the costs of accidents, which is even higher on other roads than on motorways
- the ratio of rear end accidents to the total costs is higher on motorways than on other roads
- wildlife accidents cause higher costs on other roads than on motorways.

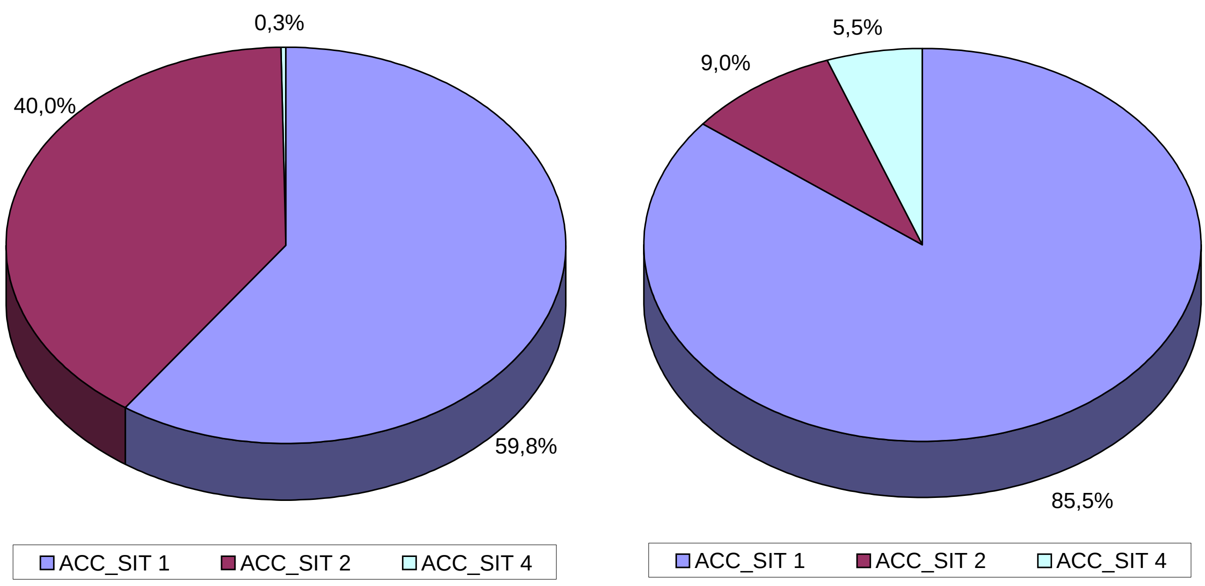


Fig. 20: Accident costs by the defined accident situations for freeways (left) and other roads (right) in the test area of Bavaria

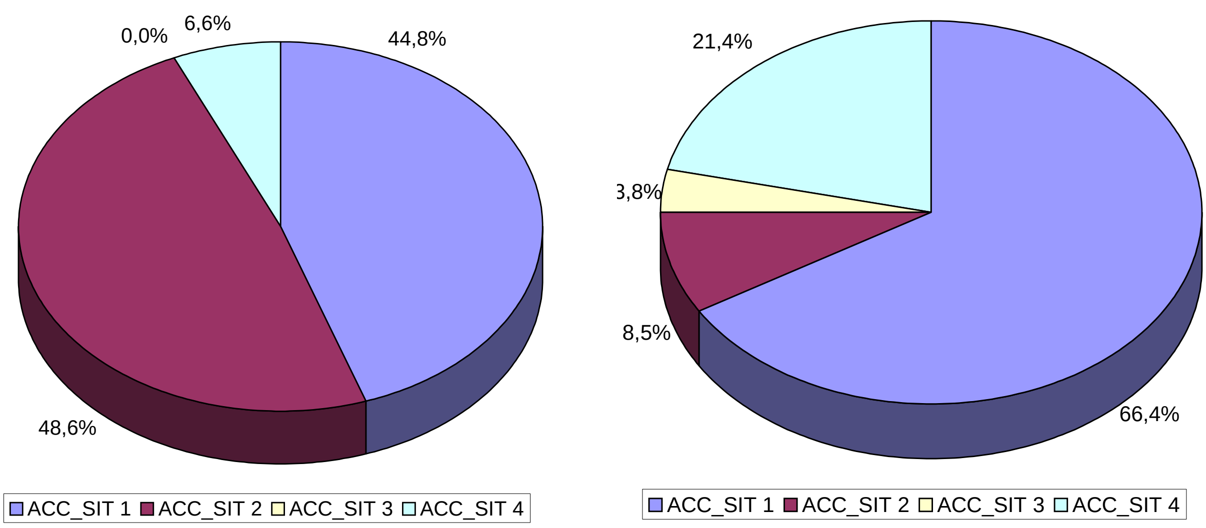


Fig. 21: Accident costs by the defined accident situations for freeways (left) and other roads (right) in the test area of Rhineland-Palatinate

5.3 Potential benefits of avoiding accidents in Germany

5.3.1 General approach to determine the number of relevant accidents in Germany

After the estimation of economic costs for accidents in the test areas it would be interesting to see how many accidents could be addressed with a SafeMAP application on the whole road network of Germany and what the potential benefit would be if these accidents could be avoided. This topic is discussed in this chapter.

The accident numbers for the analysis come – as far as possible – from the official accident statistics that is provided annually by the Federal Statistical Office in Germany. The numbers determined here are based on the statistics for the year 2002 (STATISTISCHES BUNDEAMT, 2003).

The determination of exact accident numbers related to every accident situation is only to a certain degree possible just by the use of this publication, because the three-digit accident type is not included in the statistics. According to chapter 3.1.8 a combination of accident attributes is necessary to choose the relevant accidents. The publication does not provide these combinations, so adequate assumptions have to be made here.

Official accident statistics in Germany only include accidents of category 1-4 and to some extent category 6 (see Appendix B). Accidents of category 5 (with minor property damage) are not included in the database because not all of these accidents are reported to the police. So the following numbers concentrate on categories 1-4. In the test areas also data sets of accidents with minor property damage are to some extent included.

The accident numbers will then be multiplied with the accident cost rates as shown in chapter 5.1.

5.3.2 Total number of accidents in Germany

First of all the accident numbers and accident costs of all accidents that happened in Germany 2002 will be determined. These numbers will later be used for the comparison.

In the following Table 25 the number of accidents in Germany by road types and accident categories are given. In Table 26 only accident outside of built-up areas are included.

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	720	1,847	1,873	826	947	*6,213*
2	5,318	16,578	19,398	9,301	24,249	*74,844*
3	18,587	60,074	58,706	26,229	117,401	*280,997*
4	17,979	21,981	23,202	10,047	33,382	*160,591*
all	*42,604*	*100,480*	*103,179*	*46,403*	*175,979*	*468,645*

Table 25: Total number of accidents in Germany 2002 by accident and road categories

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	720	1,475	1,500	670	235	*4,600*
2	5,318	9,616	11,823	5,667	3,256	*35,680*
3	18,587	24,548	25,726	11,881	7,167	*87,909*
4	17,979	11,675	11,968	4,932	2,806	*49,360*
all	*42,604*	*47,314*	*51,017*	*23,150*	*13,464*	*177,549*

Table 26: Accidents outside of built-up areas in Germany 2002 by accident and road categories

According to these numbers there were 468,645 accidents in Germany in 2002. In 362,054 accidents (77%) people were killed or injured. Outside of built-up areas there were 177,549 accidents in 2002 (38% of all accidents) with killed or injured persons in 128,189 accidents (72%).

For the total number of accidents in Germany the economic costs add up to about 35 billion Euro per year. By the end of August 2004 only costs of accidents up to the year 2001 were published. In the year 2000 economic costs add up to 35.6 billion Euro, in 2001 costs decreased to 34.5 billion Euro (BAST, 2002 and 2003).

The economic costs of accidents outside of built-up areas (estimated by using the cost rates shown in chapter 5.1) are given in Table 27.

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	216.00	398.25	405.00	180.90	63.45	*1,263.60*
2	1,595.40	2,596.32	3,192.21	1,530.09	879.12	*9,793.14*
3	576.20	441.86	463.07	213.86	129.01	*1,823.99*
4	332.61	151.78	155.58	64.12	36.48	*740.56*
all	*2,720.21*	*3,588.21*	*4,215.86*	*1,988.96*	*1,108.05*	*13,621.30*

Table 27: Economic costs of accidents (in million Euro) outside of built-up areas in Germany 2002 by accident and road categories

The sums in the table show that total costs of 13.6 billion Euro were caused by accidents outside of built-up areas in 2002. This is equal to approximately 39% of all costs caused by accidents in 2002.

