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CR/AEV1	Andreas Georgi	0711/811-42024	0711/811-1720	10/12/2010

Report Number
CR/AEV 10/025

R&D Report: **Final Report**

Security Class: Internal Export control relevant: No

Title: AEV-064: Annual Report 2009 – Details Accident Research

Abstract

1. Issues (situation, motivation and tasks)

AEV-064 represents the CR-Scouting activity with focus on accident research and crash simulation. The main idea of the project is to support the benefit oriented system development for active and passive safety along with the vision of injury (accident) free driving.
Key topics are:
-Benefit analyses and requirements of vehicle safety systems
-Risk analyses for future vehicle safety systems
-Input to focus roadmaps for safety systems
-Information about world wide road accidents and road safety activities
-Identify new systems in terms of accident mitigation and accident avoidance with new methods
-Know how build-up in the fields of crash and occupant simulation, human modeling, vehicle structures and occupant protection as base for future innovation
-Commission work (FAT-AK3 and 27, GIDAS, IRTAD)

2. Results

Based on the last years we can see that there is a high need of well-founded and latest information about the worldwide accident situation and the benefit estimation of new safety functions within our Bosch group. The present report contains detailed information of all studies in the field of accident research carried out in 2009.

3. Conclusions and Consequences

Since the project covers a broad variety of topics no final conclusion is given here. Please refer to the single short abstracts included in this report or the according presentations.

Document approval			
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Key Words
Traffic safety, accident research, crash simulation, occupant simulation, benefit estimation / analysis, active and passive safety, driver assistance systems, accident situation world wide including Asia, real world accident scenarios, accidents with injuries and property damage only, crash signals, injury criteria, occupant safety, safety of small and light weight vehicles

Underlying documents	**please link documents**		
Document number	**Title**	**Date**	**Responsible person**
CR/AEV 10/024	AEV-064: Annual Report 2009 – Overview Accident Research and Crash Simulation	09.12.2010	Andreas Georgi
CR/AEV 10/026	AEV-064: Annual Report 2009 – Details Crash and Occupant Simulation	13.12.2010	Andreas Georgi

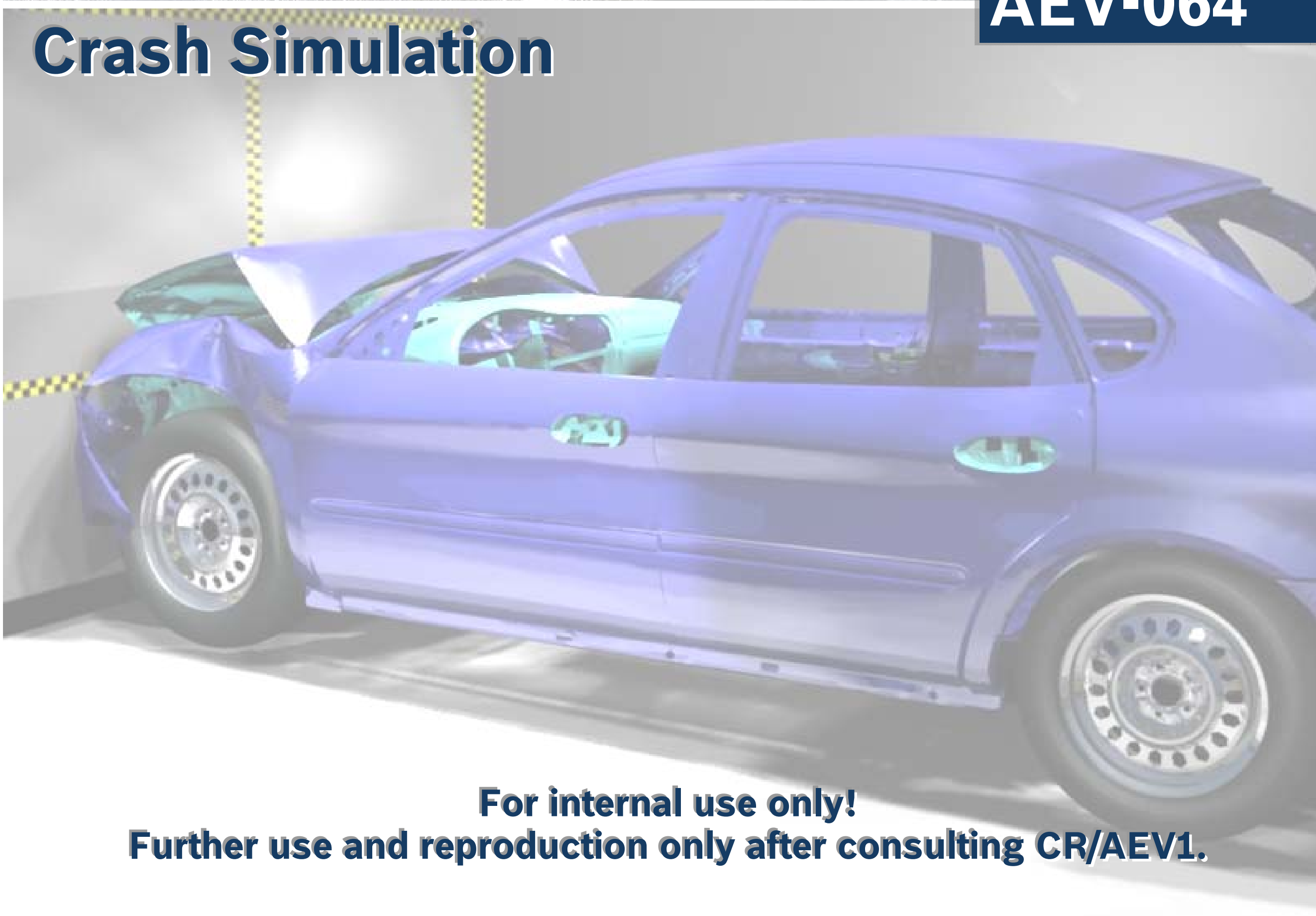
Annual Report 2009

CR/AEV

Accident Research

Crash Simulation

AEV-064



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Report

Issue 2009

Topic **Annual Report of Scouting Activity "Accident Research and Crash Simulation" (AEV064)**

Chapter

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Topic Annual Report of Scouting Activity "Accident Research and Crash Simulation" (AEV064)

Crash- & Occupant Simulation

For detailed reports please refer to the separate report with single focus on crash simulation (report number CRAEV 10/026).

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Report

Issue 2009

Topic **Annual Report of Scouting Activity "Accident Research and Crash Simulation" (AEV064)**

Abstracts of Investigated Topics in Accident Research and Crash Simulation in 2009

Topic Overview – Sub Project „Accident Research“

Person in charge: Andreas Georgi, Nils Kickler, Thomas Lich, Jörg Mönnich, Lisa Sulzberger

Chapter 4 – General Information to Accidents Situation Worldwide

Based on the last years we can see there is a high need on well-founded and latest information about the worldwide accident situation within our Bosch group. To meet all requirements we updated our standard accident research statistics arranged in different slides. The range of the presentations varies from the worldwide accident situation to different initiatives for advanced traffic safety where Bosch has its principal markets. Further on a chronological order of the accident situation or information about the major accident set-ups is supported.

The current link gives access to the continuously updated presentations for all Bosch employees and can be downloaded for distribution. We would be pleased if a reference to our department can be given in your presentations.

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Studies Accident Research

Chapter 5 – Benefit of PEBS in Germany and the United States

Nils Kickler

Scope

About 15% of accidents with personal injury in Germany and nearly 1/3 rd of those in the United States are rear end crashes. In this context, the US national highway traffic safety administration (NHTSA) intends legal regulations for the equipment of new vehicles with a forward collision warning system. In the current study, three different Bosch systems (PEBS) for forward collision warning, brake assist and automatic emergency brake were evaluated with respect to their accident avoidance potential.

Procedure

From the GIDAS accident database, more than 9000 accidents with personal image were examined, implying nearly 17000 vehicles. As the Bosch systems make use of a combination of driver warning, brake assist and automatic braking, the driver behavior was taken into account via a model combining different driver awareness, reaction times and brake strengths. Results obtained on the basis of GIDAS for the traffic situation in Germany were transferred to the US situation, using an US accident database (general estimation system, GES).

Results

About 12% (i.e. nearly 39'000) of accidents with personal injury in Germany can be addressed by PEBS systems. Driver reaction to the warning of the system has an important influence on the accident outcome, decreased in a partly autonomously braking system. For a driver with average reactions, nearly 1/3 rd of these accidents can be prevented by a warning-only system, nearly half with a system adding brake-assistance and up to almost 3 of 4 accidents adding further autonomous braking. In not prevented cases, the collision speed can be reduced between 25% and 55%, leading to reduced injury severity (quantitative evaluation under way). Accident scenarios leading to rear end crashes in the United States are similar to Germany; therefore roughly the same ratio of rear end crashes can be avoided. However, as rear end crashes occur almost twice as often in the US than in Germany, a higher influence of PEBS systems on the general accident situation can be expected.

Chapter 6 – Revision of Benefit Analysis of LDW/LKS/ASC

Nils Kickler

Scope

Lane Departure Warning (LDW) and the Lane Keeping System (LKS) are two functionalities under development by the business unit CC. The present study evaluates the accidents avoidance potential of these two systems, taking into account new specifications as compared to a former report from 2007.

Procedure

From the GIDAS database more than 8000 accidents with personal damage were examined, determining whether LDW or LKS systems could have influenced the accident outcome. For the evaluation of the warning only system (LDW), the driver's reaction time was taken into account.

Results

LDW or LKS potentially have a positive influence on 5% of accidents with personal damage in Germany (i.e. 16'400 accidents in 2005). About 0.4% (1229 cases in 2005) could possibly be prevented by an early warning of the driver, issued by a LDW system. An automatic lane keeping system shows increased efficiency, preventing potentially up to 1.6% or more than 5100 accidents in Germany. The increase in benefit stems from independence from the driver's reaction time and the capacity to influence the accident even if the driver is unable to react as in case of sudden disease.

Chapter 7 – Accident Situation of A and B Segment cars in Germany

Thomas Lich

Scope

Based on the official registration data a shift towards smaller vehicles is observed, at least for Germany but probably also within Europe in the future. About 25% of the registered passenger cars in 2008 in Germany are so called A or B segment vehicles. Due to this and future trends vehicle safety systems for this segment become more important. Therefore, accident analysis of these vehicle types is performed in order to find out whether a different accident behavior compared to all other passenger cars exists. Further, it was the aim to verify whether current driver assistance and vehicle safety systems could easily be integrated in such vehicle segments.

Procedure

The analysis is based on the GIDAS database and first separates the vehicle segments in three different categories. Only passenger cars are part of the analyses and the three different categories are divided into A, B and all other passenger cars. Active and passive safety systems will be considered. First an overview of location and severity is evaluated to focus on the most important accident types.

Results

A&B segment cars are less often involved in motorway-accidents, however, the general accident severity in this segment is increased. The severity distribution for A and B segment are nearly similar but a significant difference in terms of slight injuries compared to all other passenger cars is seen.

ESC & LDW/LKS also avoids at least 1/3 of severe accidents w/ leaving carriageway and the PEBS function avoids rear end collisions in between 1/3 and ¾ of cases. There is a significant correlation between accident leaving carriageway and ESC installation rate for the A & B segments. Therefore it can be assumed that this kind of accidents will decrease by further ESC penetration beginning in 2010! Future passive safety systems for the A and B segment have to fulfil the same safety level for each collision type as today. Continuing the analyses on severe accidents by location A&B segment vehicles have a higher share in frontal impacts if damage area is taken into account. A&B segment have more frequent incompatible collision partners in Front/Front accidents w/ higher injury severity compared to all other passenger cars.

Chapter 8: Analysis of Selected Real World Accident Scenarios

Lisa Sulzberger

Scope

With this accident data analysis the scope of Complex World Safety system and function ideas should be estimated. The results from the analysis provide information for ranking the system and function ideas. The information from the accident data can be used for function specification and system ideas in a more detailed way additionally.

Procedure

The analysis is based on reconstructed accidents with casualties from GIDAS (2001-2008). By weighting the data valid statements about all accidents with casualties in Germany are possible. For each function or new system in focus real accidents are selected. Based on these selections it is possible to determine the share of accidents in which the system might be activated and possible influence the further course of accident in a positive manner. Exemplary accidents are described in detail in order to provide an idea how the relevant accidents look like.

Determining the scopes of system and function ideas for airborne situations is only possible by analyzing single cases. The analyzed accidents concerning the relevance for airborne situations are selected by random sample.

Results

The results are separately provided for “Rotational Crashes” and “Airborne Situations”.

For Rotational Crashes it can be concluded that approximately 8% of all accidents with casualties in Germany are addressed by at least one system or function idea to this collision type.

Based on the systematic accident selection the share of accidents with a potential airborne is evaluated to 5%. The single cases analysis provides detailed information about the attributes of such airborne situations.

Chapter 9 - Forecast of Trends in Accidents with Injuries in Germany

Lisa Sulzberger

Scope

The goal of this study is a statement about future road accidents. Firstly, we are interested in trends and changes in trends until 2020. In addition to that the characteristics of future accidents are interesting for us. By using this information it is i.e. possible to determine how the accidents in future will look like. Hence it can be determined what kind of safety system can address which accidents and how often in future.

Procedure

The forecasts are based on accident data from the Federal Statistical Office in Germany. For generating a forecast the attribute “accident type” is used. This information is available for datasets from 1991 till 2008. The dataset is divided into training (1991-2006) and test data (2007/2008). For every accident type (1-7) there is a separate time series available. The seven time series are analyzed separately and for each accident type there is a model calculated extra. A convenient model for describing the trend is selected and determined by using the Box-Jenkins method. In the Box-Jenkins method the trend in the past is analyzed, described by a model equation and then transferred into the future. Hence only trends and events from the past can be transferred into the future. If it is known that trends will change in future, it will be necessary to consider this behaviour with another method. Besides that if there are events, which will only occur in future, they will have to be integrated in the forecast by additional calculation instructions.

An example for events which will only occur in future is the market introduction of safety system with an expected significant influence after the years in the modelling data on road accidents. The influence of ESC and EBA on the trend of future accidents is estimated. Only these two functions are considered concerning their influence on the trend of accidents. ESC and EBA are safety systems with a significant effect on accidents and with a significant market penetration till 2020. Hence it is assumed that by integrating these two systems in the forecast the influence of safety systems is covered well.

The determined trends should be assessed critically because firstly the datasets used for modelling are short and secondly the forecast period is quite long. Usually forecasts are only made for the next two years. For these reasons the determined forecast is mitigated with advanced forecast horizon by using an exponential function dependant on the forecast year.

Results

The number of accidents with injuries total decrease from 1991 till 2020. Starting from the last year with known data (2008) there is a reduction in all types till the last forecasted year 2020.

The size of the reduction depends on the specified accident type. The number of accidents with type 2, 3 or 5 only reduces slightly from 2008 to 2020 (<10%). There is a moderate decrease in the number of accidents of type 6 and 7 (10%-20%). The reduction in the number of accidents of type 1 and 4 is big (>30%) from 2008 to 2020. Hence there is a visible decrease in the number of accidents with injuries in all types.
The comparison of the distribution about accident types in 2008 (this is the last year with known data) with the same distribution in 2020 (last forecast year) shows only small changes. There is a slight decrease in the share of type 1 and type 4 accidents. The share of type 3 accidents increases. In sum it can be seen that most of the shares do not change significantly.
By assuming a 100% market penetration of the safety systems in 2020, there is a clear additional reduction of 16% in the number of type 6 accidents expected.
Reference: For detailed information (above the slides in the annual report 2009), please contact us for the documentation.

Chapter 10 – Extended Analysis of Accidents with Property Damage only

Nils Kickler

Scope

Accidents with damage to property only occur about ten times more often than accidents involving personal damage or death. As most often these are not police-reported, accident scenarios are largely unknown. For a part of these cases however, claims are issued to car insurances. Based on this data, the present study gives an overview of property damage accident scenarios and possible systems addressing these cases.

Procedure

In cooperation with the “Allianz Zentrum für Technik (AZT)”, claims from property damage accidents (liability and own damage claims) were used to establish a database with about 4000 cases, describing each by about 100 variables. Grouping of the cases was first performed according to their accident type and then refined using information about the accident site and vehicle dynamic.

Results

About half of the accidents with damage to property only are related to parking situations, most on parking sites or private driveways. Of the remaining, a bit less then half are collisions with vehicles or objects on a straight driving lane, which could be addressed by emergency braking systems (PEBS). Further important accident situations are crossing accidents and departure from the carriageway, including head-on collisions.

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Chapter 11 – Status Accident Research Activities in Asia

Andreas Georgi & Thomas Lich

Scope

The highest market growth in automotive market is seen in China and India. In order to evaluate their needs for vehicle safety accident data has to be taken into account. Due to this the activities to receive valuable accident data in the Eastern countries have to be increased. In addition to this it is also necessary to come up with benefit estimations of existing systems like ESC, PEBS etc. in the more developed Eastern countries like Japan or Korea.

Procedure

To expand our activities in the Eastern countries – selected Institutes / Universities as well as Governmental organizations are contacted. A first start was setup in 2009 in Japan in order to receive In-depth Accident Data or data prior to the collision from Naturalistic driving studies. In addition to that several programs were setup in China and India together with OEM to setup an In-depth-Accident investigation. By sharing knowledge based in the field of data collection and study evaluations an in kind is given in order to receive full access to the data.

Results

In China a cooperation with CATARC (China Automotive Technology and Research Center) was established in order to evaluate the benefit of the ESP system. To reach this goal accident data has to be collected and evaluated based on police reported accidents.
In Japan an access to In-depth-Accident data and data from a Naturalistic driver study was established. Due to high costs of the In-depth-accident data the current activities are on hold. Further on a database with several example videos from the Incident data was setup. Approximately 600 out of 8200 near miss accidents were coded this includes approximately 270 accidents in Japan. Further on several contacts with OEMs and other institutes were achieved. Due to this future cooperation with OEM become possible.
In India partners were identified to setup an In-depth-accident investigation. Activities are quite slow but ongoing.
In Korea several activities were setup in order to find out the status of Accident Research within this country. Several companies / institutes were identified and contacted. Most important contacts are seen with the Samsung Traffic Insurance Institute in order to cooperate in the field of In-depth-Investigations either with personal damage or only property damage only. Exchange is ongoing due to internal discussion at Samsung. Further on the Korean Transport Institute ran in cooperation with Taxi organizations an education program were data were collected prior and during an accident. The contact will be kept due to high interests of the Institute to cooperate with RB.

Chapter 12 – Overview of the Accident Situation in 2007 for Japan and Korea

Thomas Lich

Scope

In order to expand our activities in the ASEAN countries and to support our business units with standard statistics the accident scenery in those countries was investigated. The highest economic growth is seen today in some of the ASEAN countries; therefore accident research becomes more important in order to investigate in future safety technologies related to those countries. To start these activities a closer look at the more developed countries was taken. These countries are Japan and South Korea. Both countries support official statistical reports on traffic safety.

Procedure

Based on the standard statistics already setup for Germany a comparison of Japan/Korea against Germany was aimed. Therefore the task was to find equivalent information in the official reports and beyond. Also socio-economic costs were considered and part of the analysis in order to see major differences as compared to western countries.

Results

A comprehensive overview of the accident situation in Japan for 2007 and a good overview of Korea were obtained. As already known the lowest fatality rate is seen in Japan as number one currently and Korea will be at position four. For Japan detailed information on the top ten prefectures is shown which results in a more or less well common distribution of - for instance fatal accidents in all provinces. Since 2000 the number of fatalities is decreasing whereas the number of registered passenger vehicles remains the same or increases. Further, about 11.2 million reported accidents occurred in Japan, which are two times more as compared to Germany. For 2004 approximately 6 745 billion Yen were spent on the socio-economic costs of road traffic accidents in Japan. In addition, the highest share of fatal accidents occurs with pedestrians. Most of the accidents occur within urban areas whereas accidents near intersections have the highest share within this area.

Chapter 13: Information to Project “ASSESS – Assessment of Vehicle Safety Systems”

Lisa Sulzberger

Scope

In this FP7-EC-project a relevant set of test and assessment methods applicable to a wide range of integrated vehicle safety systems should be developed. Different procedure will be developed for driver behaviour evaluation, pre-crash system performance evaluation, crash

performance evaluation and socio economic assessment. The proposed set of test and assessment methods will be evaluated on the basis of actual safety systems currently offered to the market. It is planned to evaluate the developed test and assessment methods by applying them to the “BAS (Braking Assistant) Plus” of Daimler and to the “Advanced PCA (Pre-Crash Assistant)” of Toyota. It is planned to use the developed test procedures as basis for additional legislative measures on EU-level or consumer tests.
The project started in July 2009 and will last 3.5 years. It is subdivided in 7 work packages. Bosch is mainly involved in the first work package in which test scenarios will be defined based on accident data analyses. Besides Mr. Kropf (CC/NE2) is a member of the supervisory board. The participation makes it possible to monitor the activities in all work packages of the project and to intervene if necessary.

Results

At the moment there are only results from work package 1 available.
Based on accident data of different levels of detail and from different countries accidents with injuries involving at least one car are ranked concerning the accident type. In the following table the most frequently occurring accident types are given. The frequency is determined based on injury costs caused by the accident.

Rank	Accident type
1	Type 1a: Driving accident - single vehicle
2	Type 6: Accidents in longitudinal traffic (6a and 6b included)
3	Type 2&3: Accidents with turning vehicle(s) or crossing paths in junction
4	Type 4: Accidents involving pedestrians

References

For more information, please see on http://www.assess-project.eu or in deliverable D1.1.

Chapter 14: Joint Study for Determination of Safety Potential for Vans

Andreas Georgi

Scope

Even though perceived differently by the public, the accident risk of vans does not differ significantly from the one of cars or trucks. As for cars and trucks, additional efforts are needed to reduce risks and to improve the safety of vehicle occupants and other road users.
In order to determine adapted safety measures, a thorough analysis of the different accident scenarios involving vans is needed. Therefore, a corresponding research project was initiated by different German organizations (BASt – German road traffic administration, UDV – Accident research of car insurances, DEKRA, VDA – Association of German car manufacturers).

Procedure

The present analysis was based on accident data from GIDAS (German in depth accident study), data from the German car insurances, DEKRA and national statistics. The main focus was on aspects of passive and active safety as well as driver assistance systems, driver behavior and education and van load handling. Of interest were further questions of occupant safety and protection of other road users.
As a member of the VDA - automotive research association (FAT, Arbeitskreis 3) Bosch was responsible for the evaluation of the active safety systems.

Results

The results presented in this report are preliminary. Further work will compare the findings to the official German statistics and the accident situation in other European countries.
Except for small deviations, the accident scenarios of vans correspond to those of cars. Differences were found in accidents involving pedestrians, accidents involving backward driving vans and in the reasons for which the accidents occurred.
Occupant safety in vans was assessed as “good” in this study. Van occupants were found to make use of the seatbelt less often than car occupants. The injury risk for van occupants is in general below that of car occupants, unbelted occupants run higher risks than belted ones. Appropriate educational measures as well as technical solutions (i.e. seatbelt reminder) could reduce this risk.
Van drivers loose less often control over their vehicle than car drivers. Still, ESP is a useful measure and has been shown to reduce the accident risks for vans. Of further use might be lane departure warning systems and braking assistance for the prevention of rear end collisions.
Further evaluations of driver assistance systems are planned for the second project stage.

Small Studies Accident Research

Chapter 15 – Overview crash box deformation in frontal collisions of cars

Nils Kickler

Introduction

Today’s vehicle-crashboxes are soft-structured low cost extensions of the main chassis beam protecting the latter, in case of a low speed collision, from damage. Using an adaptive structure instead, increased in stiffness in case of an imminent high velocity impact, would allow shortening of the main chassis beam to reduce weight. In the current study, we have estimated the impact angles which this new structure would need to support, functioning as classical crashbox or as main chassis beam.

Procedure

From the GIDAS database, 3319 passenger cars implied in frontal collisions with personal damage were classified into cases presenting or not damage to the main chassis beam. In each class, the number of cases per impact angle was counted.

Results

In about 90% of the frontal collisions with personal damage where the main chassis beam is deformed the impact angle is below +/- 45° (relative to the vehicle's longitudinal axis). An adaptive structure presenting the same properties as the main chassis beam for impact forces within this angle segment could therefore replace the main chassis beam in most cases.

Chapter 16 – Accidents in Germany Involving Animals

Thomas Lich

Scope

Accidents involving wild animals are typically not in focus of official accident statistics reported by the police, due to the fact that those accidents normally are property damage accidents only. Nevertheless a minor share of accidents involving animals leads to personal damage and are thereby in the official statistics. In order to motivate driver assistance systems in a more advanced way this analysis was done to find out their share of significance within the accident scenery in Germany.

Procedure

Two investigations were performed in this analysis. Based on the official statistical yearbook the number of accidents involving animals was evaluated for Germany. Further on the German Insurance Association (GDV) was running an investigation on accidents involving wild animals from 1997 to 2005 within a closed area in Germany. Results of the final report were taken into account and pointed out in this report.

Results

Shares of 4.5% of all accidents with property damage only are accidents involving wild animals in Germany. Nevertheless the number of fatalities account for 19 out of 3597 accidents w/ personal injuries. Within these 3597 accidents 4183 persons suffered from injuries in 2005 in Germany. Within the investigation it was found out that for 2005 the majority of accidents occurred during night time or during dawn light conditions. Based on the official reports most of these accidents occur in rural areas.

Chapter 17 - Preset – Road leaving and High Relative Impact Speed
Lisa Sulzberger

In the first part of this analysis accidents were selected in which a car had an initial front impact after leaving the road. In about 5% of all accidents involving injuries the car crashes frontally into a pole.
Secondly, accidents with injuries are analyzed in order to determine the share of cars with high relative impact speeds in single front impacts. Cars with a single front impact and a relative collision speed of more than 44 kph take a share of about 15% of all accidents with injuries in Germany.

Chapter 18 – Rollover: Overview (JP, USA) and Truck Rollover accidents (USA)
Andreas Georgi & Thomas Lich

Scope

Rollover accidents are most often reported within the USA. In order to motivate ESP or Rollover Sensing systems in Japan an investigation on rollovers was done. Additionally, accident statistics on rollovers from US were considered. Further on the influence of ESP on rollover occurrence was pointed out based on a GIDAS analysis which was done for rollover accidents prior to this analysis (see UFO annual report in 2008). Behalf of that a short introduction to the physics behind a rollover out of longitudinal movement is given.

Procedure

In order to find out the significance of rollovers in Japan the official annual report was investigated. For the US the annual NASS report were examined due to the fact that rollover is frequently reported. The analysis of ESP influence was done within a single case analysis of 389 rollover accidents w/ personal injuries within the GIDAS database.

Results

In 2006 in Japan a share of 3% out of 886864 accidents with injuries are accidents against a fixed object or the vehicle is leaving the carriageway. Within this accident kind a share of 18% out of 6147 accidents are fatal accidents. Rollover occurrence is not reported directly but based on the accident type approx. 23% of all accidents w/ casualties a rollover occurrence is possible or occurred.

In the US the share of vehicles that rolled over in fatal crashes (21.6%) was 4 times higher than the share of injury crashes (5.3%) and 15 times higher as the proportion in property-damage-only crashes (1.4%). Compared with other vehicle types, utility vehicles experienced the highest rollover rates in fatal crashes (35.1%) and in injury crashes (9.8%).
Based on an odds-ratio calculation of GIDAS accidents it is evaluated that an ESC-system could reduce rollover occurrence by to more than 50%.

Chapter 19 – Relevance of Technical Defects in Accidents

Lisa Sulzberger

Results of analyses of technical defects in common and technical defects in accidents are collected in chapter 19. This chapter is subdivided into three parts. In the first part information with respect to technical defects of vehicles is given. DEKRA provides results from general inspections, i.e. 83% of the inspected cars are defective. Additionally more details about the defective cars are visualized in different diagrams. Furthermore, the causes for accidents with injuries are presented in several diagrams, whereby the focus is again on technical defects. Based on these diagrams statements about technical defects in accidents and accidents caused by technical defects are possible. For example in about 1.5% of all accidents with injuries there is at least one car with a technical defect involved.

The second part of the study deals with defective fuel pipes in cars after the impact. In this analysis first accidents where fuel is running out from the pipe of one vehicle are selected. Secondly the number of accidents involving burning cars is determined.
Results from analyses to stranded vehicles in Germany, USA and Japan are given in the last part of chapter 19. For example in Germany in less than 2‰ of all accidents with injuries there is a stranded vehicle involved. In the USA for instance less than 1‰ of all accidents with casualties and property damage only are contributed by a car with a technical defect in power-train.

Topic overview – sub project „Crash- and Occupant Simulation“

Person in charge: Gian Antonio D'Addetta, Maja Ivanlic, Josef Kolatschek

Studies within the Subject Area „Structure“

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Report

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Topic Annual Report of Scouting Activity "Accident Research and Crash Simulation" (AEV064)

Abstracts of Investigated Topics in Accident Research and Crash Simulation in 2009

Chapter 20 – Analysis Structural Chain of Small & Lightweight Vehicles

Gian Antonio D'Addetta

Scope

Motivated by CO2 reduction and the according weight reduction in all vehicle segments (A to E segment) as well as recent sales and future market trends towards more small and light vehicles (A, B segments) an analysis of the structural chain of recent and future lightweight vehicles and according concepts is aimed at.

Procedure

First, a study of the crash performance & efficiency of restraint systems based on publicly available crash test results (ODB 40 % Offset & Full Frontal) is accomplished. Furthermore the distribution of dissipated crash energy is analyzed component by component based on publicly available and own FEM crash simulations. An in-depth literature and case study survey of crash compatibility scenarios of small vs. large cars points out relevant problems. The above work is accompanied by consulting activities of the Arbeitsgruppe Unfallmechanik (AGU) Zürich, Switzerland (Prof. Walz & Dr. Muser). Additionally first simulation results with a simplified multibody vehicle model are generated.

Results

Based upon the above procedure know-how was built up which amongst others allows to elaborate the potential for adaptive front structures in different vehicle classes ranging from small lightweight vehicle to compact and large cars. There is a potential for adaptable front structure stiffness within the longitudinal load transfer mechanisms if the crash box & longitudinal beam are restructured. The highest potential exists for vehicles of the compact class & upwards. In the theoretical limit an up to 1/3 decrease of the average vehicle deceleration in the second crash phase is achievable. Therewith a decrease of occupant loading & injury values is expectable.

Furthermore, compatibility measures e.g. through future legislation changes could act as a further additional driving force, since a better detection of offset crashes and therewith a better adaptability to Euro NCAP (40 % ODB) vs. US NCAP (100 % full frontal) crash cases is possible.

Based on the won insights and know-how build-up in 2010ff a support by crash- & occupant simulation (FEM & MBS simulation) of the adaptive front structure project within CR is planned.

Therein, a more detailed analysis of the influence of adaptive front structures on the occupant load and injuries will be carried out.

From
CR/AEV1

Our Reference
Project staff AEV064

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24.02.2010

Report

Issue 2009

Topic Annual Report of Scouting Activity "Accident Research and Crash Simulation" (AEV064)

Abstracts of Investigated Topics in Accident Research and Crash Simulation in 2009

Chapter 21 – Adaptive Crash Structures

Maja Ivanlic

An ODB-Test with 64km/h requires a deformable structure with high stiffness to prevent great deformation of the occupant compartment. In return at low velocities the stiffness of the deformable structure should be as low as possible to keep the damage of the structure to a minimum. Different crash situations necessitate different stiffness of the frontal car structure in terms of preventing excessive deceleration levels and reaching the best occupant protection. A possible way to reduce the occupant load is to make the frontal vehicle structure adaptive thus for every crash configuration the optimum front end stiffness could be adjusted.
In view of the Adaptive Crash Structure (ACS) Project which will start in 2010 a preliminary study considering the influence of the increase of the crash box stiffness to the level of the first longitudinal member on the occupant. Furthermore an answer to the question whether the bumper foam for pedestrian safety can be omitted if the force level of the ACS is strongly reduced, is seeked. All in all this study represents the summary of different small studies.

Chapter 22 – Future Structure Concepts

Maja Ivanlic

The decrease of the CO_2-emission is a priority objective the automobile industry has to challenge in present and future. The reduction of the vehicle mass is very important for lower fuel consumption and CO_2-emission which could for example be reached by lightweight construction. Steel structures still show lightweight potential. However, an even more attractive CO_2-reduction potential for lightweight bodies in white structures could be represented by a multi material approach. A further way towards reaching an overall reduction of CO_2 is the use of an alternative mode of driving like with hybrid or electric vehicles. For this purpose new vehicle structures have to be considered for a safe embedding of the batteries into the vehicle structure. Also the additional battery weight has to be distributed equally in the vehicle.
Changed vehicle structures and weight distribution, respectively, and the trend to a higher overall structure stiffness of the vehicle have a great influence on the crash sensing and the restraint systems. The scope of this study is to work out which new technologies the automobile industry has to face in the future and what influence these new technologies have on the crash sensing and restraint systems.

From	Our Reference	Tel	Fax	Schwieberdingen
CR/AEV1	Project staff AEV064	0711/811-42024	0711/811-1720	24.02.2010

Report

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Studies within the Subject Area „Real World Safety“

Chapter 23 – Occupant Simulation in combination w/ Vehicle Dynamics for Complex World Safety (CWS)

Gian Antonio D’Addetta & Josef Kolatschek

Scope

The scope of this sub project was the determination of relevant boundary conditions of occupant simulations supporting the extension of the algorithm capability towards Complex World Safety (CWS) scenarios (based on 2009 projects of the business unit with an OEM). Therein, a check and verification of the general simulability of CWS scenarios including driving dynamics and the estimation of injury values for selected cases is planned. Finally, a derivation of criteria for the activation of restraint component should be possible.

Procedure

First step is the build-up of a simulation environment which includes the occupant simulation in combination with vehicle dynamics. This further includes the testing and processing of the available OEM scenario data with respect to simulability within the occupant simulation framework and the upset of generic off-road drive and crash scenarios (LS-Dyna) and transfer into occupant simulation (Madymo).

Results

The general ability to reproduce coupled off-road and vehicle dynamics scenarios within the CR/AEV1 simulation tool chain was shown and proven by a build-up of various OEM CWS & additional generic scenarios incl. restraint systems.
The evaluation of corresponding occupant head accelerations shows more or less acceptable injury levels in most CWS scenarios. However, the injury risk for the occupants due to secondary injuries following a preceding occupant OOP during and in particular after the CWS scenario is much higher. This yields a high potential for an earlier deployment of according restraint systems.
The positive results encouraged the continuation of the work in 2010. Due to time restrictions (reduction of weekly working hours from 40 h to 34.5 h) only 250 h of the initially planned 400 h could be invested into this sub project.

From	Our Reference	Tel	Fax	Schwieberdingen
CR/AEV1	Project staff AEV064	0711/811-42024	0711/811-1720	24.02.2010

Report

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Abstracts of Investigated Topics in Accident Research and Crash Simulation in 2009

Chapter 24 – KOLLSIM - estimation of occupant injury potential

Gian Antonio D'Addetta

Scope

The scope of the short study was the determination of the injury potential of the KOLLSIM scenario on vehicle occupants. The new CR/AEV test carrier is equipped with a system that generates high lateral pulses. This may result in a critical movement of the occupants.

Procedure

Therefore, a simulation environment for an according occupant simulation was build up. For this purpose the CWS scenario was adapted. Afterwards the measured pulses (lateral acceleration pulse) of the first KOLLSIM experiments is implemented and used for a loading of the occupant cell. The measured occupant loading is compared to vehicle dynamic and crash scenarios in order to estimate the influence on the occupants.

Results

General remark: a dummy is typically not used to estimate occupant kinematics & occupant loading for low-g cases, since no active moving & muscle activity is included in dummies compared to human occupants. Main result is that the occupant loading for the KOLLSIM pulse is comparable to the standard driving dynamics loading. The only critical point may be the neck loading, in particular the neck moment and the neck forces. An additional expertise by the Arbeitsgruppe Unfallmechanik (AGU) Zürich (Prof. Walz / Dr. Muser) states that the neck loading is not negligible and cannot fully be evaluated by these occupant simulations (see general remark).
A possible scenario could start with the half pulse and could be stepwise increased up to the maximum pulse. Thereby, the head accelerations and occupant kinematics can be controlled by an in-car camera.

Chapter 25 – Active Human Modelling for Driving Dynamics & PreCrash Phase

Gian Antonio D'Addetta

Scope

Today's dummy (CTD‘s) and human body simulation models have been developed for high-g loading (crash). However, the development of innovative safety systems in the context of Rollover, PreCrash belt tensioning, autonomous braking & steering, integrated CAPS functions etc. requires a forecast in the low-g area. The aim of the starting industrial consortia OM4IS

(Occupant Model 4 Individual Safety) is the development & build-up of an active human model for low- & high-g area in order to predict kinematics of human vehicle occupants.

Procedure

Finalization of consortia participation (agreements, financing, meeting, telecons, etc.) with Forschungsgemeinschaft virtuelles Fahrzeug (viF), TU Graz, Austria. First steps are the detailing of the project including a further adaptation of the sub-project towards the project partners, the interchange with the partners concerning the availability of in-kind work and data according to the corresponding project needs.

Results

Participation in viF consortium, whereby signature of RB including the commitment for the three year project (2009 – 2011) 20 k€ p.a. was finalized in December 2009. New partnerships with BaST and LMU München for the complete project were established in 2010. Furthermore the first encouraging results were presented, e.g. an extensive literature overview of human modelling, an investigation about the usability of the THUMS model and first principle tests with EMG-measurement of muscle activity were presented.
In 2010 sled tests and vehicle tests for an enhancement of the numerical model are planned.

Studies within the Subject Area „Signals“

Chapter 26 – Feasibility of FEM Simulation of Body Sound Crash Signals

Josef Kolatschek

Scope

In recent years the use of structure borne sound (body sound) was introduced in the area of crash sensing. The difference to classical crash sensing with acceleration sensors is the frequency range of the observed signals. Whereas the classical method uses frequencies up to ca. 400 Hz, body sound sensing is done in the range between 5 kHz and 20 kHz. Main task of this study was to show if the FE method is in principle able to simulate body sound signals, to estimate the factors influencing the quality of the simulation, to establish some preliminary guidelines concerning the simulation of crash body sound signals and to investigate with this method in detail body sound propagation within the car structure.

Procedure

Based on simulation experiments the necessary numerical procedures to simulate high frequency body sound propagation in vehicle structures were identified and described. These procedures were applied on an existing FE vehicle sub model to simulate body sound waves. The resulting signals were analyzed concerning spectral content and transformed to a standard measure used by the restraint algorithm. Effects of wave dispersion, wavelength and wave type on the signal characteristic were investigated in detail, as well as effects of sheet metal bounding technique.

Results

It could be shown that with the FE method it is possible to identify the general properties of body sound transmission in a vehicle and to identify critical car body segments to the body sound propagation. However this requires either new vehicle models or extensive rework of existing ones to reach the numerical quality necessary to a successful body sound simulation. Interaction between the waveforms compression- and bending-wave within the vehicle structure have strong influence on the crash signal and may establish non linear effects in the wave propagation.

The achieved results can be used as guideline for further application of FEM for body sound simulations. It could also be shown that FEM simulation can already be used as a tool in customer projects to identify critical areas in signal transmission, e.g. areas of strong signal attenuation. Quantitative forecast of SBS crash signals for complete vehicles seems possible, but will still require considerable effort (time frame > 2 years). Next steps should be: Assessment of the influence of typical damping material on body sound signals, systematic comparison of FEM calculations with experimental data and further investigations on the influence of joining techniques, geometry and wave properties, like dispersion, etc. and the investigation of body sound generation in the crash zone.

Chapter 27 – Geometry and Crash Compatibility (Car2Car, Truck Rear Underride)

Josef Kolatschek, Jörg Mönnich

Scope

In reality a crash is often preceded by a braking process. This causes a pitch angle of the vehicle, thus altering the crash geometry. In contrast to this, the geometrical vehicle set up for crash tests is always without a pitch angle. One goal of this study is to simulate the effect of such a pitch angle caused by braking in a crash and to asses if this puts an additional load on the occupant. Also the influence of such a pitch on the crash signals needs to be described.

Another field of geometrical crash compatibility is the truck underride case. In this context recently a new legislation was introduced by the European Union, addressing the construction of a truck rear underride protection. Here the following questions are studied: What is the relevance of underride situations, what is the influence of geometrical properties of the underride structure on the crash, what are the main crash pulse characteristics of the passenger vehicle and what is the typical deformation pattern of the passenger vehicle.

Procedure

Derived from common geometrical properties, CarSim simulations and informations from accident research, a typical pitch angle is established. Based on this pitch angle the following crash situations are simulated and the resulting signals analyzed: 32 km/h and 56 km/h full frontal against rigid barrier, 2 x 56 km/h front-front car to car collision and 80 km/h front - rear crash. For the underride problem, a barrier model, based on the constraints given by the EU rule is set up. This barrier is applied in different geometrical set-ups to simulate a vehicle underride with a speed of 56 km/h. The relevance of the underride situation is derived from accident research.

Results

A pitch angle of 2.5° seems achievable in an emergency braking procedure. Therewith, and under the precondition given by the simulated vehicle in a full frontal crash situation no increase of the occupant load is obtained. For the front-front crash situation there is a possible contribution to the occupant load. The same is true for the front-rear crash situation. In all cases the characteristics of peak height and position of peak in the acceleration signal is altered, thus influencing the behavior of any restraint algorithm sensitive to such a feature.
The truck underride crash constitutes an enhanced risk for injury and death compared to all crash situations. It can be divided into three separate phases: In phase I the acceleration signal is influenced by the detailed geometrical properties of the crash situation. In phase II the influence of the crash geometry is leveled by the fact that the interaction between vehicle and barrier gets independent of the initial geometry. Phase III is sensitive to the geometrical properties of the truck behind the underride barrier. The accelerations are in every case low, occupant load is solely introduced by deformation of the passenger compartment.
The overall influence of the initial pitch angle on the occupant seems to be low as derived from comparison of crash pulses. However this conclusion should be ascertained by direct simulation of the occupant load, including the obtained, simulated crash signals, either with MKS or with FE methods.
The influence of the observed differences of the crash signals on the restraint algorithm needs to be further studied.

The underride barrier as prescribed by the EU rule is not able to withstand a 56 km/h vehicle crash. This poses, depending on the truck geometry, a very high injury risk on the occupants. Depending on the market potential for such a product, further effort on underride severity mitigation devices is needed.

Chapter 28 – Capacitive Sensor for Side Impact

Maja Ivanlic

In a side crash the occupant is exposed to higher risk due to the smaller safety zone. Therefore the sensing principle for side impact crashes must recognize the severity of an accident with highest possible confidence and within shortest time. Several sensor principles like pressure sensors inside a door cavity or acceleration sensors are already in use. In this study the use of a capacitive sensor for detection of side impacts is introduced. This capacitive sensor uses the outer sheet metal of the door as opposite pole. A deformation of the door caused by side impact will change the distance between the poles and so the capacity of the sensor. Thus the side impacts can be recognized due to the change of capacitance. Aim of this study was to find the best mounting position for the capacitive sensor inside the vehicle door. The sensor position should be chosen in terms of highest deformation of the door. This means that in each realistic side impact enough deformation should occur at the sensor position to assure a secure detection of side crashes and to achieve the best occupant protection. The simulation results have shown that the capacitive sensor should be placed approximately at the position of the occupant in x-direction and in the middle of the door in z-direction. The exact position of the sensor should be defined for each vehicle individually due to the different sizes of vehicles/doors.

Chapter 29 – Analysis of Side Crash Signals

Maja Ivanlic

Passive restraint systems like airbags are customized by using crash signals from crash tests performed by the OEM's. These crash test data is only available at a late phase of the vehicle development process. With increasing simulation capacity and detailed high quality finite element models a calibration of restraint systems by using FEM crash signal data would be possible in an early stage of the development process. Crash signals generated in a FEM simulation are influenced by the whole car structure in particular by those parts the signal passes on the way from the impact point to the signal measure point (e.g. ECU). Not only the car structure but also the bonding technique of different parts influences the signal characteristics. This study should result in a better understanding of the crash signal propagation in a side crash. Knowledge should be built-up for the physical and mechanical procedures in a side crash during the first 20ms.

Chapter 30 – ClassFEM: Feature Space in Lateral Dynamics – A parameterized study

Josef Kolatschek

Scope

One purpose of ClassFEM is to investigate the possibility of the combination of passive safety with active safety on the basis of machine learning algorithms. One possible scenario to test this approach exemplarily is in the field of lateral driving dynamics. The main objective of this study is to provide a first insight into the characteristic and usability of the feature space of lateral dynamics for the purpose of classification algorithms on the basis of simulation results. Goal of such a classificatory is to distinguish between normal driving situations and potentially dangerous situations in order to activate reversible occupant protection actuators in the latter case.

Procedure

To achieve a high density in the feature space of lateral dynamics, a parametrizable test track for use with the simulation tool CarSim was developed. The driving of a vehicle through this test track was then simulated with a variation of the curve parameters, the vehicle speed and in normal as well as potential dangerous situations. Sensor values were recorded and analyzed for there suitability as input features for classification algorithms.

Results

Some features showed a very regular pattern, a behaviour is supported by theory. In the two dimensional feature space the possibility to distinguish normal from potentially dangerous situations already appears. Shortcomings in this study were the flat topology. On tilted or roads with slope the behaviour will be different. However this problem should be addressable by using roll or pitch data as additional features.

It seems very likely that in a high dimensional feature space and with modern classification systems, like the Support Vector Machine, one is able distinguish between normal driving and potential dangerous driving states. In combination with a relative simple algorithm concept this will allow the activation of reversible protection means with the potential to include informations of other sensors without altering the basic algorithm. Next step should be to set up a one-class classifier to produce a prototype classifier based on the here described features and to extend this concept to other situations than lateral driving.

From	Our Reference	Tel	Fax	Schwieberdingen
CR/AEV1	Project staff AEV064	0711/811-42024	0711/811-1720	24.02.2010

Report

Issue 2009

Topic Annual Report of Scouting Activity "Accident Research and Crash Simulation" (AEV064)

Abstracts of Investigated Topics in Accident Research and Crash Simulation in 2009

Chapter 31 – Misuse Loadcases

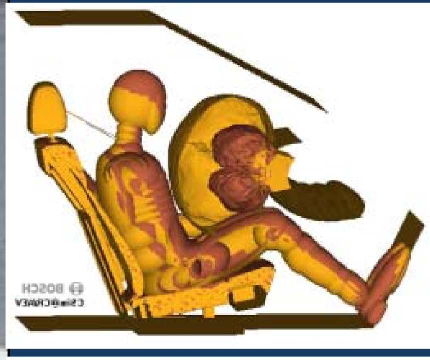
Maja Ivanlic

Driving over a curb or through a pothole at high speed can cause a wrong triggering of the algorithm. To prevent faulty triggering of the algorithm such misuse cases like hammer blow or driving through a pothole are performed and considered in the algorithm development phase based on test data. This misuse test data is only available at a late phase of the vehicle development process. With increasing simulation capacity and detailed high quality finite element models a sensitization of the trigger algorithm by using FEM misuse signal data would be possible in an early stage of the development process.
The aim of the study was to prove if it is possible to perform such misuse load cases with the available FEM models. The simulation of cases like “driving over a curb” and “driving through a pothole” have shown that none of these cases can be performed with the Taurus FEM crash model. To allow for acceptable results for acceleration signals with the Ford Taurus model a lot of modeling work on the tire model and suspension system model have to be spend. The hammer blow simulation shows a very oscillatory signal which can be reduced by using stiffness based damping.

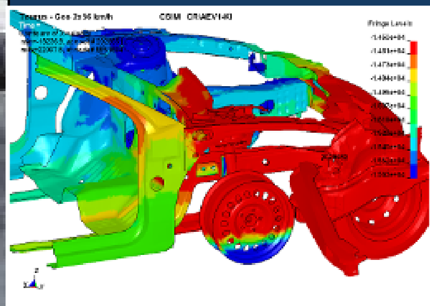
Overview of Accident Research and Crash Simulation in 2009

Accident Research and Crash Simulation CR/AEV1

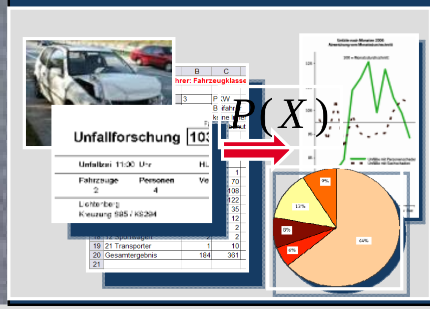
Analysis



Occupant Simulation



FEM Simulation



Statistics

Staff Objectives (in German)

Gruppenleiter: Reiner Marchthaler

Teamleitung: Andreas Georgi
Projektmanagement, Ansprechpartner Unfallforschung und Crashsimulation, GIDAS Arbeitskreis Vertreter, FAT Arbeitskreis 3, IRTAD

Unfallforschung (UFo)

Nils Kickler
Unfallanalysen und –auswertungen, Nutzwert- und Risikoanalysen von Fahrzeugfunktionen

Thomas Lich
Bewertung passiver Sicherheitssysteme, Unfallanalysen und –auswertungen, Nutzwert- und Risikoanalysen von Fahrzeugfunktionen, Ansprechpartner Raum ASIEN

Jörg Mönnich
Unfallanalysen und –auswertungen, Nutzwert- und Risikoanalysen von C2X-Funktionen, Unfallrekonstruktion, Vertreter GIDAS Expertengruppe Technik, ÖGP: „SIM TD“

Lisa Sulzberger
Unfall-, Nutzwert- u. Risikoanalysen von Fahrzeugfunktionen, Prognosemodell und statistische Methoden, EU Projekt: ASSESS

Crashsimulation (CSim)

Gian Antonio D‘Addetta
Insassensimulation, MKS-Simulation, Bewertung Insassenschutzsysteme, FAT Arbeitskreis 27 „Finite-Element-Anwendung im Automobilbau“, Active Human Modeling (Projekt: K2-vif)

Maja Ivanlic
Strukturuntersuchungen, FEM-Simulation, Crashsimulation

Josef Kolatschek
Strukturuntersuchungen, FEM-Simulation, Crashsimulation, Bewertung passiver Sicherheitssysteme

Update Accident Research (UFo)

- **Staff Ufo** within AEV-064
  - Status 2009: 4.2 staff members (constant)
  - 15% working hours reduction due to economic crisis in 2009
- **Cooperation / sub-contracting**
  - VDA FAT AK3: RB is Partner in GIDAS consortium **[status: running]**
  - Allianz Zentrum für Technik AZT: Expansion of database of accidents with property damage only, 2000 additional accidents analyzed **[status: terminated]**
  - Federal Statistical Bureau Germany (DESTATIS): Detailed official accident statistics purchased by RB **[status: running]**
  - Japan Society of Automotive Engineering (JSAE): Setup of incident database according to current JSAE data **[status: running]**
  - China Automotive Traffic Research Centre (CATARC): Support of ESC effectiveness study for China **[status: running]**
  - EU: Participation in EU funded project ASSESS **[status: running]**

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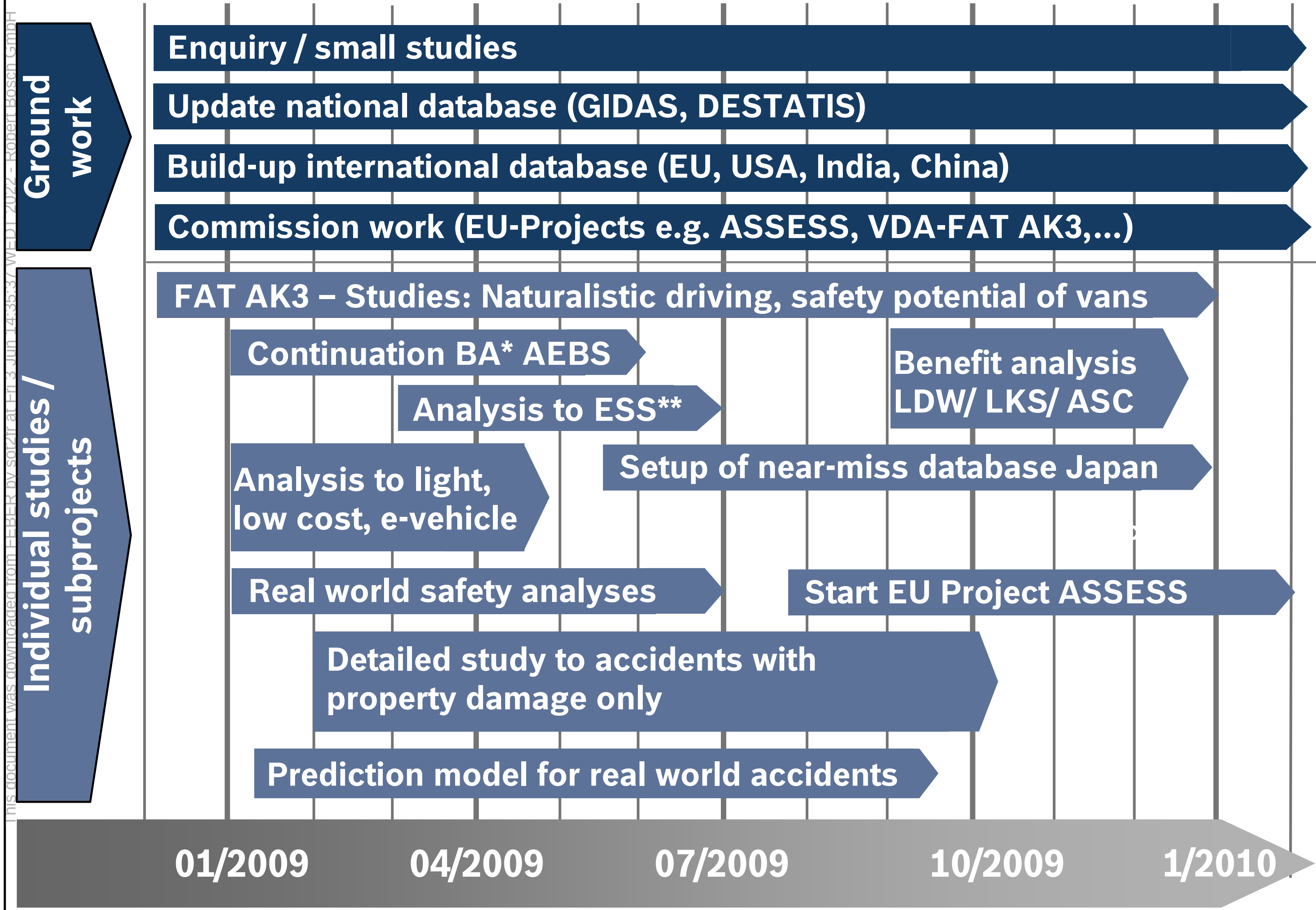
Updated version: Working hours reduction considered

Timeline 2009 accident research (UFo)



BU – clas-sification	Planned man hour in 2009
all	700
C/AI	500
C/AI	200
CC-DA	670
CC/EVM	550
CC	1150
C/AI	250
C/AI	550
C/AI	400
CR	530

Project management:
all 500h

* Benefit analysis ** Canceled due to higher analysis effort for AEBS-study

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Update Crash Simulation (1/2)

➔ **Staff CSIM** within AEV-064

- Status 2009: 2.5 staff members (constant)
  1.5 members focus FEM-Simulation
  1.0 member focus Multibody-Simulation
- 15% working hours reduction due to economic crisis in 2009

➔ **Infrastructure**

- January 2008: Start of Linux-Cluster w/ 12 nodes (3 server w/ 2 DualCore CPUs)
- October 2008: Expansion of cluster by 8 nodes (1 server w/ 2 QuadCore CPUs) cancelled due to resource limitations within RB
- Throughout 2009: Increasing capacity problems of cluster >> delay of simulation topics

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Update Crash Simulation (2/2)

Cooperation / sub-contracting

- Tecosim GmbH, Rüsselsheim: Enhancement of body-in-white model VW Golf V by addition of front components (engine, aggregates, etc.) **[status: terminated]**
- Virtuelles Fahrzeug (viF), Graz, Austria: Consortium active human modelling **[status: 1st of 3 years paid]**
- TNO Automotive, Helmond, The Netherlands: Multibody car models & creation tool, contact problematic, only 50 % of project paid (1st invoice), since no 2nd invoice received **[status: terminated]**

Software / licensing

- Change of licensing procedure for LS-Dyna (FEM-Simulation program for crash simulation): No direct assignment of SW partner DYNAmore GmbH, Stuttgart – licensing directly through RB central organisation CI/NEM3 (plan: 12 fixed CR/AEV1 locked licenses), help in preparation & transfer of activities to CI **[status: paid until 12/2010]**
- TASS Germany, Stuttgart: MADYMO (MB/FEM-Simulation program for occupant simulation) – licensing CSim on constant level, collective contracting for CC-OS/EPM & CR/AEV licenses **[status: paid until 12/2010]**

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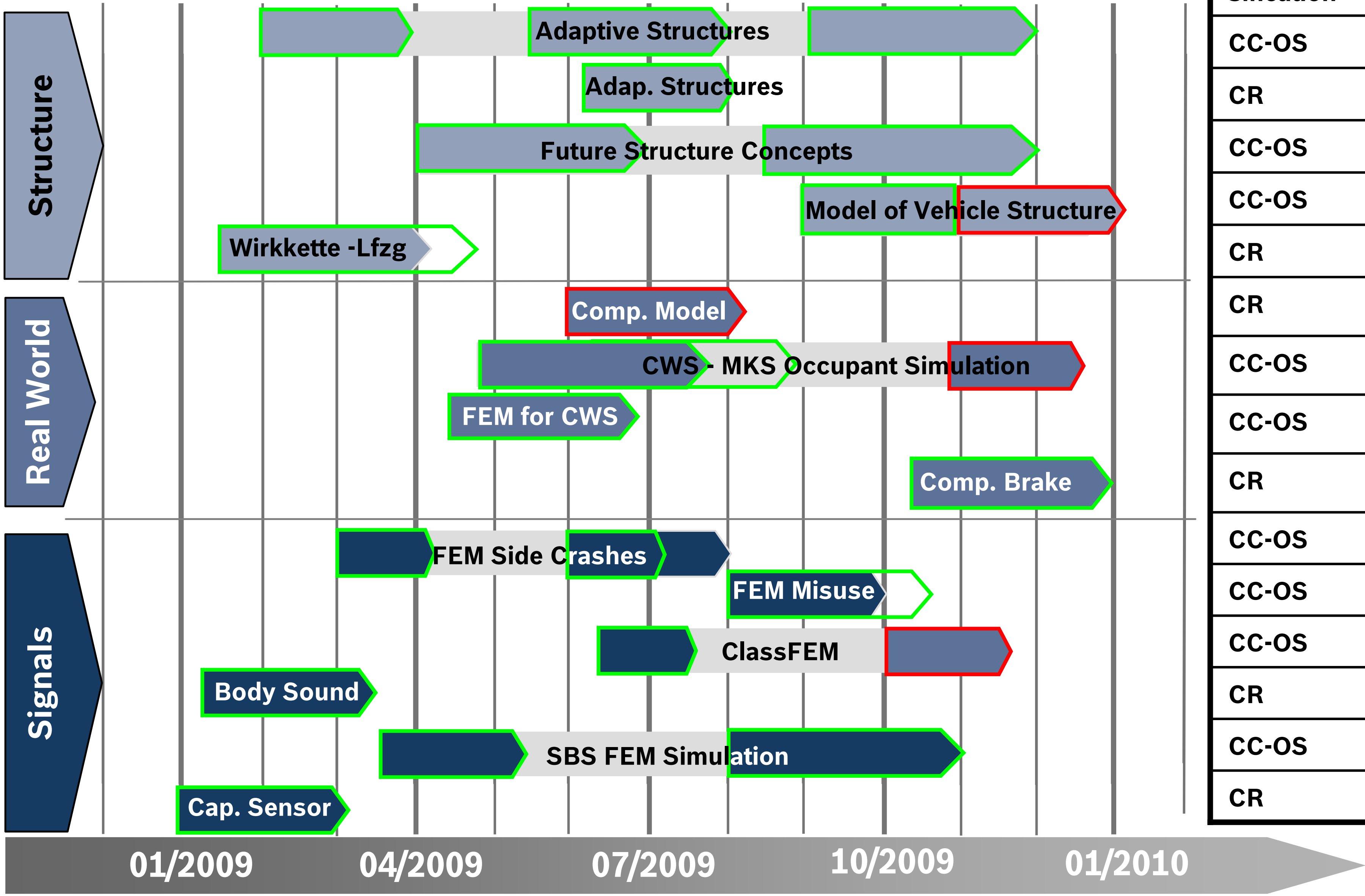
finished work package
canceled work package due to working hours reduction

Adapted timeline crash & occupant simulation



BU – clas-sification	hour plan.	dif.
CC-OS	530	0
CR	0	+150
CC-OS	350	0
CC-OS	250	0
CR	400	+100
CR	250	-250
CC-OS	400	-150
CC-OS	200	0
CR	150	0
CC-OS	250	-100
CC-OS	150	+100
CC-OS	150	0
CR	160	0
CC-OS	350	0
CR	130	0

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Accident Research RB – CR/AEV1 Standard Slides - Overview

Results of Accident Analysis

Accident Research CR/AEV1

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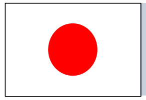
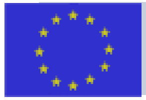
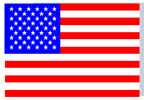
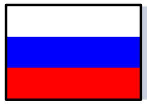
Road safety in 2007 – a public health issue

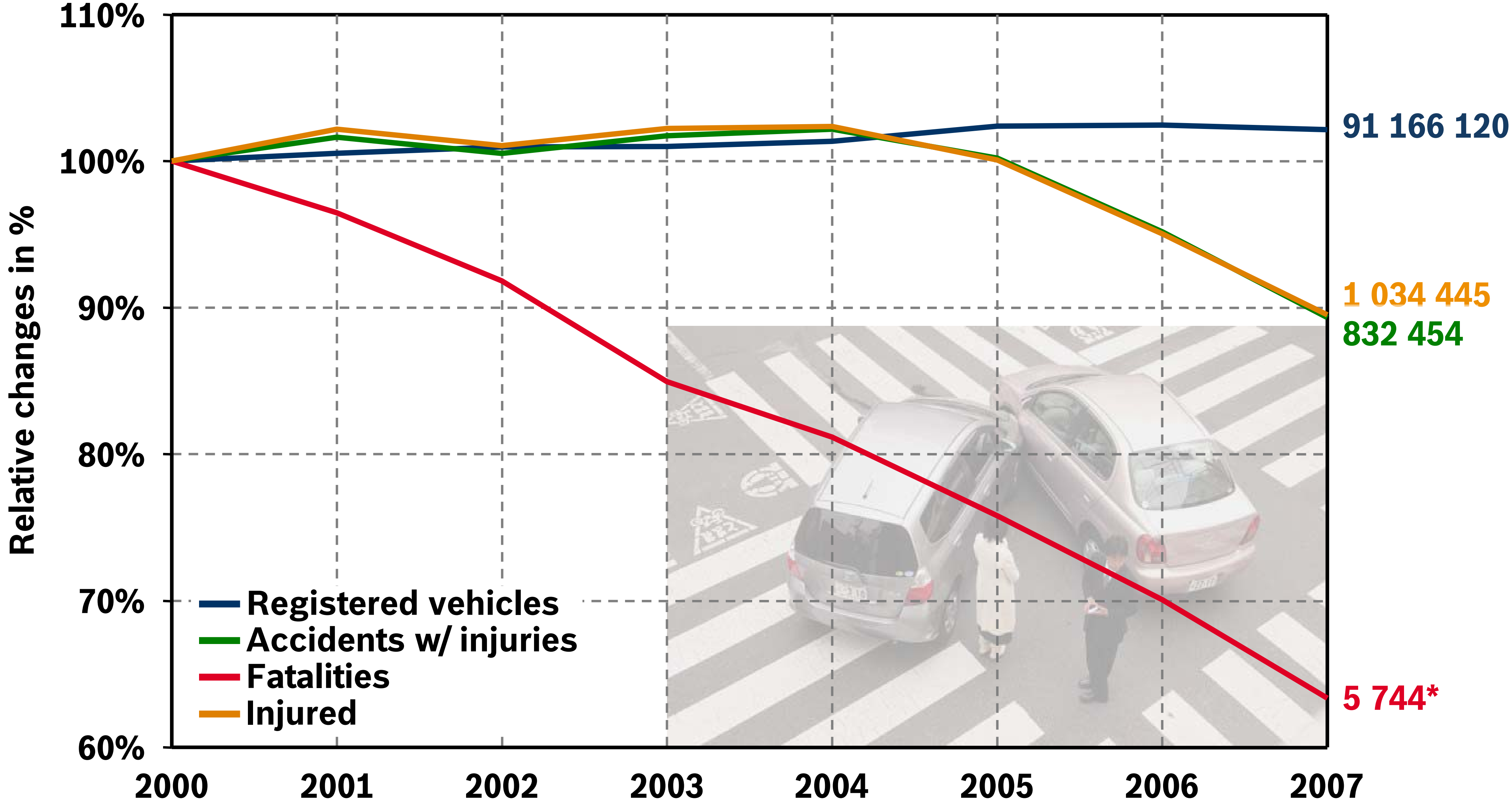
	Registered motor vehicles [Mio]	**Road accidents involving injuries** [Mio]	**Fatalities** (fatalities within 30 days after accident)	**Fatality risk per vehicle**
	91.2	0.83	**6,639**	**1 : 13,700**
	294.0	1.29	**42,485**	**1 : 6,900**
	255.7	1.75	**41,059**	**1 : 6,200**
	18.2	0.21	**6,166**	**1 : 3,000**
	49.6	0.38	**23,286**	**1 : 2,100**
	159.8	0.33	**81,649**	**1 : 2,000**
	35.4	0.23	**33,300****	**1 : 1,100**
	87.9***	0.42	**114,590**	**1 : 770**

** fatalities within 7 days after accident

*** 2006

Sources: IATSS Yearbook 2007, CARE 2007 (EU27), NHTSA Traffic Safety Facts 2007, Road Traffic Safety Authority Korea 2007, Yearbook 2006 Traffic Accidents China, DENATRAN 2007, Ministry of home affairs of the Russian Federation, Yearbook 2007 Autostat Russia, RAMI Annual Report 2007, Ministry of Home Affairs, Govt. of India

Road Traffic Accidents Japan



Source: Statistics 2007, Road accidents Japan

* Fatality within 24 hours – 6639 fatalities within 30 days after accident in 2007

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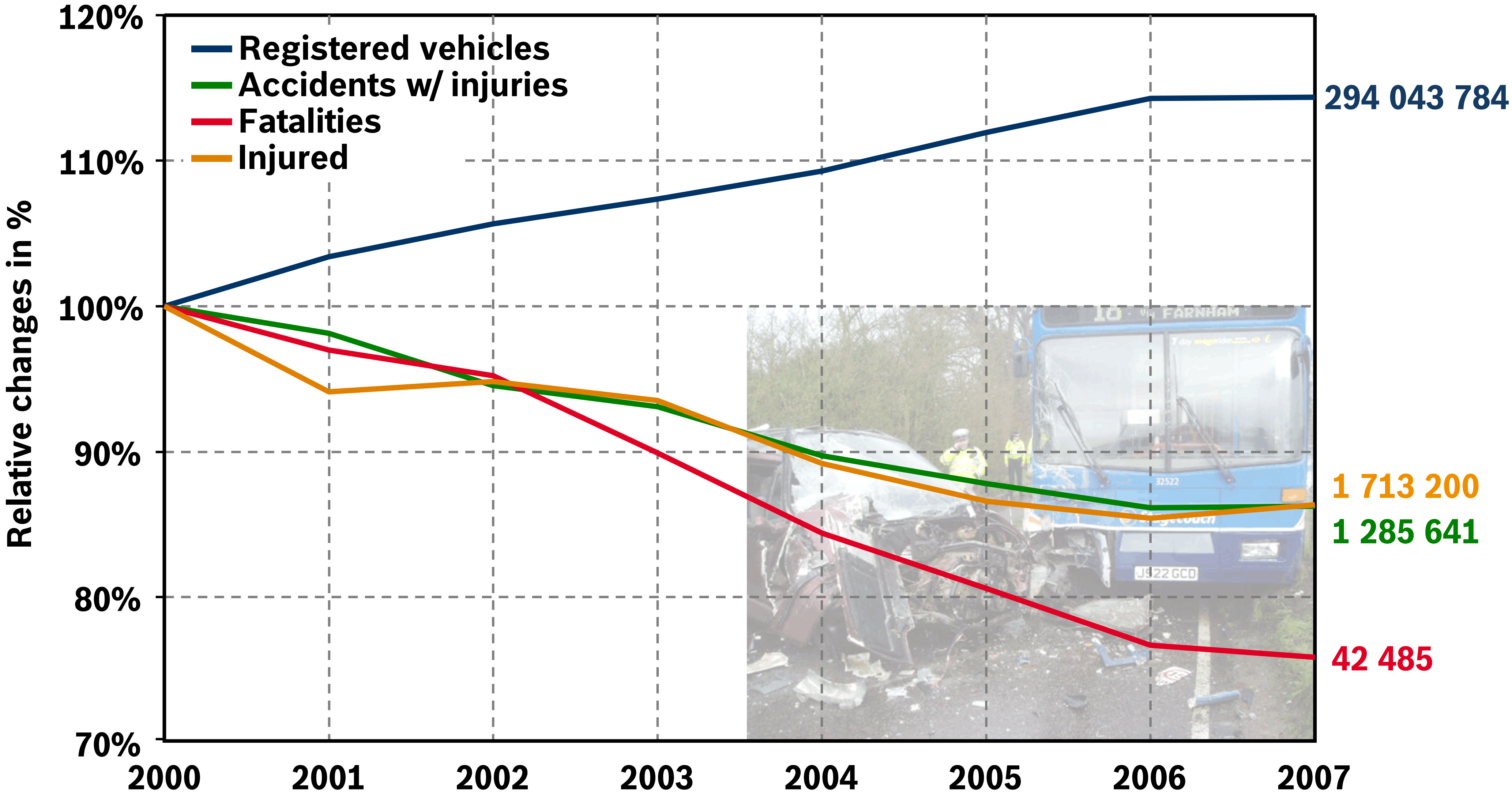
Road Traffic Accidents EU27



Source: CARE (EU27 road accident database), UN Economic Commissions for Europe and national statistics

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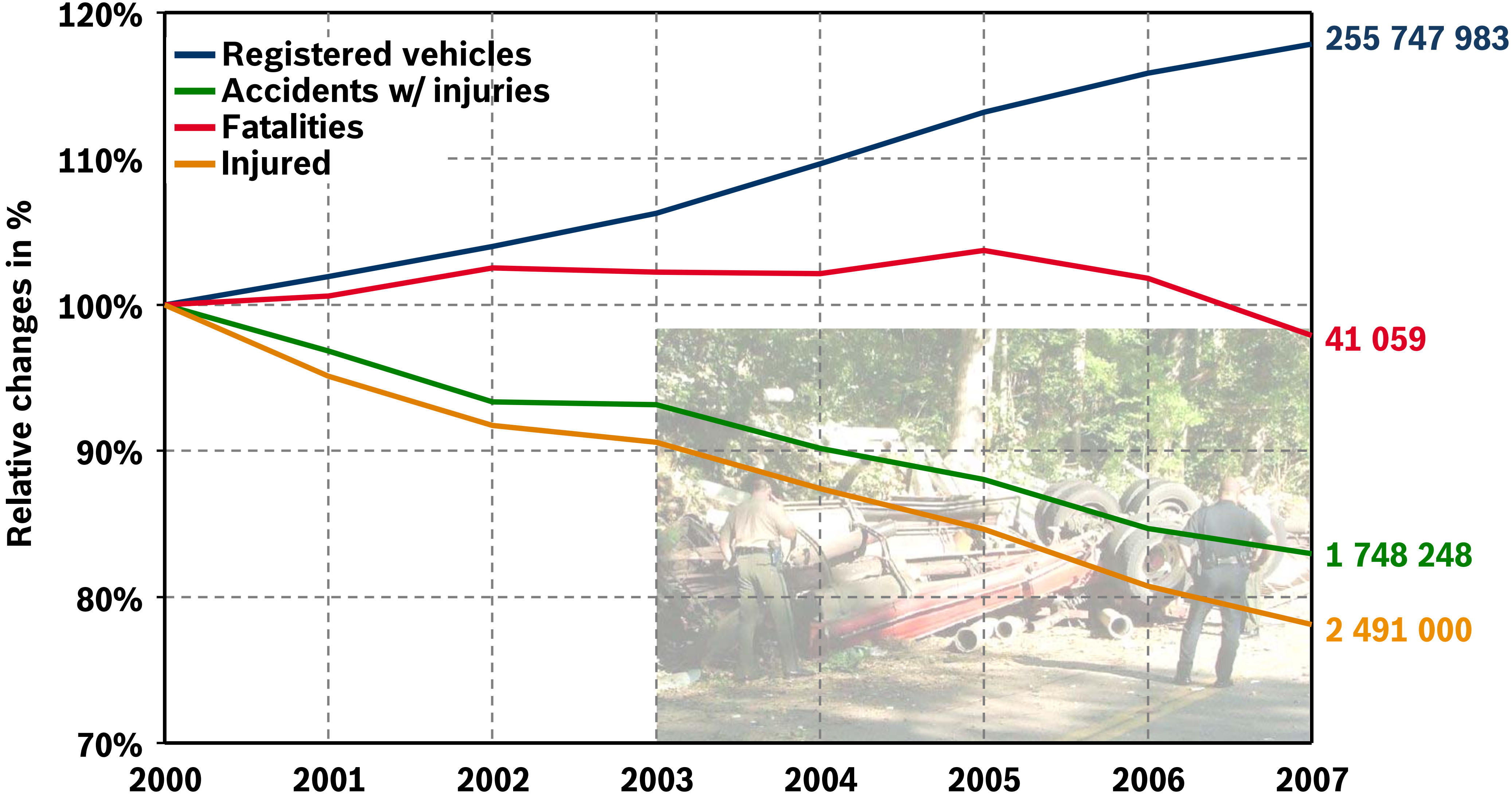
Road Traffic Accidents USA



Source: Traffic safety facts 2007

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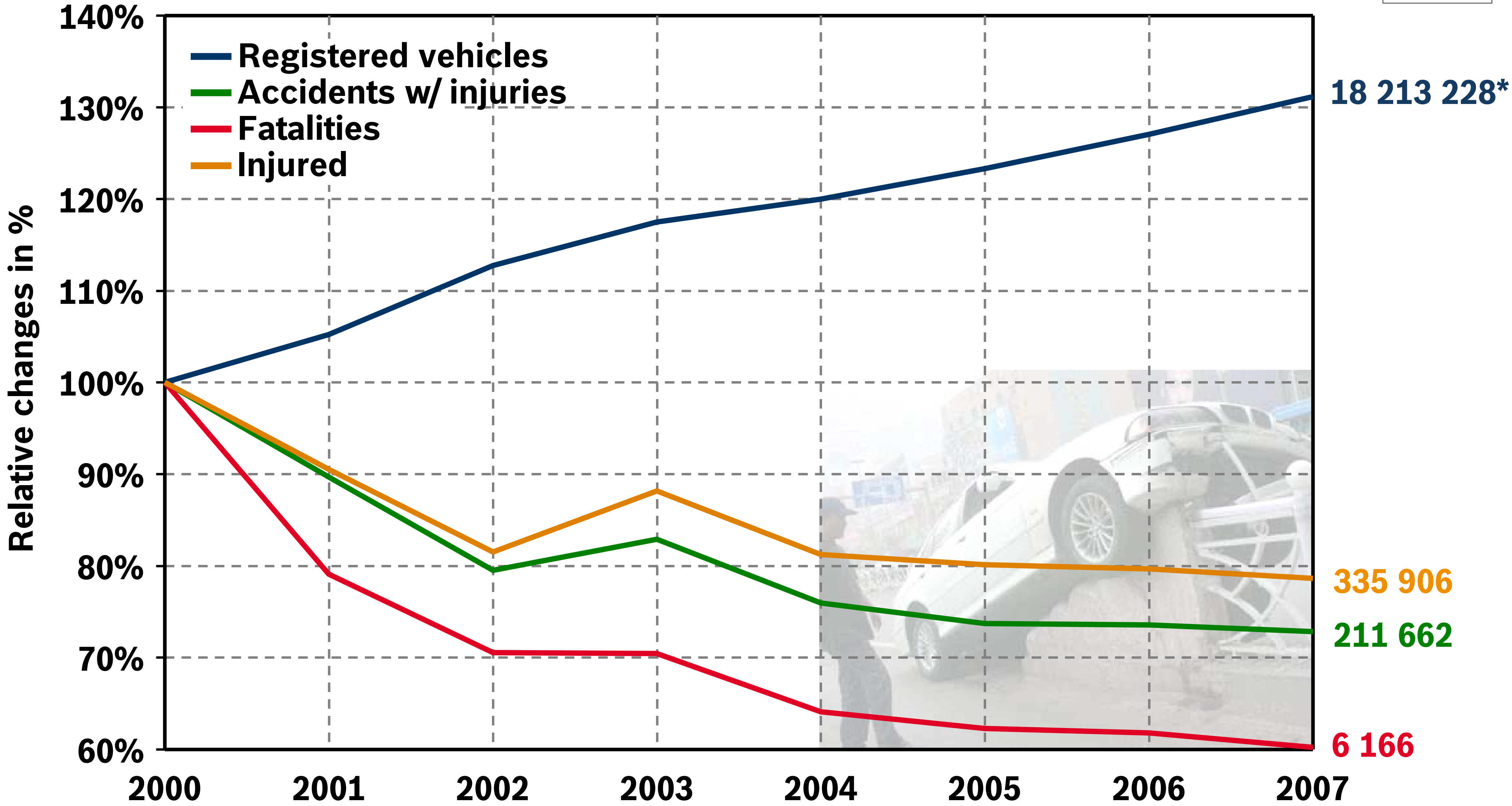
Road Traffic Accidents Korea



Source: Traffic Accident Analysis Center, Seoul

* excluding construction equipment and agricultural machinery

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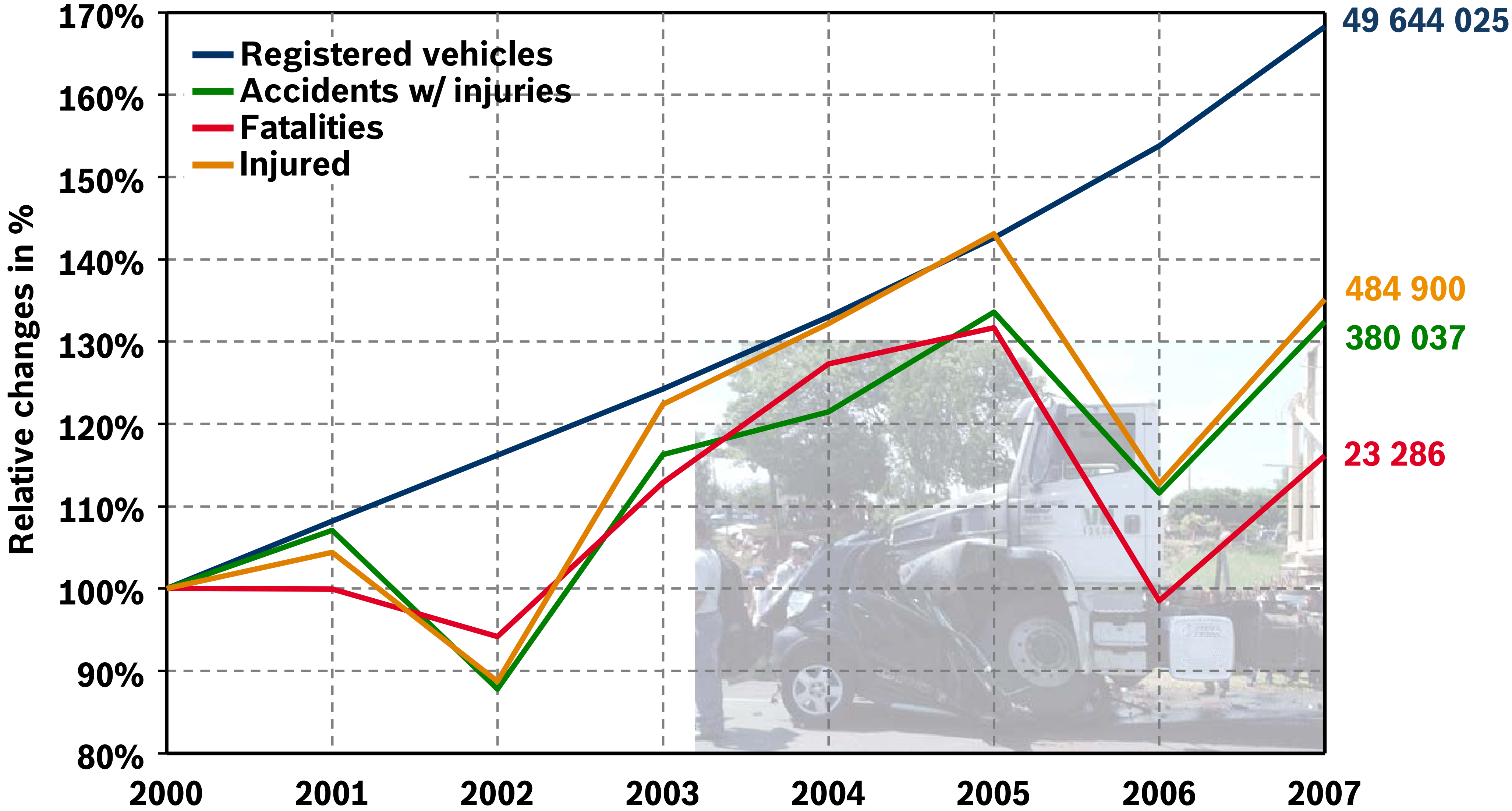
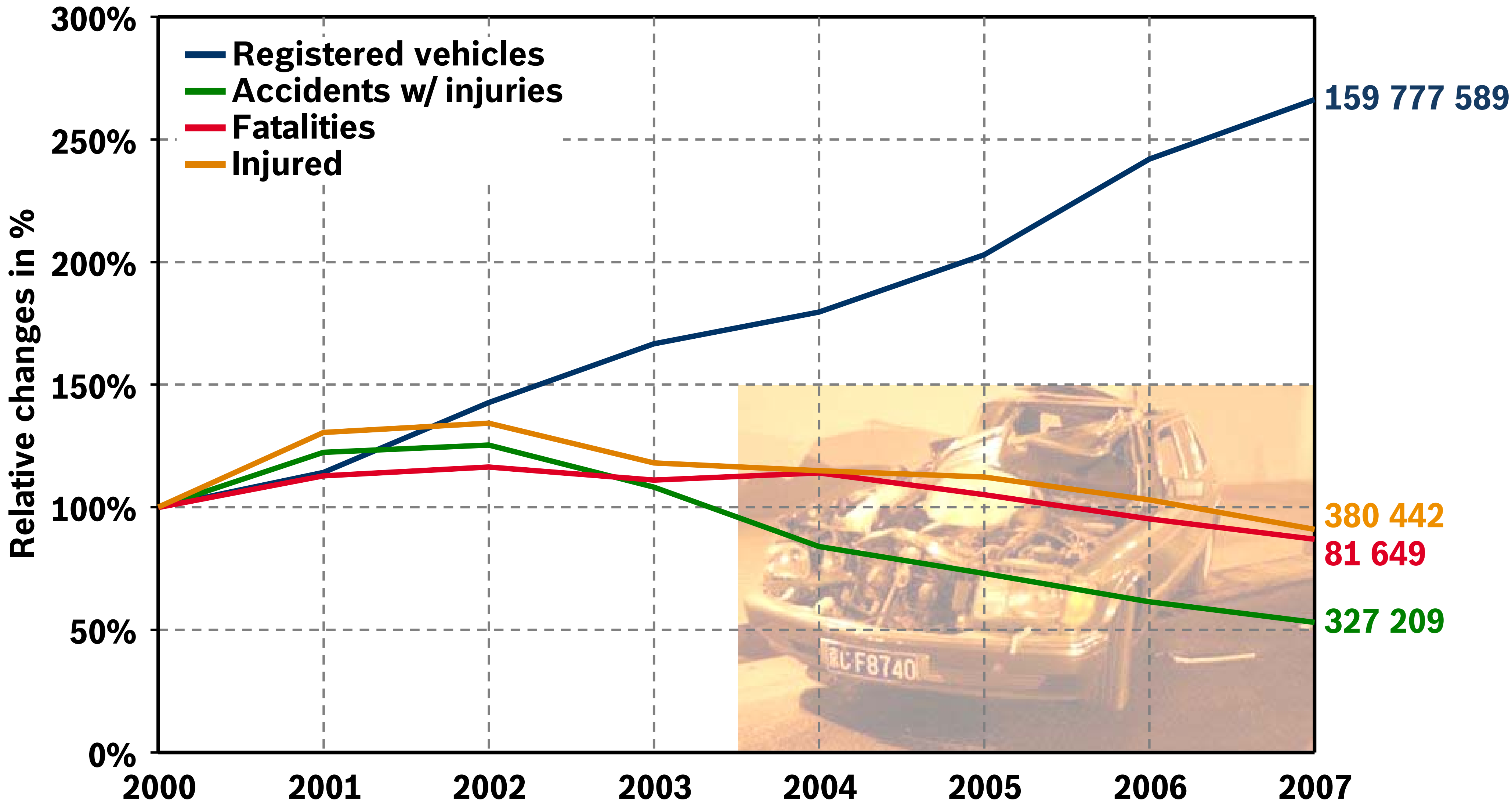
Road Traffic Accidents Brazil



Source: Anuário estatísticodo DENATRAN* - RENAEST 2007, Brazil

* DENATRAN only offers the number of victims at time and location of the accident taken by the police

Road Traffic Accidents China



Source: Road accident Statistics China, Yearbook 2007

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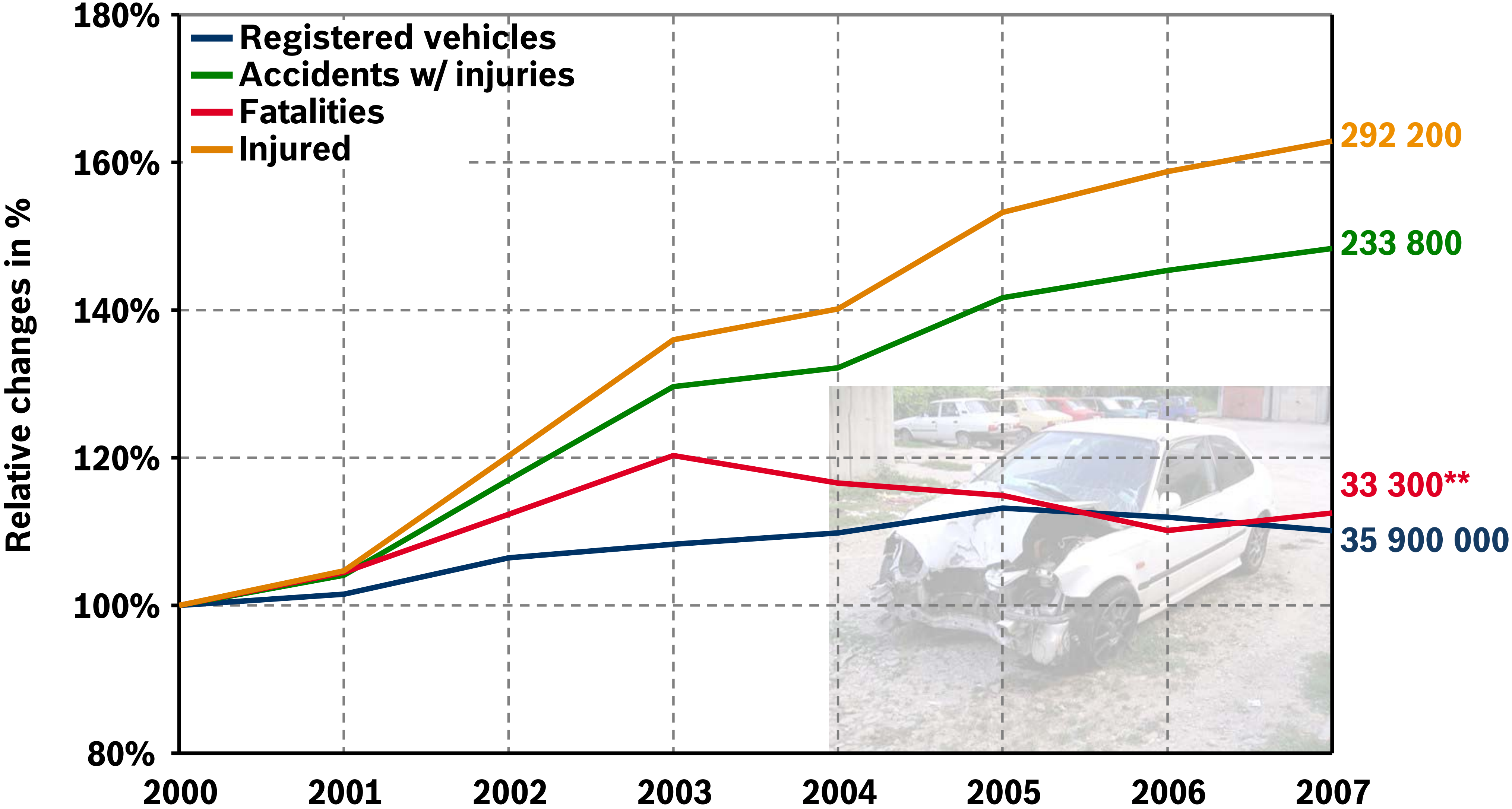
Road Traffic Accidents Russia

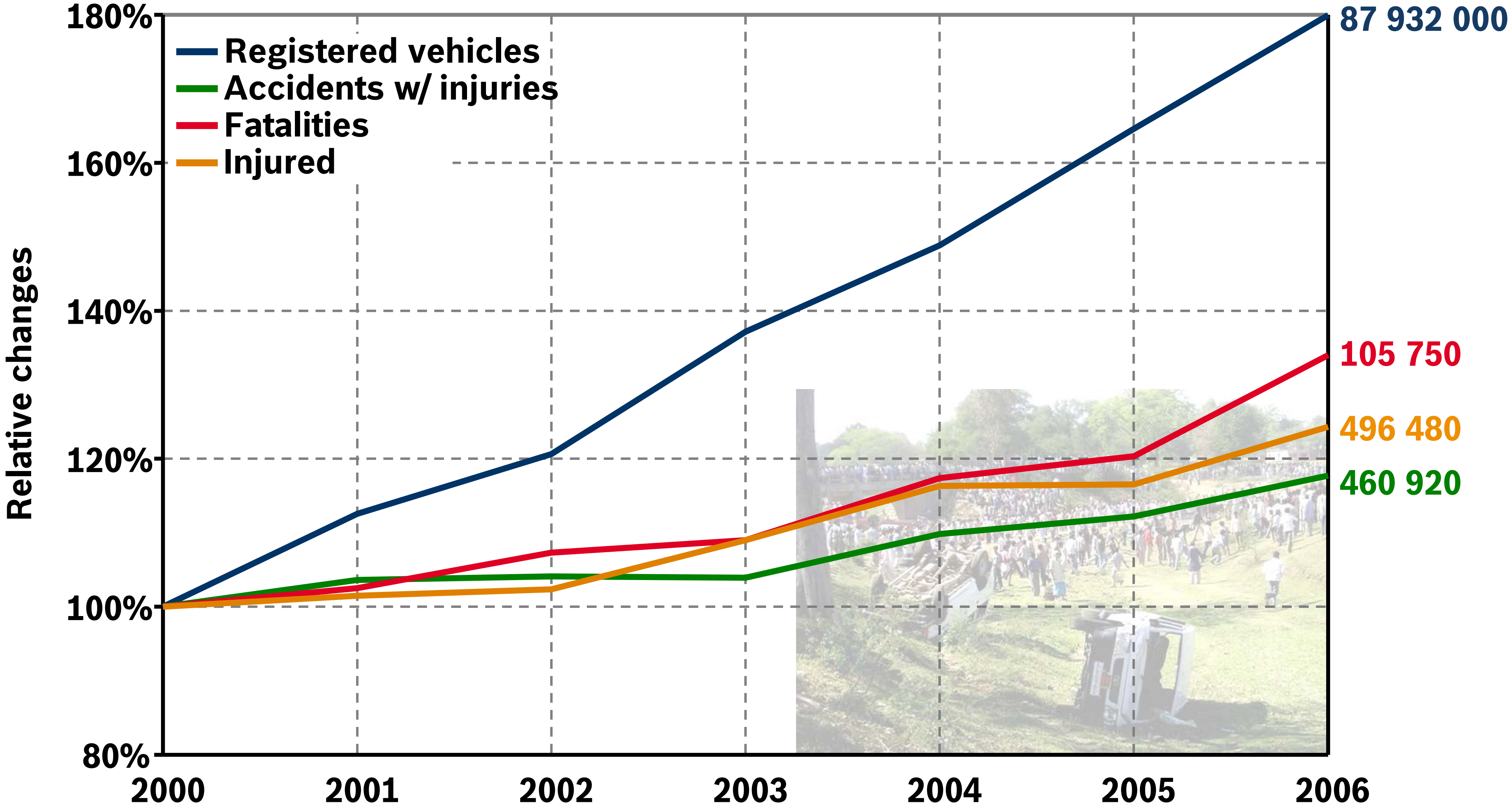


Source: Official bureau of statistics – GosKomStat 2007, RAMI Annual Report 2007, "Avtostat" Annual Report 2007-2008

* Estimations based on 2005

** fatalities within 7 days after accident

Road Traffic Accidents India*

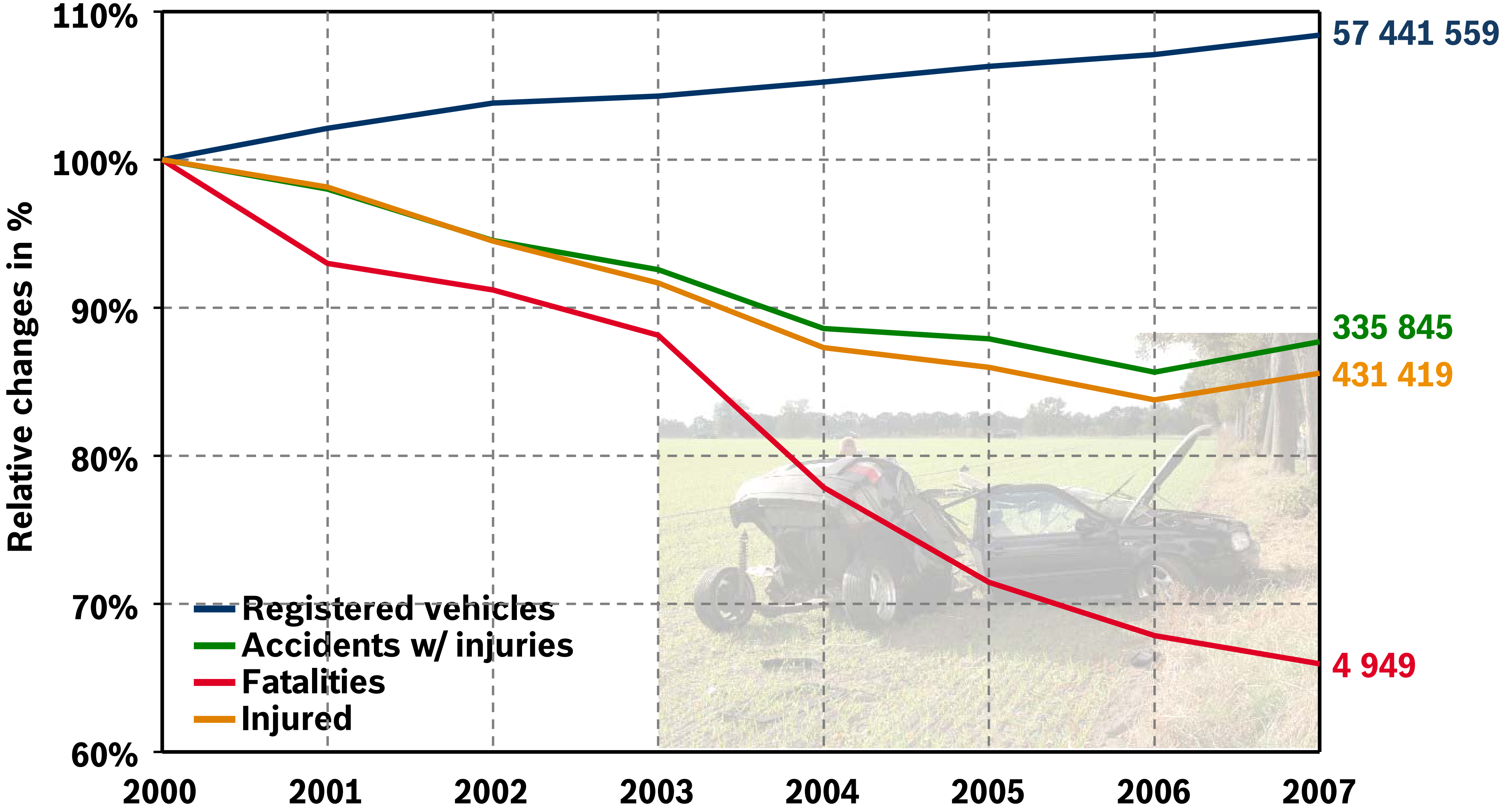


Source: Datanet India Pvt. Ltd.; Ministry of Home Affairs, Govt. of India

•Only data from year 2006 available

Preliminary data for 2007: 418.657 accidents, 114.590 fatalities (Source: Ministry of Home Affairs, Govt. of India)

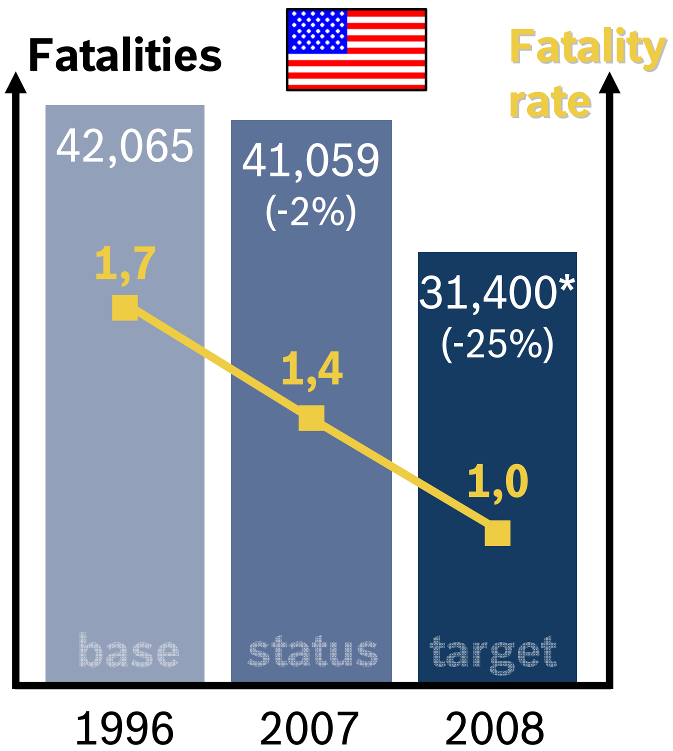
Road Traffic Accidents Germany



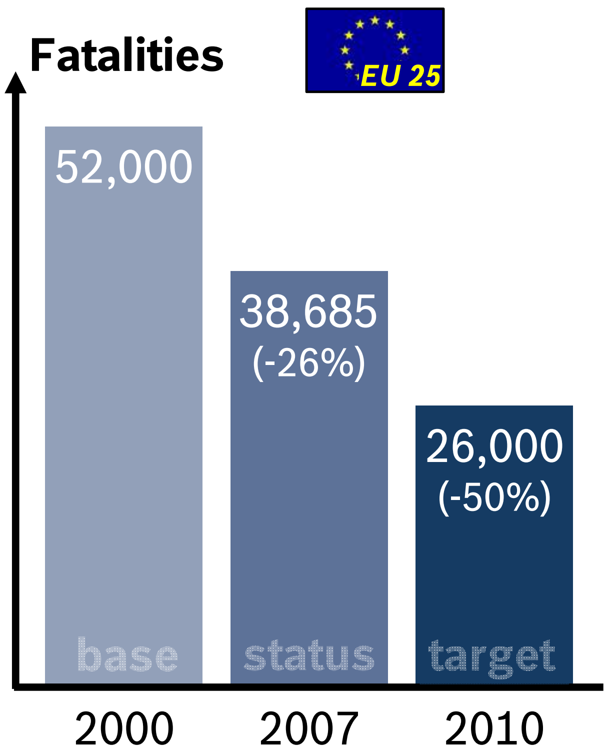
Source: Statistisches Bundesamt, Fachserie 8, Reihe 7, 2007

Initiatives in road safety - World

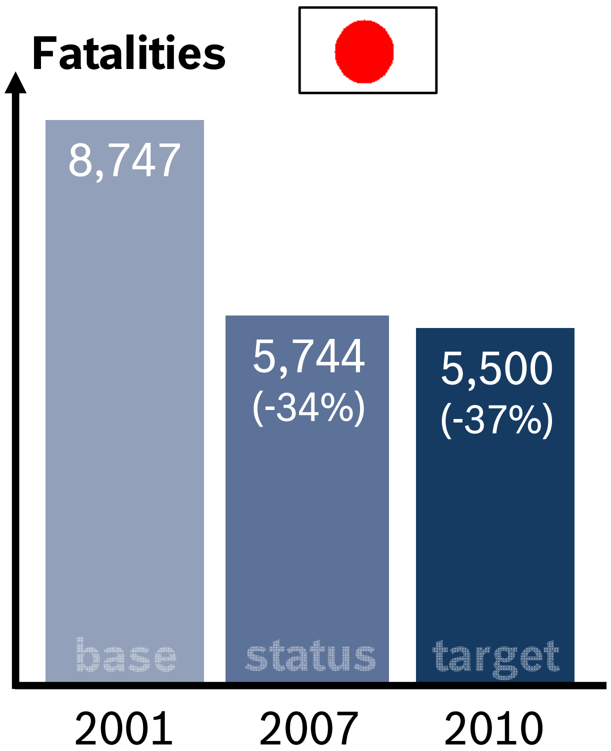
Vision: accident-free driving; status 2007



➔ Reduce **fatality rate from 1.7 to 1.0 per 100 million vehicle miles,** Department of Transportation



➔ **Halving the number** of road **fatalities** within 10 years, White paper of European transport policy



➔ **Reduce number** of road **fatalities under 5,500**, White paper on traffic accidents, Japan

** estimated*

Sources: FARS, CARE or national publications (EU25), IATSS

USA, EU 25: fatalities that occur within 30 days *Japan: fatalities that occur within 24 hours*

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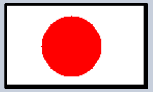
Accident figures

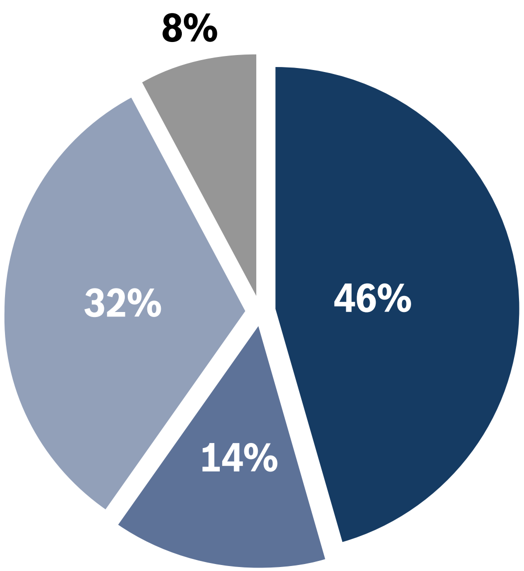
	Resident population [Mio]	Registered motor vehicles [Mio]	Injury accidents [Mio]	Fatal Accidents*	Share of Fatal accidents in injury accidents	Fatalities*
	82,3	57,4	0,34	**4609**	**1,37 %**	**4,949**
	301,6	255,7	1,75	**37248**	**2,13 %**	**41,059**
	127,8	91,2	0,83	**6483**	**0,78 %**	**6,639**

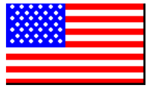
sources: StBA, GIDAS, NHTSA, IATSS, Year 2007

* for fatalities that occur within 30 days

Fatal accidents divided in main categories

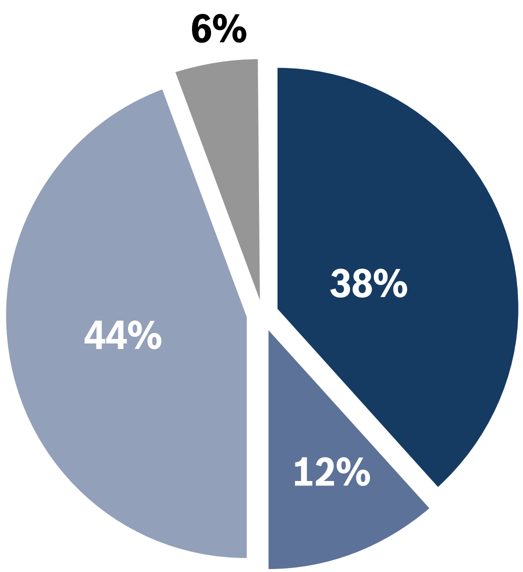
n = 4,609
accidents with fatalities

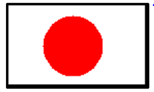




[1]

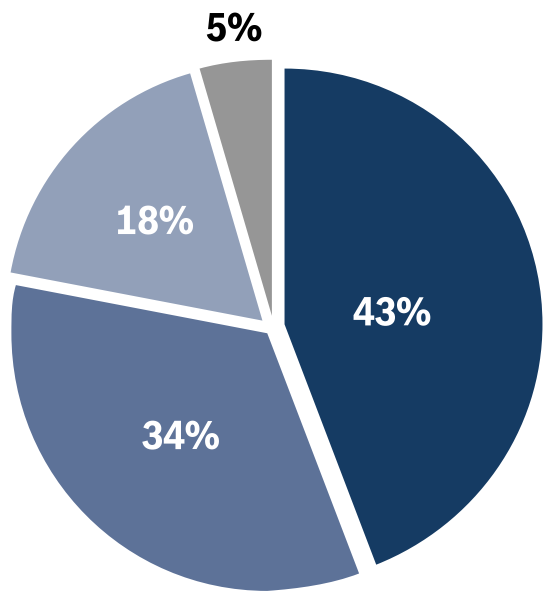
n = 37,248
accidents with fatalities





[2]

n = 5,587
accidents with fatalities



main categories:

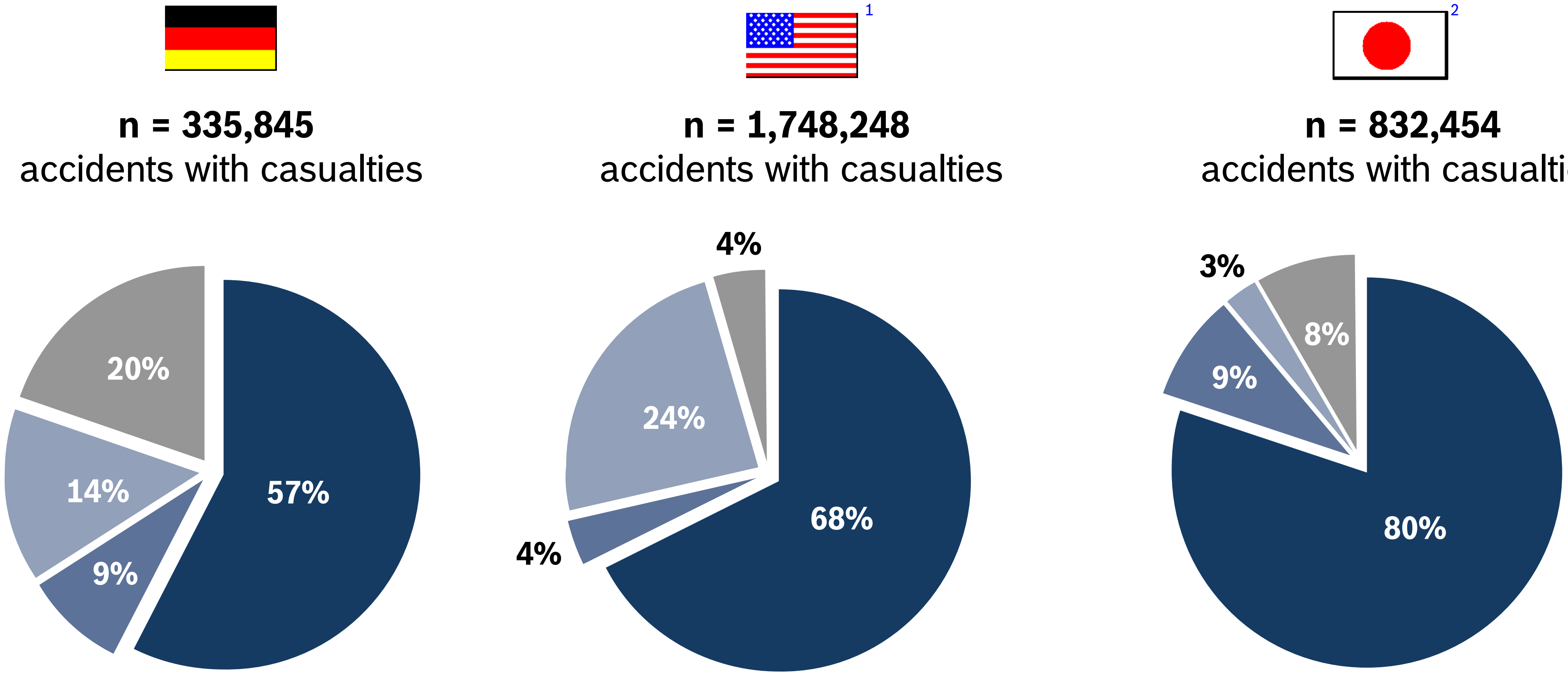
- **vehicle - vehicle**
- **vehicle - fixed object (off road)**
- **vehicle - pedestrian**
- **others (object on road, animal…)**

sources: StBA, GIDAS, NHTSA, IATSS, Year 2007

[1] USA: Vehicle to Bicycle - accidents in category „Others“

[2] Japan: Accidents without automobile involvement in category “Others”, only fatalities that occur within 24 hours

Accidents with casualties divided in main categories



main categories:

- **vehicle - vehicle**
- **vehicle - fixed object (off road)**
- **vehicle - pedestrian**
- **others (object on road, animal…)**

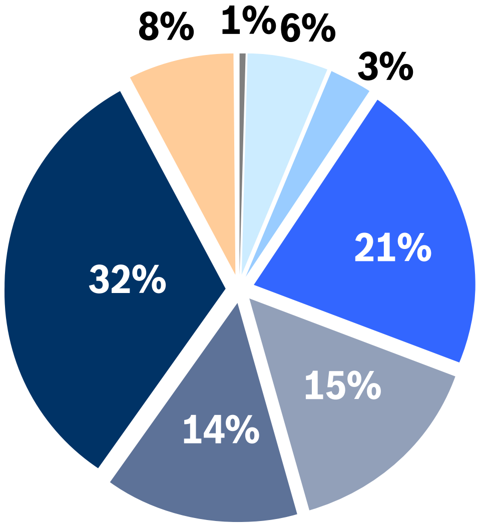
sources: StBA, GIDAS, NHTSA, IATSS, Year 2007

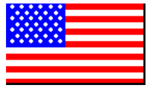
[1] USA: Vehicle to Bicycle - accidents in category „Others“

[2] Japan: Accidents without automobile involvement in category “Others”

Fatal accidents by kinds of accidents

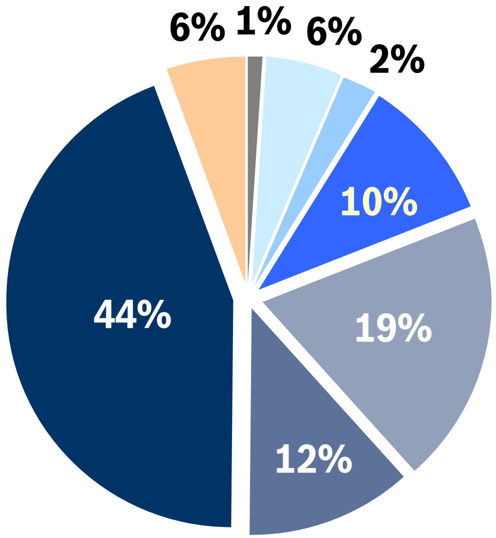
n = 4,609
accidents with fatalities

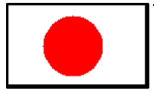




[1]

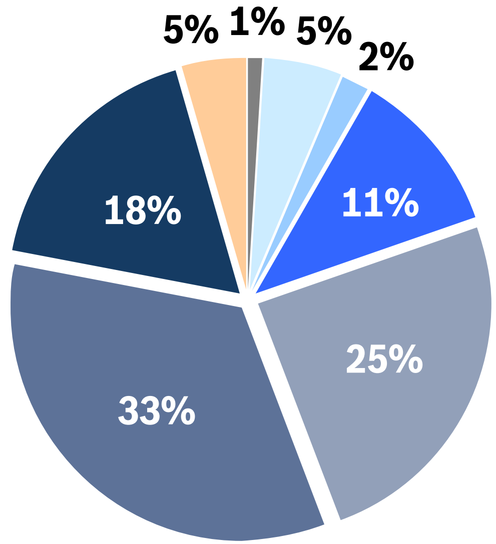
n = 37,248
accidents with fatalities





[2]

n = 5,587
accidents with fatalities



collision with …

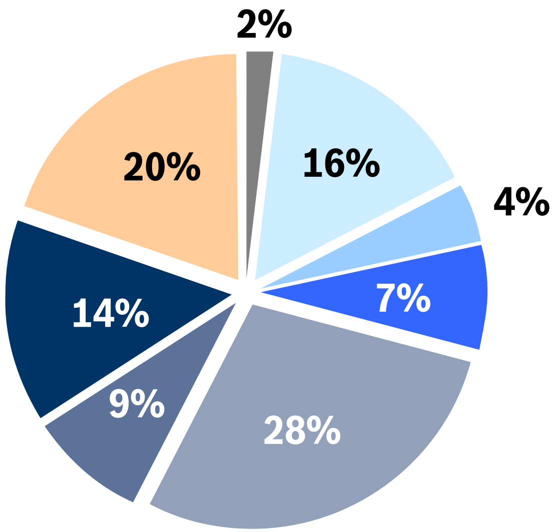
- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal …)

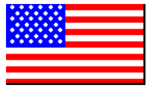
sources: StBA, GIDAS, NHTSA, IATSS, Year 2007

[1] USA: Vehicle to Bicycle - accidents in category „Others“
[2] Japan: Accidents without automobile involvement in category “Others”, only fatalities that occur within 24 hours

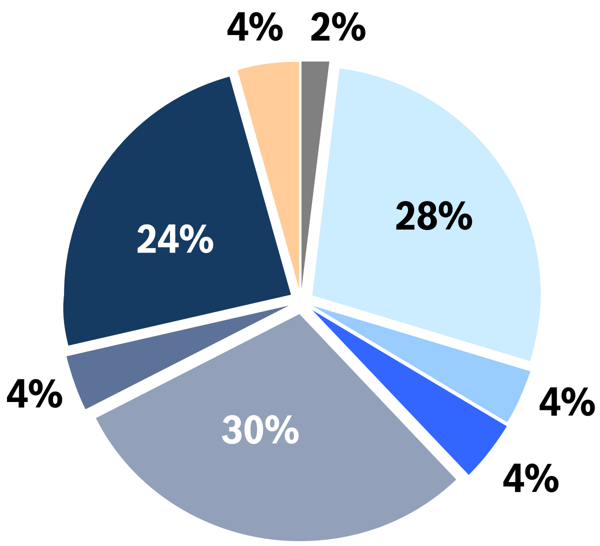
Accidents with casualties by kinds of accidents

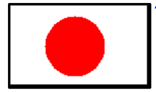
n = 335,845
accidents with casualties



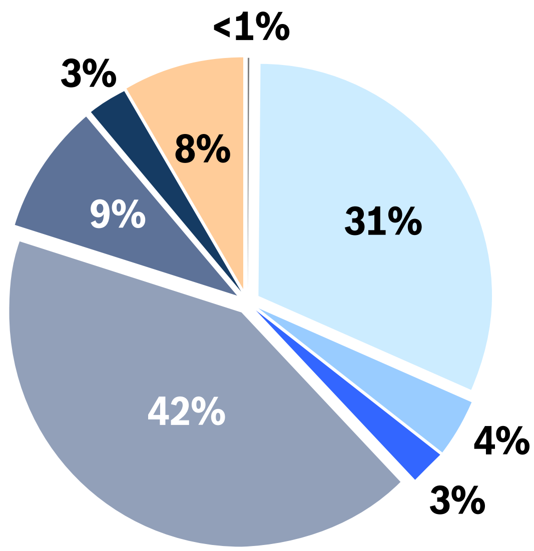
 [1]

n = 1,748,248
accidents with casualties



 [2]

n = 832,454
accidents with casualties



collision with ...