5.3.3 Driving accidents (sit. 1)

In this accident situation all accidents of basic type 1 (three-digit accident type 101-199) are integrated. The official statistics provides accident numbers distributed by the basic types. Therefore, the numbers of these accidents come directly from the statistics. Table 28 shows the number of driving accidents outside of built-up areas in Germany in 2002 that can be addressed with a SafeMAP application. Multiplying these numbers by the accident cost rates leads to resulting costs of driving accidents as given in Table 29.

As the values in the tables show, there were 69,804 driving accidents in Germany in 2002 with killed or injured persons in 47,407 accidents. This is equal to 39% of all accidents outside of built-up areas and to 37% of all accidents with killed or injured persons outside of built-up areas. Most driving accidents happened on state highways and on motorways. Accident severity increased from motorways to county roads.

Driving accidents caused economic costs in Germany of a total amount of 6.1 billion Euro in 2002. This is equal to 45% of all costs caused by accidents outside of built-up areas.

These numbers show that driving accidents are the most frequent accident type on roads outside of built-up areas and that there is a high potential to improve traffic safety with proper measures.

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	282	682	789	391	122	*2,266*
2	2,177	3,907	5,759	3,088	1,630	*16,561*
3	5,621	6,582	8,869	4,958	2,550	*28,580*
4	9,644	4,426	4,911	2,214	1,202	*22,397*
all	*17,724*	*15,597*	*20,328*	*10,651*	*5,504*	*69,804*

Table 28: Number of driving accidents (sit. 1) outside of built-up areas in Germany 2002 by accident and road categories (source: STATISTISCHES BUNDESAMT, 2003)

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	84.60	184.14	213.03	105.57	32.94	*620.28*
2	653.10	1,054.89	1,554.93	833.76	440.10	*4,536.78*
3	174.25	118.48	159.64	89.24	45.90	*587.51*
4	178.41	57.54	63.84	28.78	15.63	*344.20*
all	*1,090.36*	*1,415.04*	*1,991.44*	*1,057.35*	*534.56*	*6,088.78*

Table 29: Economic costs (in million Euro) of driving accidents (sit. 1) outside of built-up areas in Germany 2002 by accident and road categories

5.3.4 Rear end accidents (sit. 2)

Rear end accidents were represented by some well-defined three-digit accident types of the basic type 6 (accidents in longitudinal traffic). Therefore, the number of accidents in Germany can not directly be determined. It has to be estimated by the use of total numbers of accidents in longitudinal traffic and the knowledge on percentages in the test areas.

In the Bavarian test area 23% of all accidents of type 6 are rear end accidents. In the test area of Rhineland-Palatinate 15% of the accidents in longitudinal traffic are rear end accidents. These percentages are different from those mentioned in chapter 3.2.2, because here only accidents of categories 1-4 were used to get a similar basis to the accidents in Germany. The number of rear end accidents in Germany will be valued to 15% of all accidents of type 6. Table 30 shows the estimated number of rear end accidents on roads outside of built-up areas, Table 31 gives an overview about economic costs of rear end accidents in Germany in 2002.

The tables show that accidents of this situation happened 7,416 times in Germany in 2002 (4% of all accidents in Germany in 2002). There were killed or injured persons in 5,781 accidents (2% of accidents with killed or injured persons in Germany in 2002).

Rear end accidents caused economic costs of 496.3 million Euro in Germany in 2002, which is 4% of the total costs for accidents outside of built-up areas.

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	40	62	49	16	3	*170*
2	335	327	304	117	75	*1,158*
3	1,580	1,319	952	352	250	*4,453*
4	860	328	265	112	70	*1,635*
all	*2,815*	*2,036*	*1,570*	*597*	*398*	*7,416*

Table 30: Number of rear end accidents (sit. 2) outside of built-up areas in Germany 2002 by accident and road categories (based on: STATISTISCHES BUNDESAMT, 2003)

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	11.93	16.69	13.12	4.37	0.93	*47.04*
2	100.53	88.29	81.97	31.55	20.21	*322.55*
3	48.97	23.74	17.14	6.33	4.51	*100.69*
4	15.91	4.26	3.45	1.45	0.90	*25.98*
all	*177.34*	*132.98*	*115.68*	*43.71*	*26.55*	*496.26*

Table 31: Economic costs (in million Euro) of rear end accidents (sit. 2) outside of built-up areas in Germany 2002 by accident and road categories

5.3.5 Accidents while overtaking (sit. 3)

Accidents of this situation are part of the accidents in longitudinal traffic (type 6) and are represented by 5 chosen three-digit accident types. Therefore, it is once again not possible to determine the exact number of these accidents in Germany by only using the statistics. It has to be estimated as an adequate percentage of all accidents of type 6.

In the test area of Rhineland-Palatinate 5% of all accidents of type 6 were accidents while overtaking if accidents of categories 1-4 are taken as a basis for this determination. In the Bavarian test area these accidents were not in the database because it was not possible to choose these accidents without the knowledge of the three-digit accident type. It is assumed that 5% of all accidents of type 6 in Germany were accidents while overtaking. Due to the specific three-digit accident types, those accidents can not occur on motorways. So this road type is omitted in the tables. Table 32 shows the estimated number of accidents of this situation on roads outside of built-up areas. In Table 33 the economic costs for those accidents are shown.

Accidents while overtaking happened 1,531 times in Germany in 2002 (1% of all accidents outside of built-up areas), meaning that this situation is of minor importance compared to driving accidents. In 1,274 accidents people were killed or injured (1% of all accidents with killed or injured persons).

Accidents while overtaking caused economic costs of approximately 106.3 million Euro in 2002, which is 1% of the total economic costs of accidents in Germany in 2002.

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	-	21	16	5	1	*43*
2	-	109	101	39	25	*274*
3	-	440	317	117	83	*957*
4	-	109	88	37	23	*257*
all	-	*679*	*522*	*198*	*132*	*1,531*

Table 32: Number of accidents while overtaking (sit. 3) outside of built-up areas in Germany 2002 by accident and road categories (based on: STATISTISCHES BUNDESAMT, 2003)

Accident category	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	-	5.56	4.37	1.46	0.31	*11.70*
2	-	29.43	27.32	10.52	6.74	*74.01*
3	-	7.91	5.71	2.11	1.50	*17.24*
4	-	1.42	1.15	0.48	0.30	*3.36*
all	-	*44.33*	*38.56*	*14.57*	*8.85*	*106.31*

Table 33: Economic costs (in million Euro) of accidents while overtaking (sit. 3) outside of built-up areas in Germany 2002 by accident and road categories

Accident category	Motorways	Federal highways	State highways, county roads	Other roads	*All roads*
1-3	135	571	1,535	260	*2,501*
4	64	125	213	33	*435*
all	*199*	*696*	*1,748*	*293*	*2,936*

Table 34: Number of wildlife accidents (sit. 4) outside of built-up areas in Germany 2002 by accident and road categories (source: STATISTISCHES BUNDESAMT, 2003)

Accident category	Motorways	Federal highways	State highways, county roads	Other roads	*All roads*
1-3	14.18	62.81	168.85	28.60	*274.44*
4	1.18	1.63	2.77	0.43	*6.01*
all	*15.36*	*64.44*	*171.62*	*29.03*	*280.44*

Table 35: Economic costs (in million Euro) of wildlife accidents (sit. 4) outside of built-up areas in Germany 2002 by accident and road categories

5.3.6 Wildlife accidents (sit. 4)

Wildlife accidents are represented by a single three-digit accident type. Additionally, a specific general accident cause is marked. Therefore, these accidents are separately considered in the official statistics.

Accident numbers for this situation are not given as detailed as they are available for the other situations. Accidents with fatalities, serious injuries and slight injuries are combined to accidents with damage to persons. Also state highways and county roads are combined to a single road class.

In Table 34 the number of wildlife accidents outside of built-up areas in Germany in 2002 is given. In Table 35 the economic costs caused by wildlife accidents are given.

According to these numbers there were 2,936 wildlife accidents in Germany in 2002 (1% of all accidents outside of built-up areas) with killed or injured persons in 2,501 accidents (2% of accidents with killed or injured persons in Germany). There were possibly many more wildlife accidents of category 5 (see the numbers of the test area in Rhineland-Palatinate and the paper of SCHOENEBECK, 2004).

Wildlife accidents of categories 1-4 caused economic costs in the amount of 280.4 million Euro, which is equal to 2% of all economic costs caused by accidents outside of built-up areas.