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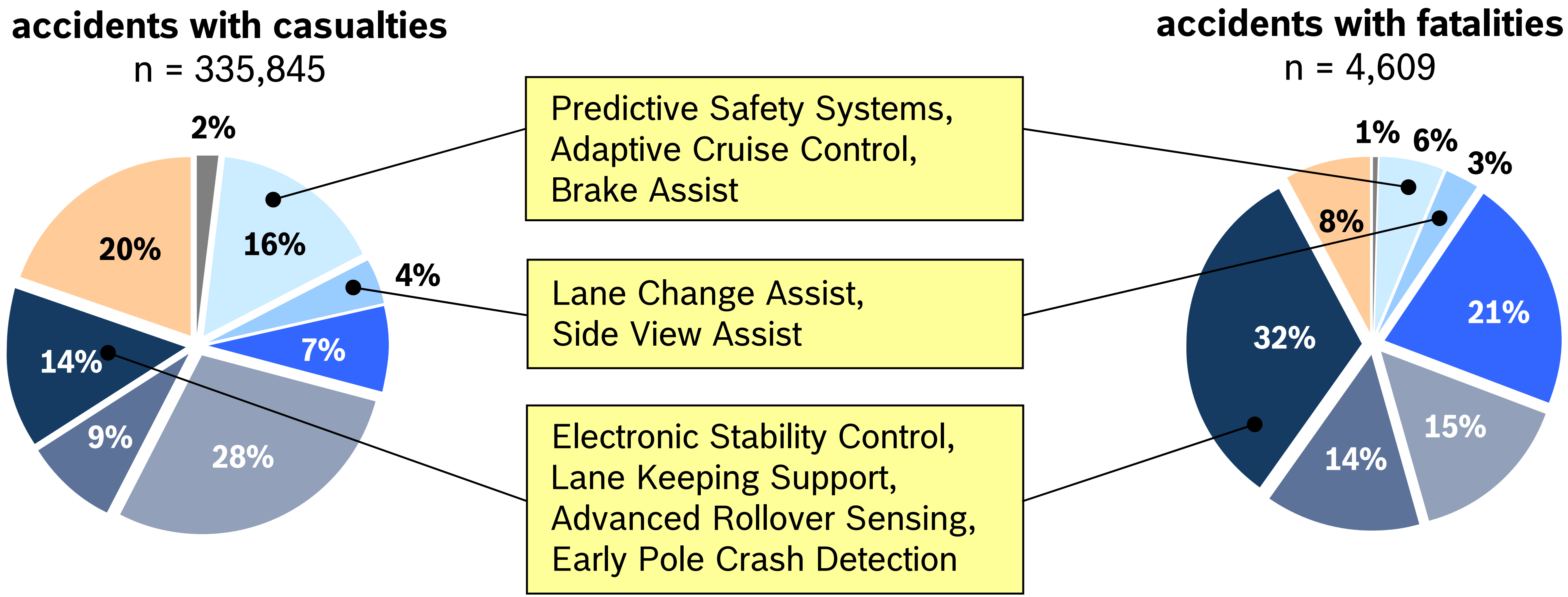
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal ...)

sources: StBA, GIDAS, NHTSA, IATSS, Year 2007

[1] USA: Vehicle to Bicycle - accidents in category „Others“
[2] Japan: Accidents without automobile involvement in category “Others”

Scope of safety functions in Germany (1/2)



collision with ...

- **parked vehicle**
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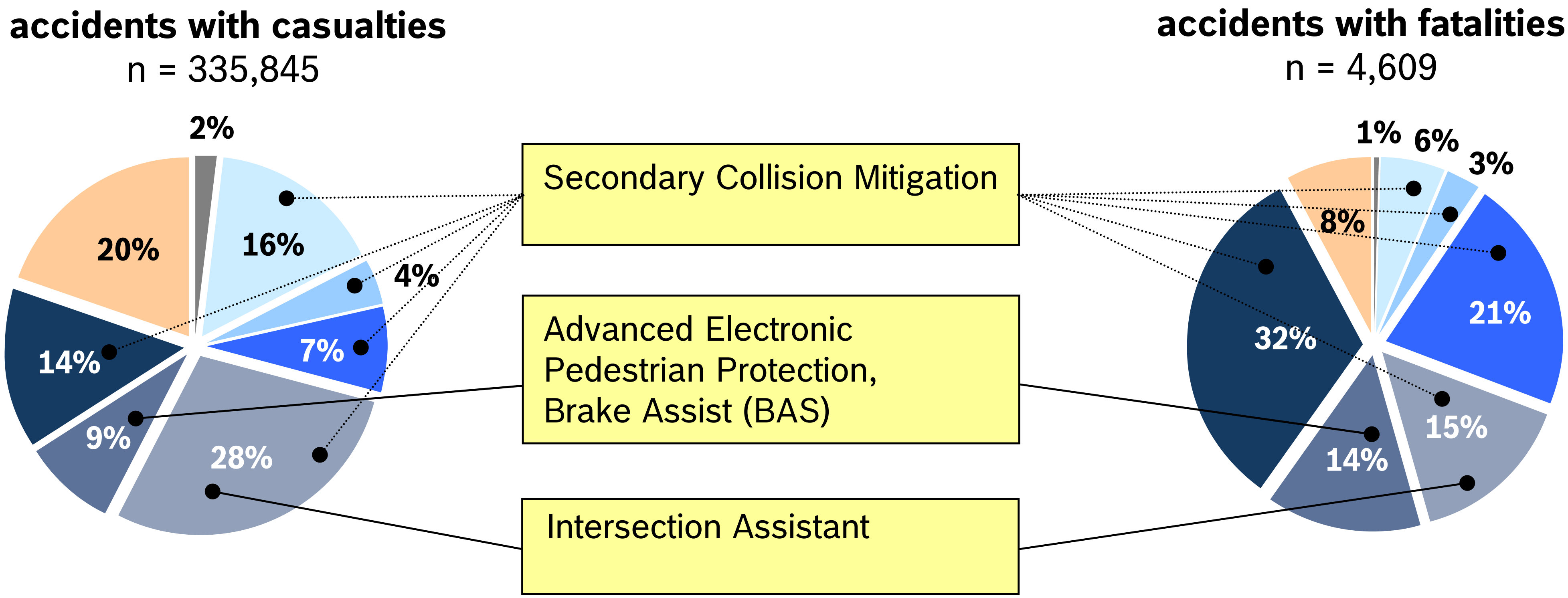
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind**
  (unknown, not fixed object, animal ...)

sources: STBA 2007

Scope of safety functions in Germany (2/2)



collision with …

- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind**
  (unknown, not fixed object, animal …)

sources: STBA 2007

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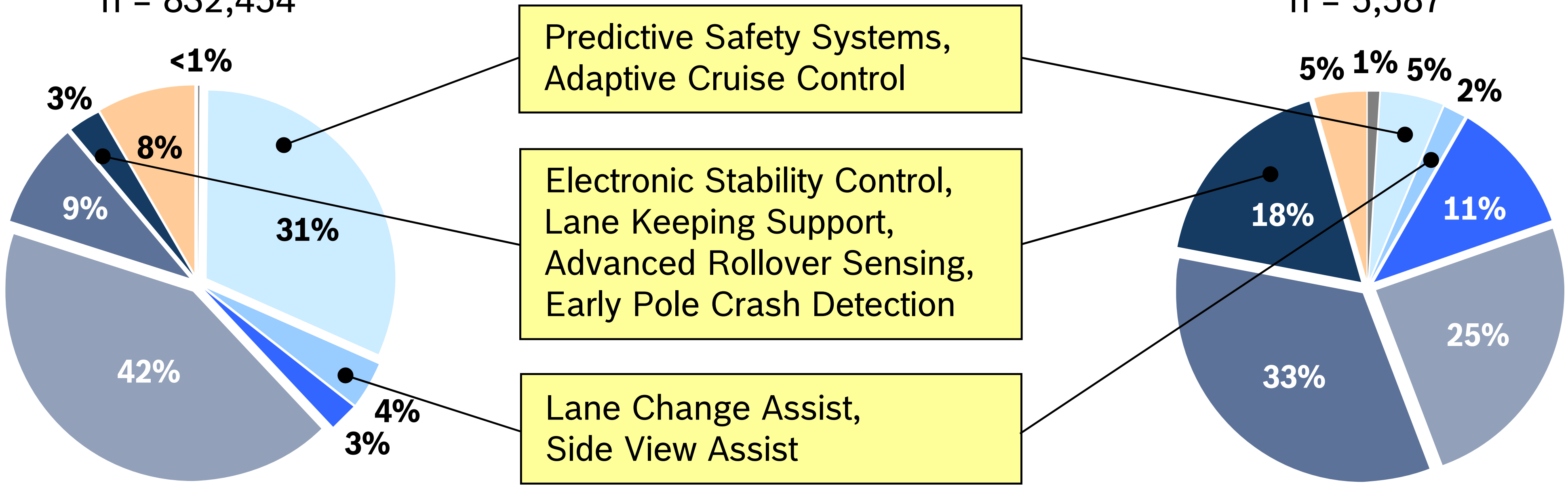
Scope of safety functions in Japan (1/2)

accidents with casualties[1]
n = 832,454

accidents with fatalities[1]
n = 5,587[2]



collision with ...

- **parked vehicle**
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- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind**
  (unknown, not fixed object, animal ...)

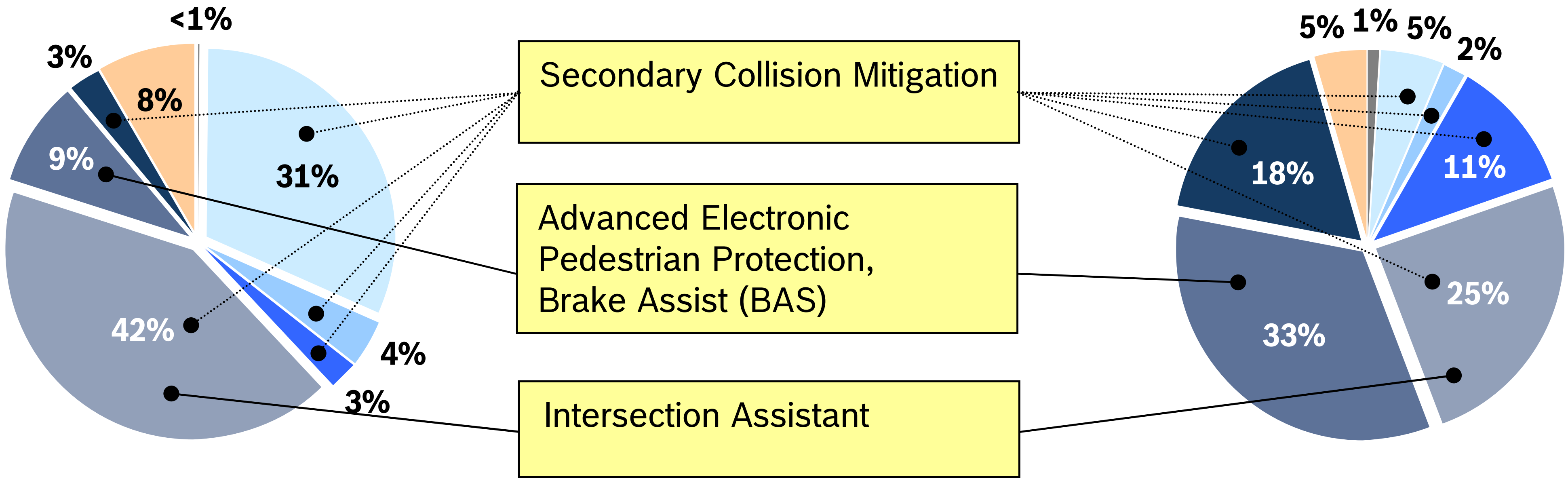
sources: IATSS 2007

[1] accidents without automobile involvement in category "Others"
[2] only fatalities that occur within 24 hours

Scope of safety functions in Japan (2/2)

accidents with casualties[1]
n = 832,454

accidents with fatalities[1]
n = 5,587[2]



collision with ...

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- **vehicle moving laterally in same direction**
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- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal ...)

sources: IATSS 2007

[1] accidents without automobile involvement in category "Others"
[2] only fatalities that occur within 24 hours

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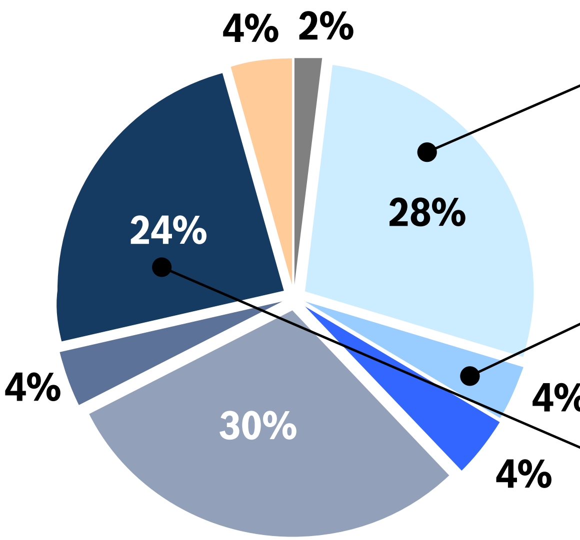
Scope of safety functions in USA (1/2)

accidents with casualties [1]
n = 1,748,248

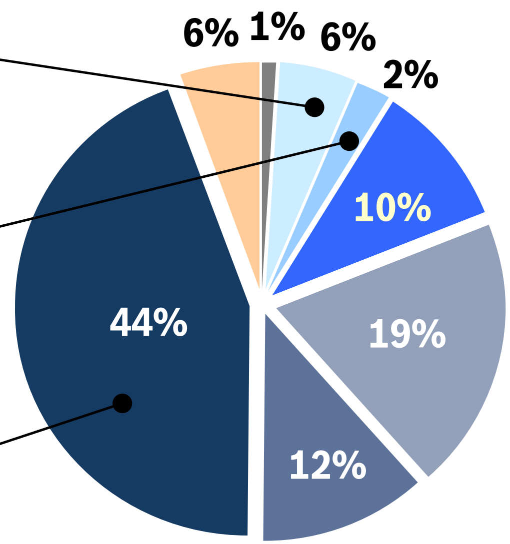


Predictive Safety Systems,
Adaptive Cruise Control,
Brake Assist

Lane Change Assist,
Side View Assist

Electronic Stability Control,
Lane Keeping Support,
Advanced Rollover Sensing,
Early Pole Crash Detection

accidents with fatalities [1]
n = 37,248



collision with …

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- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal …)

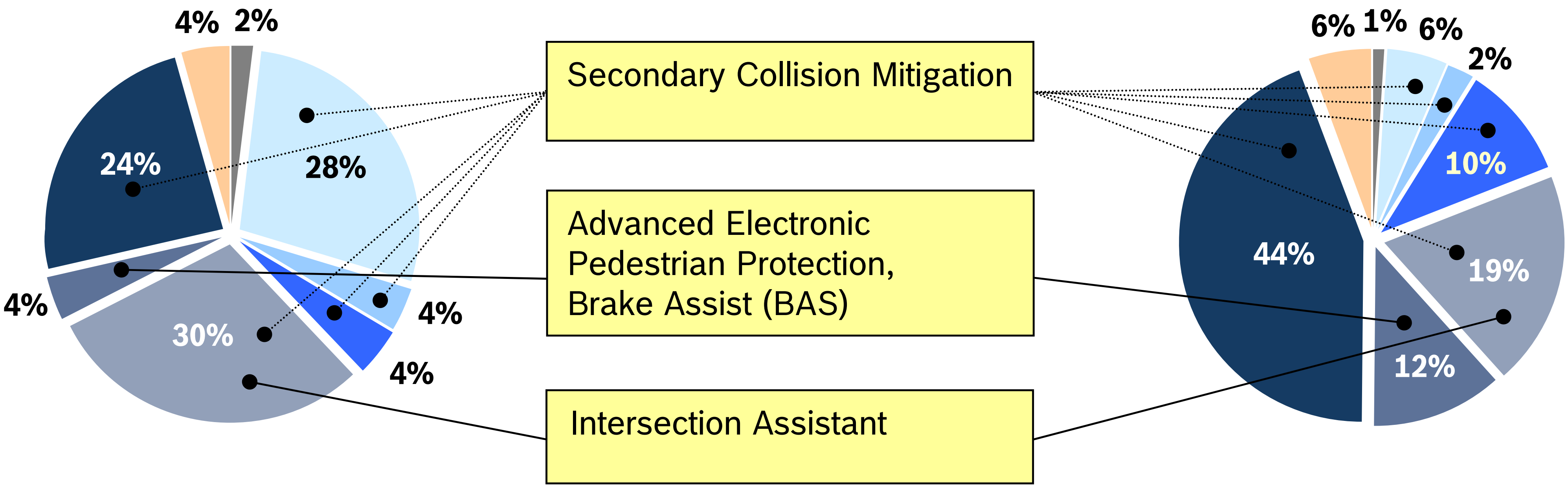
sources: NHTSA/NCSA 2007

[1] Vehicle to Bicycle - accidents in category „Others“

Scope of safety functions in USA (2/2)

accidents with casualties [1]
n = 1,748,248

accidents with fatalities [1]
n = 37,248



collision with …

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- **Accident of another kind**
  (unknown, not fixed object, animal …)

sources: NHTSA/NCSA 2007

[1] Vehicle to Bicycle - accidents in category „Others“

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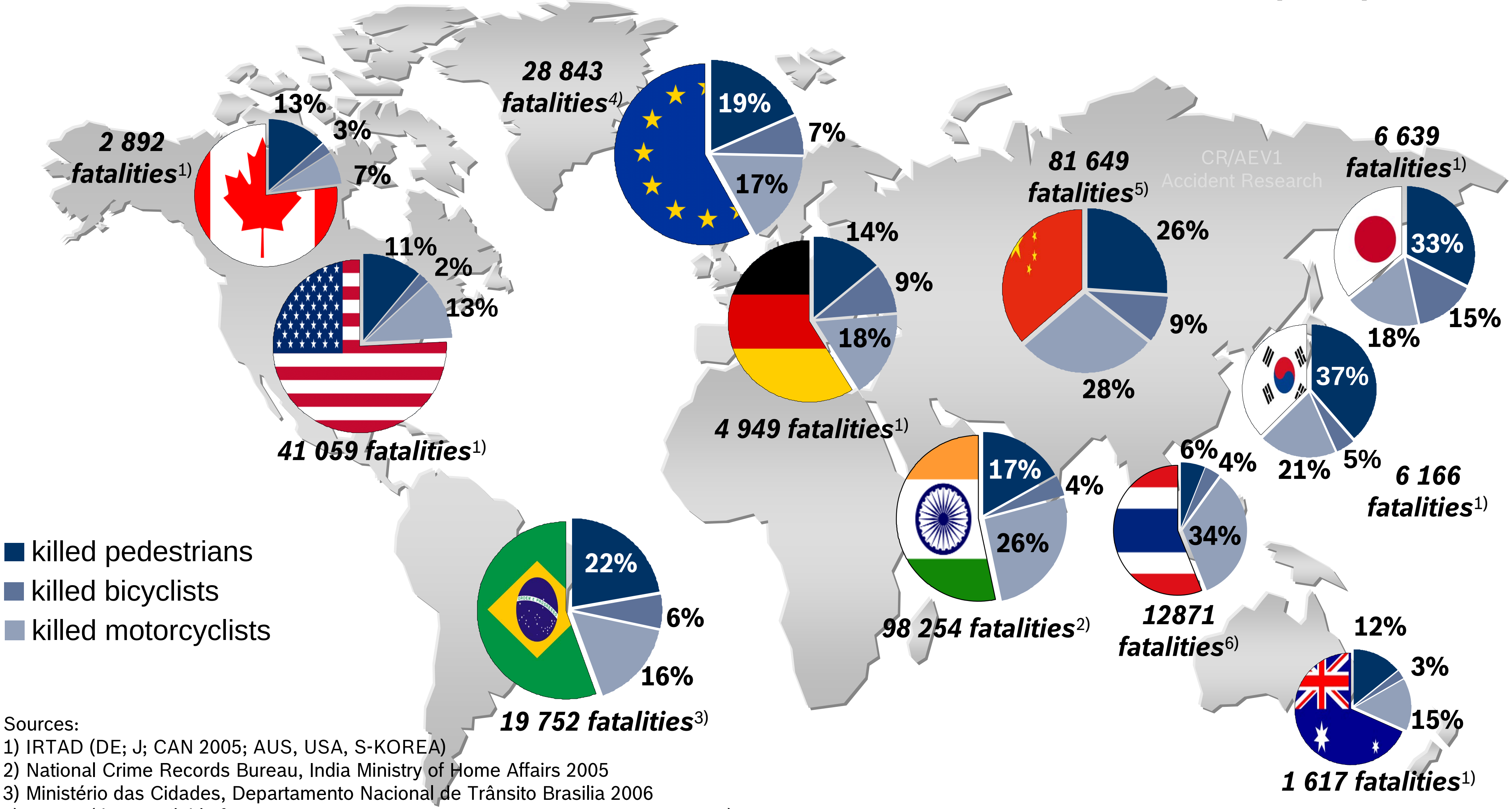
Fatalities in road traffic 2007 – share of vulnerable road users (VRU)

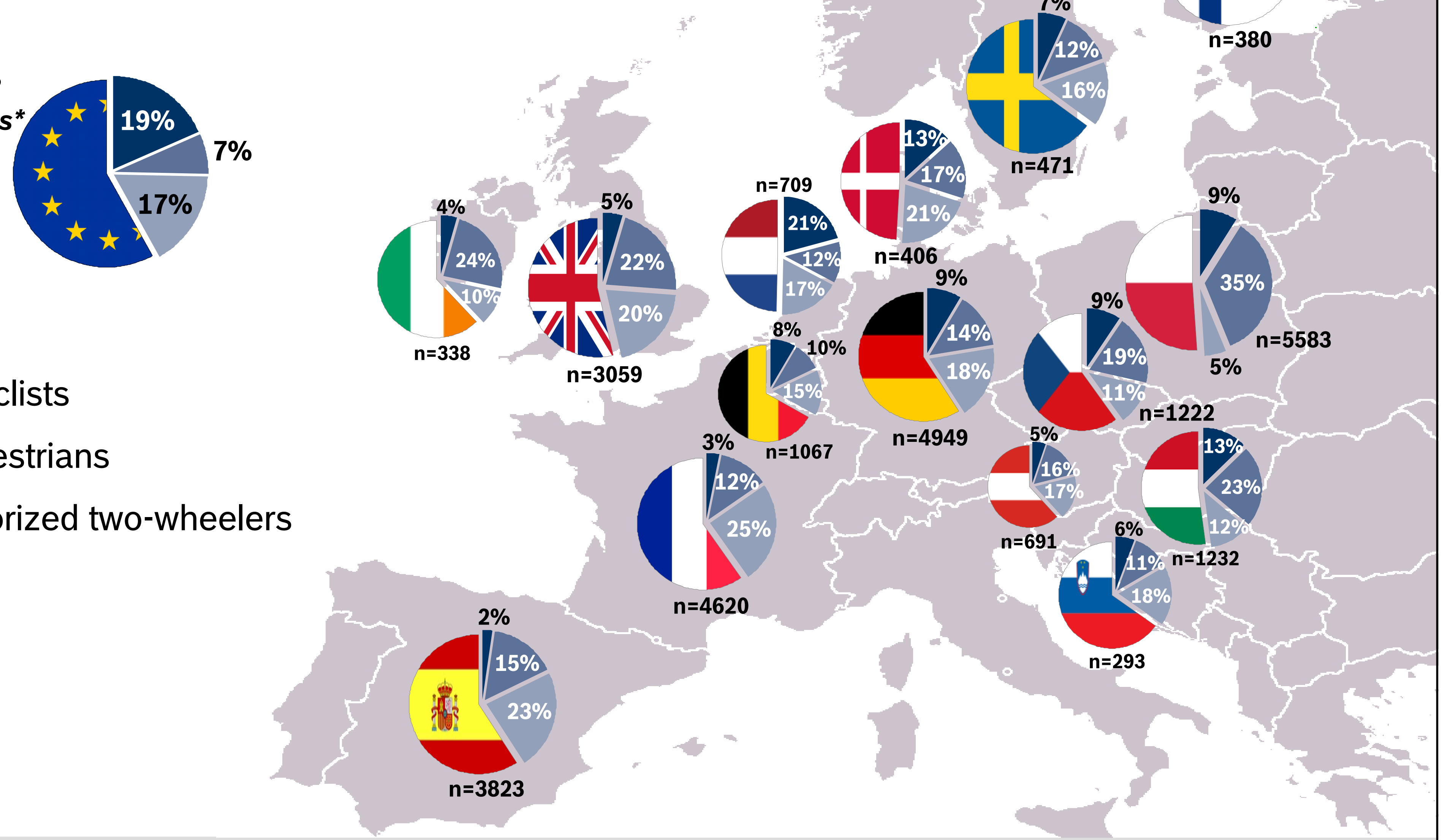


Sources:
1) IRTAD (DE; J; CAN 2005; AUS, USA, S-KOREA)
2) National Crime Records Bureau, India Ministry of Home Affairs 2005
3) Ministério das Cidades, Departamento Nacional de Trânsito Brasilia 2006
4) IRTAD (data available for AT, BE, CZ, DE, DK, ES, FI, FR, HU, IE, NL, SI, SE, UK)
5) Traffic Accidents China, Official yearbook 2007
6) Royal Thai Police, Traffic Accident National Highways 2005, data statistically blurred by estimation

Notations: data of Thailand and India as of 2005, Canada and Brazil as of 2006
known numbers 2006: fatalities 12 691 (Thailand); 105 749 (India), beneath 17 105 cyclists

Fatalities in road traffic 2007 - Europe

Share of vulnerable road users (VRU)

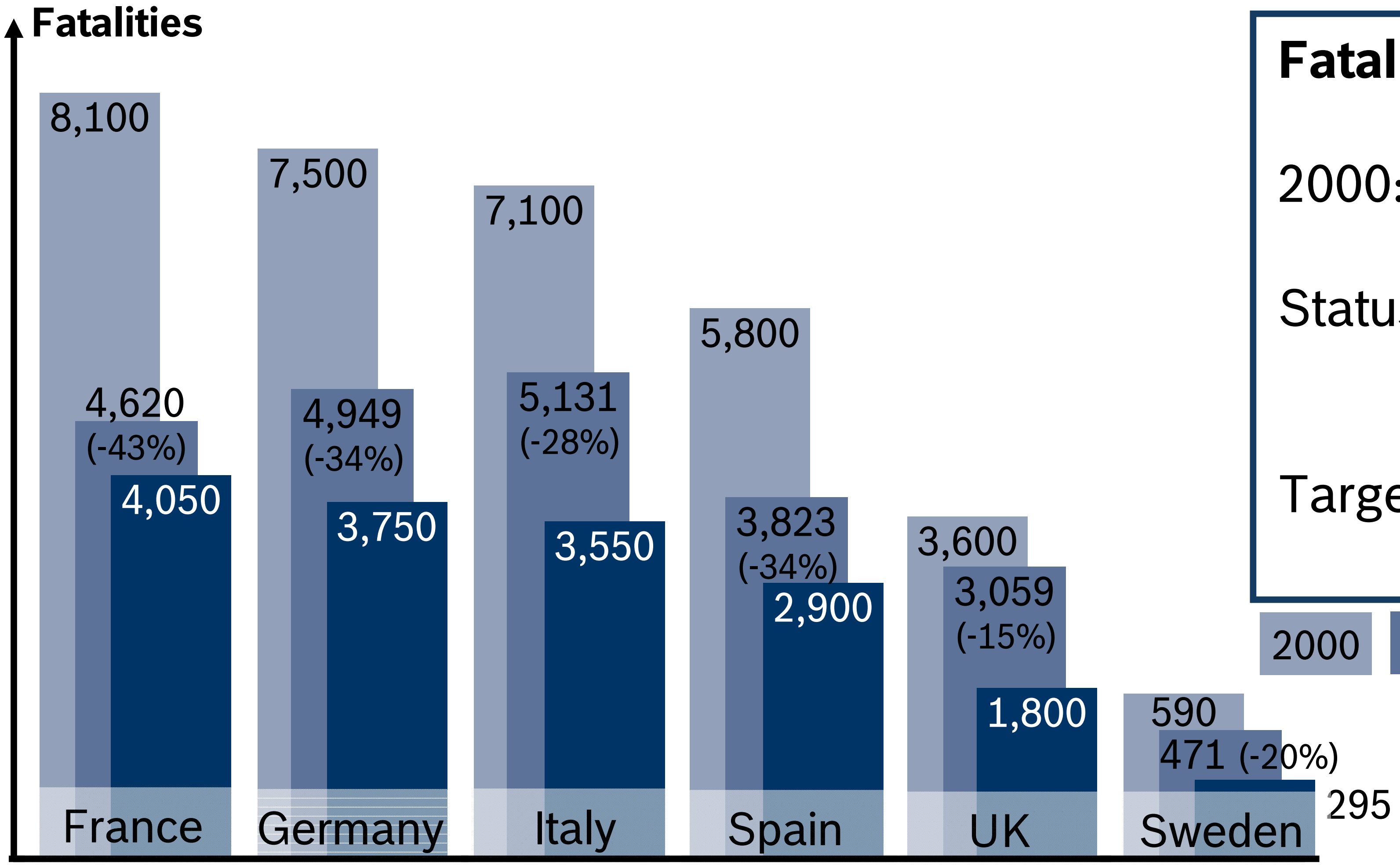


* IRTAD (data available for AT, BE, CZ, DE, DK, ES, FI, FR, HU, IE, NL, PL, SI, SE, UK)

Initiatives in road safety – Europe

25 000 LIVES TO SAVE European Road Safety Charter

Vision: accident-free driving; status 2007



Fatalities EU 25:

2000: 52,000

Status 2007: 38,685 **(-26%)**

Target 2010: 26,000 **(-50%)**

2000 | 2007 | Target 2010

Source: International Road Traffic and Accident Database IRTAD, 2007

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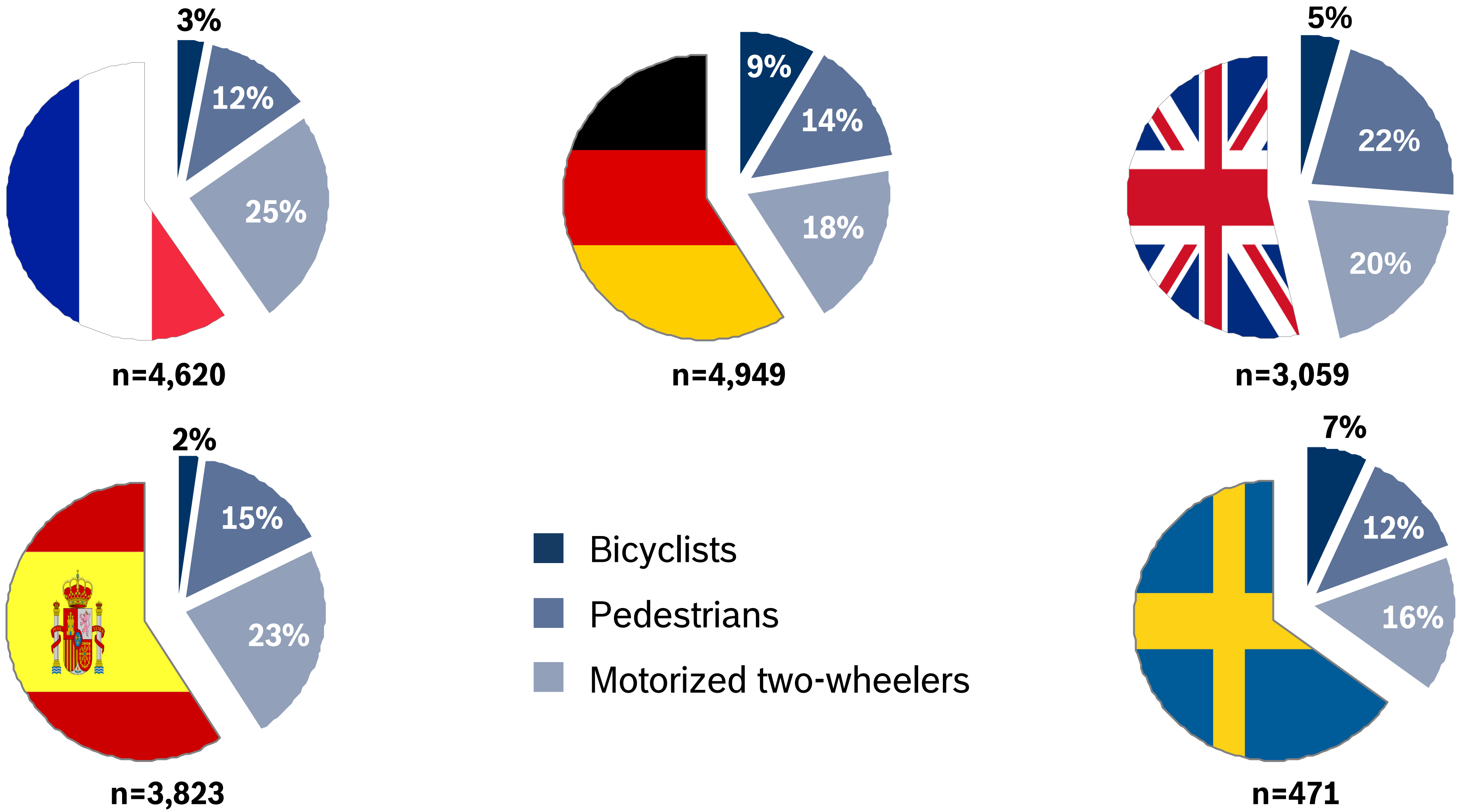
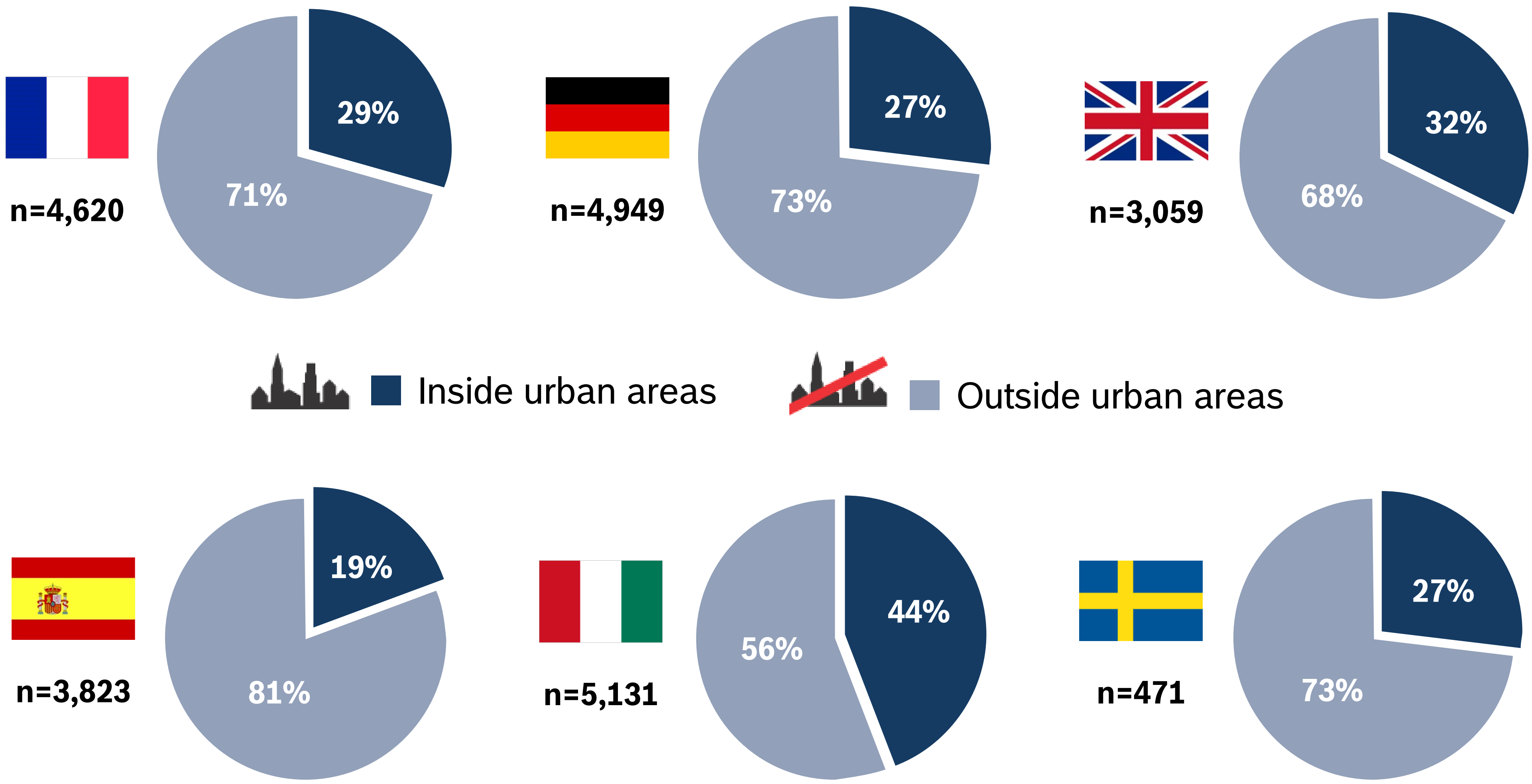
Vulnerable road users - fatalities 2007



Source: International Road Traffic and Accident Database IRTAD, 2007

Fatalities by scene of accident 2007

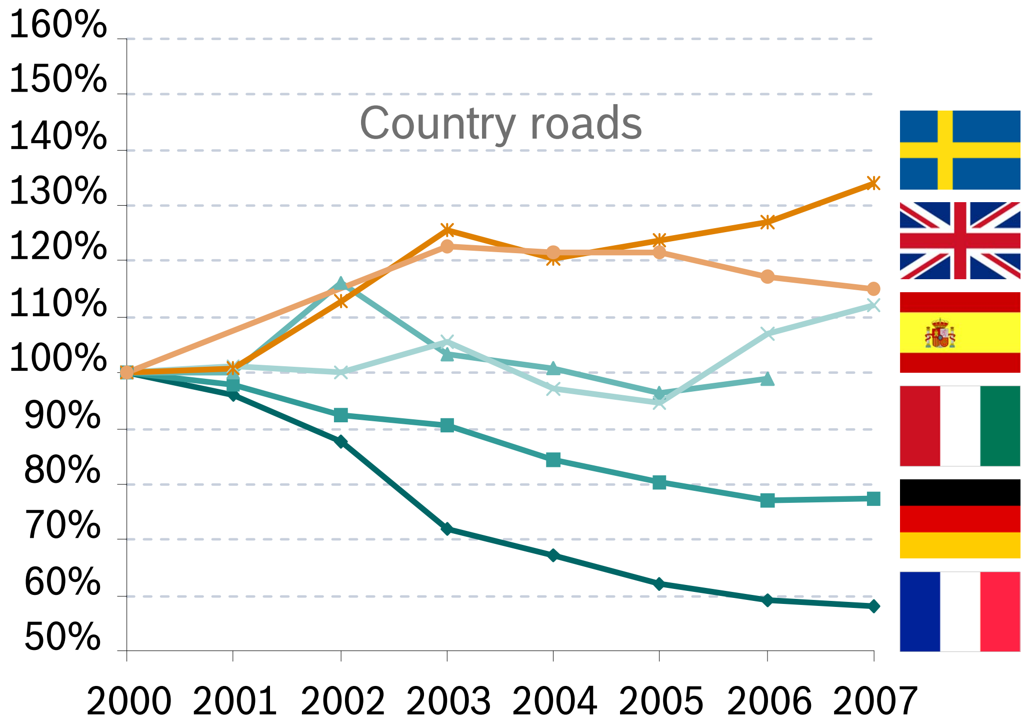


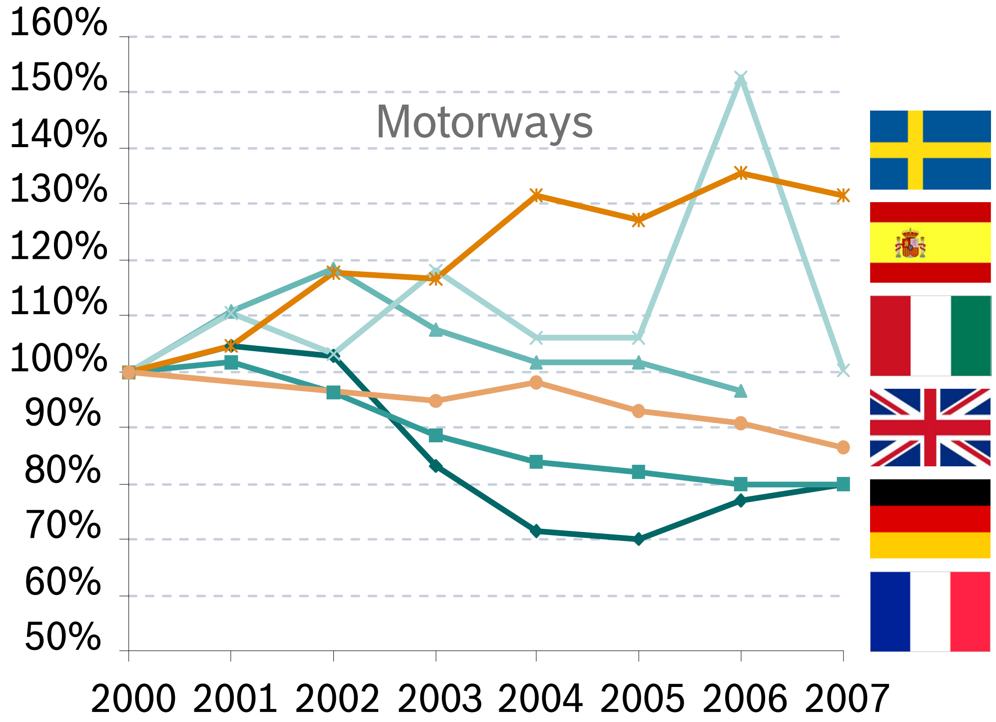
Source: International Road Traffic and Accident Database IRTAD, 2007

Injury accidents outside urban areas

Outside urban area

YEAR 2000	France	Germany	Italy	Spain	Sweden	UK*
Country roads	33,248	111,901	43,115	41,599	5,632	56,343
Motorways	7,401	25,578	13,788	3,121	1,128	9,368





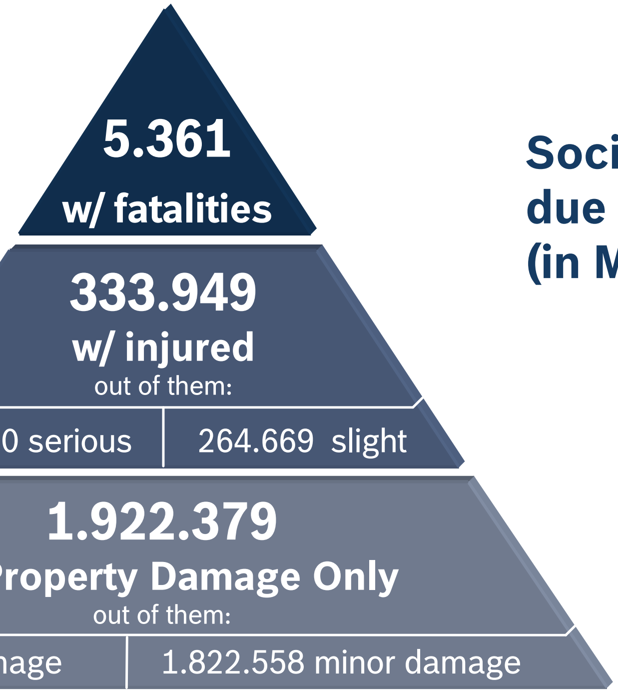
source: International Road Traffic and Accident Database IRTAD

* no data available for 2000 and 2001 in the UK

Socio-economic costs of police reported accidents in 2004

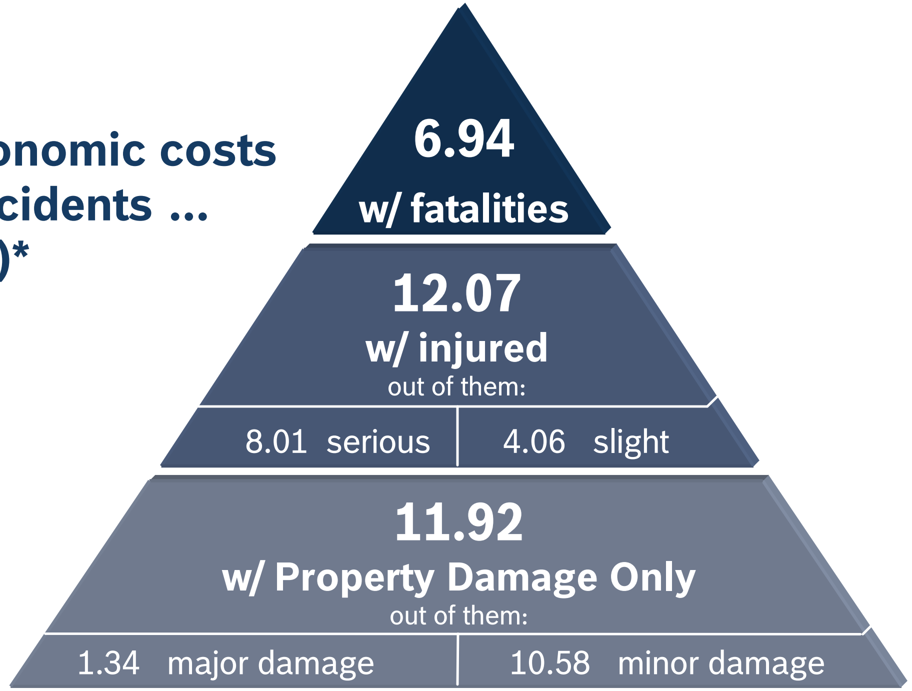
2004

Accidents ...



Source: Federal Statistical Office, Germany – Volume 8, Part 7 Accidents in 2004

Socio-economic costs due to accidents ... (in Mrd. €)*



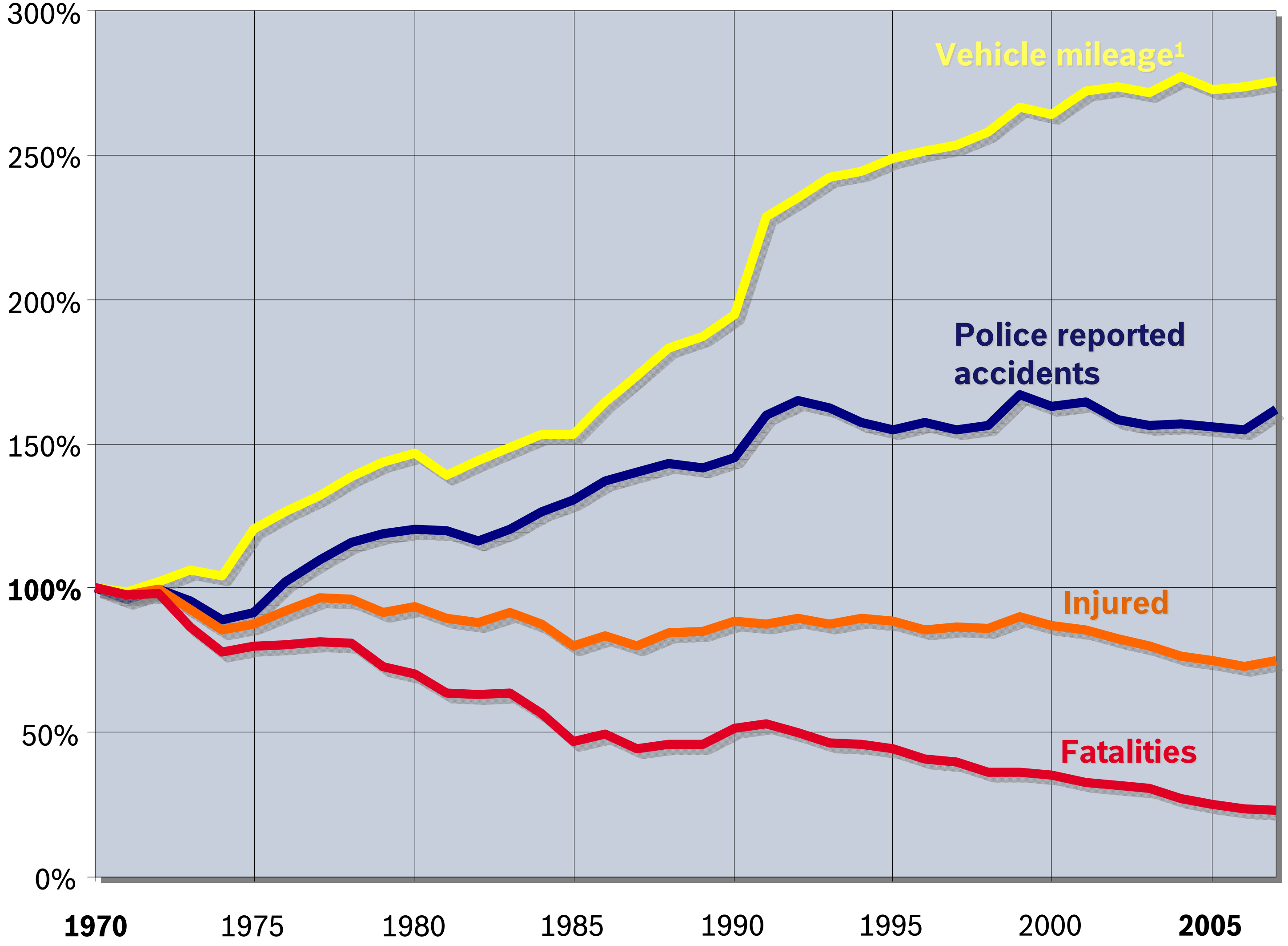
Source: BASt, Scientific information StBa info 2/06

➔ approx. 2.26 million police reported crashes in 2004 for Germany

➔ approx. 30.9 billion Euro socio-economic costs due to road accidents

* Updated data not available before end of 2009

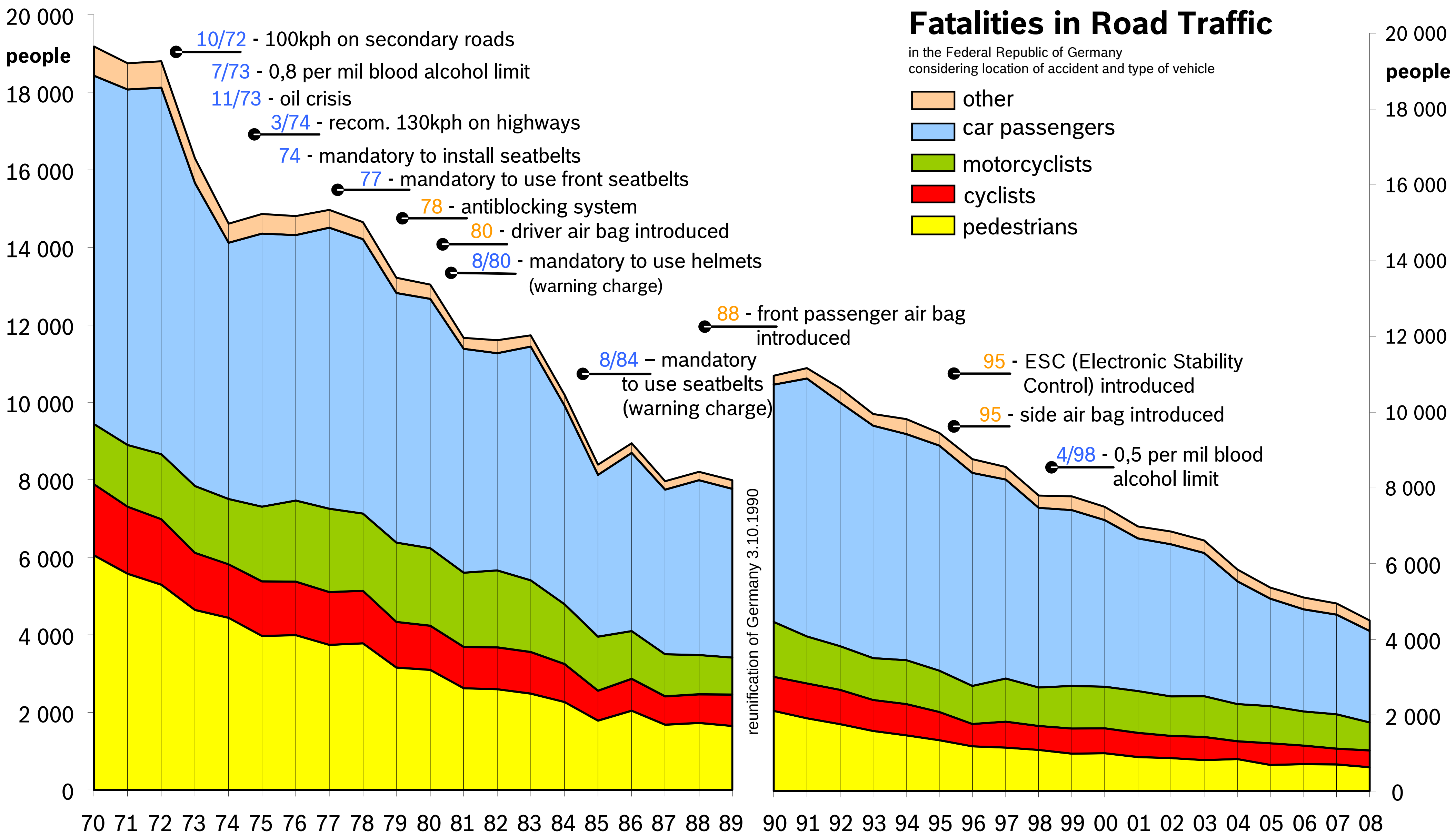
Accident details in Germany



Source:
Federal Statistical Office,
Robert Bosch Corporation
Accident Research
CR/AEV1

[1] Vehicle mileage with respect to StBA, before reunification (1991) only West Germany

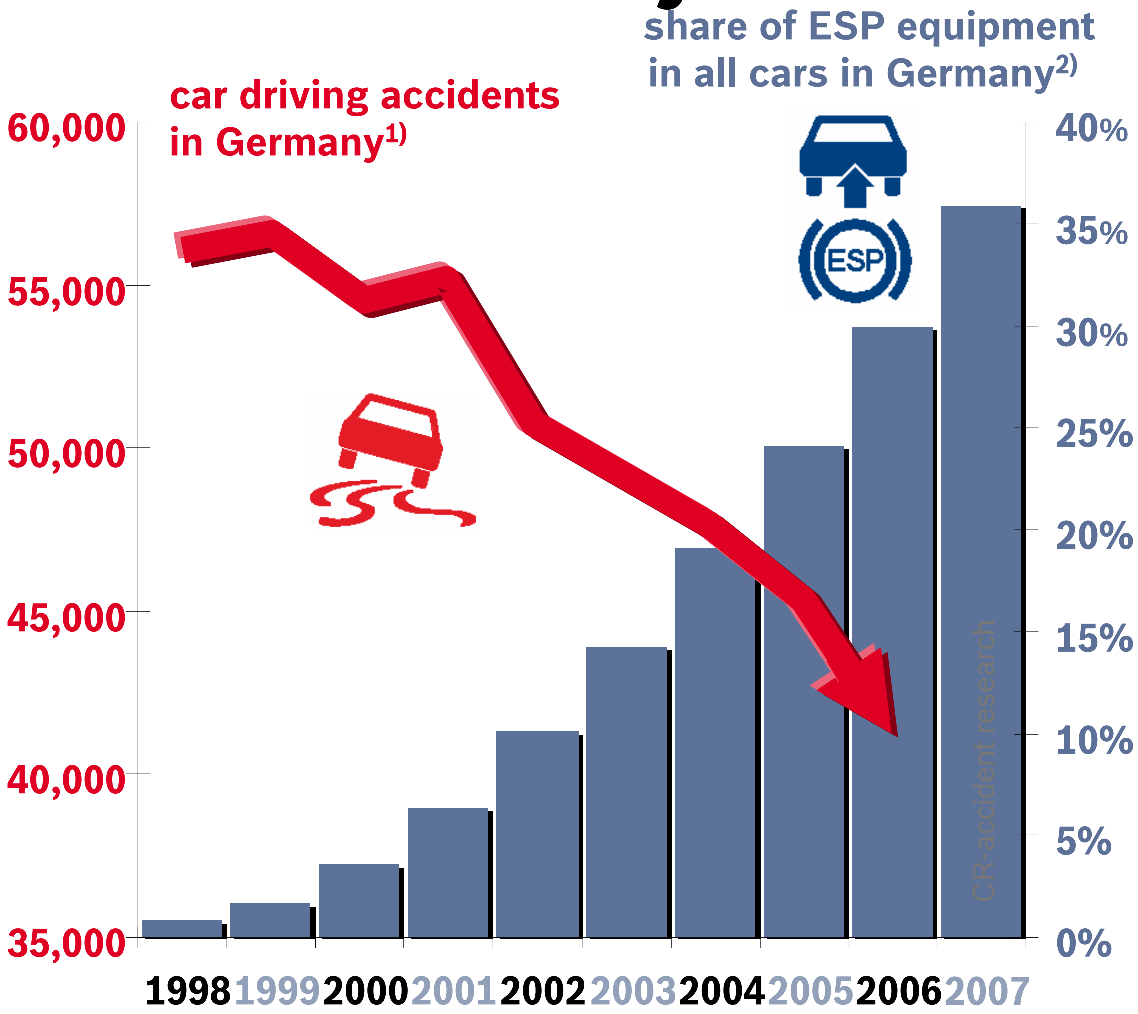
BOSCH



BOSCH CR/AEV1- accident research

BOSCH

Trend of driving accidents in Germany



- ➔ Skidding precedes approximately each second driving accident
- ➔ ESP® avoids 80% of skidding situations in accidents

- **ESP® makes a large contribution to the reduction of car driving accidents!**

sources: [1] Federal Statistical Office Germany: special study (accidents with personal injury)
[2] Institute for Transport Economics of Cologne: study "Cost-benefit-analysis of ESP"

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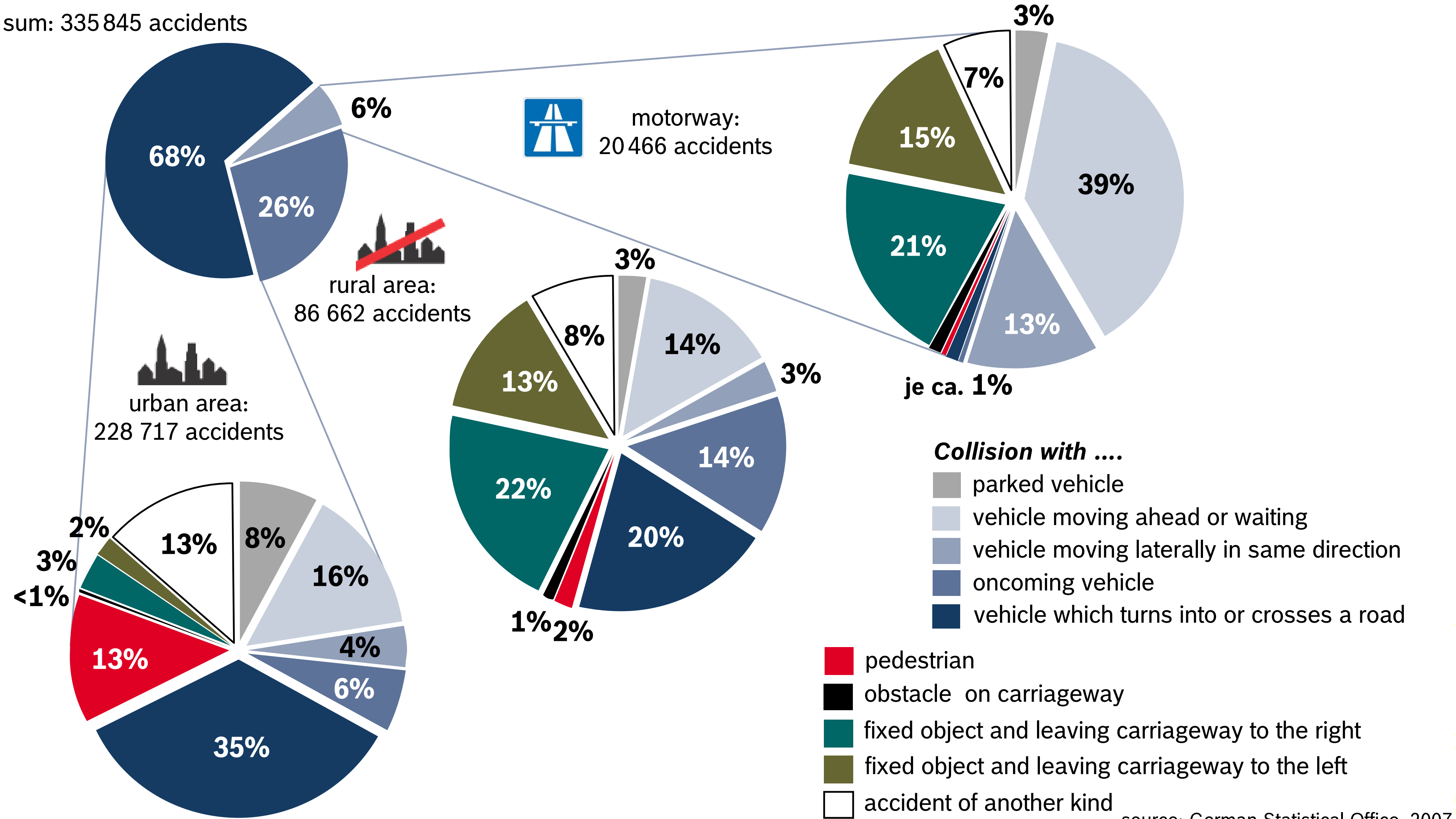
Accidents with casualties by kinds of accident



source: German Statistical Office, 2007

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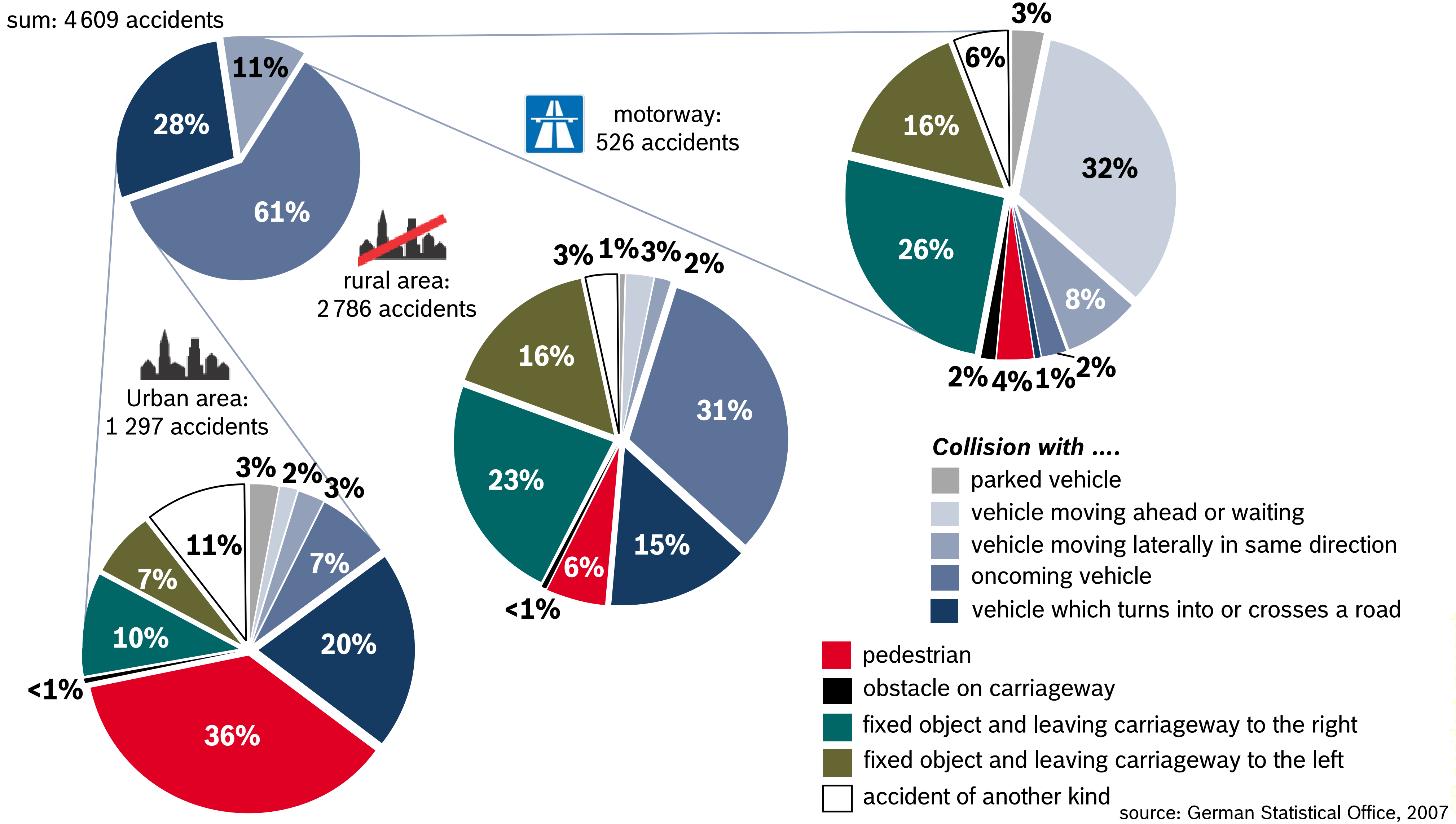
Fatal accidents by kinds of accident



source: German Statistical Office, 2007

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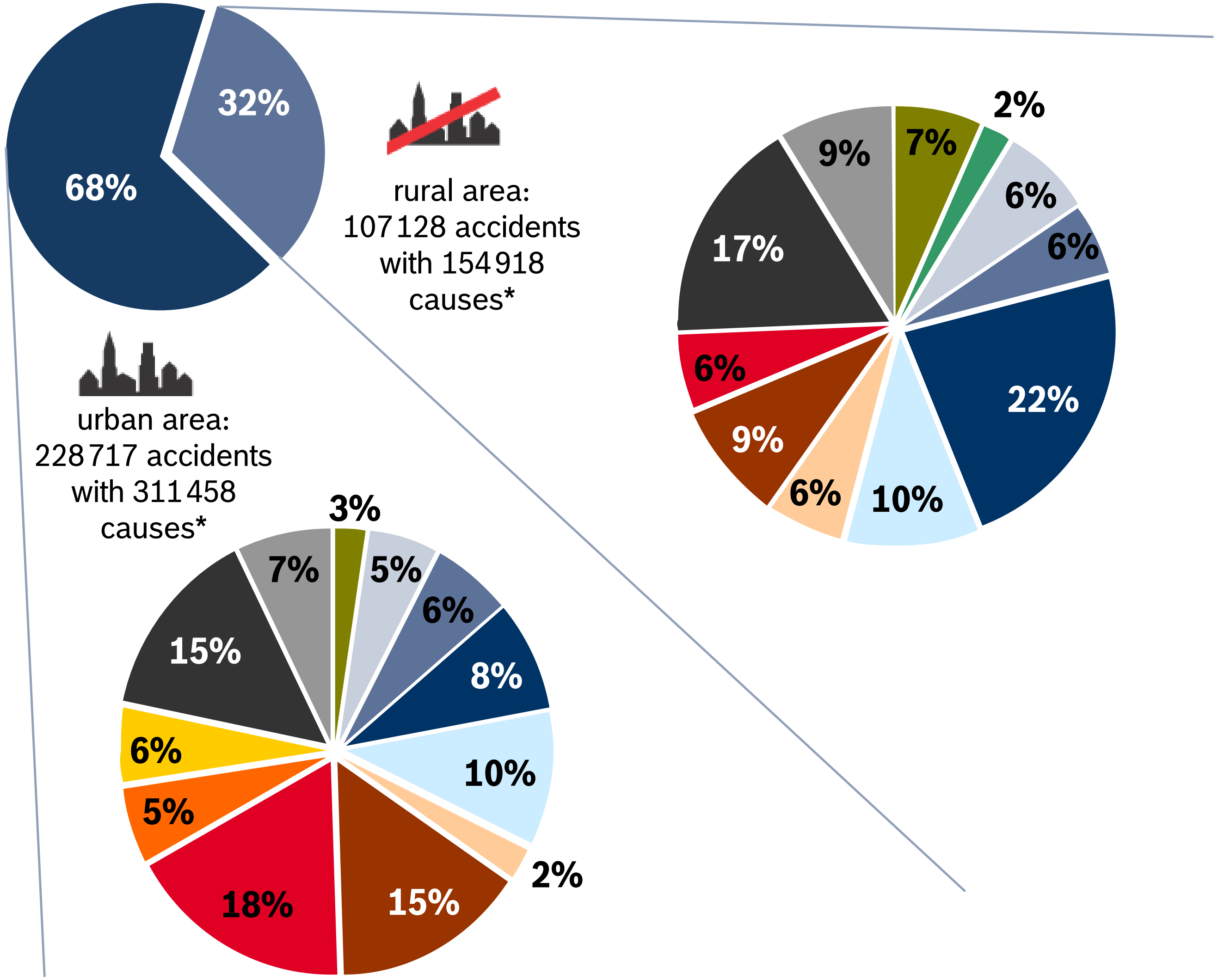
Causes for road accidents with injured

Analysis is based on 335 845 accidents in 2007



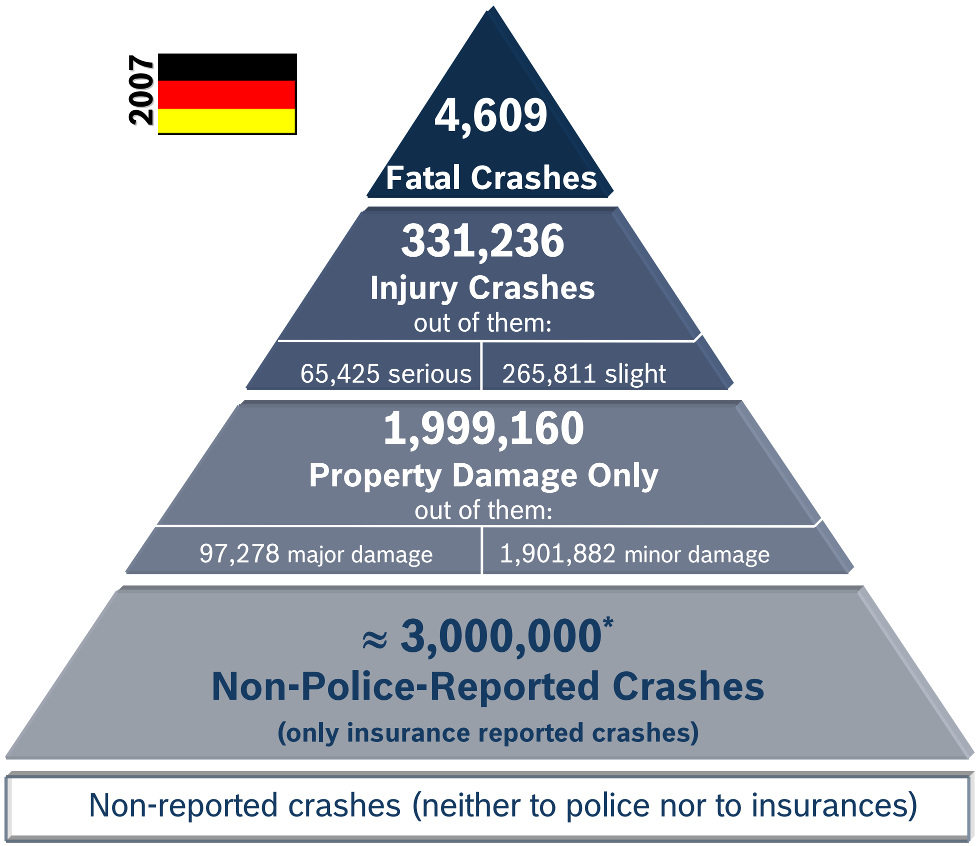
general cause of accident
- road conditions
- obstacles

mistakes of road users
- driving fitness
- use of road
- speed
- distance
- overtaking
- priority, precedence
- tuning, U-turn, reversing, entering the flow of traffic, starting off the edge of the road
- improper behavior towards pedestrians
- improper behavior of pedestrians
- other mistakes of the driver
- others

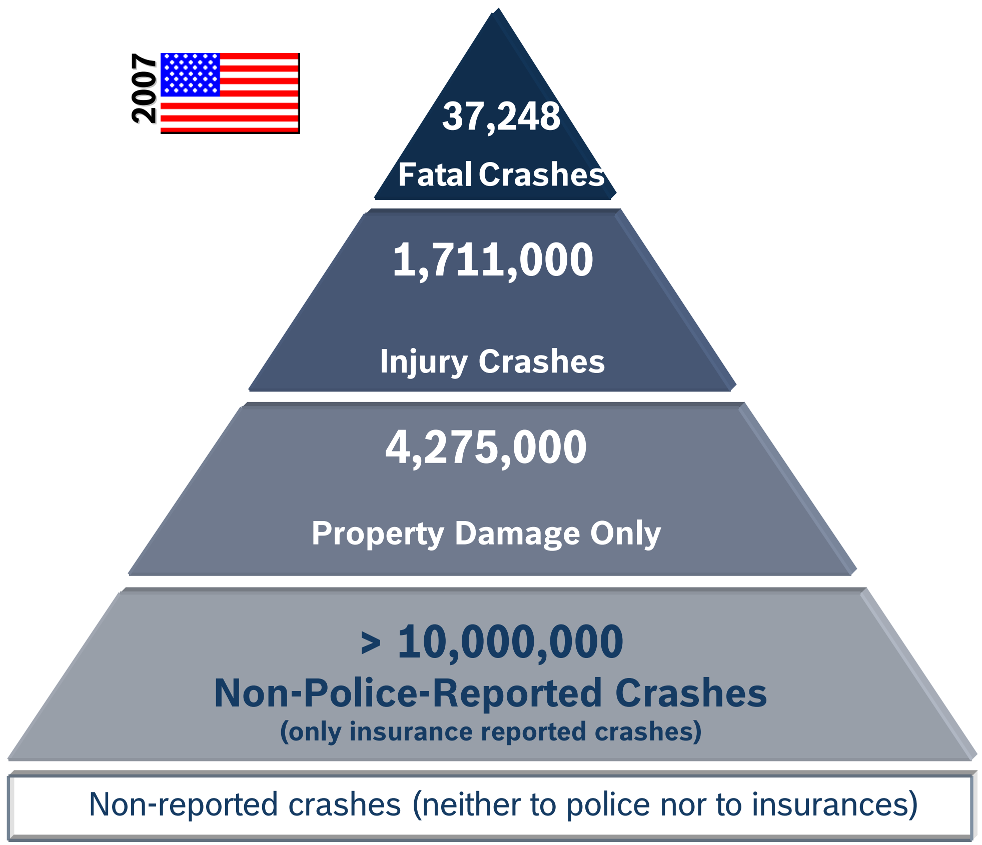
source: German Statistical Office, 2007

* In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.