5.3.7 Summary of potential benefits

In chapters 5.3.3 to 5.3.6 the number of accidents in Germany in 2002 that could be addressed by a SafeMAP application was determined for each single accident situation considered in this study. For these numbers the economic costs were estimated by using standardised cost rates.

Table 36 shows the total number of accidents in Germany in 2002 that could be addressed by SafeMAP application by the road types and the chosen accident situations. In Table 37 the economic costs caused by these accidents are summarised.

Accident situation	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	17,724	15,597	20,328	10,651	5,504	*69,804*
2	2,815	2,036	1,570	597	398	*7,416*
3	-	679	522	198	132	*1,531*
4	199	696	1,748		293	*2,936*
all	*20,738*	*19,008*	*35,614*		*6,327*	*81,687*

Table 36: Number of accidents outside of built-up areas in Germany 2002 which could be addressed by SafeMAP by road categories

Accident situation	Motorways	Federal highways	State highways	County roads	Other roads	*All roads*
1	1,090.36	1,415.04	1,991.44	1,057.35	534.56	*6,088.78*
2	177.34	132.98	115.68	43.71	26.55	*496.26*
3	-	44.33	38.56	14.57	8.85	*106.31*
4	15.36	64.44	171.62		29.03	*280.44*
all	*1,283.06*	*1,656.79*	*3,432.93*		*598.99*	*6,971.79*

Table 37: Economic costs (in million Euro) of accidents outside of built-up areas in Germany 2002 which could be addressed by SafeMAP by road categories

As these numbers show, there is a great potential for a SafeMAP system to improve traffic safety. The number of accidents that would be addressed by SafeMAP is equal to 46% of all accidents outside of built-up areas in Germany. These accidents caused 51% of the total economic costs of accidents outside of built-up areas.

5.4 Costs for the preparation of the database

Accident databases still exist at the Statistical Offices and the road authorities in Germany. It is not necessary to collect additional data. Therefore the expected costs for the preparation of the accident database are relatively low compared to the potential benefits. Permanent costs arise from:

- operation of a third party that annually collects the accident data, chooses relevant data sets and reduces the database to the relevant attributes
- automatic / manual geocoding of accident locations
- supply of the filtered database to the map providers.

A precise estimation of one-time and annual costs will be carried out in a later stage of this analysis by WP2 partners.

5.5 Interpretation of the results

In chapter 5.3 the number of accidents in Germany that could be addressed with a SafeMAP application and the economic costs that was caused by these accidents was estimated for the accident data of 2002. These annual costs amount to approximately 7 billion Euro while 81,687 accidents can be addressed with this application.

These figures are not equal to the number of accidents that could be avoided and to the annual benefit respectively.

To estimate the benefit of a SafeMAP application this sum could be used as a basis but has to be reduced because of:

- a loss of benefit due to market penetration (rate of vehicles equipped with a SafeMAP application)
- a certain rate of drivers that have a SafeMAP system installed in their car but leave it switched off for different reasons (acceptance of users)
- a certain number of hazard points that are not included in the digital map because of up-to-dateness of accident data (accident accumulations that occurred in the last months)
- a number of accidents that occur because of using a SafeMAP application (confusion of the driver after a warning is given).

A consideration of these facts will be a task of the study of the 2nd year. Up to now the estimated sum of accident costs of 7 billion Euro is the maximum of the annual potential benefit of a SafeMAP application. After the consideration of the mentioned reducing factors a more precise estimation of the potential benefit will be possible.

6 Requirements for a SafeMAP system

6.1 Reliability of accident databases

6.1.1 Possible mistakes during the acquisition of an accident

Police officers have to fill in a standardised accident form with detailed information on each accident and the involved road users (see chapter 2.1) if they were called to the accident location. Usually at the accident location they take notes with relevant information and complete the form when they are back in the office, which is sometimes not on the same day.

HAUTZINGER et al. (1985) studied possible mistakes in accident data. They stated that the acquisition of accident data by the police could be incorrect and inaccurate in many ways. During the completion of the accident forms mistakes can appear by:

- mistake in writing
- wrong choice (wrong marking at the accident forms) and
- mistakes during transferring information from the notes to the accident forms.

The subjective estimation of the accident situation by the police officers could cause irregularities. This source of error is of major importance to the reliability of accident data. The biggest source of error is traced back on the time delay between the accident itself and the completion of the accident form. The hand-written notes taken at the accident location include in most cases not enough information for a full reconstruction of the sequence of an accident. Then the police officer has to rely on his capabilities to remember all details. Therefore, mistakes appeared frequently.

However, wrong statements are not caused by the police officers only. Meant or unmeant misinformation of involved persons or witnesses of the accident could also cause distortion of the real accident situation.

The reliability of statements depends on:

- who arranges the interview,
- how the interview is carried out,
- the length of the time period between the accident and the interview and
- the mental capabilities as well as perception and memory capacity of the witnesses.

Suggestive questions by the police officers could cause unconscious mistakes in statements. The reliability of accident data strongly depends on the conditions at the accident location. Bad weather and/or traffic conditions could cause stress to the police officer and as a result unintentional mistakes. Besides the acquisition of the accident the police officers are responsible for the safety at the accident location, the organisation of first medical care of injured persons and the abolishment of dangers for environment, which are the most important tasks (HAUTZINGER et al., 1985).

Usually police officers only make a detailed draft of the accident for serious accidents (with fatalities or injuries). Practical experiences show that mistakes in measurements are often made during this task. Complete measurements of the accident location are unusual. A common mistake is the wrong measurement of the skid marks. Normally the measurement of the skid marks ends at the rear end of the vehicle. But during a later analysis it is not clear whether the vehicle continued rolling or the skid marks below the car ended at the front axle. This fact can causes a wrong calculation of the speed during a later analysis (IFU, 2004).

The insufficient education and training of police officers can also be a cause for mistakes during the acquisition of an accident. Furthermore, the inadequate technical equipment leads to mistakes in the accident forms.

The sources of error during the acquisition of accident data by the police could be combined to the following points:

- mistakes in writing and transferring
- mistakes caused by distorted cognition
- mistakes caused by bad memory capacity
- mistakes caused by wrong statements of accident involved road users or witnesses
- mistakes caused by stress at accident location
- mistakes caused by insufficient education and training of police officers (HAUTZINGER et al., 1985).

6.1.2 Preparation of accident forms by the Statistical offices

The completed accident forms are sent to the Statistical office of the appropriate Federal State by the Police department. Only accidents of categories 1-4 and 6 are intended to be processed at the Statistical offices. Within 30 days a re-declaration of fatalities takes place if necessary (in Germany a person who dies within 30 days after an accident because of the injuries is counted as an accident victim).

Based on the accident forms a database is created. First of all the accident forms are examined according to their completeness. If necessary details will be added or corrected.

Afterwards a standardised automated plausibility check is conducted. Accident data is tested for permissibility, completeness and internal consistency by using combination and addition tests. For instance it is checked if only allowed characters are used for each attribute and if certain combinations of attributes are correctly declared.

This algorithm delivers error logs if any test result is negative. Based on these protocols missing attributes will be added or wrong attributes will be corrected. This plausibility checks ensures a certain quality of the accident data. The check fails if mistakes in data sets are not based on logical or inconsistencies in form (HAUTZINGER et al., 1985).

From experts point of view the error ratio during transformation of accident forms to digital accident databases is less than 1% (BENNER, 2004). In his opinion the specification of the accident location is often incorrect with regard to nodes and mileage (based on mistakes by police officers and not by the Statistical offices).

6.1.3 Experiences of the project team during the preparation of accident data

During the work on the accident database of the Bavarian test area the geocoding information had to be added to the data sets (see specification of data in chapter 2.4.3). It was not possible to geocode 318 out of 3256 accidents (10%) due to different reasons:

- the accident happened on roads that are not in the appropriate area
- the given accident location was contradictorily or not accurately defined
- the given mileage does not fit the feasible mileage of the road.

The project team was not able to check whether the given mileage was correct determined according to characteristics at the accident location (curve or intersections). It is assumed that these specifications are false to a certain degree, as stated by BENNER (2004).

In addition it was determined that single accidents were included twice in the database with different identity numbers. It seems as if such a mistake can not be detected by the plausibility checks running at the Statistical offices.

To improve the reliability of accident data with regard to the point of the location specifics, a software package is already available in Germany. The program EUSKa ("Elektronische Unfalltypen-SteckKarte" = electronic map to show accident accumulations) is able to work in the police patrol car and can automatically determine the co-ordinates of the accident location by using the information of a GPS-sensor. Furthermore, the accident forms can be completed and accident analyses can be carried out. Finally, a map showing accident accumulations can be created.