Accident figures Germany – USA (2007)



sources: Federal Statistical Office, Germany
* GDV-yearbook (estimation)



sources: NHTSA / NCSA

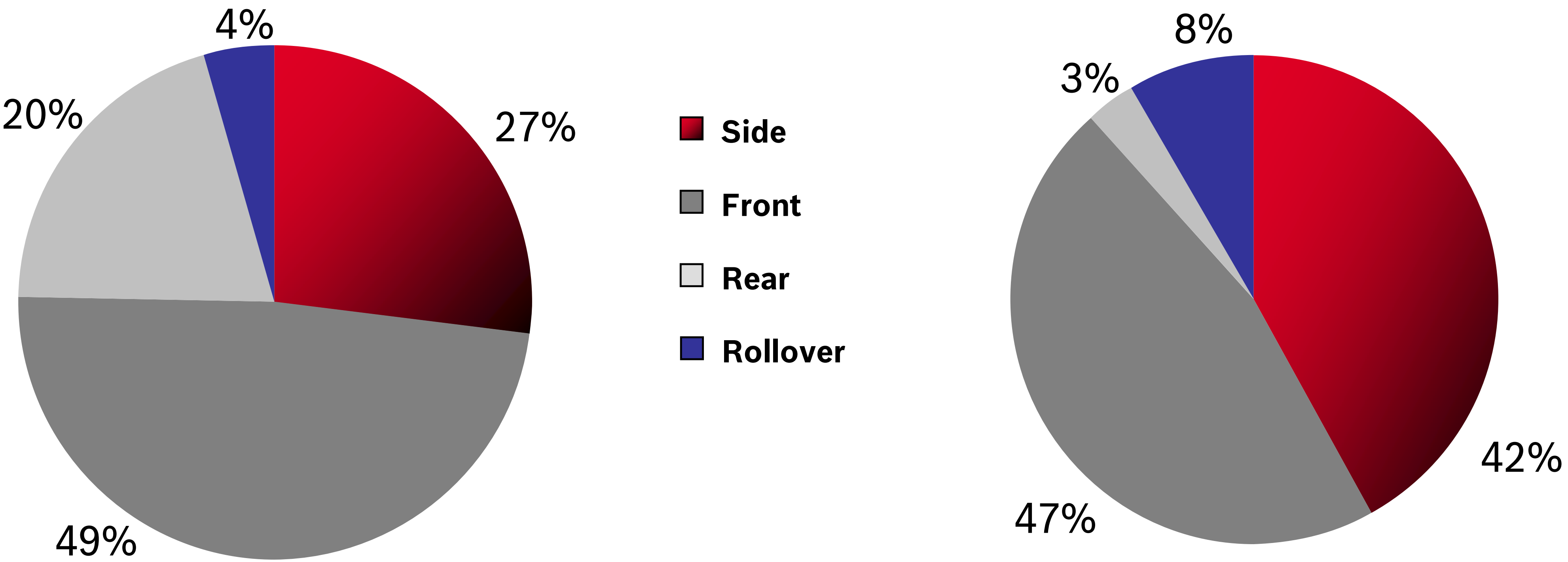
- ➔ approx. 5.3 million reported crashes in Germany
- ➔ approx. 16.0 million reported crashes in USA

Main damage area of vehicles involved in accidents

vehicles* with

*at least one **injured** occupant*

*at least one **killed** occupant*



6.217 Vehicles

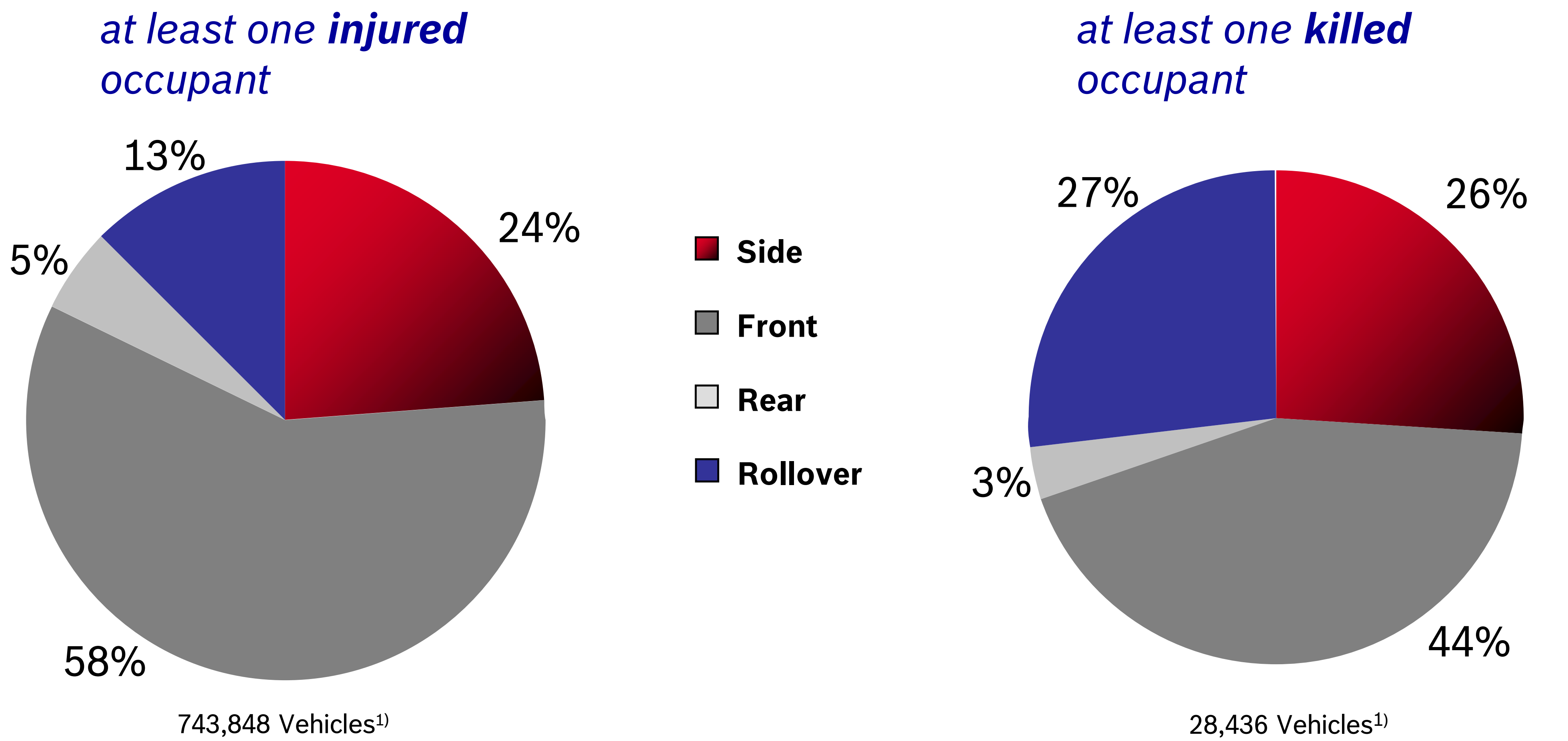
97 Vehicles

Source: GIDAS (2001-2006) weighted by official accident statistics, Bosch accident research CR/AEV

* Accident with unknown main damage area or unknown occupant injury severity are not considered

Main damage area of vehicles involved in accidents

vehicles* with

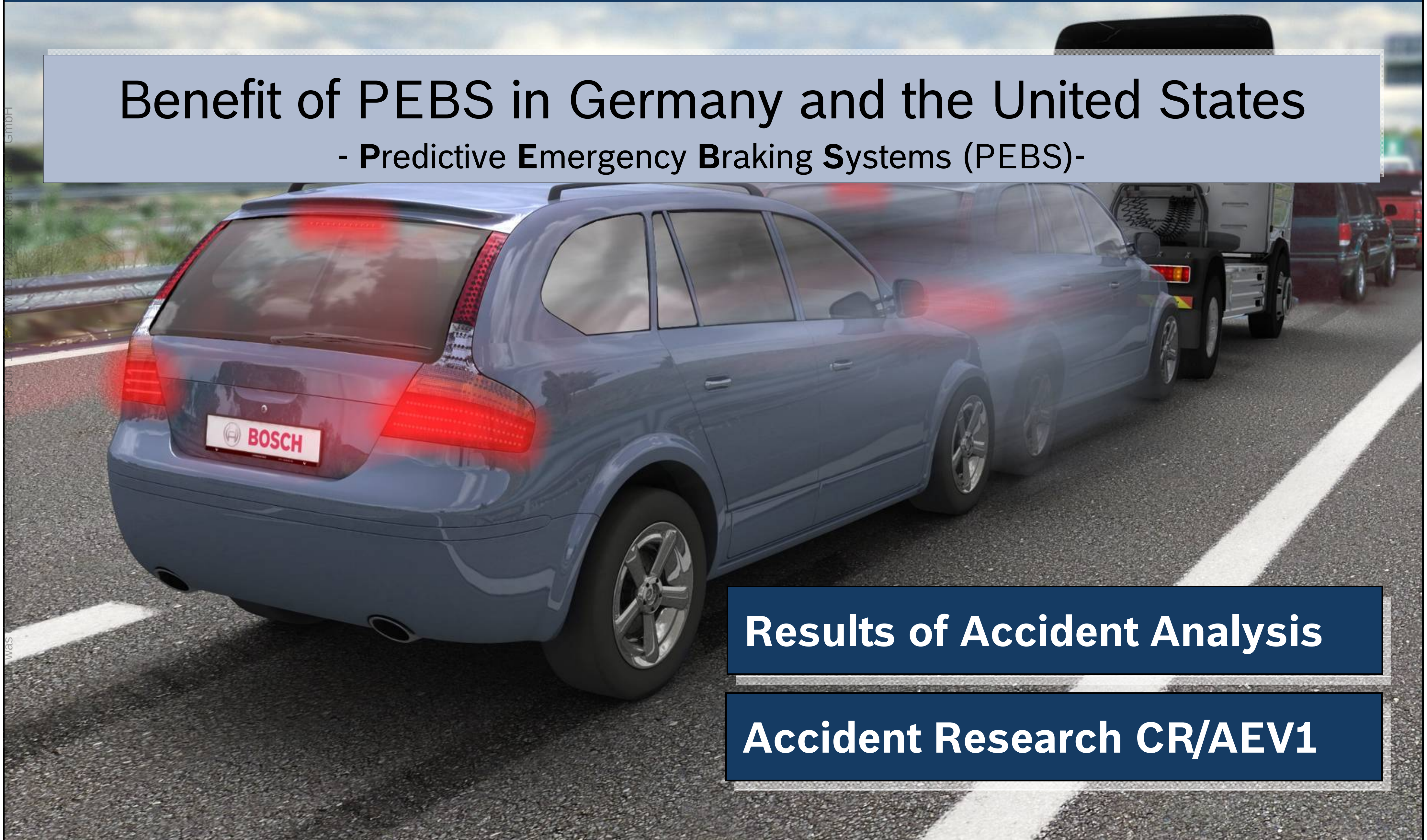


1) Sources: GES - and FARS – data from year 2005 (refer to total accident statistics in the US), Bosch accident research CR/AEV

* vehicles with unknown main damage area or unknown occupant injury severity are not considered

Benefit of PEBS in Germany and the United States

- **P**redictive **E**mergency **B**raking **S**ystems (PEBS)-



Results of Accident Analysis

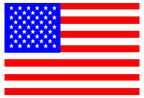
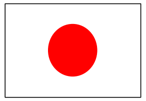
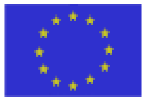
Accident Research CR/AEV1

- **Motivation and approach**
- Modeling of driver behavior
- Benefit of the Predictive Emergency Brake Systems (PEBS) of Bosch
- Comparison of FCW (NewNCAP) vs. PCW (Bosch)
- Benefit of PEBS in the United States
- GIDAS[1] accident example
- Summary
- Appendix

[1] German-In-Depth-Accident Study – www.gidas.org

Motivation

→ **Relevance of rear end crashes with injuries in 2006:**

	Number of rear end crashes	Share in all accidents
	500,000	28%
	284,000	32%
	266,000	16%
	49,200	15%

Real world accident example

Source: Youtube.com

→ Rear end crashes with injuries are very relevant

→ Between 80% and 90% of all rear end crashes are caused by cars

Sources: NHTSA/NCSA, IATSS, DESTATIS Year 2006, UNECE accident report, own calculation, EU27

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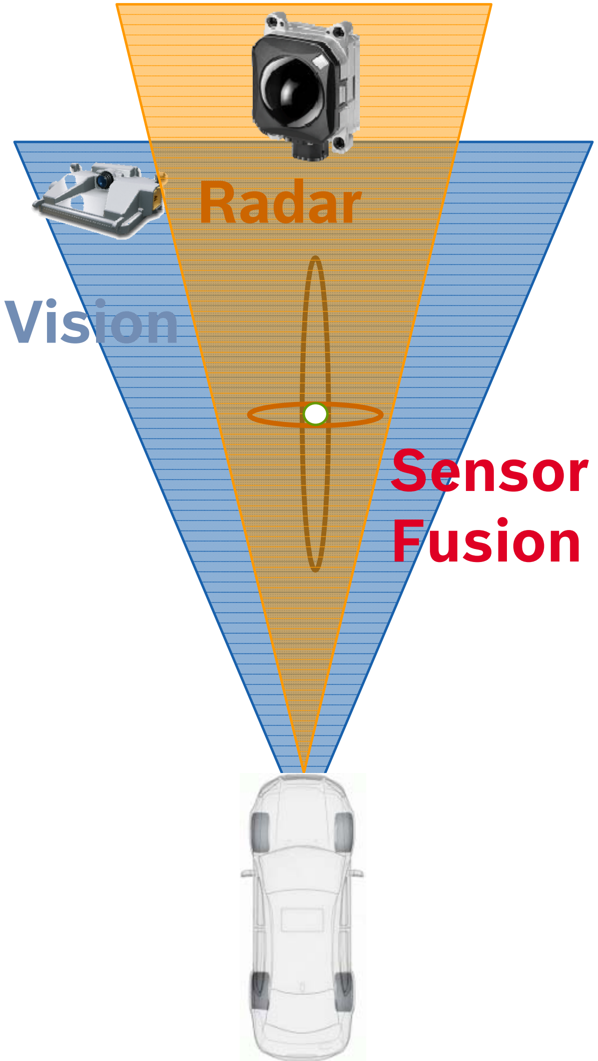
Functions examined for Benefit Analysis

Object Detection & Verification



PCW Predictive Collision Warning
(Radar only)
- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

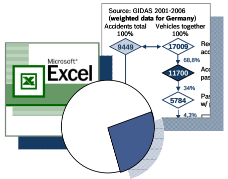
EBA Emergency Braking Assist
(Radar only)
- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

AEB Automatic Emergency Braking
(Radar + video)
- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

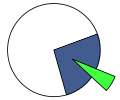
Approach

Conventional:

GIDAS database → Field of effect → Function description and effect to accident → Benefit/ avoidance potential

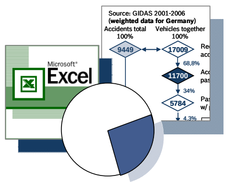


$f(x)$

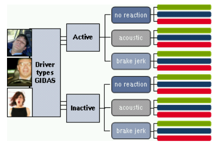


New approach for rear end crash avoidance systems:

GIDAS database → Field of effect → Function description and effect to accident → **Driver Model** combination of different driver characteristics → Benefit/ avoidance potential



$f(x)$



PEBS field of effect - Only PEBS benefit for passenger cars was evaluated in this study

Most common accident types

61 traffic jam – following vehicle	28,4%
60 ahead driving and following vehicle	28,2%
62 traffic regulation – following vehicle	22,9%
20 turning left – following vehicle	7,8%
72 turn	6,6%

Accidents

9323 GIDAS weighted (2001-2005/6)* — 100%

GIDAS German In-Depth Accident Study

12%

1103 accidents with at least one PEBS vehicle

Vehicles

16773 involved vehicles (36881 collisions) — 100%

16764 first collision — 100%

3964 relevant accident types — 24%

2779 forward moving vehicles — 17%

1504 frontal impact direction and frontal damage — 9%

1160 Passenger cars in relevant accidents — 7%

Exclusion criteria

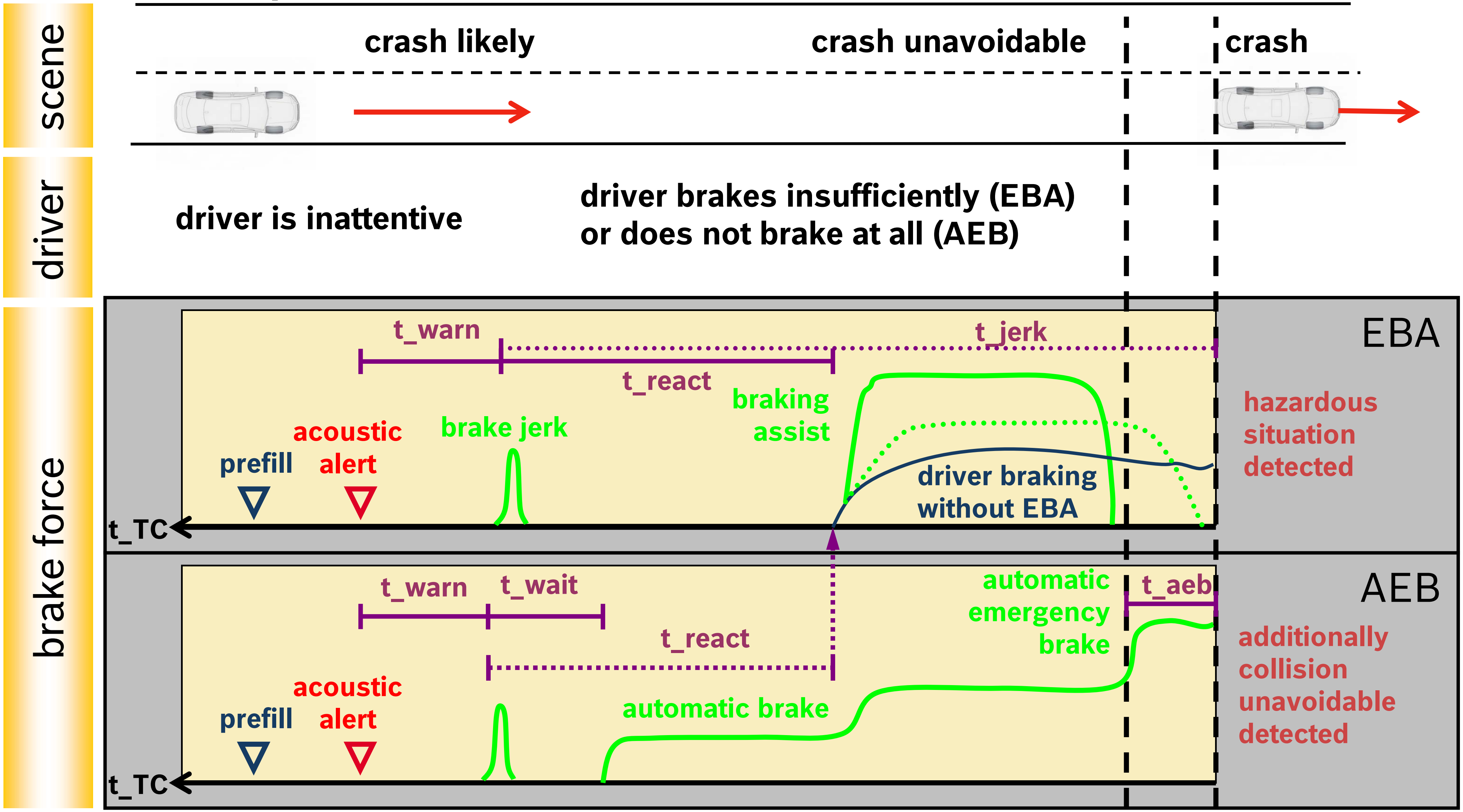
- only first real collision (sequences w/o collision not considered)
- irrelevant accident types
- backward driving or standing vehicles
- vehicles with no front impact direction or rear end damage
- Ego-vehicle no passenger car, opponent pedestrian, wrong orientation, overtaking accidents

Results

12% of all accidents with personal injuries in Germany (7% of all damaged cars) are PEBS related accidents with at least one relevant PEBS vehicle (remark: almost 39000 accidents per annum in Germany)

* Reconstructed GIDAS accidents 2001 – 2006 in Dresden and 2001 – 2005 in Hanover

Basic operation of PEBS in a rear end crash



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[1)] German-In-Depth-Accident Study – www.gidas.org

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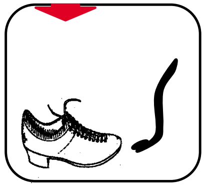
Driver braking behavior in GIDAS

Base: GIDAS 2005/6
1103 weighted, reconstructed and relevant rear end crashes

31%

No brake reaction
Drowsy, divert or incapable driver

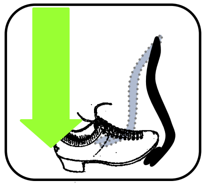


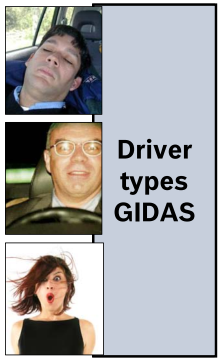
49%

Weak brake performance
Average driver, too late or light deceleration

20%

Adequate deceleration
Too late reaction





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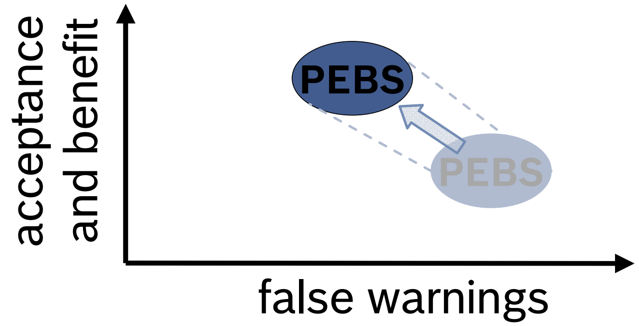
Degrees of driver activity

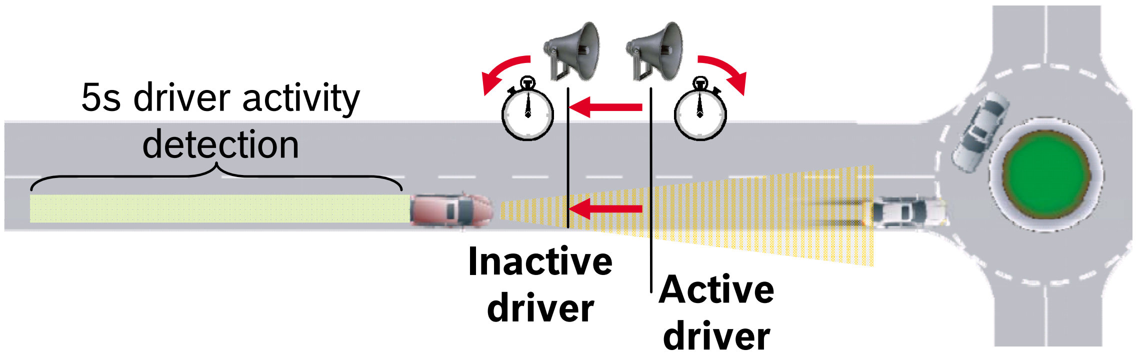
BOSCH PEBS: Online detection of driver activity for situation modeling
→ Warning time adjustment

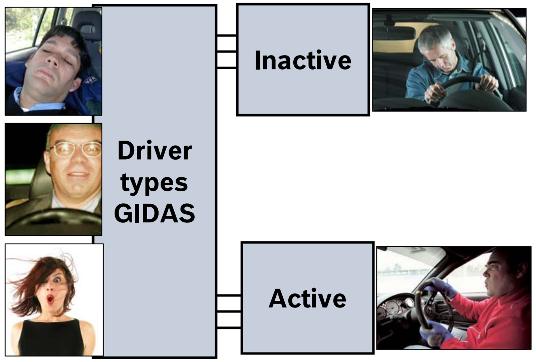
Advantages of using
a driver activity recognition



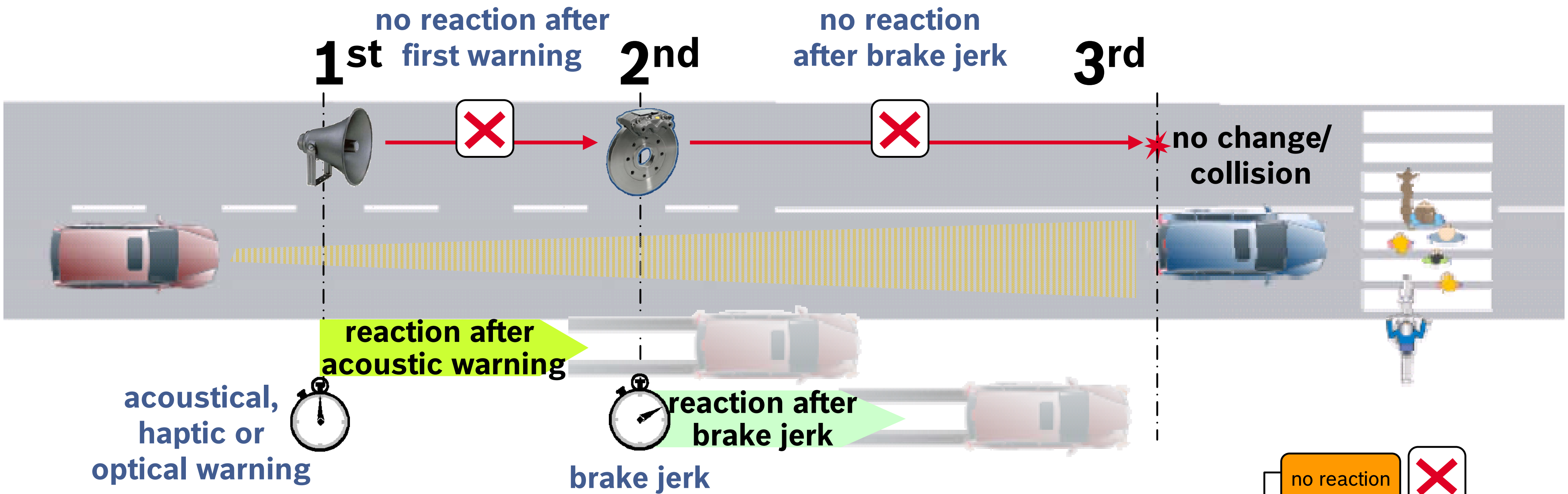
Classifier for bringing the warning time forward:

earlier warning for an inactive driver,
later warning for an active driver



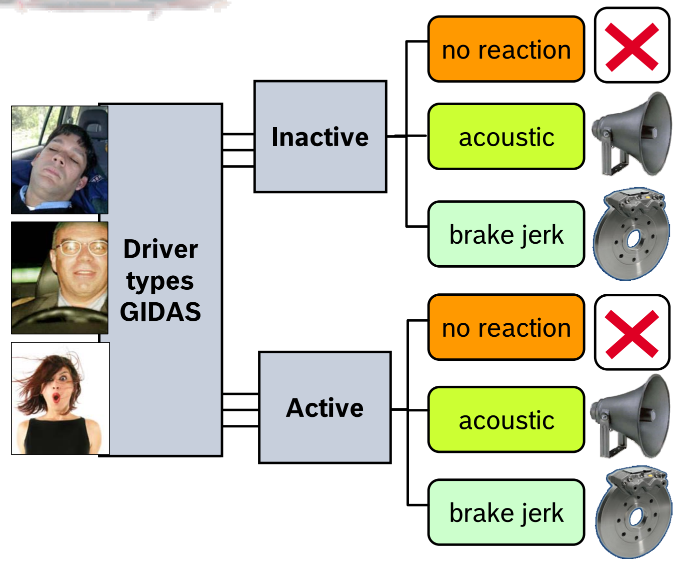


Brake initiating warning type



Assumption for distribution

✗	no reaction	10%
acoustic	reaction after acoustic warning	50%
brake	reaction after brake jerk	40%



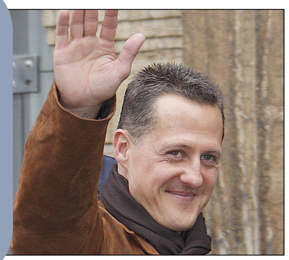
Driver reaction types

Realistic driver:

Reaction:
1s after acoustic warning
0,7s after brake jerk
80% deceleration

Best driver:

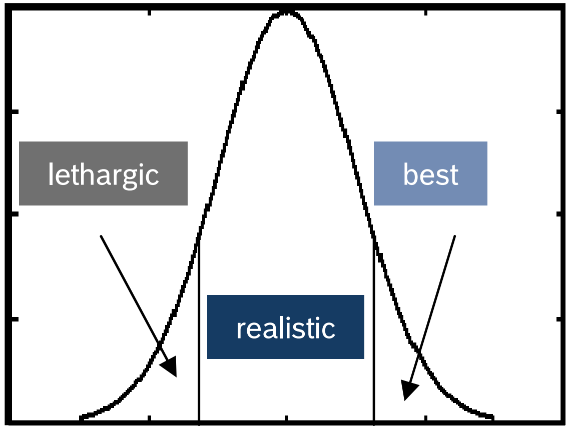
Reaction:
0,7s after acoustic warning
0,4s after brake jerk
100% deceleration



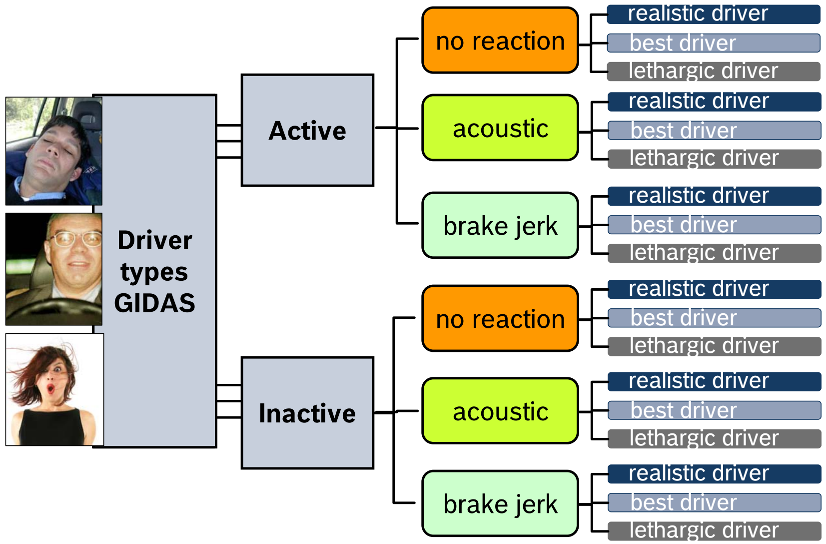
Lethargic driver:

Reaction:
2s after acoustic warning
1,5s after brake jerk
60% deceleration

Expected driver population

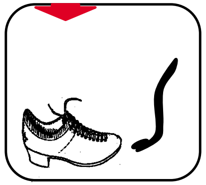


PEBS – driver model



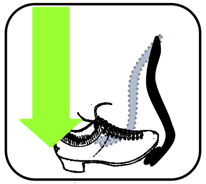
Driver model – Summary

GIDAS	**Test drives** (CR/AEY)	**CR/AEV**
Deceleration in real accident scenario	Driver activity assumed	Driver reaction to PEBS warning assumed



No braking → 30% active / 70% inactive

Medium deceleration → 50% active / 50% inactive



Full deceleration → 70% active / 30% inactive

PEBS warning time

	best	realistic	lethargic
10% No reaction			
50% Acoustic	0.7 s	1 s	2 s
40% Brake jerk	0.4 s	0.7 s	1.5 s
...braking with	100%	80%	60%

Knowing the deceleration of the ego vehicle if equipped with an PEBS function, a new collision speed can be calculated in the accident scenario (accident avoided if new collision speed is zero)

- → Motivation and approach
- → Modeling of driver behavior
- → **Benefit of the Predictive Emergency Brake Systems (PEBS) of Bosch**
- → Comparison of FCW (NewNCAP) vs. PCW (Bosch)
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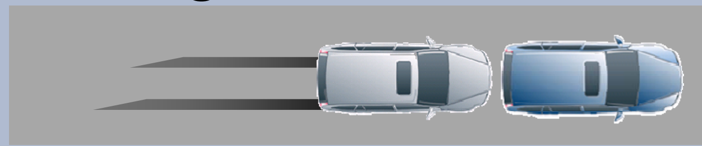
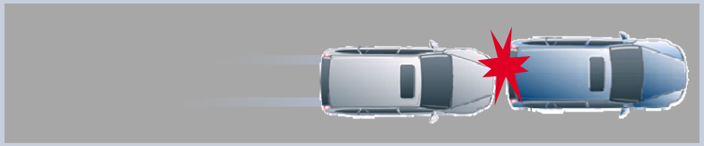
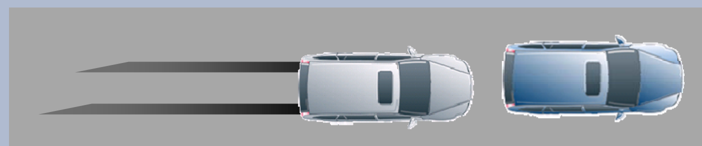
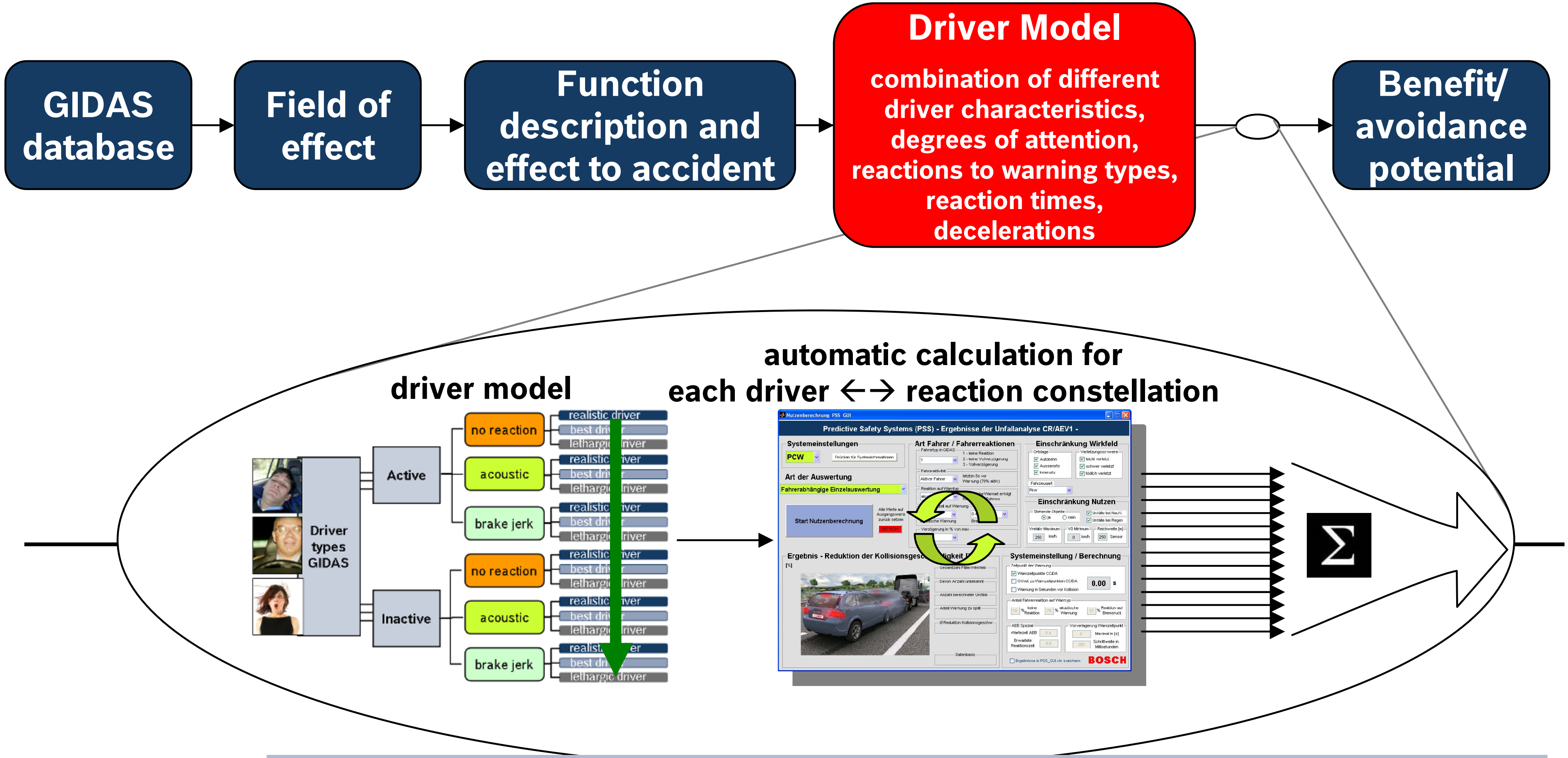
[1)] German-In-Depth-Accident Study – www.gidas.org

Potential benefit of collision warning systems

w/o collision warning system		**w/** collision warning system
	**Brake initiation after warning (for drowsy or divert driver)**	**braking at all** 
	**Bringing braking time forward (for those who launched braking too late)**	**earlier braking** 
	**Manuel brake boosting after system alert**	**increased deceleration** 

➔ collision avoidance or speed reduction

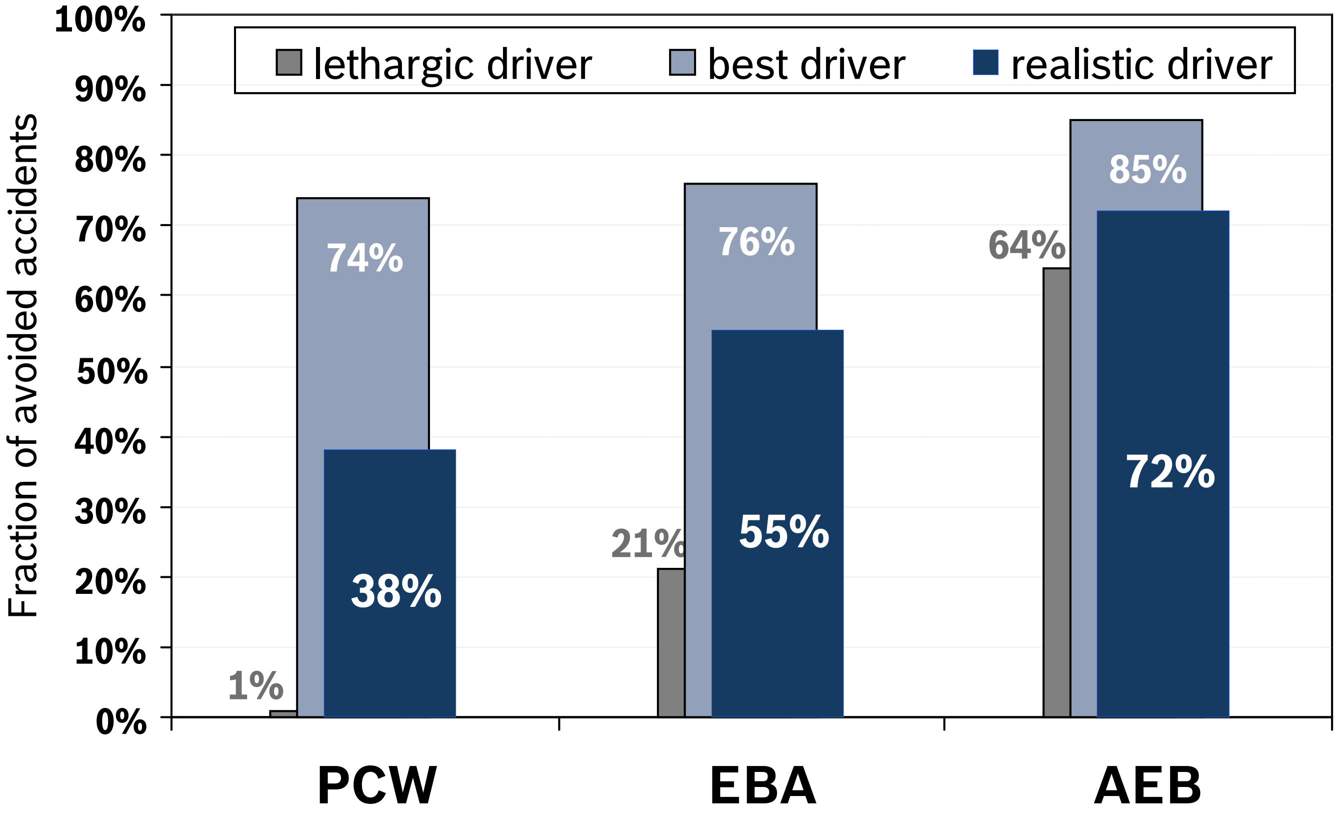
Calculation of overall benefit



➔ **For each driver scenario various single calculations are done.**

➔ **The result will be summarized.**

Rear-end crashes: Fraction of avoided accidents



PCW Predictive Collision Warning
- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

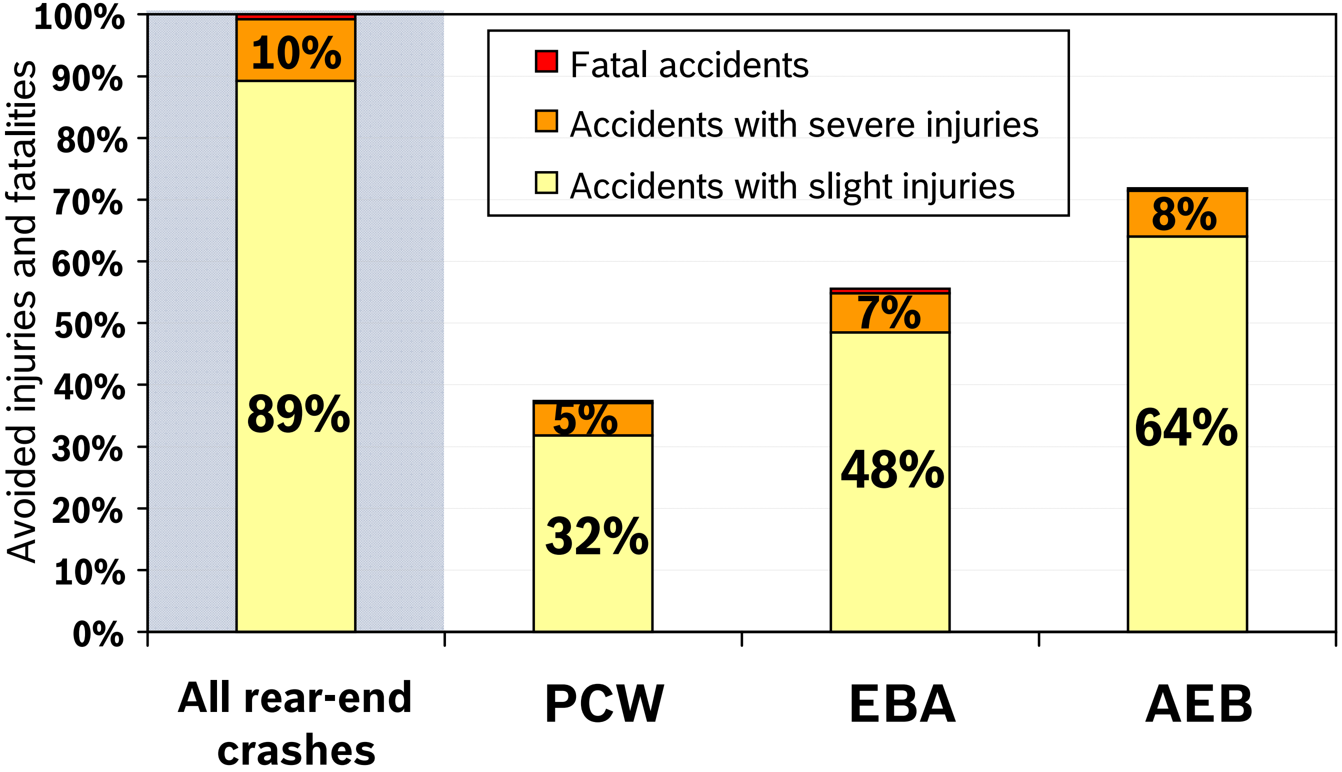
EBA Emergency Braking Assist
- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

AEB Automatic Emergency Braking
- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

➔ High accident avoidance potential by PCW, EBA and AEB in rear-end crashes

Source: Bosch Analysis of GIDAS Database (2001-2005), 1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

Rear-end crashes: Injuries and fatalities avoided by PEBS-functions*



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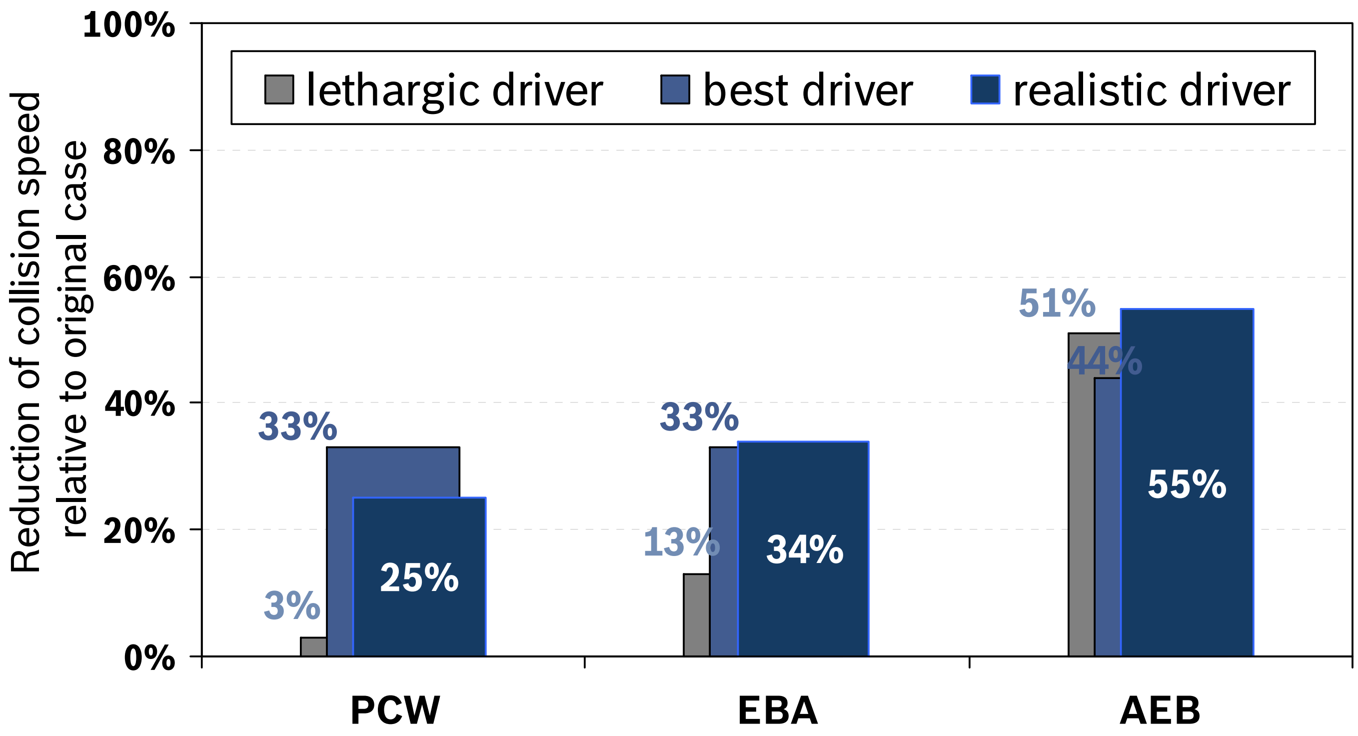
→ **PEBS functions are expected to avoid at least**
- half (PCW) up to three-quarter (AEB) of rear-end crashes with <u>severe</u> injuries
- one-third (PCW) up to two-third (AEB) of rear-end crashes with <u>slight</u> injuries

Source: Bosch Analysis of GIDAS Database (2001-2005), 1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

* for realistic driver

Rear end crashes: Average reduction in collision speed for not avoided rear-end crashes



PCW Predictive Collision Warning (Radar only)

- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

EBA Emergency Braking Assist (Radar only)

- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

AEB Automatic Emergency Braking (Radar + video)

- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

→ Even if the rear-end collision cannot be avoided by PCW, EBA or AEB, the collision speed is still strongly reduced, leading to reduced accident severity

Source: Bosch Analysis of GIDAS Database (2001-2005), 1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

[1)] German-In-Depth-Accident Study – www.gidas.org

Comparison of FCW vs. PCW: Functional description

PCW

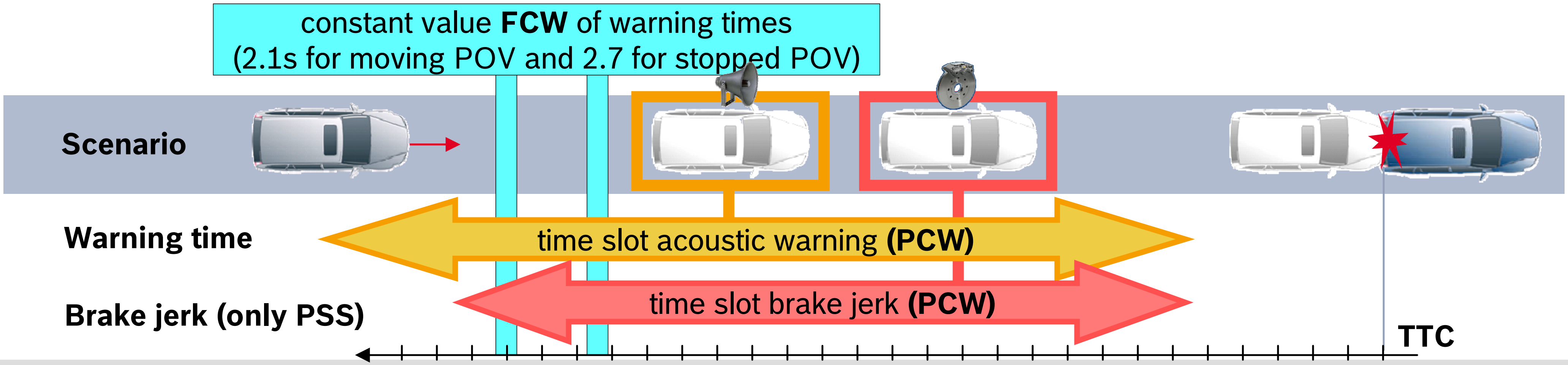
BOSCH

- Two warning modes (acoustic warning and brake jerk)
- Works in every speed range
- No minimum speed
- **PCW only warning** with wide spread of warning time values
- **Brake support** with **EBA** system, support is set to 100% deceleration
- Operates during bad weather conditions and night

FCW

NHTSA

- **Only** acoustic/haptic/optic warning
- Maximum relative speed of 80 km/h
- **Min. 30 km/h** initial speed
- For each setup only **one warning time** defined and
- **No variation** over complete speed range (warning time linked to initial speed of **POV** [Principal Other Vehicle])
- No function within rain and night



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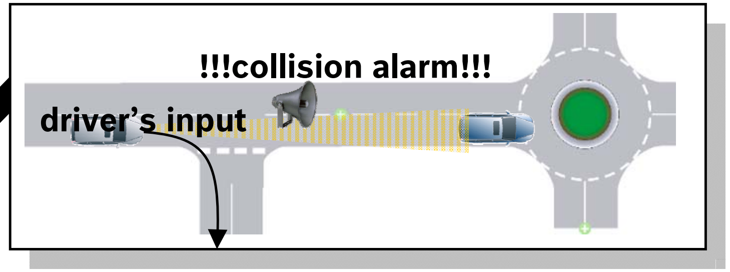
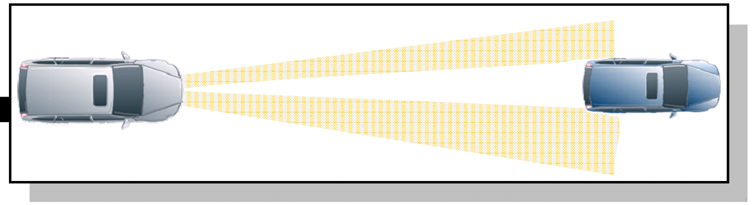
Comparison of FCW vs. PCW: Functional restrictions

Assumption: Increased warning delays in Feb '09 FCW specifications reduce false warnings, leading thereby to higher system acceptance i.e. less systems disabled by drivers

Reason for failure	Description	PCW	FCW 1) Jul '08	FCW 2) Feb '09
System switched off	Driver disables system due to frequent false /too early warnings	0%	10%	0%
Drowsy, divert or incapable driver	Driver is not able to react	8%	8%	8%
Sensor spec/failure	Failure of function or algorithm	1%	4%	4%
Opponent	Opponent not detectable	1%	3%	3%
	sum:	10%	25%	15%





➔ **Assumption:** In 25% 1) or 15% 2) of all cases (depending on FCW specifications) the FCW will have no influence on the accident outcome

[1] 2.1s for moving POV (principal other vehicle) and 2.7 for stopped POV
[2] 2.0s for moving POV (principal other vehicle) and 2.1 for stopped POV

Driver reaction types for FCW

Assumption: Increased warning delays in Feb '09 FCW specifications[2] reduce false warnings, leading thereby to higher system credibility and quicker / stronger driver reaction.
Evaluation with Feb '09 specifications[2] only performed for realistic driver.

Realistic driver

FCW specifications Jul'08 [1]
Reaction time acoustic warning: 1.5s
Deceleration: 60%
FCW specifications Feb'09 [2]
Reaction time acoustic warning: 1.3s
Deceleration: 80%

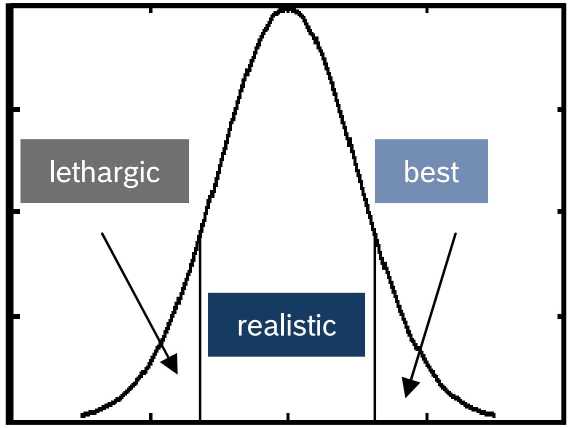
Best driver

FCW specifications Jul'08 [1]
Reaction time acoustic warning: 1s
Deceleration: 80%

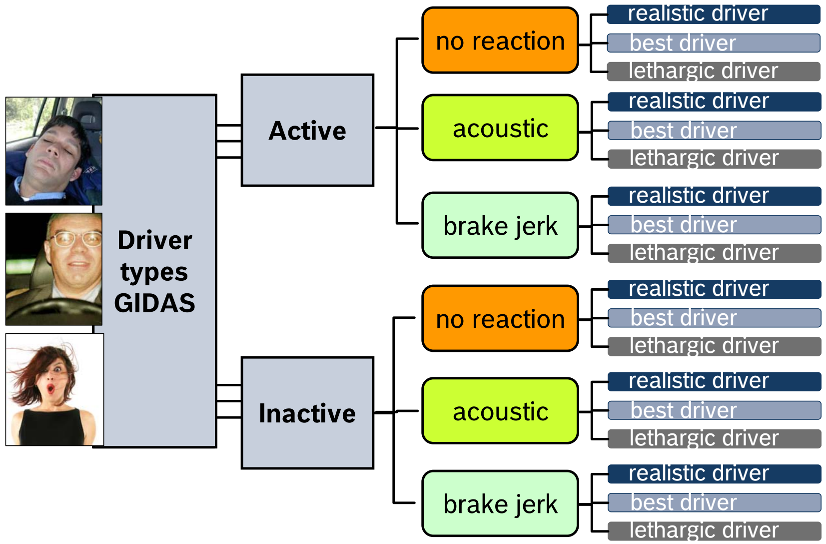
Lethargic driver

FCW specifications Jul'08 [1]
Reaction time acoustic warning: 2s
Deceleration: 40%

Expected driver population



PEBS – driver model

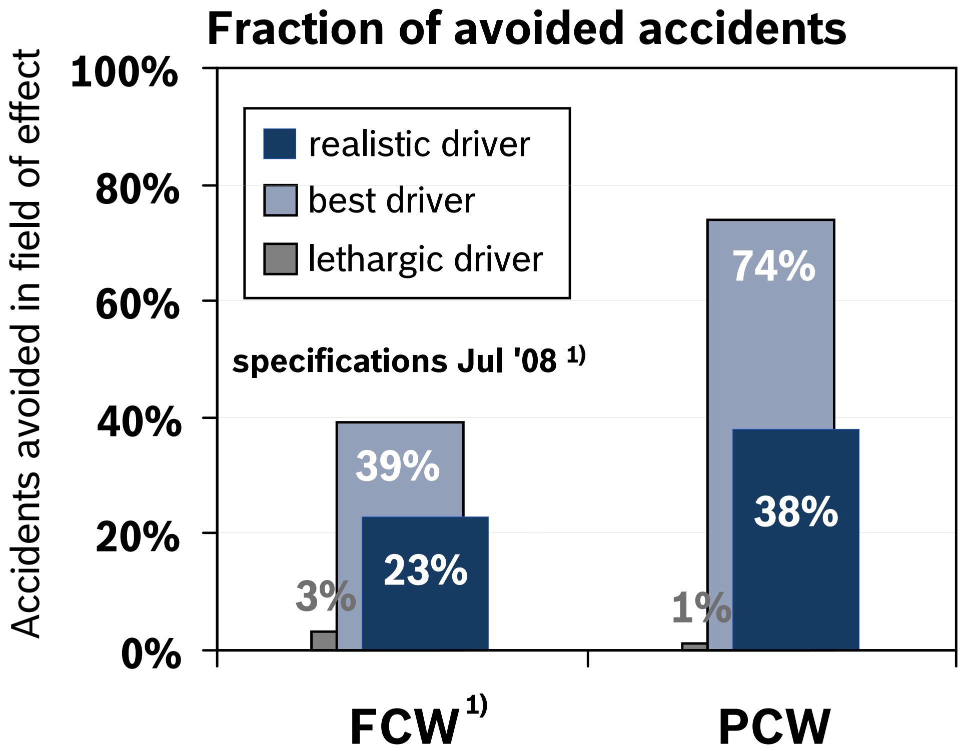


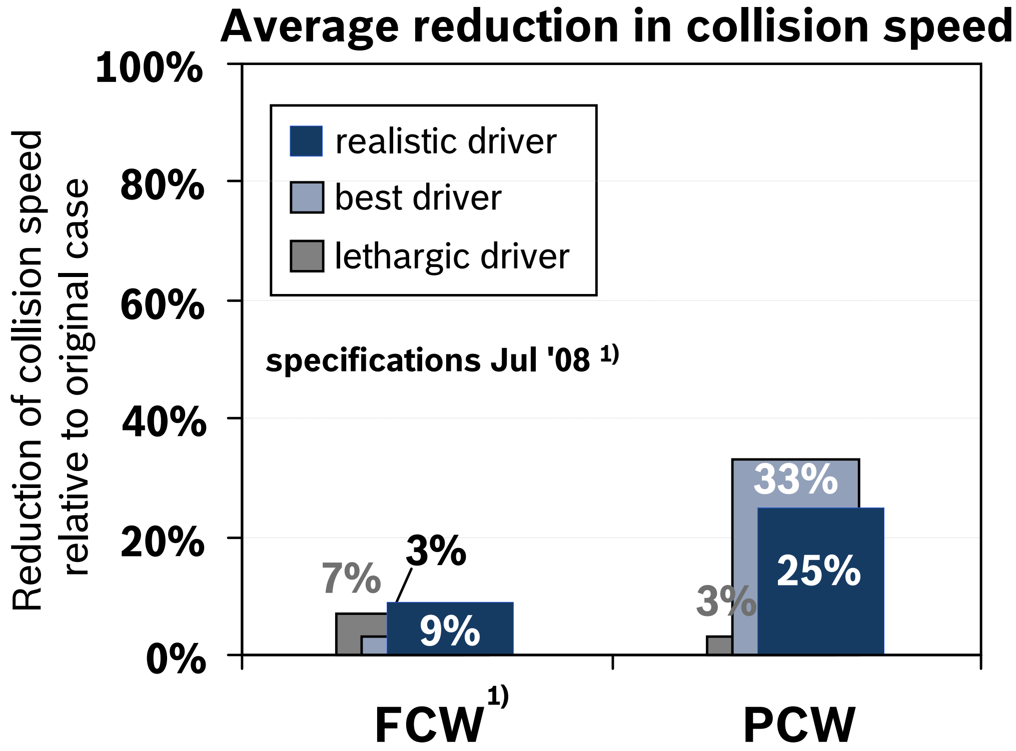
[1] 2.1s for moving POV (principal other vehicle) and 2.7 for stopped POV
[2] 2.0s for moving POV (principal other vehicle) and 2.1 for stopped POV

BOSCH

Results of comparison: FCW[1)] vs. PCW

→ Benefit calculation of FCW based on NewNCAP basic requirements (**specifications Jul '08 [1)]**, constant values of warning times, no function at night and under rainy conditions)





→ **Bosch PCW will have a significantly higher benefit as compared to the FCW-function**

→ **Due to constant and early warning times of FCW [1)] false warnings are expected in one of 10 cases as compared to Bosch PCW (FCW specifications Jul '08 [1)]).**

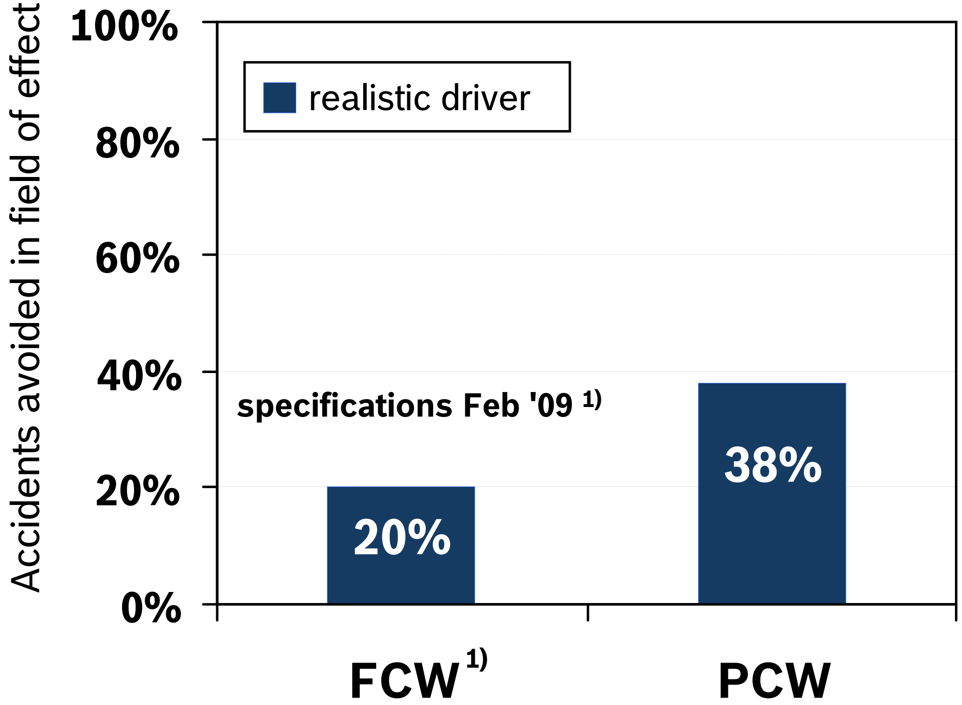
Source: Bosch Analysis of GIDAS Database (2001-2005), modeled under idealized conditions

[1)] 2.1s for moving POV (principal other vehicle) and 2.7 for stopped POV (FCW specifications Jul '08)

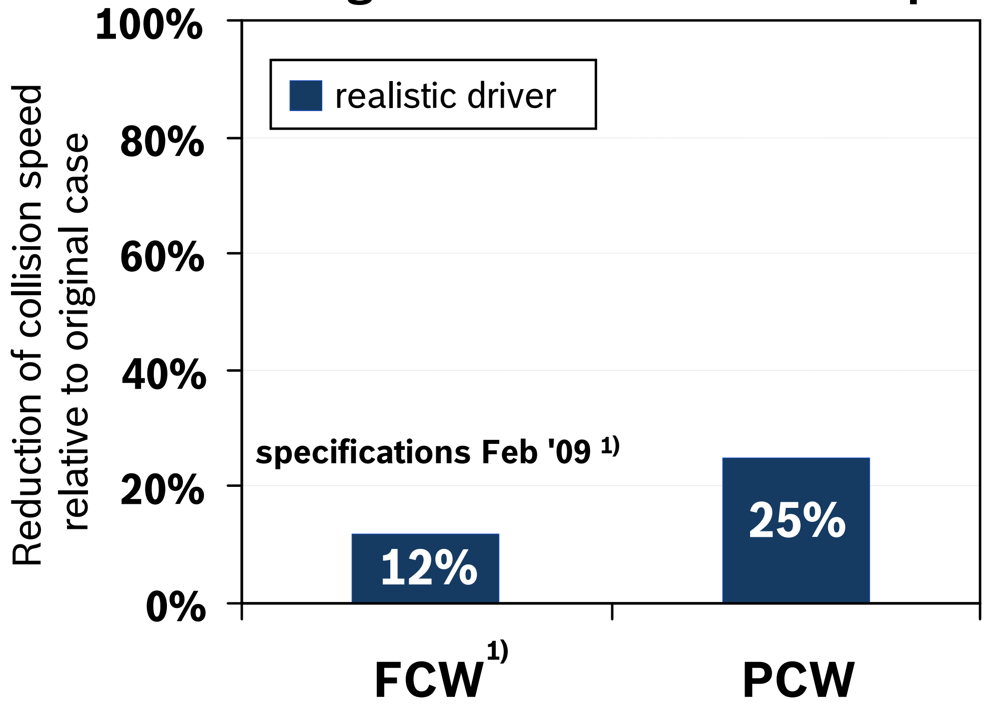
Results of comparison: FCW[1)] vs. PCW

➔ Benefit calculation of FCW based on NewNCAP basic requirements (**specifications Feb '09** [1)], constant values of warning times, no function at night and under rainy conditions)

Fraction of avoided accidents



Average reduction in collision speed



➔ **Bosch PCW will have a significantly higher benefit in comparison to FCW-Function**

➔ **Reduced warning times[1)] lead to less false warnings and higher system acceptance**

Source: Bosch Analysis of GIDAS Database (2001-2005), modeled under idealized conditions

[1)] 2.0s for moving POV (principal other vehicle) and 2.1 for stopped POV (FCW specifications Feb '09)

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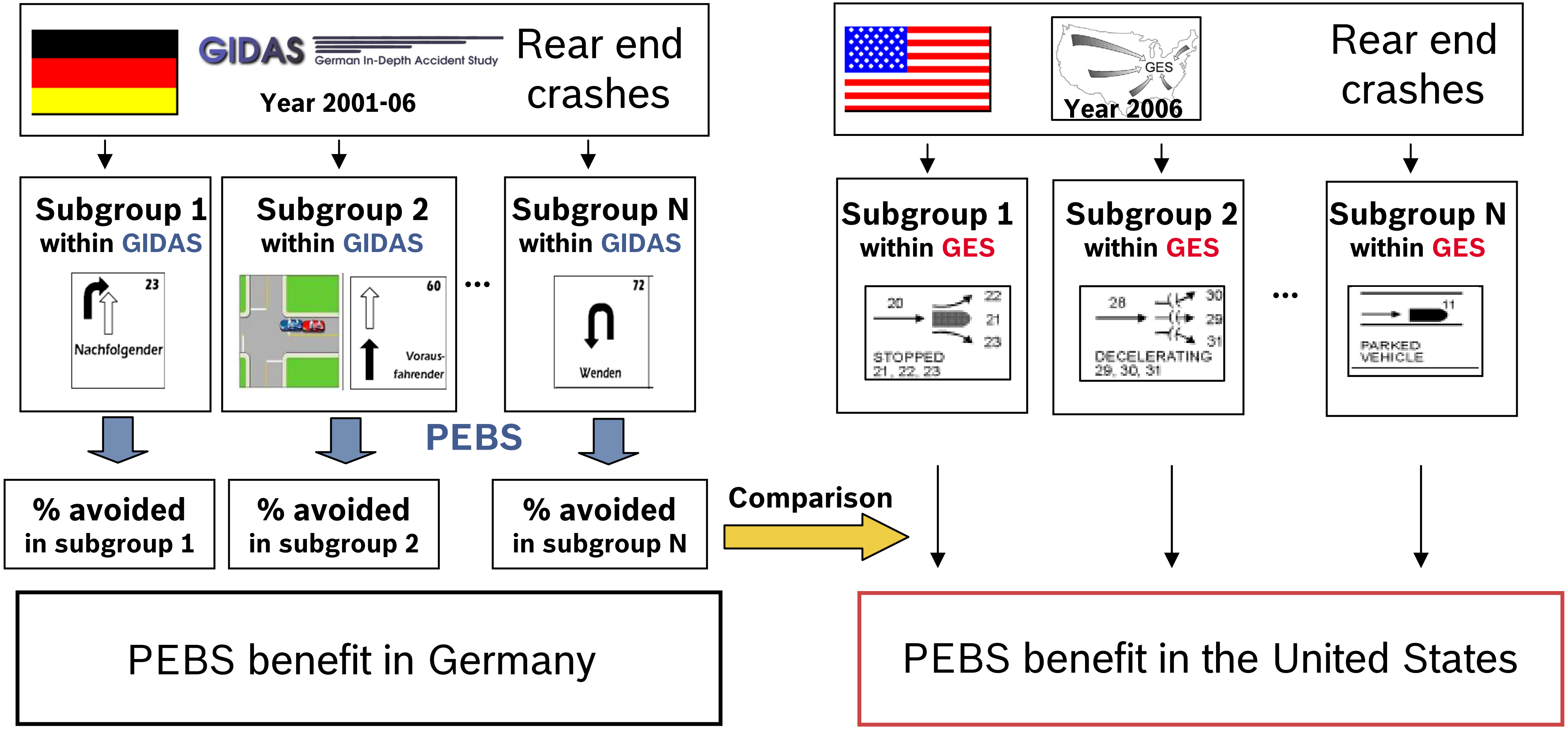
[1)] German-In-Depth-Accident Study – www.gidas.org

Transfer from GIDAS to GES - Overview



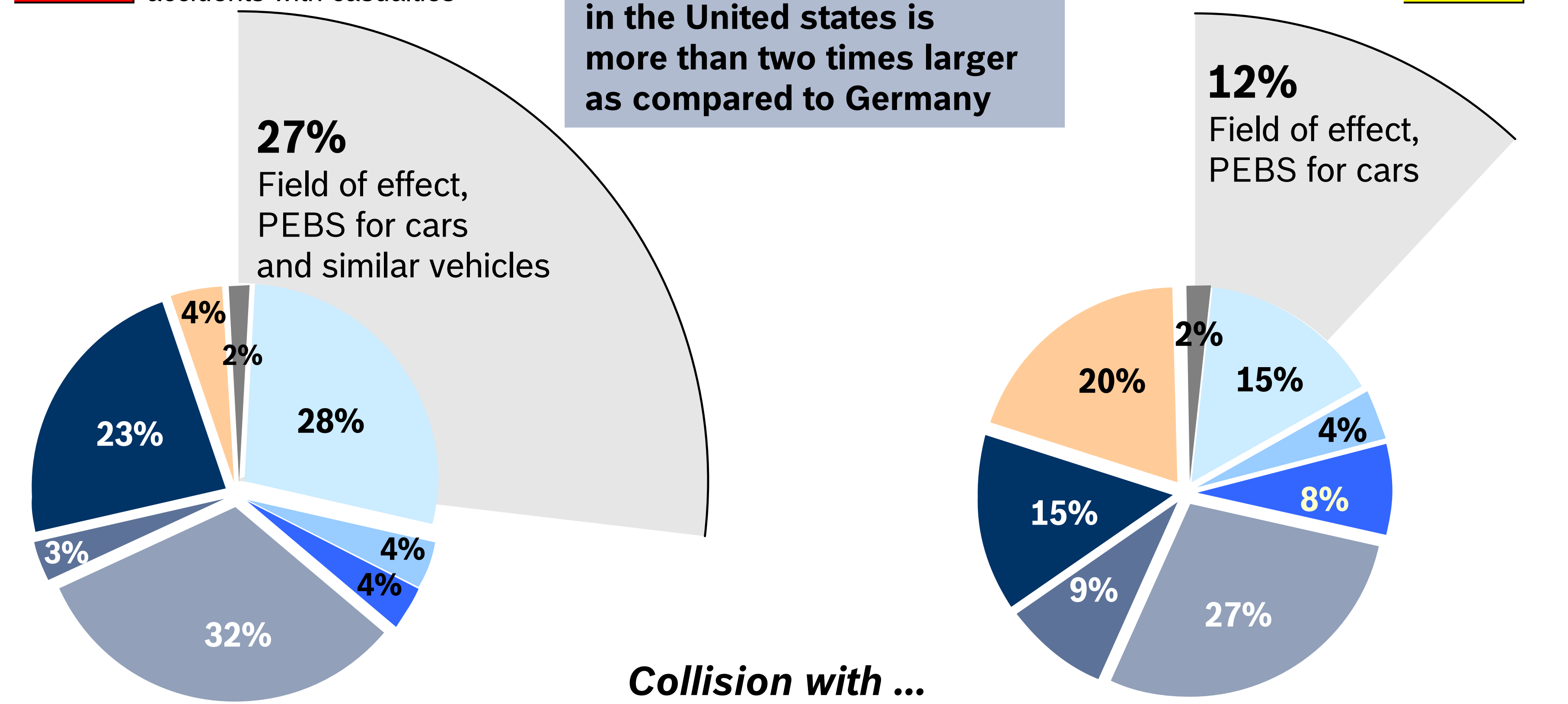
➔ **Transfer of results from Germany to the United States via comparison of accident types**

Accident types with casualties addressed

1,784,588
accidents with casualties[1]

The field of effect for PEBS in the United states is more than two times larger as compared to Germany

327,984
accidents with casualties



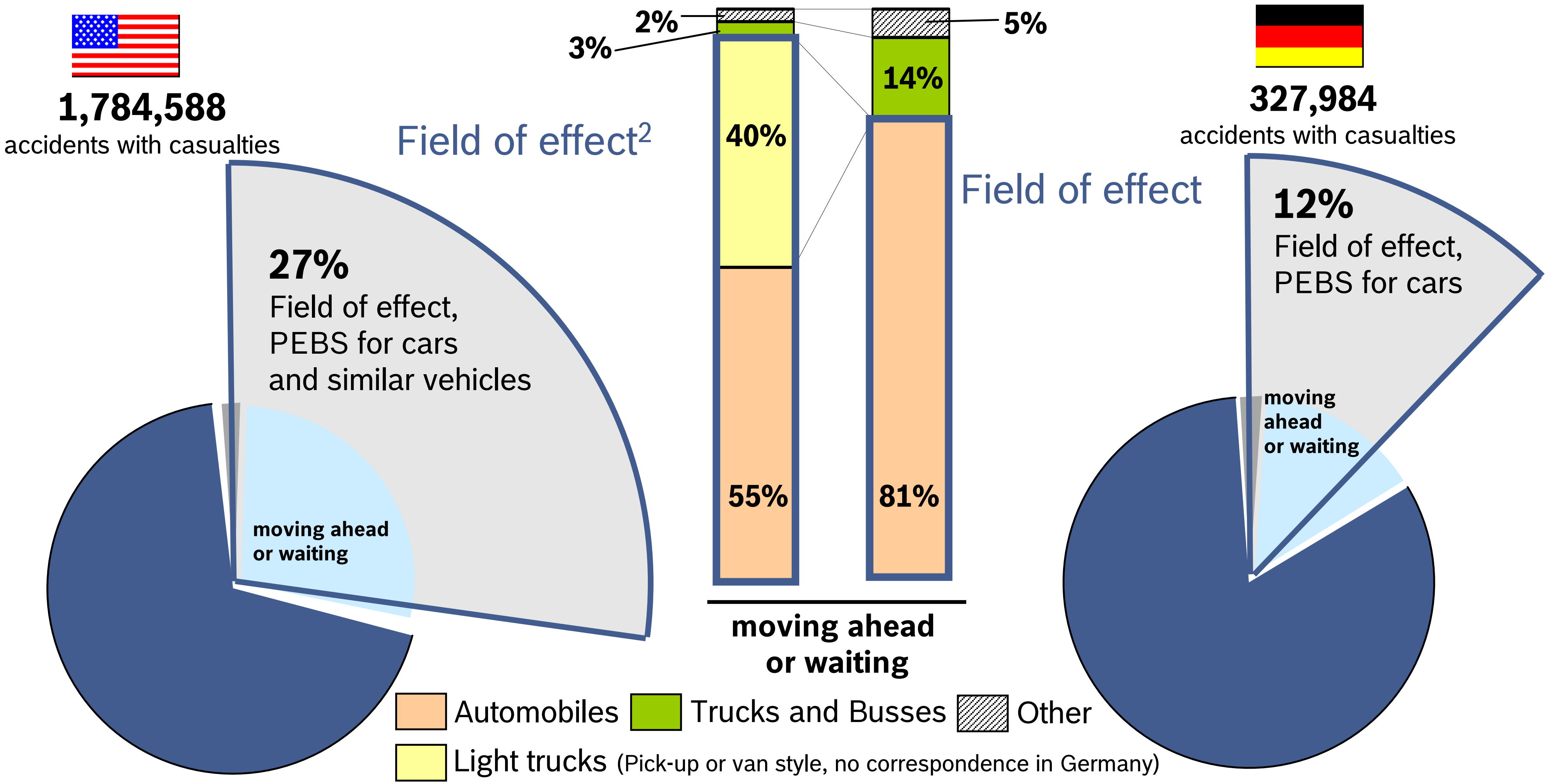
Collision with …

- parked vehicle
- vehicle which turns into or crosses a road
- vehicle moving laterally in same direction
- oncoming vehicle
- vehicle moving ahead or waiting
- pedestrian
- fixed Object (vehicle leaving carriageway required)
- Accident of another kind (unknown, not fixed object, animal etc)

sources: StBA, GIDAS, GES, NHTSA, Year 2006

[1] USA: Vehicle to Bicycle - accidents in category „Others“

Types of vehicles[1] in the PEBS field of effect

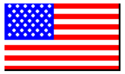


➔ High occurrence of light trucks in the PEBS field of effect in the US as compared to Germany

sources: StBA, GIDAS, GES, NHTSA, Year 2006

1) Vehicle type colliding with a preceding vehicle in a rear end crash ;
2) Field of effect USA according to Farmer CM, *Crash avoidance potential of five vehicle technologies*, IIHS (2008),

Accident variable in GES (TYPE_ACC)

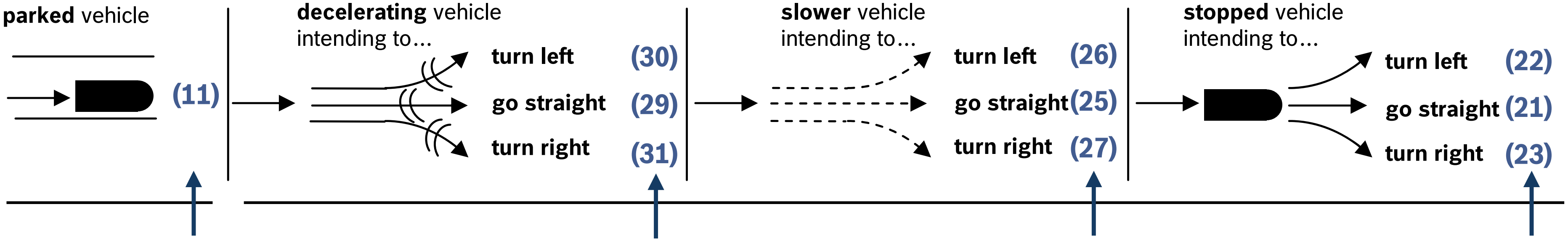


Year 2006

In **GES**, an accident type (ACC_TYPE) is associated with each vehicle involved in the accident.

For PSS relevant situations, the accident type number of the preceding vehicle is associated with the whole accident (new variable TYPE_ACC).

Collision with ...



If, in a case, one vehicle was associated with one of these accident types, the whole accident receives this number as label (new variable TYPE_ACC)

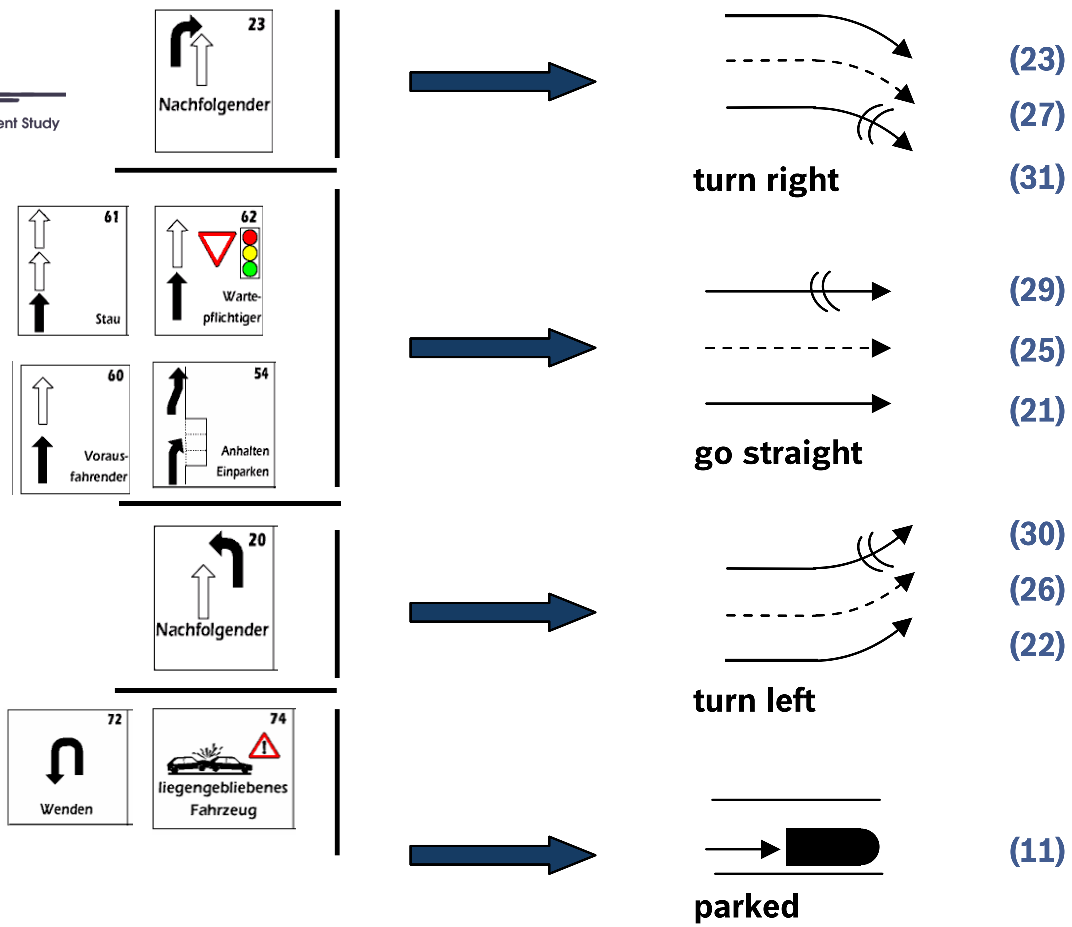
➔ **Definition of an accident type comparable between Germany and the United States in GES**

Accident variable in GIDAS (TYPE_ACC)

Year 2001-06

GIDAS German In-Depth Accident Study

In **GIDAS**,
the complete accident is described by one variable (UTYP)



New variable TYPE_ACC

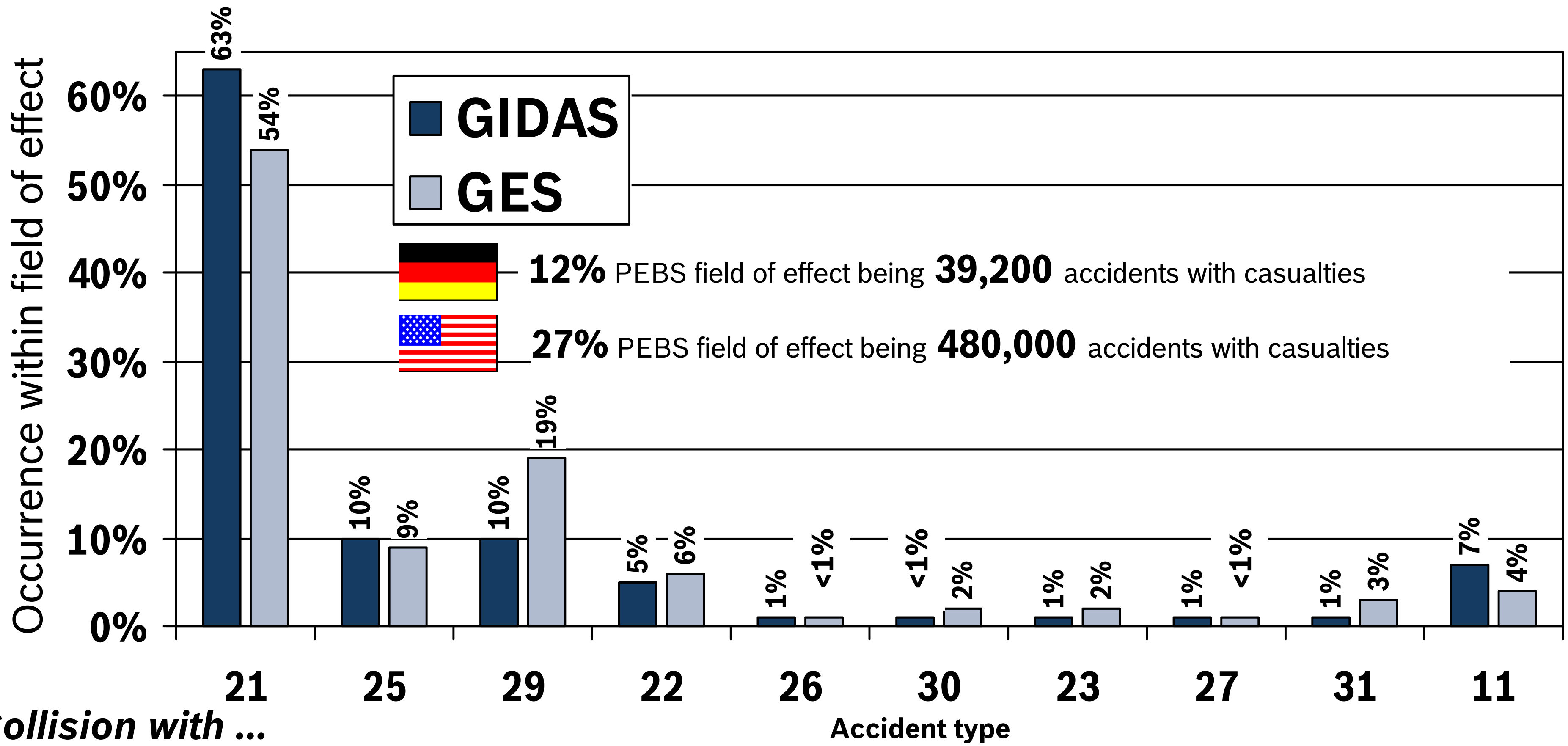
Separate UTYP into:

- **decelerating**
- **slower**
- **stopped**

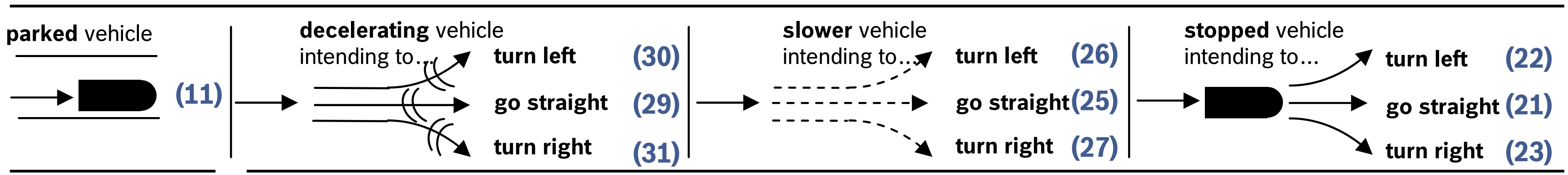
according to further data from GIDAS

➔ **Definition of an accident type comparable between Germany and the United States in GIDAS**

Accident types within the PEBS field of effect



Collision with ...



➔ **About similar accident type distribution in the PEBS field of effect in Germany and the US**

sources: GIDAS, GES, Year 2006, DESTATIS

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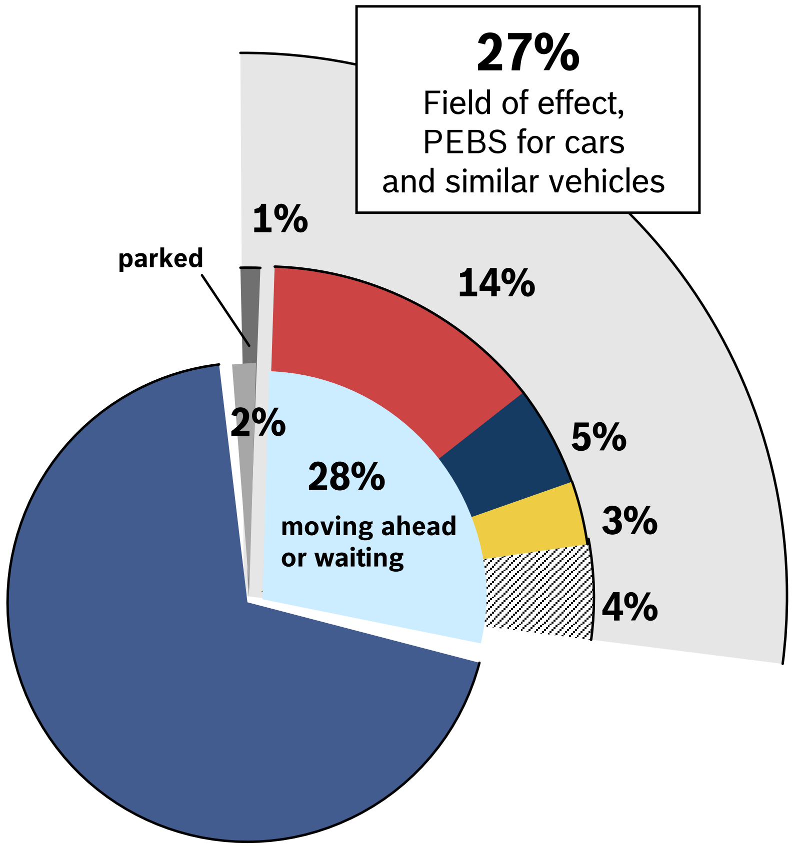
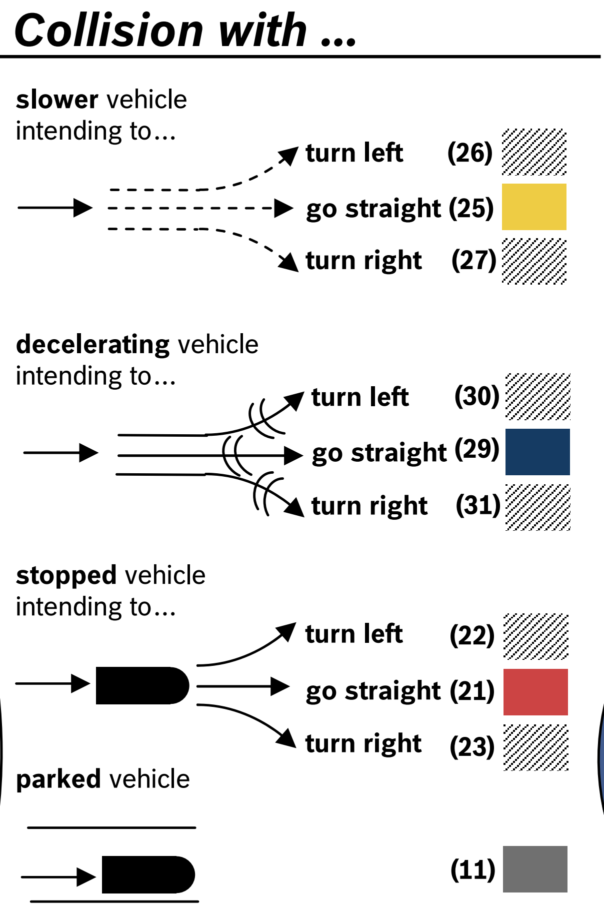
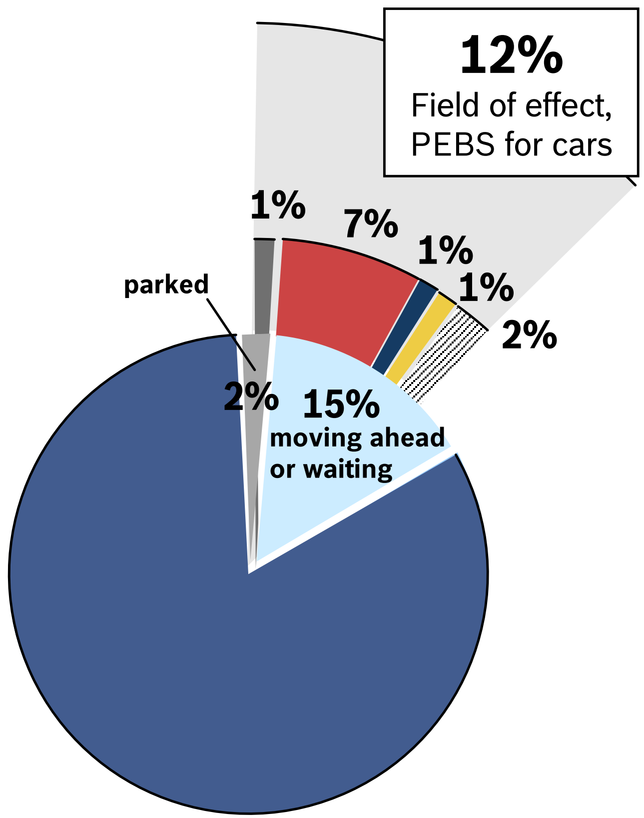
Accident types with casualties addressed

1,784,588
accidents with casualties





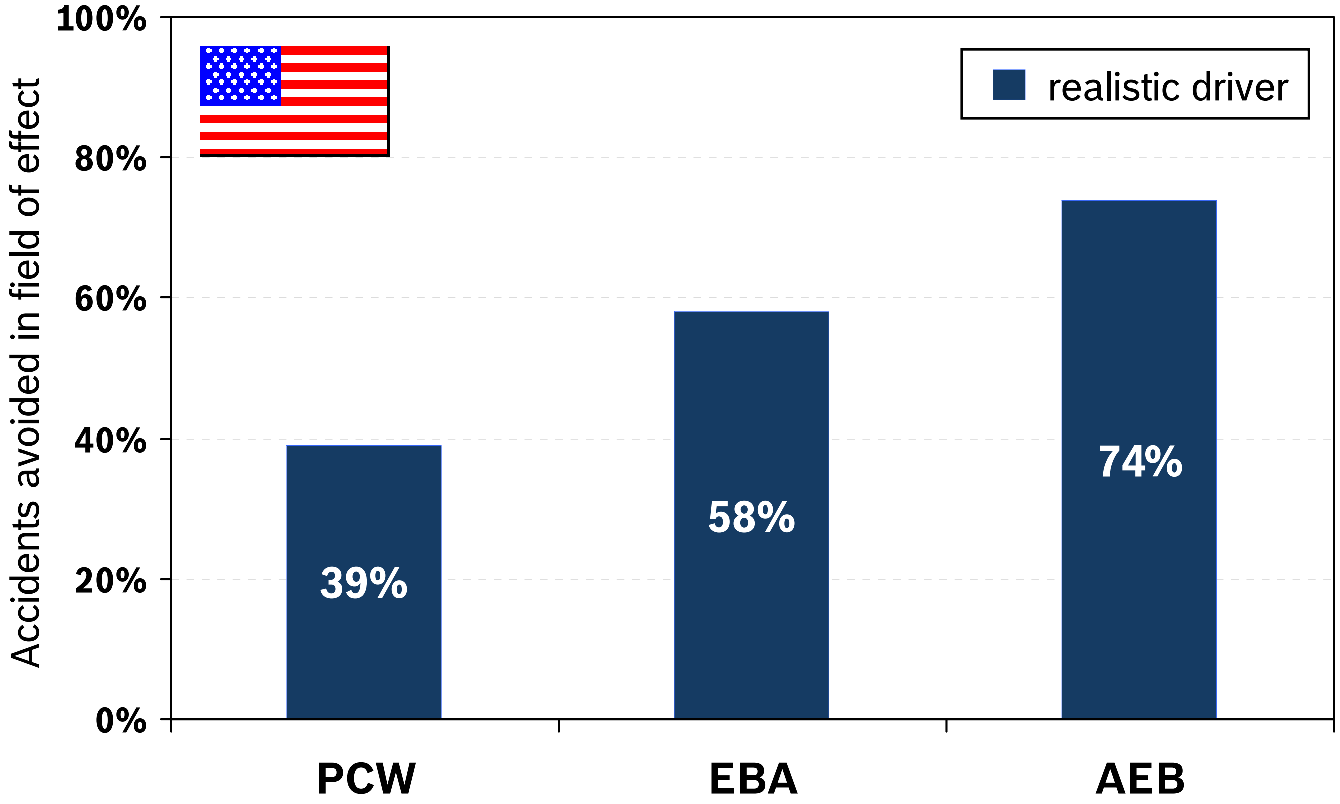
327,984
accidents with casualties



➔ **Most rear end crashes in the United States and in Germany involve a stopped car**

sources: StBA, GIDAS, GES, NHTSA, Year 2006

Rear-end crashes: Accidents avoided by PEBS-functions in the US



PCW Predictive Collision Warning (Radar only)

- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

EBA Emergency Braking Assist (Radar only)

- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

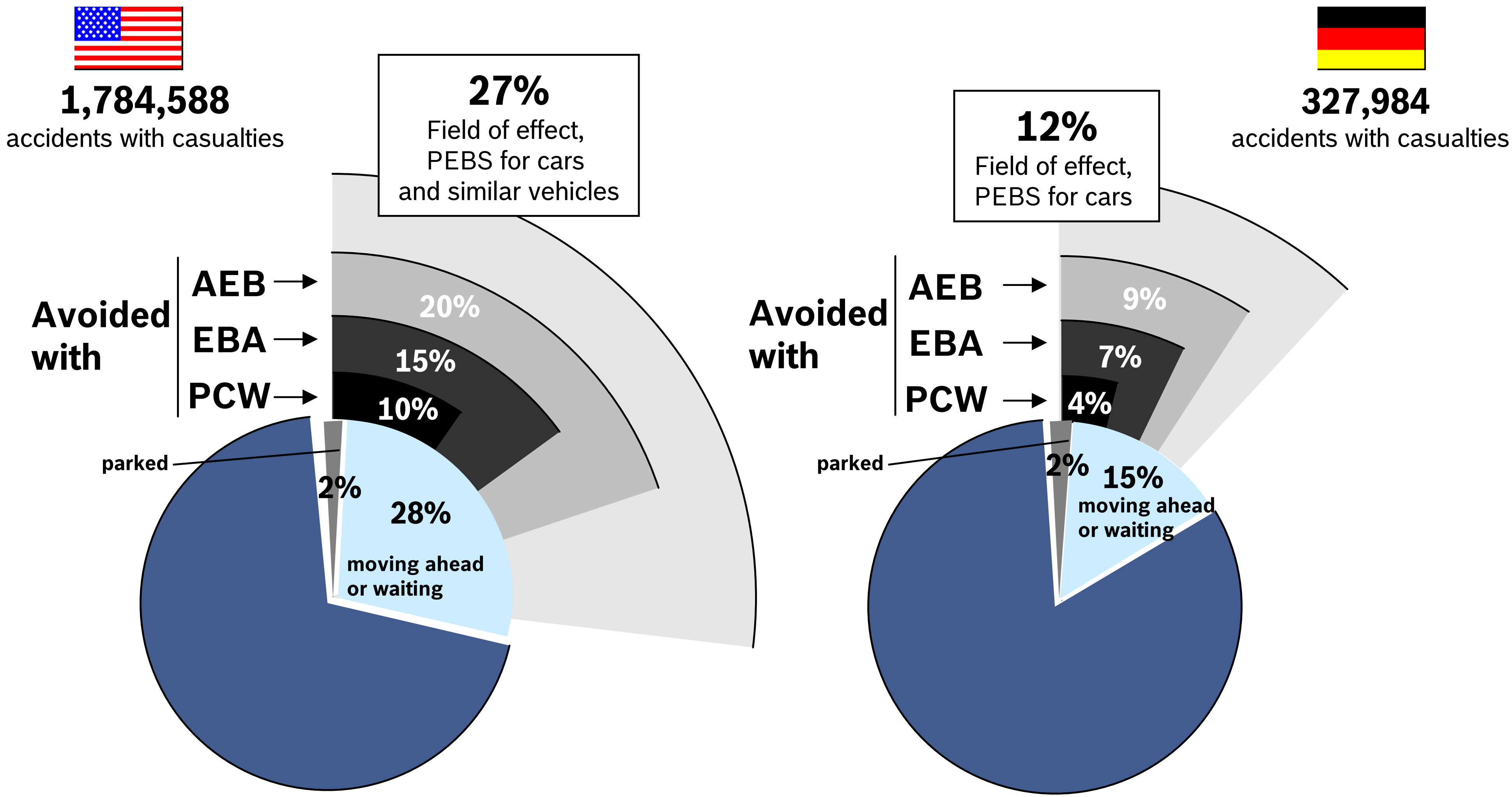
AEB Automatic Emergency Braking (Radar + video)

- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

➔ High accident avoidance potential by PCW, EBA and AEB in rear-end crashes for realistic drivers is expected in the United States, similar to predictions for Germany

Source: Analysis of GIDAS database (2001-2005) and GES (2006),
1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

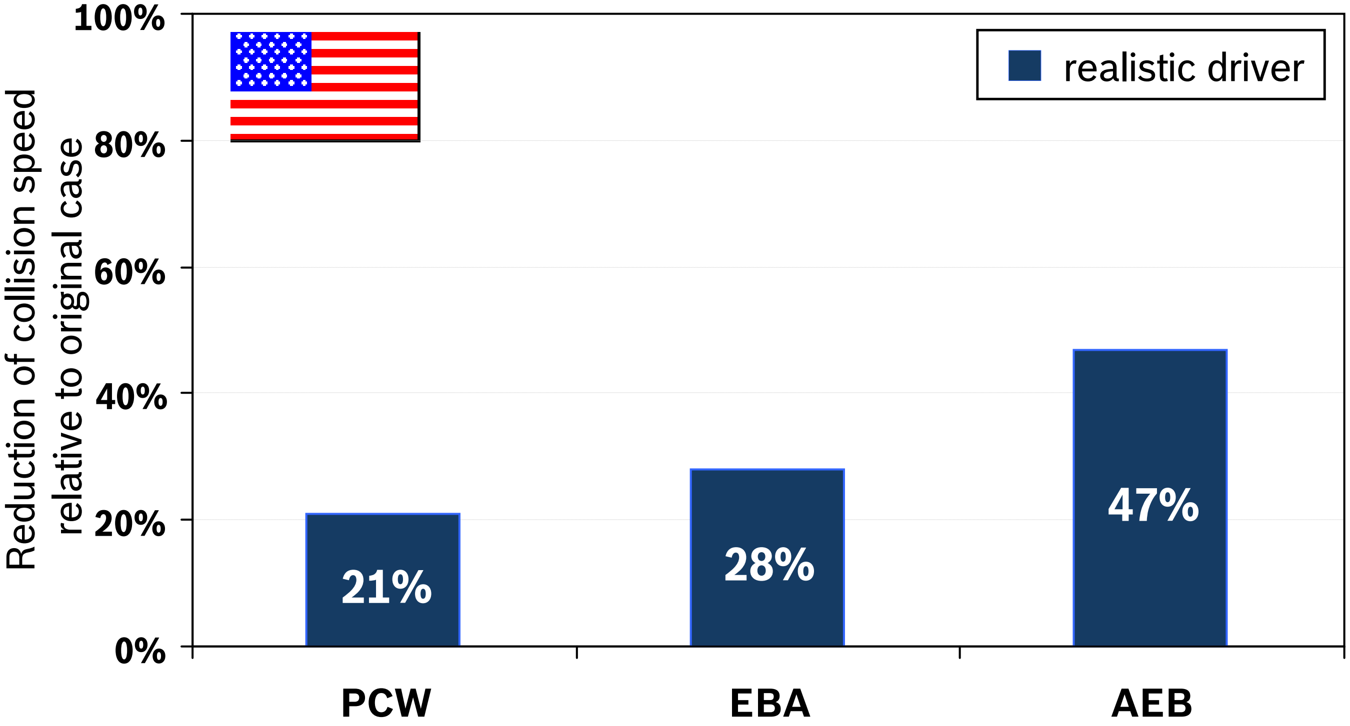
Accidents with casualties avoided



➔ **Two times increased avoidance potential for PEBS in the US as compared to Germany**

Source: Analysis of GIDAS database (2001-2005) and GES (2006),
1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

Rear end crashes: Average reduction in collision speed for not avoided rear-end crashes



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- automatic partial braking
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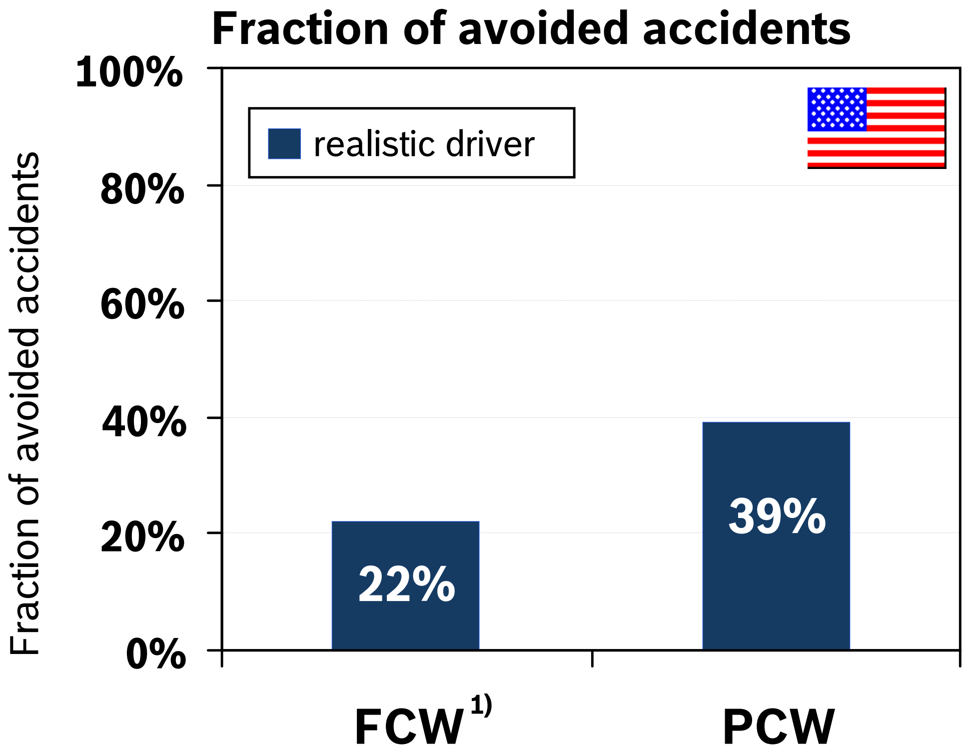
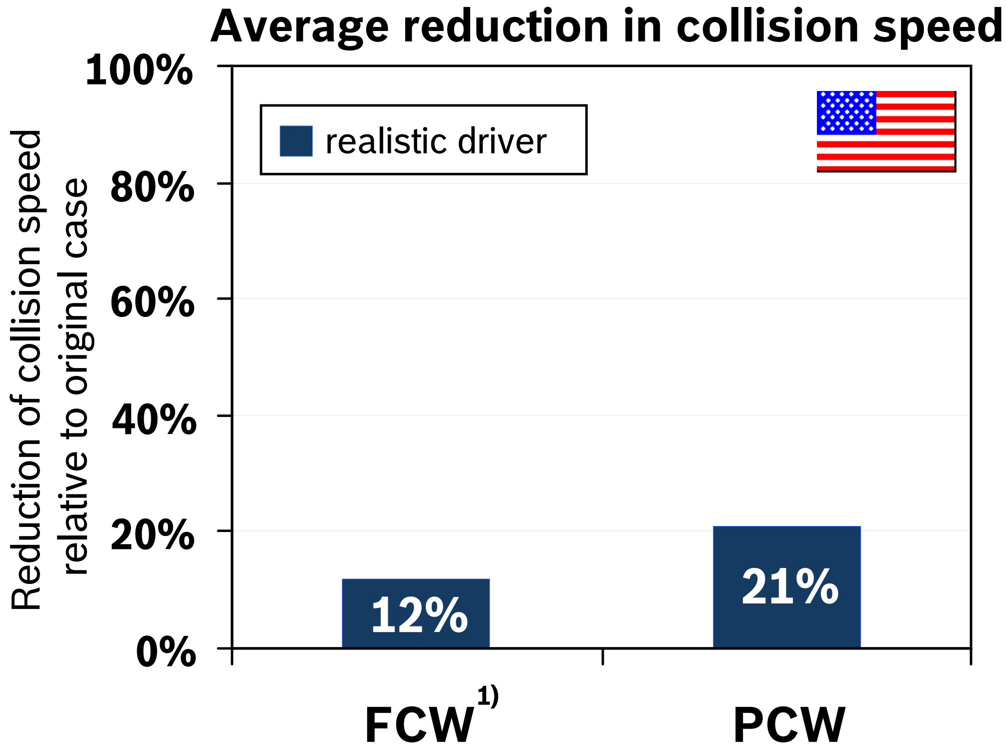
→ **Even if the rear-end collision cannot be avoided by PCW, EBA or AEB, the collision speed is still strongly reduced, leading to a reduced accident severity**

Source: Analysis of GIDAS database (2001-2005) and GES (2006),
1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

Results of comparison: FCW[1)] vs. PCW

➔ Benefit calculation of FCW based on NewNCAP basic requirements (specifications Feb '09 [1)], constant values of warning times, no function at night and under rainy conditions)





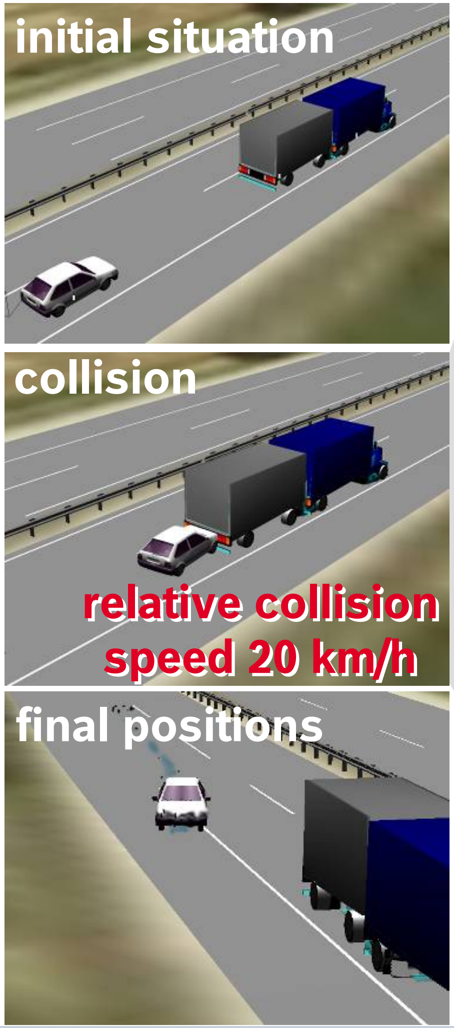
➔ Bosch PCW will have a significant higher benefit in comparison to FCW-Function
➔ Reduced warning times[1)] lead to less false warnings and higher system acceptance

Source: Analysis of GIDAS database (2001-2005) and GES (2006),
1103 rear end crashes caused by cars, modeled under idealized conditions with a function specification close to market

[1)] 2.0s for moving POV (principal other vehicle) and 2.1 for stopped POV (FCW specifications Feb '09)

[1] German-In-Depth-Accident Study – www.gidas.org

Accident example (motorway)



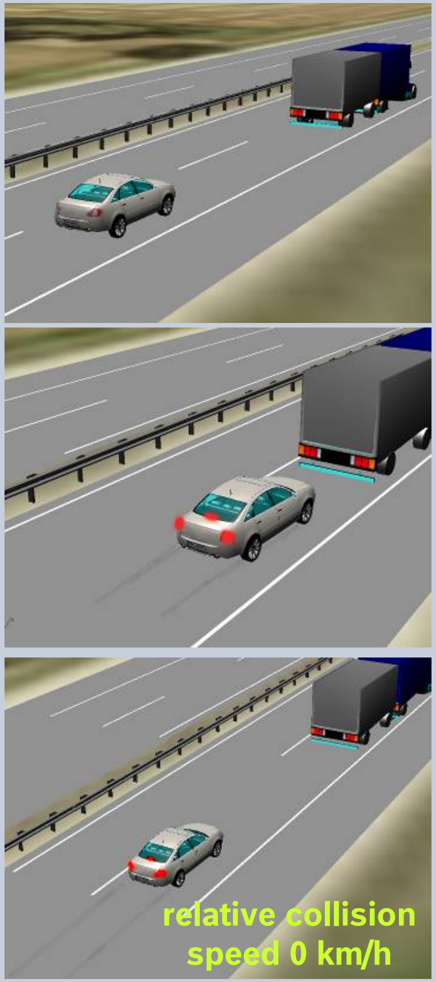
Initiator of accident (car):
collision speed 110 km/h

main reason/ consequences:
inattention
one person injured

Collision opponent (truck):
collision speed 90 km/h

Situation w/ EBA system

(warning and brake support with driver intervention)



0,0s
acoustical warning
1,4s ttc
(driver inactive classified)

+1s
assumed driver brake reaction: 1s after acoustic warning, maximum braking as a result of brake power support via EBA

+1,5s
accident avoided, max. closing distance 0.5m

Accident would be avoided with Bosch EBA system!

*GIDAS 0120020592 : Accident on German „Autobahn“

[1] German-In-Depth-Accident Study – www.gidas.org

Summary

- Driver model enabled benefit analysis for driver initiated collision mitigation system
- High avoidance potential of rear-end crashes by PEBS-functions in Germany and in the United States
- In not avoided accidents, PEBS-functions lower the collision speed, leading to a strong reduction in injury severity
- Bosch PCW will have a significant higher benefit in comparison to FCW-Function based on NewNCAP basic requirements.
- Automatically accident benefit calculation offers new ways of parameter and system variation
- Driver behavior has high influence on system benefit, therefore needs to be taken into account during warning strategy layout.

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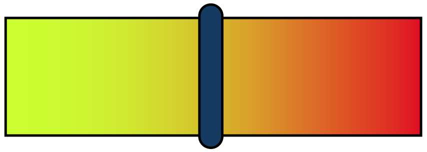
[1] German-In-Depth-Accident Study – www.gidas.org

Validity of estimated values and assumptions

	Variable	kind of assumption	reliability of assumption	verification of variables	estimated effort
	**Driver type I-III**	Source: GIDAS database no assumption, values generated from representative accidents		verification not necessary	**0**
	**Driver activity**	Source: CC-DA and CR/AEY values are generated from results of test drives coordinated by HMI experts (CR/AEY-Manstetten)		verification in extensive field tests possible (activity detection in real accident scenarios)	**high**
	**Reaction to warning type**	Source: Assumption CR/AEV internal estimation		verification in extensive tests with PSS vehicles possible (detection of brake activating warning type)	**high**
	**Driver reaction time and deceleration**	Source: External studies range of values was extracted from various studies due to driver reaction in emergency brake situations		verification basically not necessary but: reaction times not emulated in real accident scenarios, possible in naturalistic driving study (cars equipped w/ PSS)	**naturalistic driving study USA/ Germany**

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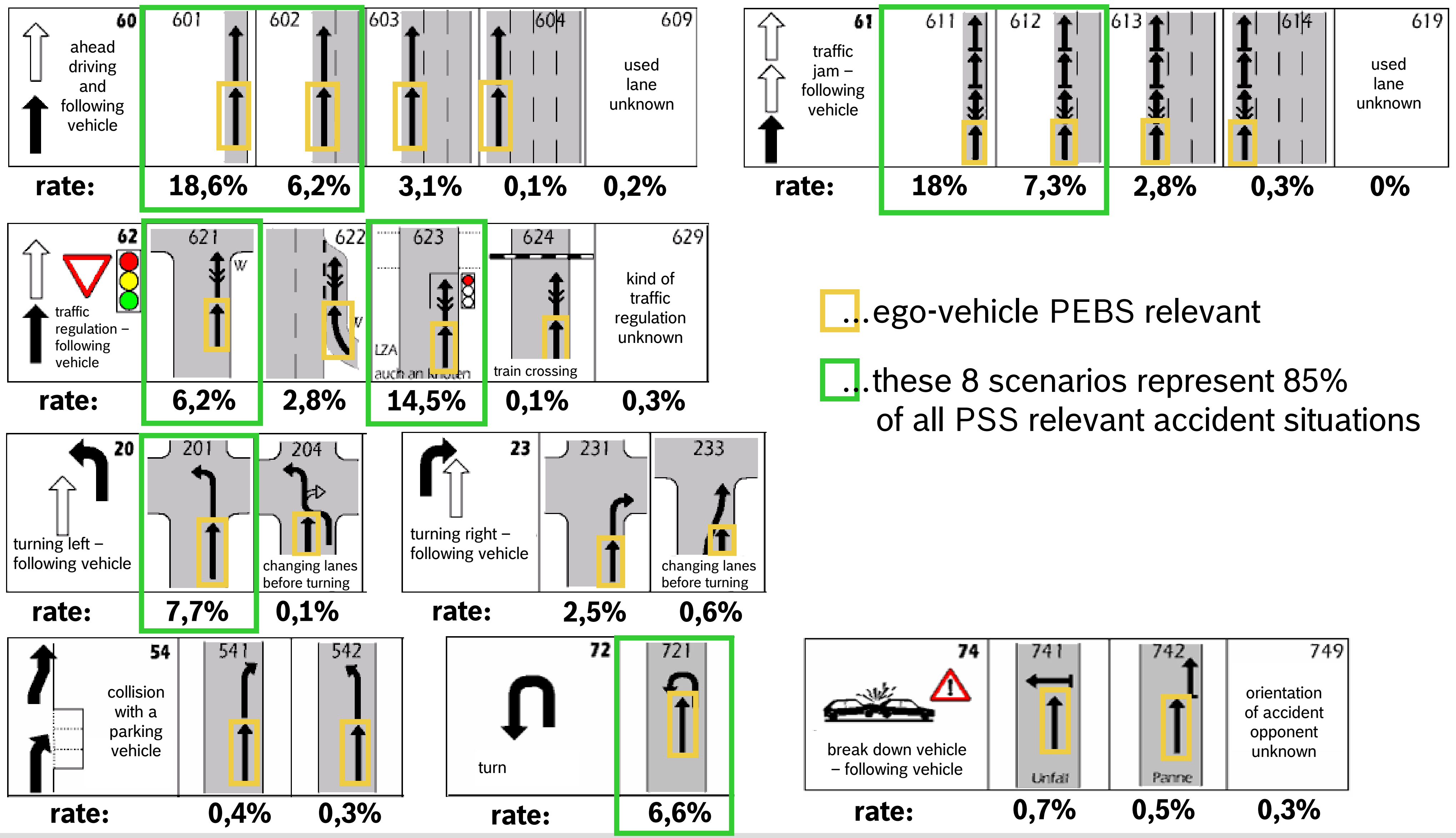
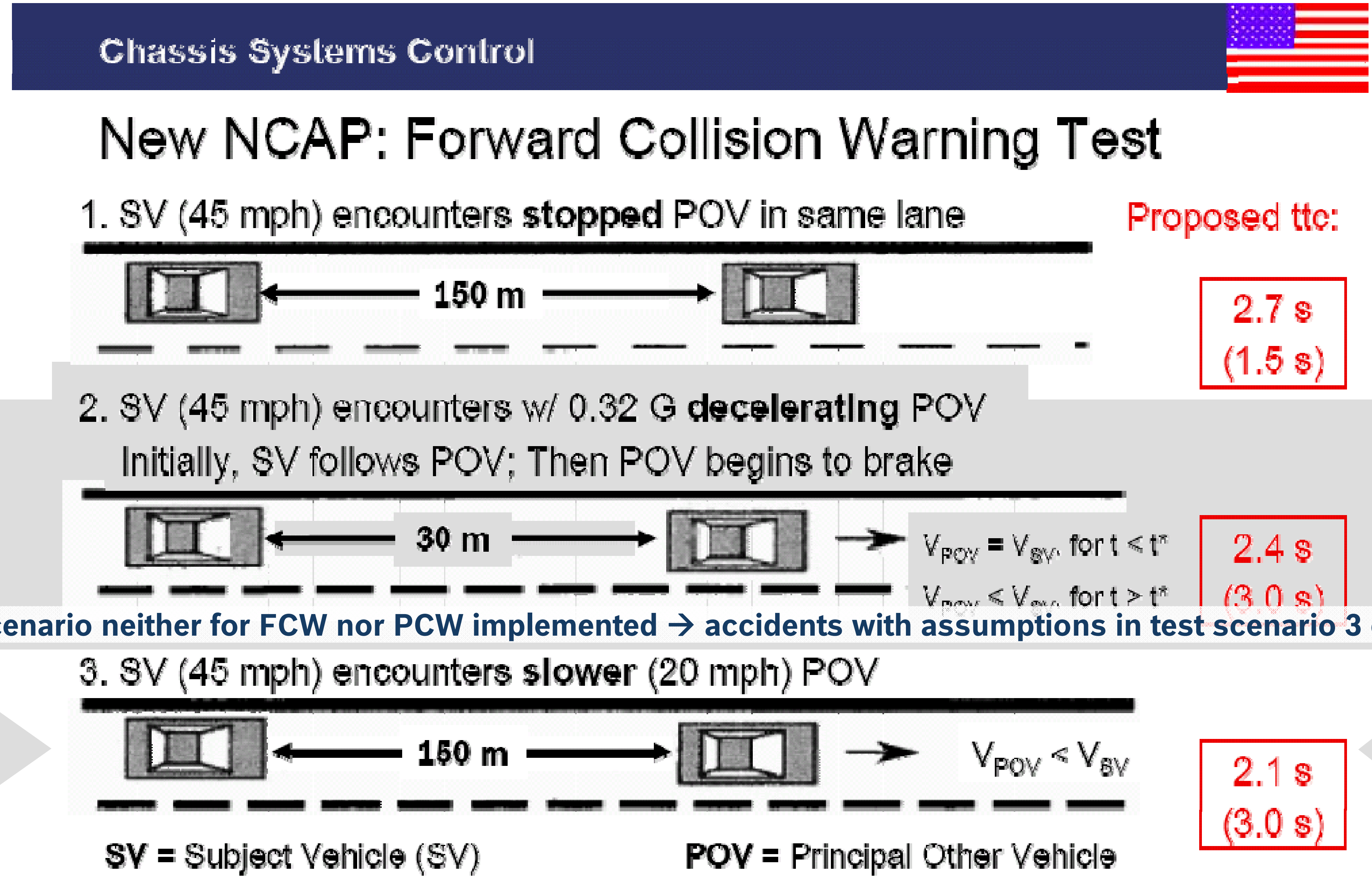
Relevant accident types and distribution*/**



* Source: images from GDV accident type catalog

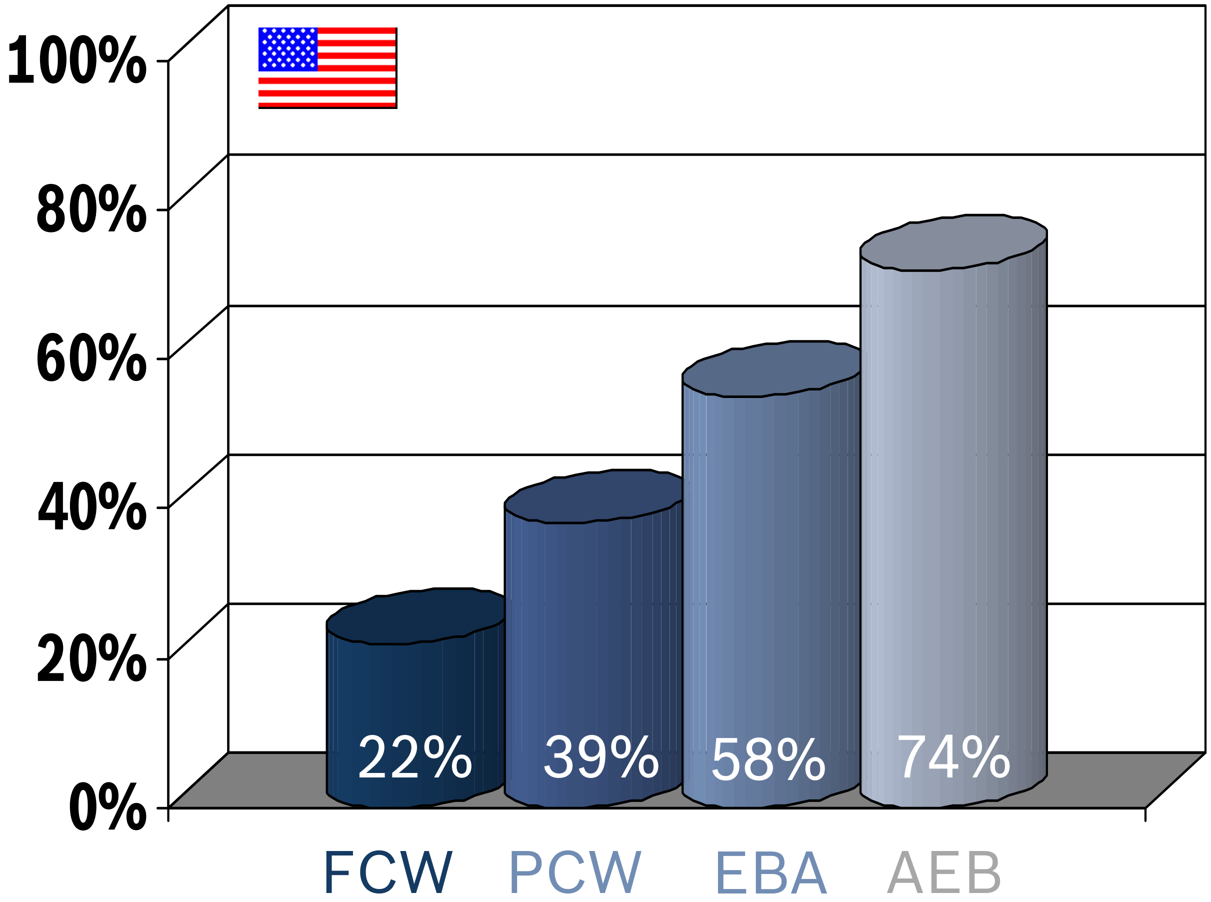
** All reconstructed GIDAS accidents during 2001 – 2006 in Dresden and during 2001 – 2005 in Hanover

FCW requirements for new NCAP Test specifications Jul '08



2nd test scenario neither for FCW nor PCW implemented → accidents with assumptions in test scenario 3 considered

Rear-End Crashes: Fraction of Avoided Accidents



FCW[1] (NHTSA minimum requirements)
- acoustic or visual warning
- warning at fixed time to collision

specifications Feb '09 [1]

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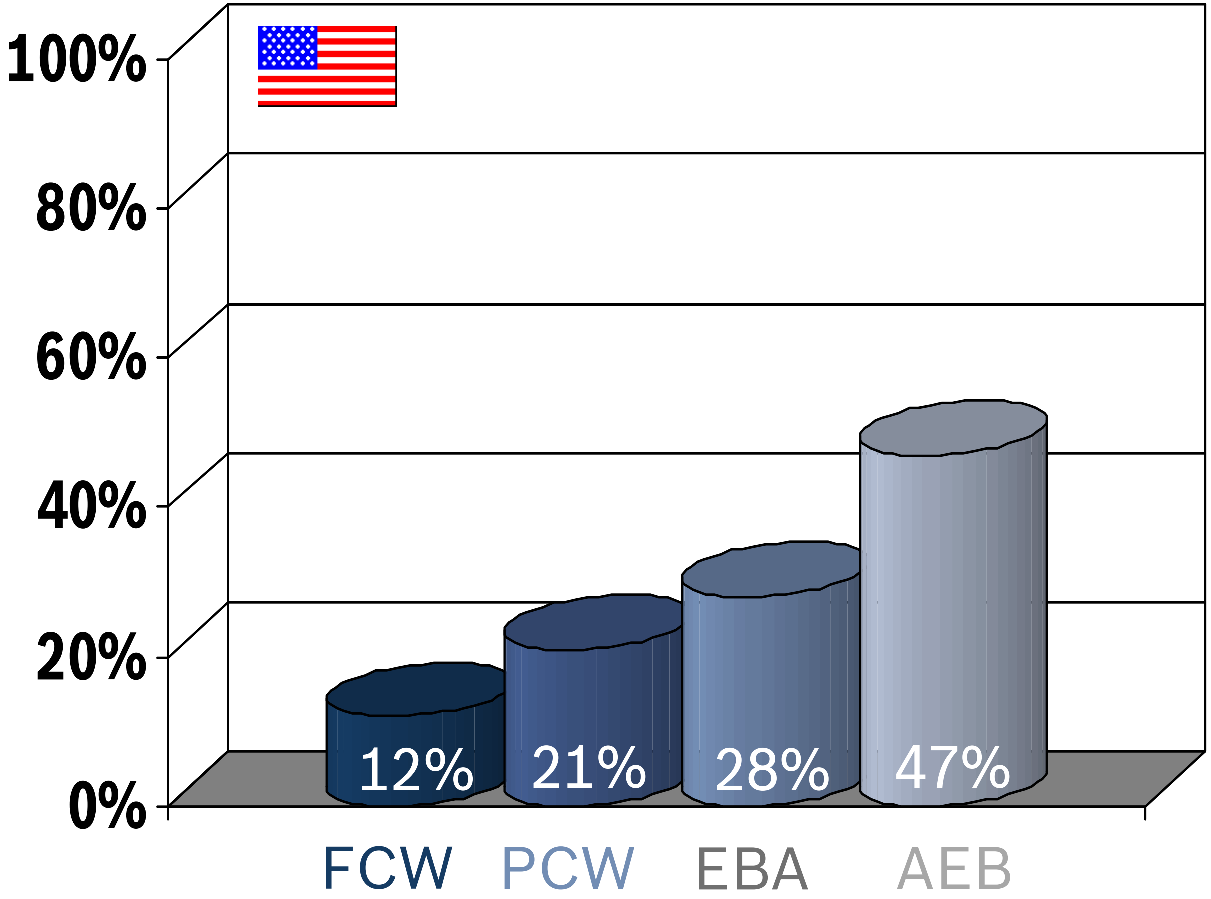
[1] 2.0s for moving POV (principal other vehicle) and 2.1 for stopped POV (FCW specifications Feb '09)

Rear-End Crashes:
Average reduction of Collision Speed for not avoided accidents



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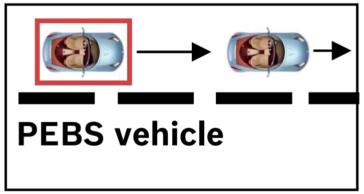
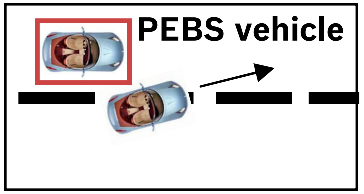
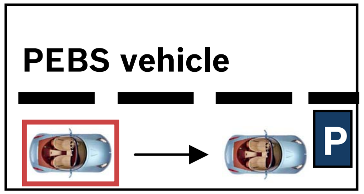
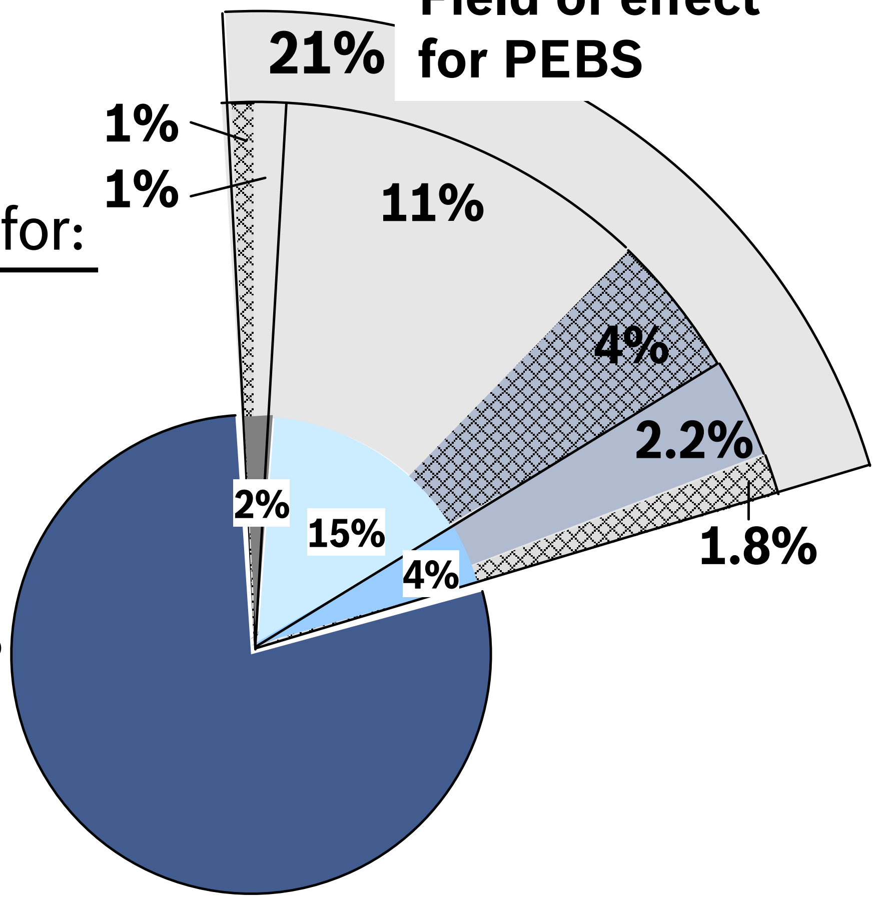
Accidents with personal injury: Field of effect for PEBS

327,984 Accidents with casualties per year

Collision with vehicle:			Field of effect for:		
15%	Moving ahead or waiting: Longitudinal traffic		Cars	11%
			Trucks, busses and other	4%
4%	Moving laterally in same direction: Cut-in situations		Cars	2.2%
			Trucks, busses and other	1.8%
2%	Parked		Cars	1%
			Trucks, busses and other	1%



→ **PEBS for passenger cars can address about 14% of all accidents with personal injury, 12% stemming from longitudinal traffic and further 2.2% from cut-in situations**

Source: Bosch Analysis of GIDAS Database (2001-2006/2008), modeled under idealized conditions with a function specification close to market

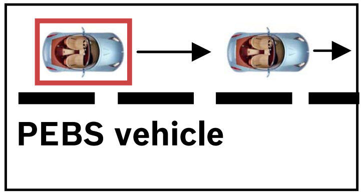
Accidents with personal injury: Field of effect for PEBS

327,984 Accidents with casualties per year

Collision with vehicle:

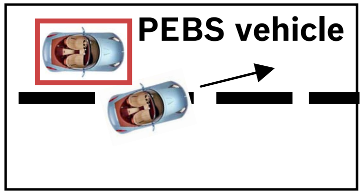
Field of effect for:

15% Moving ahead or waiting: Longitudinal traffic



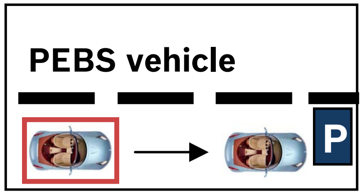
Cars		11%
Trucks, busses and other		4%

4% Moving laterally in same direction: Cut-in situations

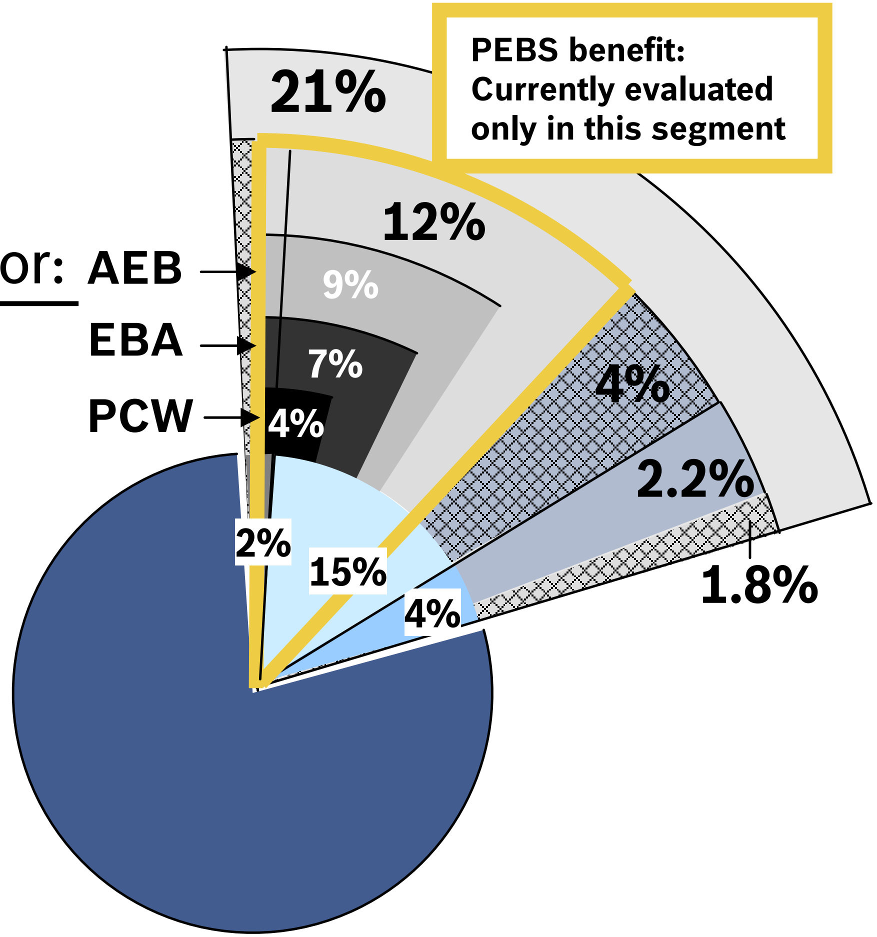


Cars		2.2%
Trucks, busses and other		1.8%

2% Parked



Cars		1%
Trucks, busses and other		1%



➔ Current evaluation of an PEBS benefit was restricted to passenger cars parked and in longitudinal traffic i.e. about 12% of all accidents with personal injury in Germany

Source: Bosch Analysis of GIDAS Database (2001-2006/2008), modeled under idealized conditions with a function specification close to market

Case selection in GIDAS (numbers below represent weighted cases)

Accidents

11670 reconstructed accidents
(GIDAS 2001-2008, Status = 4)

↓

583 accidents with cut in situations
BETNR = 1, KNR = 1, UTYP = 631 - 652

Vehicles

127 accidents
of a passenger car
with an unknown opponent
FART_Gegner empty and FART = 3

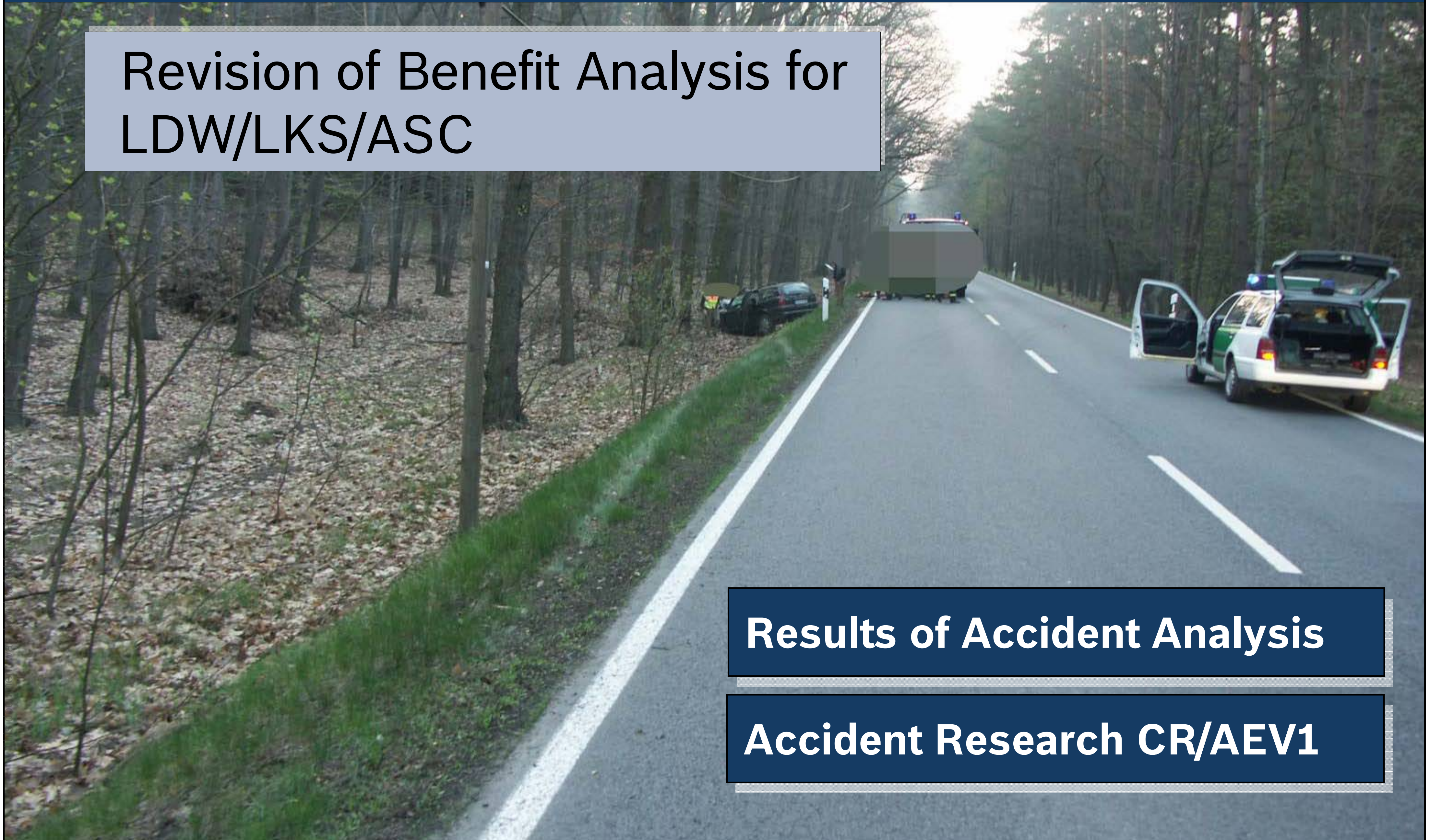
196 accidents
of a passenger car
with a known opponent
FART_Gegner = 3

↓

323 accidents or 55% of the accidents
with cut in situations and personal injury in Germany
are PSS relevant
Sum of the above

Source: Bosch Analysis of GIDAS Database (2008)

Revision of Benefit Analysis for LDW/LKS/ASC



Results of Accident Analysis

Accident Research CR/AEV1

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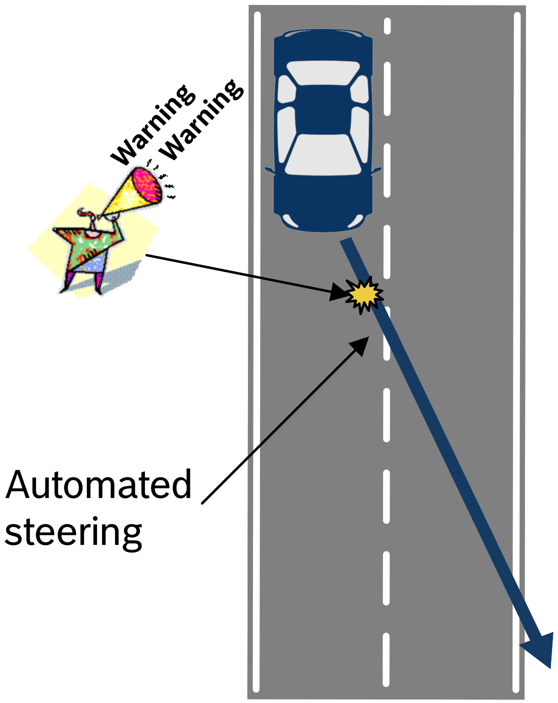
Introduction

Reevaluation of three systems for the prevention of unintended lane departure, taking into account improved system specifications
(i.e. automatic lane keeping by ASC and further small modifications)

LDW – lane departure warning
Warning the driver about 0.2 sec before lane crossing, the driver needs to adjust the vehicle's trajectory

ASC - automatic steering control
LKS - lane keeping system
Keeping the vehicle on the driving lane without driver interaction



Analysis mandated by CC, where LDW, ASC and LKS systems are currently under development

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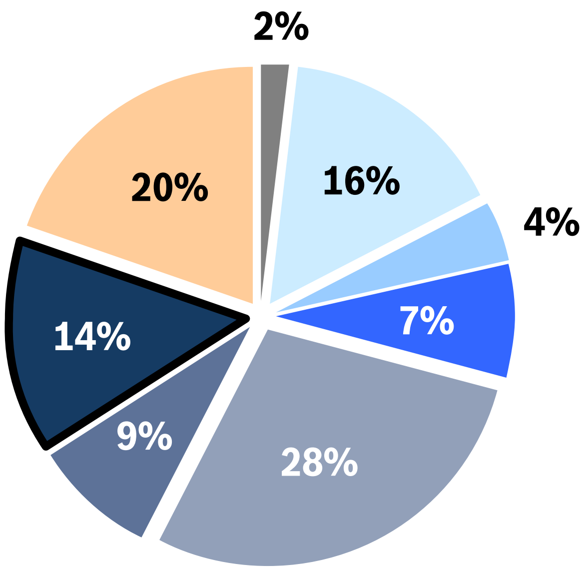
Distribution of accident kinds

Accidents with casualties

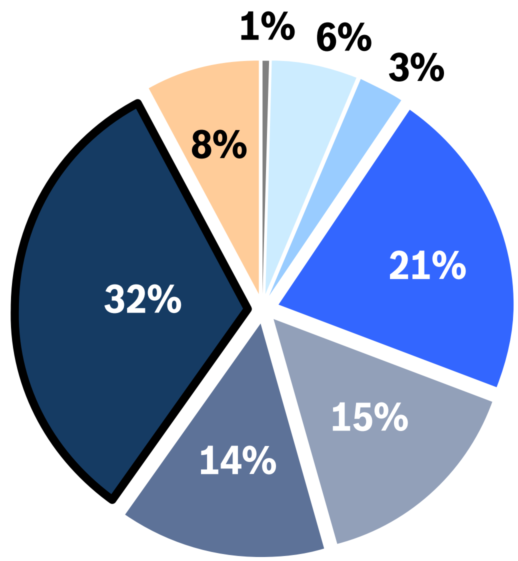
335 845 accidents[1)]



- Collision with parked vehicle
- Collision with another vehicle moving ahead or waiting
- Collision with vehicle moving laterally in same direction
- Collision with another oncoming vehicle
- Collision with another vehicle with turns into or crosses a road
- Collision between vehicle and pedestrian
- Leaving the carriageway to the right or left
- Other accident

Accidents with fatalities

4 609 fatal accidents[1)]

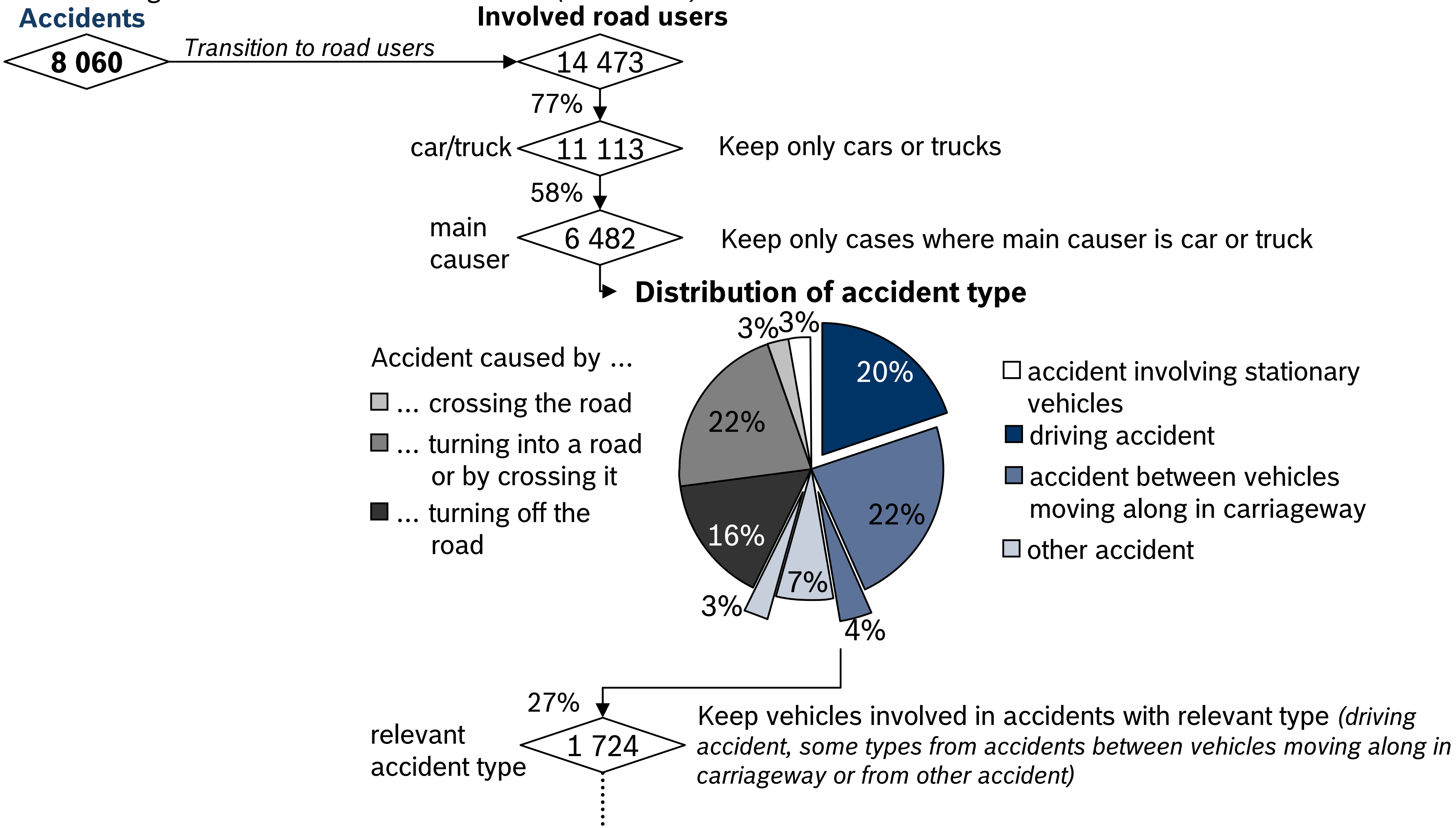


➔ In fatal accidents vehicles most often leave the carriageway

1) Source: Federal Statistical Office, Germany (2007)

Field of effect

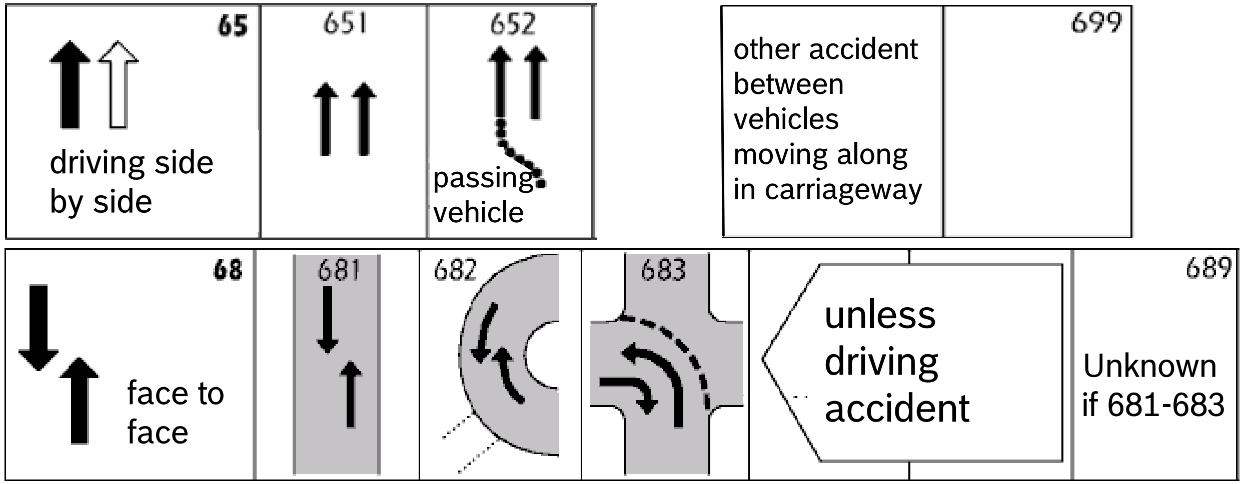
GIDAS weighted reconstructed accident data (2001-2006)



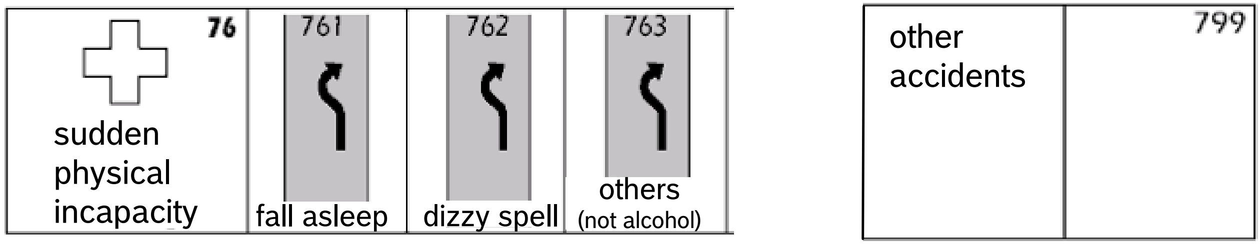
Accident types addressed by LDW and LKS-ASC

Driving accident: “The accident was caused by the driver’s losing control of his vehicle (due to unadapted speed or misjudgement of the course) without other road user having contributed this. As a result of uncontrolled vehicle movements, however a collision with other road users may have happened” (*StBA, Fachserie Verkehr*)

Accidents between vehicles moving along in carriageway



Other accidents



Revision of benefit analysis for LDW/LKS/ASC

Involved road users

- Relevant accident type: **1 724**
- 98% → Relevant main cause: **1 693** — Keep vehicles that are involved in an accidents in which the behavior or characteristic of the driver is the main cause for the accident *(i.e. vehicle damages are excluded)*
- 28% → Relevant vehicle related cause: **475** — Reject vehicles in which the driver uses the wrong road/lane, is not fit to drive or makes another mistake *(i.e. drivers who make mistakes like going over the speed limit, ignoring safety distance or right of way are excluded)*
- 99% → Forward moving vehicle: **468** — Keep only forward moving vehicles
- 97% → Road is not covered: **453** — Keep cases where the road surface is not covered by snow, white frost or black ice
- 94% → Vehicle leaves lane/carriageway: **428** — Reject vehicles leaving the lane or carriageway before the 1st impact

Transition to accidents

5.3%
of accidents with injured in Germany

428

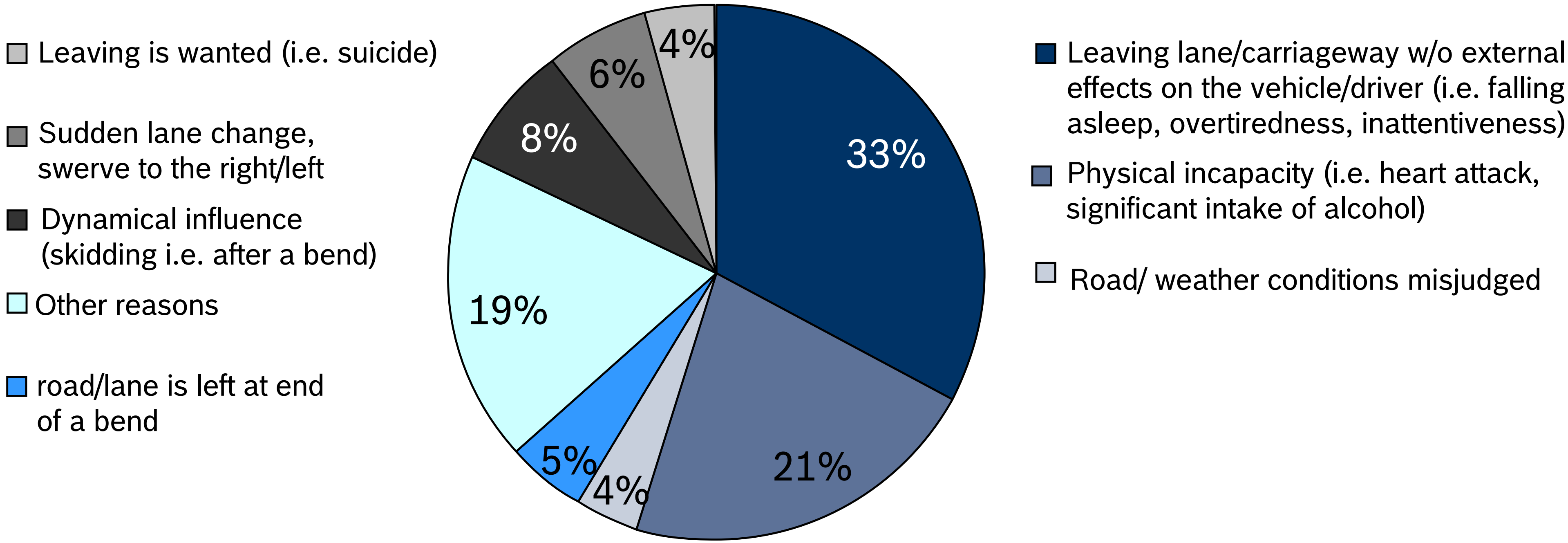
Field of effect

- ➔ The field of effect summarizes accidents where a vehicle leaves the carriageway or lane because of a driver error
- ➔ The accidents in the field of effect, 5.3% of all accidents with injured in Germany, could be influenced by a LDW/LKS-ASC system (i.e. *~17 800 accidents in Germany***)

* GIDAS weighted, reconstructed accident data (2001-2006): basis 8060 accidents
** Federal Statistical Office data for Germany (2007), 335‘845 accidents with personal damage

Distributions within the field of effect

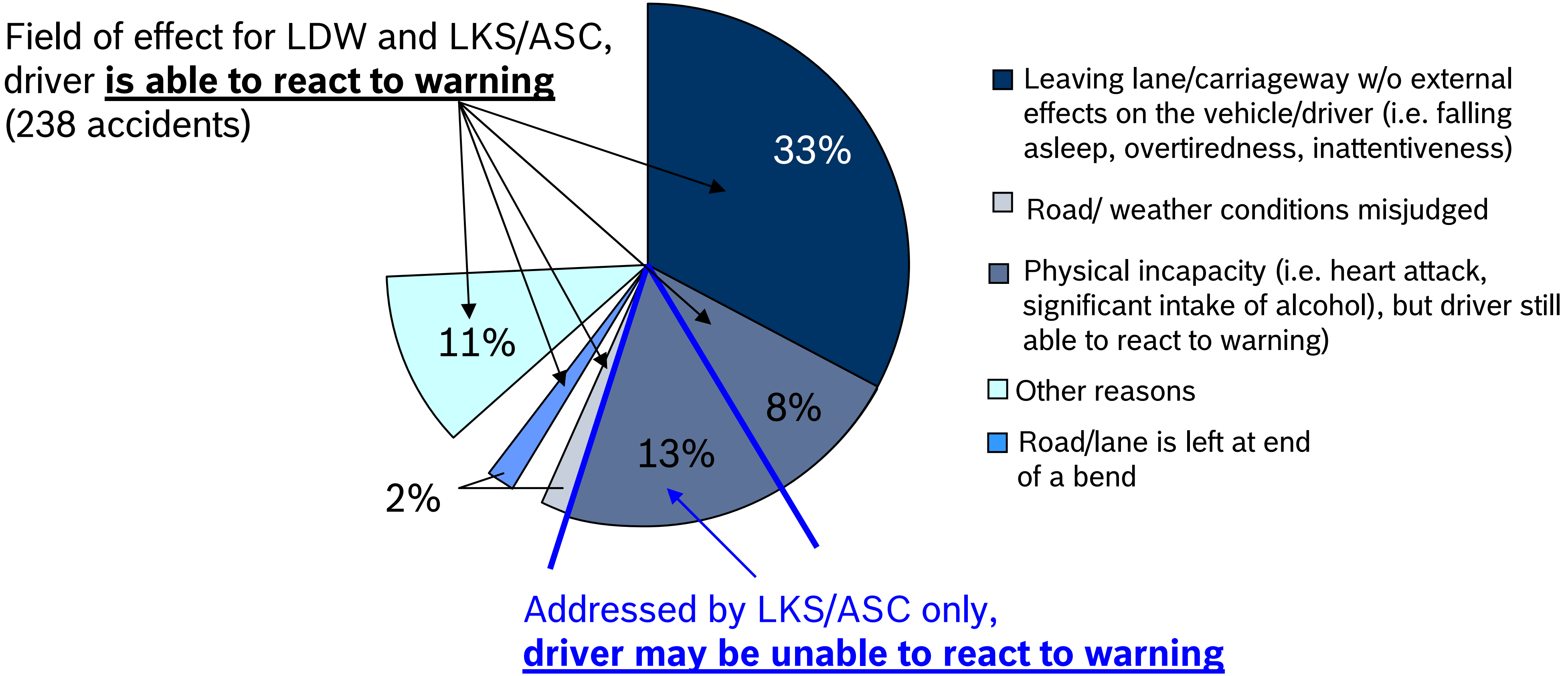
Reasons for leaving the lane/carriageway *(428 vehicles)*



➔ Within these:
Selection of vehicles with a cause for road/lane departure which can be influenced by LDW/LKS-ASC

Distributions within the field of effect

Reasons for leaving the lane/carriageway



➔ These lane departures*) are susceptible to be prevented by LKS/ ASC or LDW

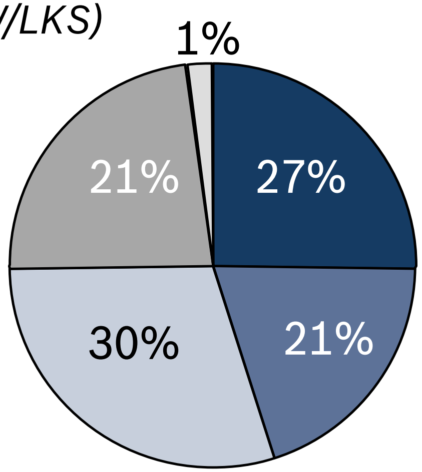
➔ The following distributions are based on 238 accidents (field of effect for LDW and LKS/ASC)

*) We do not speak of accident prevention here as preventing the lane departure might lead to another accident kind, for example collision with an object on the driveway

Distributions within the field of effect: Road type

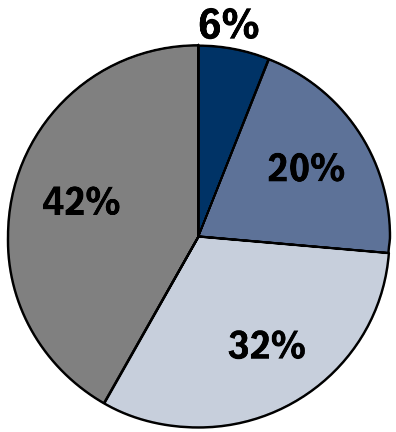
LDW/LKS/ASC relevant cases[1)]
(238 accidents susceptible to be influenced by LDW/LKS)

- freeway (BAB)
- federal highway (*Bundesstraße*)
- highway (*Landstraße*)
- urban road
- others



Official Statistics *(accidents with injured in Germany, 336 619 accidents)*

- freeway (BAB)
- federal highway (*Bundesstraße*)
- highway (*Landstraße*)
- others (urban roads included)



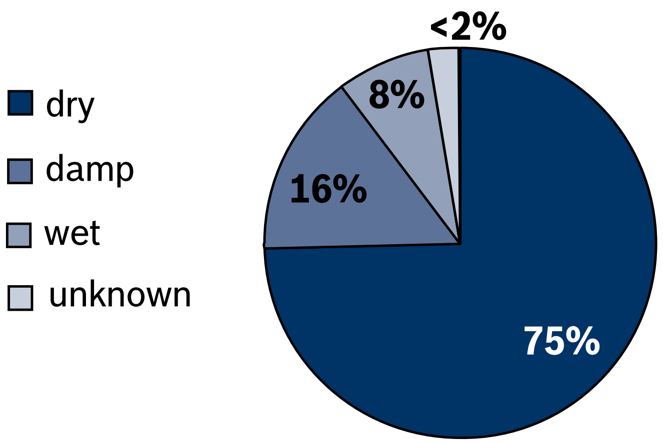
Note: 1% ⇔ 2.4 accidents

→ About half of the LDW/LKS-ASC relevant accidents occur on freeways or federal highways
→ Compared to all accidents in Germany, LDW/LKK-ASC relevant accidents occur more frequently on freeways than on other roads (*LDW/LKS: 27%, all: 6%*)

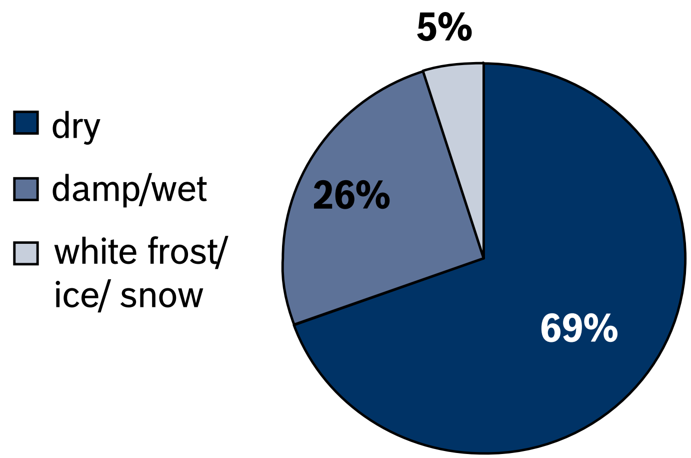
1) One accident per vehicle

Distributions within the field of effect: Road conditions

LDW/LKS/ASC relevant cases[1)]
(238 accidents susceptible to be influenced by LDW/LKS)



Official Statistics *(accidents with injured in Germany, 336 619 accidents)*



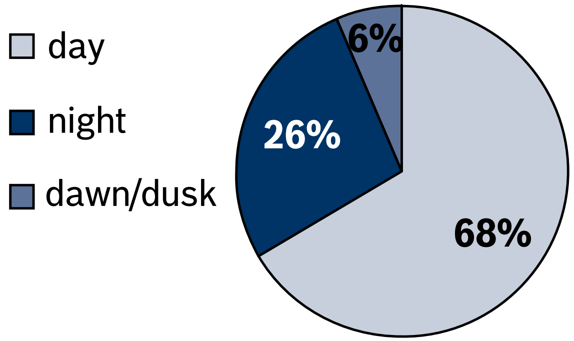
Note: 1% ⇔ 2.4 accidents

- ➔ 75% of the LDW/LKS-ASC relevant accidents occur on dry roads
- ➔ LDW/LKS-ASC relevant accidents tend to occur more often on dry roads as compared to all accidents with personal injury

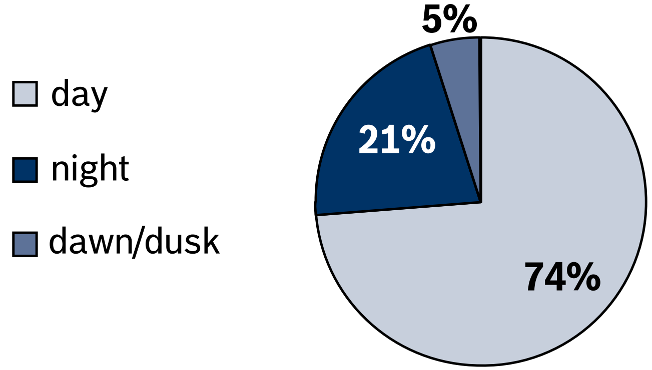
1) One accident per vehicle

Distributions within the field of effect: Time

LDW/LKS/ASC relevant cases[1)]
(238 accidents susceptible to be influenced by LDW/LKS)



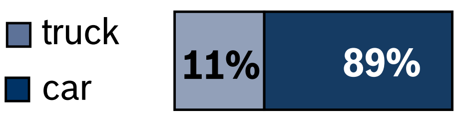
Official Statistics *(accidents with injured in Germany, 336 619 accidents)*



- ➔ 2/3rd of LDW/LKS-ASC relevant accidents occur during daytime
- ➔ Slightly more LDW/LKS-ASC relevant accidents occur during night as compared to all accidents with personal damage in Germany

Distributions within the field of effect: Vehicle type

LDW/LKS relevant cases *(238 vehicles[1)] in accidents susceptible to be influenced)*



- ➔ About 11% of the vehicles in relevant cases are trucks
- ➔ This share is comparable to the share of trucks in all accidents with personal injury in Germany

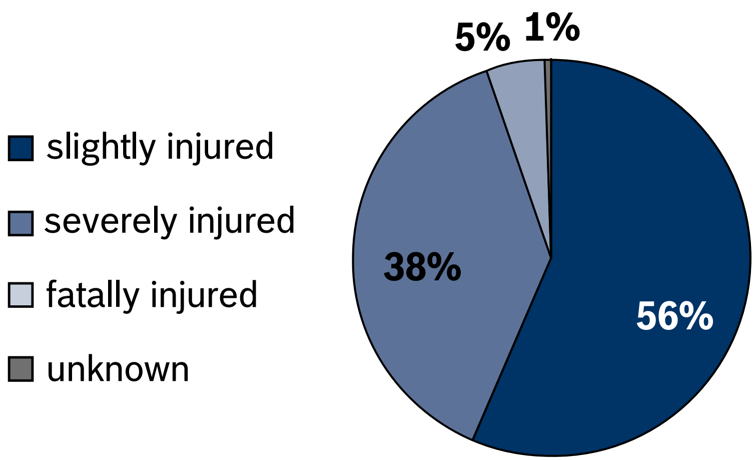
1) One accident per vehicle
Note: 1% ⇔ 2.4 accidents

Revision of benefit analysis for LDW/LKS/ASC

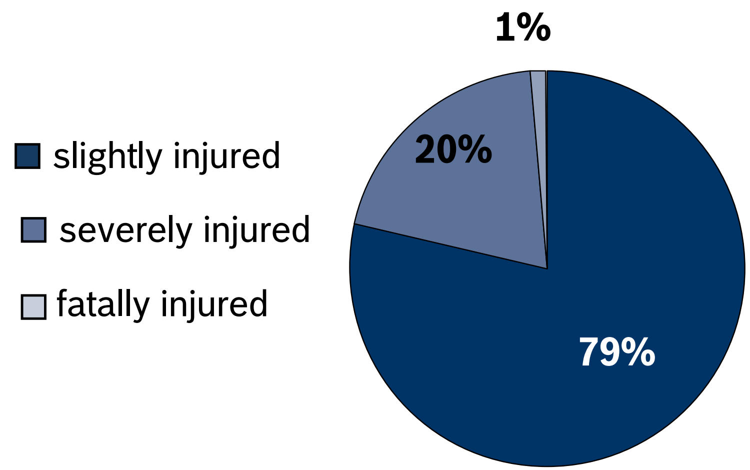
Chapter 06

Distributions within the field of effect: Injury severity

LDW/LKS/ASC relevant cases[1)]
(238 accidents susceptible to be influenced by LDW/LKS)



Official Statistics *(accidents with injured in Germany, 336 619 accidents)*



Note: 1% ⬄ 2.4 accidents

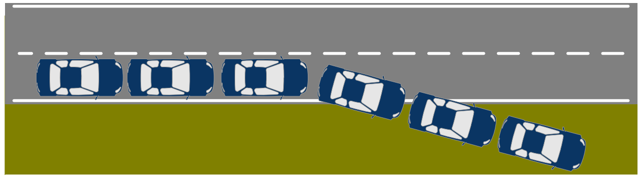
➔ In about 43% of the LDW/LKS relevant accidents at least one person is severely or fatally injured

➔ Injury severity in LDW/LKS-ASC relevant accidents is higher than on average of all accidents with personal injury

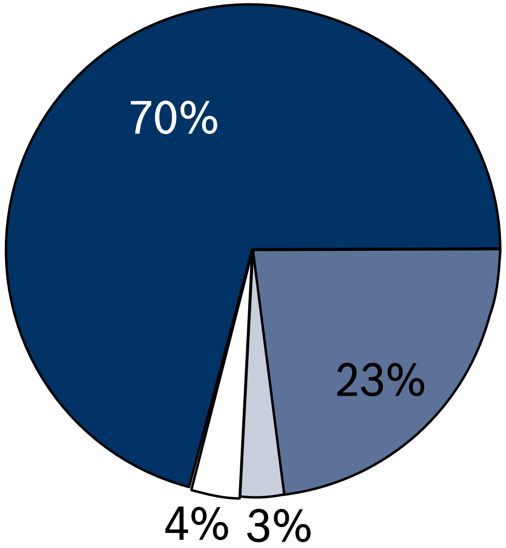
1) One accident per vehicle

Revision of benefit analysis for LDW/LKS/ASC

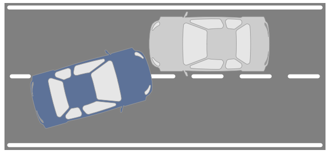
Distributions within the field of effect: Kind of accident



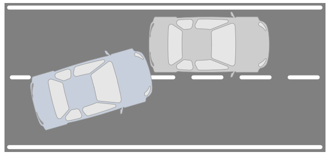
■ Leaving the carriageway to the left/right



□ others



■ collision with another oncoming vehicle



□ collision with another vehicle moving ahead or waiting

Note: 1% ⬄ 2.4 accidents

- ➔ In 26% of cases the LDW/LKS-ASC relevant vehicle collides with another vehicle[1)]
- ➔ In most cases (70%) the collision occurs outside of the carriageway[1)]

1) One accident per vehicle

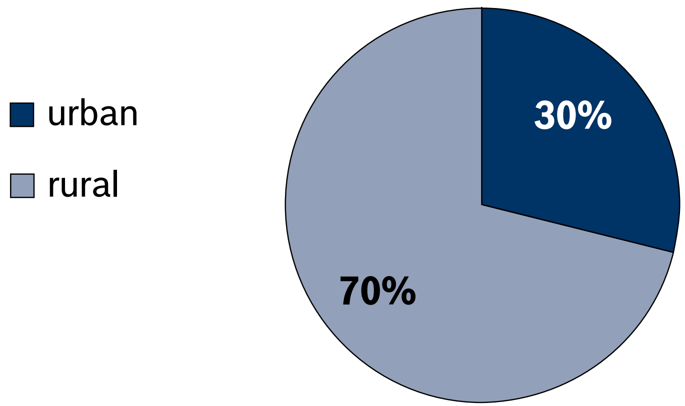
BOSCH

Revision of benefit analysis for LDW/LKS/ASC

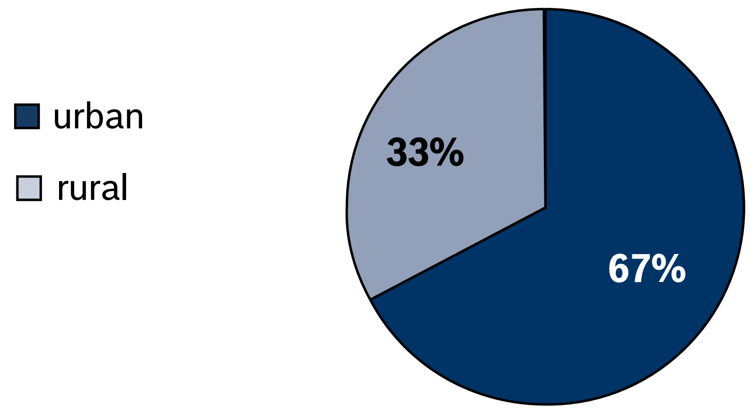
Distributions within the field of effect: Accident location

LDW/LKS/ASC relevant cases

(238 accidents susceptible to be influenced by LDW/LKS)



Official Statistics *(accidents with injured in Germany, 336 619 accidents)*



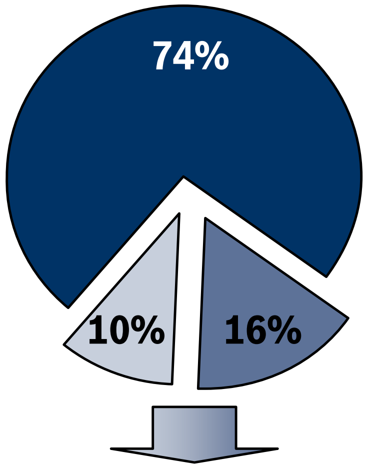
Note: 1% ⇔ 2.4 accidents

- ➔ Most of the LDW/LKS-ASC relevant accidents occur in rural areas
- ➔ LDW/LKS-ASC relevant accidents occur more than twice as often in rural areas as compared to accidents with personal injury in general

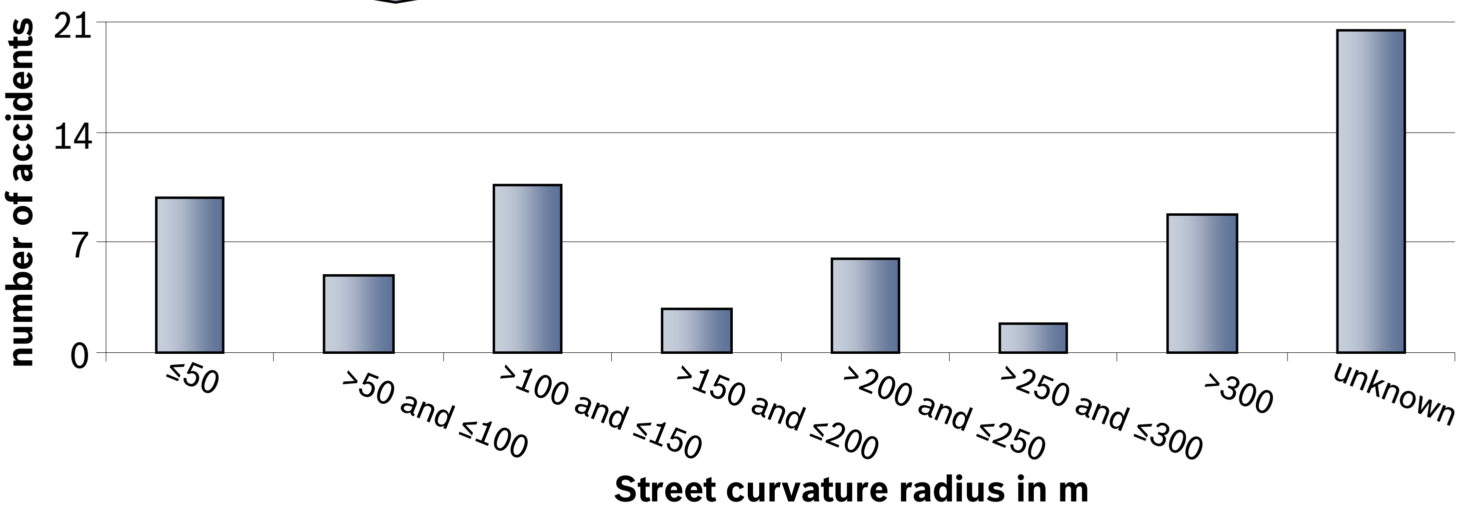
1) One accident per vehicle

BOSCH

Distributions within the field of effect: Road curvature



→ Most departures occur on a straight road



→ No relation visible between curvature radius and frequency of lane departure

1) One accident per vehicle
Note: 1% ⇔ 2.4 accidents

Revision of benefit analysis for LDW/LKS/ASC

Distributions within the field of effect:
Road curvature and side of driving lane departure

Note: 1% ⇔ 2.4 accidents

Share within accidents susceptible to be influenced by LDW/LKS-ASC *(238 accidents[1])*		Departure side: Left	Departure side: Right
	Straight	34%	40%
Road curvature	Left	8% 2)	8%
Road curvature	Right	9%	1% 2)

➔ The lane is left to both sides with approximately the same frequency *(49% - 51%)*

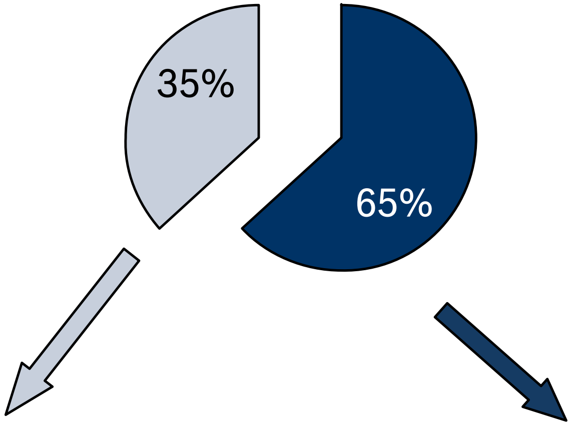
1) One accident per vehicle
2) Accidents while leaving the driving lane to the left in left bends are increased as compared to accidents while leaving to the right in right bends by curve cutting situations.

BOSCH

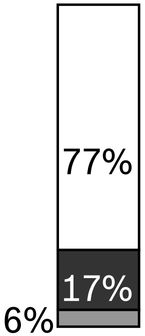
Distributions within the field of effect: Road attributes – lane separation

☐ With structural separation from oncoming traffic (*i.e. guard rail, traffic island*)

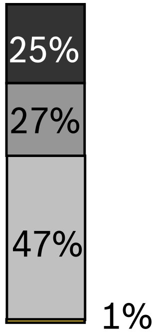
■ Without structural separation from oncoming traffic



Kind of road
(based on 82 vehicles)



Kind of road
(based on 150 vehicles)



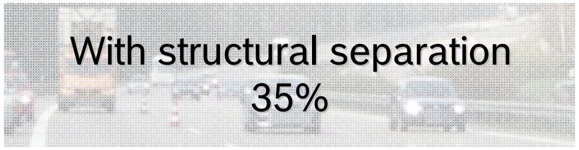
☐ freeway (*BAB*)
■ federal highway (*Bundesstraße*)
■ urban road
☐ highway (*Landstraße*)
■ others

➔ Accidents on roads with structural separation from oncoming traffic are mostly freeway accidents (3/4rd of cases)
➔ Accidents on roads without structural separation are mostly highway accidents (1/2 of cases)

1) One accident per vehicle
Note: 1% ⇔ 2.4 accidents

BOSCH

Distributions within the field of effect: Road attributes – lane used



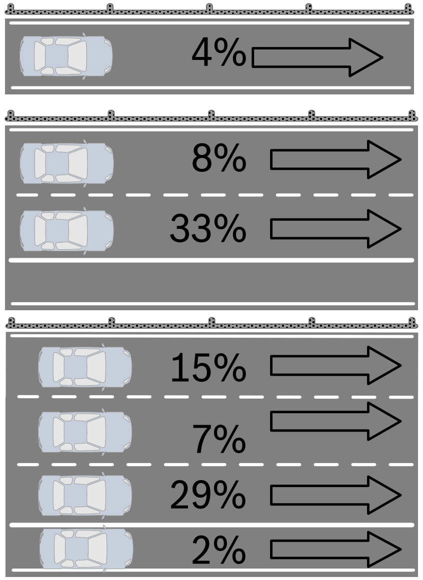
With structural separation 35%

Number of lanes and lane used before lane departure *(based on 82 vehicles)*

1 lane

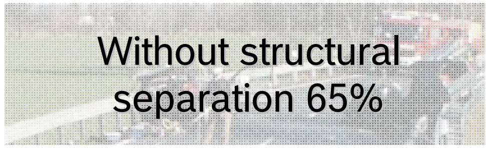
2 lanes

3 lanes



other scenarios: 2%

➔ **On roads with a structural separation most of the vehicles drive on the right lane before leaving *(~62%)***

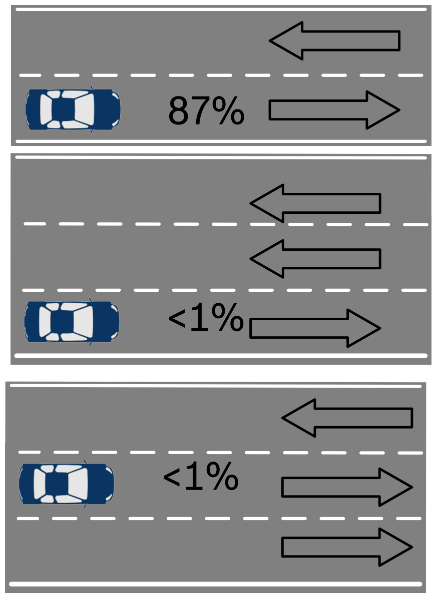


Without structural separation 65%

Number of lanes and used lane before lane departure *(based on 150 vehicles)*

1 lane in driving direction

2 lanes in driving direction



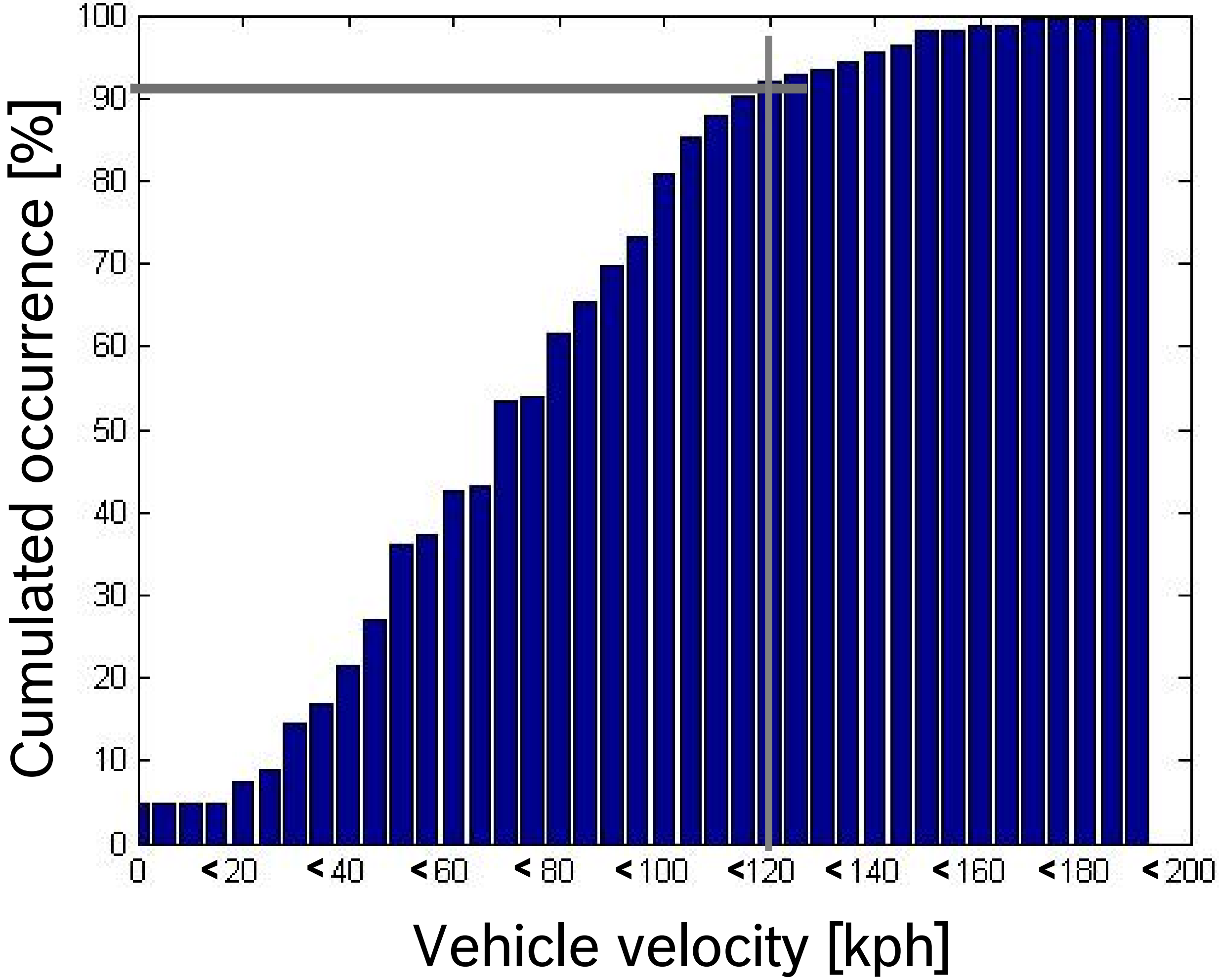
other scenarios: 12%

➔ **In ~87% of accidents on a road with structural separation the vehicle is driven on a road with one lane in each direction**

1) One accident per vehicle

Note: 1% ⇔ 2.4 accidents

Vehicle velocity before lane departure *(based on 238 vehicles)*



- **In LDW relevant accidents about 90% of the vehicles travelled at velocities below 120 kph before lane departure**

BOSCH

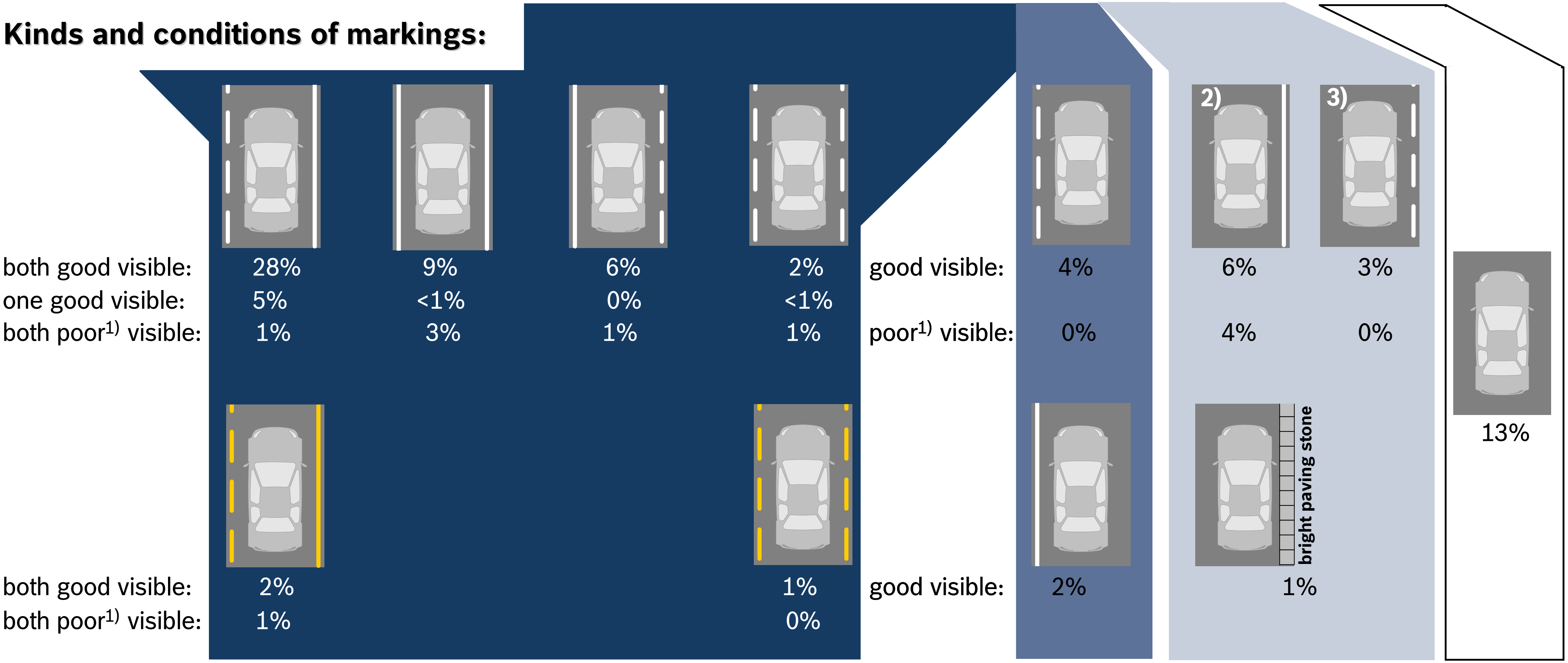
Distributions within the field of effect: Road markings

Note: 1% ⇔ 2.4 accidents

Availability of markings:

left **and** right side	**only** on the **left** side	**only** on the **right** side	no road marking	unknown
62%	6%	14%	13%	5%

Kinds and conditions of markings:



1) i.e. worn, separated or dirty markings
2) urban/rural roads with marginal strip but without mid-line
3) multilane urban road with curb as structural separation in the middle

Evaluation of LKS/ASC efficiency

Vehicles or accidents[1] within field of effect (cf. slide 5)

Accidents with personal damage addressed by LDW, LKS-ASC → 5%

428 — Field of effect LDW and LKS-ASC (cf. slide 5)

295 — Keep cases susceptible to be influenced by LKS-ASC
(i.e. driver may be unable to react, adding cases compared to LDW)

283 — Keep cases where angle of lane departure ≤ 35°
(7 unknown omitted. We assume here that the angle of an initial lane departure is below the angle of a subsequent departure from the paved road (example: skidding and road departure after first contact with grass strip next to road))

248 — Keep cases with bend radius ≥ 100 m
(18 unknown omitted)

152 — **Keep all cases with initial velocity ≥ 65 km/h (or collision speed ≥ 65 km/h)**

added rural cases with initial velocity ≤ 65 km/h — 172

118 — Keep cases where lane marked left and right — 131

110 — Keep cases with lane width between 2.4 m and 4.5 m
(all cases on highways included) — 1.5% 121

Accidents with personal damage prevented by LKS-ASC
(vehicle kept on road by system) → 1.4%

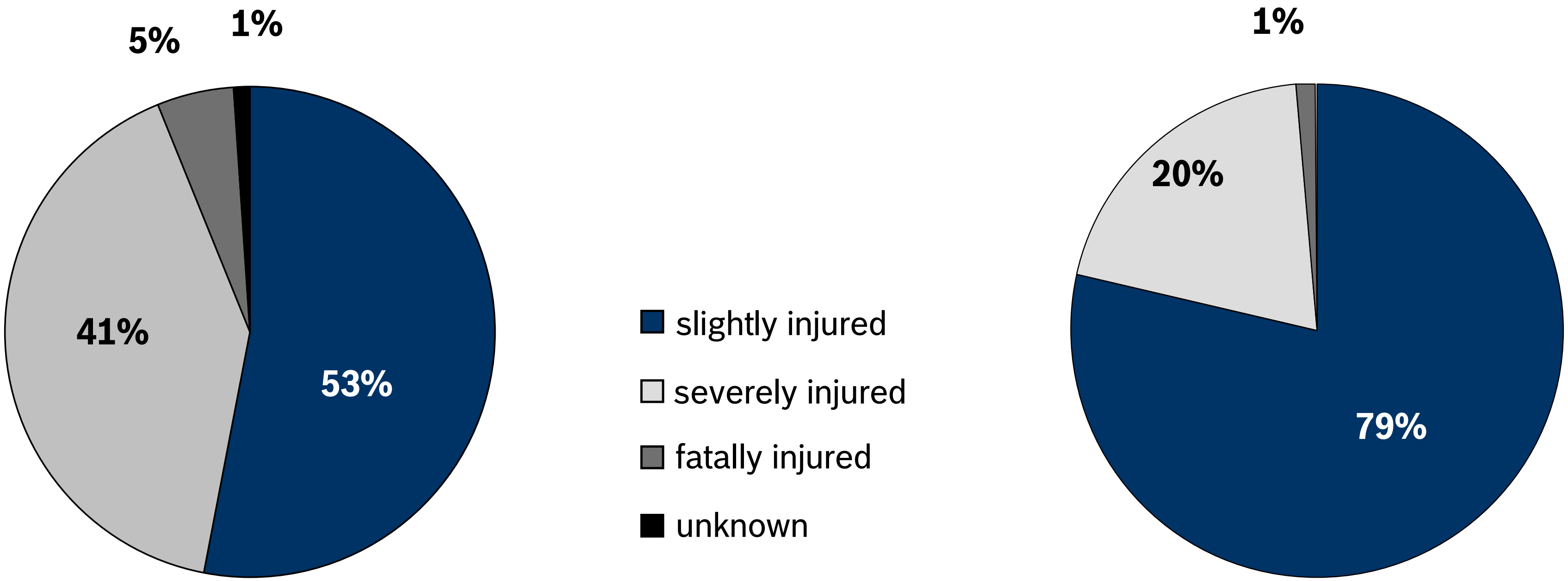
In about 1.4% of all accidents with damage to persons in Germany the accident can be avoided with LKS/ASC (4700 accidents [2]))

1) GIDAS (2001-2006), reconstructed accidents, corrected for sample bias. At this stage of the present study, the number of vehicles corresponds to the number of accidents
2) Based on Federal Statistical Office data for Germany (2007), 335845 accidents with personal damage

Distribution of injury severity in LDW/LKS-ASC relevant accidents

Accidents prevented by LKS-ASC
(1.4% to 1.5% of accidents with personal damage in Germany, vehicle kept on road by system)[1)]

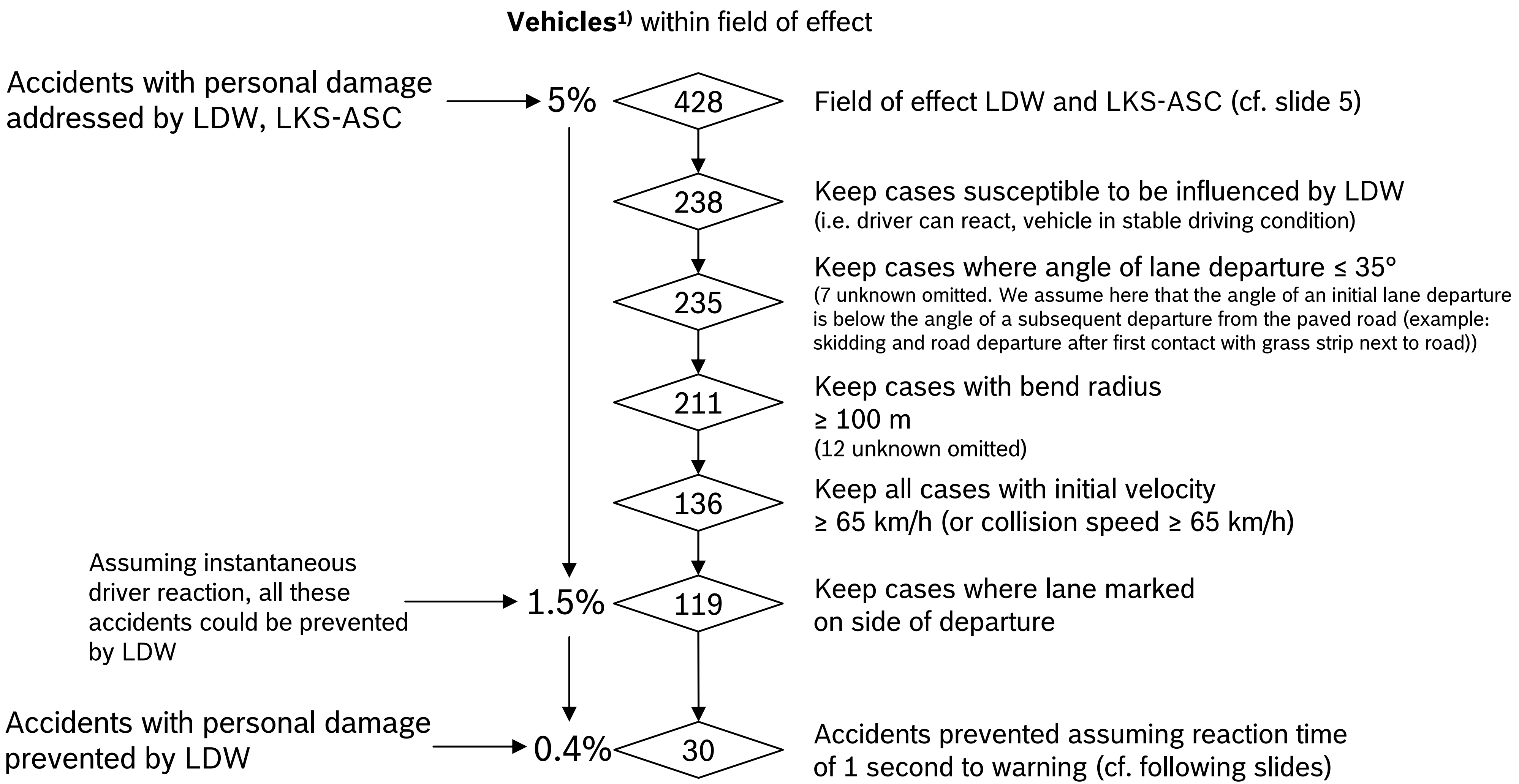
Official Statistics
(accidents with injured in Germany, 336 619 accidents)



➔ LKS-ASC prevents mostly severe accidents
➔ About 250 accidents with fatalities could be prevented by LKS-ASC per year in Germany[2)]

1) GIDAS weighted, reconstructed accident data (2001-2006): basis 8060 accidents
2) Assuming 100% fitment rate of LKS-ASC

Evaluation of LDW efficiency – Field of effect



- **About 0.4% of accidents with personal damage in Germany[2] or 1343 cases could be prevented by LDW**

1) GIDAS (2001-2006), reconstructed accidents, corrected for sample bias. At this stage of the present study, the number of vehicles corresponds to the number of accidents

2) Based on Federal Statistical Office data for Germany (2007), 335845 accidents with personal damage

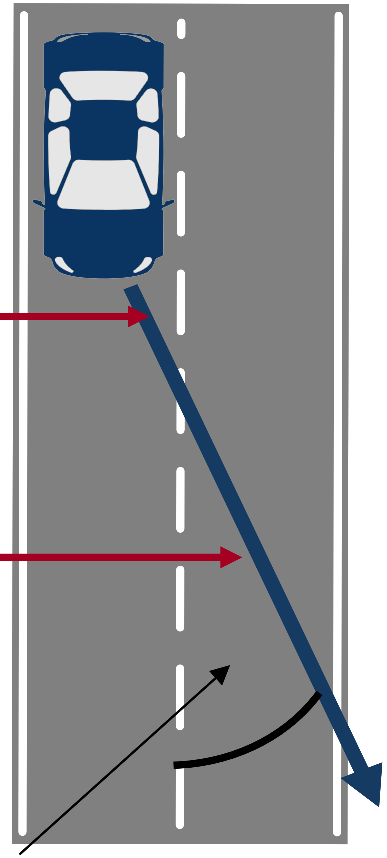
Evaluation of LDW efficiency – Procedure

A warning is issued when the vehicle will cross the white line within 0.2 s and is at a distance below 0.4 m to the white line

1)

If one second later, the vehicle is still on paved subsoil, the case is counted as prevented, else as not prevented

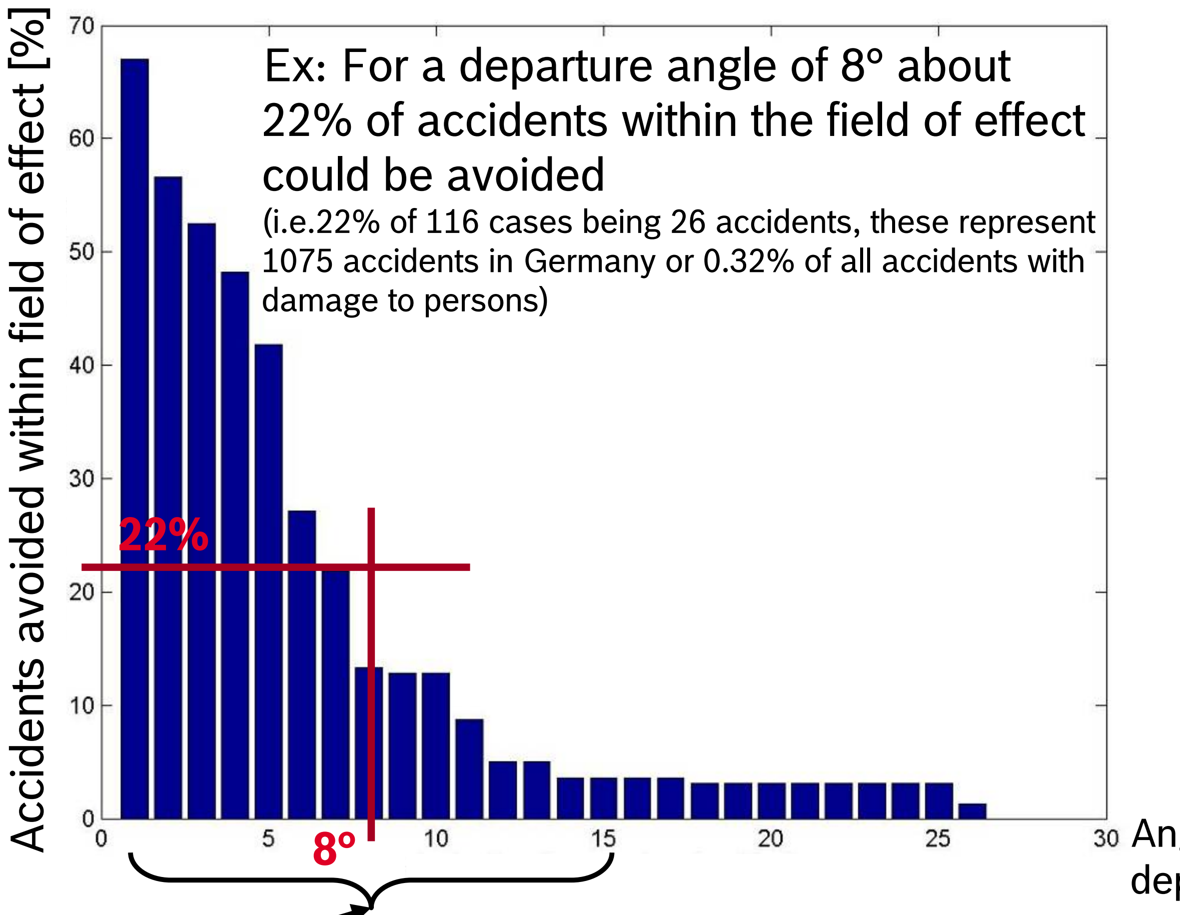
2)

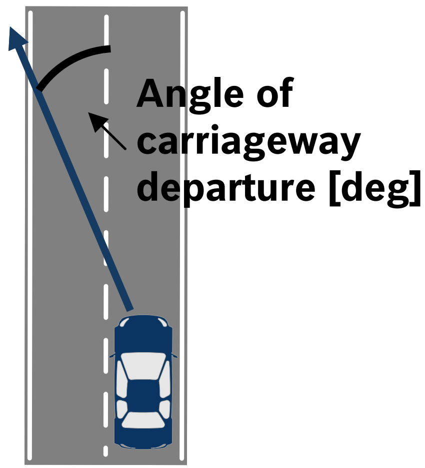


Angle of carriageway departure [deg]

This evaluation was only performed for accidents which have occurred on a straight road

Evaluation of LDW efficiency - Result





- For an angle of departure ≤ 15°, on average 25% of cases where a warning is issued can be prevented[1)]
- These represent 1343 accidents or 0.4% of all accidents with damage to persons in Germany[2)]

1) We assume here an equal distribution of lane departure angles between 1° and 15°. Analysis based on 78 GIDAS cases
2) Based on Federal Statistical Office data for Germany (2007), 335845 accidents with personal damage

Summary of results

Of accidents with personal damage in Germany (335‘845 in 2007[1)]) ...

- LDW and LKS-ASC systems can address about **5.3%** or **17800** cases
- LDW, under optimal conditions[2)], could prevent lane departure in 1.5% or 5038 cases. Taking the driver's reaction into account, this reduces to **0.4%** or **1343** cases
- LKS-ASC could prevent lane departure in **1.4%** or **4700** cases. Increase in benefit as compared to LDW stems from independence to the driver's reaction

Prevention of lane departure might not necessarily prevent the accident, for example in the case of an obstacle on the driving lane

1) Based on Federal Statistical Office data for Germany (2007), 335845 accidents with personal damage
2) Assuming instantaneous reaction to LDW warning

Accident Situation of A and B Segment Cars in Germany

Results of Accident Analysis

Accident Research CR/AEV1

BOSCH

Content

- **Motivation**
  - **Environmental legislation pushes trend towards smaller and lighter cars**
    - **Cascade from large to medium/small cars expected**
    - **Structural safety ("inherent") of smaller (low budget) cars inferior compared to large ones (real world accidents)**
    - **Higher risks for passengers in small cars and others assumed**

- **Status quo: Registration versus accident involvement by segments**

- **Overview**
  - Accident involvement by location, injury severity and segment

- **Focus on active safety**
  - Involved cars by kind of accident and segment – focus rural area and higher injury severity
  - Scope of safety functions for active safety

- **Focus on passive safety**
  - Involved cars by main damage area and segment – focus rural area and higher injury severity
  - Focus: Front/Front impacts for rural area and higher injury severity

- **Summary**

BOSCH

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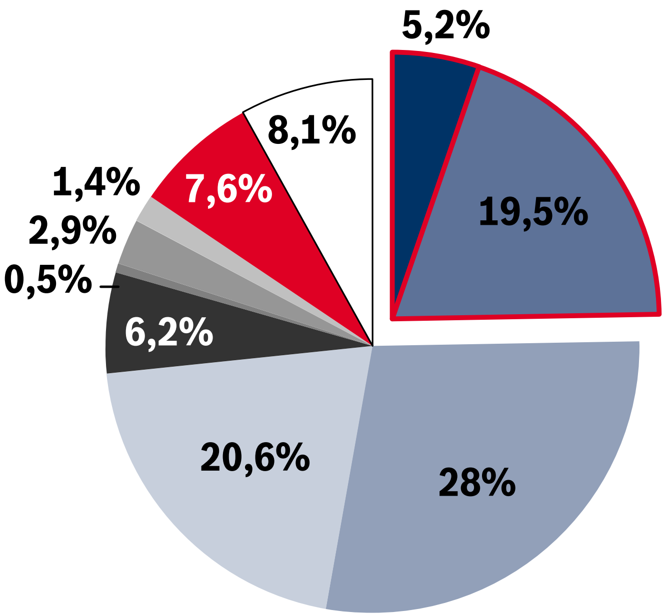
- **Summary**

BOSCH

Status quo: Car segments in KBA[1)2)] vs. GIDAS[3)]

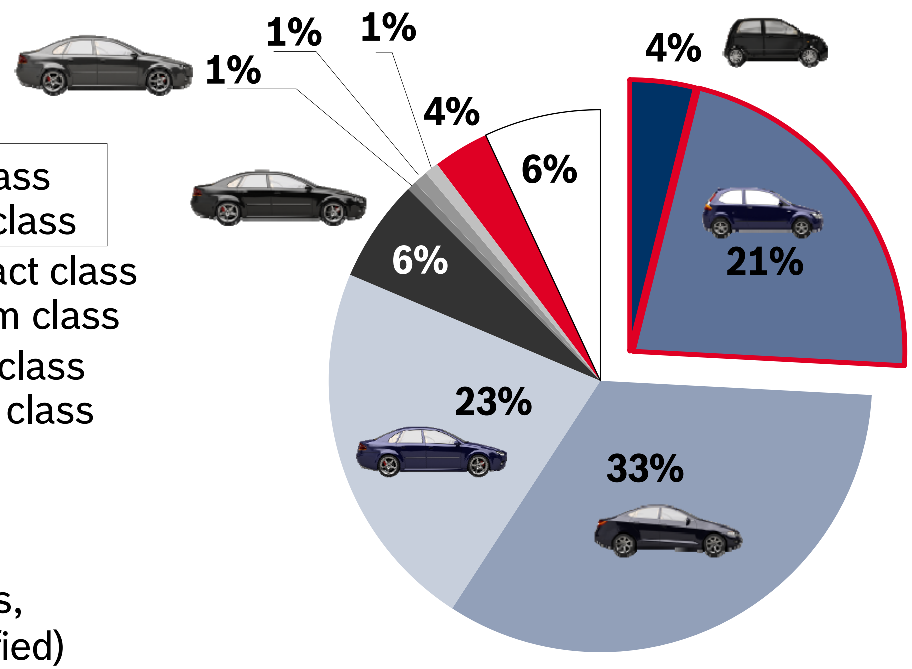
KBA[1)2)]



Population of passenger cars by **segment**
(n=41 183 594)

GIDAS German In-Depth Accident Study *(2001-2008)*

- A Segment: Mini class
- B Segment: Small class
- C Segment: Compact class
- D Segment: Medium class
- E Segment: Upper class
- F Segment: Luxury class
- Off-road vehicle
- Sports vehicle
- Vans
- Others (incl. Utilities, Caravan, not specified)



Population of passenger cars by **segment**
(n=16 259) in GIDAS

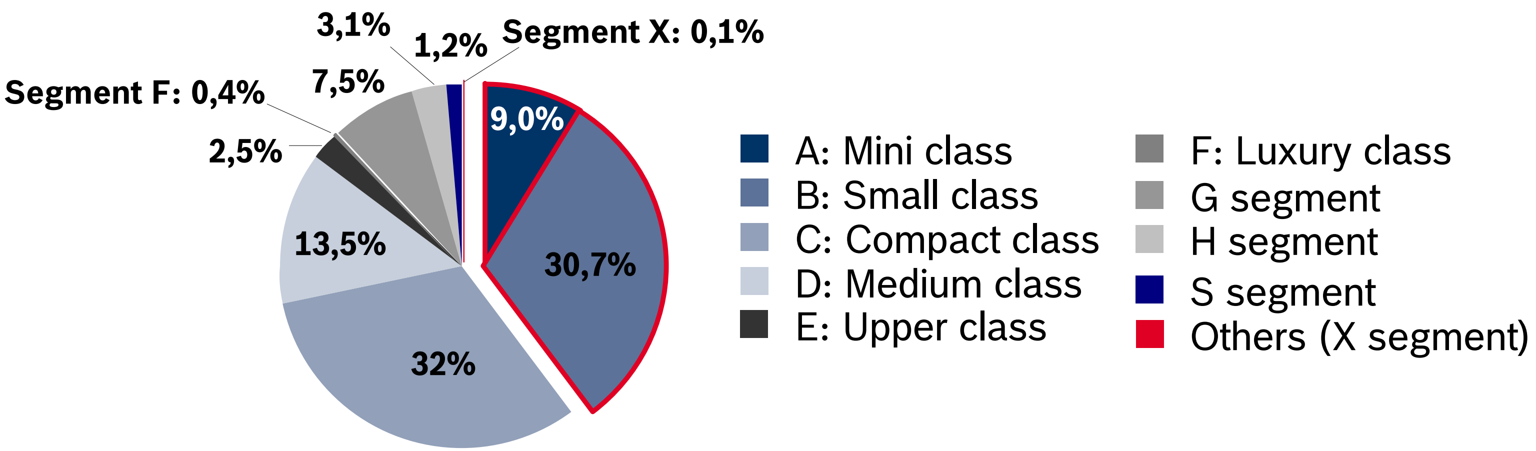
➔ **25% of the registered passenger cars in Germany are related to A & B segment.**
➔ **A & B segment have nearly the same share in accident involvement as registered.**
➔ **<u>Thesis:</u>**
- **Higher penetration of A & B segment results in higher accident involvement.**

[1)] Source: KBA 2008
[2)] Only registered cars after 1990
[3)] GIDAS is representative for the accident analysis regarding car segments especially segment A+B. – GIDAS DB Set 311208

Distributions of new registered cars in other countries[1)]

Year 2008

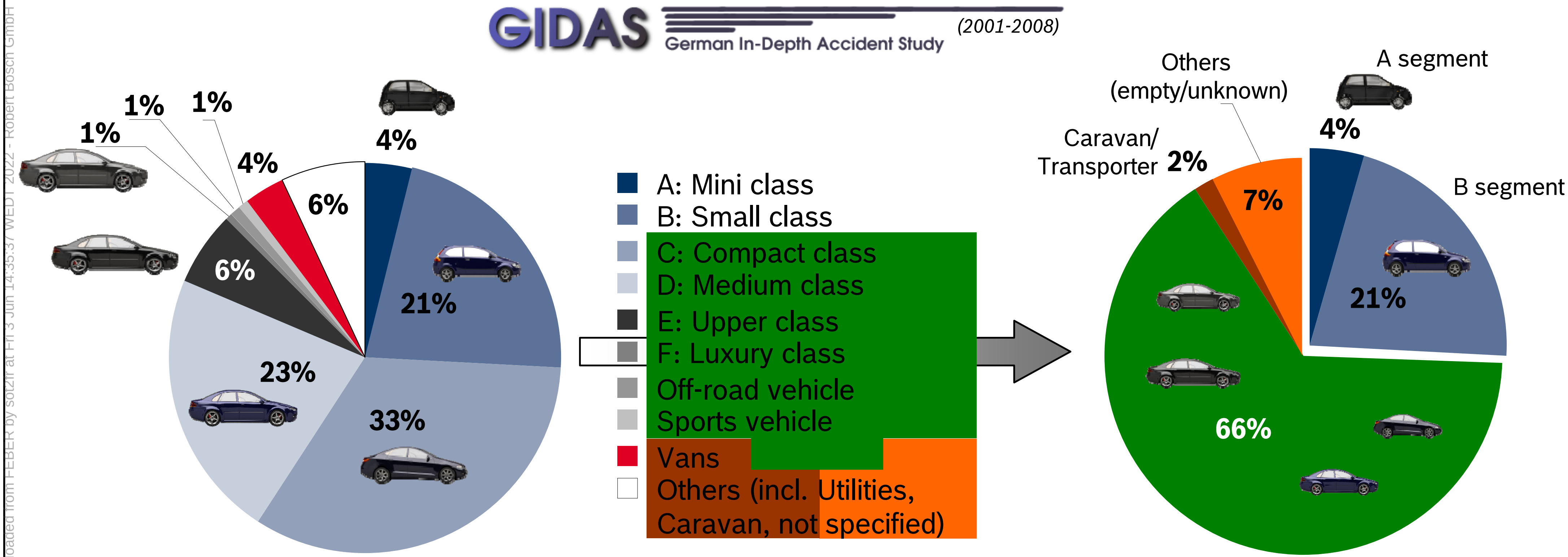
Car volume distribution	A Segment	B Segment	C Segment	D Segment	E Segment	F Segment	G Segment	H Segment	S Segment	X Segment	Total
France	160.582	824.407	646.737	199.412	20.564	2.640	94.721	80.291	9.012	711	2.039.077
Germany	159.873	673.313	1.035.434	544.849	143.652	23.894	240.561	152.094	60.082	3.722	3.037.474
Italy	449.978	795.414	479.284	180.469	24.451	3.559	189.353	32.698	15.611	5.756	2.176.573
Spain	43.366	317.923	494.648	158.058	19.782	2.169	103.308	15.870	5.175	877	1.161.176
United Kingdom	136.026	625.472	715.924	339.664	59.181	11.490	157.143	39.806	41.114	1.872	2.127.692
Share in total	***9,0%***	***30,7%***	***32,0%***	***13,5%***	***2,5%***	***0,4%***	***7,5%***	***3,1%***	***1,2%***	***0,1%***	***100,0%***



➔ 40% of the new registered cars in 5 EU countries are related to A & B segment.
➔ A & B segment <u>are more common</u> in other countries compared to Germany.
➔ Vehicles therefore have to be considered in future regarding safety development.