The software package is already used by police departments in several Federal States in Germany for their accident analyses. But the add-on to locate the accidents in a digital map is not used by any police department.

6.2 Accident database requirements

To prepare a database for a SafeMAP system the geocoding of each accident data set is essential. Software tools to directly determine the co-ordinates of the accident location using GPS-signals (EUSKa) or to supplementary geocode data sets using given information of the accident location (UNFAS) are already available but not used everywhere. It is desirable that police departments use up-to-date technical equipment to determine the accident location exactly and to avoid corresponding sources of error in the database. If the accident location could be estimated more exactly, a major source of error will be eliminated. Moreover the reliability of the accident databases has to be increased by:

- continuing education of police officers in the acquisition of an accident
- use of software package EUSKa (or other) at the accident location to complete the accident form (a check whether not all attributes are marked is included)
- additional test algorithms to fix errors in the databases (e.g. 2 data sets for a single accident).

Although the determination of SafeMAP relevant accident data sets is possible without the three-digit accident type (see chapter 3.1.8), the availability of these single types is desirable. The relevant attributes could be chosen exactly by this attribute. In addition, accidents while overtaking (cat. 3) can only be considered if the three-digit accident type is available.

An important point according to the functionality of the SafeMAP application is the up-to-dateness of the accident data. The in-car database should include accident data for a period of 2 or 3 years. Accident data is only valid for road sections that are currently in the same state as they were at the time of the accident.

For road sections that were reconstructed and got a new alignment or even a new surface, the circumstances leading to an accident could be completely different. Therefore, the accident data for those sections should not be included.

To check whether a reconstruction has taken place the road databases of the road authorities could be used (e.g. OKSTRA in German road construction offices). This would be an additional task for the office that is preparing the database (see chapter 5.4).

7 Analysis of the French Accident Database

7.1 Compatibility of database filters

The SafeMAP application described in the previous sections was developed based on the accident data that is available in Germany. In a next step, it has to be investigated whether the proposed system can also be applied to other (for this project particularly the French) accident databases. Thus, it has to be verified that all required information and attributes are available in the French accident database. The analysis is based on the complete list of attributes that is included in the French accident data (Appendix C).

As stated in Chapter 3.1, only those accidents that meet certain conditions have to be included in the safety system. Chapter 3.1.2 through 3.1.8 specify criteria that can be used to identify those accidents relevant for the SafeMAP system. The choice of accidents based on these criteria represents the database filter.

The four circumstances that are described in chapter 3.1.2 through 3.1.5 (road type, construction zone, type of vehicle, and influence of drugs and alcohol) represent basic parameters that are used to isolate the relevant accidents. Table 38 shows that (except for the identification of construction zones, which apparently is not included) all the required attributes are given in the French database.

In addition to the basic attributes, the number of accidents can also be limited by the accident situation. Similarly to what is described in Chapter 3.1.7 and 3.1.8, it was analysed whether the four relevant accident situations can be identified based on the information included in the French accident database. Table 39 summarizes the results of this

Attribute	Specification	Available in French Database?
road type	category and localisation (e.g. outside of build-up area)	yes
construction zone	apparently not available	-
type of vehicle	passenger cars, busses, delivery and freight trucks, semi trailer trucks, tractors, special trucks	yes
drugs and alcohol	driver problem and alcohol	yes

Table 38: Availability of attributes for the database filter in the French accident database

Accident Situation	Available Attributes in French Database	Detection feasible?
driving accident	(sporting speed = yes)	yes
rear end accident	collision type = rear-end	yes
overtaking	(collision type = head-on) & (main action before accident = overtaking)	yes
wildlife accident	moving obstacle = wild animal	yes

Table 39: Feasibility of detecting the four relevant accident situations in the French database

analysis. As can be seen in the table, the French database provides sufficient information for the detection of relevant accident situations.

The analysis of the French accident database proves that almost all of the required attributes representing the database filter are available. Thus, a similar database filter could be applied to the French database.

7.2 Compatibility of the Accident – Road Element Matrix

The basic idea of the accident – road element matrix is to compare the current driving situation with the accident data that is provided in the filtered database. A list of attributes that are required for the creation of a specific warning is given in Table 9 (see chapter 3.4).

The analysis of the French accident database, which is summarized in Table 40, shows that (expect for the legal speed limit) all of the required attributes are available. Thus, the concept of the road element matrix could be applied to the French accident database without further modification.

7.3 Future Prospects

The analysis of the French accident database showed that the SafeMAP-concept could be applied in France without any major modification. This leads to the conclusion that the proposed system can be operated not only in Germany, but in every country that provides a complete and geo-referenced accident database.

With the ongoing harmonisation of accident databases all around Europe including the increasing

Group of attributes	Relevant attributes in French database	Completeness of French data
location	XY-co-ordinates (geocoding)	yes
	road number	yes
	driving direction, mileage	yes
accident data	accident situation	yes
	lighting conditions, road conditions	yes
	time	yes
	month	yes
	day of week	yes
	general cause	yes
	speed limit	-
vehicle and driver	type of vehicle	yes
	driver's age	yes
	Excessive (sporting) speed	yes

Table 40: Completeness of French database for the creation of a specific warning

use of geo-coding information, this clearly indicates the future potential of this application.

Presently first steps for a standardised European accident database are made. The European Union initiated the CARE database ("**C**ommunity database on **A**ccidents on the **R**oads in **E**urope") that collects accident data of 10 EU member states. Currently data on 20 million accidents with killed or injured persons is included since 1991. The data is based on the accident forms from the individual accidents. Because of the differences in the structure of accident databases in different countries the CARE database includes only few attributes (COMMISSION OF THE EUROPEAN COMMUNITIES, 2004).

The European Union just initiated the SAFETY NET project with the goal to expand the number of countries included in the CARE database to 27. Also risk exposure data and road safety performance indicators are to be included in the database.

8 Summary and Outlook

The EU set the goal to reduce road fatalities by half between 2000 and 2010. The development and provision of intelligent in-vehicle safety systems has a great potential to improve traffic safety. The analyses in this report show that a SafeMAP system as described here can provide a great contribution to reach this ambitions goal.

The SafeMAP system is an in-car safety system that can warn a driver of safety-related deficiencies of the road section ahead. If a warning is given, the driver can slow down and pay special attention while driving through this section. He will hopefully drive safely without the risk of an accident.

There are different applications possible to assist a driver while driving through a section with a comparably high risk of getting into an accident:

- information about the legal speed limit
- calculation of a safe speed in curves using data on road surface and geometry
- identification of dangerous road sections considering bad configurations of geometric parameters.

In this report a differing approach was presented and analysed. Thereby the system is able to analyse accident data and to compare it with the current circumstances. If the current situation matches the circumstances of previous accidents to a particular degree, a warning will be generated. This means that a warning will only be given at road sections where accidents have frequently happened in the past and only in the case of a particular similarity of the accidents and the current situation. Furthermore it is not necessary to collect data like road geometry or surface to realise this SafeMAP application.

During the SafeMAP project the partners have defined different applications that will be included in a digital map (e.g. legal speed sign, safe speed in curves). In this connection SafeMAP will be a map-based safety system that combines several single applications in one system.

The approach described in this report is complementary to other applications like safe speed in curves which was studied by the French SafeMAP partners. With the calculation of a safe speed in curves a warning can only be generated for curves. The application using accident data can also warn the driver against critical straight sections but will not work at recently built roads or at road sections where no accident had happened in the past. With the calculation of a safe speed also recently built curves could be considered.

On the basis of a survey about the structures of existing accident and road databases, two test areas were chosen to analyse the accident data and to define rules to prepare the relevant data. During the detailed accident analysis, four situations were defined that are potential scenarios for a warning of the driver. These situations are mainly based on the three-digit accident type that is currently available in the accident databases of Rhineland-Palatinate only. In addition, rules were developed to choose the relevant data from databases that only provide the one-digit accident type. A rough analysis of the French accident database structures has shown that the accident situations can also be extracted from this database.

It is quite clear that not all of the attributes given in the accident database are essential for the algorithm to create a warning. Therefore, all available accident attributes were reviewed with regard to the usefulness of each attribute and a list of relevant attributes was provided.

As a result of the detailed accident analysis, a method was developed to compare the current circumstances with the accident data and to generate a warning in case of a certain compliance of the current situation with historical accident circumstances at this site. In the assessment process, the accident attributes are weighted by a factor according to the risk to be involved into an accident. Wildlife accidents have to be considered separately because the risk of such an accident does not depend on the type of vehicle, the driver or the driving direction, but rather on the month, the time of the day and the region.