1) Source: Currently J.Loose CC/MKC2 by mail 10.08. 2009

Definition of car types[1,2] used for analysis



Population of passenger cars by **segment** (n=16 259)

[1] GIDAS; n = 16259 cars total – 703 defined as mini cars; 2001-2008 weighted by UFAKTOR
[2] Selection represents only example of classification taking structural behavior and model year into account
This has to be updated if a newer database version is used

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    - Higher risks for passengers in small cars and others assumed
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- **Overview**
  - Accident involvement by location, injury severity and segment
- **Focus on active safety**
  - Involved cars by kind of accident and segment – focus rural area and higher injury severity
  - Scope of safety functions for active safety
- **Focus on passive safety**
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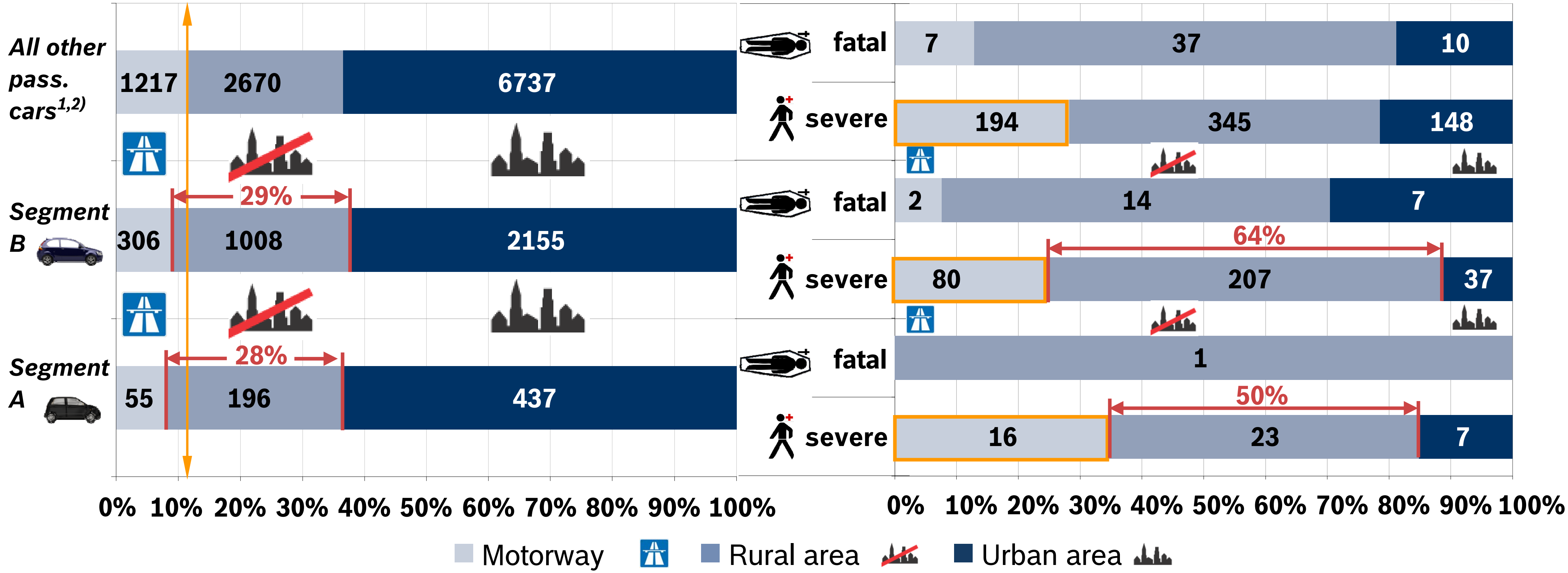
- **Summary**

BOSCH

Cars involved in accidents with casualties by location & severity

Involved cars in accidents with casualties by car segment and location (*n=14 781*)

Severe and fatal injured occurred within the car involved in accidents with casualties by car, segment and location for belted occupants (*n=1 135*)



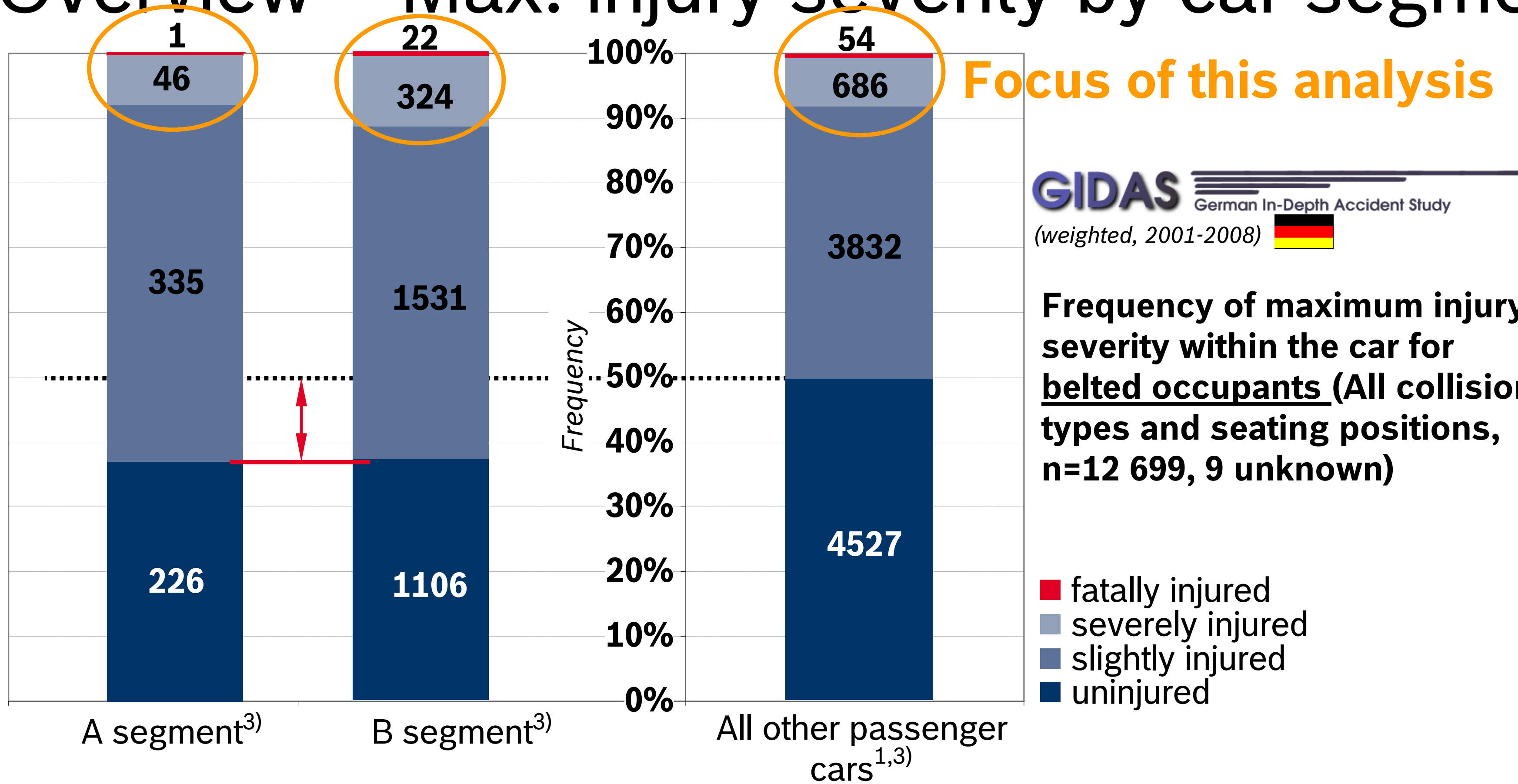
➔ **Less involvement of A&B segment in acc. on motorway but in relation they are more severe.**

➔ **More than half of severe & fatal injuries occurred in rural areas this is also true for A&B segment.**

[1] Sedan car class := Small, compact, middle, upper and luxury class

[2] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**

Overview – Max. injury severity by car segment[2)]



Frequency of maximum injury severity within the car for belted occupants (All collision types and seating positions, n=12 699, 9 unknown)

→ **Distribution of severity for A and B segment are nearly similar.**
→ **Significant difference in terms of slight injuries compared to all other passenger cars.**

[1)] Sedan car class := Small, compact, middle, upper and luxury class
[2)] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**
[3)] Unknown excluded: A seg.=0; B seg.=2; All pass. = 7

Content

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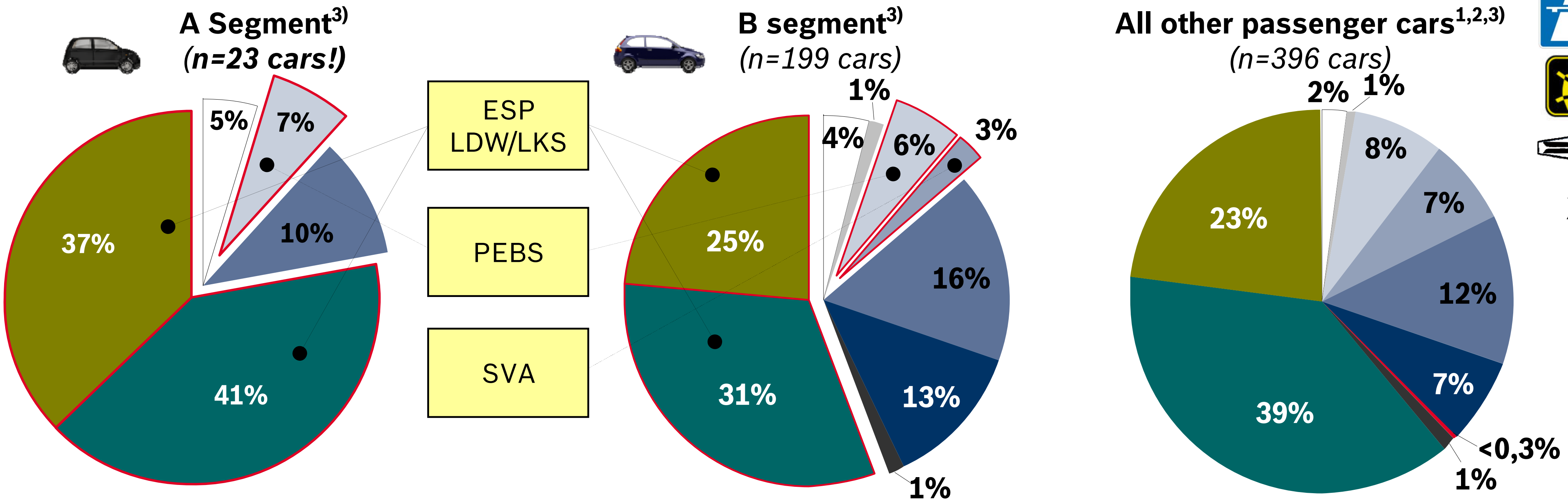
- **Summary**

BOSCH

Accident Situation A and B Segment cars Germany

Main acc. causer vehicle by kind of accident in rural area & motorway
Scope of safety functions for accidents w/ severe and fatal injuries, belted only



- accident of another kind
- parked vehicle
- vehicle moving ahead or waiting
- vehicle moving laterally in same direction
- oncoming vehicle
- vehicle which turns into or crossing a road
- pedestrian
- obstacle on carriageway
- fixed object & leaving carriageway right
- fixed object & leaving carriageway left

➔ At least 1/3 of severe accidents w/ leaving carriageway could be avoided by ESC & LDW/LKS.
➔ Rear end collisions can be addressed by PEBS functions avoiding between 1/3 and ¾ of cases.
➔ Future active safety systems (avoidance) must provide the same functions as for larger cars.

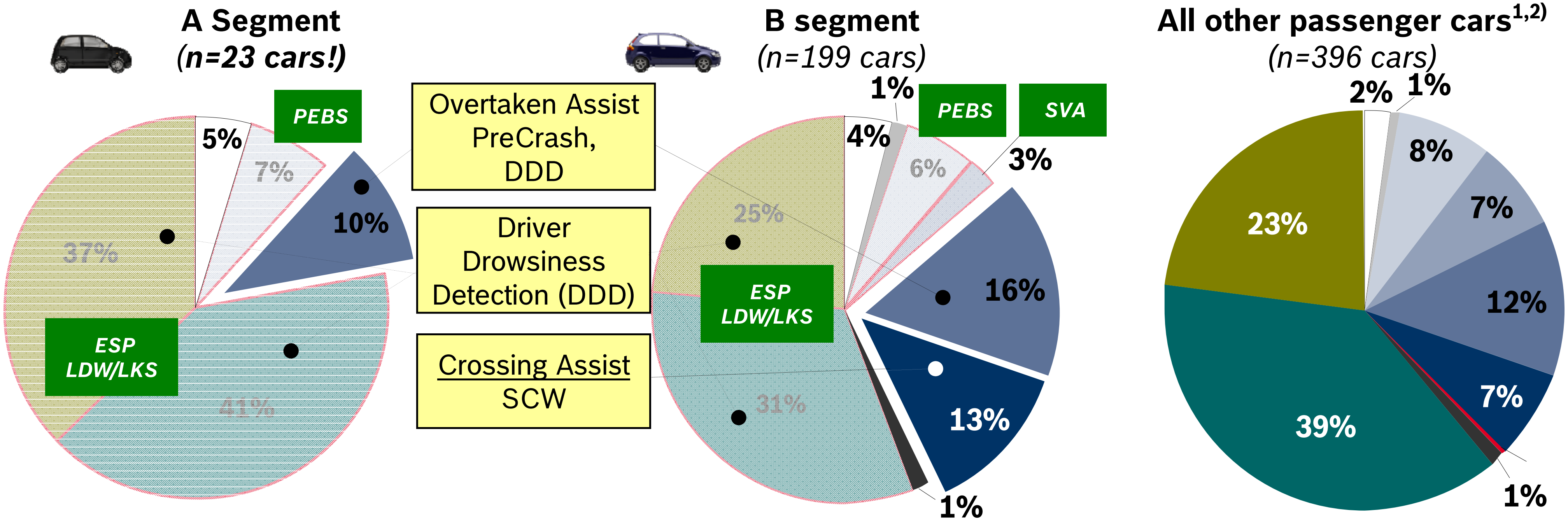
[1)] Sedan car class := Small, compact, middle, upper and luxury class
[2)] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**
[3)] Considering unbelted:28 veh. inA seg./243 in B seg. and 495 all other pass. cars, but similar distribution

BOSCH

Accident Situation A and B Segment cars Germany

Main acc. causer vehicle by kind of accident in rural area & motorway

- Scope of safety functions for accidents w/ severe and fatal injuries, belted only



- accident of another kind
- parked vehicle
- vehicle moving ahead or waiting
- vehicle moving laterally in same direction
- oncoming vehicle
- vehicle which turns into or crossing a road
- pedestrian
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- fixed object & leaving carriageway right
- fixed object & leaving carriageway left

➔ The remained kind of accidents could be addressed by an Overtaken Assist / Pre-Crash and a Crossing Assist for accidents against oncoming vehicles and crossing accidents respectively[3].

➔ DDD could address remained accidents where the vehicle leaves the carriageway[3]. This could be an effective and a low-cost solution.

[1] Sedan car class := Small, compact, middle, upper and luxury class
[2] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**

[3] Further investigations and analysis have to be done.

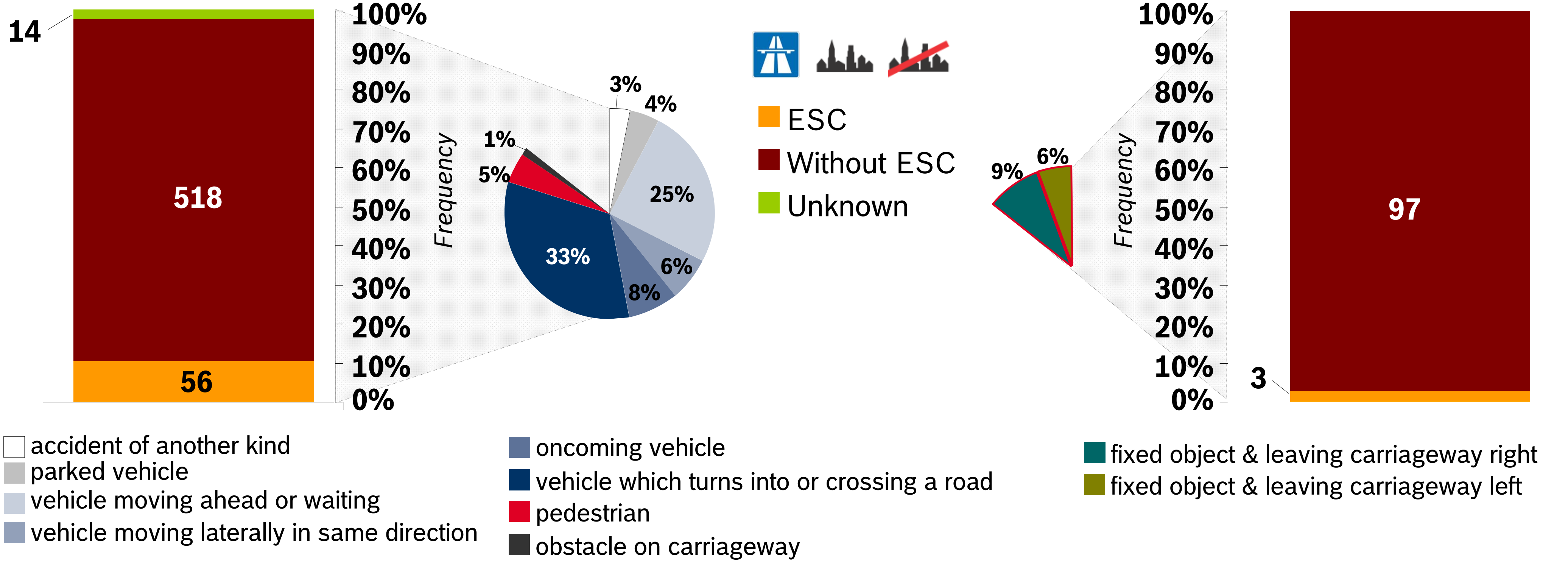
BOSCH

Accident Situation A and B Segment cars Germany

Thesis: Less ESC installation rate within A segment effects accident kind *"leaving carriageway"*

Mini vehicle class equipped w/ ESC involved in all other accident kind except leaving carriageway (n=588)

Mini class vehicle equipped w/ ESC involved in accident kind leaving carriageway (n=99)



➔ There is a significant relation between accident leaving carriageway and ESC installation rate for the A segment. Therefore it can be assumed that this kind of accidents will decrease by further ESC penetration beginning in 2010!

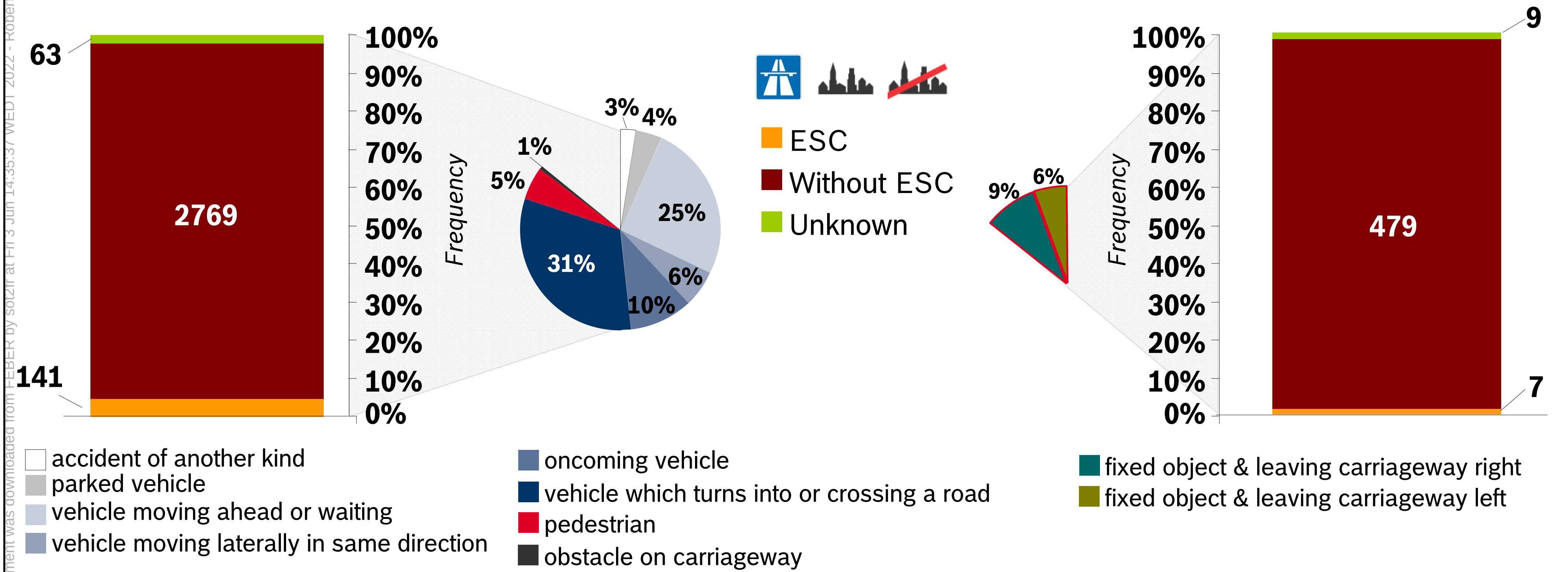
BOSCH

Accident Situation A and B Segment cars Germany

<u>Thesis:</u> Less ESC installation rate within <u>B segment</u> effects accident kind *“leaving carriageway”*

Mini vehicle class equipped w/ ESC involved in all other accident kind except leaving carriageway (n=2974)

Mini class vehicle equipped w/ ESC involved in accident kind leaving carriageway (n=495)



➔ Comparing to the A segment the B segment has also a high relation between accident leaving carriageway and ESC installation rate. Due to this it also can further be assumed that this kind of accidents will decrease by further ESC penetration beginning in 2010!

Content

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- **Summary**

BOSCH

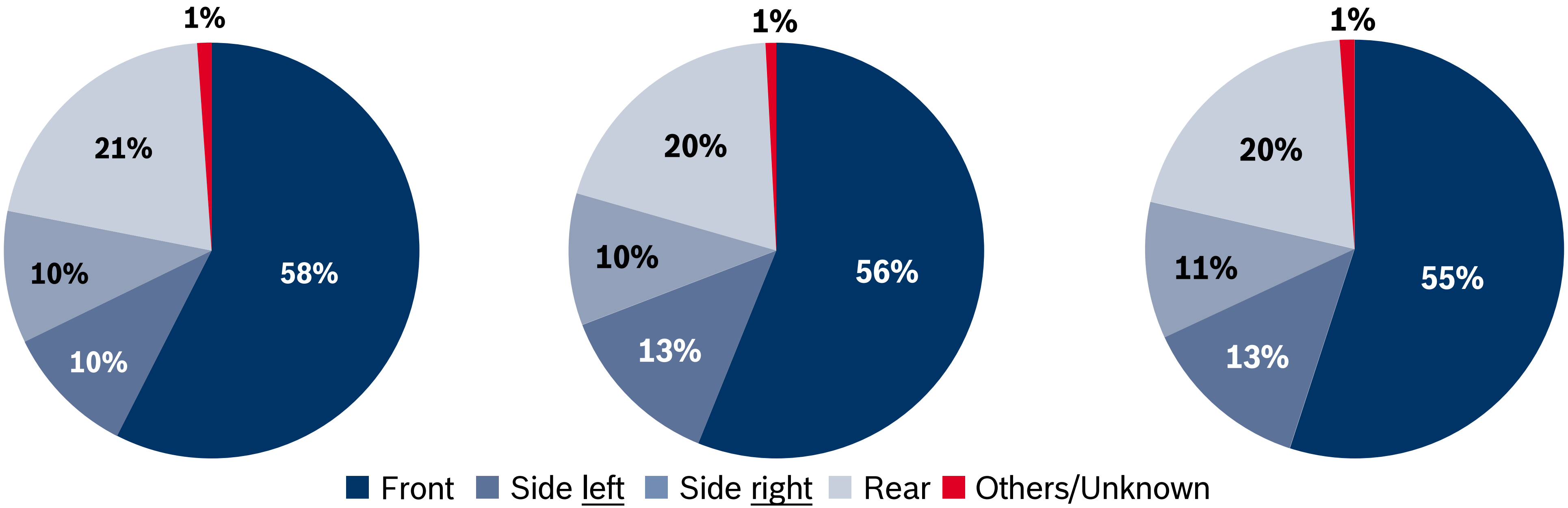
Vehicle class by main damage area[2)]

GIDAS German In-Depth Accident Study
(weighted, 2001-2008)

A Segment
Mini vehicle class
(n=688 vehicles)

B segment
Small vehicle class
(n=3468 cars)

All other passenger cars[1)]
(n=10 623 cars)

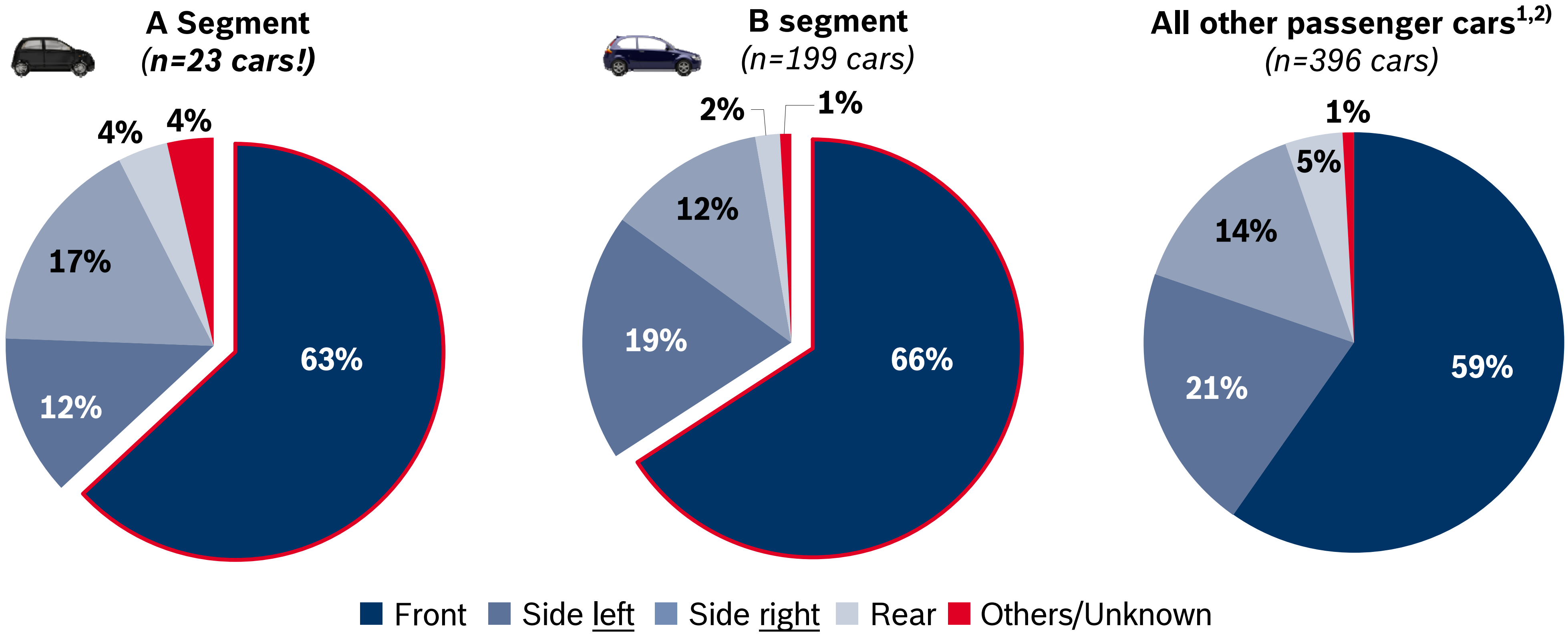


➔ **All car segments have the same share of collision type regardless severity and location.**
➔ **Future passive safety systems (mitigation) have to fulfill the same safety level for each collision type as today.**

[1)] Sedan car class := Small, compact, middle, upper and luxury class
[2)] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**

Accident Situation A and B Segment cars Germany

Main acc. causer vehicle by collision type in rural area & motorway
for accidents w/ severe and fatal injuries, belted only



➔ **Continuing the analyses on severe accidents by location A&B segment vehicles have a higher share in frontal impacts if damage area is taken into account.**

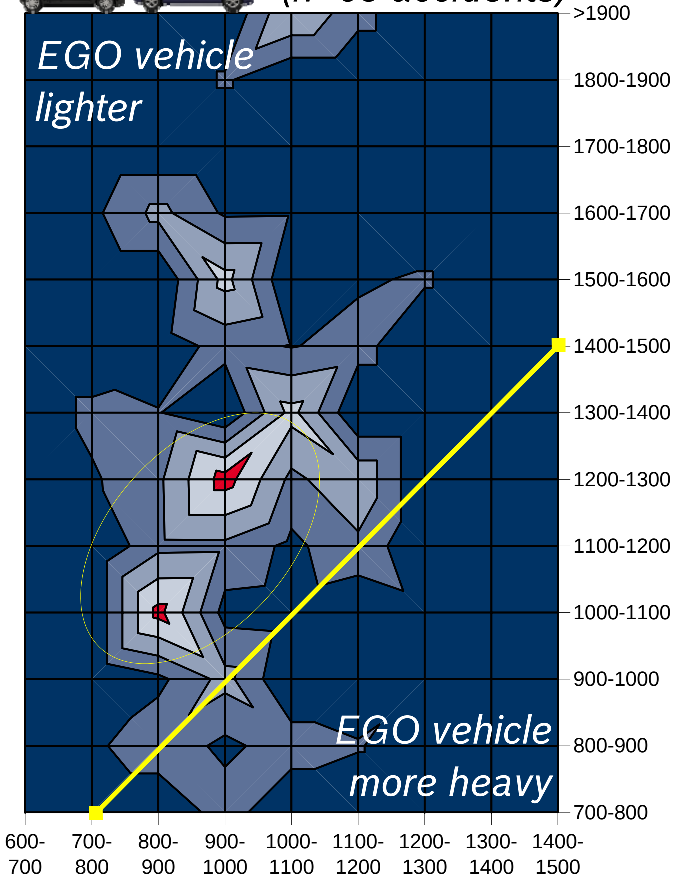
➔ **Due to mass incompatibility in frontal impacts and less performed passive safety systems A&B segment tends to more severe accidents.**

[1)] Sedan car class := Small, compact, middle, upper and luxury class
[2)] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**

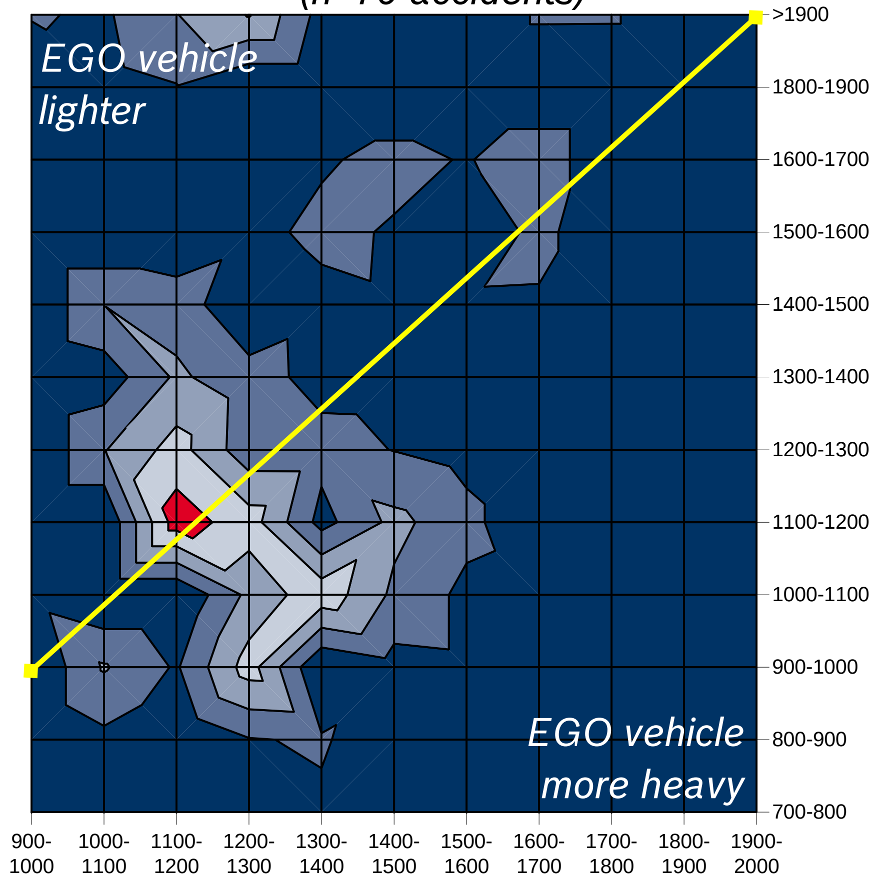
Accident Situation A and B Segment cars Germany

Mass by car segment for cars in front-front collisions against cars
in rural area & motorway for accidents w/ severe and fatal injuries, belted only

A / B Segment
(n=63 accidents)

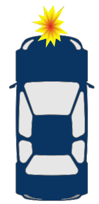


All other passenger cars[1,2)]
(n=79 accidents)



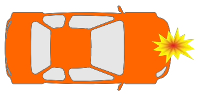
Frequency
- 4-5
- 3-4
- 2-3
- 1-2
- 0-1

m2 in kg



Opponent

EGO



m1 in kg

➔ **cars in A&B segment have more frequent incompatible collision partners in Front/Front accidents w/ higher injury severity compared to all other passenger cars[3)].**

[1)] Sedan car class := Small, compact, middle, upper and luxury class
[2)] Trucks/Caravan,others and unknown excluded – **No. of cars: 1480**

[3)] Further investigations and analysis have to be done.

BOSCH

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BOSCH

Summary

- Accident involvement of A & B segment highly correlated to vehicle registrations.
- Still high penetration of A & B segment in Europe – safety issues have to be considered in future development
- Existing safety systems like ESC have a high accident avoidance potential within the A & B segment.
- Potentials could be seen for systems which address accidents against oncoming vehicles and crossing accidents.
- Still unaddressed accidents have to be analyzed e.g. alcohol influence

BOSCH

Analysis of Selected Real World Accident Scenarios

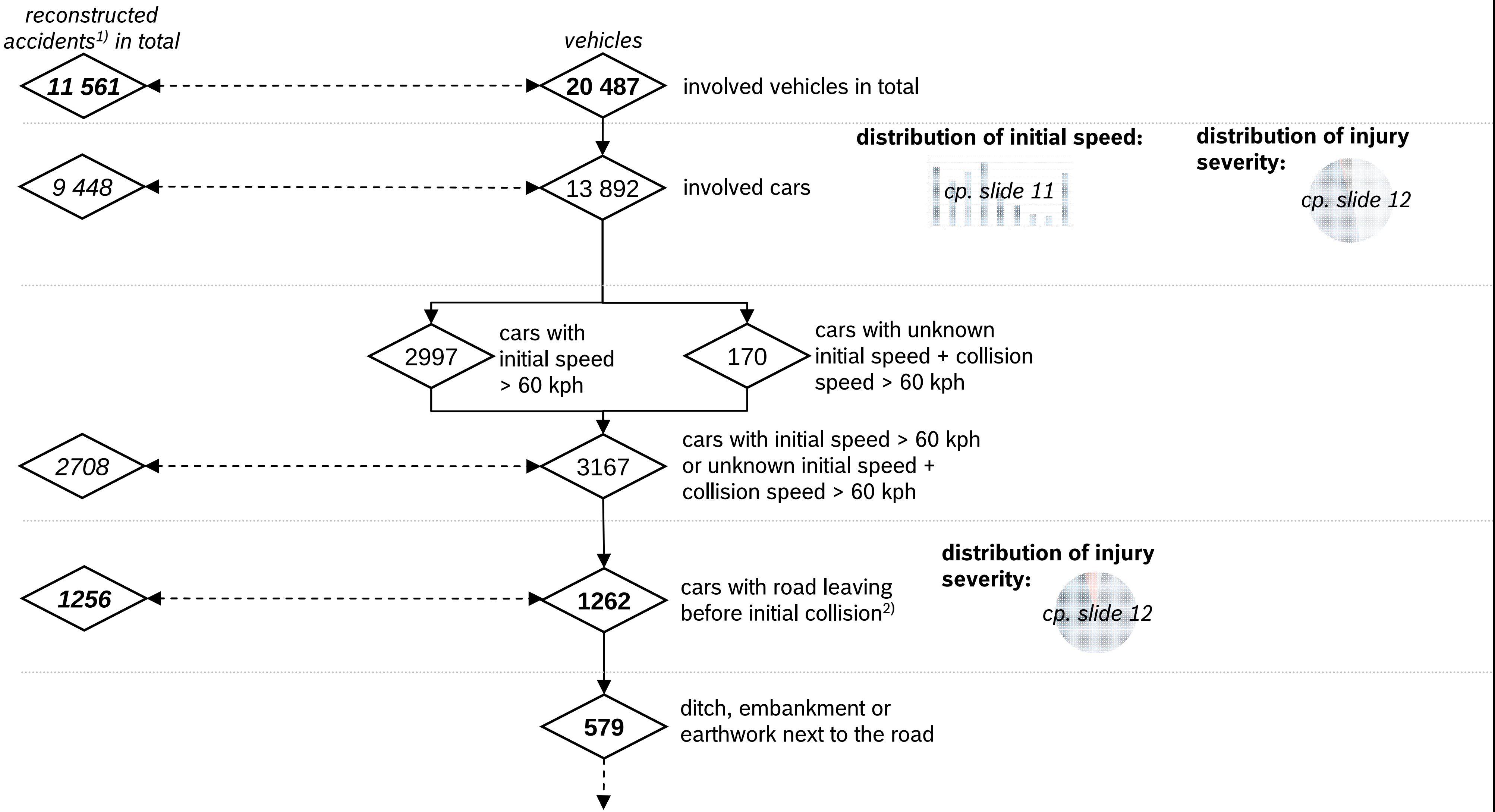
Results of Accident Analysis

Accident Research CR/AEV1

Content

1. Field of Effect of Rotational Crashes

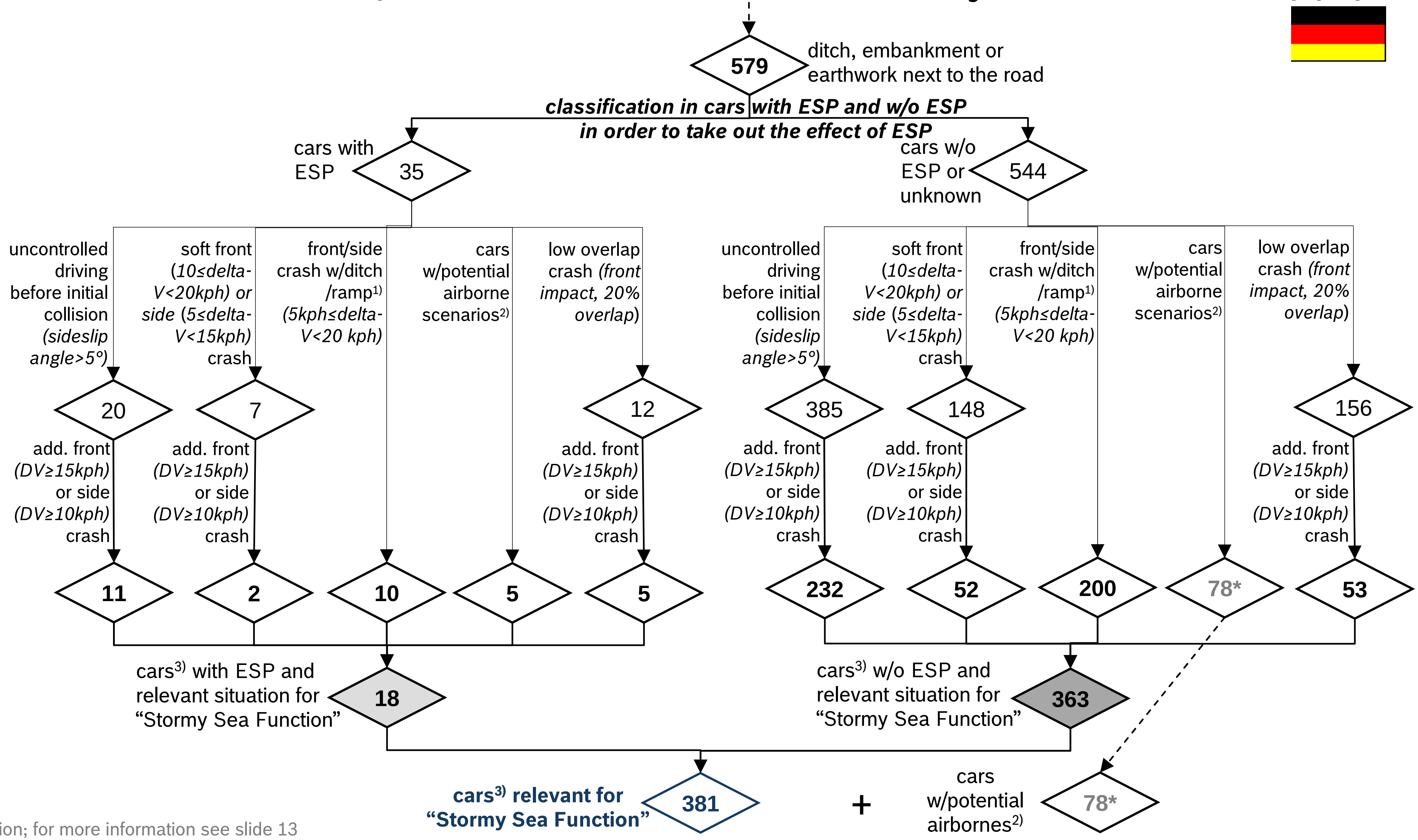
Selection of Cars w/Situations Relevant for “Stormy Sea Function” (1/2)



1) Source: GIDAS 2001-2008 *(weighted data for Germany)*

2) impact w/change in speed≥3 kph or impact causing damages or change in moving direction (no determination of small collisions)

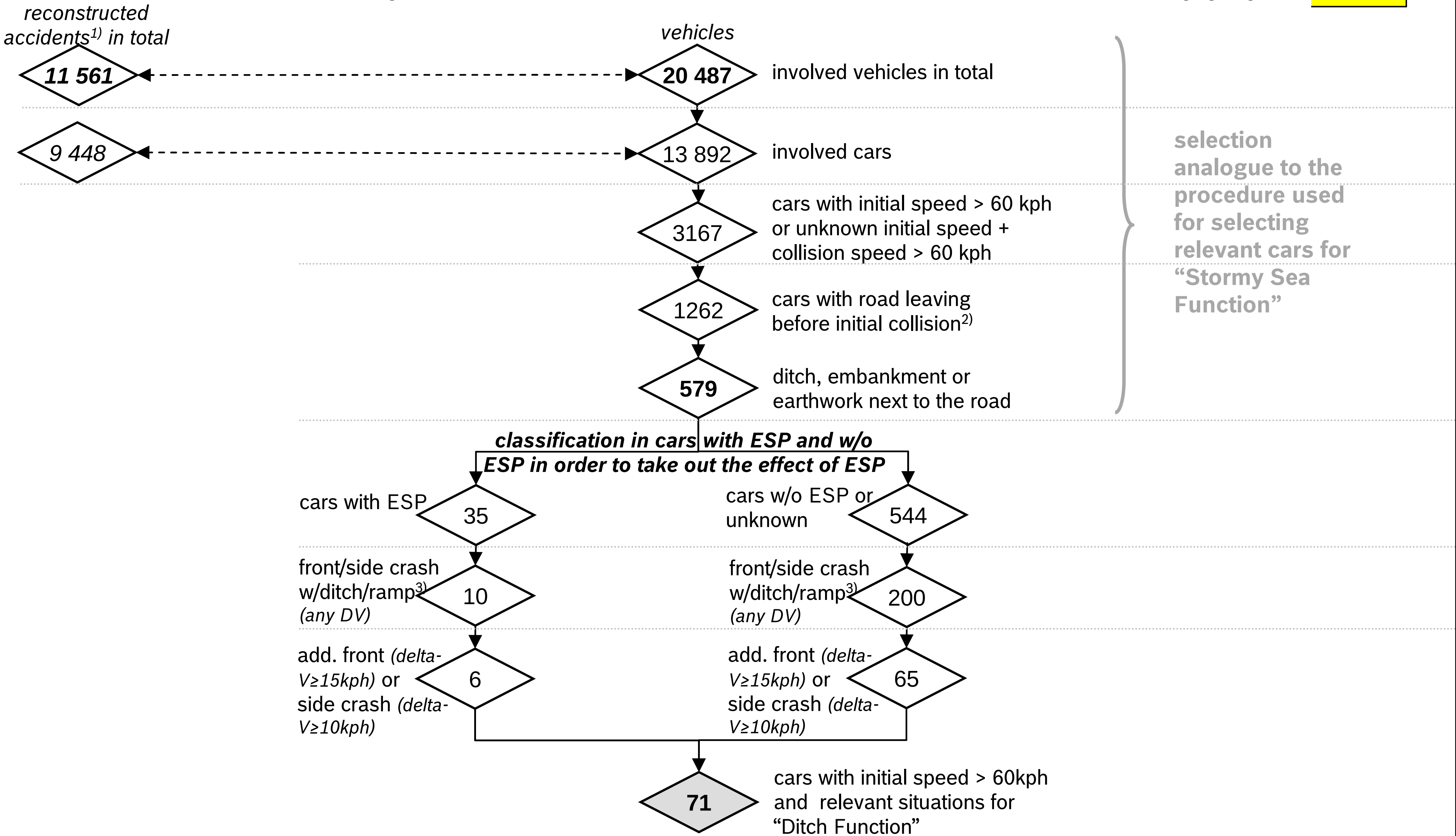
Selection of Cars w/Situations Relevant for “Stormy Sea Function” (2/2)



*estimation; for more information see slide 13

1) Only criterion “collision with ditch” is considered; if there was a rollover before the collision with the ditch this accident would not be considered
2) The number of cars w/potential airborne scenarios can be only determined by single case analyses
3) If there are cars which are addressed by two or more criteria the cars will be only considered once in the sum

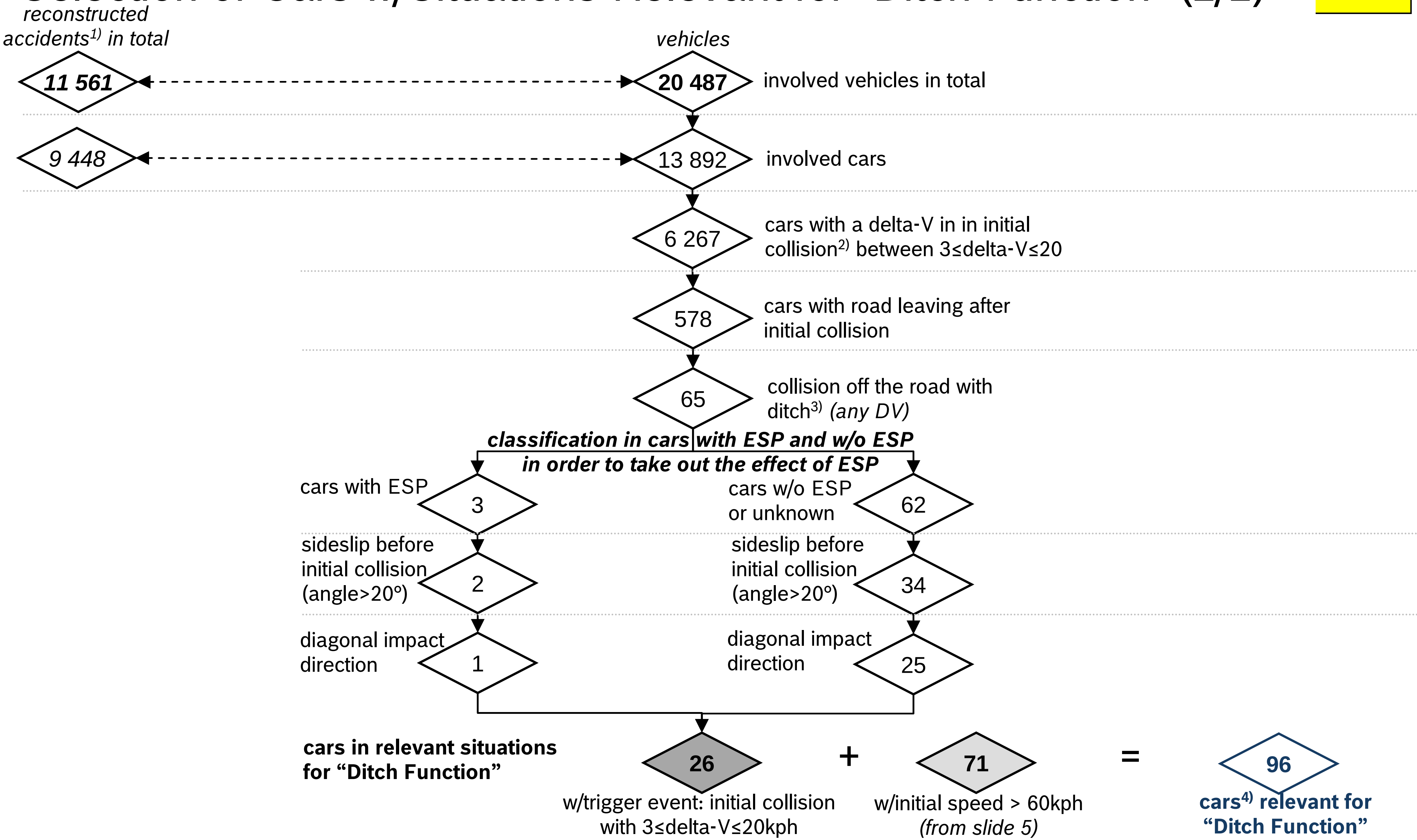
Selection of Cars w/Situations Relevant for “Ditch Function” (1/2)



1) Source: GIDAS 2001-2008 *(weighted data for Germany)*
2) impact w/ change in speed≥3 kph or impact causing damages or change in moving direction (no determination of small collisions)
3) Only criterion “collision with ditch” is considered; if there was a rollover before the collision with the ditch this accident would not be considered

1. Field of Effect of “Rotational Crashes”

Selection of Cars w/Situations Relevant for “Ditch Function” (2/2)



1) Source: GIDAS 2001-2008 *(weighted data for Germany)*
2) impact w/ change in speed≥3 kph or impact causing damages or change in moving direction (no determination of small collisions)
3) Only criterion “collision with ditch” is considered; if there was a rollover before the collision with the ditch this accident would not be considered
4) If there are cars which are addressed by two or more criteria the cars will be only considered once in the sum

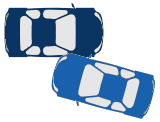
Selection of Cars w/Situations Relevant for “Side Tackling Function”

reconstructed accidents[1] in total | *vehicles*

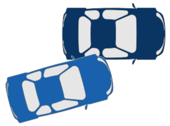
- **11 561** ↔ **20 487** involved vehicles in total
- *9 448* ↔ 13 892 involved cars
- 4 087 initial collision[2] is side impact
- 2 356 change in speed during collision above thresholds *(delta-V≥5kph)*

Car2Vehicle

- 1 866 collision opponent: other vehicle
  - 103 point of impact behind first quarter of car (A-pillar) + collision angle c between vehicles: 160° ≤ |c| ≤ 180°



  - 190 point of impact in front of last quarter of car (C-pillar + collision angle c between vehicles: |c| ≤ 20°



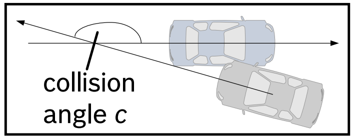
  - 293

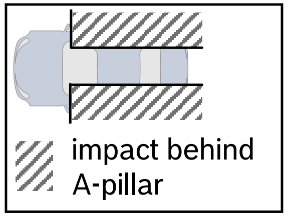
Car2Object

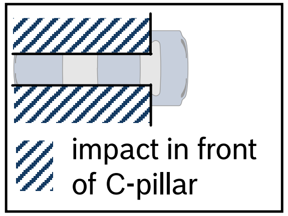
- 490 collision opponent: fixed object
  - 257 point of impact behind first quarter of car (A-pillar), cp. sketch
  - 27 no uncontrolled driving maneuver before collision *(sideslip angle ≤ 5°)*

cars relevant for “Side Tackling Function” **320**

Definitions:





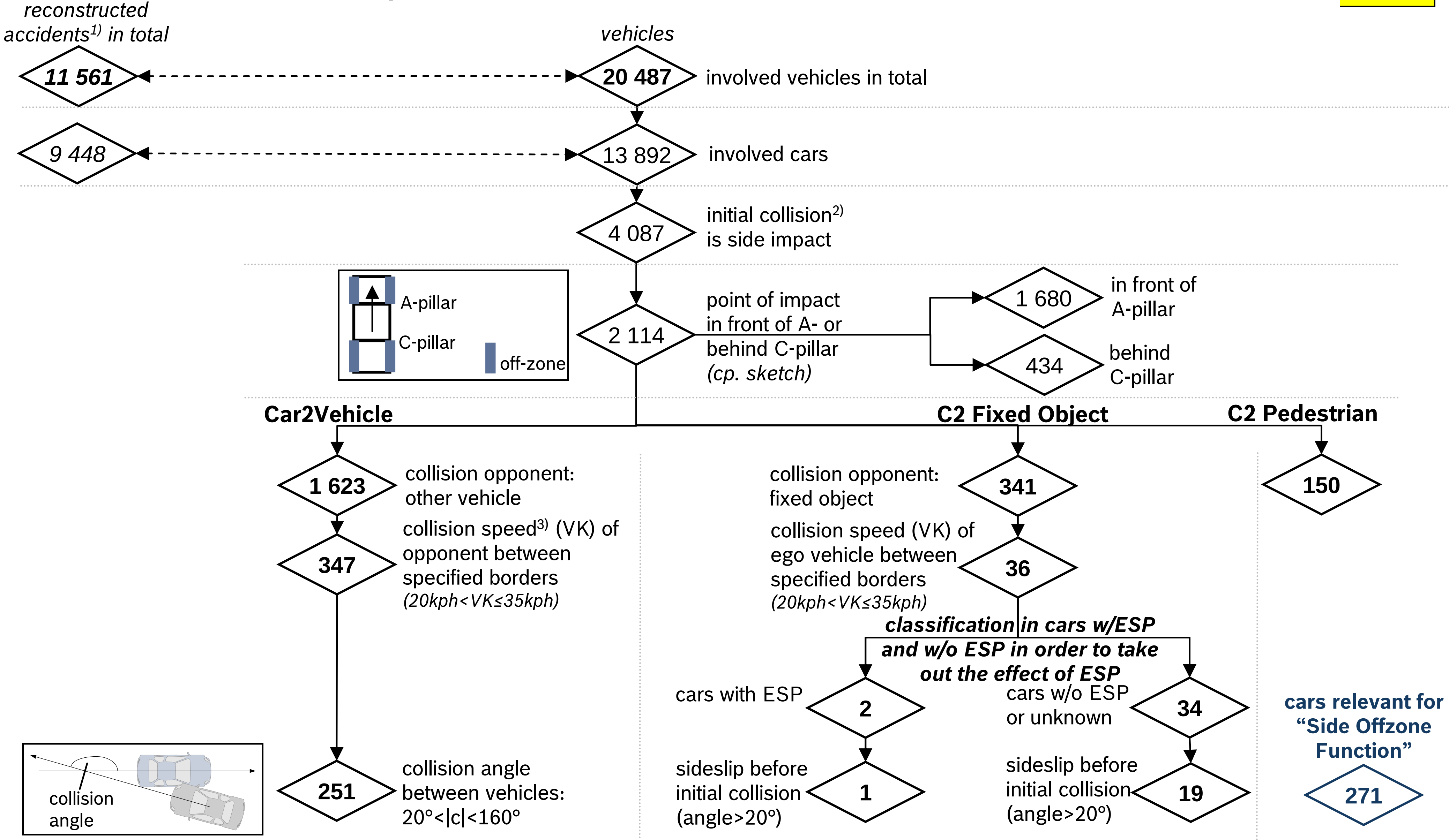


1) Source: GIDAS 2001-2008 *(weighted data for Germany)*

2) impact w/change in speed≥3 kph or impact causing damages or change in moving direction (no determination of small collisions)

1. Field of Effect of "Rotational Crashes"

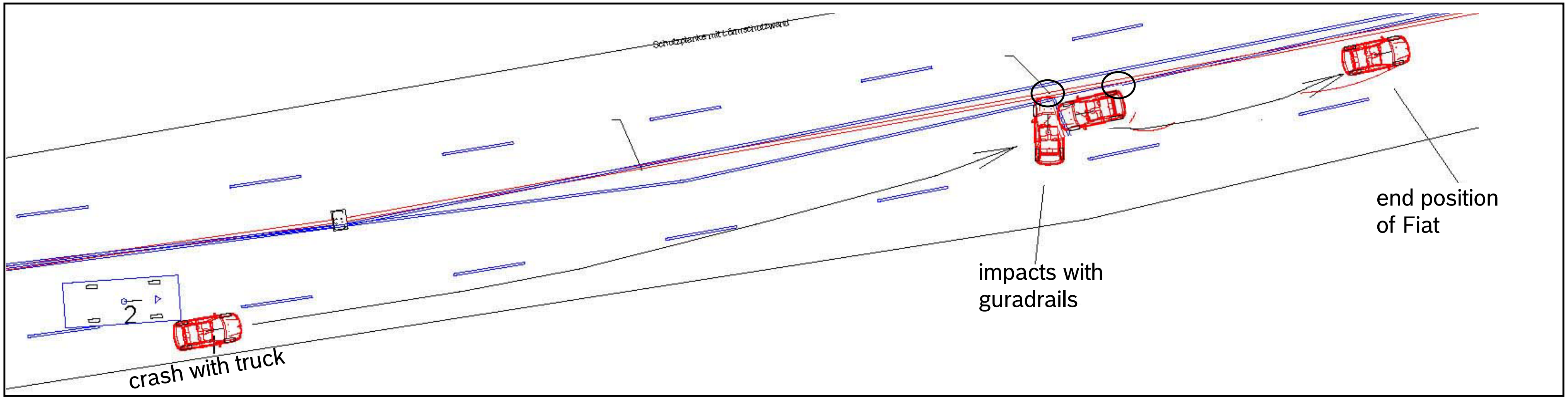
Selection of Cars w/Situations Relevant for "Side Off-Zone Function"



1) Source: GIDAS 2001-2008 *(weighted data for Germany)*
2) impact w/change in speed≥3 kph or impact causing damages or change in moving direction (no determination of small collisions)
3) Attention: this is not the relative speed!

Example to Side Off-Zone crash: ***#30040628****

The relevant car is hit at the left hand side by a truck (delta-v=6kph). Because of this collision the relevant Fiat Punto starts skidding and crashes in the following two times with the guardrail (delta-v=26kph). The occupant of the relevant car is injured with MAIS 1. The thorax and curtain airbag on the right-hand side are both deployed.



sketch of accident

deformation of first impact

deformation of the impacts with guardrail

deployed bags

* GIDAS 2001-2008 *(weighted data for Germany)*

Summary: Accidents in the Field of Effect of “Rotational Crashes”

	accidents[1)]	vehicles		
Total	*11 561*	20 487		
Addressed by “Rotational Crashes” functions together[2)]	*926*	971	+	78* cars w/potential airbornes
addressed by “Stormy Sea Function”	*381*	381	+	78* cars w/potential airbornes
addressed by “Ditch Function”	*95*	96		
addressed by “Side Tackling Function”	*280*	320		
addressed by “Side Off-zone Function”	*270*	271		

*estimation; for more information see slide 4

➔ Functions to “Rotational Crashes” address in sum 971 cars in 926 accidents (estimated value for potential airbornes is not included in the sum, vehicles could be addressed more than one function characteristics)

➔ Referred to all accidents with casualties this is a share of ~8%.

➔ The share of cars with relevant course for functions to “Rotational Crashes” is often slightly increased for cars w/o ESP compared to cars w/ESP. With increasing market penetration of ESP the field of effect will decrease, hence the determined field of effect can be seen as an upper border.

1) Source: GIDAS 2001-2008 *(weighted data for Germany)*

2) If there are cars which are addressed by two or more criteria the cars will be only considered once in the sum

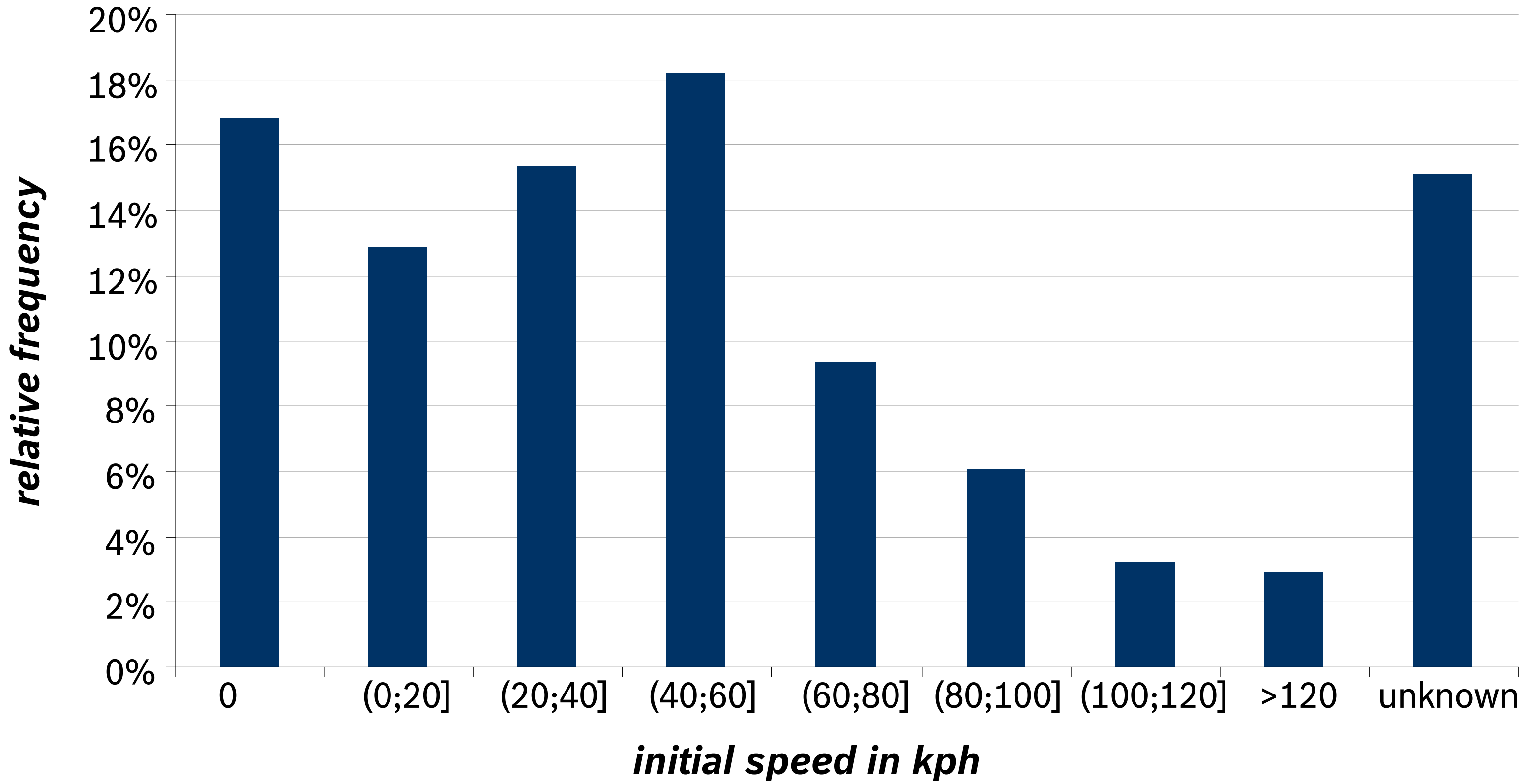
1. Field of Effect of “Rotational Crashes”

Histogram of Initial Car Speeds

BACKUP

involved cars[1)]

13 892



1) Source: GIDAS 2001-2008 *(weighted data for Germany)*

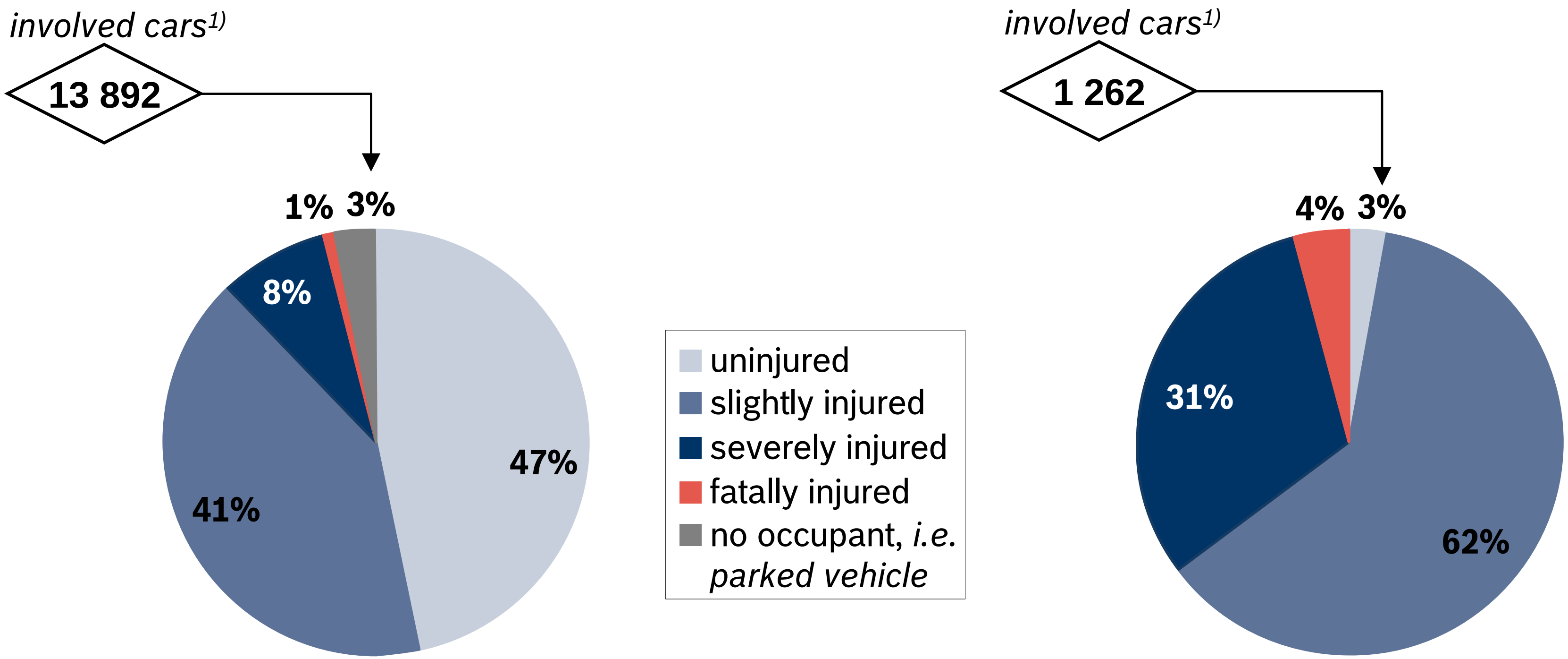
BOSCH

Maximal Occurring Occupant Injury Severities -

BACKUP

in all cars involved in accidents:

in cars with road leaving before initial collision[2)]:



➔ It is expected that the vehicle age has an influence on the injury severity of the occupants. Due to this the distribution of the vehicle age was compared between all cars involved in accidents and in cars with road leaving before initial collision. There was no significant difference determined. Hence the following statement is valid: The injury severity of car occupants is increased in accidents with road leaving compared to cars involved accidents with casualties in total.

1) Source: GIDAS 2001-2008 *(weighted data for Germany)*

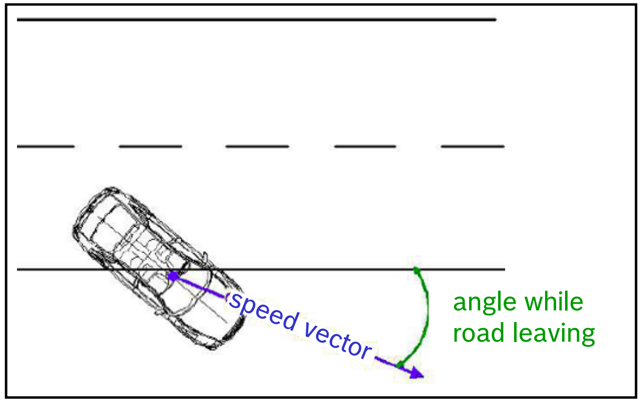
2) impact w/change in speed≥3 kph or impact causing damages or change in moving direction (no determination of small collisions)

Estimating Number of Cars with ESP and Airborne

BACKUP

➔ Statement: ratio between the cars with ESP + airborne scenarios and cars with ESP = ratio between cars w/o ESP + with airborne scenarios and cars w/o ESP

➔ In order to consider this statement the distributions of the angels while road leaving (cp. sketch) are analyzed. The initial speed is expected to be similar because here only cars are considered with a speed >60kph while road leaving. The sideslip angle while road leaving would be another interesting information but is not available for a sufficient big number of cars.
Distribution of angle while running off road:



angle while running off road	cars[1] w/ESP	cars[1] w/o ESP or unknown	
<=10°	12 *(34%)*	166 *(31%)*	
(10°;20°]	6 *(17%)*	175 *(32%)*	} common consideration
(20°;30°]	6 *(18%)*	54 *(10%)*	} common consideration
(30°;40°]	1 *(3%)*	16 *(3%)*	
(40°;50°]	0 *(0%)*	4 *(1%)*	
unknown	10 *(28%)*	128 *(24%)*	
sum	35 *(100%)*	544 *(100%)*	

➔ If angles between 10° and 20° and between 20° and 30° are considered in common it can be concluded that the distributions of angles while running off the road is similar for cars w/ and w/o ESP

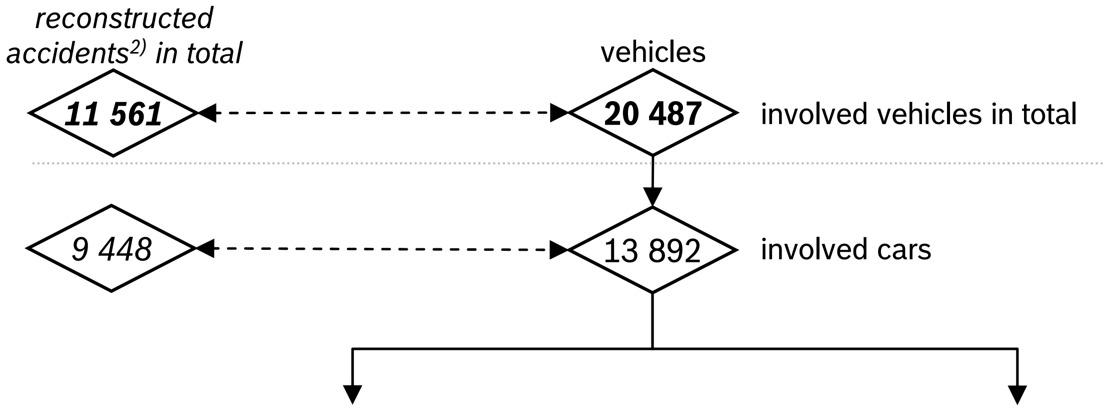
➔ Hence the statement can be used for generating a first estimation about the number of cars with ESP and airborne

1) Source: GIDAS 2001-2008 *(weighted data for Germany)*

Content

2. Cars with Airborne Situations

Overview on Available GIDAS Data to Airborne[1)] Events



car takes off
<u>on</u> the road

- ➔ Automatic selection from the database is not possible because convenient information about a car taking off on the road is not coded (information about street geometry missing e.g. hilltop)
- ➔ Because of scarce occurrence of e.g. high hilltops on German roads, it is assumed that airborne events <u>on</u> the street occur very rarely
- ➔ One rare example for an airborne event on the road could be found (see slide 16)

car takes off
<u>beside</u> the road

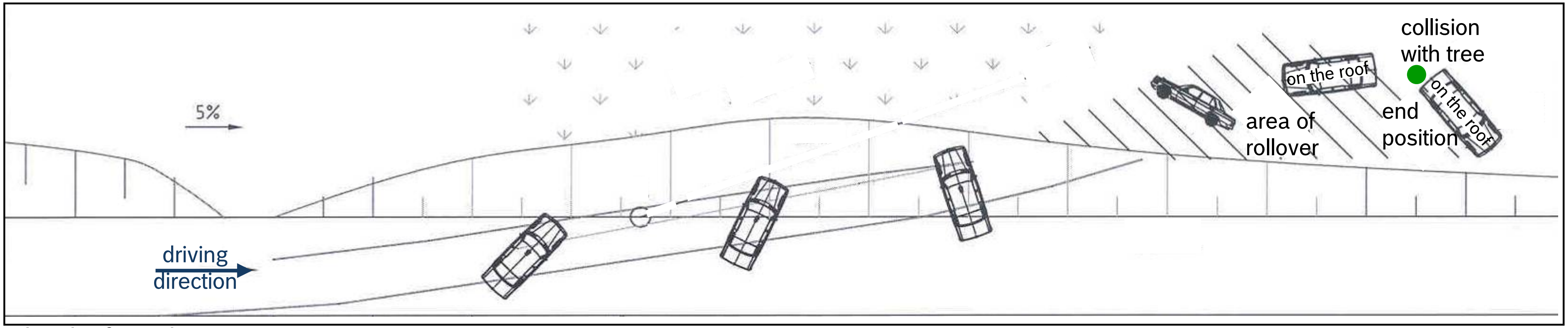
- ➔ Preliminary selection of relevant cars in the database is possible (see following slide)
- ➔ However, airborne is not directly coded
- ➔ single cases analysis necessary

1) An airborne situation is given if all wheels do not touch the subsoil at the same point in time

2) Source: GIDAS 2001-2008 *(weighted data for Germany)*

Example to Airborne[1)] Event on the Road: ***#1020333****

The relevant car crosses a hilltop, gets in the following out of control and leaves the road to the left-hand side. The car skids diagonally on the soft subsoil and rolls over the passenger side on the roof (cf. sketch). After the collision with the tree the car rotates into its end position. Only the collision with the tree causes a delta-v (36 kph) over airbag thresholds. The driver is not injured. We assume that taking off of the car is possible after the hilltop because the car gets out of control. But taking off cannot be proven with traces.



sketch of accident

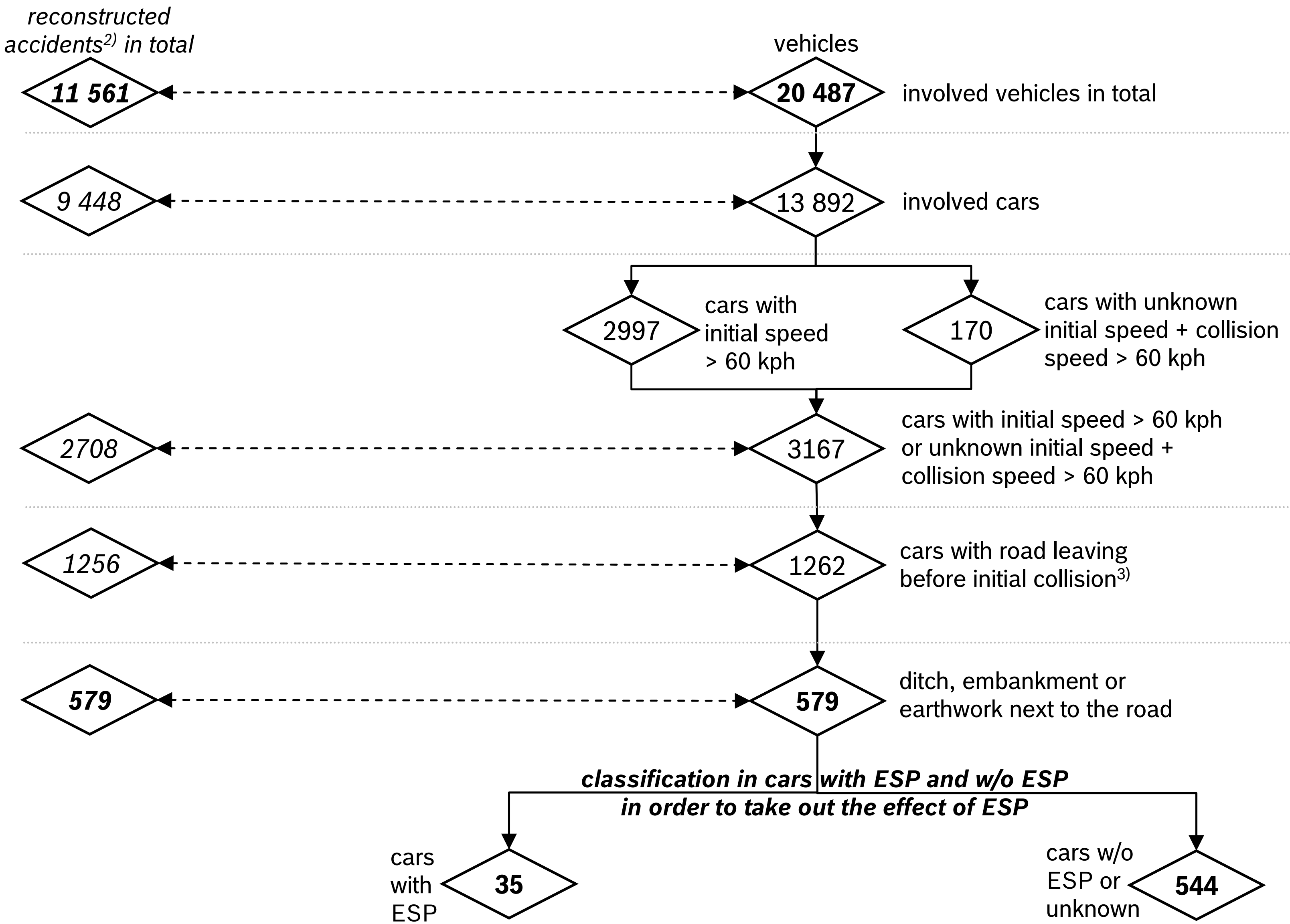

view of the car before hilltop


tire marks in view of the car


marks of rollover *(view opposite to driving direction)*

* GIDAS 2001-2008 *(weighted data for Germany)*
1) An airborne situation is given if all wheels do not touch the subsoil at the same point in time

Selection of Cars with Potential Airborne[1)] Scenarios



1) An airborne situation is given if all wheels do not touch the subsoil at the same point in time
2) Source: GIDAS 2001-2008 *(weighted data for Germany)*
3) impact w/ change in speed w/ more ~3 kph or impact causing change in moving direction or damages (small collisions are not determined)

Random Sampling for Single Case Analysis

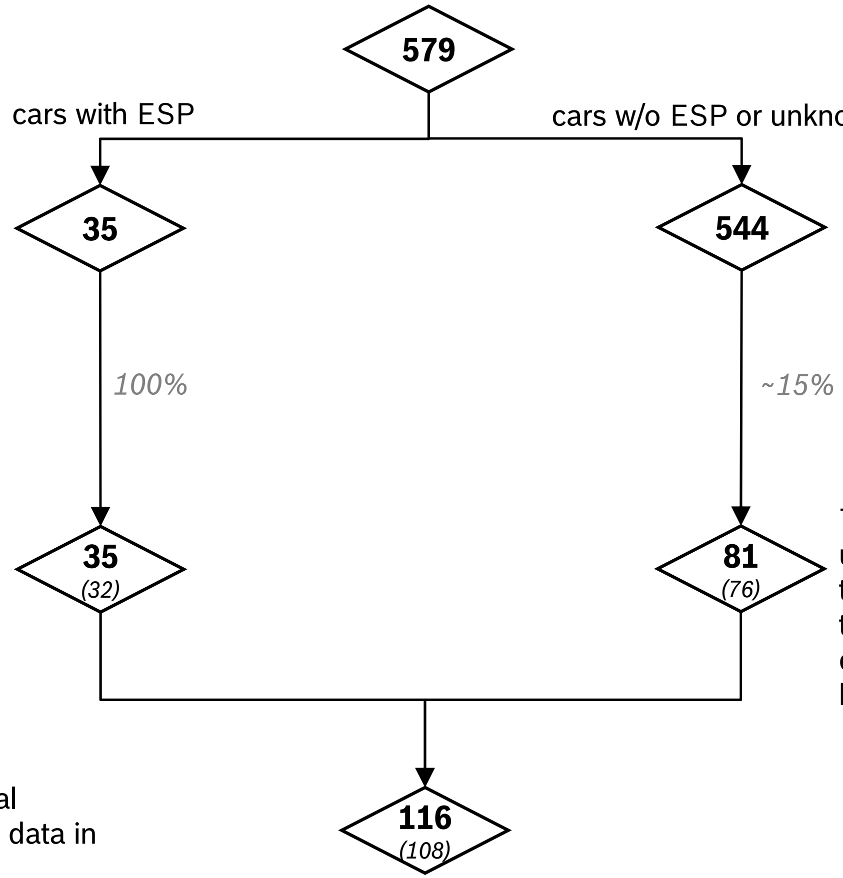
cars[1)] with possible airborne[2)] scenarios

classification in cars with ESP and w/o ESP in order to take out the effect of ESP

share of cars analyzed in detail

cars used for single case analysis (weighted data in bold type; unweighted data in brackets and in italics)

cars used for single case analysis in total (weighted data in bold type; unweighted data in brackets and in italics)

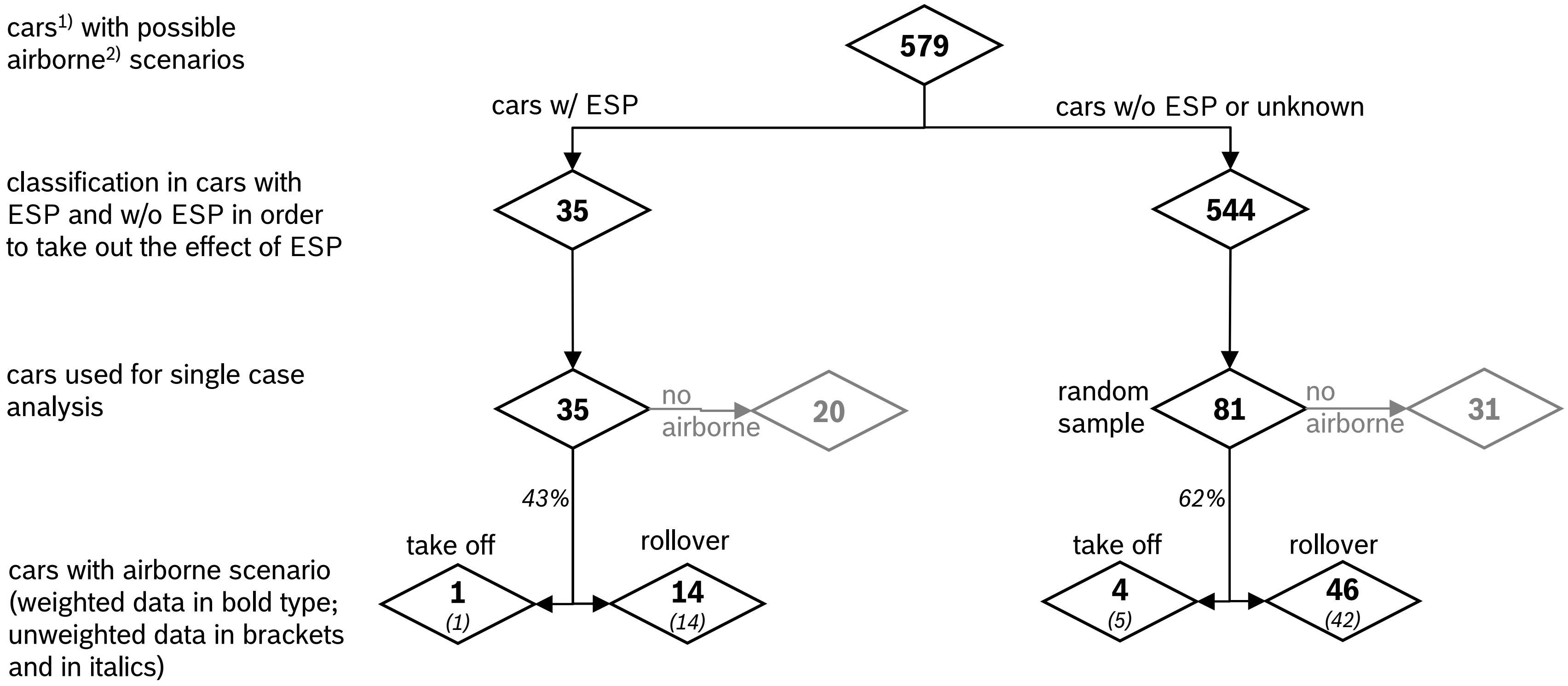


These 81 cars are selected in a random way under the condition that the distribution of the injury severity in the sample is equal to the distribution in all 544 cars (weighted data in bold type; unweighted data in brackets and in italics)

➔ In single case analyses there are 20% of the cars with potential airborne scenarios investigated in detail

1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008
2) An airborne situation is given if all wheels do not touch the subsoil

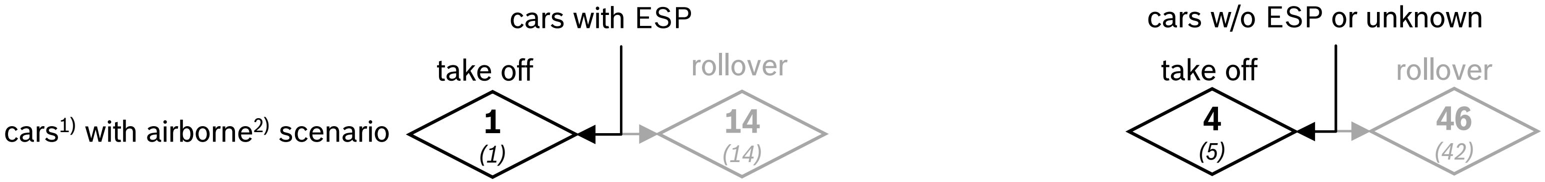
Single Case Analysis



- ➔ For the 5 weighted cars with “take off” the initiating situation, the “flight”, the landing and additional circumstances of the accidents are determined in detailed single case analyses
- ➔ To cars with “rollover” situations information about the rollover is provided, besides 4 accidents are exemplarily described in order to get an impression about these accidents
- ➔ For rollovers there were already other accident data analyses made (cp. ROSEI, II)

1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008
2) An airborne situation is given if all wheels do not touch the subsoil

Cars with Airborne Scenario “Take off”



	Crash-ID* w/ESP #30060594	w/o ESP or unknown #1040542	#1060065	#30040418	#30060045	#30060543
Reason for road leaving	Driver inattentive	Nonconformist speed	Nonconformist speed	Nonconformist speed	Skidding after slight road leaving	Skidding after slight road leaving
Angle while road leaving	~2°**	12°	4°	~10°**	~30°**	~20°**
Reason for airborne	Driving on increasing guard-rail (ramp effect)	Flying over ditch situated along the road	Driving on increasing guard-rail (ramp effect)	Flying over deep ditch	Crossing decreasing embankment	Crossing decreasing embankment
Roll angle*** before take off with all 4 wheels (rotation to the left: “+”, to the right: “-”)	small (about -5°)	small (about 5°)	medium (about 15°); ROSEI-relevant	small (about -5°); estimated at that time as car separates from tree	small-moderate (between about -5 and about -10°); ROSE II relevant	moderate (about 10°); ROSE II relevant
speed*** before take off	124 kph	105 kph	50 kph	46 kph	46 kph	75 kph
flying distance***	27m	3m	10 m	4m	2m	3m
flying time***	0.8s	0.1s	0.7s	0.3s	0.2s	0.1s
Comparison point of take off and point of touchdown (standard for comparison is point of take off)***	equal level (about 0m)	lower level (about -1m)	equal level (about 0m)	equal level: (about 0m)	lower level (about -1m)	lower level (about -1.75m)

* additional information to these accidents is collected on the following slides

** angle was not coded, value measured in sketch

*** estimated values, taken from sketch or pictures or calculated with reconstructed values

1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008

2) An airborne situation is given if all wheels do not touch the subsoil

2. Cars with Airborne Situations

continued from slide before:

	Crash-ID* **w/ESP** #30060594	**w/o ESP or unknown** #1040542	#1060065	#30040418	#30060045	#30060543
Max. injuries (AIS, type)	AIS 2, spine	AIS 5, head	AIS 1, spine, upper & lower extremities	AIS 1, spine, upper & lower extremities	AIS 1, head, thorax	AIS 1, head, face, spine
Causation of injuries	By sheet structure	Strong deformations of roof caused by skidding on it after rollover (after airborne)	By body movement & instrument panel in front crash w/ guardrail (before airborne)	By body movement, instrument panel, steering column and glass A-B in front crash w/ tree	By belt deflector, front door trim in crash with tree stump (after airborne)	By own action, body movement, head rest in crash with field while landing (after airborne)
Airbag availability, deployment	Front & side bags available, side deployed	Only front bags available, no deployment	No bags available	Only front bags available, deployed	Only front bags available, deployed	Only front bags available, no deployment
Time of deployment	In rollover (after airborne)	---------	---------	Probably in 1st crash w/ tree	Probably in crash w/ stump	---------
Assessment concerning benefit of systems for airborne situations	Benefit possible because airborne initial event but inconvenient for statements about injuries because person w/ max. injury severity not belted	Airborne initial event but → no benefit expected because injuries caused by deformations in rollover	Airborne after collision causing max. injuries → no benefit of systems for airborne situations expected	Airborne after collision causing max. injuries and probably after airbag deployment → no benefit expected	Airborne initial event → benefit of systems possible because injuries caused in collision after airborne	Airborne initial event → benefit of system possible because injuries caused in touchdown with field
Influence of add. equipment w/ ESP	--- (already equipped w/ESP)	Change in course of accident expected	No change expected	No change expected	Change in course of accident expected	Change in course of accident expected

* additional information to these accidents is collected on the following slides

BOSCH

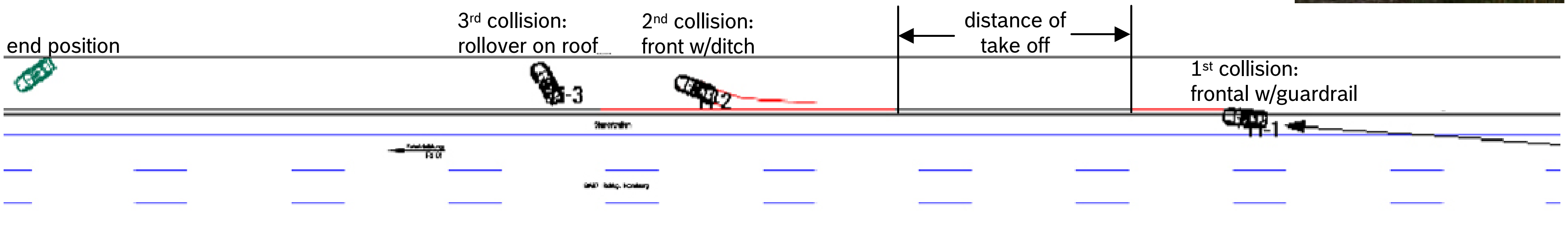
Example for Cars[1)] *with ESP* and Airborne[2)] Scenario “Take off”

#30060594

The driver of a VW Phaeton is inattentive and the car gets off the road. At the edge of the road there is a guardrail. The car crashes with the lower part of the front into the guardrail with a speed of about 135kph, moves along the increasing rail and takes off. The VW is isolated from road surface for about 25m. Then the car lands on the guardrail, crashes frontal into the ditch adjacent to the hard shoulder and starts overturning.

In the car there are 4 occupants. Only one person is injured. This occupant is not belted! The maximal occurring injury severity of MAIS 2 is caused by the front collision with the ditch after landing.

Front-, upper and lower side-bags are available in the car. The curtain-bags on the right-hand side of the car are deployed.



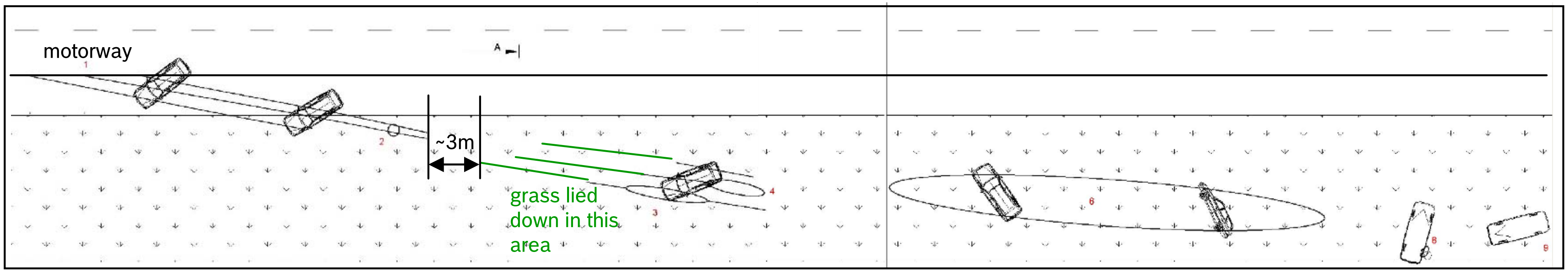
1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008
2) An airborne situation is given if all wheels do not touch the subsoil

Examples to Cars[1)] ***w/o ESP or unknown*** & Airborne[2)] Scenario "Take off"

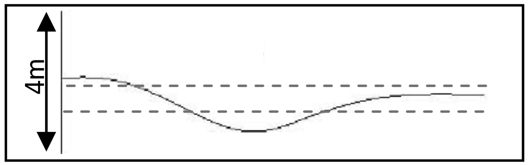
#1040542

A Citroen Xantia (1995 model) gets off the road to the right-hand side with a speed of ~110 kph. While road leaving the car skids with driver side ahead. The car crosses a ditch. In the decreasing part of the ditch there are no tracks of the car. But in the increasing part there can be throw ups of the subsoil found caused by the left front and back wheel. Subsequently the car rolls over, crashes into a tree and stops lying on the roof. There is one occupant in the car who is fatally injured with MAIS 5. The fatal injuries are mainly caused by the movement of the car on the roof which leads to strong deformations.
In the car there are only front bags available which are not deployed.
Besides it is expected that the oversteering of the car at the beginning of the accident will be almost completely avoided by ESP. Hence the equipment of the vehicle with ESP will change the course of the accident.

sketch:



profile of ditch:



1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008
2) An airborne situation is given if all wheels do not touch the subsoil

2. Cars with Airborne Situations

continued from slide before:

accident scene

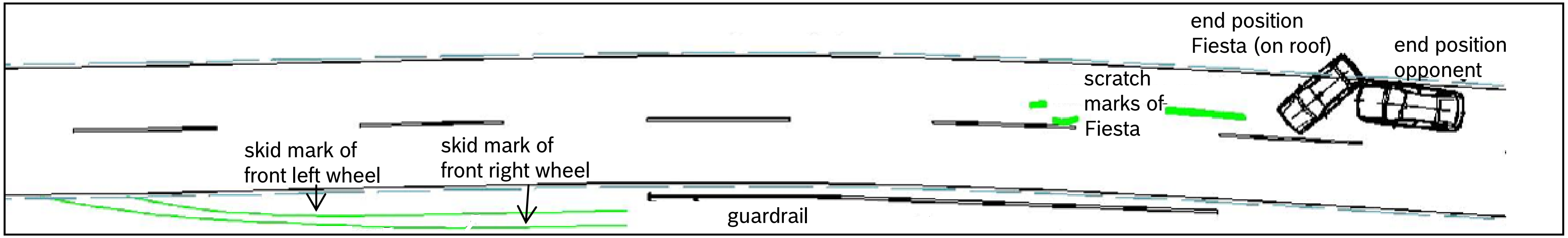
damaged car

BOSCH

#1060065*

A Ford Fiesta (1993 model) gets off the road to the right-hand side with a speed of ~70 kph because of nonconformist speed. The car skids while road leaving and crashes frontal with the guardrail. The increasing construction has an effect on the car like a ramp and the car takes off. While being above subsoil the car makes a quarter to a half rotation around the longitudinal axis in the direction of the driver side. The car lands on the roof on the oncoming lane. An approaching vehicle does not manage to stop in front of the car, hence there is still one more collision.
In the car there is 1 occupant who suffers severe injuries with unknown MAIS. The maximal occurring injury severity is caused in the first collision (front crash with guardrail). But it is not known if belts are used.
In the car there are not any airbags available.
It is expected that the equipment of the car w/ESP will not change the course of the accident noticeably.

sketch:



accident scene:

damaged car:

*source: GIDAS 2001-2008

#30040418*

A Smart (2002 model) gets off the road to the right-hand side with a speed of ~65 kph and crashes frontal into a tree with a speed of 56 kph. The car takes off because of the collision (tree has an effect on the smart like a base). The car rotates around the vertical axis for more than 360° and lands into a deep ditch standing diagonally on the passenger side.

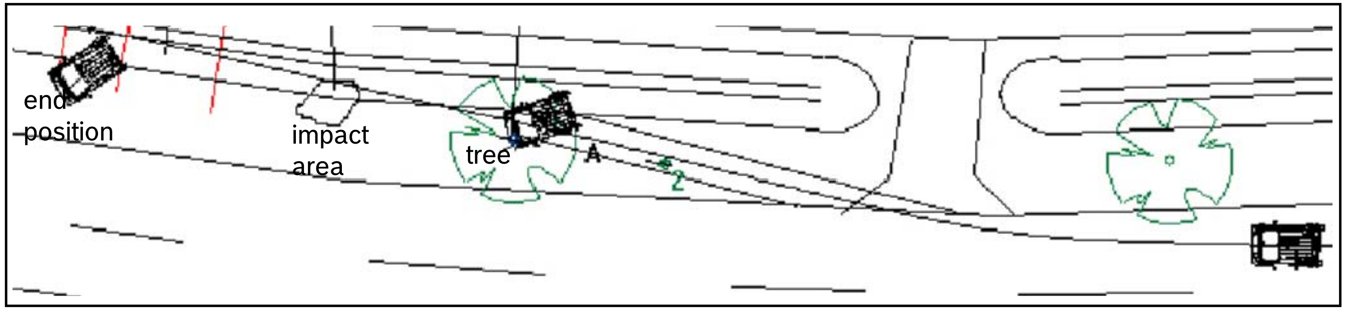
In the car there is 1 occupant who suffers slight injuries with MAIS 1. The injury severity is mainly caused by initial collision with the tree (front crash with delta-V of 14 kph). In the car there are only front airbags available and they are deployed.

A Smart of this model year is equipped with a pared-down version of ESP (*Trust-Plus*). There is no change in the course of accident by the equipment of the car with a current version of ESP expected.

accident scene:

damaged car:

sketch:



* source GIDAS 2001-2008

#30060045*

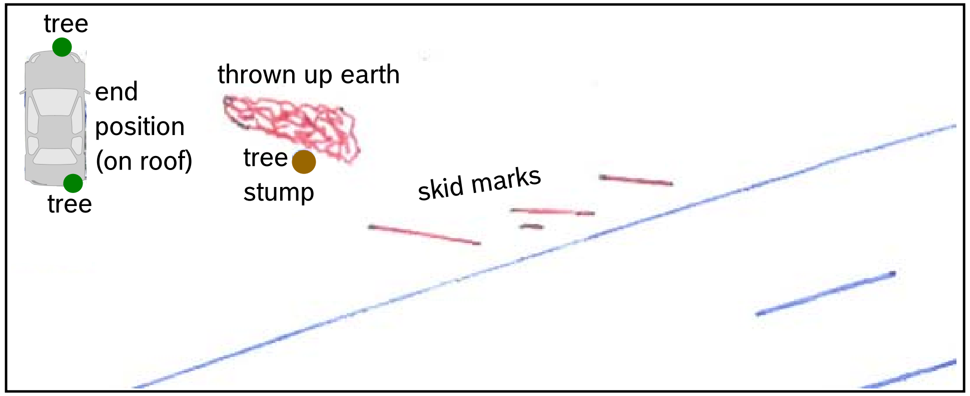
A Nissan Micra (1999 model) starts skidding after colliding slightly with the guardrail on the left-hand side. The car leaves the road to the right-hand side with a speed of 56 kph. Along the road there is a decreasing embankment. The car leaves the surface while crossing the ditch. The moving direction of the Nissan Micra after road leaving is diagonal with the driver side ahead. After take off the car get caught on a tree stump and the left front wheel is ripped off. Subsequently the car rolls over the longitudinal axis (180°) via the driver side and crashes with the rear into a tree.

In the car there is 1 occupant who suffer slight injuries with MAIS 1. The injury severity is mainly caused by colliding with tree stump after the airborne (driver side crash with delta-V of 15 kph).

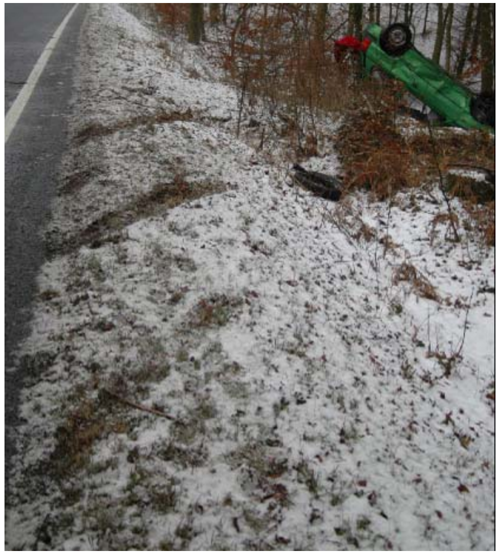
In the car there are only front airbags available and they are deployed.