On the basis of the accident analysis the number of accidents in Germany that can be addressed with this system was determined. It was shown that 46% of all accidents outside of built-up areas can be addressed with the SafeMAP application. Using standardised accident cost rates the annual economic costs caused by these accidents were estimated to approximately 7 billion Euro for Germany. These costs were set as the maximum potential benefit, as these accidents could be addressed by the system. To which degree this potential could be realised depends on market penetration, on the acceptance of drivers as well as other facts that has to be studied in the 2nd year.

So it is the aim of the 2nd year analysis to further specify the expected benefit of SafeMAP. For that purpose, a demonstrator will be built and test drives will be conducted. The tests will help to assess the potential of avoiding accidents and the acceptance of this system more precisely.

Up to now, the feasibility and the great potential to avoid accidents has been shown in this report.

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Appendix A – Questionnaire

Name der Behörde ______________________________

Anschrift ______________________________

Ansprechpartner ______________ Durchwahl ______________

Ruhr-Universität Bochum
Lehrstuhl für Verkehrswesen
z.H. Herrn Regler

44780 Bochum

Forschungsprojekt "SafeMAP – Sozioökonomische Bewertung einer speziellen digitalen Karte für sicherheitsrelevante Fahrzeugapplikationen" im Auftrag der BASt
Erhebung der Struktur der Unfalldatenbanken
1. Wird in Ihrer Behörde eine computergestützte Unfalldatenbank geführt? ☐ ja ☐ nein *(Ende)*
1.1. Werden alle Unfälle gespeichert? ☐ ja ☐ nein, nur folgende Unfälle: ....
1.2. Wie wird der Unfalltyp ermittelt? ☐ dreistellig ☐ zweistellig ☐ einstellig ☐ keine feste Regelung
1.3. Liegt eine Georeferenzierung der Unfalldaten vor? ☐ ja ☐ nein *(weiter mit Frage 1.5.)* ☐ nur teilweise, und zwar für ....

Formular_StaLA.doc Seite 1

Fig. A-1: Questionnaire to the Statistical Offices of the Federal States (Page 1 of 2)

1.4. Welches Koordinatensystem wird für die Georeferenzierung verwendet?

☐ Gauss-Krüger ☐ GPS (Global Positioning System)

☐ anderes, und zwar: ....

1.5. Sind die Unfalldaten für das gesamte Bundesland zentral gespeichert?

☐ ja, in unserer Behörde ☐ nein, keine zentrale Speicherung

☐ ja, zuständig ist: ....

....

1.6. Handelt es sich um einen standardisierten Datensatz?

☐ ja, und zwar: ....

☐ nein *(Bitte ggf. Datensatzbeschreibung beifügen!)*

1.7. Ergänzungen zu Unfalldatenbanken

....

....

....

Verfügbarkeit der Daten

2. Würden Sie einer Bereitstellung von Datensätzen durch ihre Behörde für das oben genannte Forschungsvorhaben im Rahmen der datenschutzrechtlichen Bestimmungen zustimmen?

☐ ja ☐ nein

☐ mit folgender Einschränkung / unter folgenden Auflagen:

....

....

Bitte senden Sie den ausgefüllten Fragebogen an die oben angegebene Adresse.

Vielen Dank für Ihre Teilnahme!

Seite 2

Fig. A-2: Questionnaire to the Statistical Offices of the Federal States (Page 2 of 2)

Name der Behörde ______

Anschrift ______

Ansprechpartner ______ Durchwahl ______

Ruhr-Universität Bochum
Lehrstuhl für Verkehrswesen
z.H. Herrn Regler

44780 Bochum

Forschungsprojekt "SafeMAP – Sozioökonomische Bewertung einer speziellen digitalen Karte für sicherheitsrelevante Fahrzeugapplikationen" im Auftrag der BASt
Erhebung der Struktur der Straßendatenbanken
1. Wird in Ihrer Behörde eine computergestützte Straßendatenbank geführt? ☐ ja ☐ nein *(weiter mit Frage 2)*
1.1. Welche Elemente sind in der Datenbank enthalten? ☐ nur Netzknoten ☐ einzelne Straßenelemente im Lageplan ☐ einzelne Straßenelemente im Höhenplan ☐ weitere, und zwar: ....
1.2. Liegt eine Georeferenzierung der einzelnen Datensätze vor? ☐ ja, für alle Elemente ☐ ja, nur für Netzknoten ☐ nein *(weiter mit Frage 1.4.)* ☐ nur teilweise, und zwar für ....

Formular_Strbauamt.doc Seite 1

Fig. A-3: Questionnaire to the Road Construction Offices of the Federal States (Page 1 of 4)

1.3. Welches Koordinatensystem wird für die Georeferenzierung verwendet?

☐ Gauss-Krüger ☐ GPS (Global Positioning System)

☐ anderes, und zwar: ....

1.4. Sind die Straßendaten für das gesamte Bundesland zentral gespeichert?

☐ ja, in unserer Behörde ☐ nein, keine zentrale Speicherung

☐ ja, zuständig ist: ....

....

1.5. Handelt es sich um einen standardisierten Datensatz (z.B. nach den Vorgaben von OKSTRA)?

☐ ja, und zwar: ....

☐ nein *(Bitte ggf. Datensatzbeschreibung beifügen!)*

1.6. Verwendet Ihre Behörde ein Programmsystem zur grafischen Darstellung der Straßendaten (z.B. NWSIB)?

☐ ja, und zwar: ....

☐ nein

1.7. Ergänzungen zu Straßendatenbanken

....

....

....

Erhebung der Struktur der Unfalldatenbanken

2. Wird in Ihrer Behörde eine computergestützte Unfalldatenbank geführt?

☐ ja ☐ nein *(weiter mit Frage 3)*

2.1. Werden alle Unfälle gespeichert?

☐ ja ☐ nein, nur folgende Unfälle:

....

Seite 2

Fig. A-4: Questionnaire to the Road Construction Offices of the Federal States (Page 2 of 4)

2.2. Wie wird der Unfalltyp ermittelt?

☐ dreistellig ☐ zweistellig

☐ einstellig ☐ keine feste Regelung

2.3. Liegt eine Georeferenzierung der Unfalldaten vor?

☐ ja ☐ nein *(weiter mit Frage 2.5.)*

☐ nur teilweise, und zwar für ....

....

2.4. Welches Koordinatensystem wird für die Georeferenzierung verwendet?

☐ Gauss-Krüger ☐ GPS (Global Positioning System)

☐ Streckenkilometer / Polarkoordinaten

☐ anderes, und zwar: ....

2.5. Sind die Unfalldaten für das gesamte Bundesland zentral gespeichert?

☐ ja, in unserer Behörde ☐ nein, keine zentrale Speicherung

☐ ja, zuständig ist: ....

....

2.6. Handelt es sich um einen standardisierten Datensatz?

☐ ja, und zwar: ....

☐ nein *(Bitte ggf. Datensatzbeschreibung beifügen!)*

2.7. Ergänzungen zu Unfalldatenbanken

....

....

....

Seite 3

Fig. A-5: Questionnaire to the Road Construction Offices of the Federal States (Page 3 of 4)

Verfügbarkeit der Daten
3. Würden Sie einer Bereitstellung von Datensätzen durch ihre Behörde für das oben genannte Forschungsvorhaben im Rahmen der datenschutzrechtlichen Bestimmungen zustimmen?
☐ ja ☐ nein
☐ nur Straßendaten ☐ nur Unfalldaten
☐ mit folgender Einschränkung / unter folgenden Auflagen:
....
....

Bitte senden Sie den ausgefüllten Fragebogen an die oben angegebene Adresse.

Vielen Dank für Ihre Teilnahme!

Seite 4

Fig. A-6: Questionnaire to the Road Construction Offices of the Federal States (Page 4 of 4)

Appendix B – Accident Characteristics in German Databases

Accident categories – Unfallkategorien

Depending on the consequences of the accident, a classification into different accident categories is possible. The criterion for the classification is in each case the most severe consequence, which is suffered by any involved person. The accident categories are drawn in 1 to 6, seen in Table B-1.

The combination of different accident categories is also meaningful. So it is possible to group accidents of the categories 1 and 2 to accidents with serious personal damage. Further information are provided by FGSV (2003).

Accident Category	Heaviest Consequence	Description
Category 1	Accident with killed person	Minimum one killed person
Category 2	Accident with serious injuries	Minimum one seriously injured person but no fatalities
Category 3	Accident with slight injuries	Minimum one slightly injured person but no seriously injured persons or fatalities
Category 4	Severe accident with property damage	Accidents with property damage (no damage on persons) and case of penalty or indication, with minimum one vehicle which is not ready to drive anymore
Category 5	Other accident with property damage	Accident with property damage (no damage on persons): - with elements of an offence or administrative offence complaint without alcoholic influence in which the vehicles are ready to drive - fractionally elements of a crime, independent thereof, whether vehicles are ready to drive or not
Category 6	Other accident with property damage and drink-driving	Accidents with property damage (no damage on persons), where all vehicles are ready to drive and minimum one road user is under the influence of alcohol

Table B-1: Accident Categories as defined by FGSV, 2003

Accident types – Unfalltypen

The accident type describes the conflict situation which finally causes the accident. It is possible that collisions with other road users happen in process of the accident or that a vehicle runs off the road. The proper criterion for classification is the situation which caused the accident.

It is a matter of a pedestrian cross accident (type 4), if a driver is forced to brake because of a crossing pedestrian and a following vehicle crashes into his car. This type of accident is not called an accident in longitudinal traffic because the main reason was the pedestrian crossing the road.

In the Table B-2 are the seven basic accident types with their description listed.

The basic types could be divided into a two-digit sub ranking category or a three-digit single type, depending from the conflict situation. In the already mentioned paper of the FGSV (2003) are the precise conflicts with their single types pictured in pictograms. An extract of this catalogue is shown in the picture below.

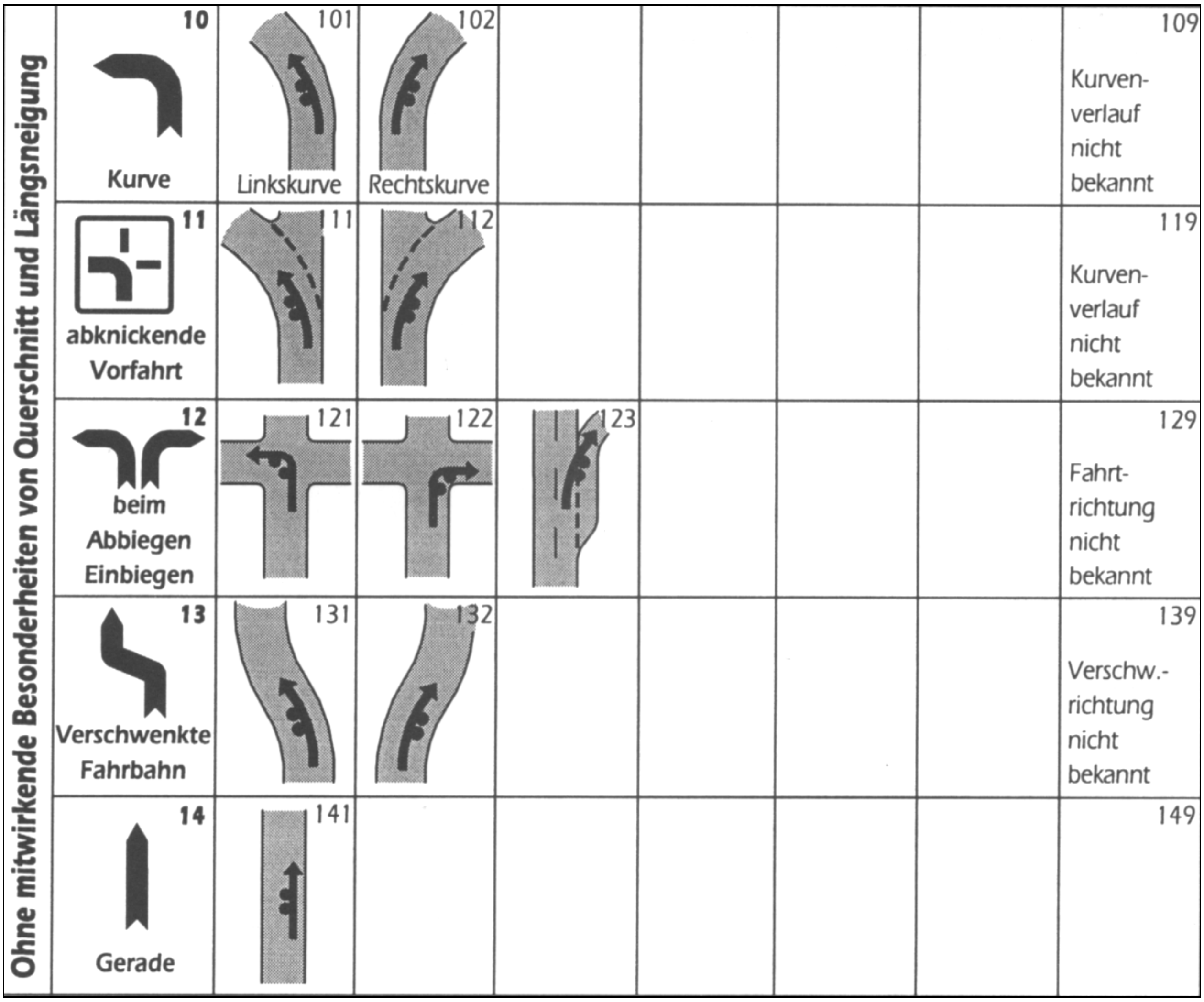

Fig. B-1: Overview on conflict situations (extract) to define the accident type as given by FGSV, 2003

Accident Type	Description
Type 1 Driving Accident	The accident was activated by a loss of control over the vehicle (because of a speed level that is not appropriate for the routing of the street or the road conditions), without exertion of influence of other road users. As a result of uncontrolled movements of the vehicle a collision with other road users could have happened.
Type 2 Turn Off Accident	The accident was activated by a conflict between a turning vehicle and another vehicle (also pedestrians), which drove in the same or the opposite direction at an intersection, T-junction or entrance.
Type 3 Turn Into/Cross Accident	The accident was activated by a conflict between a turning or crossing vehicle, which is beholden to wait, and another vehicle with right of way at an intersection, T-junction or exit road.
Type 4 Pedestrian Cross Accident	The accident was activated by a conflict between a vehicle and a pedestrian in case the vehicle was not turning off the road and the pedestrian was not walking along the street. This also counts if the pedestrian is not struck by the vehicle.
Type 5 Parked Vehicle Accident	The accident was activated by a conflict between a moving vehicle and a vehicle, which parked/stopped or makes movements in connection with parking/stopping.
Type 6 Accident in longitudinal traffic	The accident was activated by a conflict between road users who moves in the same or opposite direction unless the accident belongs not to another type of accident.
Type 7 Other Accident	Accident which doesn't belong to types 1-6. Examples: U-Turn, reversing, obstacle or animal on road, sudden vehicle damage (brakes, tires or other).

Table B-2: Basic Accident Types and Descriptions as given by FGSV, 2003

Accident kinds – Unfallarten

Beside the accident type the accident kind is important for the specification of an accident. The accident kind gives information if the road user clashed and if so, how they clashed. There are 10 possible accident kinds.

Thereby, the accident kind is not inevitable bound to a decisive accident type. But some of the accident kinds could increasingly appear in connection with a certain accident type. So one can find the accident kind 8 and 9 (run off the road left or right) frequently in combination with accident type 1 (driving accidents).

The table below gives an overview on the different accident kinds and their descriptions.

The accident kind is remarked in the standardised accident forms, as the accident type and the accident category is. The combination of the accident type and kind is used by the authorities for the analysis of the road safety and for the identification of hot spots and weaknesses of the infrastructure.

Accident Kind	Description
Accident Kind 1	Collision with other vehicle which starts, stops or parks
Accident Kind 2	Collision with other vehicle which drives ahead or waits
Accident Kind 3	Collision with other vehicle which drives lateral in the same direction
Accident Kind 4	Collision with other vehicle which drives in the opposite direction
Accident Kind 5	Collision with other vehicle which is turning into or crossing
Accident Kind 6	Collision between vehicle and pedestrian
Accident Kind 7	Collision with obstacle on the road
Accident Kind 8	Run off the road right
Accident Kind 9	Run off the road left
Accident Kind 0	Accident of other kind

Table B-3: Accident kinds and their descriptions

Accident causes – Unfallursachen

It is possible to mark up to 3 accident causes for every involved road user in the accident forms and in the data sets of the statistical offices of the Federal States. An overview on the numbers of the accident causes is given below. Also one can see a description of the accident causes.