It is expected that the oversteering of the car at the beginning of the accident will be almost completely avoided by ESP. Hence the equipment of the vehicle with ESP will change the course of the accident.

sketch:



accident scene:



damaged car:

* source GIDAS 2001-2008

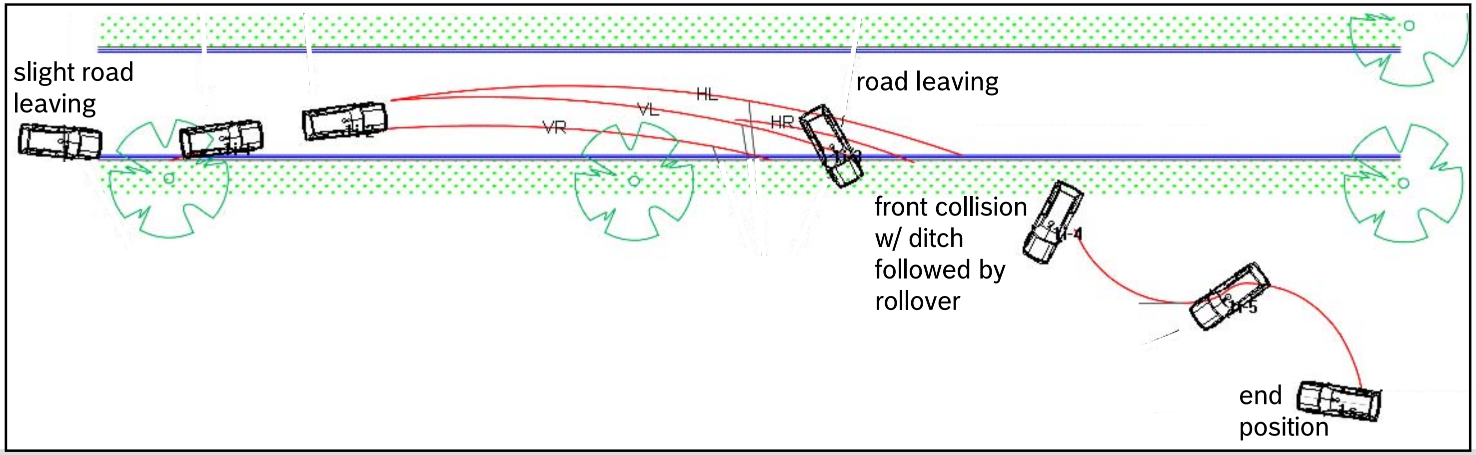
#30060543*

A VW Passat (model unknown) starts skidding after slight road leaving. Subsequently the car skids to the right-hand side, gets off the road. The car crosses the decreasing embankment without touching the subsoil. Subsequently the VW crashes frontal into the field with a speed of ~75kph. The car rolls over via the driver side and stops standing on the wheels.
In the car there are 2 occupants. The driver suffers the maximal occurring injury severities with MAIS 1. The injury severity is mainly caused by landing in the ditch after taking off (front crash with delta-V of 15 kph).
In the car there are front airbags available but they are not deployed.
It is expected that the equipment of the vehicle with ESP will change the course of the accident because the oversteering of the car at the beginning of the accident will be almost completely avoided by the system.

accident scene:

damaged car:

sketch:

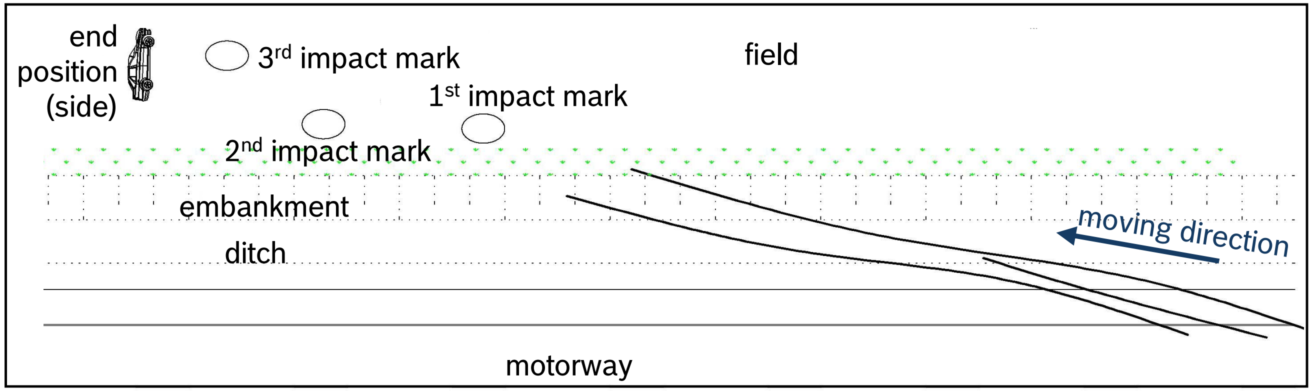


* source GIDAS 2001-2008

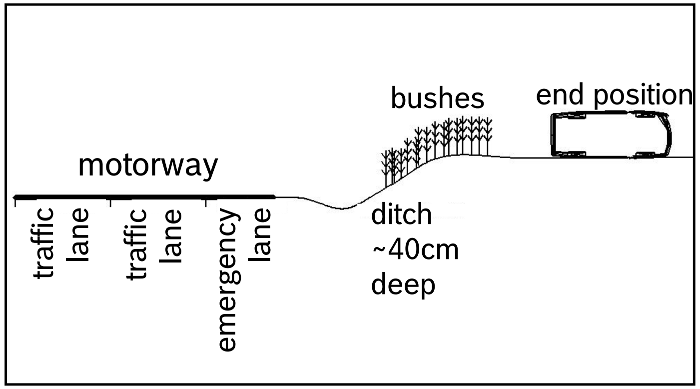
Example[1] to Airborne[2] Event Take Off: ***#1050563****

BACKUP

The relevant car w/o ESP leaves the motorway to the right-hand side and crosses a rising embankment. After the embankment the car loses holding and takes off (cf. sketch distance between end of trace marking and 1st impact mark). The car has several rollovers after landing on the soft subsoil and stops on the passenger side.
The car occupant does not wear seat belts and falls out of the car during the course of accident. The driver is injured with MAIS 2.



sketch of accident



transverse profile of accident

road leaving

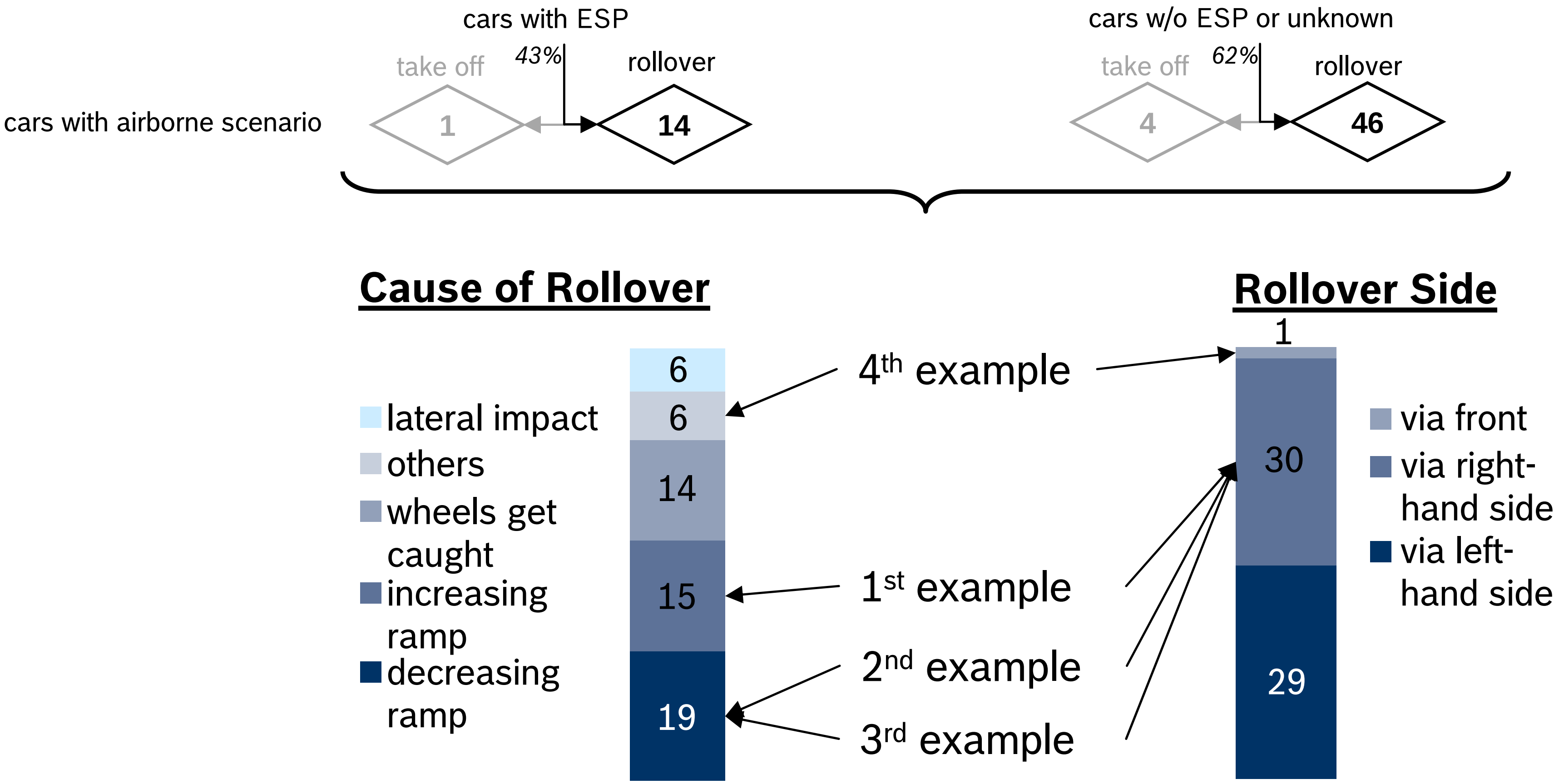
end position

1) This is an additional example which is not selected in the random sample. Hence it can be only taken as an additional information.
2) An airborne situation is given if all wheels do not touch the subsoil

* source: GIDAS 2001-2008

BOSCH

Cars[1)] with Airborne[2)] Scenario "Rollover"



➔ These 4 examples for cars with a rollover during the course of accident are described on the next slides

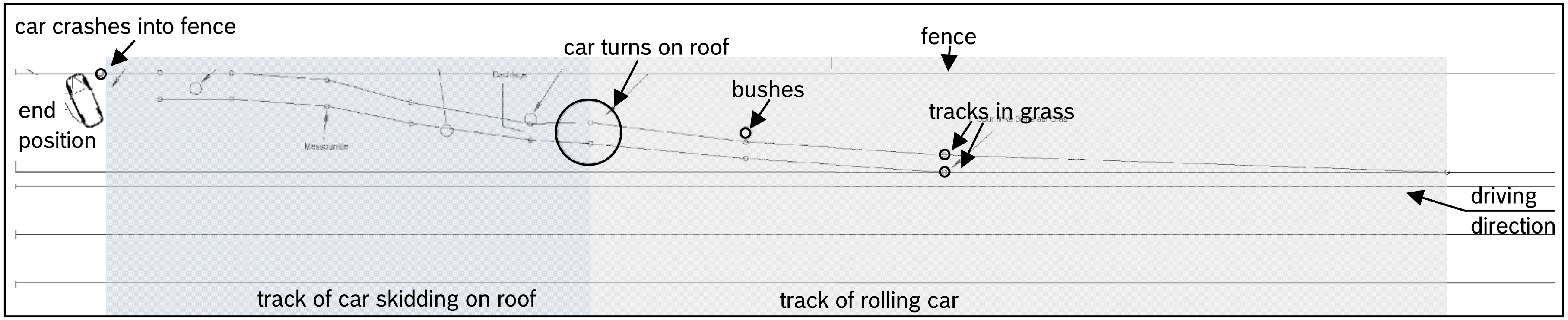
1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008
2) An airborne situation is given if all wheels do not touch the subsoil

Examples for Cars[1)] with Scenario “Rollover”

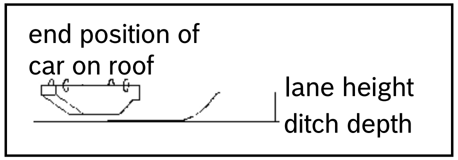
#1050056 – *car is equipped w/ESP*

A Opel Vectra (2003 model) gets off the road. Off the road the car moves with a sideslip angle, crashes into bushes, gets caught by the subsoil, starts overturning and crashes into a wire fence while skidding on the roof. In the car there are 3 occupants. All persons are injured, out of them one is severely injured with MAIS 4. It is not known which crash causes the maximal injury severity. Front-, upper and lower side-bags are available in the car and deployed. It is assumed that the side-bags deployed in the rollover. The deployment of the front bags cannot be assigned exactly to one collision. The car has two front collisions: the initial collision with bushes (delta-V: 11kph) and the last collision with the fence (delta-V: 13 kph).

sketch



profile of ditch



accident scene

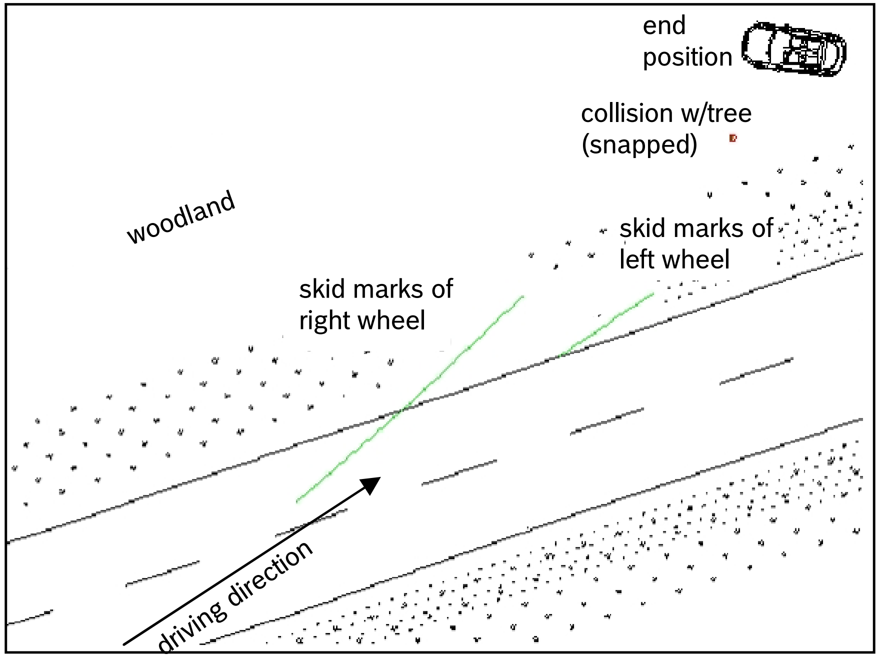
car in end position

1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008

#1050194* – *car is not equipped w/ESP*

A Ford Puma (2001 model) gets off the road to the left-hand side with a speed of ~50 kph because of nonconformist speed. Off the road the car skids with the passenger-side first down a decreasing embankment and crashes with passenger-side into a tree (between B- and C-pillar) while rolling over. The tree bursts and subsequently the car carries on rolling over the longitudinal axis (turn around passenger side) and comes into its end position lying on the roof.
In the car there are 2 occupants who both suffer slight injuries (driver: MAIS 2, passenger: MAIS1). The maximal occurring injury severity is caused while rolling over.
In the car there are only front airbags available which are not deployed.
Besides it is expected that the oversteering of the car at the beginning of the accident will be almost completely avoided by ESP. Hence the equipment of the vehicle with ESP will change the course of the accident.

sketch:



accident scene

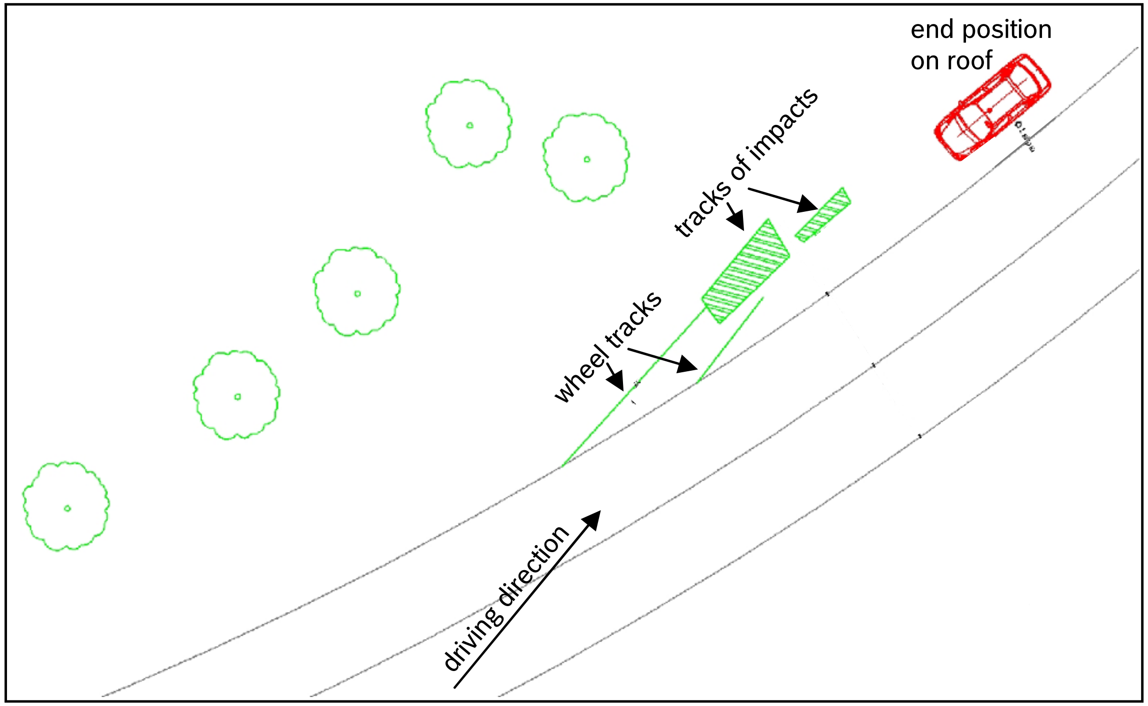
damaged car

* source GIDAS 2001-2008

#1070074* – *car is equipped w/ESP*

A Citroen C5 (2002 model) gets off the road to the left-hand side. Off the road the car climbs up an increasing embankment. Subsequently the car rolls over its right vehicle side (speed of about 25kph) onto the roof. The cars moves on the roof into its end position in the ditch.
In the car there is 1 occupant who is slightly injured with MAIS 1. The injury severity is caused while rolling over.
The information about the availability of airbags misses in the database, but it is assumed that all bags are available. None of the bags is deployed.

sketch



car in end position

* source GIDAS 2001-2008

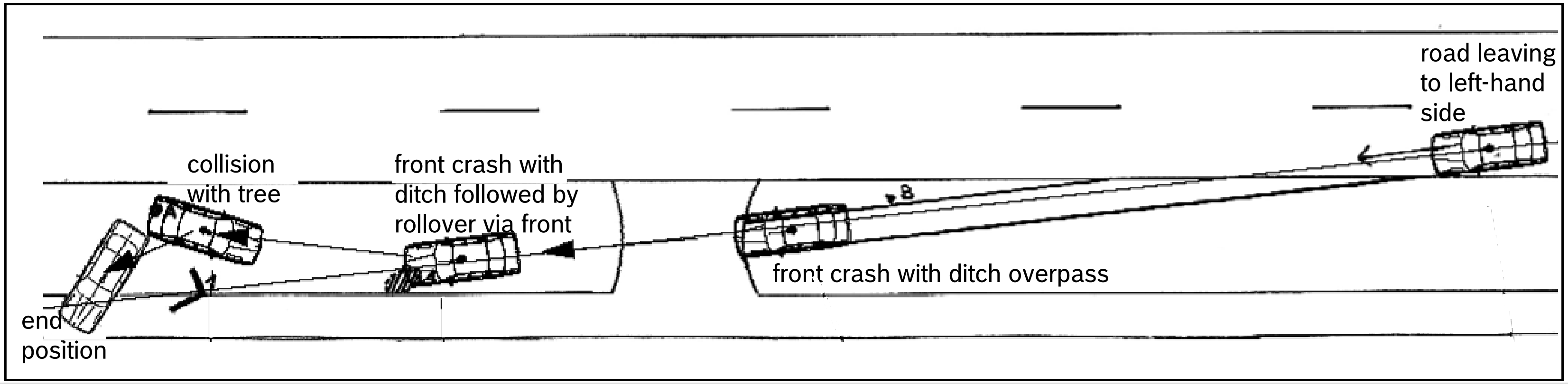
#30040412* – car is <u>not</u> equipped w/ESP

A BMW 530 (1998 model) gets off the road to the left-hand side because of nonconformist speed. The car crashes frontal with a speed of 120 kph into a ditch overpass and rolls over. The car turns via front around the longitudinal (360°), transversal (180°) and vertical axis (50°) and lands with the wheels. Subsequently the BMW crashes with its rear into a tree (speed before crash: 78 kph). In the car there is 1 occupant who suffers slight injuries with MAIS 1. The injury severity is mainly caused in the first collision (front crash with ditch overpass). In the car there are not any airbags available.
The car does not oversteer before road leaving. Hence it is expected that the equipment of the car w/ESP will not change the course of the accident noticeably.

accident scene:

damaged car:

sketch:

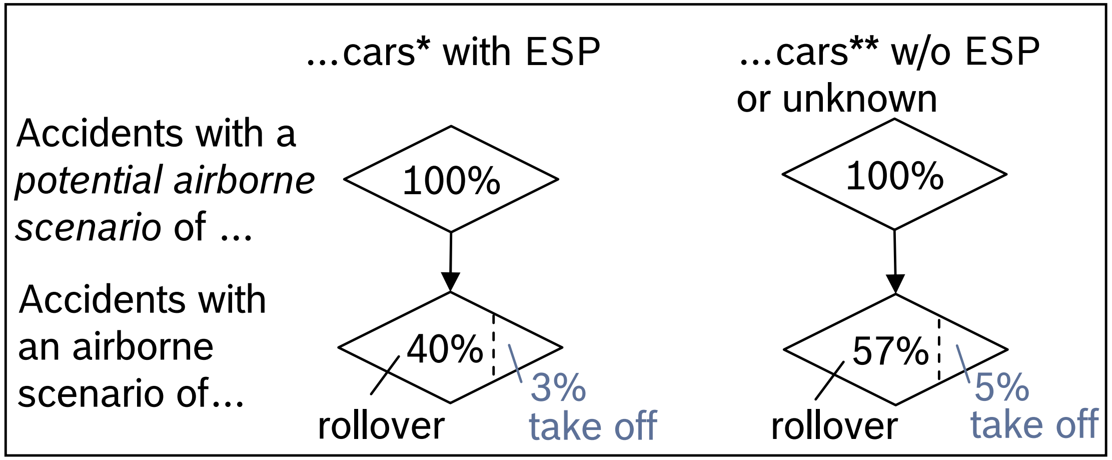


* source GIDAS 2001-2008

Summary

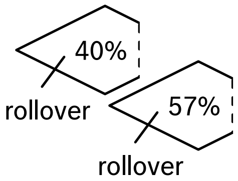
➔ A car[1] with a ***potential airborne[2] scenario*** is involved **in about 5%** of all accidents with injuries

➔ In 6% of these accidents the car with the potential airborne scenario is equipped with ESP, in the remaining 94% the car is either not equipped with ESP or the equipment is unknown



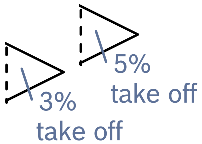
* absolute number: 35 cars   ** absolute number: 544 cars, but for analysis about airborne situations there are 81 cars used which are selected by chance

➔ The share of accidents with an airborne situations on accidents with potential airborne situations is lower for cars w/ESP (43%) than for cars w/o ESP or unknown (62%) equipment



➔ More than **98%** of the cars (independent of ESP equipment) w/airborne situation "rollover" **roll over via** right-hand or left-hand **vehicle side**

➔ It is expected that occupants would be generally protected by a ROSE system



➔ The **flying times** of cars with "take off" are between **0.1s and 0.8s**

➔ The cars with airborne situation "take off" can be categorized as followed:

a) car crosses decreasing embankment w/o touching it (#1040542, #30060045, #30060543)

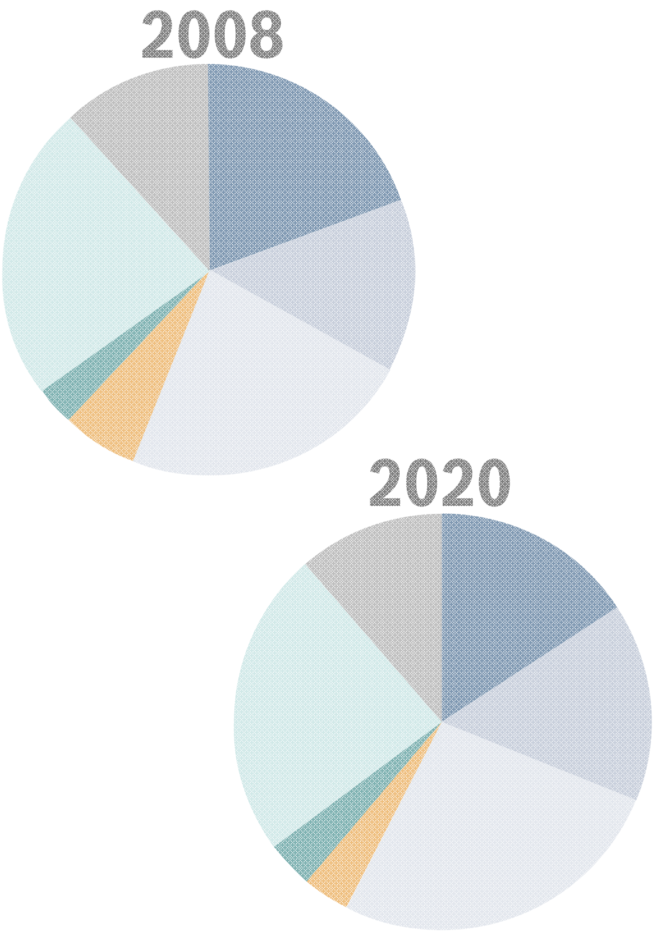
b) car crashes with guardrail which has an effect like a ramp (#30060594, #1060065)

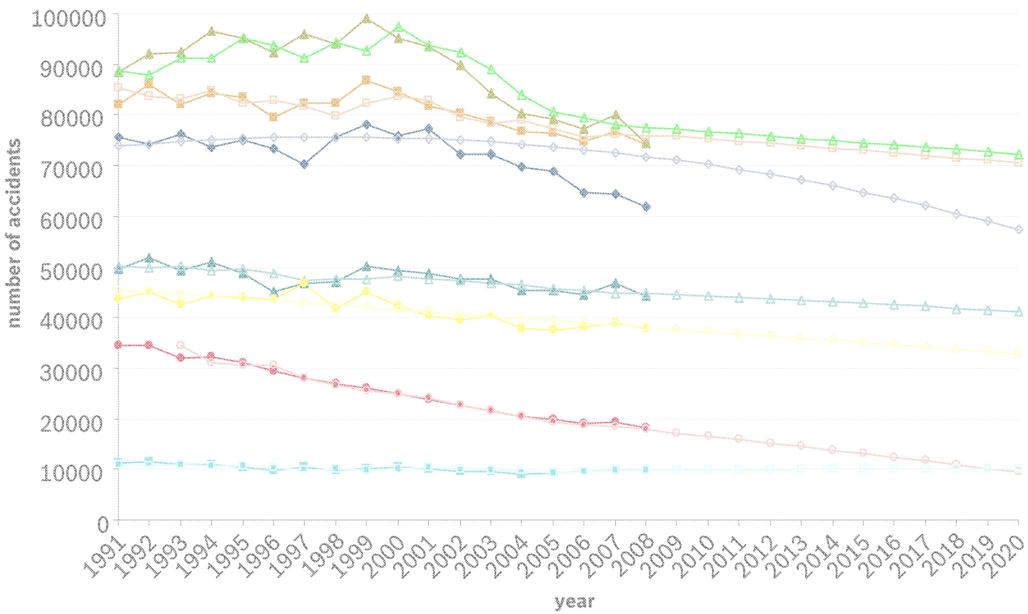
c) car crashes with tree which has an effect like a ramp (#30040418)

1) Cars involved in accidents with casualties, source: weighted data from GIDAS 2001-2008

2) An airborne situation is given if all wheels do not touch the subsoil

Forecast of Trends in Accidents with Injuries in Germany





Results of Accident Analysis

Accident Research CR/AEV1

BOSCH

Contents

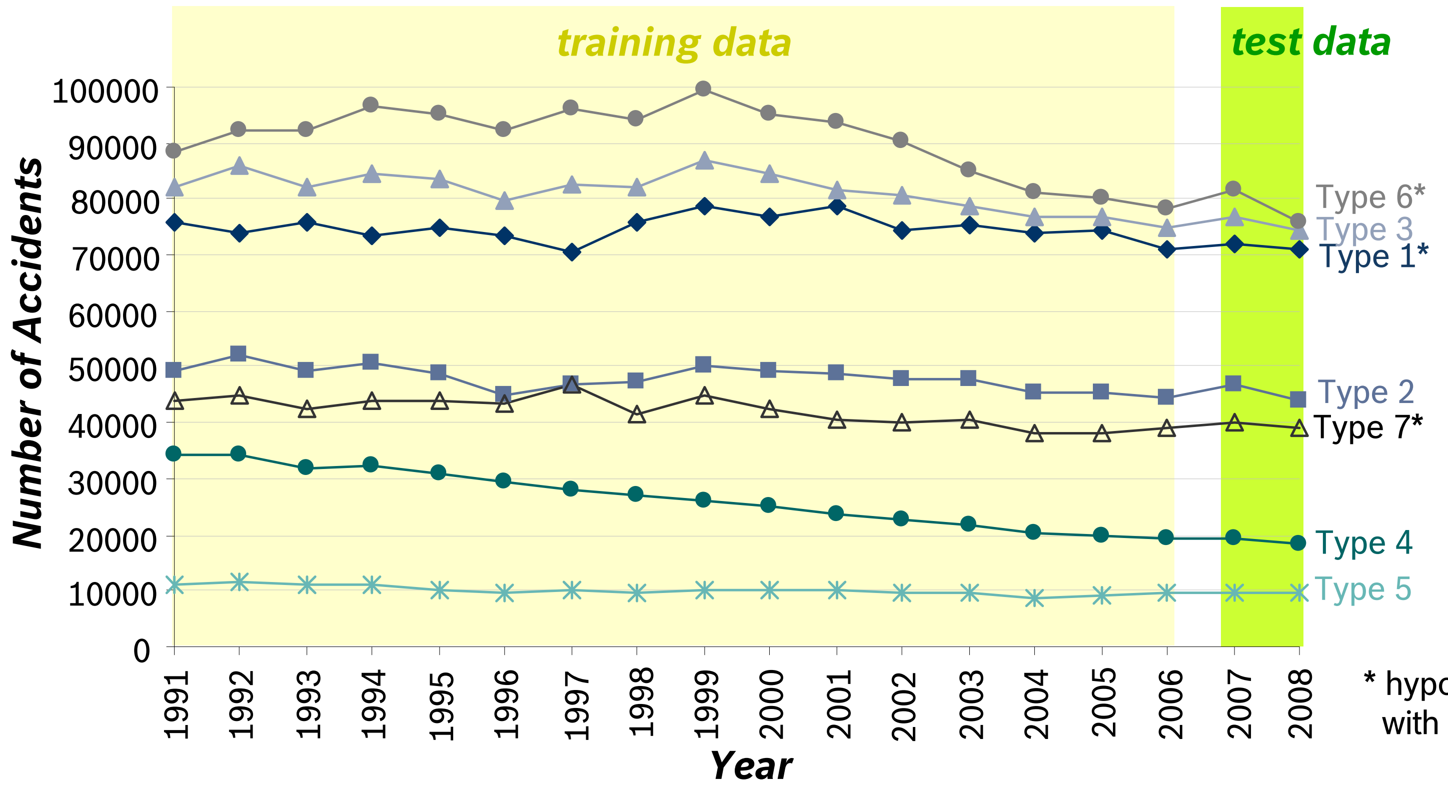
1. Used Methodology of Forecast Generation

Overview

Past + present	*Accidents with injuries in Germany subdivided in types (1991-2008)*	**Data**
Univariate analyses *(separate for each accident type)*	**Time series analyses** (trends from the past are considered, analyzed and transferred into the future)	**Step I**
	Integration of effects caused by **safety systems** on the evolution of accidents	**Step II**
	Weakening of the determined **trend** until 2020	**Step III**
Future	*Estimated number of accidents with injuries in Germany subdivided in types (2020)*	**Forecast**

Used Data

- accidents[1)] with injuries in Germany subdivided in types (1991-2008)
- division in training (1991-2006) and test data (2007/2008)
- hypothetic number of accidents of type 1, 6 and 7 in order to remove the effect of ESC on accidents in the past and present[2)]



* hypothetic accident data
with removed effect of ESC

1) source: special analysis by the Federal Statistical office
2) procedure for removing the effect of ESC in accident data is described on BACKUP slides

Time Series Analysis *(Step I)*

- univariate analysis (each time series are considered exclusively)
- Method: Box-Jenkins (SAS-procedure "arima")
- Method for model parameter estimation: "conditional least square"

Basic Information to and Limit of Time Series Analysis

- trends from the past are considered, reproduced with the models and transferred in the future
  - ➔ forecast is based on past/present trends and events only
  - ➔ expected events or changes of trends in the future cannot be considered in the classical time series analysis

Some Theory

- model equations for forecasts based on time series analysis consist of:
  1. reproducing the trend in time series with differencing or with a (linear, quadratic, exponential, or ...) regression model (trend component)
  2. reproducing the structure of the stochastic process in the residual (trend component - real time series data) with an autoregressive, moving average or a mixed process
- *for more detailed information, please see documentation about forecast generation*

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Schematic Description of the Methodology

1. Creation of different models considering trend in the time series with different assumptions for stochastic processes for the training data

model I
- assumed process A (*i.e. AR(1)*)
- assumed process B (*i.e. MA(1)*)
- …

model II
- assumed process A (*i.e. AR(1)*)
- assumed process B (*i.e. MA(1)*)
- …

model III
- assumed process A (*i.e. AR(1)*)
- assumed process B (*i.e. MA(1)*)
- …

…

2. Based on SBC-Statistics for each model the process with best fit is selected

model I
- assumed process B (*i.e. MA(1)*)

model II
- assumed process C (*i.e. MA(2)*)

model III
- assumed process B (*i.e. MA(1)*)

…

3. By comparing forecasted values (based on model equations) with real numbers in the test data (2007/2008) model with the best forecast correctness is selected

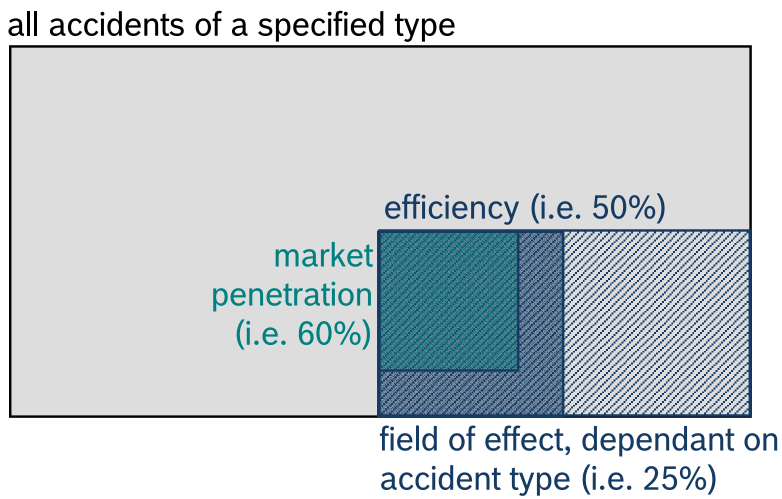
model III
- assumed process B (*i.e. MA(1)*)

Integration of Safety Systems *(Step II)*

- Integrated systems: ESC and EBA
- Reasons for separate integration:
  a) effect of system on reducing number of accidents should be quantified
  b) up to now EBA poorly penetrated in market → w/time series analysis not reproducible

Description of the Methodology

- **field of effect** is determined based on current accident data; information is provided depending on specified accident type *(system influence only on cars expected)*
- **efficiency** is taken from pre-studies; assumed to be equal for all accident types
- **market penetration** is estimated *(standard for comparison: all passenger cars in Germany);* assumed to be equal in all accident types



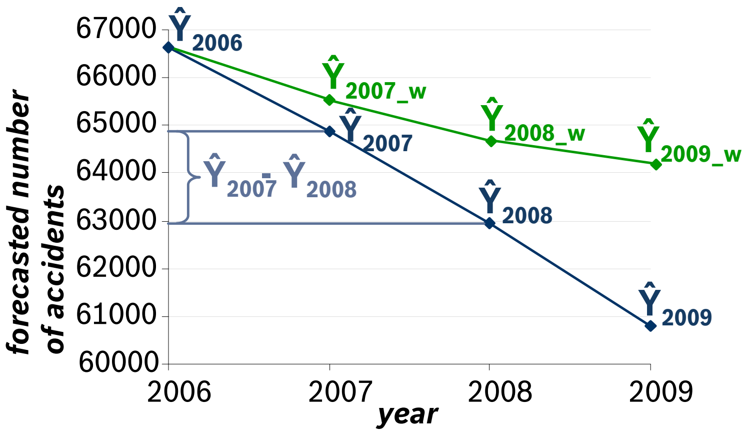
- **number of avoidable accidents** ($accav_{type\_x}$) by a system is calculated with equation *(i)*

(i) $$\boxed{accav_{type\_x} = acc_{type\_x} \cdot f_{type\_x} \cdot eff \cdot mp_z}$$

acc_{type_x} ...number of accidents of accident type x
f_{type_x} ... share of field of effect for accident type x
eff ... efficiency of the function
mp_z ... market penetration in year z

Weakening the Determined Trend *(Step III)*

- reason: effects of current events and measures are usually limited and effects will usually decrease in the future
- trend is interpreted/simplified as the change of the forecasted number of accidents between two years ➔change between two years must be weakened
- change is weakened dependant on the time space between last year used for model generation and the forecast year
- *for weakening (year=2007…2020)* use of: $\hat{Y}_{year\ w} = \hat{Y}_{year-1\ w} + (\hat{Y}_{year} - \hat{Y}_{year-1}) \bullet e^{b(2006-year)}$



Example: $\hat{Y}_{2008\_w} = \hat{Y}_{2007\_w} + (\hat{Y}_{2008} - \hat{Y}_{2007}) \bullet e^{b(2006-2008)}$

- with the specification of *b* the expected reliability of the trend can be adjusted

Believe in trend to …	b=0.01	b=0.05	b=0.1
In 1st forecast year *(2007)*	99%	95%	90%
In last forecast year *(2020)*	87%	50%	25%

Example *(b=0.05)*:

$\hat{Y}_{2008\_w} = \hat{Y}_{2007\_w} + (\hat{Y}_{2008} - \hat{Y}_{2007}) \bullet e^{-0,1}$

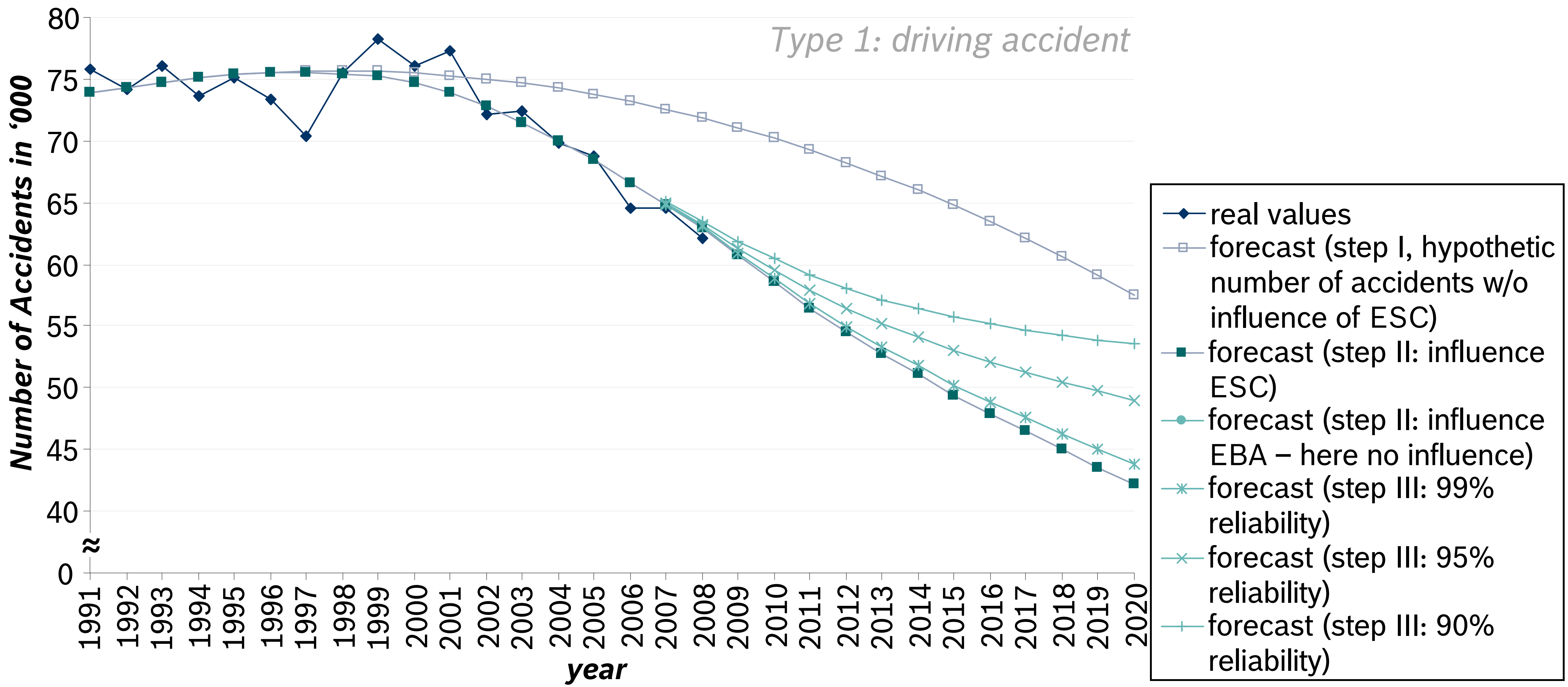
In the 2nd forecast year the determined trend is assumed to be correct to 90%.

Contents

2. Results

Progress in Accident Types (real values & forecast)

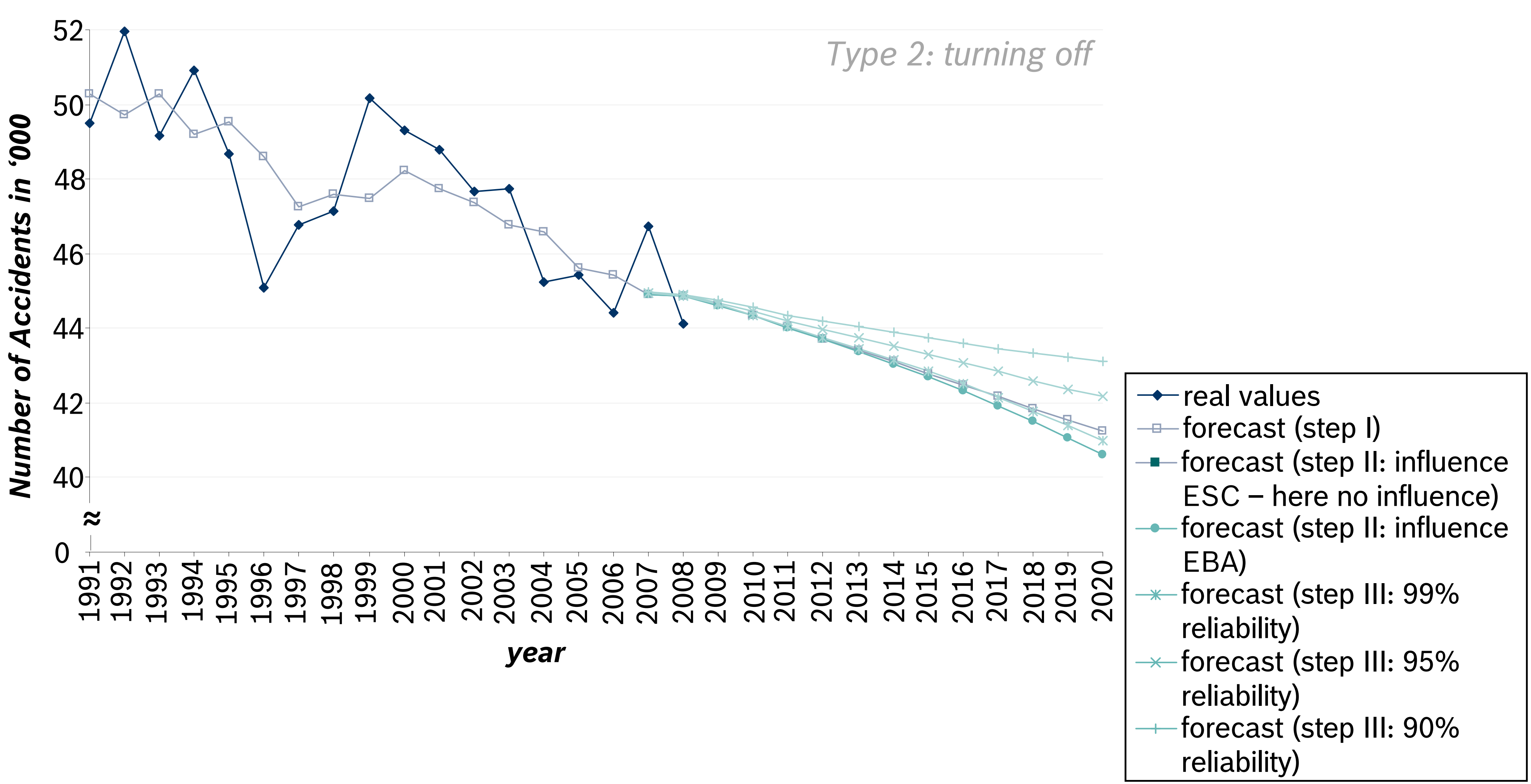
Accident Type 1*



*Quadratic regression model, for model equations and significance of model parameters, please see in documentation

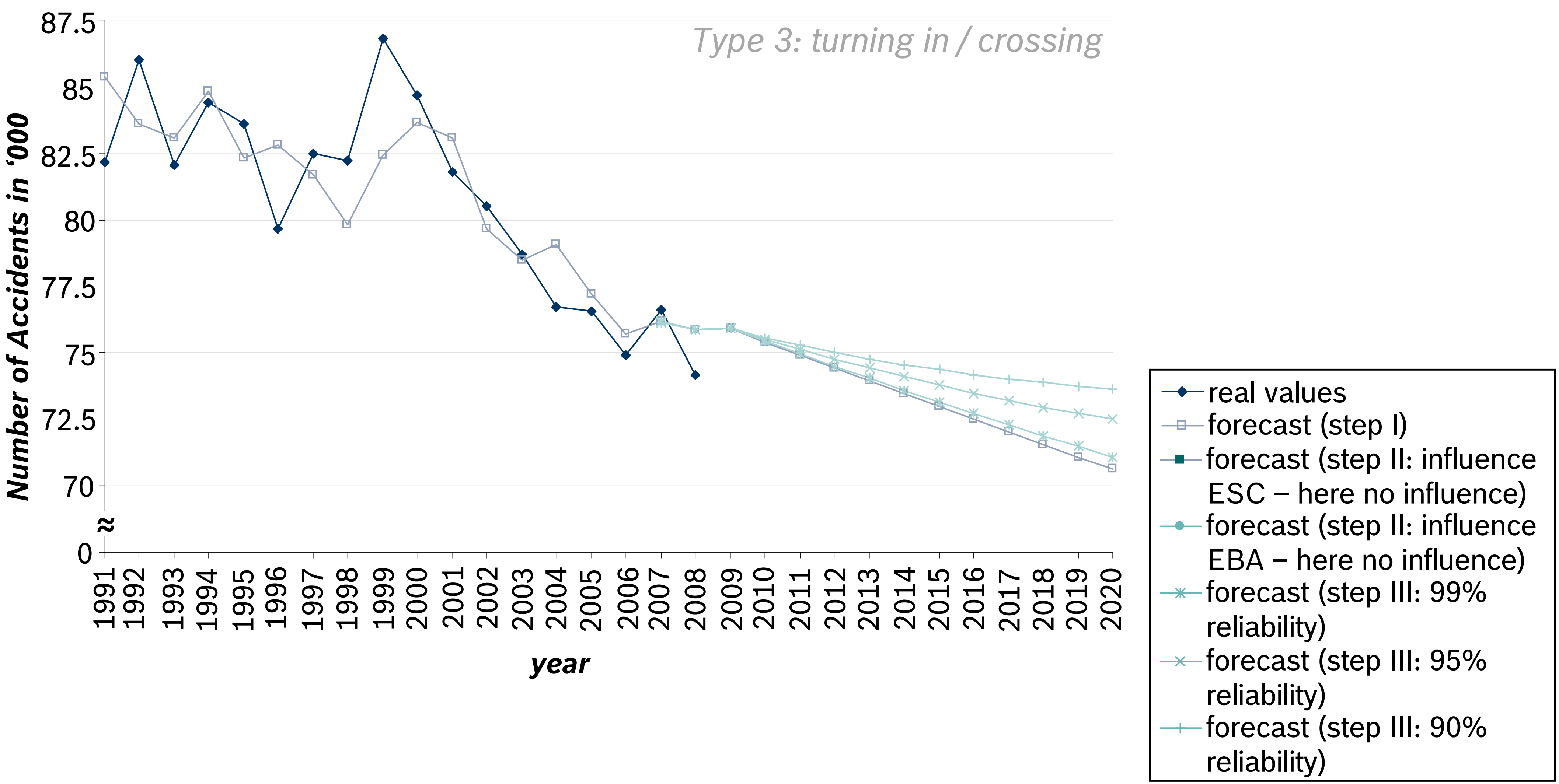
Forecast of Trends in Accidents w/Injuries in D

Accident Type 2*



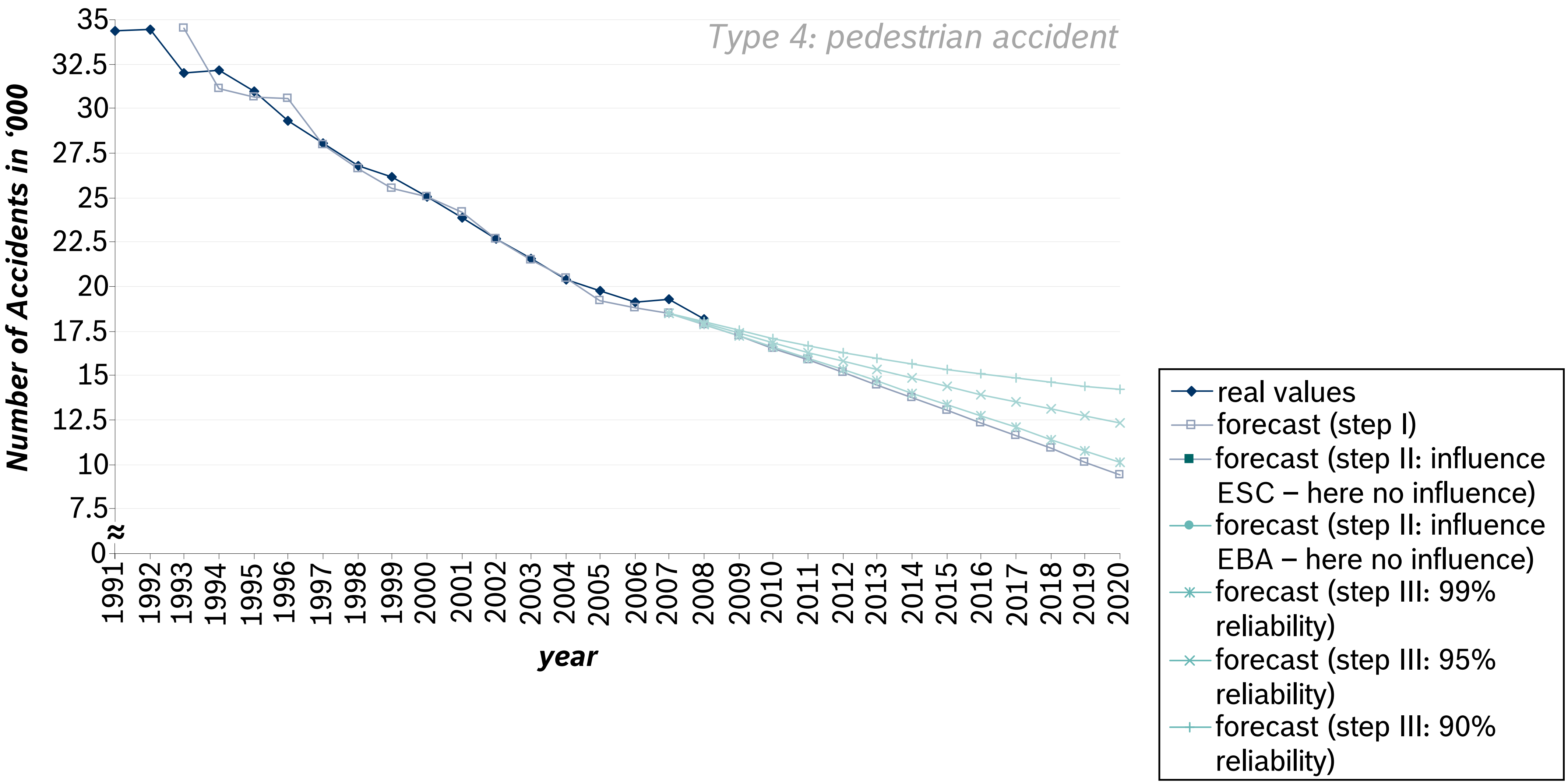
*Linear regression model with assumed AR(1)-process, for model equations and significance of model parameters, please see in documentation

Accident Type 3*



*Exponential regression model with assumed MA(2)-process, for model equations and significance of model parameters, please see in documentation

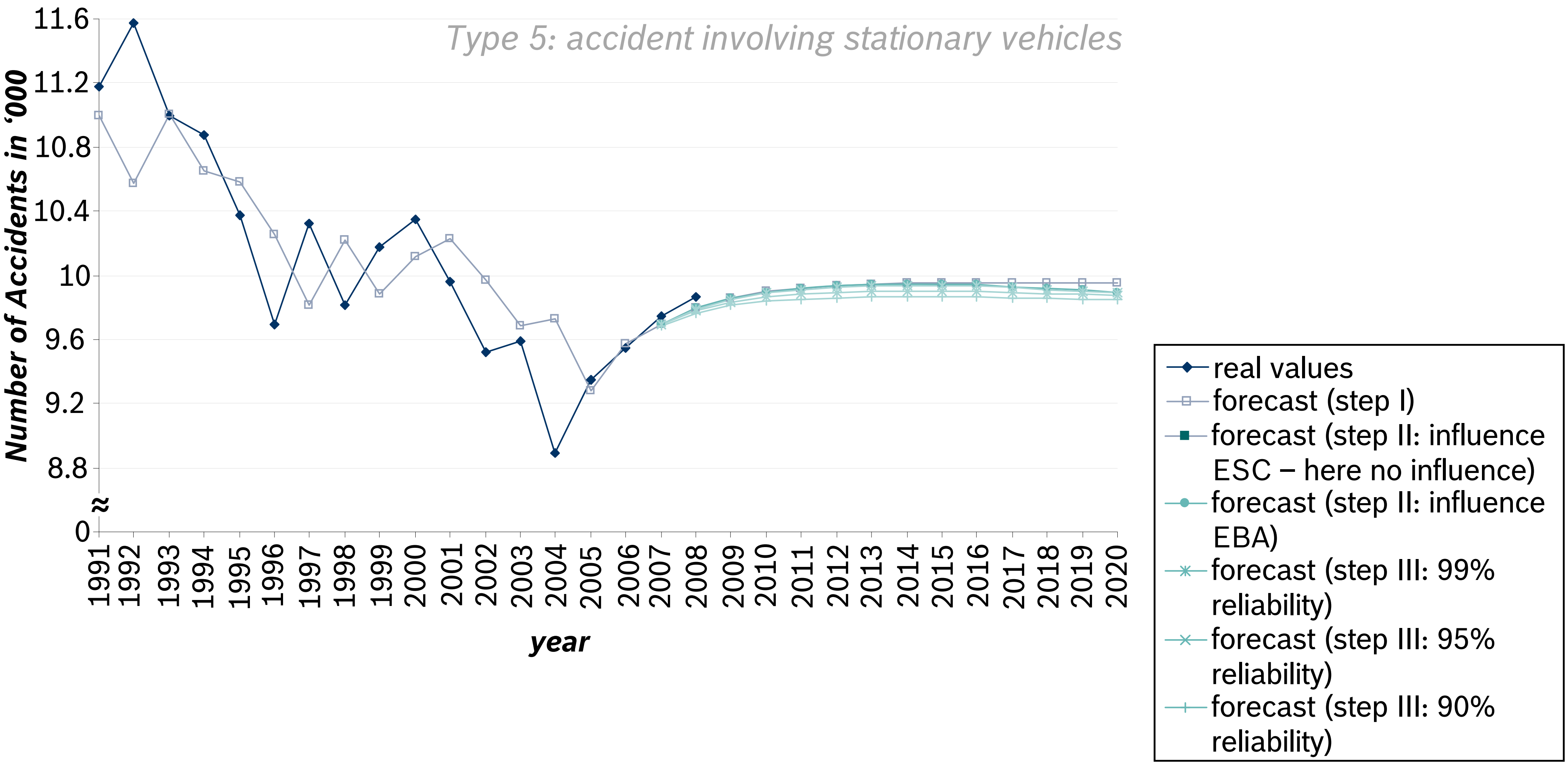
Accident Type 4*



*Model with 2nd differences and AR(1)-process, for model equations and significance of model parameters, please see in documentation

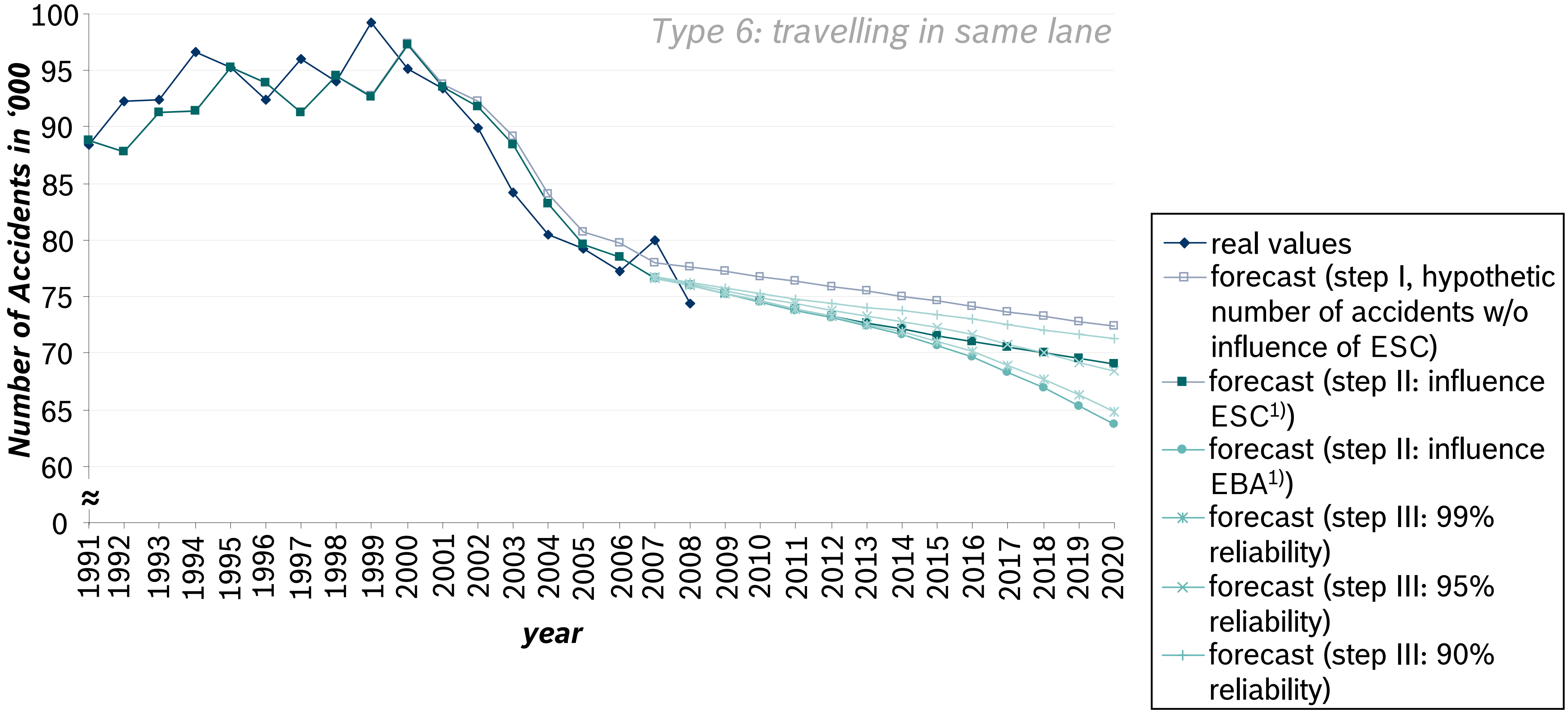
Forecast of Trends in Accidents w/Injuries in D

Accident Type 5*



*Hyperbolic regression model with assumed AR(1)-process, for model equations and significance of model parameters, please see in documentation

Accident Type 6*

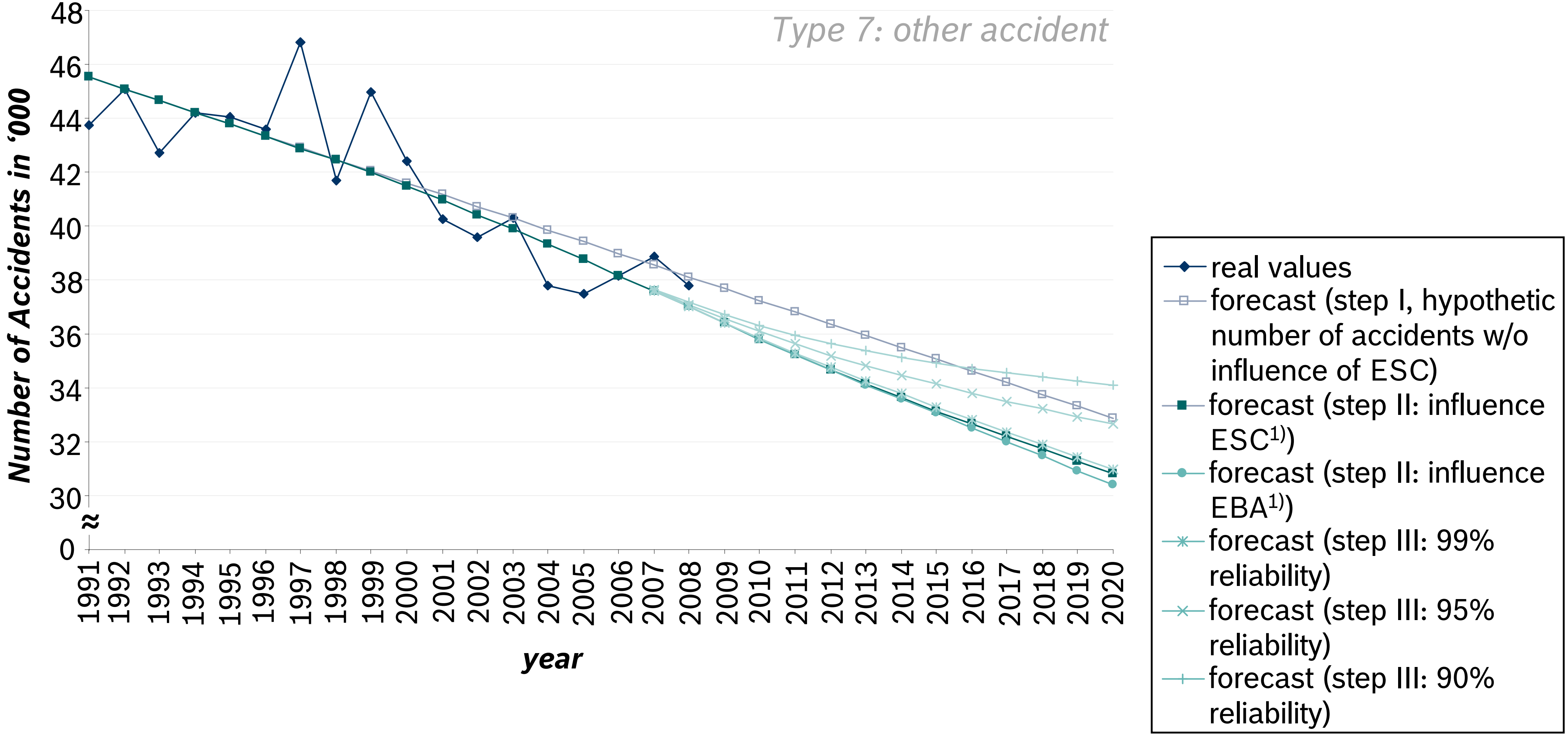


1) only small overlap in sphere of influence of ESC and EBA, this overlap is not considered in the model

*Exponential regression model with assumed AR(1)-process, for model equations and significance of model parameters, please see in documentation

Forecast of Trends in Accidents w/Injuries in D

Accident Type 7* *(linear regression model)*

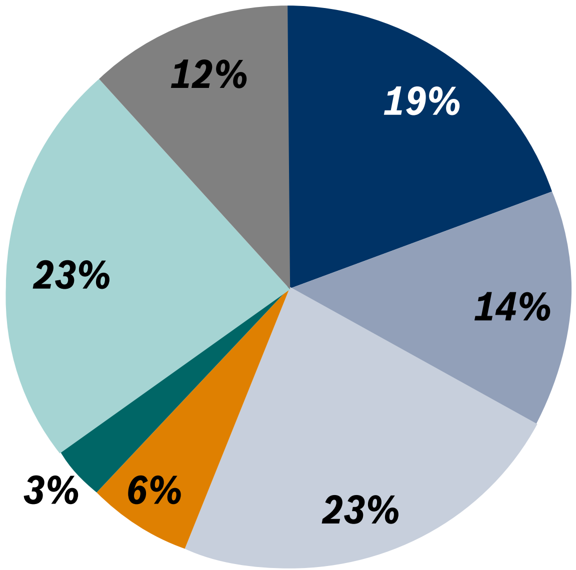


1) only small overlap in sphere of influence of ESC and EBA, this overlap is not considered in the model

*Linear regression model, for model equations and significance of model parameters, please see in documentation

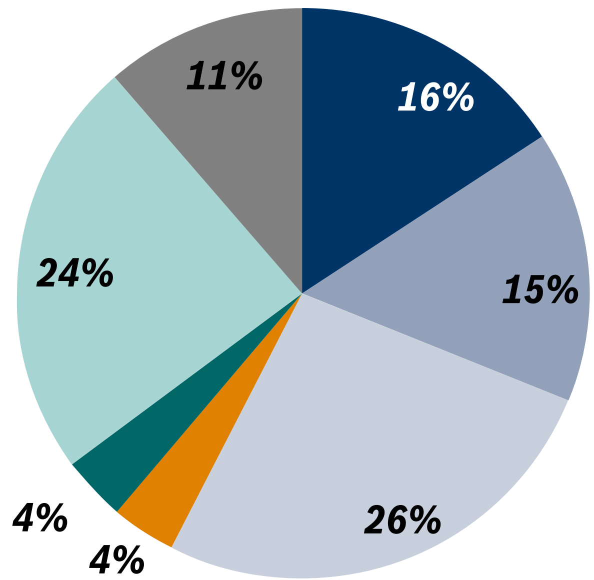
Distribution of Accident Types: 2008 Compared to 2020

2008
(basis: 320 614 real accidents)



- type 1: driving accident
- type 2: turning off
- type 3: turning in / crossing
- type 4: pedestrian accident
- type 5: accident involving stationary vehicles
- type 6: travelling in same lane
- type 7: other accident

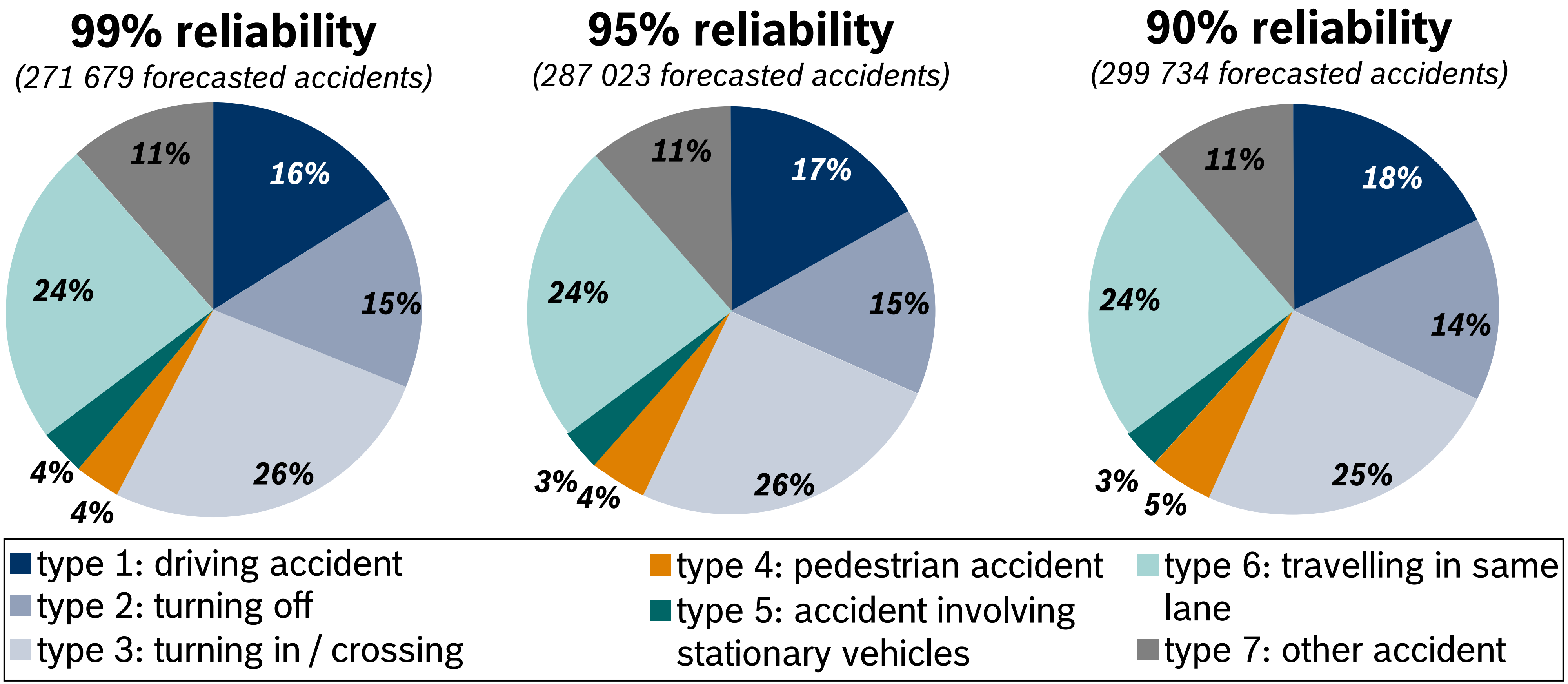
2020
(basis: 266 789 forecasted[1)] accidents)



➔ The forecasted distribution of accident types in 2020 slightly differs from the real distribution in 2008: disproportionate decrease of driving and pedestrian accidents, disproportionate increase of crossing accidents

1) 100% reliability assumed

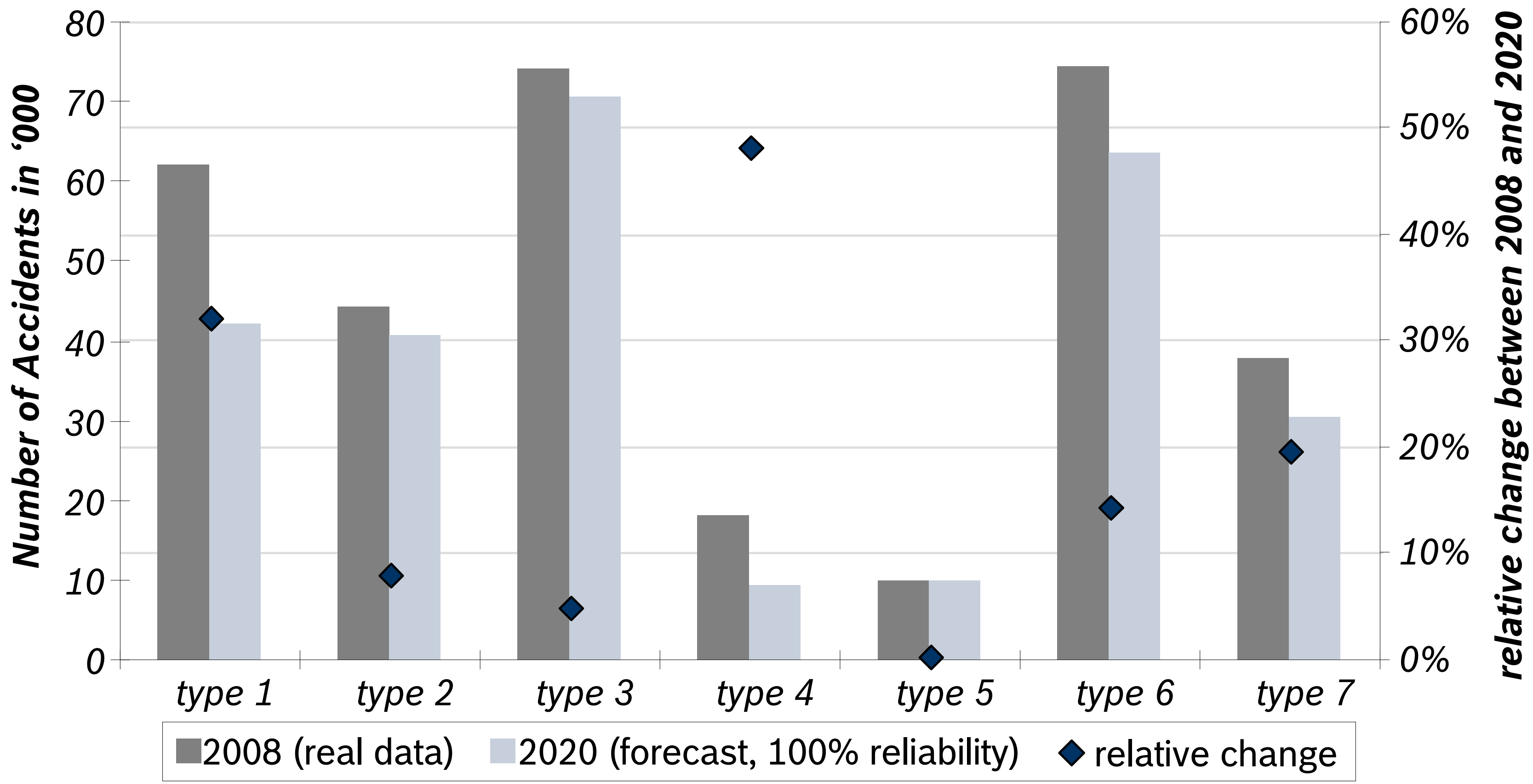
Distribution of Accident Types in 2020 with Differently Assumed Reliabilities[1)]



➔ With differently assumed reliabilities the forecasted distribution of accident types in 2020 differs only very little.

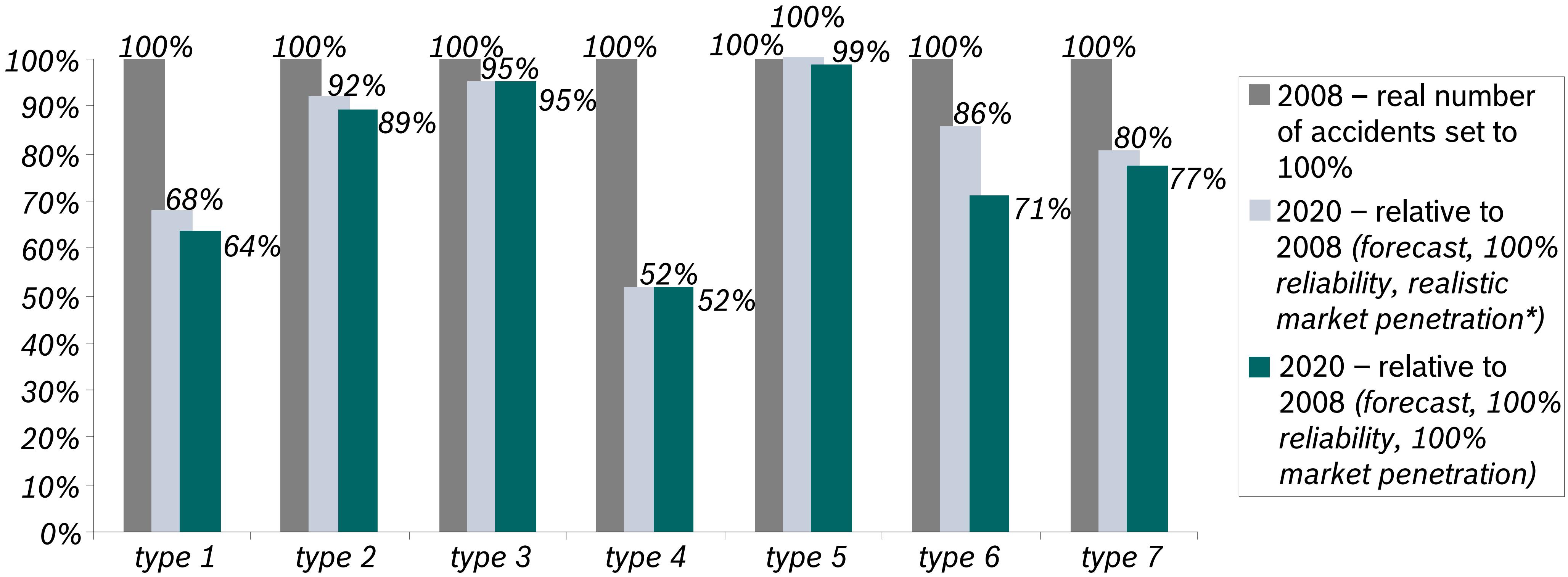
1) Reliability is specified for the first forecast year (with increasing intervals from last year used for modeling the reliability decreases, i.e. 1st forecast year: 95% → 10th forecast year: 61%)

Change in Shares of Accidents from 2008 to 2020



➔Small decrease in the number of accidents of types 2, 3 and 5 expected (<10%)
➔Moderate decrease in the number of accidents of types 6 and 7 expected (10%-20%)
➔Big decrease in the number of accidents of types 1 and 4 expected (>30%)

Additional Reduction in 2020 under the Assumption of 100% Market Penetration of ESC and EBA



➔ Significant reduction in type 6 accidents if assuming 100% market penetration (reason: big influence of EBA and high increase of market penetration)

➔ No change in type 3 and 4 because considered systems do not influence these types

➔ In remaining types poor decrease if assuming 100% market penetration (reason: avoidance potential moderate or realistic market penetration relative high

*For information about assumed market penetration of ESC and EBA in 2020 , please see in documentation

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Use of Results

1. The distribution of accident types shows how the most frequently occurring accidents will look like in future
   - ➔**Scope of safety systems** in future can be determined
   - ➔Determination of **safety systems with a big sphere of influence** by using the occurrence frequencies (*i.e. rear end crashes happen with a frequency of 24%)*.
   - ➔**Fields of effect** of assessed safety systems on real current data can be adjusted for valid statements about the influence in 2020 by using scaling factors. The factors are determined with the following instruction:

$$factor_{typeX} = \frac{\dfrac{numberAcc2020_{typeX}}{numberAcc2020}}{\dfrac{numberAccCurrent_{typeX}}{numberAccCurrent}}$$

, *where*

$numberAcc2020_{typeX}$...forecasted number of accidents of type X in 2020
$numberAcc2020$...forecasted number of accidents in 2020
$numberAccCurrent_{typeX}$ ...current number of accidents (i.e. in 2008) of type X
$numberAccCurrent$...current number of accidents (i.e. in 2008)

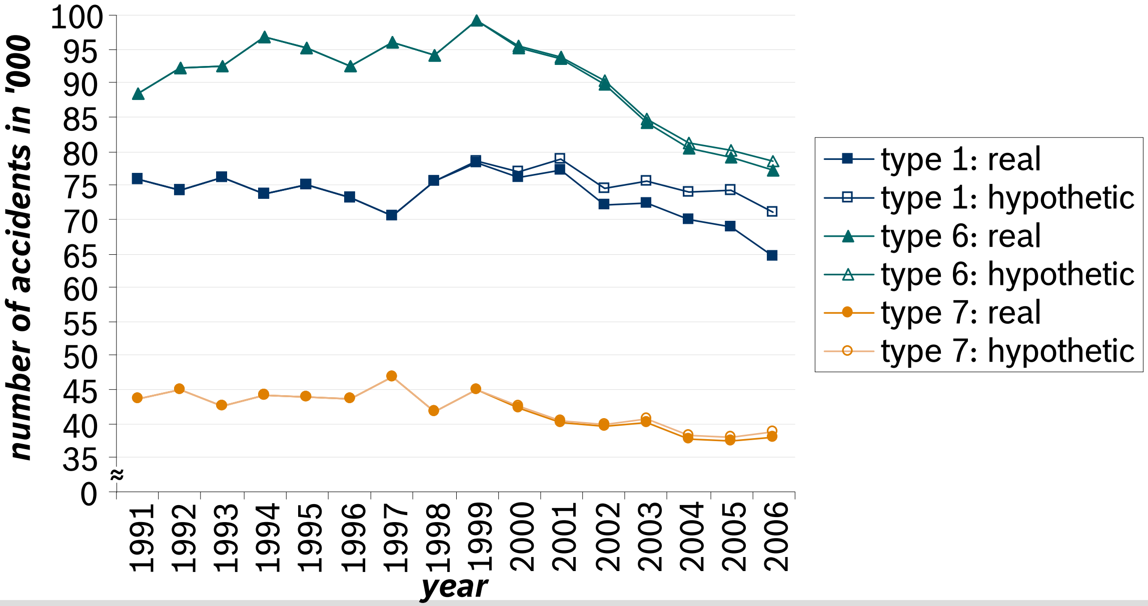
   - ➔ The selection of accident types not covered by available safety systems shows for which **accident types** new **systems** will be needed **to be developed**

2. The trend in the number of accidents of a specified type between 2008 and 2020 shows in which type the number declines sharply and in which it declines poorly
   - ➔**identification of accident types** for which additional **measures** are **necessary** for reducing accident numbers

Removing Effect of ESC in accident data

BACKUP

- <u>Reason:</u> significant effect of ESC on past and current accidents[1)] expected because of market penetration of the system
- <u>Procedure</u> used for removing effect of ESC in real accident data, explained by using accident type 1 as an example:
  1. Calculating number of avoidable accidents $accav_{type\_x}$ by ESC (procedure as described on slide 7)
  2. Calculating number of hypothetical $acchypoth_{type\_x}$ number of accident without influence of ESC by: $acchypoth_{type\_x} = acc_{type\_x} + accav_{type\_x}$
- <u>Result:</u>



➔ *With increasing market penetration the number of avoided accidents by ESC rises, hence the hypothetic number of accidents increases*

➔ *Dependant on the accident type the effect of ESC varies and with this effect the number of hypothetic accidents varies (i.e. many accidents of type 1 can be avoided, in type 6 only few accidents can be avoided)*

Extended Analysis of Accidents with Property Damage only

BOSCH Allianz

Results of Accident Analysis

Accident Research CR/AEV1

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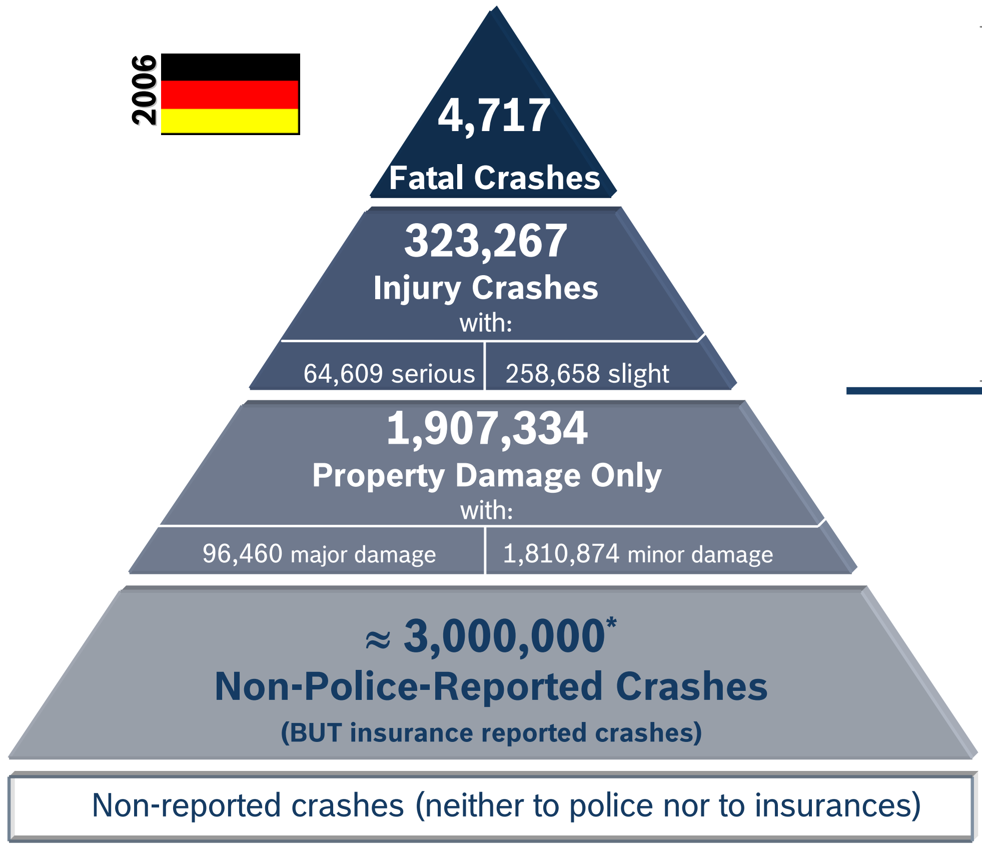
Available data sources for accidents in Germany



sources: Federal Statistical Office, Germany
* GDV-yearbook (estimation)

GIDAS – German In-Depth Accident Study

AZT/Bosch – property damage database

➔ Approx. 5.2 million reported accidents in Germany

This study:
Distribution of accident scenarios in property damage accidents

Database description

BOSCH
CR/AEV 1

Allianz
Allianz Zentrum für Technik

- **Built from accidents announced to Allianz-Insurances by clients**
- **Cases stem from automobile liability- and own damage-claims** (GER Haftpflicht, Kasko)
- **Cases were randomly selected among car accidents with property damage**
- **Information about case is based on**
  - ⇨ **Claim declarations to Allianz in standardized form (always available)**
  - ⇨ **Expert opinions**
  - ⇨ **Expert photos**
  - ⇨ **Attesting witnesses protocols**

  not always available

... approx. 100 pieces of information coded for each accident

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Database comparison

	Property damage accident database (BOSCH, Allianz)	Personal injury accident database (GIDAS German In-Depth Accident Study)
Data sampling	• Documents provided to Allianz by **costumers and experts** • Allianz customers from south-east Germany • Car accidents with **property damage** only	• On site documentation by **experts** • Two German sampling areas (Hannover, Dresden) • **Personal injury** accidents only
Data content	up to 107 information coded	up to 3500 information coded
Supplementary material available to Bosch	• **Expert photos** of damaged car for own damage claims only, 1356 cases • Expert's estimation of damage cost	• **Highly detailed photos** from accident site, • Technical car details • Police-, GIDAS expert-, Medical-report
Number of cases	3'986 cases	~15'000 cases
Years	2004 and 2007 (2 years)	2001 to 2008 (7 years)

⇨ The information available (quantity and quality) on property damage accidents is far below the information available on accidents with personal injury

Database evolution

Acquisition of additional data

	Year 2004	→	Year 2007
Accident description	up to 67 variables	⇨	40 **additional** variables (technical vehicle details etc)
Supplementary material available to Bosch	438 cases with photos and garage invoice	⇨	918 **additional** cases with photos and garage invoice (can be used for coding of new variables)
Number of cases	2000 cases	⇨	1986 additional cases

⇨ Three times more cases with photo documentation in the combined database (2004, 2007)
⇨ Increase of the statistical significance of results by doubling the number of cases

Distribution of cases - Methodology

Grouping of cases

- Aim: Description of the property damage accident situations in Germany by groups containing >> 1 accident (i.e. non-trivial subgroups)

- Initial grouping by the accident type to summarize the field of effect for existing security system concepts
- Additional distinction by locality (urban/rural) or accident site (parking, private driveway etc.)
- Further grouping by vehicle velocity and movement direction (forward/backward)
- Evaluation of additional information from photos for a subgroup of cases

Weighted sum

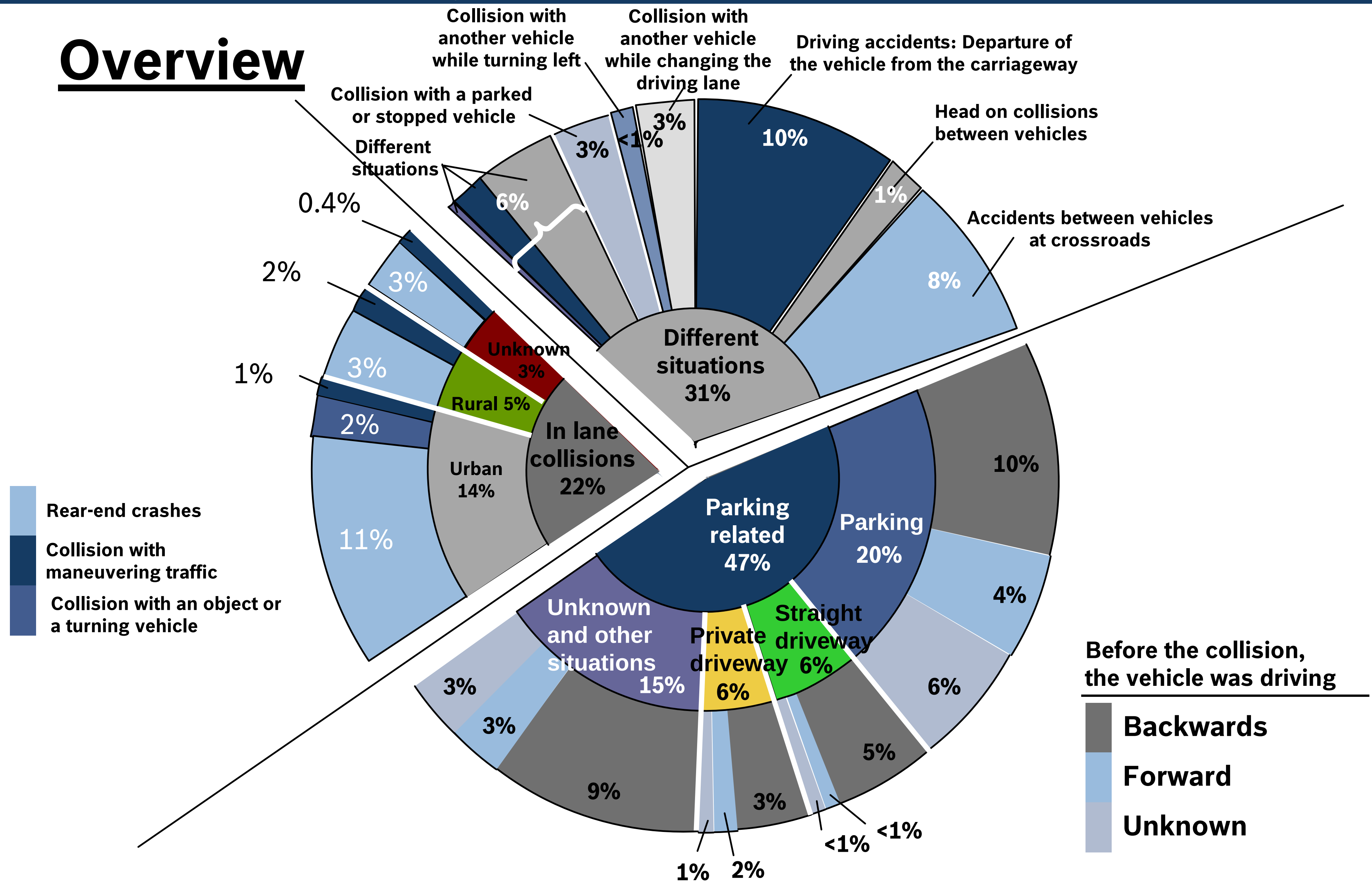
- Aim: Correction of differences between database sample and German-wide accident distribution (i.e. non-representative sampling)

- Approximate correction possible for 1000 of 3986 cases (police reported accidents)
- Repartition of accident type in database adapted to mean distribution in two German provinces
- Repartition of accident locality in database adapted to mean distribution in Germany

BOSCH

Extended analysis of accidents with property damage only

Distribution representative for Germany



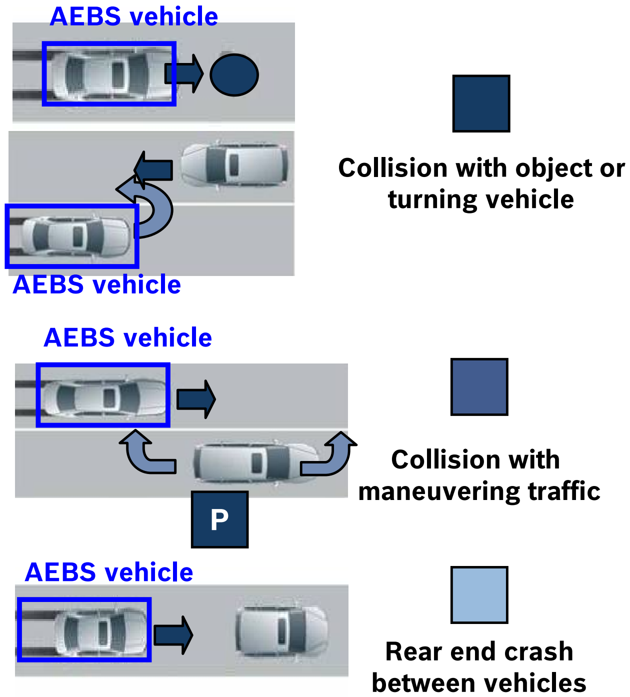
Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

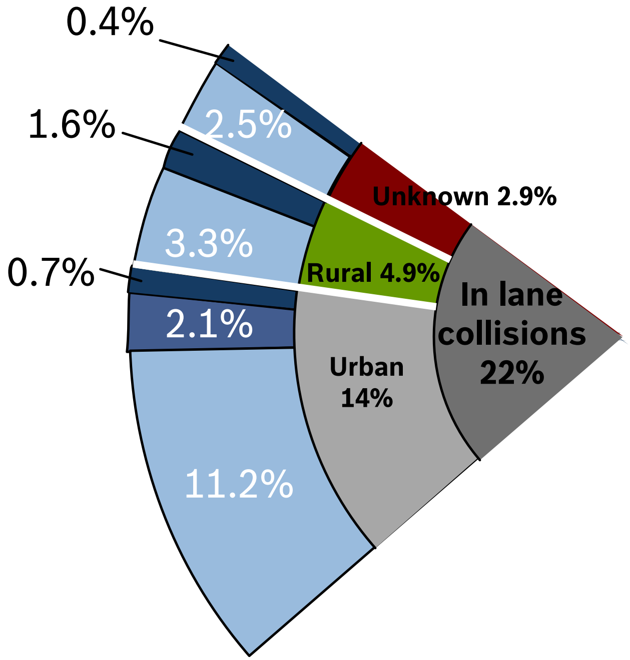
Collisions with vehicles and other obstacles in driving lane

Relevance of Advanced Emergency Braking Systems (AEBS)

AEBS
recognizing objects and vehicles turning into driving lane
3%
field of effect

AEBS
current system definition
19%
field of effect





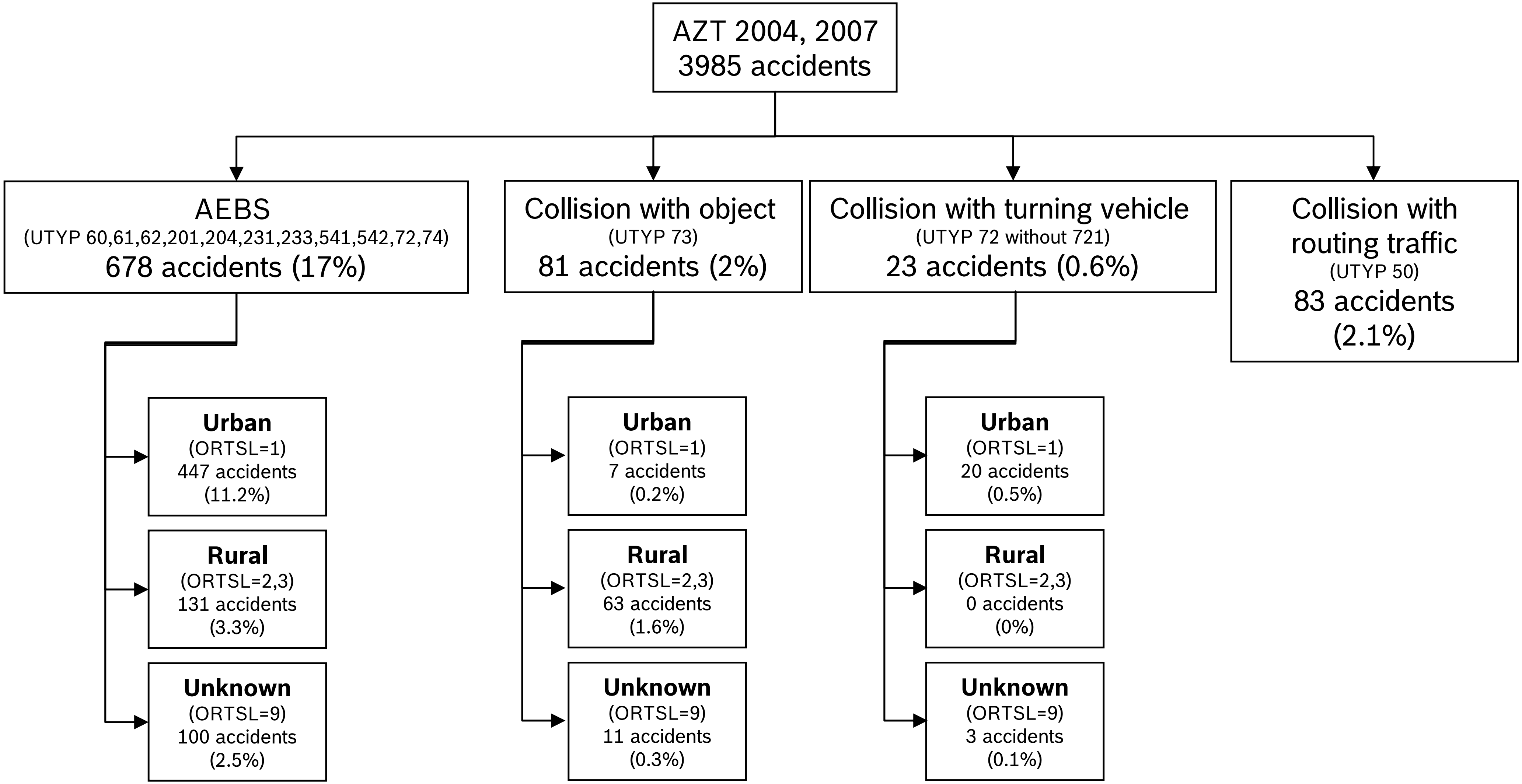
Sum: 22%
Field of effect for AEBS

- AEBS in its current definition could address about **19%** of all accidents with property damage
- AEBS recognizing objects and turning vehicles could address further **3%** of accidents with property damage

Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

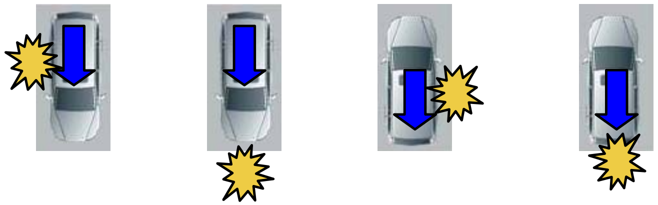
Extended analysis of accidents with property damage only

Distribution representative for Germany



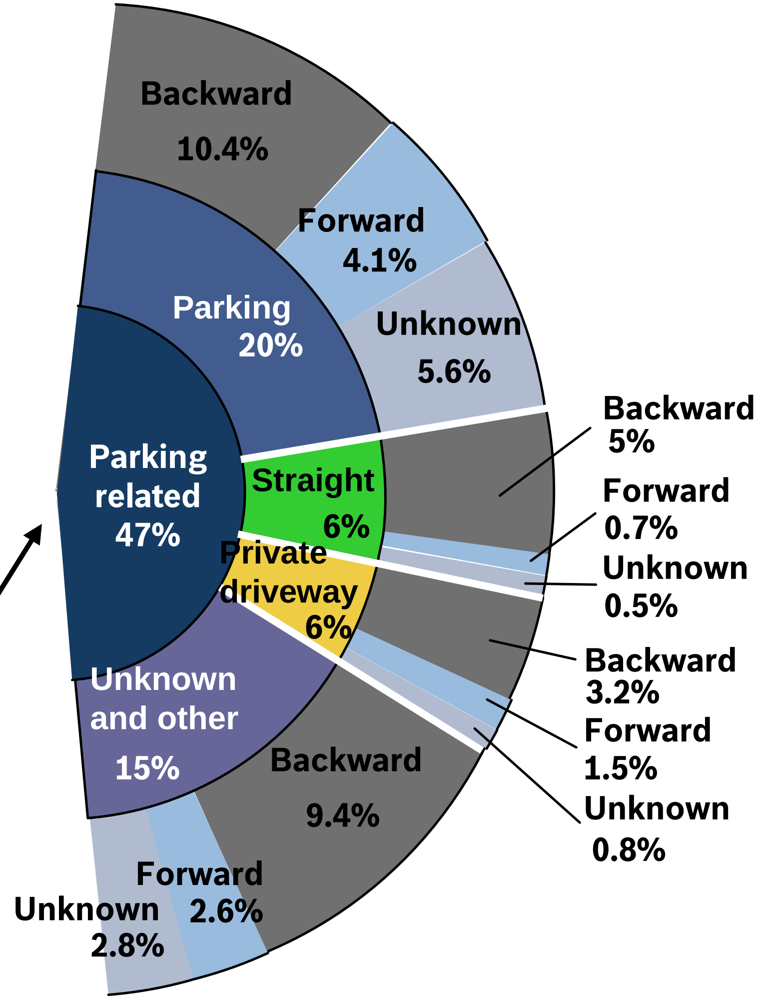
Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

Collisions in parking related situations



Damage	Driving forward		Driving backward	
	left or right	front	left or right	back
Collision with car	2%	2%	2%	6%
Collision with pole	5%	1%	4%	2%
Collision with barrier	4%	1%	2%	2%
Other or unknown	1%	1%	1%	2%

(Damage to standing vehicle and other 9%)