The accident causes are divided into insufficient roadworthiness, wrong behaviour of motorists, wrong behaviour of pedestrians, unfavourable road conditions, unfavourable weather conditions obstacles on the road and other causes.

No.	Description of Accident Cause	No.	Description of Accident Cause
	Roadworthiness		**Overtaking**
01	Influence of Alcohol	16	Prohibited Overtaking on right Lane
02	Influence of other Intoxicant (e.g. drugs, dope)	17	Overtaking in spite of oncoming traffic
		18	Overtaking in spite of unclear traffic situation
03	Overfatigue	19	Overtaking in spite of insufficient visibility
04	Other physical or mental deficiencies	20	Overtaking without attention of following traffic and/or without timely notice of sheering out
	Failure of Drivers		
	Road Using	21	Failure while arranging in the right lane after overtaking
10	Use of wrong lane (also carriageway) or other prohibited road parts	22	Other Failures while overtaking (e.g. without sufficient lateral distance, at pedestrian crossing see Pos. 38,39)
11	Offence of the command to use the right lane		
		23	Failure while overtaking by another vehicle
	Speed		
			Driving past
12	Excessive Speed and Break of Speed Limit	24	Ignore of right of way while driving past a stopped vehicle, barriers or obstacles (§ 6) (except of Pos. 32)
13	Excessive Speed in other cases		
	Safety Distance	25	Ignore of following traffic while driving past a stopped vehicle, barriers or obstacles and/or without timely notice of sheering out
14	Insufficient Safety Distance (other causes which lead to an accident should be assigned to the appropriate positions like Speed, Overfatigue, etc.)		
			Driving side by side
15	Hard Breaking of vehicle which drives ahead without urgent reason	26	Incorrect lane change while driving side by side or ignore of merging traffic (§ 7) (except of Pos. 20, 25)

Table B-4a: Accident causes as given by German Catalogue

No.	Description of Accident Cause	No.	Description of Accident Cause
	Right of Way	46	**Ignore of regulations for Lighting (except Pos. 50)**
27	Ignore of Priority to the right		**Loading, Occupancy**
28	Ignore of traffic signs managing right of way (§ 8) (except of Pos. 29)	47	Overloading, Over-Occupancy
29	Ignore of right of way of through traffic at motorways or similar roads (§ 18, para. 3)	48	Insufficient Safety of loading or car accessory
30	Ignore of right of way by vehicles leaving country lanes and forest tracks	49	**Other Drivers Causes**
31	Ignore of traffic control by police officers or traffic lights (except of Pos. 39)		**Technical Deficiencies, Service Deficiencies**
32	Ignore of Right of Way of oncoming vehicles (Sign 208 StVO)	50	Lighting
33	Ignore of Right of way of railway vehicles at railway crossings	51	Tire Equipment
	Turning, U-Turning, Reversing, Running-in, Starting	52	Brakes
35	Failure while turning (§ 9) (except Pos. 33, 40)	53	Steering
36	Failure while U-Turning or Reversing	54	Draw Bar
37	Failure while Running into flowing traffic (e.g. from a premises, from other parts of the road or starting from the side)	55	Other Deficiencies
	Wrong Behaviour to Pedestrians		**Wrong Behaviour of Pedestrians**
38	at zebra crossing		**Wrong Behaviour while Crossing the Road**
39	at pedestrian crossing	60	at locations where pedestrian traffic was regulated by police officers or traffic lights
40	while turning	61	at pedestrian crossings without regulation by police officers or traffic lights
41	at a bus stop	62	near intersections or T-junctions, traffic lights or pedestrian crossings at heavy traffic
42	at other points		**At other locations**
	Parked Vehicle, Safe Traffic	63	Abrupt Appearing from behind an Obstacle
43	Prohibited Stopping or Parking	64	without paying attention to vehicles traffic
44	Insufficient Protection of stopped or broke-down vehicle, accident locations or school busses where children get in or out	65	other wrong behaviour
45	Wrong Behaviour while getting in/out or loading/unloading	66	**Non-use of the sidewalk**
		67	**Non-use of correct road side**
		68	**Playing at or besides the road**
		69	**Other Failure by Pedestrians**

Table B-4b: Accident causes as given by German Catalogue

No.	Description of Accident Cause	No.	Description of Accident Cause
	Road Circumstances		**Climatic Influences**
	Glazed or Slippery Road		**Bad Visibility because of**
70	Contamination by emanative Oil	80	Fog
71	Other Contamination by Road Users	81	heavy rain, hail, snow flurry etc.
72	Snow, Ice	82	blinding sun
73	Rain	83	**crosswind**
74	Other Influences (foliage, alluvial clay)	84	**Thunderstorm or other Climatic Conditions**
	Road Conditions		**Obstacles**
75	Lane Grooves in Connection with Rain, Snow or Ice	85	Not or insufficient saved Working Zone on the Road
76	Other Conditions	86	Game Animals on the Road
77	**non-proper State of traffic signs or traffic devices**	87	Other Animals on the Road
78	**Insufficient Lighting of the Road**	88	Other Obstacles in the Road (except of Pos. 43, 44)
79	**Insufficient Protection of Railway Crossings**	89	**Other Causes** (short description necessary)

Table B-4c: Accident causes as given by German Catalogue

Types of Traffic Participation – Arten der Verkehrsbeteiligung

In Germany there are several groups of traffic participation available to classify a road user which is involved in an accident. According to this classification the type of traffic participation will be attached to the personal data of every involved road user in the accident form.

The following table gives an overview on all types of traffic participation and the belonging key number.

For SafeMAP application only accidents with passenger cars (key number 21), busses (30-35), delivery and fright trucks (41-48) and semitrailer trucks (51-59) were chosen. Therefore the type vehicle used by the first involved road user (the responsible party) is relevant.

No.	Description of Traffic Participation	No.	Description of Traffic Participation
01	Moped (until 50 ccm / 40 km/h; insurance licence plate number)	51	Other Semitrailer truck with or without semitrailer
02	Motor-assisted bicycle (until 25 km/h; insurance licence plate number)	52	Semitrailer truck with fuelling semitrailer
		53	Agricultural tractor with or without trailer
11	Motorcycle (more than 80 ccm)	54	Other tractor with or without trailer
12	Light Motorcycle (until 50 ccm, more than 40 km/h; official licence plate number)	55	Tractor with fuelling vehicle
		57	Fuel tank truck
15	Scooter (more than 80 ccm)	58	Truck with special constructions
21	Passenger car and station wagon (also with caravan or trailer)	59	Other vehicle (fire engine, refuse lorry...)
30	Omnibus	61	Tram
32	Coach	62	Train
33	Public-transit bus	71	Bicycle
34	School bus	81	Pedestrian
35	Trolley bus	82	Trolley, pushcart
41	Delivery and freight truck without trailer	83	Person with animals, herdsman
43	Fuelling vehicle without trailer	91	Yoked cart
45	Delivery and freight truck with trailer	92	Other and unknown vehicle
48	Fuelling vehicle with trailer	93	Other person

Table B-5: Types of Traffic Participation as given by German Catalogue

Description of Attributes in Accident data sets

Short cut.	Description
COORD_X	Easting of Gauss-Krueger Co-ordinates
COORD_Y	Northing of Gauss-Krueger Co-ordinates
COS	Class of Street
	1 = motorway
	2 = federal highway
	3 = state highway
	4 = county road
NOS	Number of Street
LET_STR	Letter according to Number of Street
BLOCK	Block according to Street
NODE_A	First node of appropriate road section
LET_A	Letter according to first node
NODE_B	Second node of appropriate road section
LET_B	Letter according to second node
KM	Mileage of accident location
DIR_TR	Direction of Travelling
	1 = with ascending mileage
	2 = with descending mileage

Short cut	Description
ACC_SIT	Relevant accident situation
	1 = Driving Accident
	2 = Rear End Accidents
	3 = Accidents while Overtaking
	4 = Wildlife Accidents
LIGHT	Lighting Conditions
	0 = Daylight
	1 = Twilight
	2 = Darkness
ROAD	Road Conditions
	0 = dry
	1 = wet
	5 = slippery (oil, foliage...)
	7 = glazed frost or snow
TIME	Time of accident
MONTH	Month of accident
DAY	Accident’s day of week

Table B-6a: Description of attributes in accident data sets

Short cut.	Description	Short cut	Description
CAUSE	General causes due to road and weather conditions or obstacles	CAUSE	85 = not saved or insufficient saved working zone on the road
	70 = Slippery road conditions due to oil on the road		86 = game animals on the road
	71 = Slippery road conditions due to other pollution		87 = other animals on the road
	72 = Slippery road conditions due to snow or ice on the road		88 = other obstacles on the road
	73 = Slippery road conditions due to rain		89 = other causes
	74 = Slippery road conditions due to other influences (foliage, clay)	SPEED	Speed limit at accident location
	75 = lane grooves in connection with rain, snow or ice	VEH	Type of vehicle used and possible summarisation of vehicle types
	76 = other road conditions		21 = passenger cars, also with trailer
	77 = no proper state of traffic signs or traffic devices		31 = omnibusses
	78 = insufficient illuminating of the road		32 = coaches
	79 = insufficient saving of cross-ings		33 = public-transit busses
	80 = obstruction of sight due to fog		34 = school busses
	81 = obstruction of sight due to heavy rain, hail, snow flurry		35 = trolley busses
	82 = obstruction of sight due to glare sunlight		41 = delivery and freight trucks with-out trailer
	83 = side wind		43 = fuelling vehicle without trailer
	84 = obstruction of sight due to thunderstorm or other weather conditions		45 = delivery and freight trucks with trailer
			48 = fuelling vehicle with trailer
			51 = other semitrailer trucks with or without semitrailer
			52 = semitrailer trucks with fuelling semitrailer
			53 = agricultural tractors with or without trailer

Table B-6b: Description of attributes in accident data sets

Short cut.	Description	Short cut	Description
VEH	54 = other tractors with or without trailer 55 = tractors with fuelling vehicle 57 = fuel tank trucks 58 = trucks with special constructions 59 = other vehicles (fire engine, refuse lorry...)	SEX	Driver's sex 1 = male 2 = female
		LICENCE	Age of driving licence
AGE	Driver's age	EXC_SP	Excessive speed – Accident cause due to driver's mistake 1 = excessive speed and break of speed limit (accident cause 12) 2 = excessive speed in other cases (accident cause 13)

Table B-6c: Description of attributes in accident data sets

Appendix C – Accident Characteristics in France

The following list shows the structure of the French National accident database BAAC (provided by French partners). The parameters are divided into the four sections with information to characteristics, localisation, vehicles and drivers. For each attribute possible options to mark are given.

1. Characteristics

day of the week

- Monday = 1, …, Sunday = 7

date

- year
- month
- day

light

- daylight = 1
- twilight = 2
- night without street lighting = 3
- night with street lighting switched off = 5
- night with street lighting switched on = 6

time

- hour
- minute

localisation

- outside of built-up areas = 1
- 1 – 500 inhabitants = 2
- 501 – 2,000 inhabitants = 3
- 2,001 – 5,000 inhabitants = 4
- 5,001 – 20,000 inhabitants = 5
- 20,001 – 50,000 inhabitants = 6
- 50,001 – 100,000 inhabitants = 7
- 100,001 – 300,000 inhabitants = 8
- more than 300,000 inhabitants = 9

number of the department and district

intersection

- not at an intersection = 1
- X intersection = 2
- T intersection = 3

intersection (cont.)

- Y intersection = 4
- more than 4 arms = 5
- roundabout = 6
- square = 7
- level crossing = 8
- other = 9

weather

- normal conditions = 1
- slight rain = 2
- serious rain = 3
- snow = 4
- fog = 5
- serious wind = 6
- lighting = 7
- covered = 8
- other = 9

collision type

- frontal = 1
- rear-end = 2
- side swipe = 3
- chain reaction = 4
- multiple = 5
- other collision = 6
- no collision = 7

address

type of day

- the day before holiday
- holiday

geocoding

Table C-1a: Characteristics of French National Accident Database (BAAC)

2. Localisation	
Category • motorway = 1 • national road = 2 • departmental road = 3 • local road = 4 • outside of public network = 5 • parking = 6 • other = 7 Traffic • single direction = 1 • bi-directional = 2 • separated roadway = 3 • other = 4 Number of lanes Roadway marking • yes or no Special lane • for cycle only = 1 • cycle way = 2 • reserved lane = 3 Longitudinal profile • flat = 1 • slope =2 • crest = 3 • dip = 4 Horizontal profile • straight section = 1 • left curve = 2 • right curve = 3 • S-curve = 4 Mileage • N° • meter	State of the road • comfortable = 1 • good = 2 • deformed = 3 • scattered object = 4 • bad visibility = 5 • scattered gravel = 6 • other = 7 Width (meter) State of the surface • normal =1 • wet = 2 • puddle =3 • flood =4 • snow = 5 • mud = 6 • ice = 7 • oil = 8 • other =9 Building • tunnel =1 • bridge = 2 • access road = 3 • railway = 4 • crossroad =5 • pedestrian area = 6 • toll area = 7 Accident situation • roadway = 1 • urgency way = 2 • shoulder = 3 • pavement = 4 • cycle way = 5

Table C-1b: Characteristics of French National Accident Database (BAAC)

2. Localisation	
Environment • built-up area not in town = 1 • no built-up area in town = 2 • monitored school point = 3 • unsupervised school point = 4 • bus stop = 5	Environment (cont.) • no shoulder = 9 • trees = 10 • increase in number of lanes = 12 • decrease in number of lanes = 13 • …
3. Vehicles	
Category • bicycle = 1 • motorbike = 5 • car = 7 • truck (3.5t – 7.5t) = 13 • truck (> 7.5t = 14 • … Special vehicle • taxi =1 • ambulance = 2 • fire engine = 3 • police car = 4 • school bus = 5 • hazardous materials transport = 6 • other = 7 Owner • driver = 1 • stolen car = 2 • owner in agreement = 3 • administration = 4 • company = 5 Vehicle problem • mechanic = 1 • lighting = 2 • worn out tire = 3 • burst tire = 4	Vehicle problem (cont.) • loading = 5 • moving = 6 • other = 9 Loading • solid =1 • liquid = 2 • gas = 3 • animal = 4 • other = 9 Insurance • yes or no Fixed obstacle • park vehicle = 1 • tree = 2 • metal crash barrier = 3 • concrete crash barrier = 4 • other crash barrier = 5 • wall, bridge = 6 • signs = 7 • post = 8 • urban facilities = 9 • parapet = 10 • traffic island, refuge = 11 • walk pavement = 12 • embankment slope, ditch = 13

Table C-1c: Characteristics of French National Accident Database (BAAC)

<table>
<tr><th colspan="2">3. Vehicles</th></tr>
<tr><td>Fixed obstacle
• other obstacle on the roadway = 14
• other obstacle on the shoulder = 15
• run off the road and no obstacle = 16
• other = 17
Moving obstacle
• pedestrian = 1
• vehicle = 2
• wild animal = 3
• vehicle on railway = 4
• other = 9
Initial collision point
• front = 1
• front right = 2
• front left = 3
• rear = 4
• rear right = 5
• rear left = 6
• right side = 7
• left side = 8
• multiple = 9
Main action before accident
• no modification of the direction = 01
• same direction
• same lane = 2
• between two lanes = 3</td><td>Main action before accident (cont.)
• going backward = 4
• wrong way = 5
• crossing central reservation = 6
• bus way, same direction = 7
• bus way, opposite direction = 8
• inserting action = 9
• U-turn = 10
• changing to left lane = 11
• changing to right lane = 12
• moving to left = 13
• moving to right = 14
• left turn = 15
• right turn = 16
• left overtaking = 17
• right overtaking = 18
• crossing the roadway = 19
• parking action = 20
• avoidance action = 21
• door opening = 22
• no parking stopped = 23
• parking = 24
Number of persons
Sporting speed
• yes or no</td></tr>
<tr><th colspan="2">4. Drivers</th></tr>
<tr><td>Localisation in the vehicle
Category
• driver =1
• passenger =2
• pedestrian = 3</td><td>Severity
• unharmed
• dead
• serious injured
• slight injured</td></tr>
</table>

Table C-1d: Characteristics of French National Accident Database (BAAC)

4. Drivers	
Socio-professional category • professional driver = 1 • … Sex • male =1 • female =2 Nationality Department or country Birthday • month and year Driver problem • fatigue = 1 • medicament – drug = 2 • disability =3 • disturbed attention = 4 • drinking apparent = 5	Alcohol • impossible =1 • refused = 2 • blood test = 3 • ethylotest = 4 • no known result =5 • negative detection = 6 Alcohol level Licence date Driving licence • valid =1 • out-of-date = 2 • take off =3 • learning = 4 • bad category = 5 • licence default = 6

Table C-1e: Characteristics of French National Accident Database (BAAC)