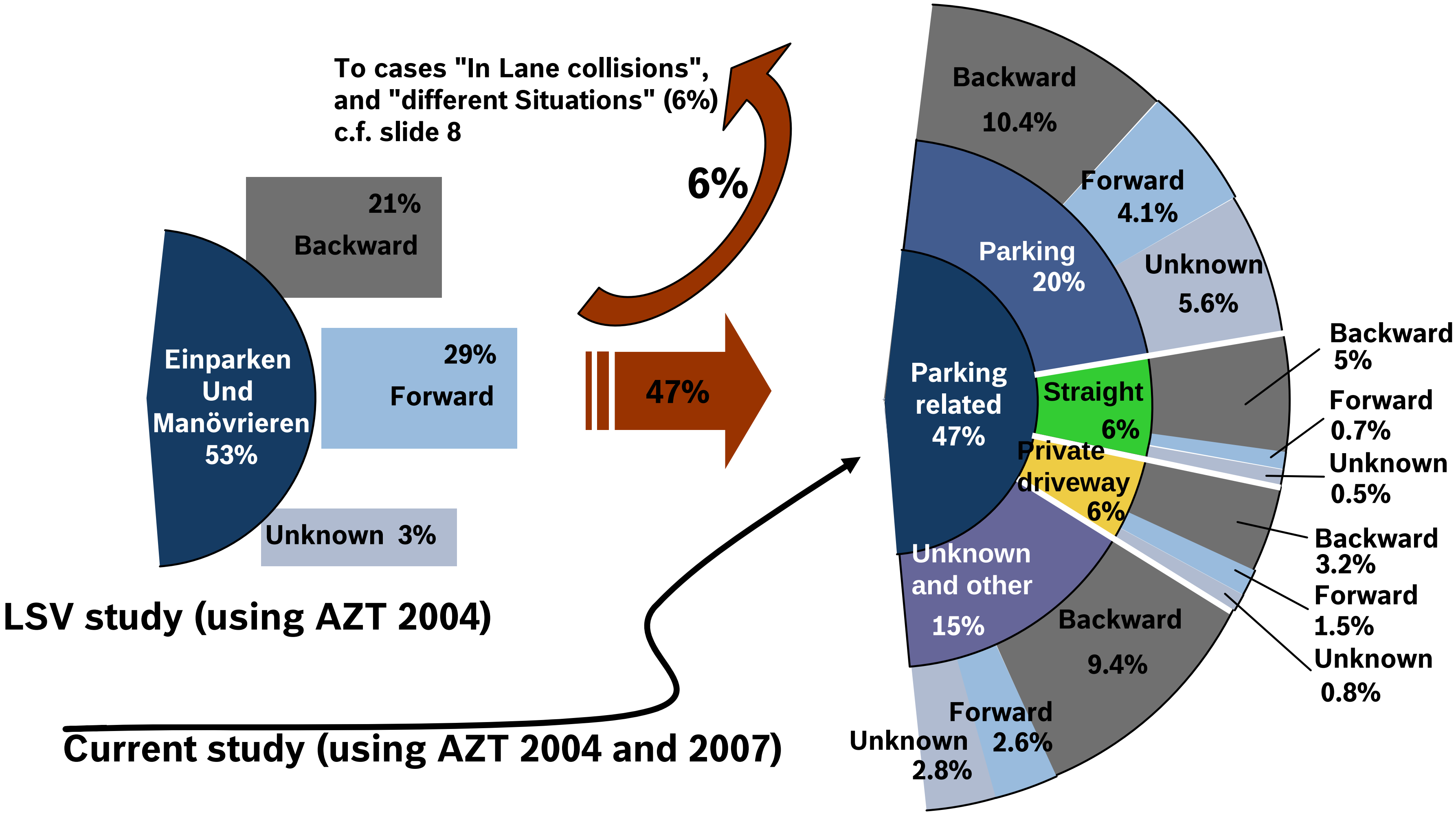


- At low speed, most property damage accidents occur while driving backwards (i.e about 2/3 of parking related cases)
- Most property damage accidents at low speed occur on parking sites

Note: Distribution of accident situation (left hand) based on 401 cases for which additional information was derived from accident pictures

Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

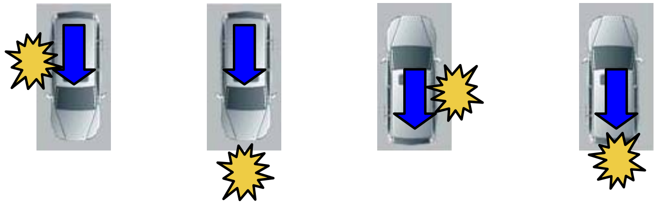
Comparison with "Low speed value functions (LSV)" study



• Similar distribution of low speed / parking related cases reported in LSV and current study

Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

Comparison with "Low speed value functions (LSV)" study



Damage	Driving forward: left or right	Driving forward: front	Driving backward: left or right	Driving backward: back
Collision with car	2%	2%	2%	6%
Collision with pole	5%	1%	4%	2%
Collision with barrier	4%	1%	2%	2%
Other or unknown	1%	1%	1%	2%
(other 9%) SUM	12%	5%	9%	12%	Current study (using AZT 2004 and 2007)
(other 4%)	15%	13%	10%	11%	LSV study (using AZT 2004)

Sum: 38%
Field of effect for
Assistant for parking related situations

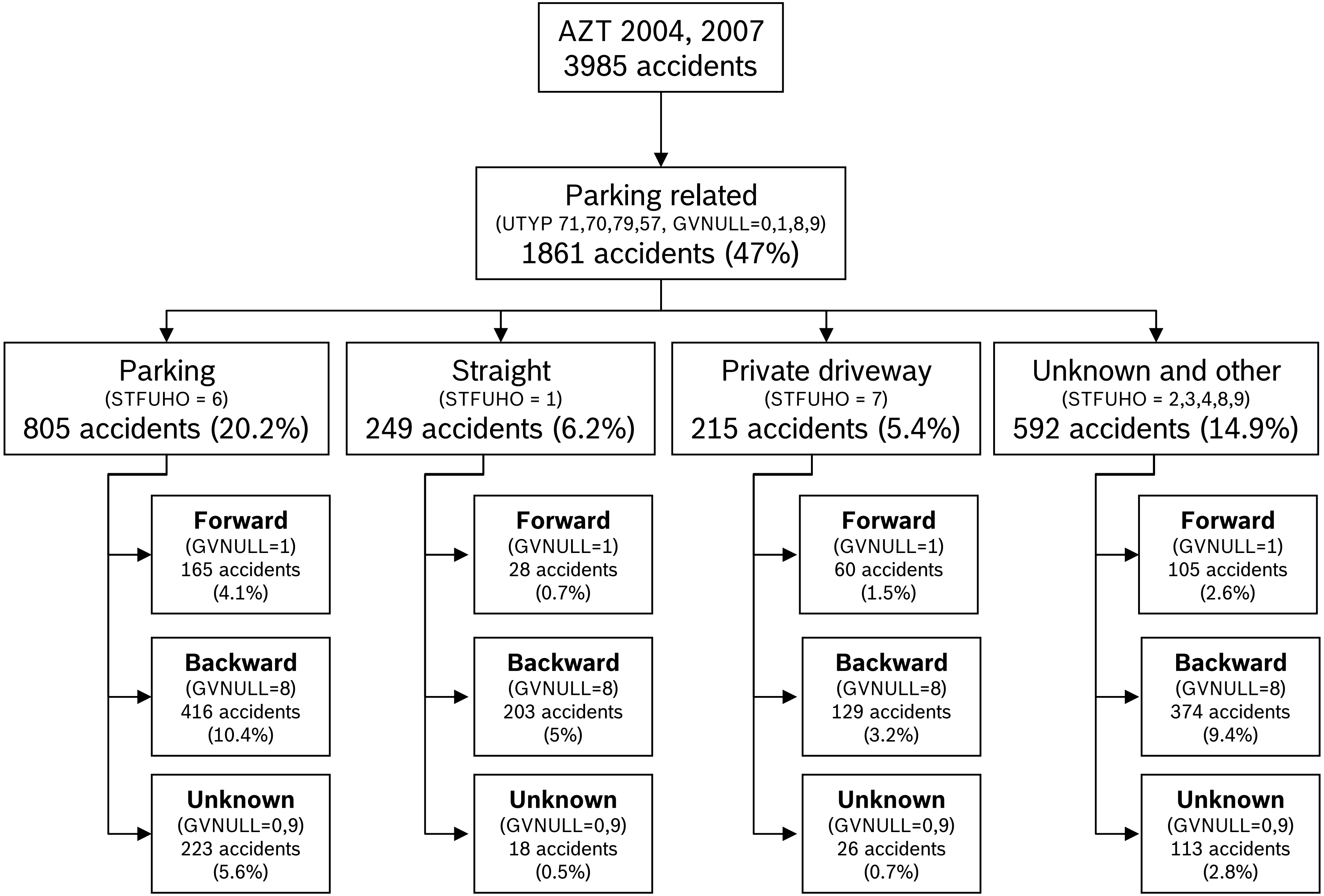
Cases in current study assigned to field "In lane collisions"

Comparable within precision of results

- Similar distribution within low speed / parking related cases reported in LSV and current study

Extended analysis of accidents with property damage only

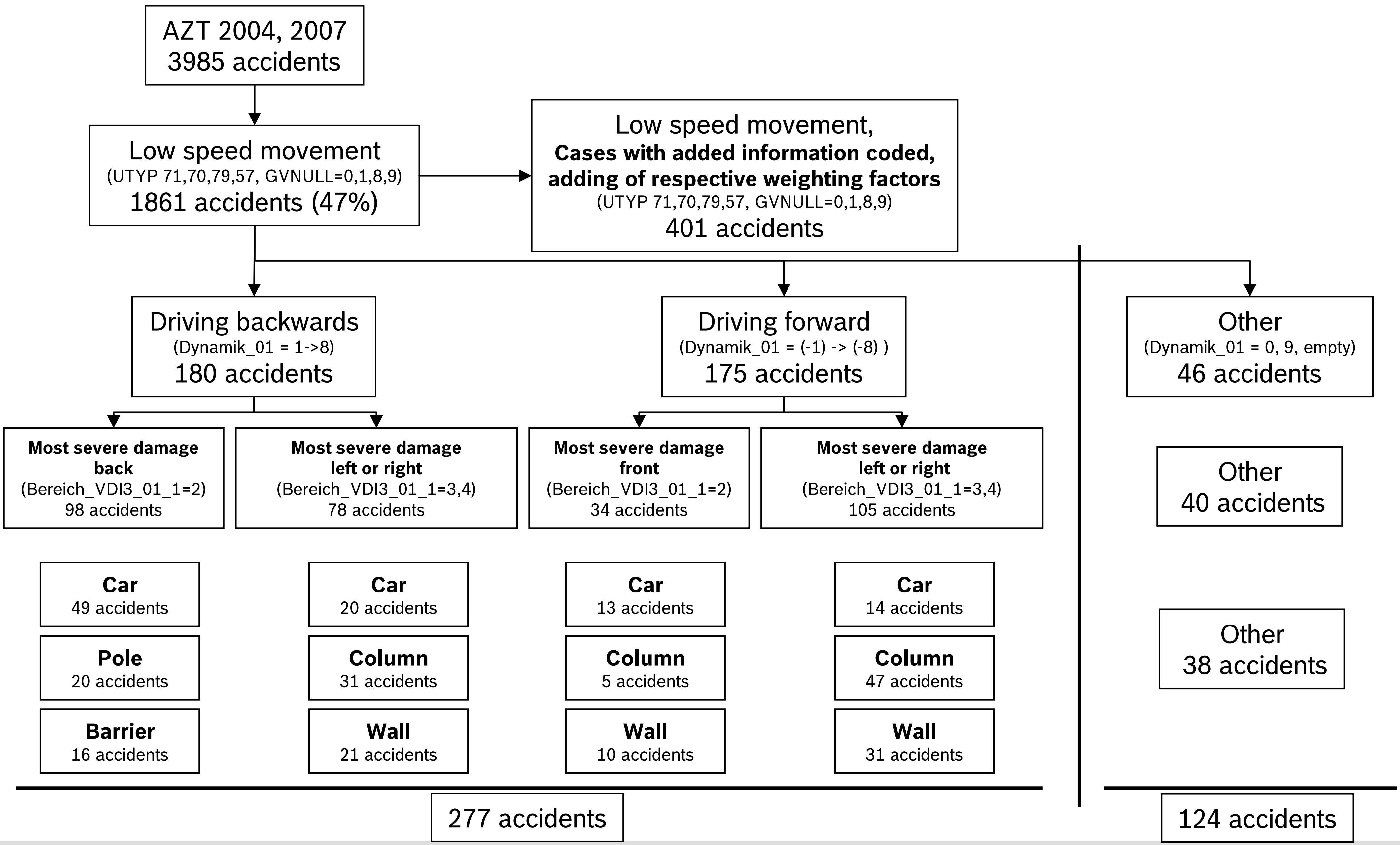
Distribution representative for Germany



Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

Extended analysis of accidents with property damage only

Distribution representative for Germany



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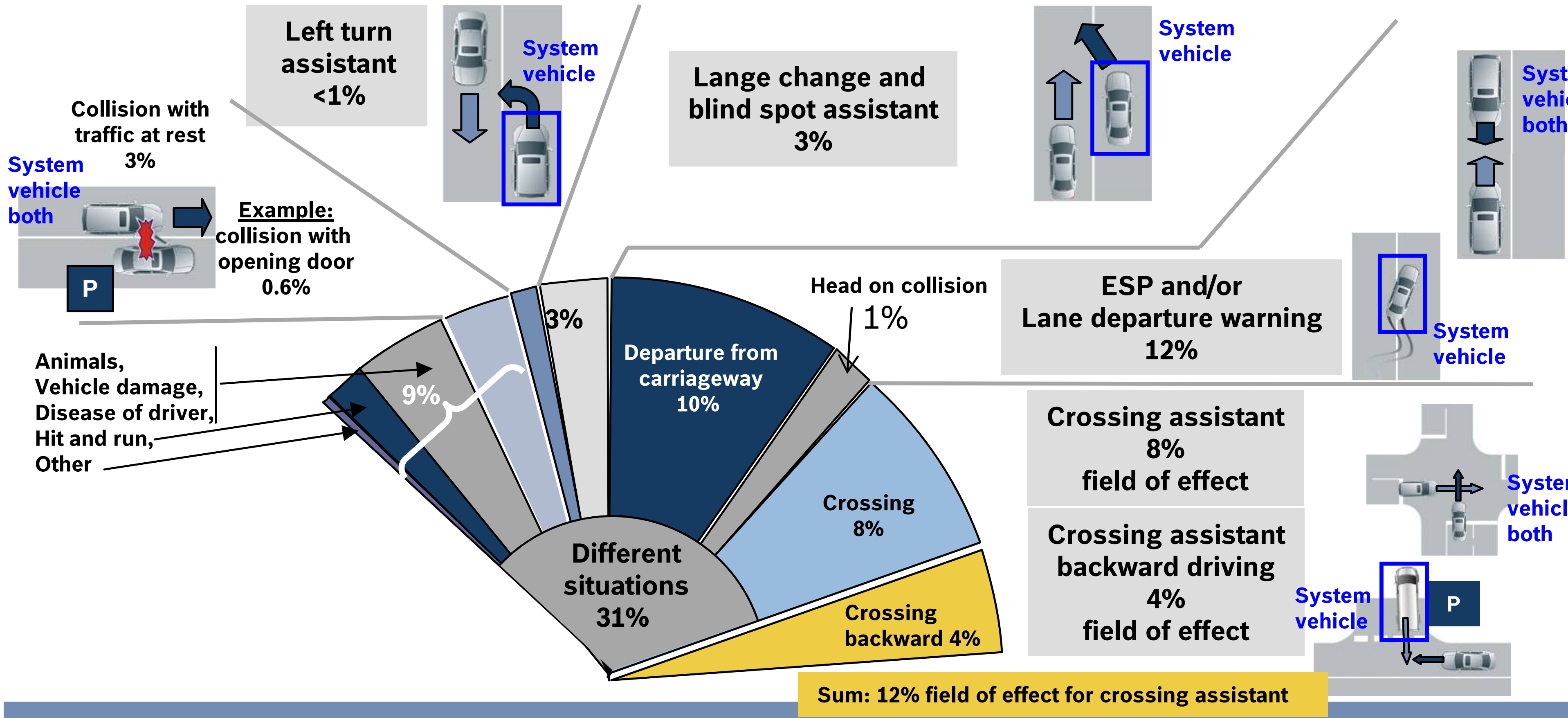
Relevance of assistance systems in different situations



- ESP/ Lane departure warning could address 12% of property damage accidents
- A system for crossing situations could address 12% of all property damages
- Assistance in crossroad situations could address 8% of property damage accidents
- A system assisting while leaving a parking slot backwards and crossing could address 4% of property damages

Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

Extended analysis of accidents with property damage only

Distribution representative for Germany

AZT 2004, 2007
3985 accidents

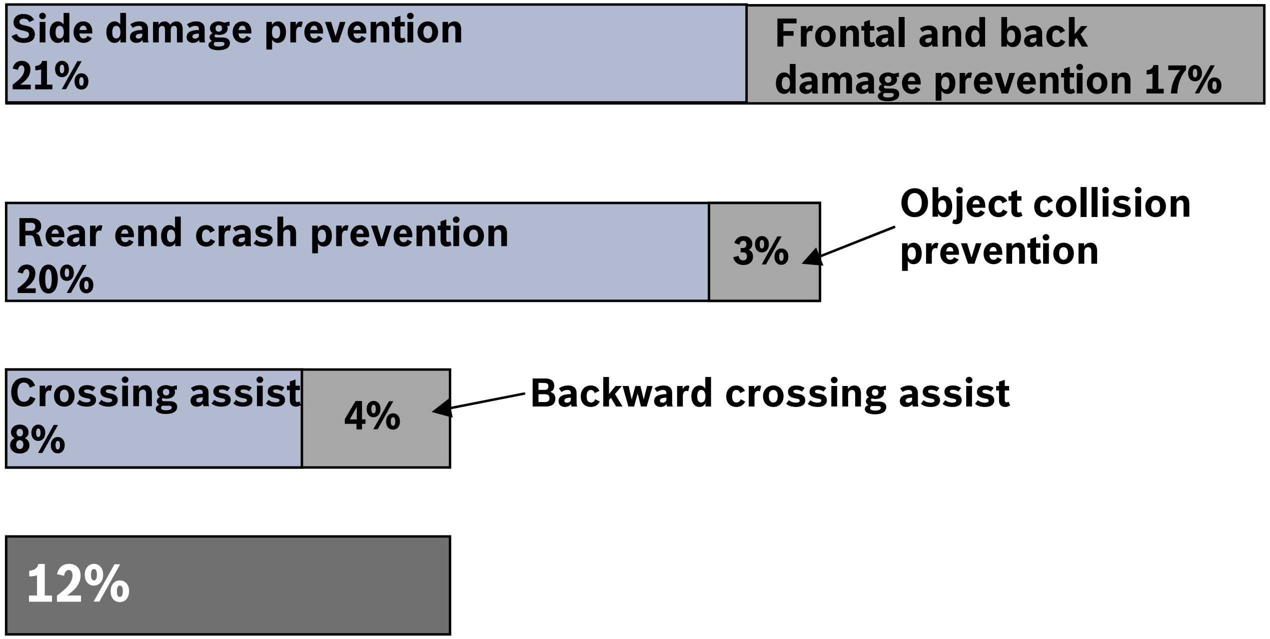
- **Crossing**
  (UTYP 30-39, 232, 25, 26, 27, 29)
  326 accidents (8.2%)
- **Head on collisions**
  (UTYP 66, 68)
  63 accidents (1.6%)
- **Departure from carriageway**
  (UTYP 1)
  393 accidents (9.9%)
- **Lane change / blind spot monitoring**
  (UTYP 63, 64, 65, 202)
  117 accidents (2.9%)
- **Left turn assistant**
  (UTYP 21)
  39 accidents (1%)
- **Collision with traffic at rest**
  (UTYP 51 to 59 without 57)
  123 accidents (3.1%)
- **Animal, vehicle damage, disease, hit-run, other**
  (UTYP 75, 76, 77, 7(hit and run), 69)
  232 accidents (5.8%)

Crossing backward
(UTYP=714, 715, 571, 572, 579, GVNULL_1 = 8)
157 accidents
(3.9%)

Source: Allianz Zentrum für Technik, 3985 accidents (2004, 2007)

Summary – Field of effect (max.) for different systems addressing property damage accidents

System	Field of effect
Assistant for parking related situations, velocity < 50 km/h	38%
AEBS	22%
Crossing assistant	12%
ESP / Lane departure	12%



Outlook

- Further analysis of the AZT database could distribute cases according to sensor concepts instead of using accident types
- Further use could be made of the clear-text accident description, possibly by automatic extraction of information
- Use concepts of statistical database analysis for information gain (i.e. clustering, association rule mining) ?

Status Accident Research Asian Countries (December 2009)

Results of Accident Analysis

Accident Research CR/AEV1

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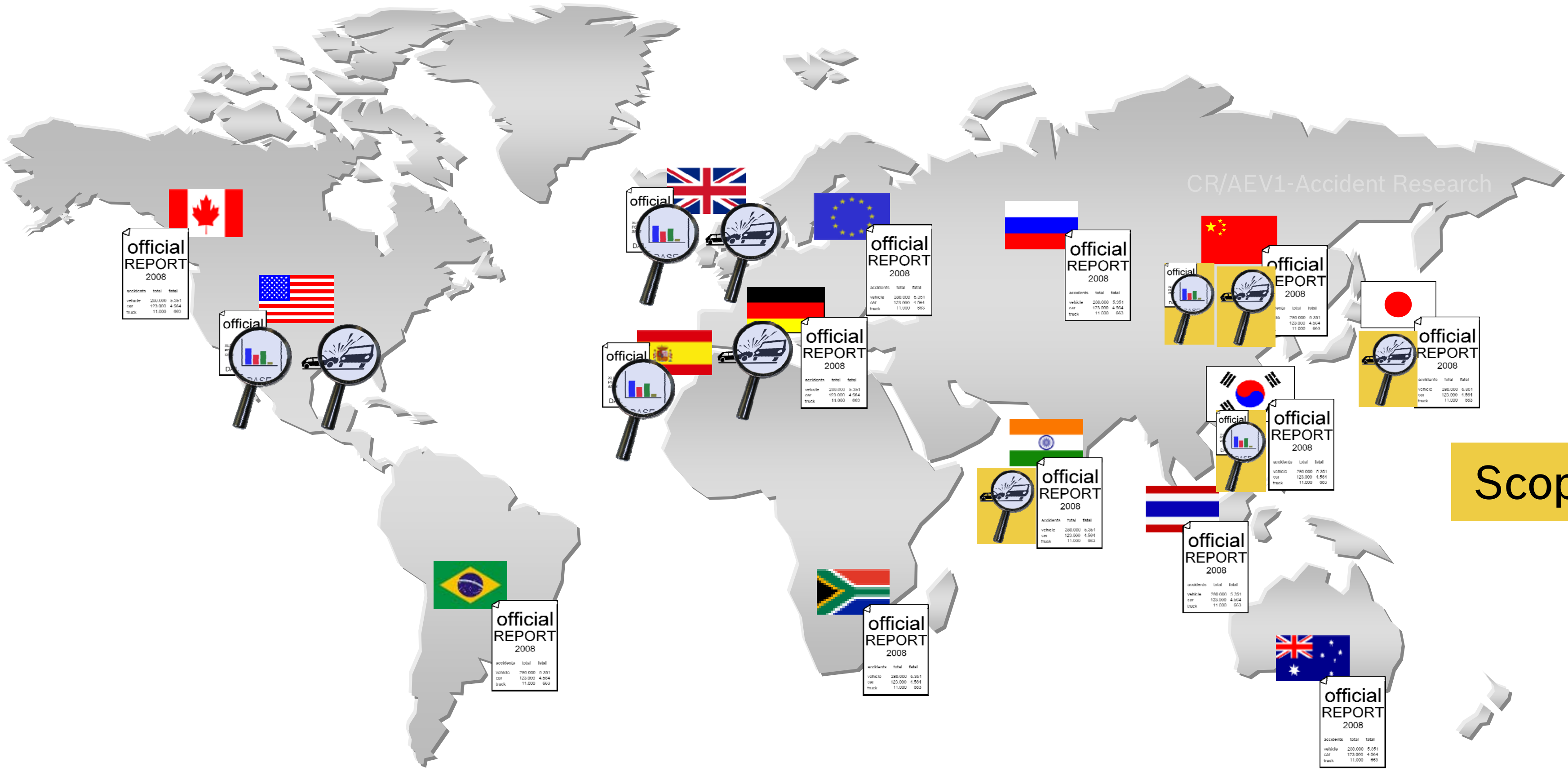
Available data sources for RB – planned extension



Scope of work

➔ Extension of detailed knowledge regarding traffic accidents in Asian countries necessary

➔ Access to naturalistic driving data also under consideration

In-depth data
- manifold detailed data to individual accidents
- represents a small subset of all accidents

Detailed official data
- detailed data to all police reported accidents
- individual analysis possible

Official reports
- information/statistics to all police reported accidents
- slightly detailed

Activities China

1 ➔ ***CATARC (China Automotive Technology & Research Center) – Official data***

- Collection of 50,000 accidents with personal damage (ESP effectiveness study)
- Useful data with pictures interesting for RB (approx. 100 police reports viewed by Gi)
- Access to this data gathers unfiltered overview of the real accident situation in China
- Depth of data is limited
- Database completed by the end of 2011

➔ **Full data access for internal RB-purposes guaranteed (no contract – up to now no financial support)**

➔ **RB inkind : Support and education of CATARC employees, transfer of knowledge regarding accident research**

2 ➔ ***Tongji-University (Shanghai) – In-depth data collection***

- Project start: 2006
- Initiator: VW with high personal effort
- Collection of roughly 100 accidents/a in Shangai according to GIDAS data parameter
- Follow up activities planned in 2010 controlled by a consortium with VW, GM, Autoliv and RB as members.
- For industrial use more accident cases requested at least ≥200 acc./a due to more financial support
- Contract partner Tongji-University less cooperative, RB costs approx. 10K€ p.a.

➔ **Next steps: Proposal for time and project schedule by Tongji-University T: E11/09**

3 ➔ ***CATARC – In-depth data collection in Tianjin***

- Accident data collection in the area of Tianjin and Beijing possibly planned by CATARC
- Target data for setup of this project by end of 2010
- CATARC asked RB for support in setting up such a project (education of employees, data base setup etc.)

➔ **Next steps: Waiting for proposal of project plan T: 01/10**

Activities Japan

1 ➔ ***ITARDA-Access – In-depth data***

- Meeting in August 2009 – Introduction to Bosch Accident Research
- Costs ~500€/case, Budget CR/AEV 10T€ = 20 cases maximal
- Annual membership of ITARDA necessary, additional fee ~1 200€/a.

➔ **Next steps: Status on hold due to economic situation and limited data access.**

2 ➔ ***Honda – Accident Research JP – Two-wheeler (HGA) and four-wheeler (HGT)***

- Setup of initial contact between – Accident Research – HGT (08/2009) and HGA (08/+**02.10/2009**)
- Honda (HGT) internal study CMBS system already done. No further evaluations of PEBS needed.
- Honda (HGA) asked for cooperation regarding benefit estimation of motorcycle ABS Asia

➔ **Next steps: HGA starts activities in 04/2010 – Definition of needed parameters in order to fulfill the study based on RB UFO requirements**

3 ➔ ***Japan Society of Automotive Engineering / Tokyo University – Naturalistic Driving Data***

- Incident data collected using black box & videos in cooperation with taxi companies (100 taxis).
- Access for RB for free if several requirements will be fulfilled.
- Data collection finished in Feb. 2010 – ~600 near-miss accidents coded and black box data collected

➔ **Next steps: Finalizing database, study of rear-end impacts, published at JSAE in 3rd quarter in 2010 in order to fulfill JSAE requirements. Setup of study with Tokyo University on pedestrian accidents.**

THE UNIVERSITY OF TOKYO

4 ➔ ***Toyota Motor Corporation***

- Meeting RB-G4/TMC – Proposal of information exchange on Accident Research
- Toyota shows interests for information exchange

➔ **Next steps: Status on hold – activities on request**

5 ➔ ***Mazda***

- Contact setup during IRTAD conference in 09/2009. Presentation material sent to Mazda.

➔ **Next steps: Status on hold – activities on request**

Activities India

1 ➔ ***ARAI (Automotive Research Association of India) – In-depth data collection around Pune area***

- Workshop together with ARAI, VW, RB and Daimler in Pune in May 2009
- Aim: Setup of in-depth accident data collection, in the area around Pune with approx. 100-150 accidents annually
- ARAI shows high interests regarding a common project.
- Proposal of time schedule agreed till June 2009 from ARAI
- **Status: No feedback up to know**

➔ **Next steps: 2nd reminder otherwise selection of variant 2**

2 ➔ ***JP Research – In-depth data collection around Chennai and Banglaore***

- Knowledge on data collection by JP Research. Pilot project carried out in Chennai
- Company owner: Amerindian nationality
- Project proposal covers in-depth data collection in Chennai and Banglaore with 100 accidents annually
- Further discussions with other OEM and suppliers ongoing in order to setup consortium
- Current proposed RB funding approx. 100K€/p.a. but ongoing discussion

➔ **Next steps: Common project proposal with significant reduced RB funding.**

Activities Korea

1 → ***Korea Transportation Safety Authority – Official data***

- Contact setup during IRTAD conference Dr. Byongho Choe
- Aim: Access to more detailed information on accidents with personal injuries in Korea
- TS also needs access to official police reported data (ROTA)
- **Next steps: Status on hold – possible introduction of Accident Research RB in order to find out if common projects possible.**

2 → ***KOTI – The Korean Transport Institute – Naturalistic driving study***

- Cooperation with taxi companies in order to educate taxi driver by using video and event data recorder
- Meeting 12/2009, Presentation of Accident Research RB
- High interest in possible common study due to need of further evaluation of accident data. KOTI has never done any studies. Support towards RB with education video for internal purposes.
- **Next steps: Data collection ends in 2010 – E-Mail exchange to keep contact**

3 → ***Samsung Traffic Safety Research Institute – Property damage database / In-depth database***

- 1st meeting Sept. 2009 / 2nd meeting Jan. 2010, Contact Dr. Hong (former GM)
- Samsung Insurance collects accident data with property damage only
- High interest in cooperation together with Bosch but current internal structural discussions ongoing
- Aim RB: Setup or cooperation partner in order to setup in-depth accident data or property damage database
- **Next steps: On hold till internal targets clear – E-Mail exchange to keep contact also from local RB members in order to promote ESP in Korea.**

4 → ***Hyundai***

- Meeting in Sep. 2009 in order to find out if Accident Research is running at Hyundai
- No activities by Hyundai itself. Accident Research is done with external partners like Samsung.
- **Next steps: No activities**

Further IRTAD conference contacts in 2009

BOSCH

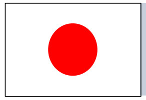
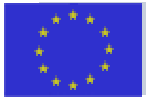
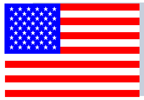
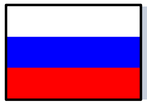
Overview of the Accident Situation 2007 for Japan and Korea

Results of Accident Analysis

Accident Research CR/AEV1

BOSCH

Road safety in 2007 – a public health issue

	Registered motor vehicles [Mio]	Road accidents involving injuries [Mio]	Fatalities	Fatality risk per vehicle
			(fatalities within 30 days after accident)	
	91.2	0.83	6,639	1 : 13,700
	294.0	1.29	42,485	1 : 6,900
	255.7	1.75	41,059	1 : 6,200
	18.2	0.21	6,166	1 : 3,000
	49.6	0.38	23,286	1 : 2,100
	159.8	0.33	81,649	1 : 2,000
	36.9*	0.23	33,300**	1 : 1,100
	87.9***	0.42	114,590	1 : 770

* 2005

*** 2006

** fatalities within 7 days after accident

Sources: IATSS Yearbook 2007, CARE 2007 (EU27), NHTSA Traffic Safety Facts 2007, Road Traffic Safety Authority Korea 2007,Yearbook 2006 Traffic Accidents China, DENATRAN 2007, RAMI Annual Report 2007, Ministry of Home Affairs, Govt. of India

Accident figures

	Resident population [Mio]	Registered motor vehicles [Mio]	Injury accidents [Mio]	Fatal Accidents*	Share of Fatal accidents in injury accidents	Fatalities*
Germany	82,3	57,4	0,34	**4609**	**1,37 %**	**4949**
USA	301,6	255,7	1,75	**37248**	**2,13 %**	**41059**
Japan	127,8	91,2	0,83	**6483**	**0,78 %**	**6639**
Korea	48,5	18,2	0,21	**5867**	**2,77 %**	**6166**

sources: StBA, NHTSA, IATSS, IRTAD, Year 2007

* for fatalities that occur within 30 days

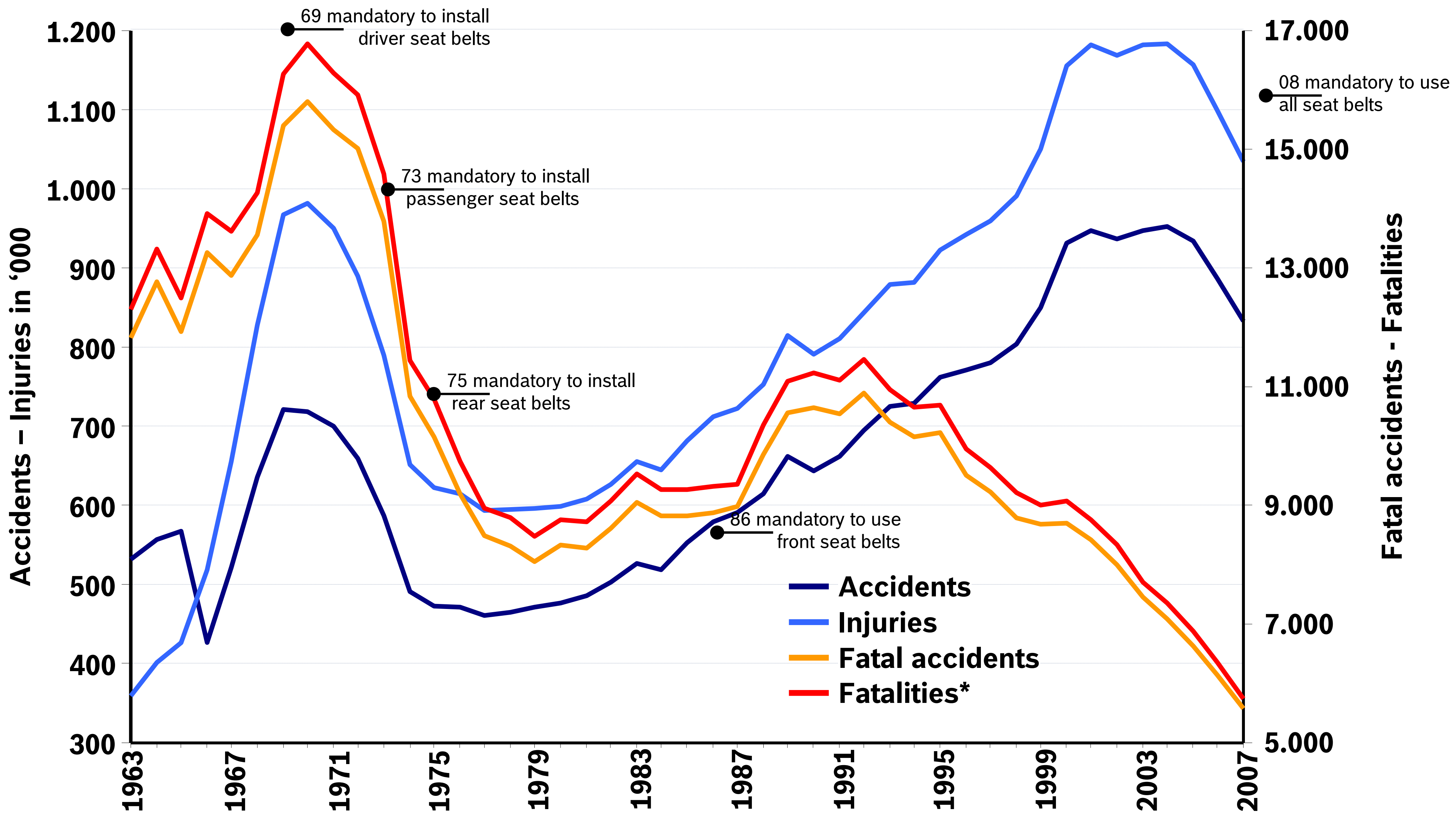
Accident figures - Top 10 Prefectures 2007

	Motor vehicles owned [Mio]	Injury accidents	Fatal accidents	Fatalities*	Fatality risk per vehicle	Share of fatal accidents in injury accidents
Tokyo	4.6	66,516	247	269	**1 : 17,100**	**0,37%**
Osaka	3.8	57,387	234	248	**1 : 15,200**	**0,41%**
Aichi	5.0	54,726	267	288	**1 : 17,200**	**0,49%**
Kanagawa	4.0	49,535	212	237	**1 : 16,900**	**0,43%**
Fukuoka	3.2	45,191	193	199	**1 : 16,000**	**0,43%**
Saitama	3.9	44,140	217	228	**1 : 17,200**	**0,49%**
Shizuoka	2.8	38,244	170	188	**1 : 15,000**	**0,45%**
Hyogo	3.0	37,181	207	231	**1 : 12,800**	**0,56%**
Chiba	3.5	30,531	233	254	**1 : 13,600**	**0,76%**
Hokkaido	3.7	23,460	259	286	**1 : 12,900**	**1,10%**

Sources: www.kotsu-anzen.jp/

* fatalities within 30 days after accident

Road Traffic Accidents in Japan 1963-2007



Source: IATSS 2007 * Fatality within 24 hours – 6639 fatalities within 30 days after accident in 2007

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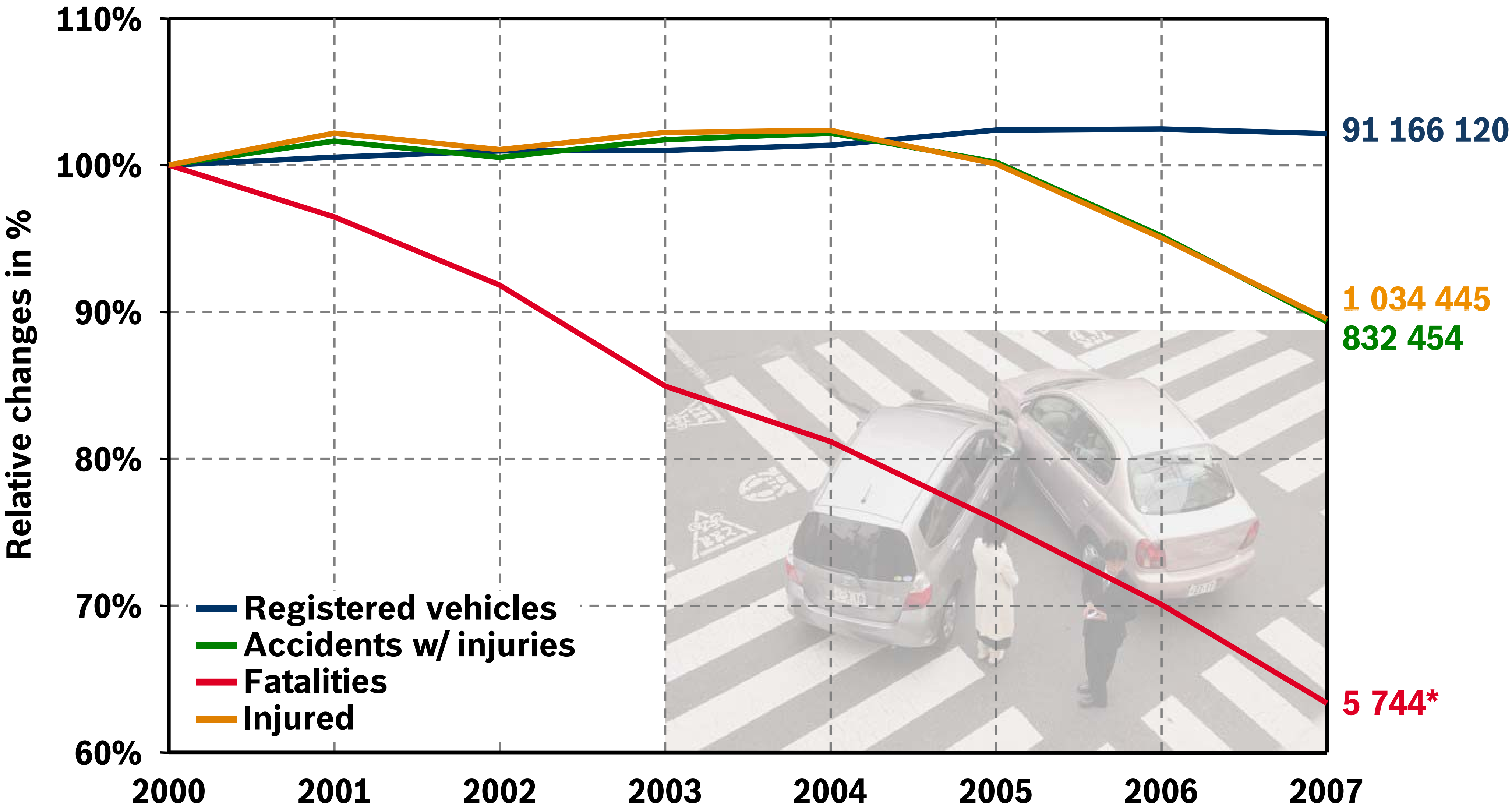
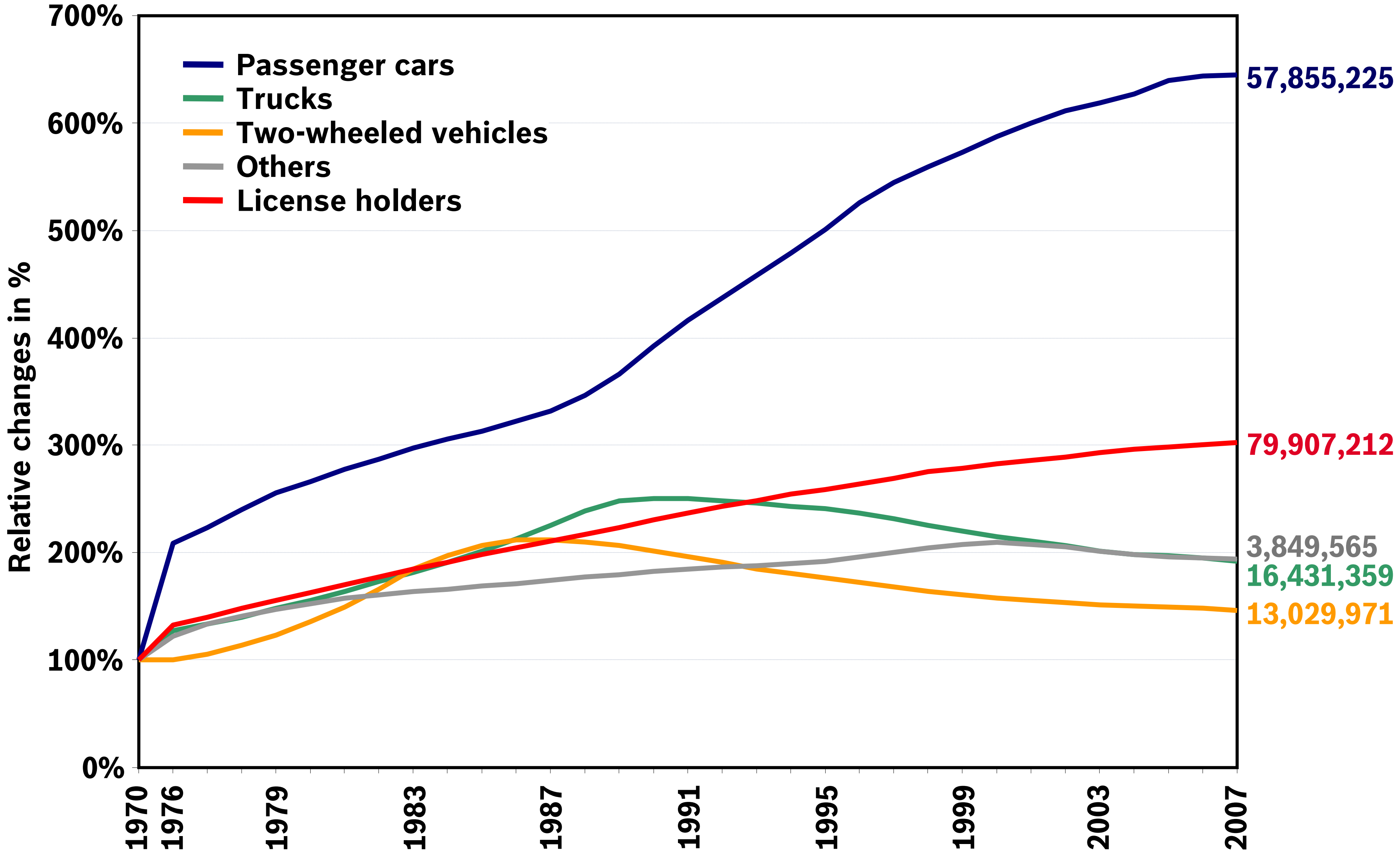
Road Traffic Accidents Japan



Source: Statistics 2007, Road accidents Japan

* Fatality within 24 hours – 6639 fatalities within 30 days after accident in 2007

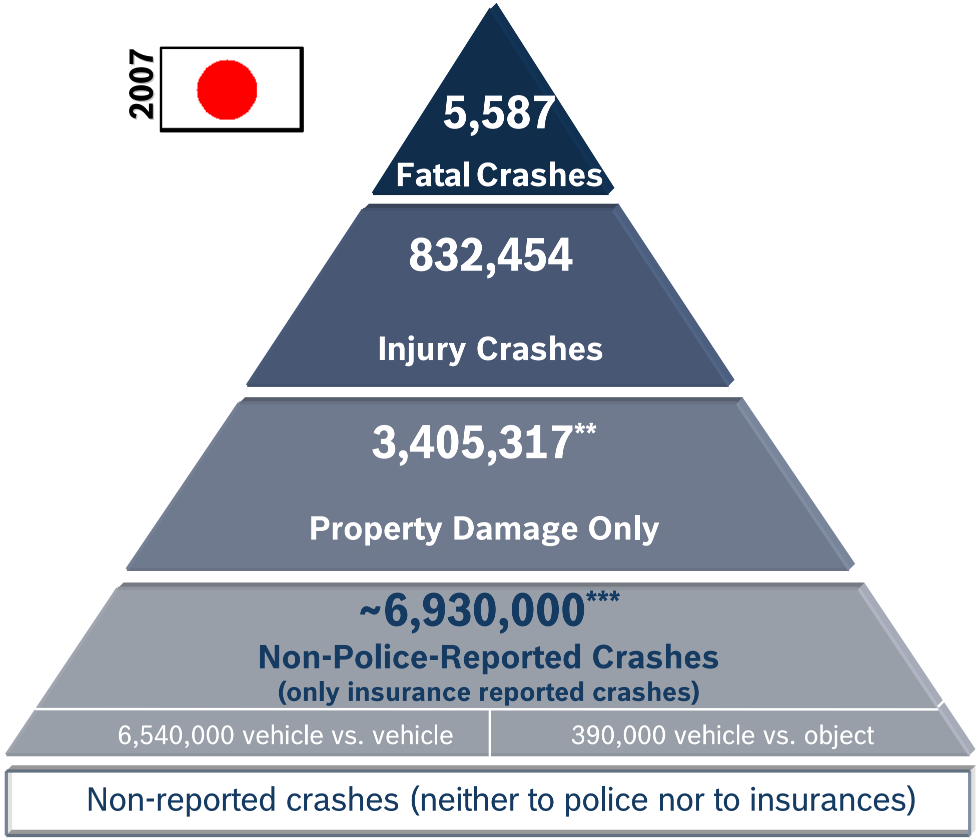
Registered vehicles and license holders - 1970-2007



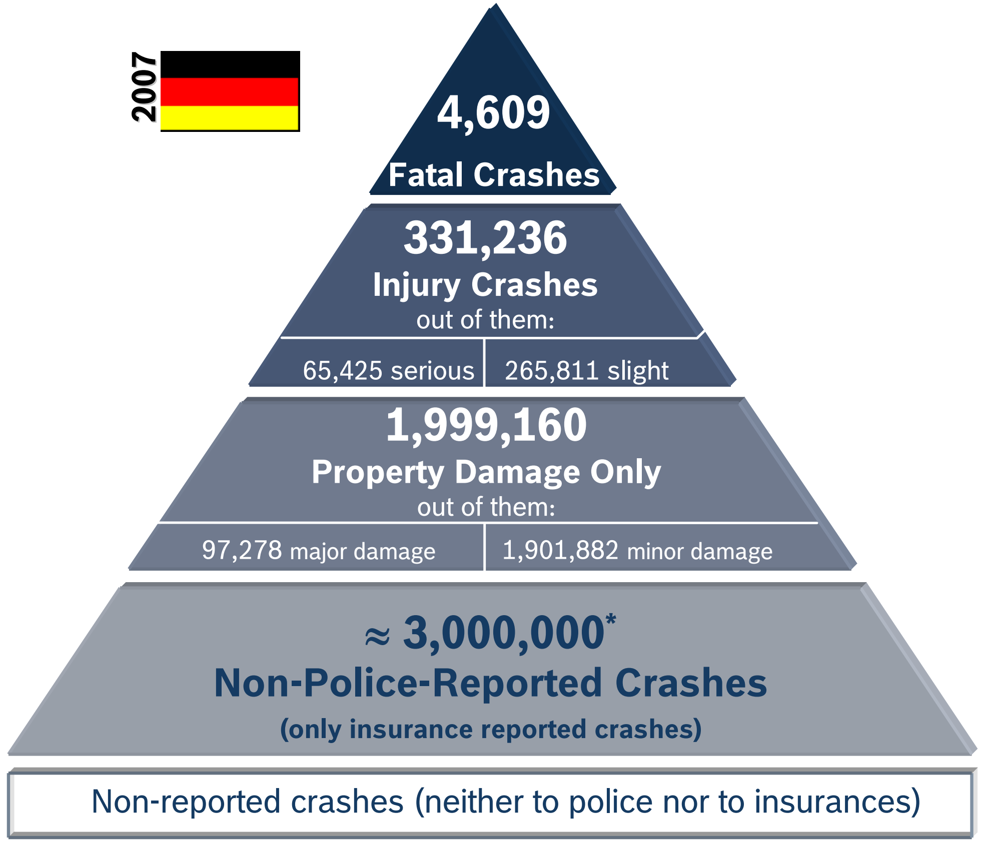
Source: IATSS 2007

BOSCH

Accident figures Japan – Germany (2007)



sources: IATSS, Cabinet Office Japan, SONPO
** 2004
*** 2006



sources: Federal Statistical Office, Germany
* GDV-yearbook (estimation)

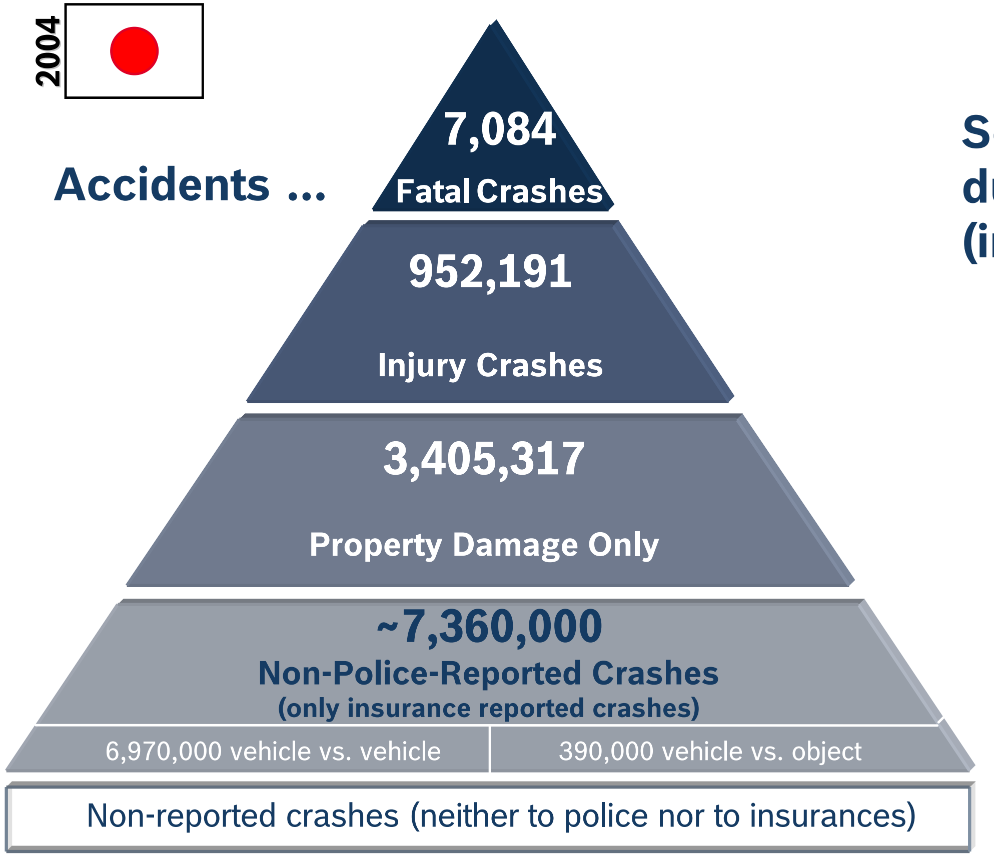
➔ approx. 11.2 million reported crashes in Japan

➔ approx. 5.3 million reported crashes in Germany

Economic losses caused by road traffic accidents

2004

Accidents ...



sources: IATSS, Cabinet Office Japan, SONPO

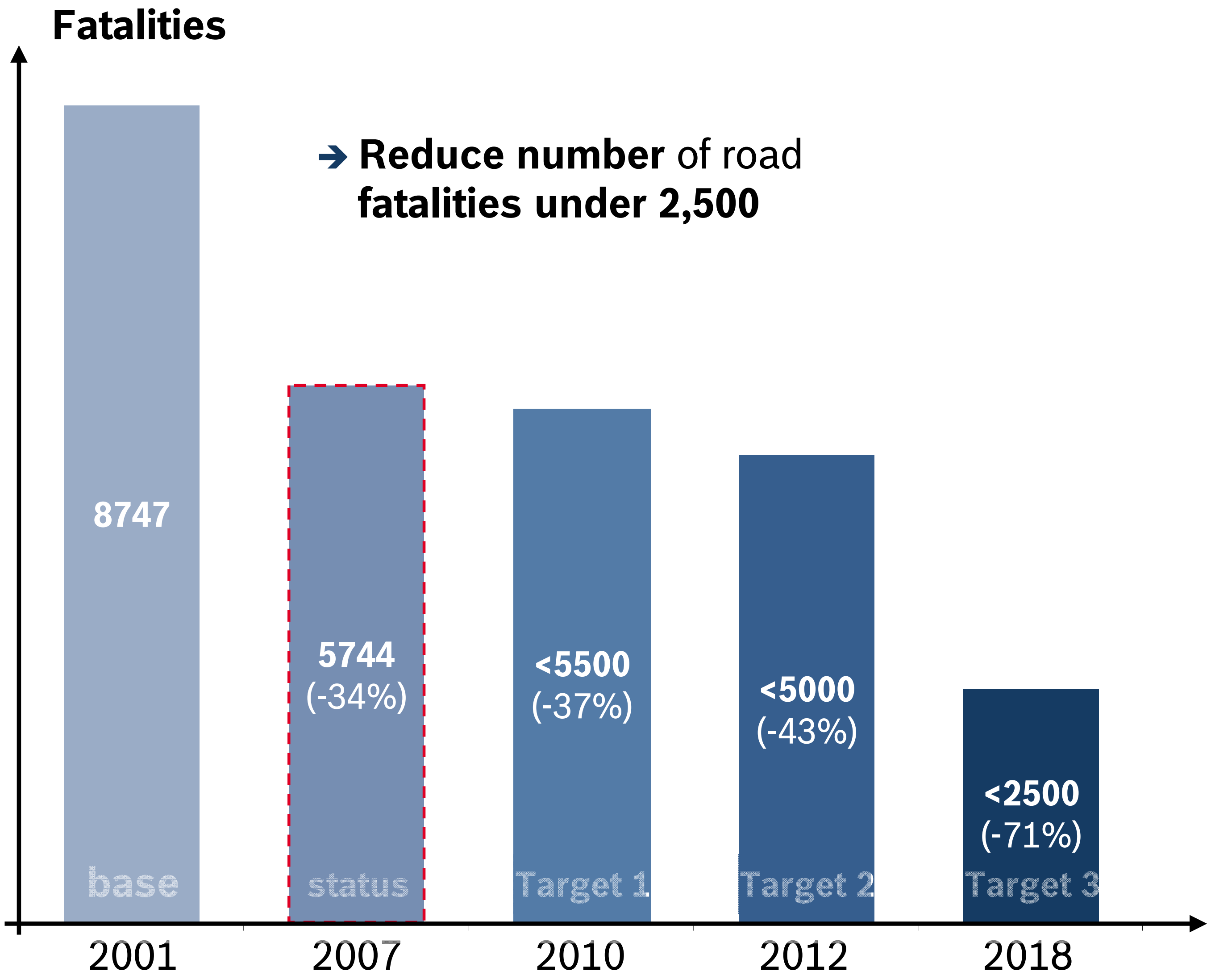
Socio-economic losses due to accidents ... (in Billion Yen)

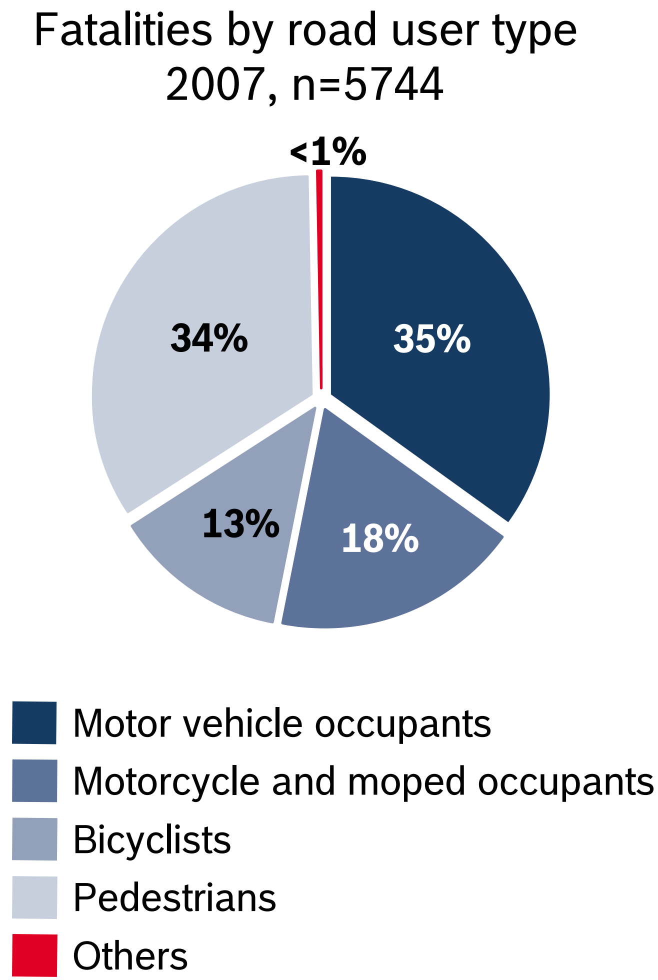
sources: White paper on Traffic safety Japan 2007, Cabinet Office

- ➔ approx. 11.7 million reported crashes in Japan
- ➔ approx. 6,745 billion Yen socio-economic costs due to road traffic accidents

* Death-related losses (non-financial losses, e.g. accident-related pain, suffering, reduced quality of life; calculation based on willingness to pay)
** Personal losses (lost earnings, medical expenses, compensation), *** Employer losses (due to employee's inability to work)

Initiative in road safety – Japan

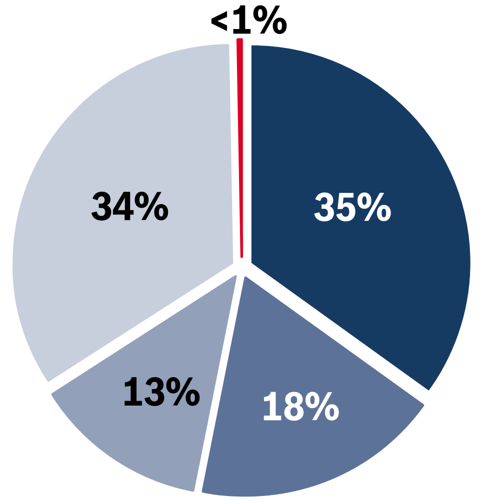




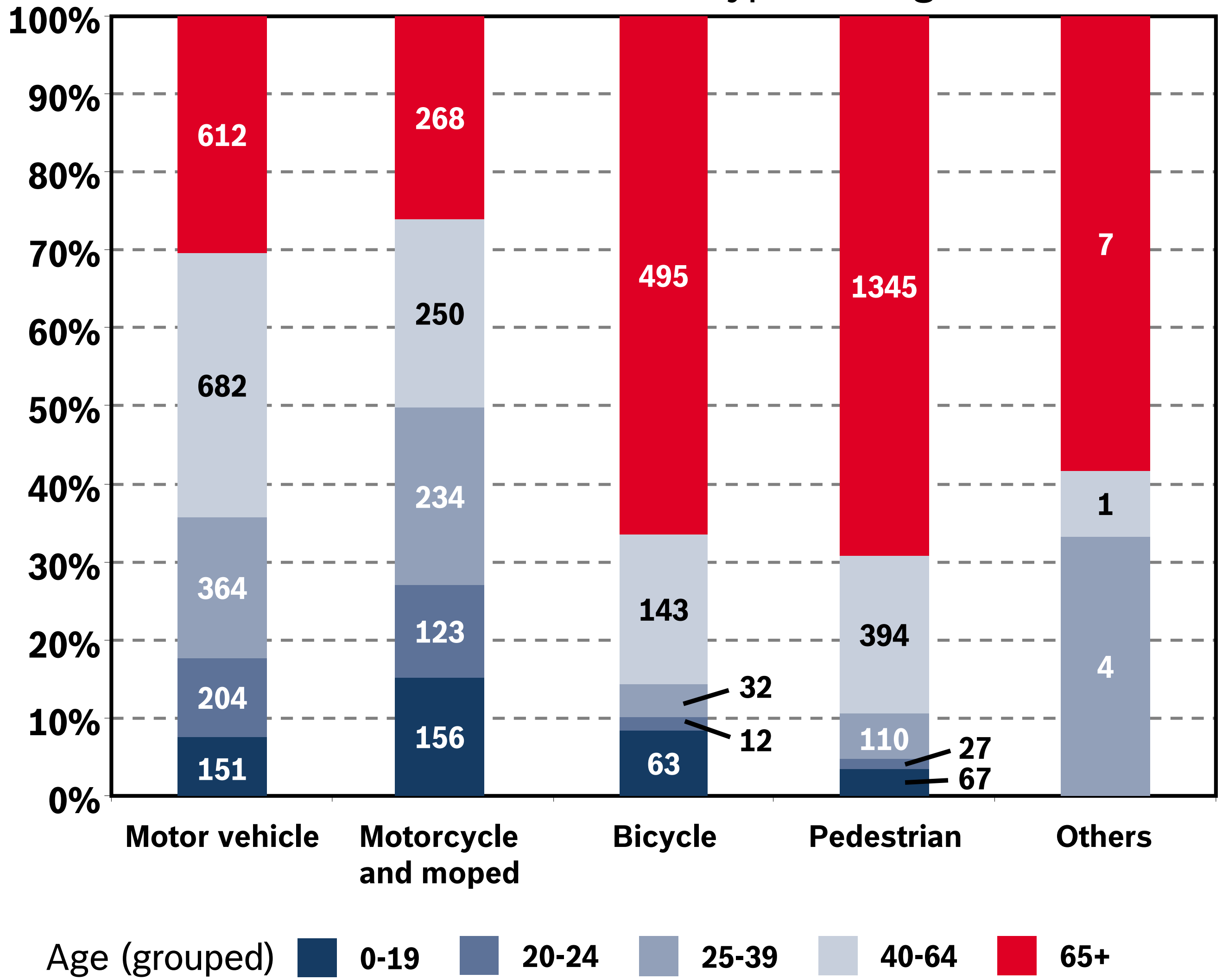
Source: White Paper on Traffic Safety in Japan 2007 and 2009 (jap. version), Cabinet Office.
Japan: fatalities that occur within 24 hours

Fatalities by road user type and age 2007

Fatalities by road user type 2007, n=5744



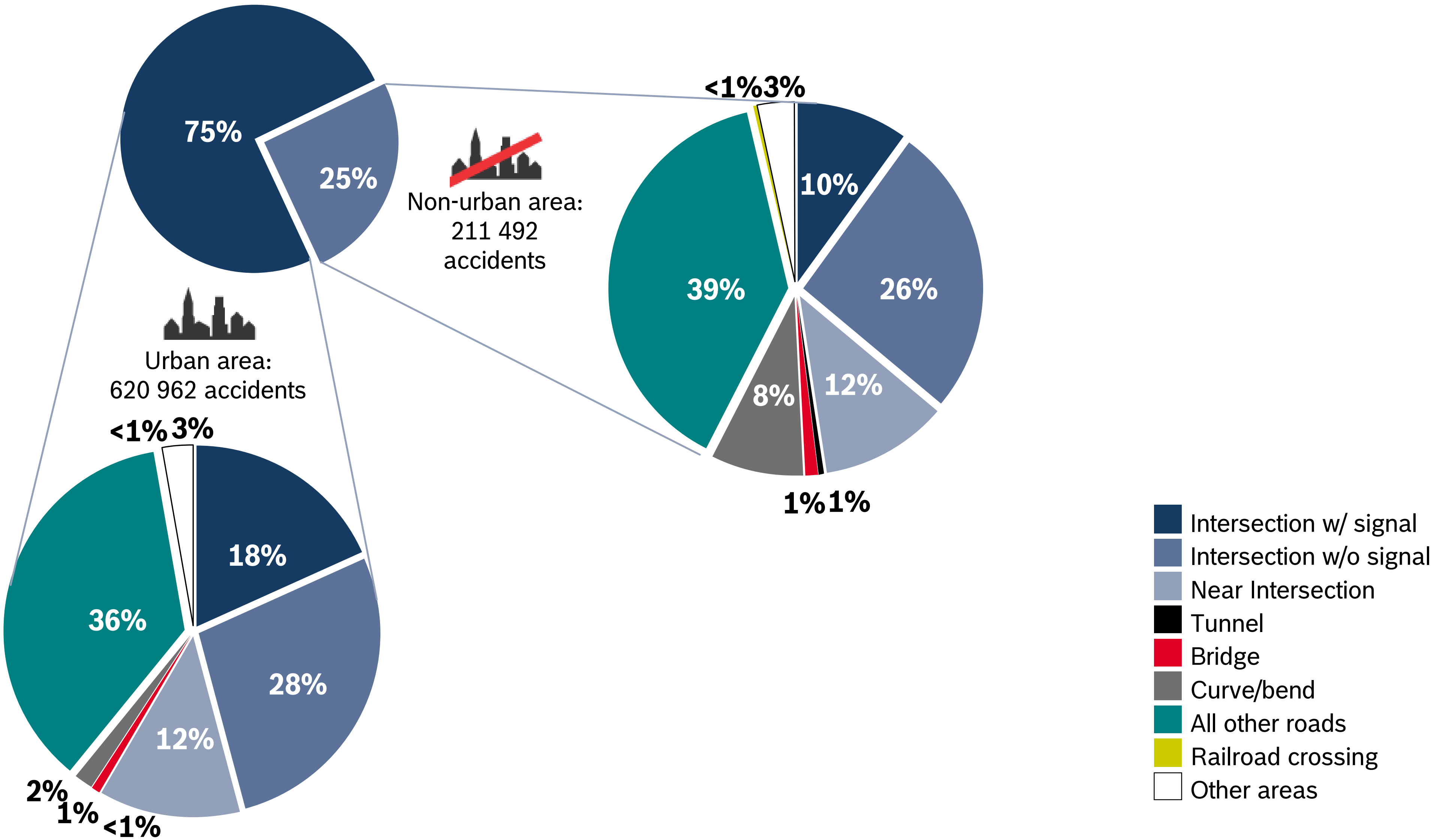
Fatalities road user type and age



Source: IATSS 2007

Accident Situation in 2007 for Japan and Korea

Accidents with casualties by location and road type 2007

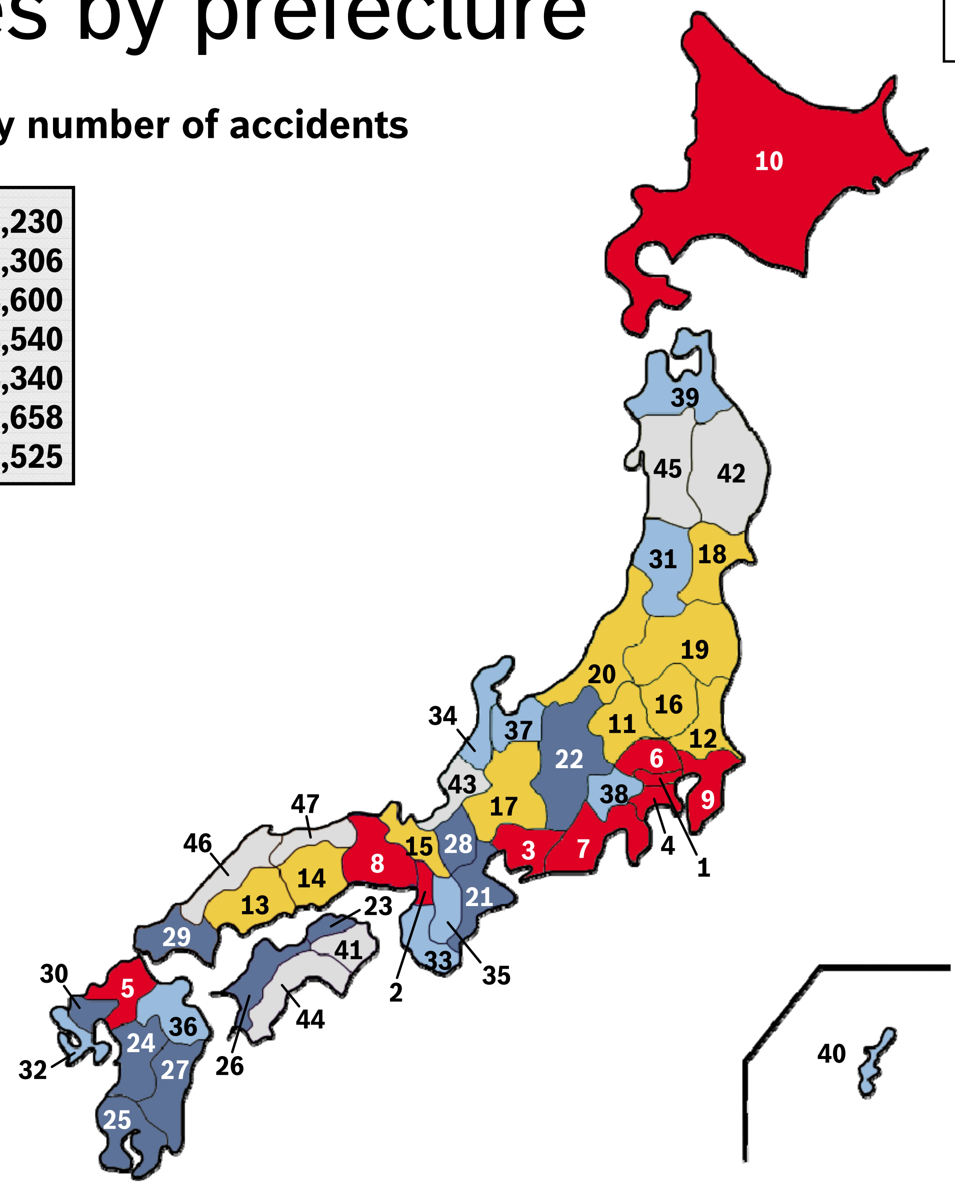


Source: IATSS 2007

Accidents with casualties by prefecture

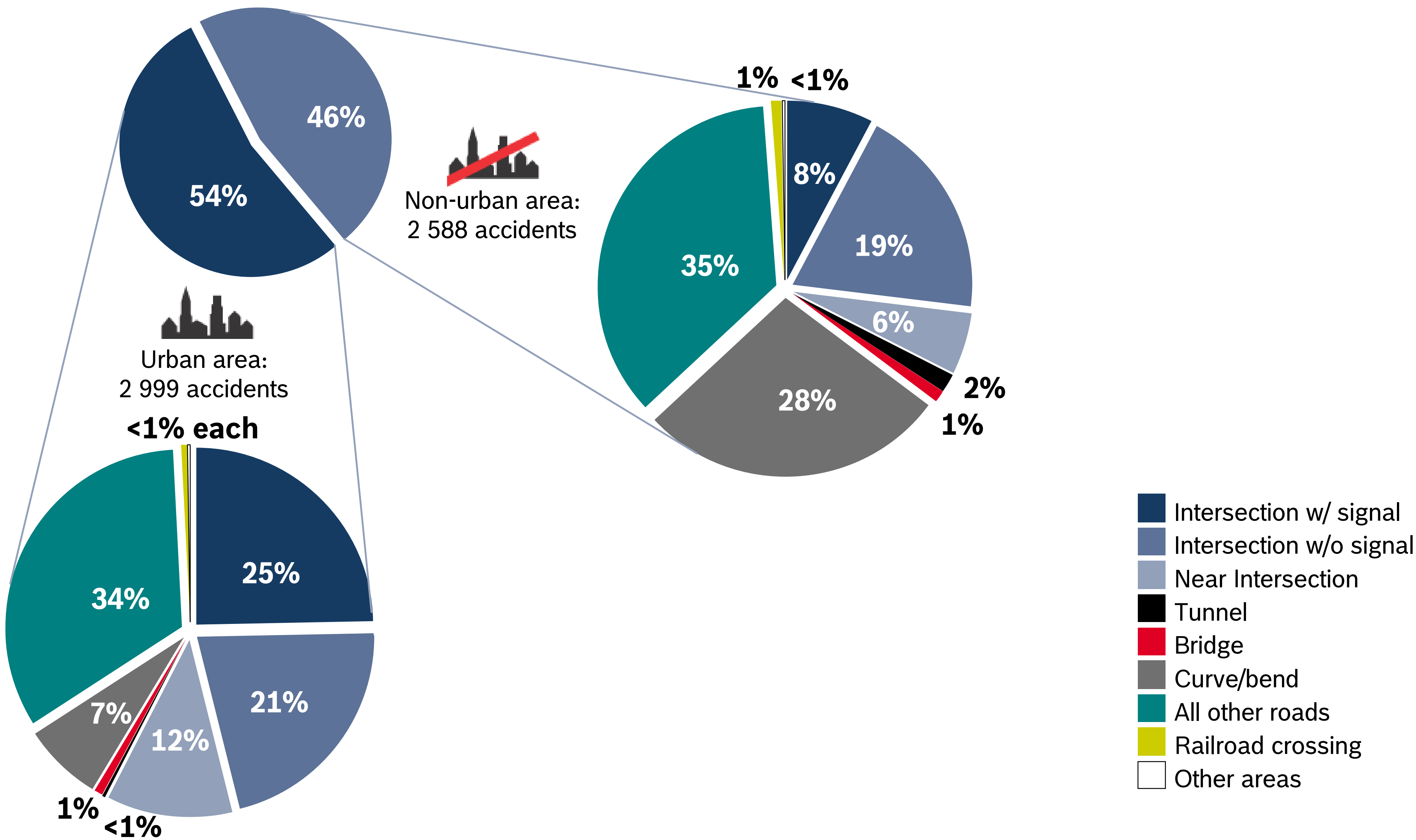
All 47 prefectures of Japan in descending order by number of accidents

1 Tokyo	66,516	21 Mie	41 Tokushima	6,230
2 Osaka	57,387	22 Nagano	42 Iwate	5,306
3 Aichi	54,726	23 Kagawa	43 Fukui	4,600
4 Kanagawa	49,535	24 Kumamoto	44 Kochi	4,540
5 Fukuoka	45,191	25 Kagoshima	45 Akita	4,340
6 Saitama	44,140	26 Ehime	46 Shimane	2,658
7 Shizuoka	38,244	27 Miyazaki	47 Tottori	2,525
8 Hyogo	37,181	28 Shiga		
9 Chiba	30,531	29 Yamaguchi		
10 Hokkaido	23,460	30 Saga		
11 Gunma		31 Yamagata		
12 Ibaraki		32 Nagasaki		
13 Hiroshima		33 Wakayama		
14 Okayama		34 Ishikawa		
15 Kyoto		35 Nara		
16 Tochigi		36 Oita		
17 Gifu		37 Toyama		
18 Miyagi		38 Yamanashi		
19 Fukushima		39 Aomori		
20 Niigata		40 Okinawa		



Source: www.kotsu-anzen.jp

Fatal accidents by location and road type 2007



Source: IATSS 2007

Fatal accidents by prefecture

All 47 prefectures of Japan in descending order by number of accidents

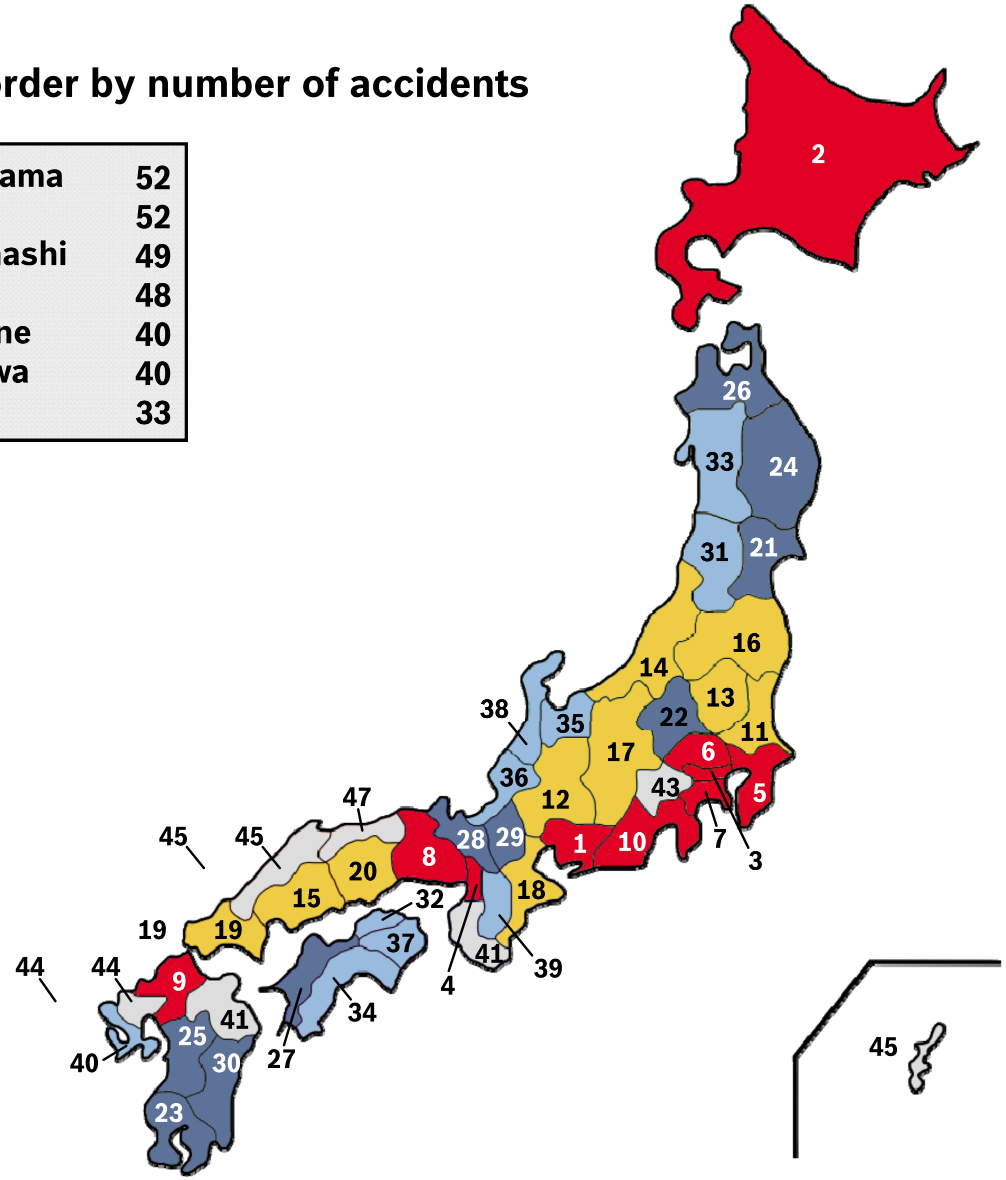
Prefecture	Accidents
1 Aichi	267
2 Hokkaido	259
3 Tokyo	247
4 Osaka	234
5 Chiba	233
6 Saitama	217
7 Kanagawa	212
8 Hyogo	207
9 Fukuoka	193
10 Shizuoka	170

11 Ibaraki
12 Gifu
13 Tochigi
14 Niigata
15 Hiroshima
16 Fukushima
17 Nagano
18 Mie
19 Yamaguchi
20 Okayama

21 Miyagi
22 Gunma
23 Kagoshima
24 Iwate
25 Kumamoto
26 Aomori
27 Ehime
28 Kyoto
29 Shiga
30 Miyazaki

31 Yamagata
32 Kagawa
33 Akita
34 Kochi
35 Toyama
36 Fukui
37 Tokushima
38 Ishikawa
39 Nara
40 Nagasaki

Prefecture	Accidents
41 Wakayama	52
41 Oita	52
43 Yamanashi	49
44 Saga	48
45 Shimane	40
45 Okinawa	40
47 Tottori	33

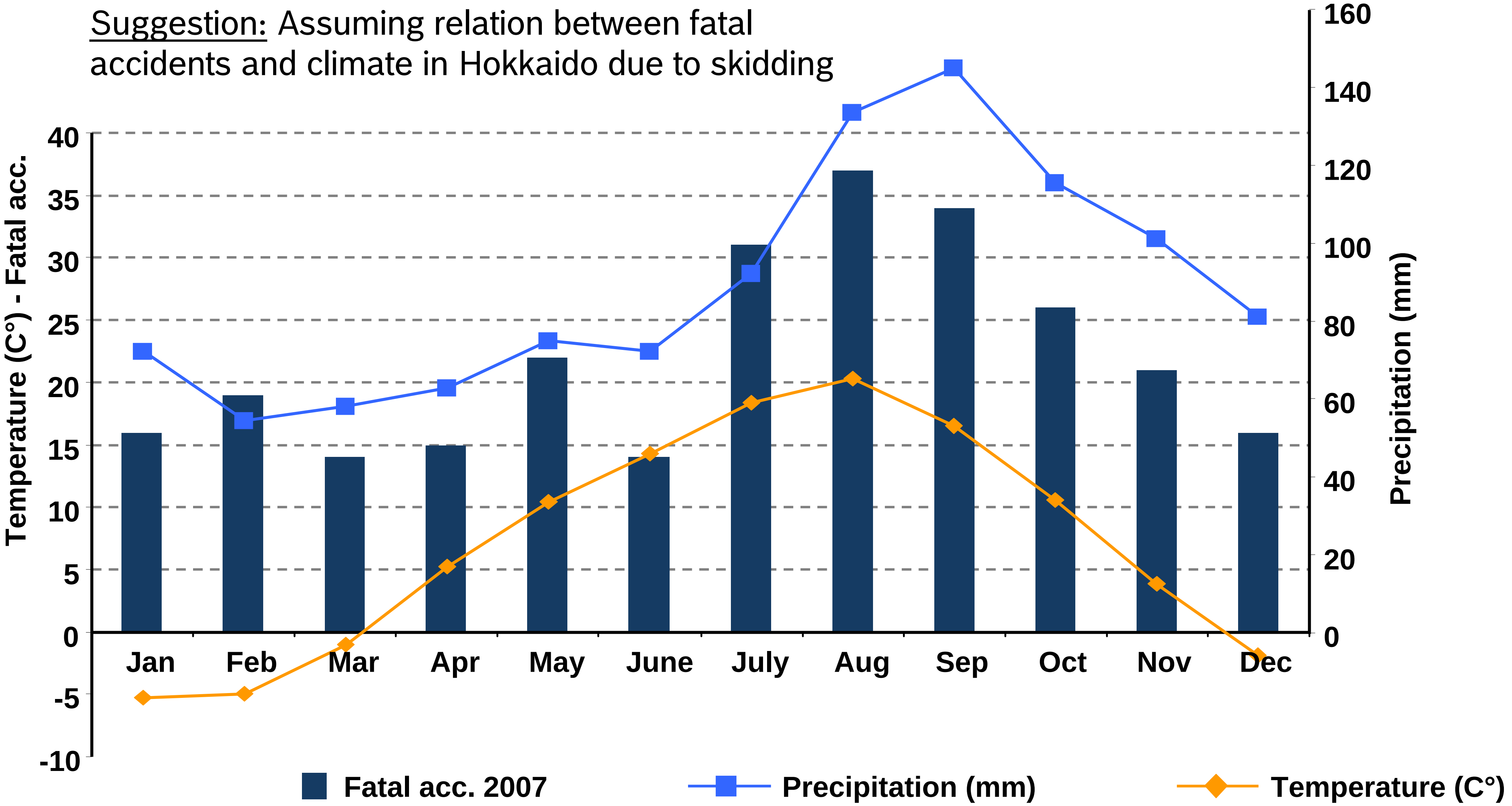


Source: www.kotsu-anzen.jp

BOSCH

Hokkaido – Climate vs. fatal accidents

Suggestion: Assuming relation between fatal accidents and climate in Hokkaido due to skidding



Source: www.kotsu-anzen.jp, Japan Statistical Yearbook 2009, Chapter 1 - Land and Climate

South Korea

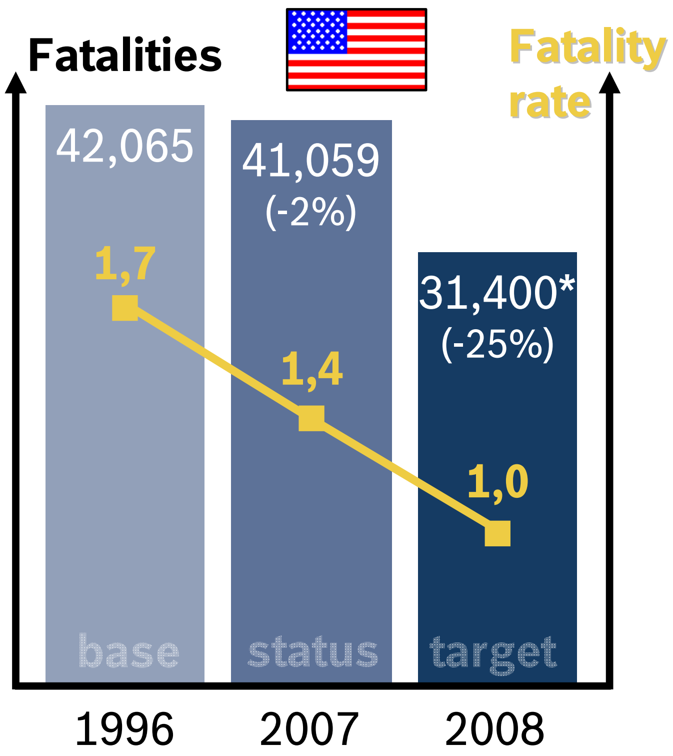
Bosch Accident Research

Accident research CR/AEV1

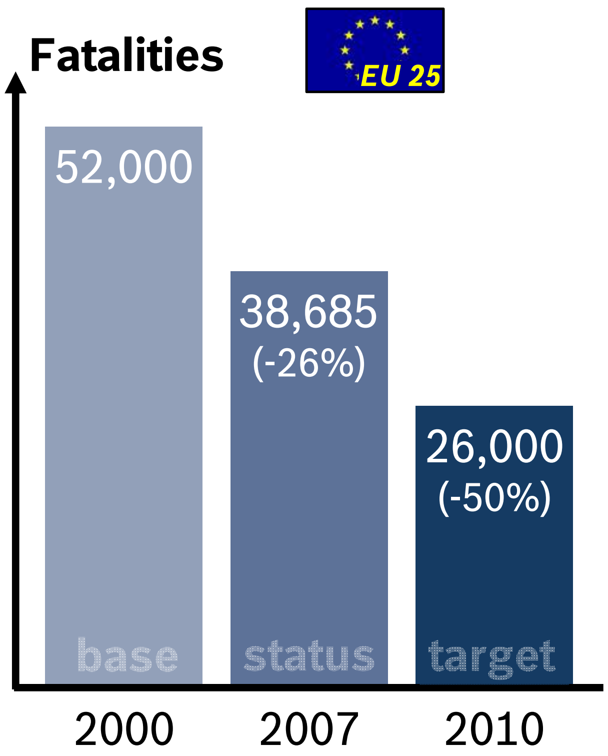
BOSCH

Initiatives in road safety - World

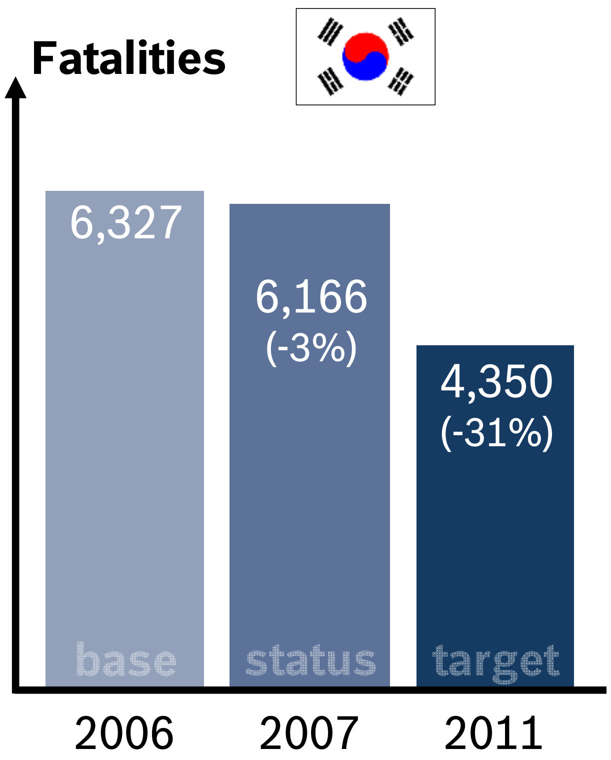
Vision: accident-free driving; status 2007



→ Reduce **fatality rate from 1.7 to 1.0 per 100 million vehicle miles,** Department of Transportation



→ **Halving the number** of road **fatalities** within 10 years, White paper of European transport policy

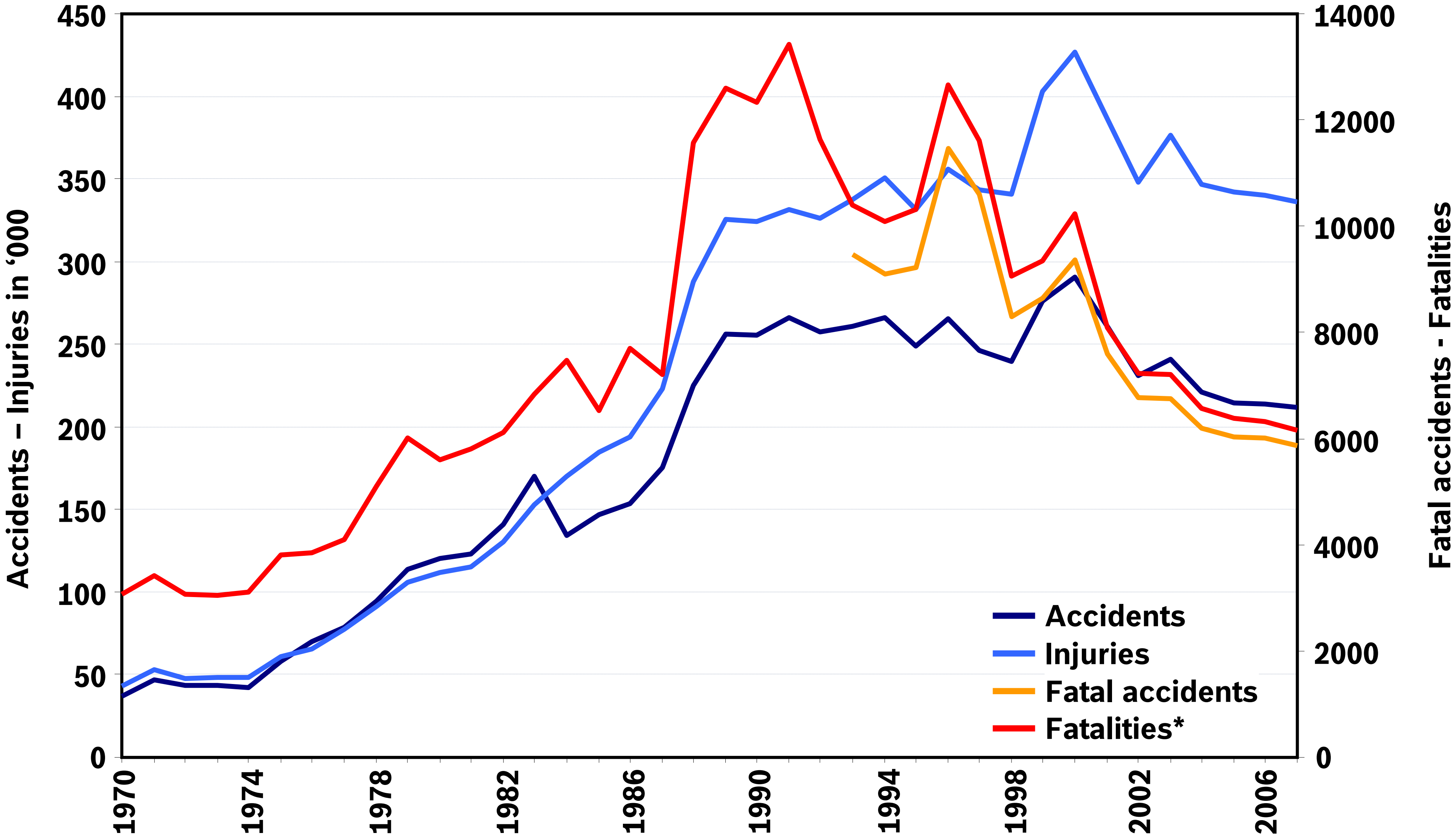


→ **Reduce number** of road **fatalities to 4,350**, National transport safety strategy, Korea

** estimated*

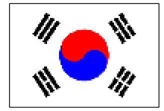
USA, EU 25, Korea: fatalities that occur within 30 days
Sources: FARS, CARE or national publications (EU25), UNESCAP (Korea)

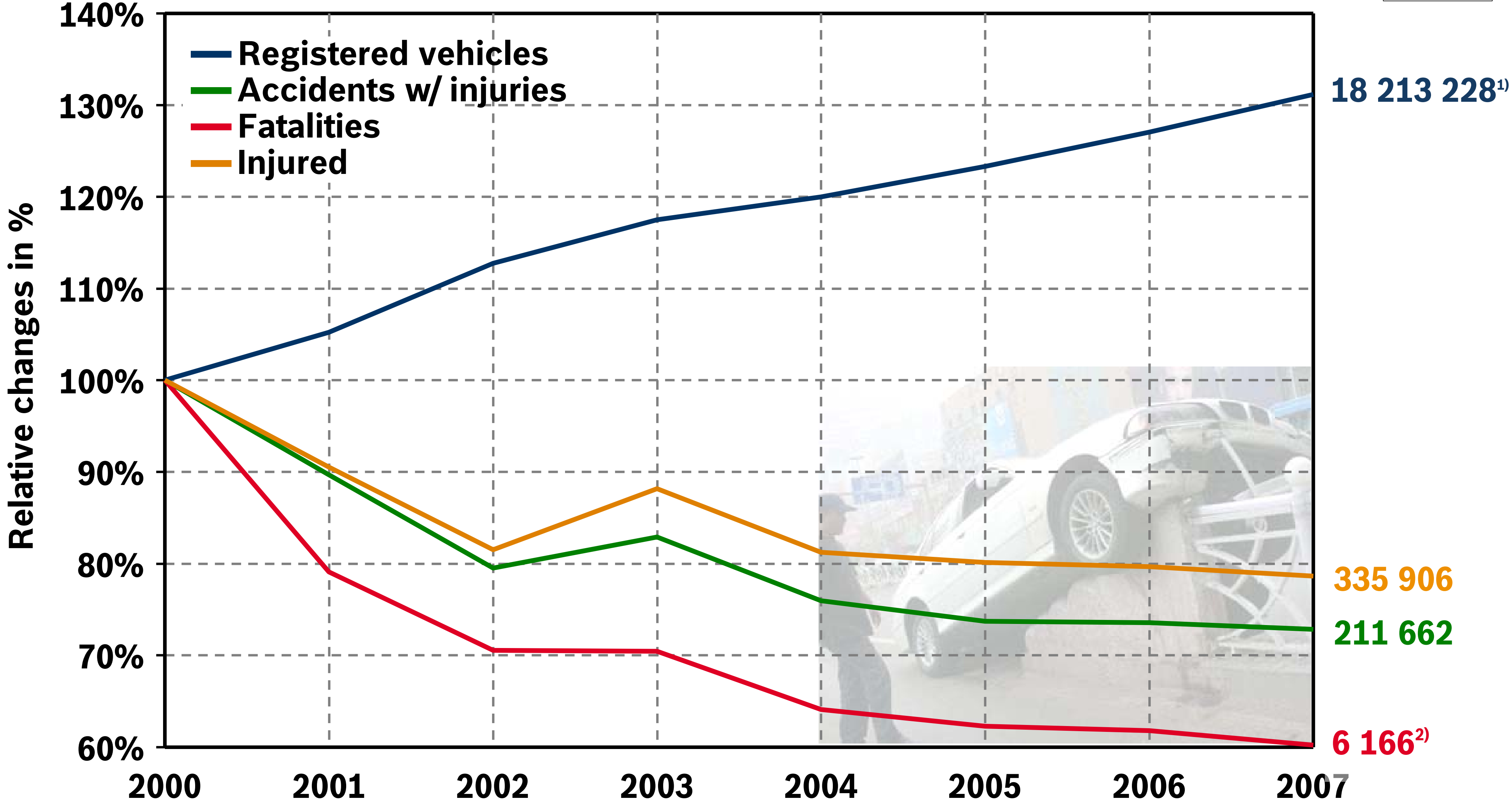
Road Traffic Accidents in Korea 1970-2007



Source: ROTA 2007 * Fatalities that occur within 30 days after accident

Road Traffic Accidents in Korea 1970-2007





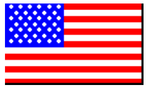
Source: Traffic Accident Analysis Center, Seoul

[1)] Excluding construction equipment and agricultural machinery

[2)] Fatalities that occur within 30 days after accident

Fatal accidents divided in main categories

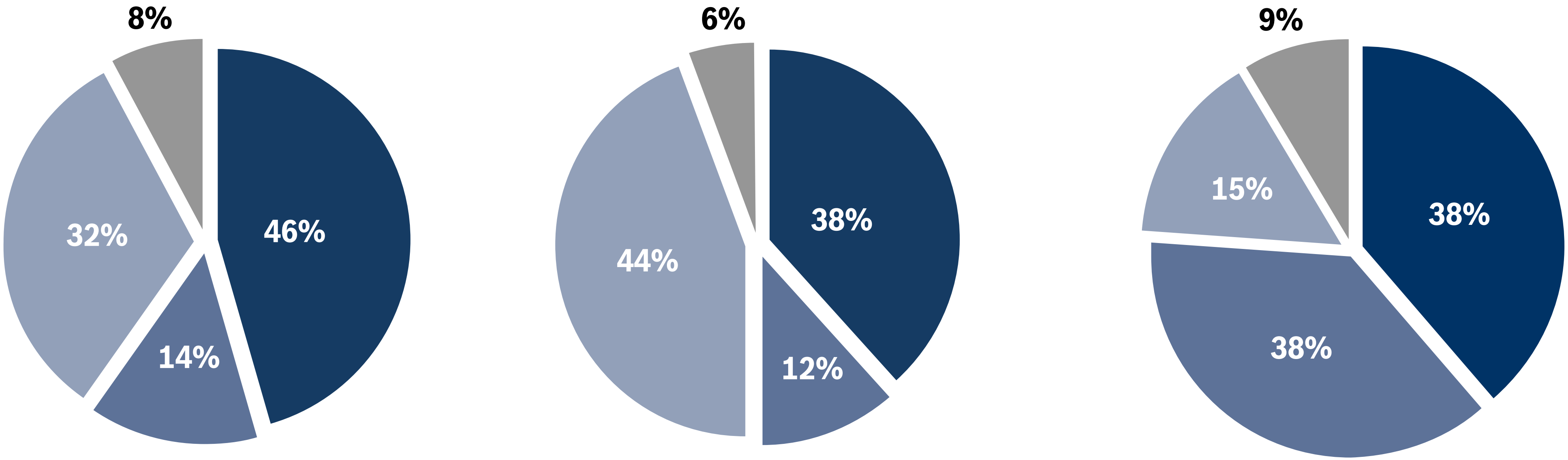
n = 4,609
accidents with fatalities

[1]

n = 37,248
accidents with fatalities

[2]

5,867
accidents with fatalities[3]



main categories:

- vehicle - vehicle
- vehicle - fixed object (off road)
- vehicle - pedestrian
- others (object on road, animal...)

sources: StBA, GIDAS, NHTSA, ROTA, Year 2007

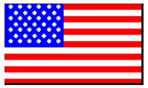
[1] USA: Vehicle to Bicycle - accidents in category „Others"

[2] Korea: Accidents without automobile involvement in category "Others"

[3] Fatalities that occur within 30 days

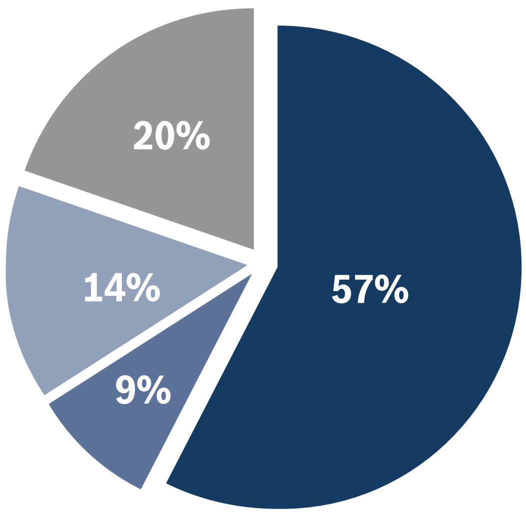
Accidents with casualties divided in main categories

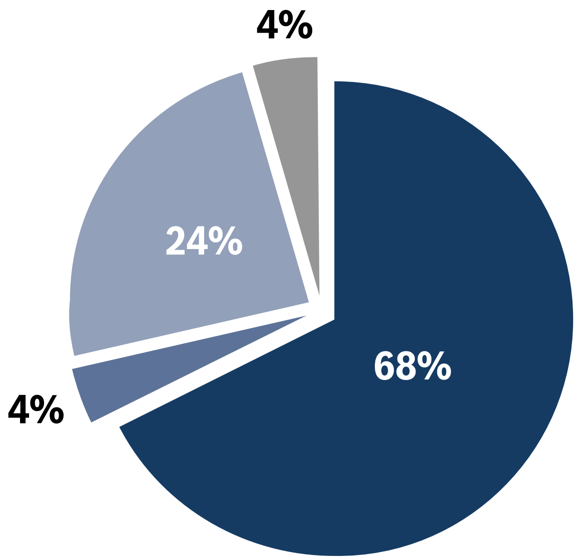
n = 335,845
accidents with casualties

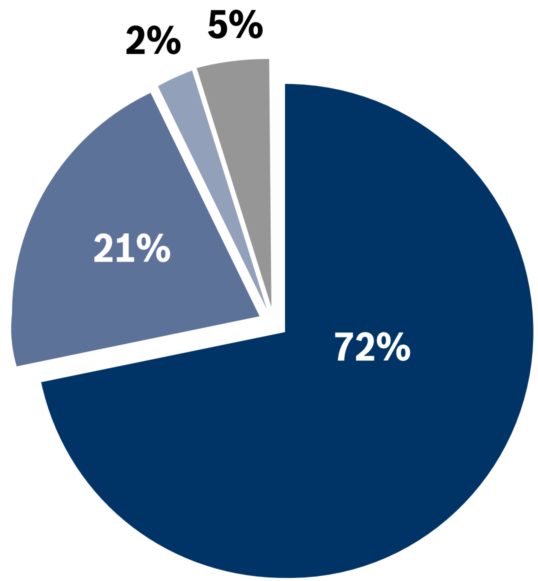


n = 1,748,248
accidents with casualties

211,662
accidents with casualties







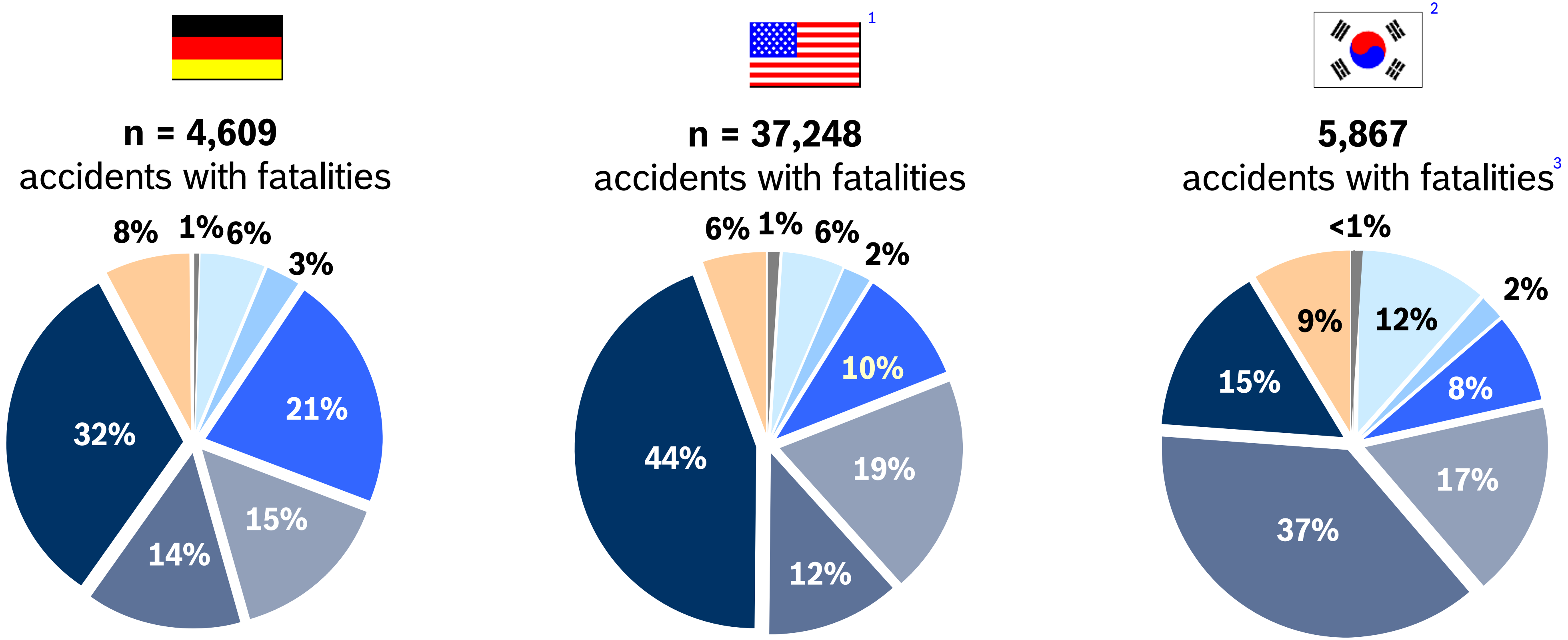
main categories:

- **vehicle - vehicle**
- **vehicle - fixed object (off road)**
- **vehicle - pedestrian**
- **others (object on road, animal...)**

sources: StBA, GIDAS, NHTSA, ROTA, Year 2007

[1] USA: Vehicle to Bicycle - accidents in category „Others“
[2] Korea: Accidents without automobile involvement in category “Others”

Fatal accidents by kinds of accidents



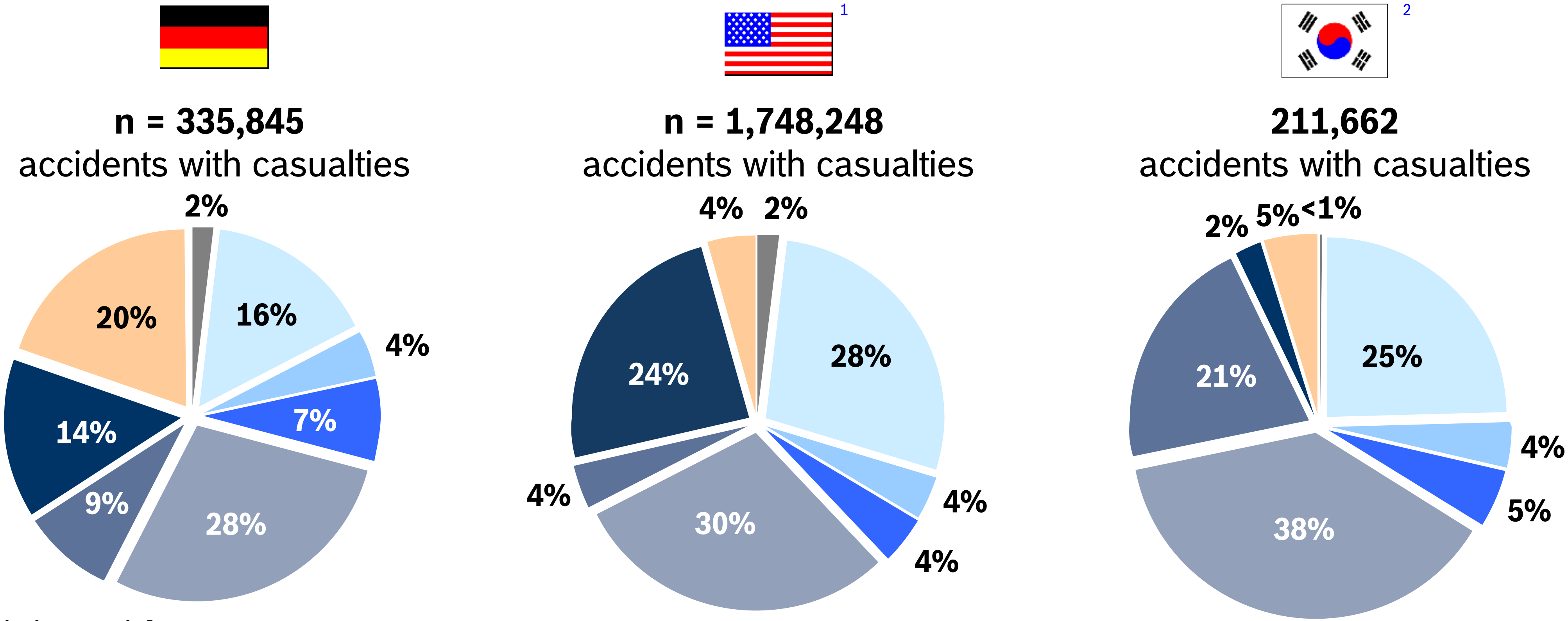
collision with …

- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal …)

sources: StBA, GIDAS, NHTSA, ROTA, Year 2007

[1] USA: Vehicle to Bicycle - accidents in category „Others"
[2] Korea: Accidents without automobile involvement in category "Others"
[3] fatalities that occur within 30 days

Accidents with casualties by kinds of accidents



collision with ...

- **parked vehicle**
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- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal ...)

sources: StBA, GIDAS, NHTSA, ROTA, Year 2007

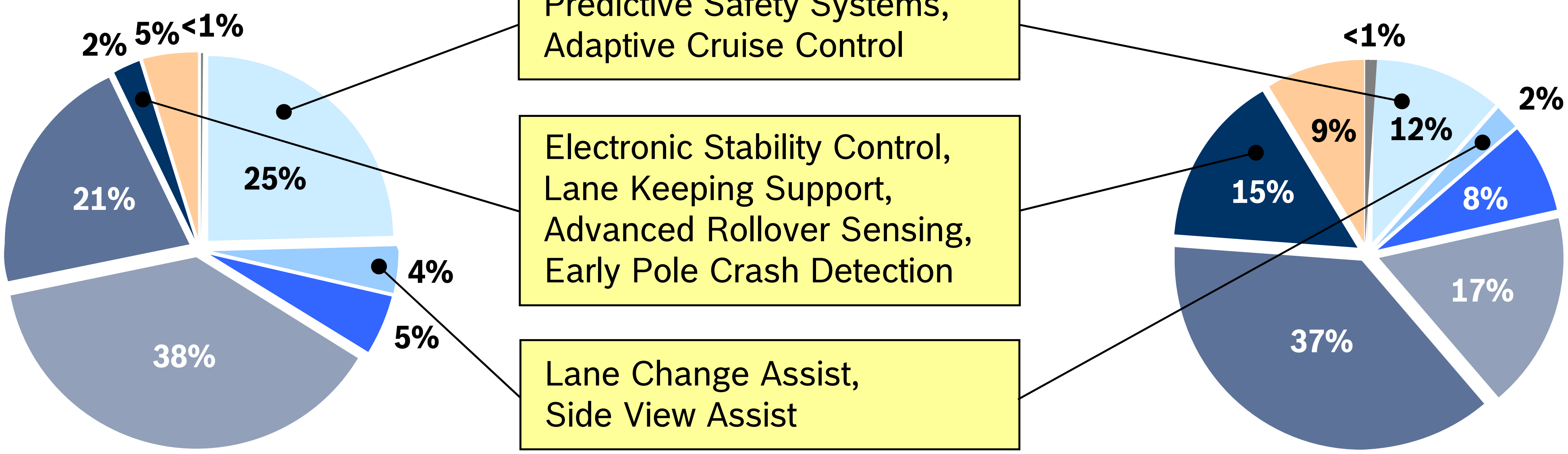
[1] USA: Vehicle to Bicycle - accidents in category „Others“

[2] Korea: Accidents without automobile involvement in category “Others”

Scope of safety functions in Korea (1/2)

accidents with casualties[1]
n = 211,662

accidents with fatalities[1]
n = 5,867[2]



collision with …

- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal …)

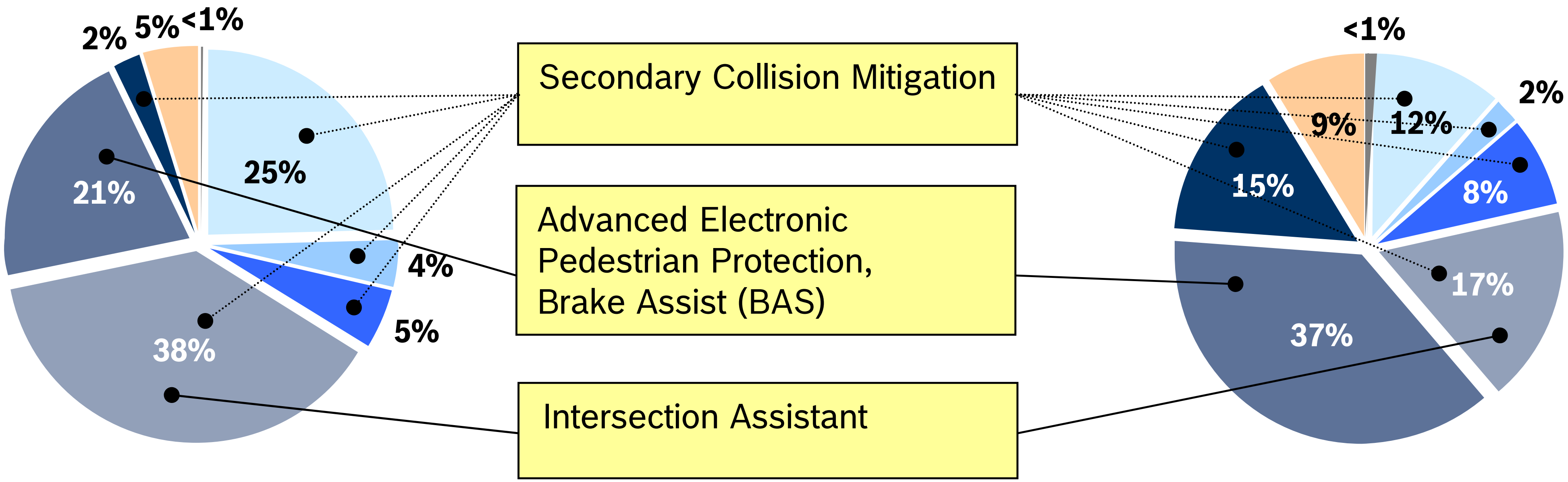
sources: ROTA 2007

[1] Accidents without automobile involvement in category "Others"
[2] Fatalities that occur within 30 days

Scope of safety functions in Korea (2/2)

accidents with casualties[1]
n = 211,662

accidents with fatalities[1]
n = 5,867[2]



collision with ...

- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind**
(unknown, not fixed object, animal ...)

sources: ROTA 2007

[1] Accidents without automobile involvement in category "Others"
[2] Fatalities that occur within 30 days

BOSCH

Information to Project "Assessment of Vehicle Safety Systems"

ASSESS
ASSESSMENT OF VEHICLE SAFETY SYSTEMS

SEVENTH FRAMEWORK PROGRAMME

The ASSESS project has been made possible by a finiancial contribution by the European Commission under Framework Programme .

Overview & Status 2009

Accident Research CR/AEV1

BOSCH

Content

1. Description of Project

Objective and Scope – Participants –Work Plan

2. Status and Outlook

Implemented Work & First Results – Planned Work in 2010

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Objective and Scope

- ➔ development of a relevant set of test and assessment methods applicable to a wide range of integrated vehicle safety systems
- ➔ in order to generate suitable assessment methods, procedures will be developed for driver behavior evaluation, pre-crash system performance evaluation, crash performance evaluation and socio economic assessment
- ➔ proposed set of test and assessment methods will be evaluated on the basis of actual safety systems currently offered on the market

- ➔ duration: 42 months (start: 1st July 2009)
- ➔ total budget: ~ 5.4 M€ (~3.6 M€ public funding from FP7 EC)
- ➔ budget of Bosch: ~126 T€ (~68 T€ public funding from FP7 EC)
- ➔ website: http://www.assess-project.eu

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Participants

FTSS, BASt, Bosch, Chalmers, Daimler, IDIADA, PSA, TNO, TOYOTA, TRL, TRW, Uniresearch, TUG, CEESAR,UOC

Members in Supervisory Board

Industry

- Prof. Dr. Schöneburg (Head of Passenger Car Safety Development, Daimler)
- Dr. Strutz (Head of Passenger Car Safety Development, VW)
- Mr. B. Niclot (Head of Advanced Engineering / Chassis Systems and Active Safety, PSA)
- Mr. J. Ivarsson (Manager for Safety Strategy and Requirements, Volvo)
- Mr. Kropf (Vice President Advanced Engineering and Vehicle Motion & Safety, Robert Bosch)

Research/preparation of protocols & regulations

- Mr. Pierre Castaing (Manager Road Safety Section, UTAC
- Prof. A. Seeck (Head of Division Automotive Engineering, BASt)

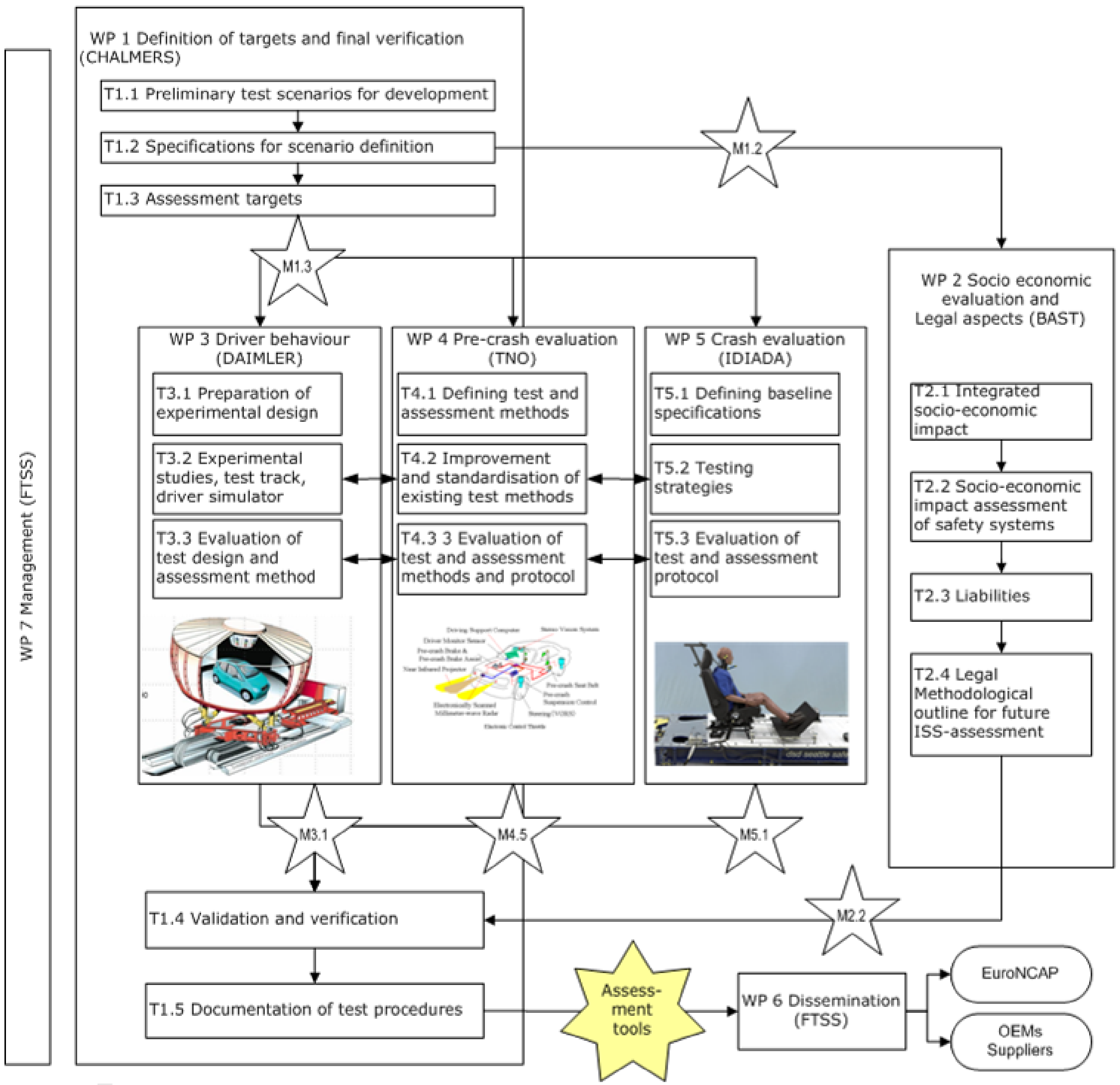
Regulatory/NCAP

- Dr. Michiel van Ratingen (Secretary General EuroNCAP)
- Mr. Ian Jarnold* (Department for Transport WP29 member)

*at the moment not confirmed

Work Plan

Overview Project Structure



Information to the work packages:

WP1*: Identification of possible test scenarios (including information to test conditions, i.e. speeds and environment, i.e. road) based on accident data and Field Operational Tests (FOT)

WP2: Development of analytical framework for determining the socio-economic impact of safety systems + development of methodological approach to evaluate legal and liability effects

WP3: Investigation of driver behavior in relation to an integrated safety system and evaluation of assessment methodologies concerning system performance and related behavioral aspects

WP4: Supply of final proposal of a test and assessment protocol for the pre-crash assessment of integrated safety systems

WP5: Generation of a complete guide for the evaluation of the crash performance of pre crash systems

WP6: Exchange of information between industry, research partners and relevant stake holders

WP7: Coordination of the project

*support of Bosch mainly in this work package (time period of WP1: 2009 and 2010)

Content

1. Description of Project
   Objective and Scope – Participants –Work Plan

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   Implemented Work & First Results – Planned work in 2010

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Implemented Work & First Results

- ➔ Work from task 1.1 of work package 1 is finished
- ➔ Previous research projects which contain issues important for the ASSESS project *(like APPROSYS, AEBS, PReVENT, PReVAL, TRACE, eIMPACT, CHAMELEON, SAFETY TECHNOPRO, eVALUE, NDS)* are collected and sumed up (for detailed information, please see in deliverable D1.1)
- ➔ For accident analyses national databases (STATS19, *Great Britain*, STRADA, *Sweden*) and in-depth data (GIDAS, *Germany*, OTS, *UK*) are used
- ➔ Only accidents with injuries involving at least one car are used
- ➔ The necessary attributes for the analyses of the used databases are harmonized, as an example the newly defined groups of the accident type are given:

  Type 1a: Driving accident – single vehicle
  Type 1b: Driving accident – multiple vehicles
  Type 2&3: Accidents with turning vehicle(s) or crossing paths in junction
  Type 4: Accident involving pedestrian(s)
  Type 5: Accidents with parked vehicles
  Type 6a: Accidents in longitudinal traffic – same direction
  Type 6b: Accidents in longitudinal traffic – opposite direction
  Type 7a: Other accident type – single vehicle
  Type 7b: Other accident type – multiple vehicles

➔ Accident Type[1)] Distribution

Accident type frequency	Type 1a: Driving accident – single vehicle	Type 1b: Driving accident – multiple vehicles	Type 2&3: Accidents with turning vehicle(s) or crossing paths in junction	Type 4: Accident involving pedes-trian(s)	Type 5: Accidents with parked vehicles	Type 6a: Accidents in longitudinal traffic – same direction	Type 6b: Accidents in longitudinal traffic – opposite direction	Type 7a: Other accident type – single vehicle	Type 7b: Other accident type – multiple vehicles
GIDAS	13%	5%	38%	7%	3%	21%	3%	4%	6%
OTS	24%	-	31%	9%	2%	10%	21%	3%	-
STRADA	29%	-	28%	8%	2%	19%	7%	8%	-

➔ the occurring injuries in accidents are considered by weighting the accidents with a factor which is based on injury costs; the assigned factor is built with the following formula: *Number of slightly injured persons· 0.011 + Number of seriously injured persons · 0.11 + Number of fatalities · 1*

➔ Accident Type[1)] Distribution weighted with injury cost factors and ranking of the accident types concerning their occurring frequencies

Accident type frequency	Type 1a: Driving accident – single vehicle	Type 1b: Driving accident – multiple vehicles	Type 2&3: Accidents with turning vehicle(s) or crossing paths in junction	Type 4: Accident involving pedes-trian(s)	Type 5: Accidents with parked vehicles	Type 6a: Accidents in longitudinal traffic – same direction	Type 6b: Accidents in longitudinal traffic – opposite direction	Type 7a: Other accident type – single vehicle	Type 7b: Other accident type – multiple vehicles
GIDAS	23% (1*)	10% (4)	27% (2)	8% (5)	1% (8)	15% (3)	6% (6)	5% (-*)	4% (7)
OTS	31% (1)	-	22% (3)	13% (4)	1% (7)	9% (5)	22% (2)	2% (6)	-
STRADA	34% (1)	-	22% (2)	7% (5)	1% (7)	11% (4)	19% (3)	6% (6)	-

* for ranking accident of type 1a) and type 7a) are considered together in GIDAS

1) groups as defined on previous slide

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Status and Outlook

➔ Ranking of the accident types[1)] by injury costs for injury accidents

Rank	Accident type
1	Type 1a: Driving accident - single vehicle
2	Type 2&3: Accidents with turning vehicle(s) or crossing paths in junction
3	Type 6b: Accidents in longitudinal traffic - opposite direction
4	Type 6a: Accidents in longitudinal traffic - same direction
5	Type 4: Accidents involving pedestrians

relevant accident scenarios for pre-crash systems

➔ Ranking of the accident types[1)] and first impact point[2)] by injury costs for injury accidents

Rank	GIDAS	OTS
1	Front impact in Type 2&3	Rear impact in Type 6a
2	Rear impact in Type 6a	Front impact in Type 2&3
3	Side impact in Type 2&3	Front impact in Type 6a
4	Front impact in Type 6a	Front impact in Type 1

1) groups as defined on previous slide
2) the information about accident type and impact point together is only available in GIDAS and OTS

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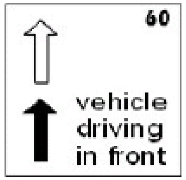
Planned Work in 2010

➔ To the ranked accident scenario more detailed information is provided for specifying test scenarios. This information is given by providing the distribution of the 2-digit code accident types.

<u>Example:</u>



60 – conflict between a vehicle and another vehicle driving in front on the same lane.

➔ Based on the information about the accident types coded with 2-digit test scenarios will be defined

➔ For specifying the defined test scenarios concerning additional attributes like speeds, collision angles, ... the accident databases are analyzed and distributions of necessary variables are provided.

Joint Study for Determination of Safety Potentials for Vans

Gemeinschaftsprojekt Sicherheit von Kleintransportern

Status October 2009

Raimondo Sferco/Roland Schäfer (Ford)

Joachim Scheerer (Daimler)

Andreas Georgi (Bosch)

Walter Niewöhner (DEKRA)

Dr. Matthias Kühn/Jenö Bende (UDV)

Project Description

- **Goal:**
  - Determination of reasonable measures to increase safety of vans
- **Partners:**
  - Unfallforschung der Versicherer (UDV)
  - Verband der Automobilindustrie (VDA)
  - DEKRA
  - BASt
- **Funding:**
  - By project partners
- **Duration:**
  - Phase I runs until May 2010
  - Optional phase II depends on findings of phase I

Project Description

- **Content:**
  - Aspects of active and passive safety
  - Consideration of self- and partner protection including driver aspects
- **Project description**
  - Phase I:
    - Literature survey incl. analysis of political, legal and consumer aspects
    - Analysis by using accident databases (UDV, GIDAS, DEKRA, etc.)
    - Analysis of accident situation and determination of countermeasures
    - Assessment of countermeasures regarding safety potential
  - Phase II:
    - Optional phase II depends on findings of phase I

Project Description

- **Work packages and changed time table:**

		10/ 08	11/ 08	12/ 08	01/ 09	…	07/ 09	08/ 09	09/ 09	10/ 09	11/ 09	12/ 09	01/ 10	02/ 10	03/ 10	04/ 10	05/ 10
AP1	Bewertende Literaturstudie																
AP2	Erfassung/Auswertung der Unfalldaten																
AP3	Ableitung/Definition von Maßnahmen																
AP4	Analyse des Sicherheitspotentials																
AP5	Übertragbarkeit/Anwendbarkeit der Ergebnisse auf Europa																
AP6	Zusammenführung der Ergebnisse und Maßnahmenempfehlung																

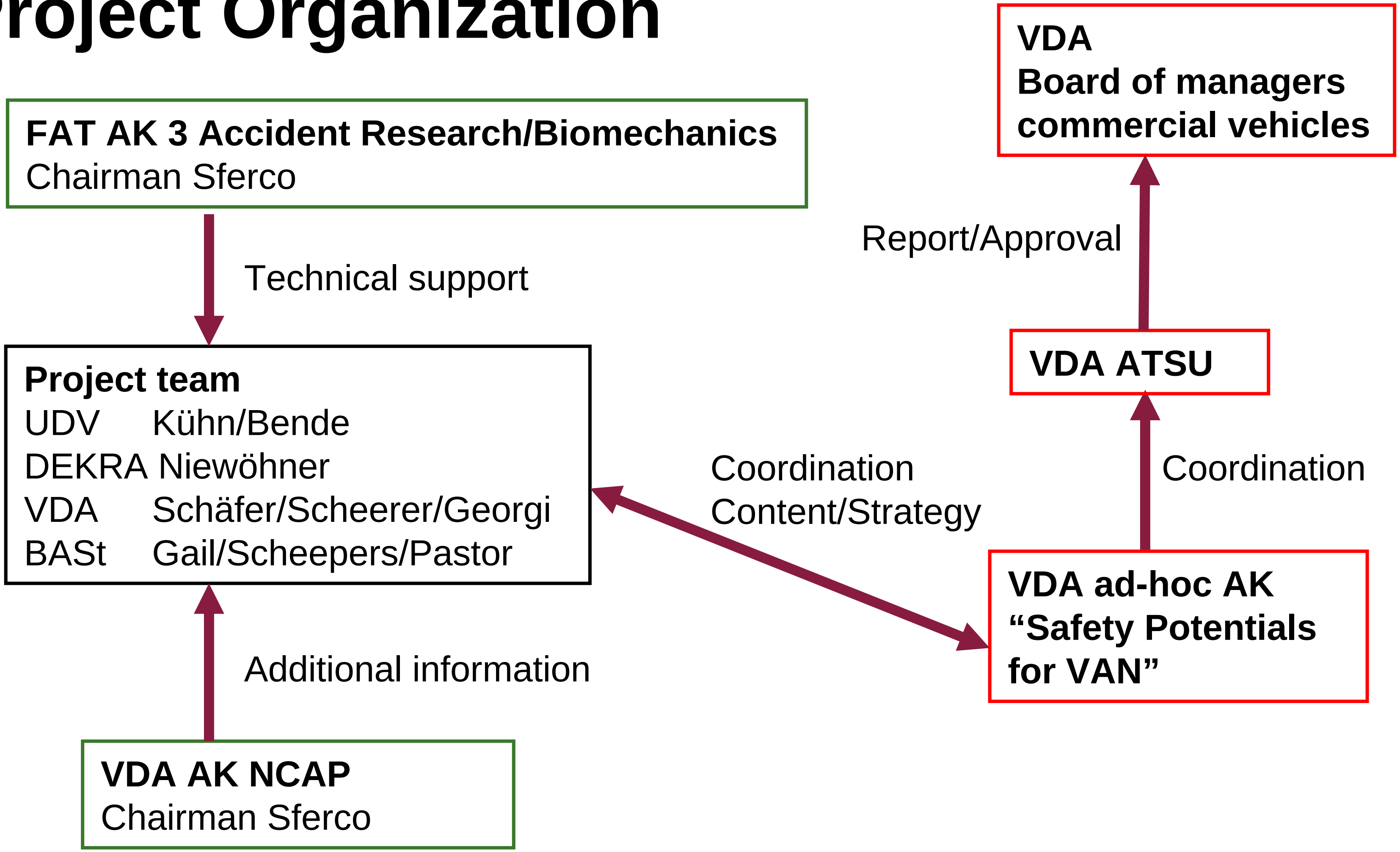
Data Sources / Databases (DB)

	GIDAS	nat./internat. Statistics	UDV-DB	DEKRA-DB	OEM-DB
Responsible	VDA	DEKRA/BASt	UDV	DEKRA	VDA
Support	Ford VW Daimler Bosch BASt	DEKRA Ford (Stats19) BASt Daimler Bosch			Daimler VW Ford

In Depth Databases

	GIDAS	UDV	DEKRA
Area of investigation	around Hanover + Dresden	Germany	Germany
Excluding days/times	none	none	none
Selection criteria	at least one injured person	at least one injured person + costs of at least 15,000 €	mainly accidents with injured persons, possible damage only accidents, order given by police (indicates higher accident severity)
Representativeness	representative	representative in relation to the costs	representative in relation to heavy accident (high accident severity)
Collected information	2,000	300	800
Included cases	~18,000	~4,000	~2,500
Comments	detailed information regarding injuries + reconstruction	detailed information regarding accident costs	detailed information regarding reconstruction

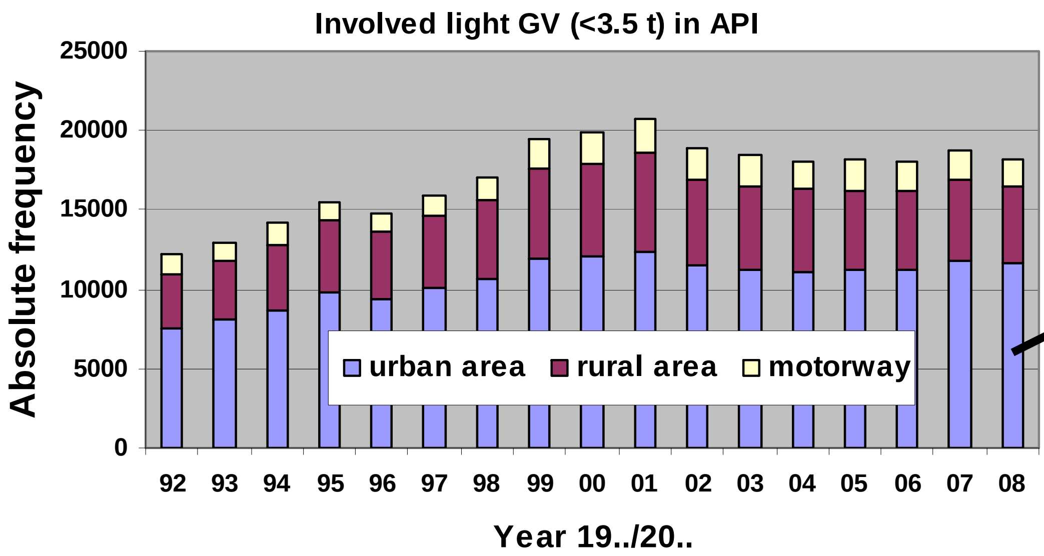
Project Organization

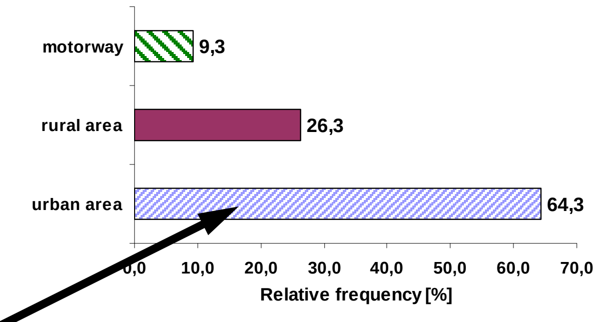


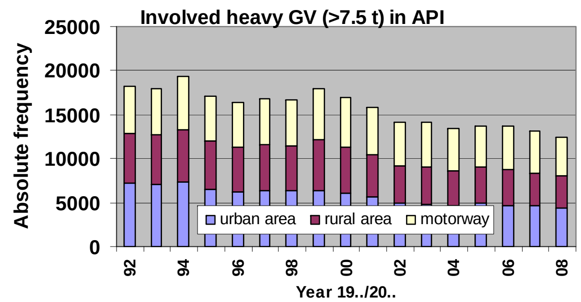
Official Accident Statistics of Germany

BAST, Federal Road Research Institute, Germany
DEKRA

Germany - Accident Statistics



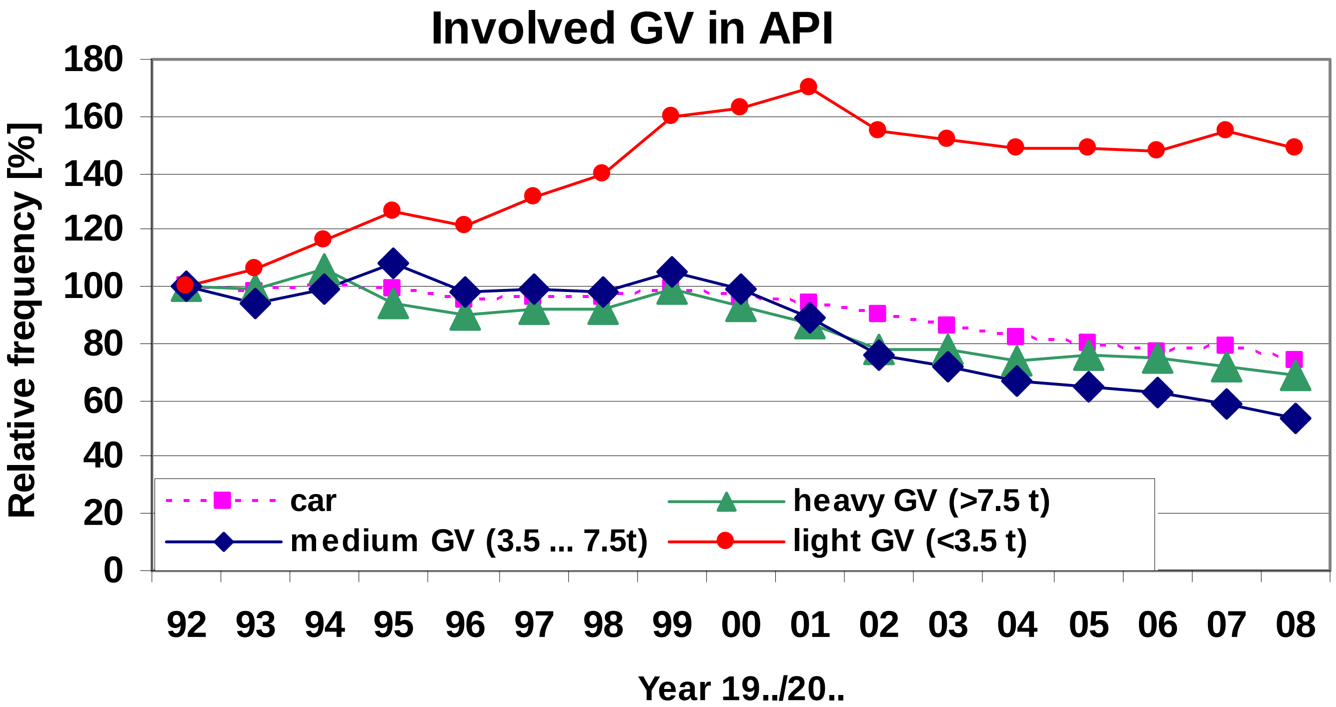




API – accident with personal injury
GV – goods vehicles

Source: StBA

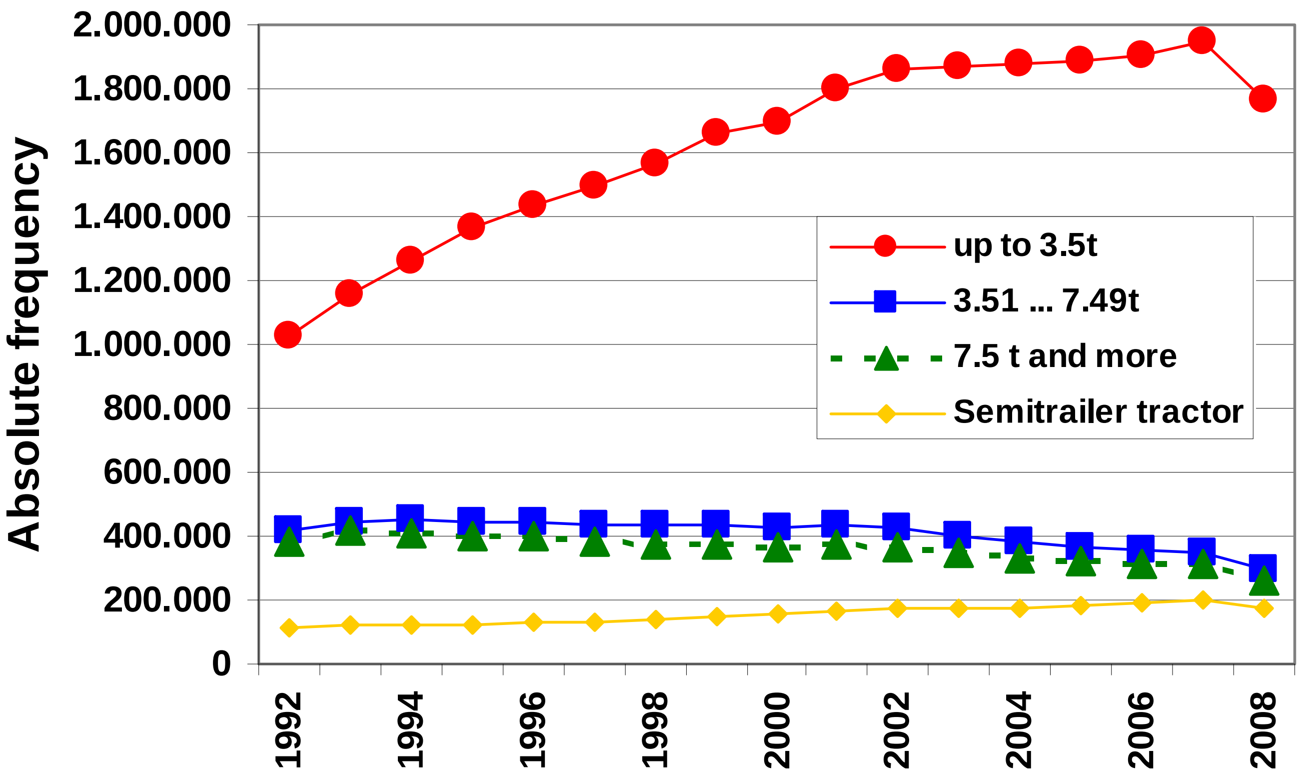
Germany - Accident Statistics



API – accident with personal injury
GV – goods vehicles

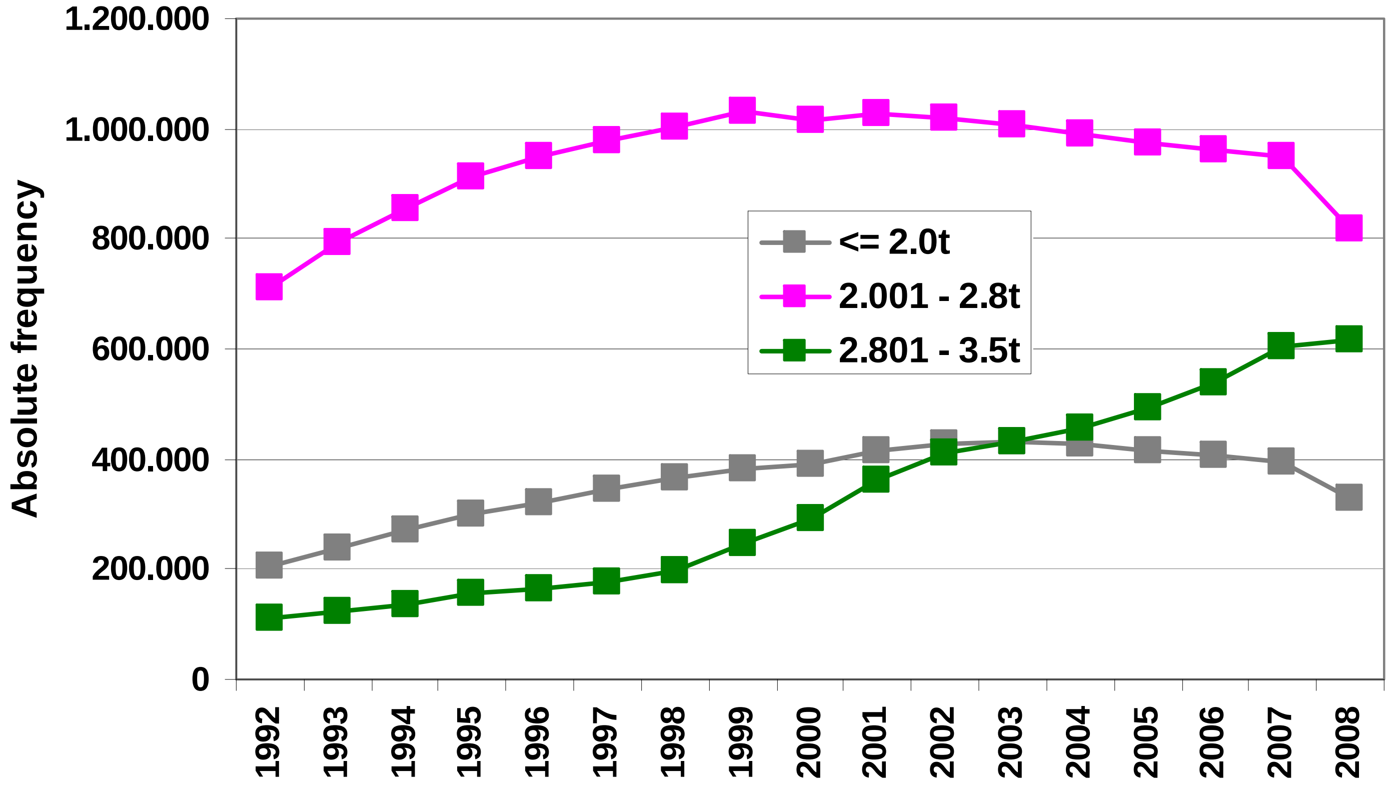
Source: StBA

Germany – Registered Trucks



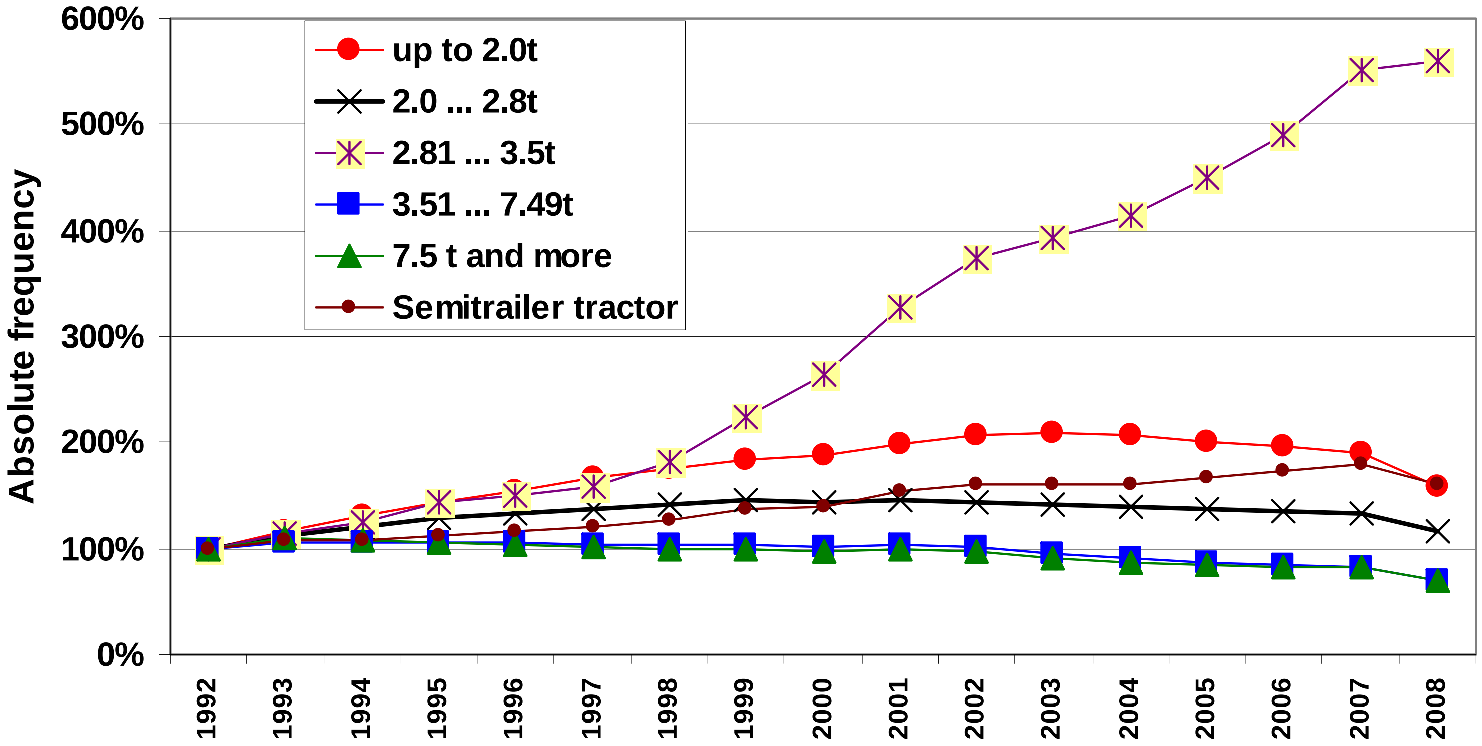
Source: KBA

Germany – Registered Trucks (< 3.5t)



Source: KBA

Statistics – Germany – Registered Trucks



Source: StBA

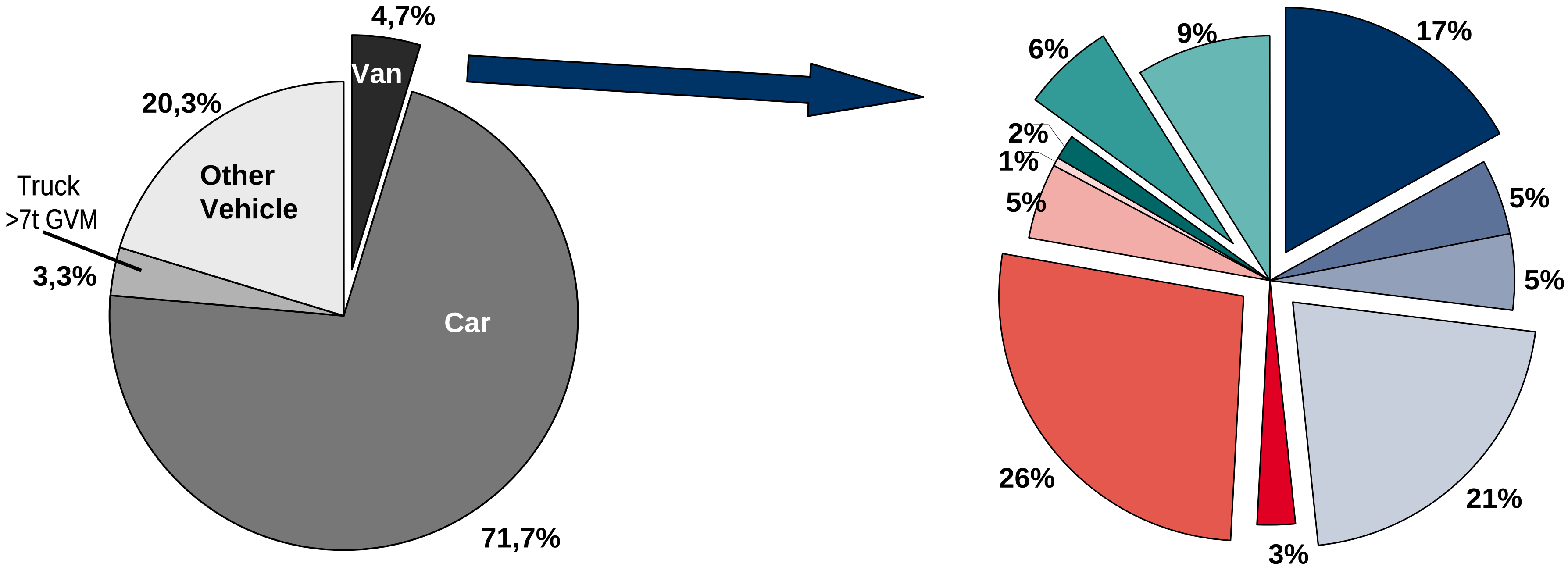
GIDAS and UDV Data Base Analysis: Active Safety in Van Accidents

Robert Bosch GmbH, Accident Research
German Insurance Association, UDV

Accident Scenarios Investigated (Active Safety)

Main causer of all accidents
(n=11694)

Accident scenarios caused by Vans
(n=550)



- **Loss of control accident**
- Turning off and oncoming vehicle
- Turning off and pedestrian/cyclist
- **Turn into or crosses a road**
- Pedestrian accident
- **Rear-end crash**
- Lane change accident
- Accident while overtaking
- Accident with oncoming vehicle
- **Driving backward**
- Other accident

Investigated scenarios

Definition vans: goods vehicles and mini busses from 2.0t - 3,5t

Source: GIDAS 12.2008

Accident Scenarios Investigated (Active Safety)

Details

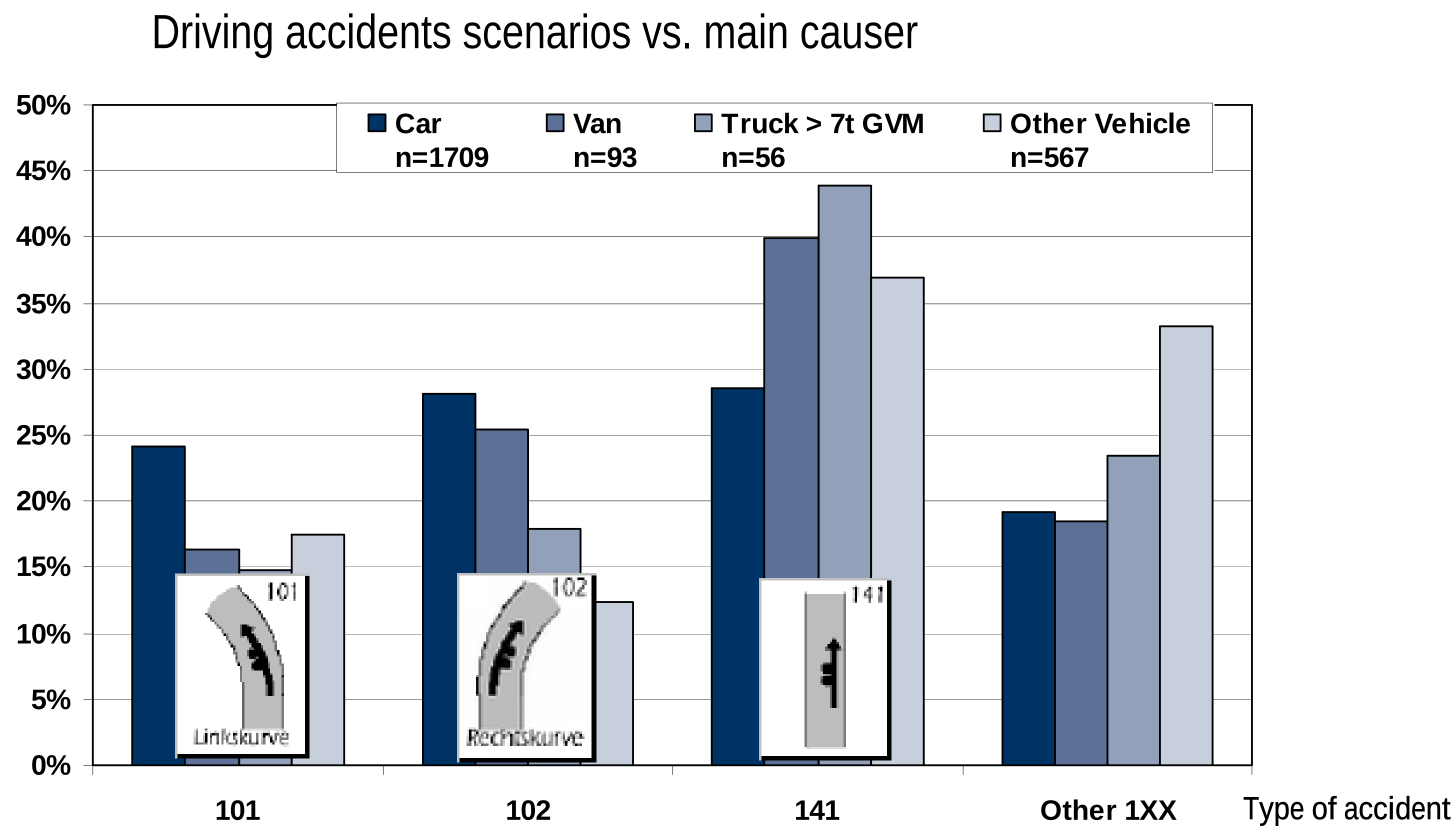
	Main causer									
	Car n=8391		Van n=550		Truck > 7t GVM n=382		Other Vehicle n=2372		Total n=11694	
Accident scenario	n	%	n	%	n	%	n	%	n	%
Loss of control accident	1709	20,4%	93	16,8%	56	14,7%	567	23,9%	2425	20,7%
Turning off and oncoming vehicle	581	6,9%	29	5,2%	12	3,1%	51	2,2%	673	5,8%
Turning off and pedestrian/cyclist	321	3,8%	28	5,0%	20	5,4%	52	2,2%	421	3,6%
Turn into or crosses a road	2250	26,8%	117	21,2%	63	16,5%	782	33,0%	3212	27,5%
Pedestrian accident	169	2,0%	14	2,6%	4	1,1%	78	3,3%	266	2,3%
Rear-end crash	1824	21,7%	148	26,9%	122	31,9%	234	9,9%	2328	19,9%
Lane change accident	390	4,6%	28	5,0%	46	12,2%	110	4,6%	574	4,9%
Accident while overtaking	84	1,0%	3	0,6%		0,0%	22	0,9%	109	0,9%
Accident with oncoming vehicle	244	2,9%	9	1,7%	8	2,0%	144	6,1%	405	3,5%
Driving backward	163	1,9%	34	6,1%	13	3,5%	14	0,6%	225	1,9%
Other accident	656	7,8%	49	8,8%	37	9,7%	317	13,3%	1058	9,0%
Total	8391	100,0%	550	100,0%	382	100,0%	2372	100,0%	11694	100,0%

4 accident scenarios are investigated.

UDV – Data base:
Similar distribution of the four scenarios

Source: GIDAS 12.2008

Scenario: Driving Accidents (Loss of Control)

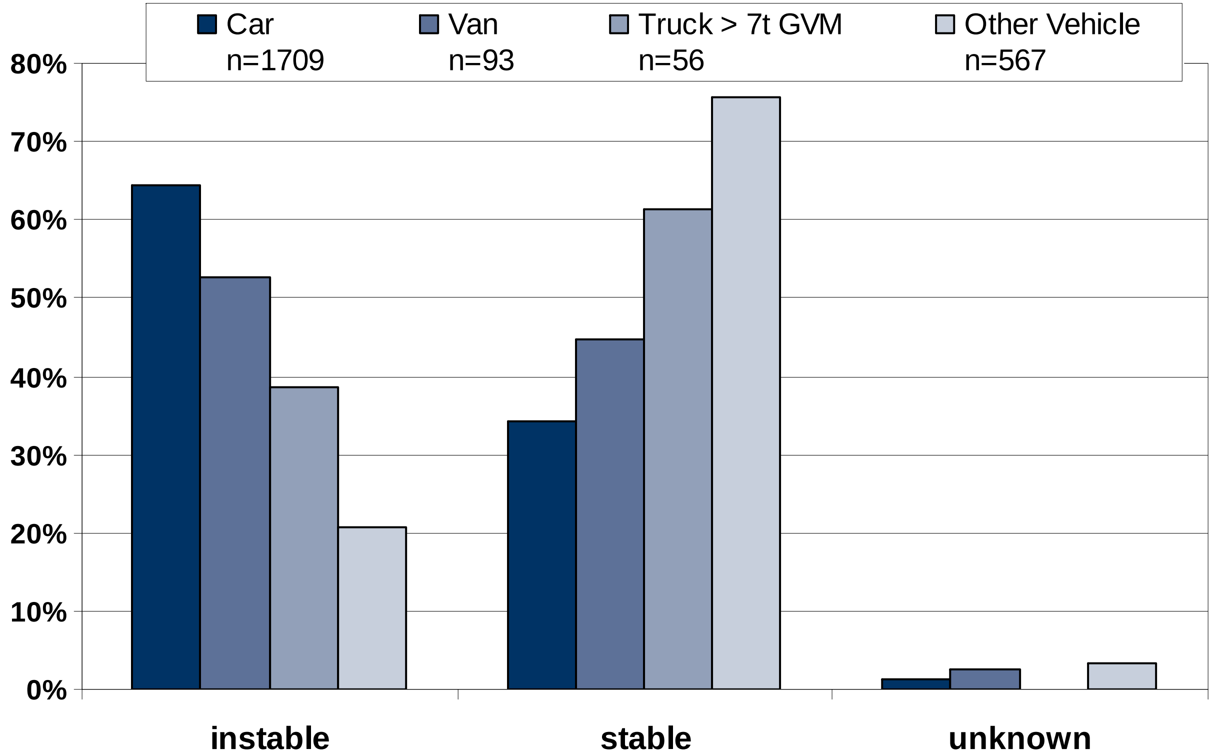


➔ In accidents caused by vans, one of six (approx.) is a driving accident
➔ Van and truck drivers loose control less often in turns than car drivers

Source: GIDAS 12.2008

Scenario: Driving Accidents (Loss of Control)

ESP relevance: Instable driving maneuver in driving accidents prior to first impact



UDV – Data base:
70% ESP relevance in driving accidents of vans (n=33)

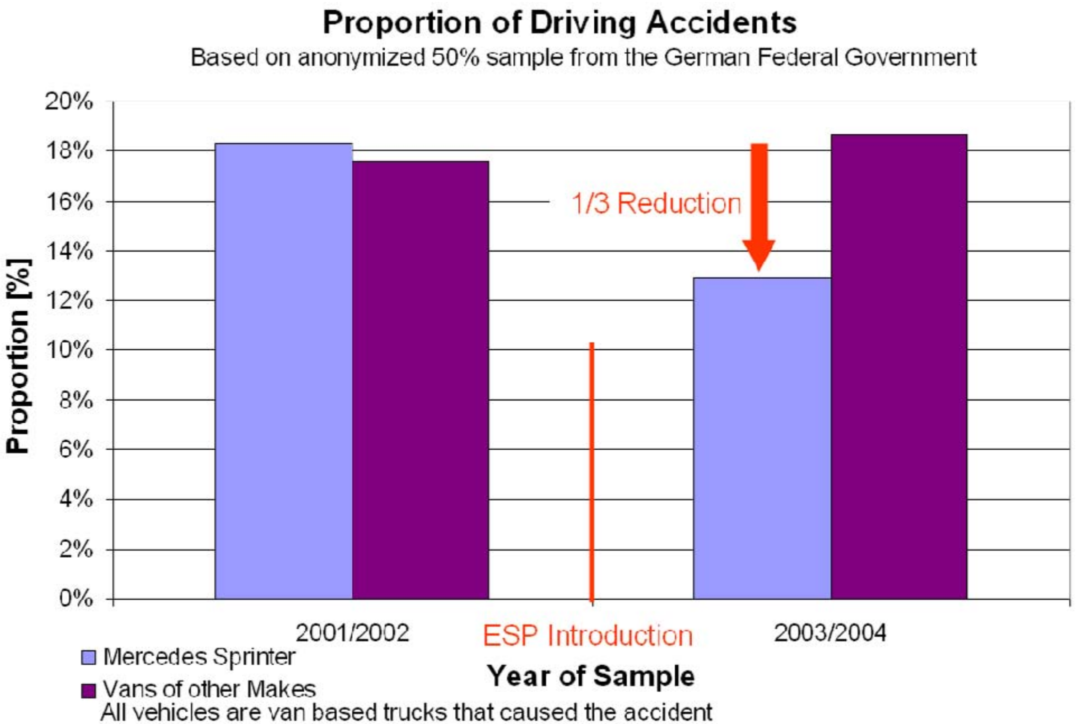
➔ Half of all driving accidents of vans follow an instable* driving maneuver which could be addressed by ESP

* Oversteering or understeering

Source: GIDAS 12.2008

German Federal Statistics: Effect of ESP on Driving Accident*

- 1805 driving accidents with injuries involving vans occured in 2006 in Germany



- Equipping all Vans with ESP driving accidents of Vans could be reduced substantially

*Accidents caused by driver's losing control of vehicle without contribution of other road users

Source: Daimler EP/SPF 2009, Destatis

Scenario: Driving Accidents (Loss of Control)

Estimation of the relevance of Lane Departure Warning (LDW) for driving accidents of vans

17%

➔ 17% of all accidents caused by vans are driving accidents (93 cases)

➔ Relevance of LDW was estimated under the following assumptions:

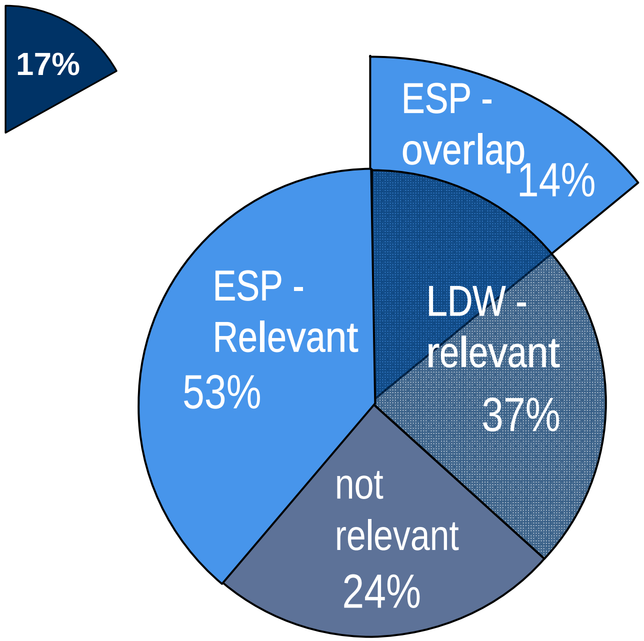
- Initial speed of the involved van higher than 60kph
- At least one visible road marking exists (lane leaving side)
- All kinds of white road markings are detectable by the system
- No function within areas with construction work
- Bends can be handled by the function (radius >200m)
- No benefit expected in case of speeding, evasive maneuvers, road surface covered by snow or sudden car damage

Single case analysis of these 93 driving accidents which are caused by vans

Source: GIDAS 12.2008

Scenario: Driving Accidents (Loss of Control)

Estimation of the relevance of Lane Departure Warning (LDW) in driving accidents for vans



Van
(n=87*)

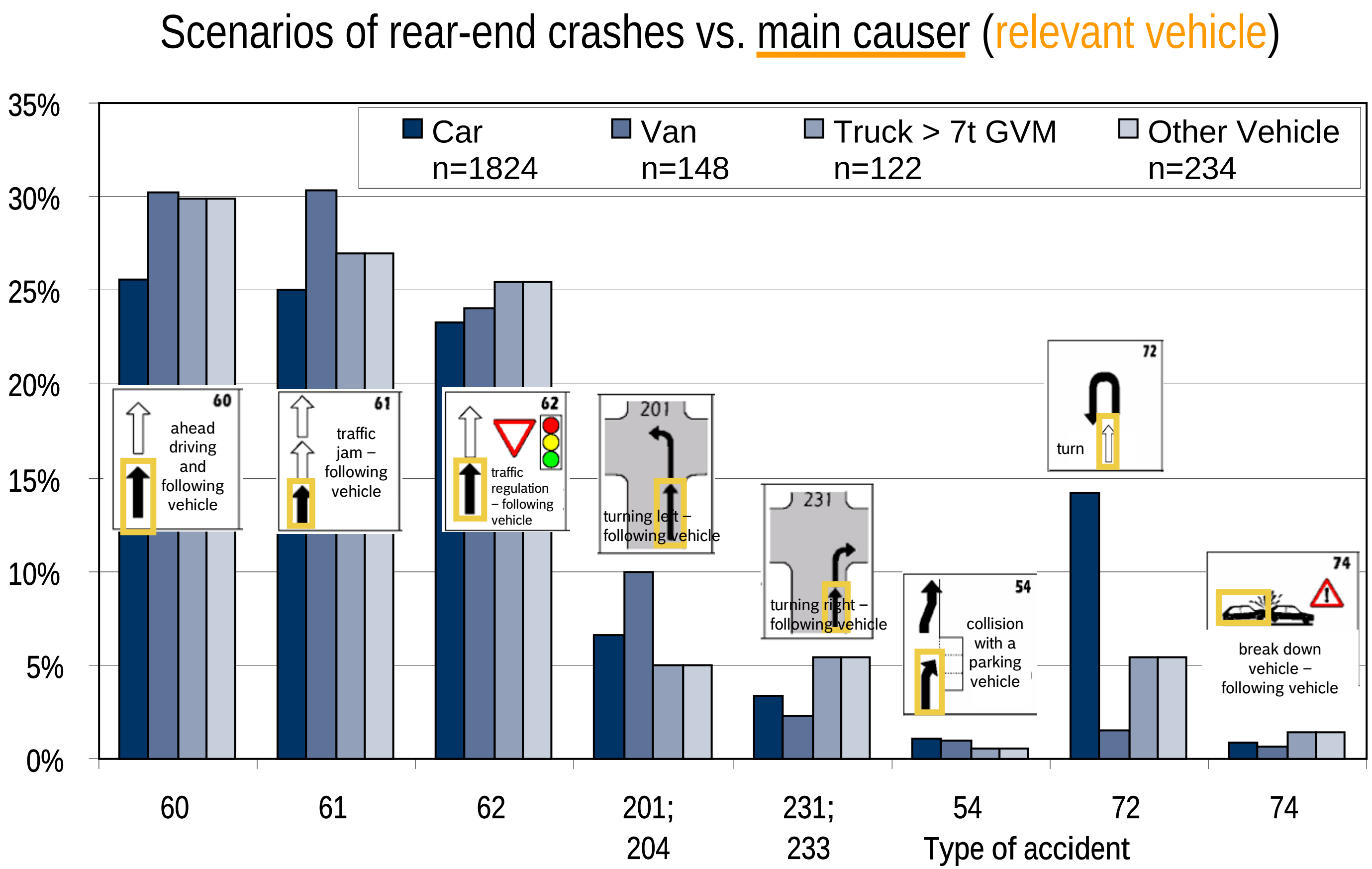
- ➔ 37% of all driving accidents caused by vans are LDW relevant. (n=32)
- ➔ Both functions LDW and ESP could be able to avoid 14% of these accidents. (n=12)

UDV – Data base:
30% LDW relevance in driving accidents of vans (n=33)
12% of these accidents could be avoidable by LDW and ESP (n=4)

* Due to coding mistakes 5 accidents excluded

Source: GIDAS 12.2008

Scenario: Rear-end Crashes



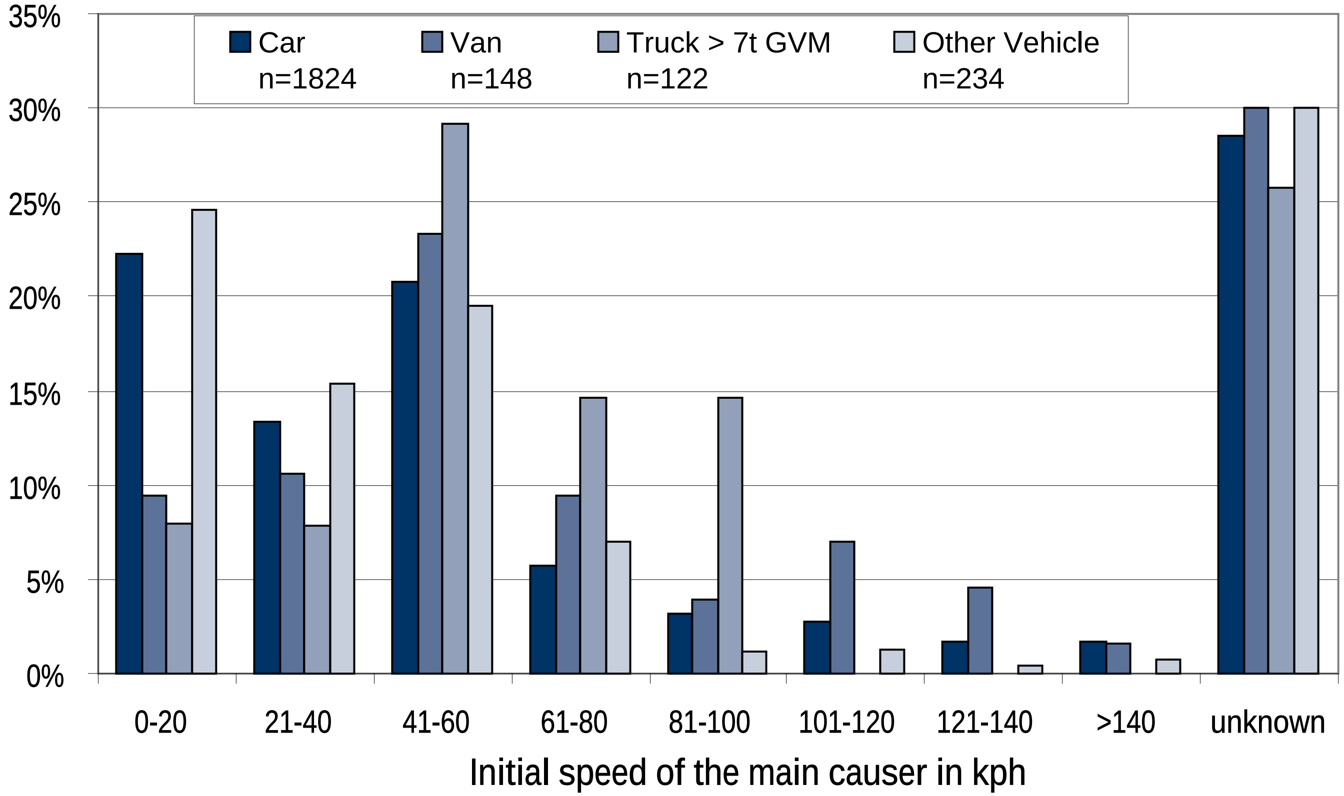
→ About 85% of all van caused rear-end crashes belong to accident type 60, 61 or 62

95% in the UDV database

Source: GIDAS 12.2008

Scenario: Rear-end Crashes

Initial speed of the main causer in rear-end crashes

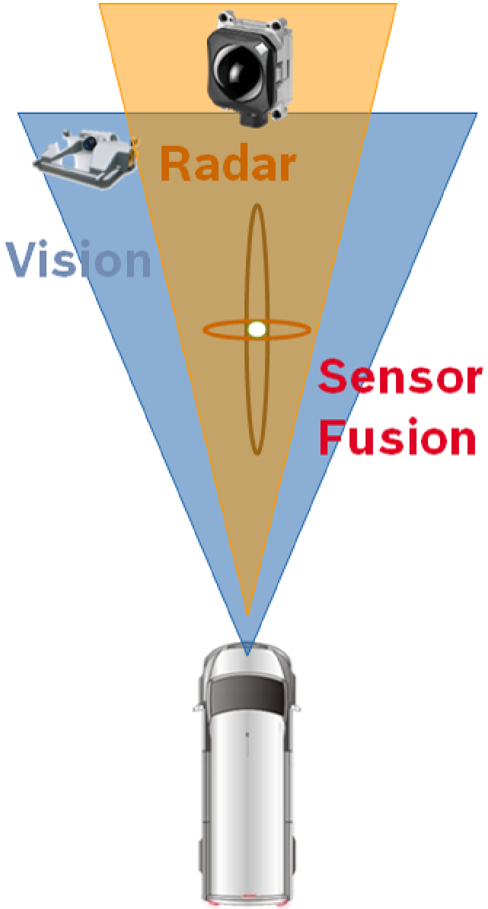


→ Between 20 kph and 100 kph, the initial speed of vans and cars in rear end crashes is similar

Source: GIDAS 12.2008

Van Rear-end Crashes: Examined Functions

Object Detection & Verification



Source: Bosch accident research, 2009

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PCW Predictive Collision Warning
(Radar only)

- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

EBA Emergency Braking Assist
(Radar only)

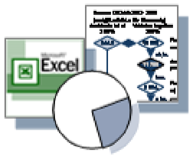
- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

AEB Automatic Emergency Braking
(Radar + video)

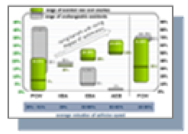
- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

Van Rear-end Crashes: Benefit Analysis Procedure

GIDAS database → **Field of effect** → **Function description and effect to accident** → **Driver Model: Combination of different driver characteristic** → **Benefit/ avoidance potential**



$f(x)$

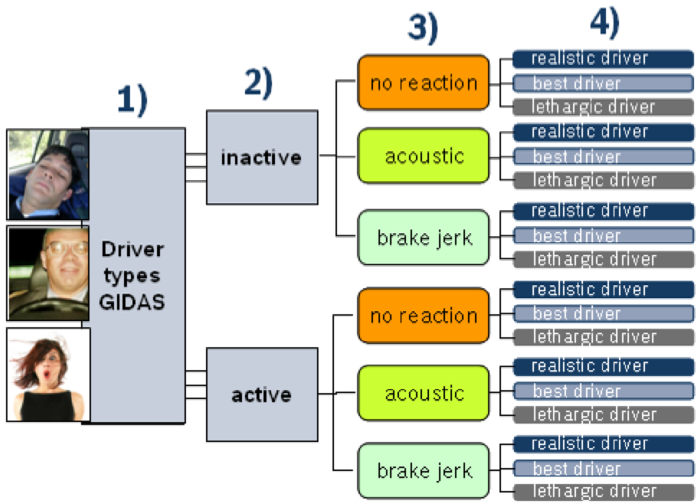


In driver model considered:

1) Real brake reaction (no braking, partial or full braking)
2) Degrees of attention (active, inactive)
3) Driver reaction on different warnings
4) Different types of drivers (reaction times, braking decelerations)

Source: Bosch accident research, 2009

AEBS – driver model

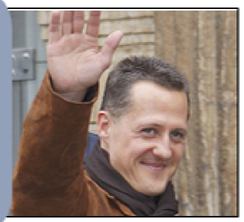


Van Rear-end Crashes: Benefit Analysis Procedure

Driver reaction to function

Realistic driver:
reaction times: 1s after acoustic warning / 0,7s after brake jerk, 80% deceleration

Best driver:
reaction times: 0,7s after acoustic warning / 0,4s after brake jerk, 100% deceleration

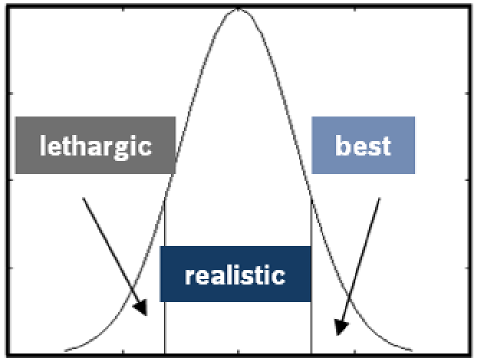


Lethargic driver:
reaction times: 2s after acoustic warning / 1,5s after brake jerk, 60% deceleration

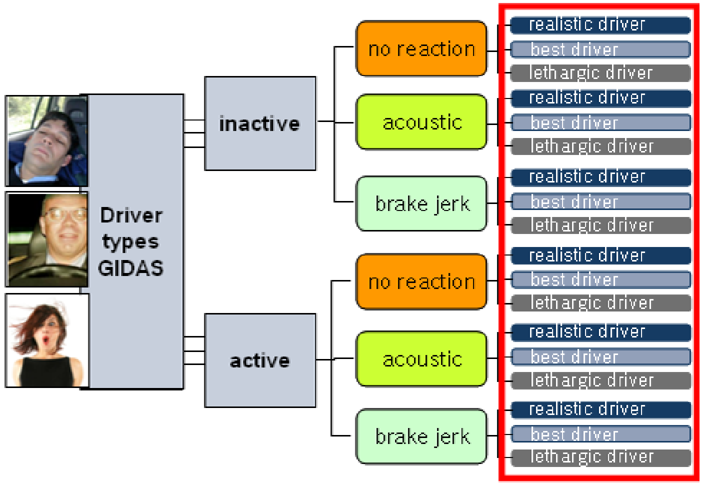
Pictures taken from internet

Source: Bosch accident research, 2009

Expected driver population

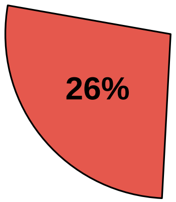


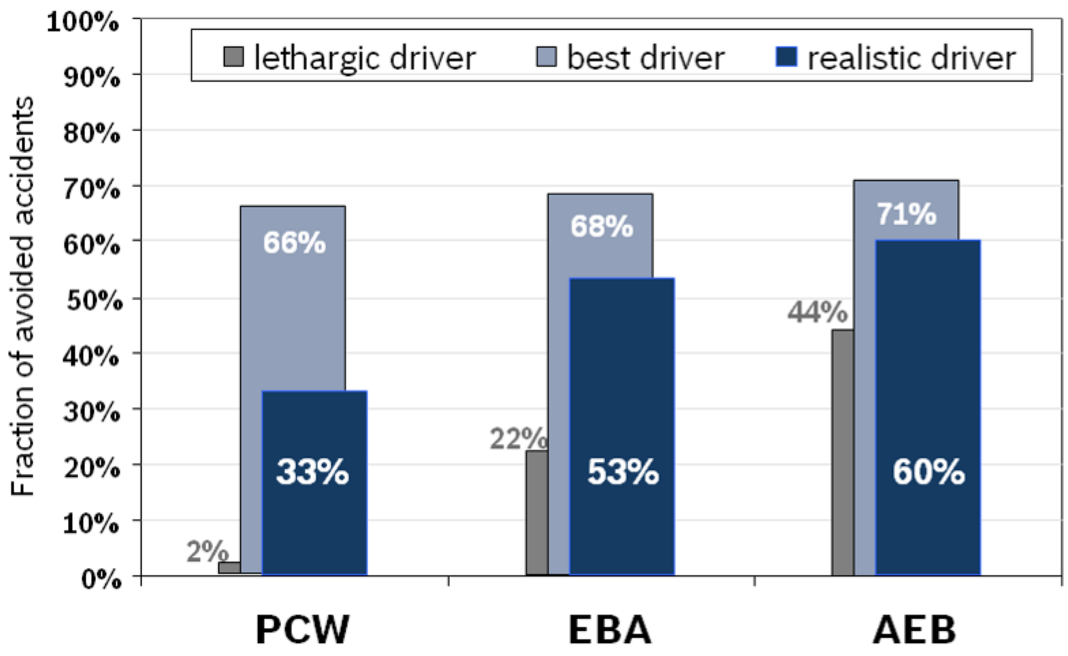
AEBS – driver model



Van Rear-end Crashes: Fraction of Avoided Accidents

➔ Reduced braking deceleration of vans considered: $a_{van} = 0.85\ a_{car}$





PCW Predictive Collision Warning
- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

EBA Emergency Braking Assist
- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

AEB Automatic Emergency Braking
- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

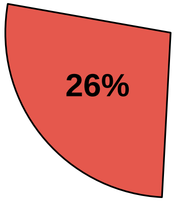
➔ In accidents caused by vans, one of four (approx.) is a rear-end collision

➔ 1/3 up to 60% (depending on function specifications) of these accidents could be avoided by predictive warning or automatic braking assuming realistic driver

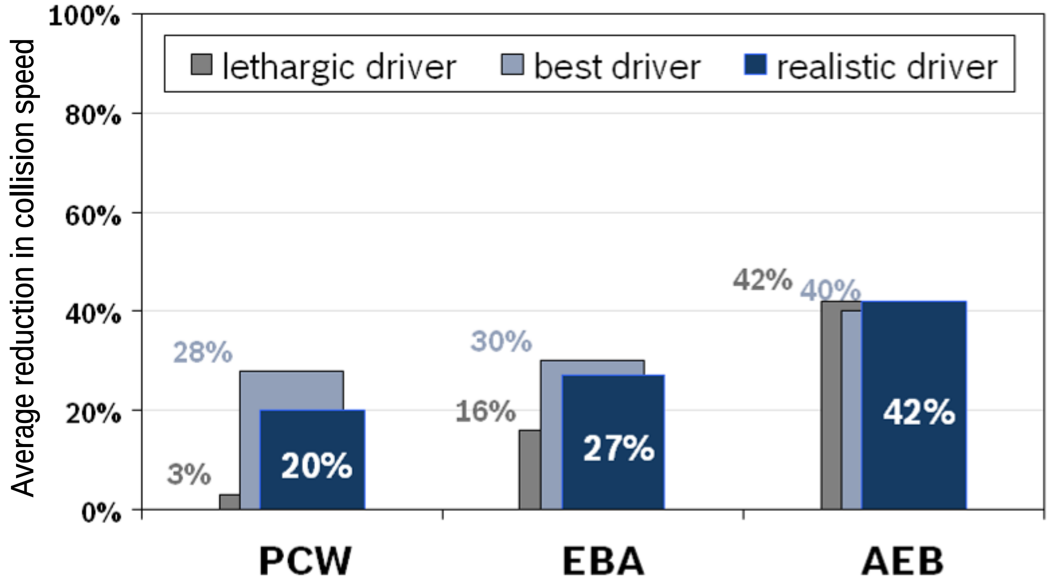
➔ Equipping all vans with EBA 0,65% of all accidents with injuries are avoidable

Source: Bosch Analysis of GIDAS Database (12/2008); 148 rear end crashes caused by vans; modeled under idealized conditions with a function specification close to market; standing vehicles can be managed by these functions

Van Rear-end Crashes: Average Reduction in Collision Speed for not Avoided Rear-end Crashes



➔ Reduced braking deceleration of vans considered: $a_{van} = 0.85\ a_{car}$



PCW Predictive Collision Warning
- warning cascade including brake jerk
- driver monitoring to optimize warning strategy
- adapted system reaction for stationary objects

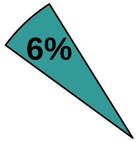
EBA Emergency Braking Assist
- includes PCW
- target braking for optimized brake support to avoid collision (driver initiated)

AEB Automatic Emergency Braking
- includes EBA
- automatic partial braking
- automatic full braking when collision unavoidable

➔ Even if the rear-end collision cannot be avoided by PCW, EBA or AEB, the collision speed is still strongly reduced, leading to reduced accident severity

➔ Equipping all vans with EBA 0,57% of all injury accidents occur at a collision speed reduced by 27% on average

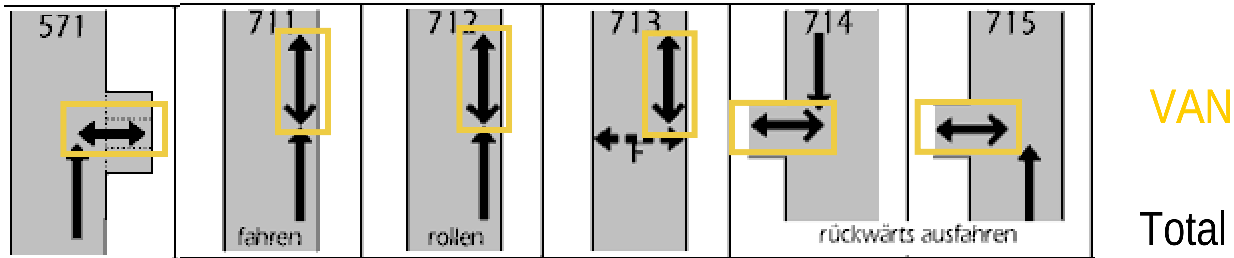
Source: Bosch Analysis of GIDAS Database (12/2008); 148 rear end crashes caused by vans; modeled under idealized conditions with a function specification close to market; standing vehicles can be managed by these functions



Scenario: Van Drives Backward

- ➔ In 6% of all accidents caused by vans the van was driving backwards.
- ➔ Single case analysis of 34 relevant accidents. (In 4 accidents no pictures available.)
- ➔ **30 accidents** are the basis for this analysis.

Accident scenarios – driving backwards




	571	711	712	713	714	715	Total
Rear window + exterior rearview mirrors	1	2		10		2	15
Only exterior rearview mirrors		2	2	7	2	2	15

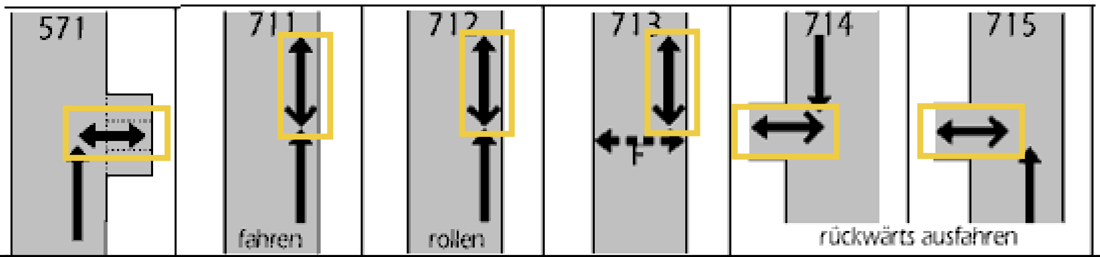
➔ From all van accidents occuring while driving backwards, more than half are described by accident type 713 almost 70% in the UDV database.

Source: GIDAS 12.2008

6%

Scenario: Van Drives Backward

Accident scenarios vs. opponent



VAN

Opponent	571	711	712	713	714	715	Total
Car	1				2		3
Bicycle		2				4	7
PTW		2					2
Pedestrian			2	17			19
Total	1	4	2	17	2	4	30

➔ While driving backwards, collisions occur most frequently with pedestrians
(over 75% in the UDV database were pedestrians; similar high percentage of the accident type 713)

Source: GIDAS 12.2008

6%

Scenario: Van Drives Backward

Visibility through rear window (n=15)

Opponent visible: 3 cases
- 1 case collision w/ another car
- 2 cases collision w/ pedestrian

Opponent not visible: 12 cases
- Obstructed view by load: 8 cases
- Tinted/dirty rear windows: 2 cases
- Small partition window: 2 cases

➔ In 12 out of 15 cases the opponent was not visible for the driver through the rear window.

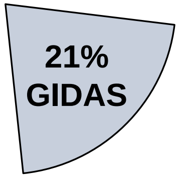
Age and body height of the involved pedestrians (n=19)

Age:
- 16 of the involved pedestrians are older than 60 years
- One child (10years) was involved

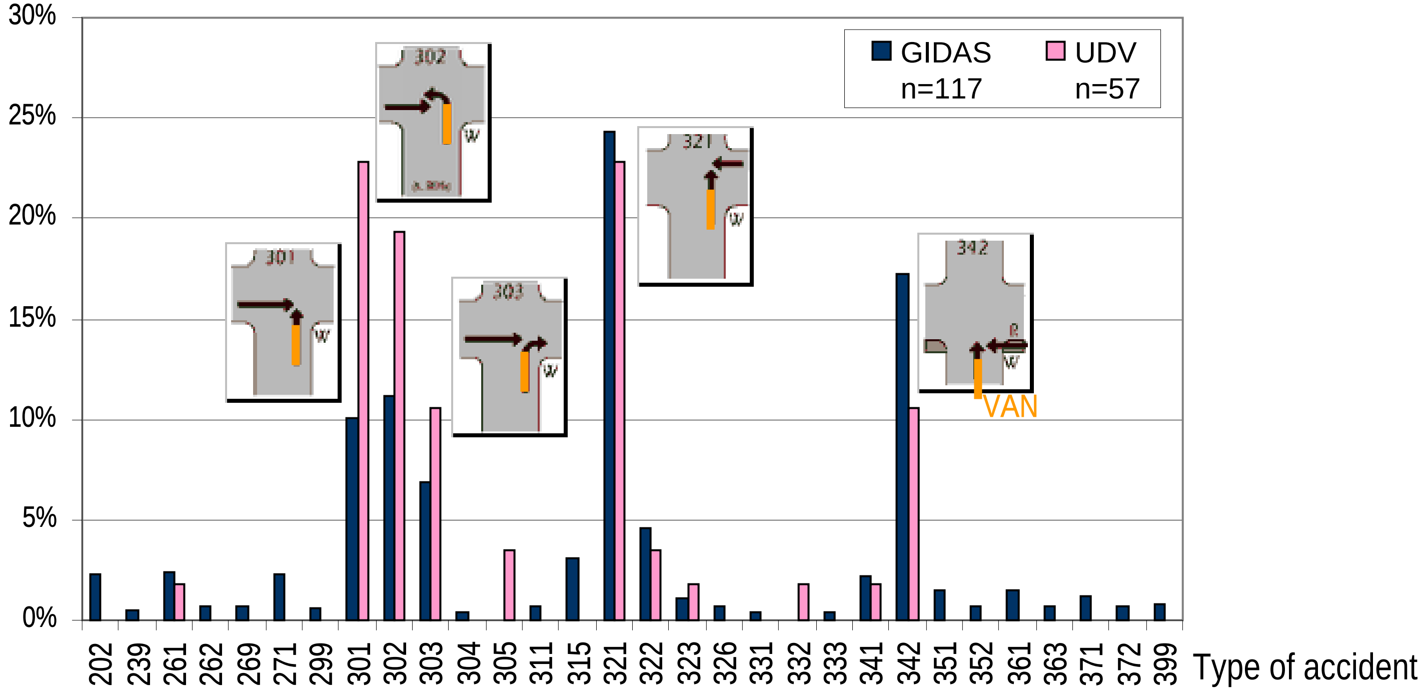
Body height:
- 12 of the involved pedestrians are smaller than 170cm.

Source: GIDAS 12.2008

Scenario: Van Turns into or Crosses a Road



Comparison of van “turn into” or “road crossing” scenarios



➔ In accidents caused by vans, one of five (approx.) is a “turn into” or “road crossing” accident*.

➔ Further analysis of this scenario have to be discussed during the next weeks.

* Scenarios turning off - collision with oncoming vehicle and turning off - collision with pedestrian/cyclist are excluded.

Source: GIDAS 12.2008 and UDV-Database

Accident Scenarios Investigated (Active Safety)

The following classification for the accident scenarios was used.

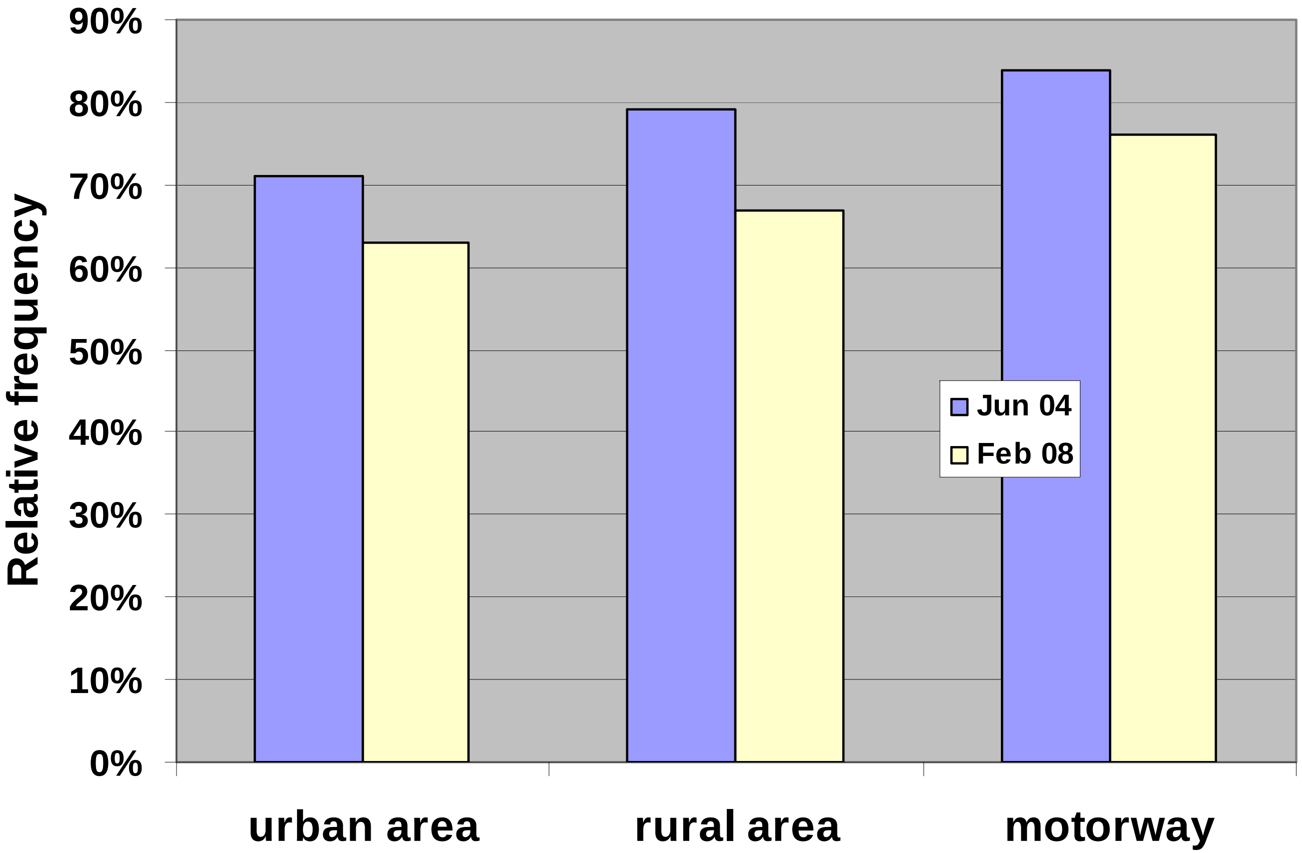
Backup

Nr.	Accident scenario	UTYP short	Addressed functions
1	Loss off control accident (driving accident)	10 to 19	ESP, lane departure / lane keeping systems
2	Turning off and collision with oncoming vehicle	21	Turn assistant for oncoming traffic
3	Turning off and pedestrian/cyclist	221 to 224, 241 to 244	Blind spot monitoring for pedestrian / cyclist accidents
4	Turn into or crosses a road	30-39 Rest 20 to 29	Intersection assistant
5	Pedestrian accident	40 to 49; 67	Pedestrian protection active/passive
6	Rear-end crash	60, 61, 62, 201, 204, 231, 233, 541, 542, 72, 74	Collision warning and emergency braking systems
7	Lane change accident	63, 64, ev. 65	Lane changing assistant, Blind spot monitoring
8	Accident while overtaking	66	Car2X
9	Accident with oncoming vehicle	68	Lane keeping systems, ESP
10	Driving backward	71, 57	Extended parking aid systems
11	Other accident	Rest of resting traffic and other accidents	

GIDAS Analysis:
Self- and Partner Protection
in Van Accidents

Ford Werke GmbH
ASO, Automotive Safety Office

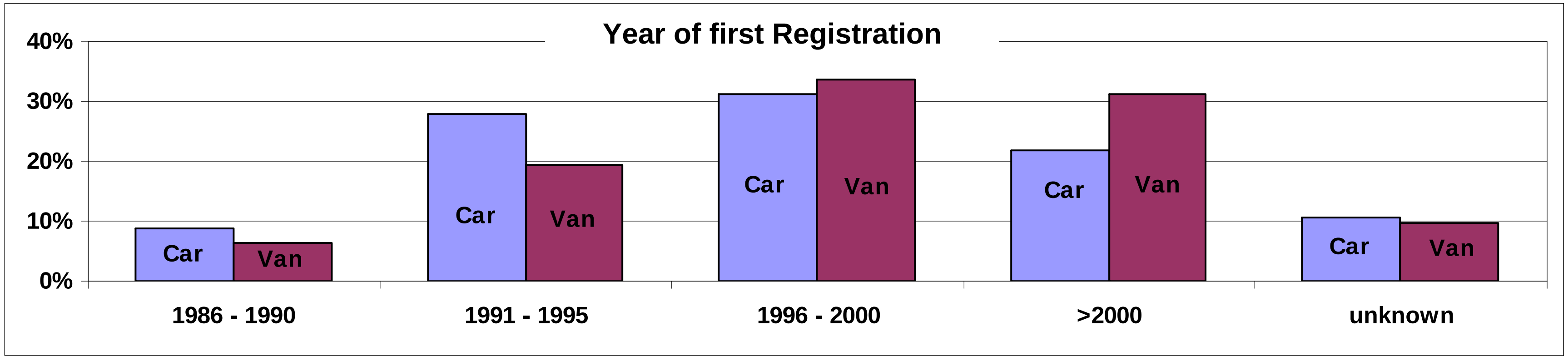
Seat Belt Use of Van Drivers



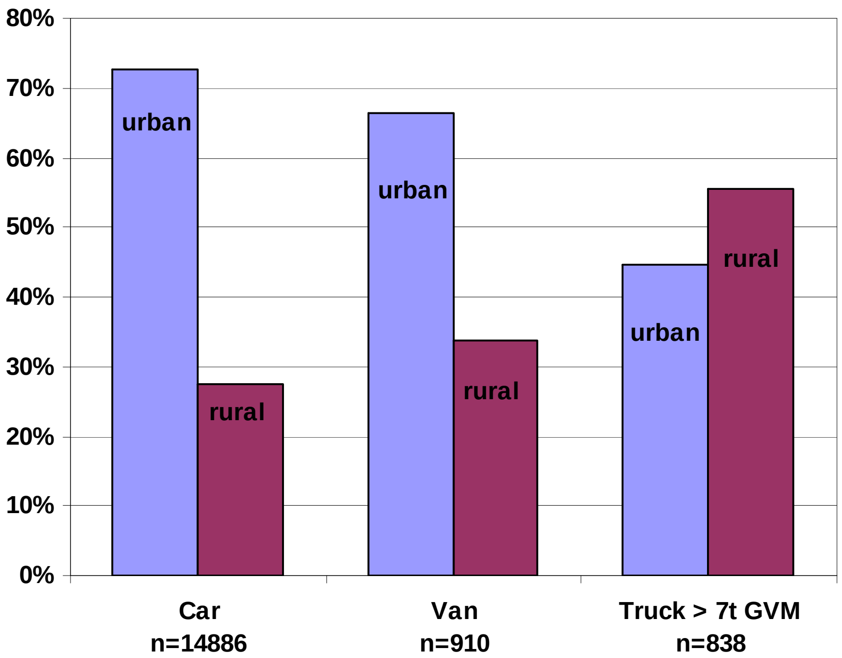
Source: DEKRA investigation

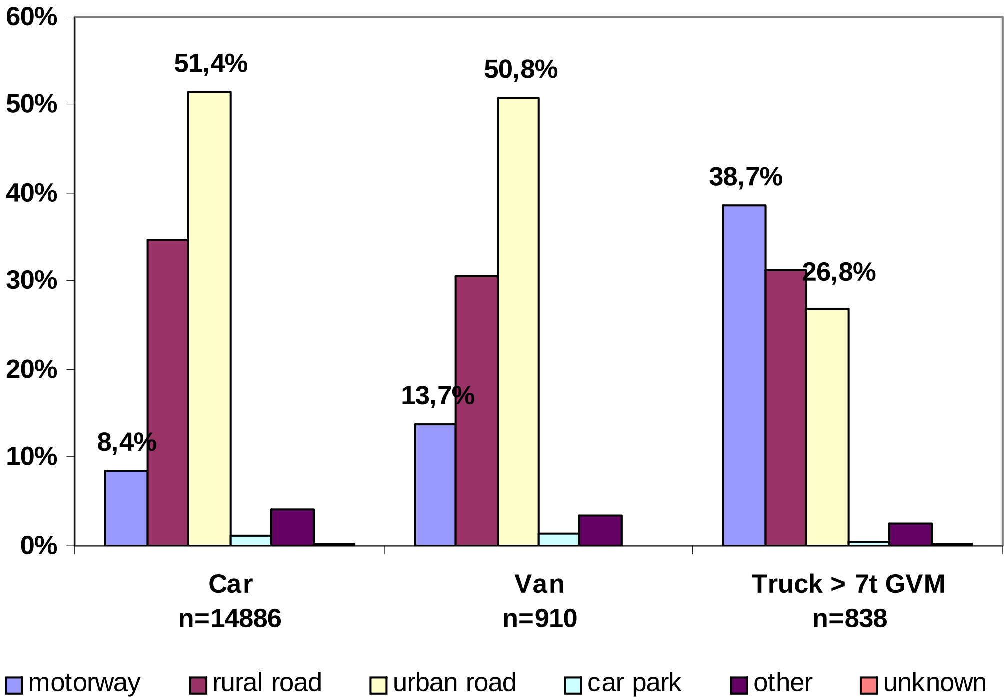
Basic Figures

Accident years: 2001 – 2008		Number of accidents n = 13575	
	Passenger Cars	**Vans** 2t < GVM < 3,5t (Front-axle to R-point < 1100mm)	**Trucks** > 7 tons
Number of vehicles (Year of first Reg. > 1985)	14.866	910 (incl. 323 Minibuses)	838
Number of occupants	21.868	1.411	917
- Front Seat Occupants (FSO) with known MAIS	18.965	1.185	N/A



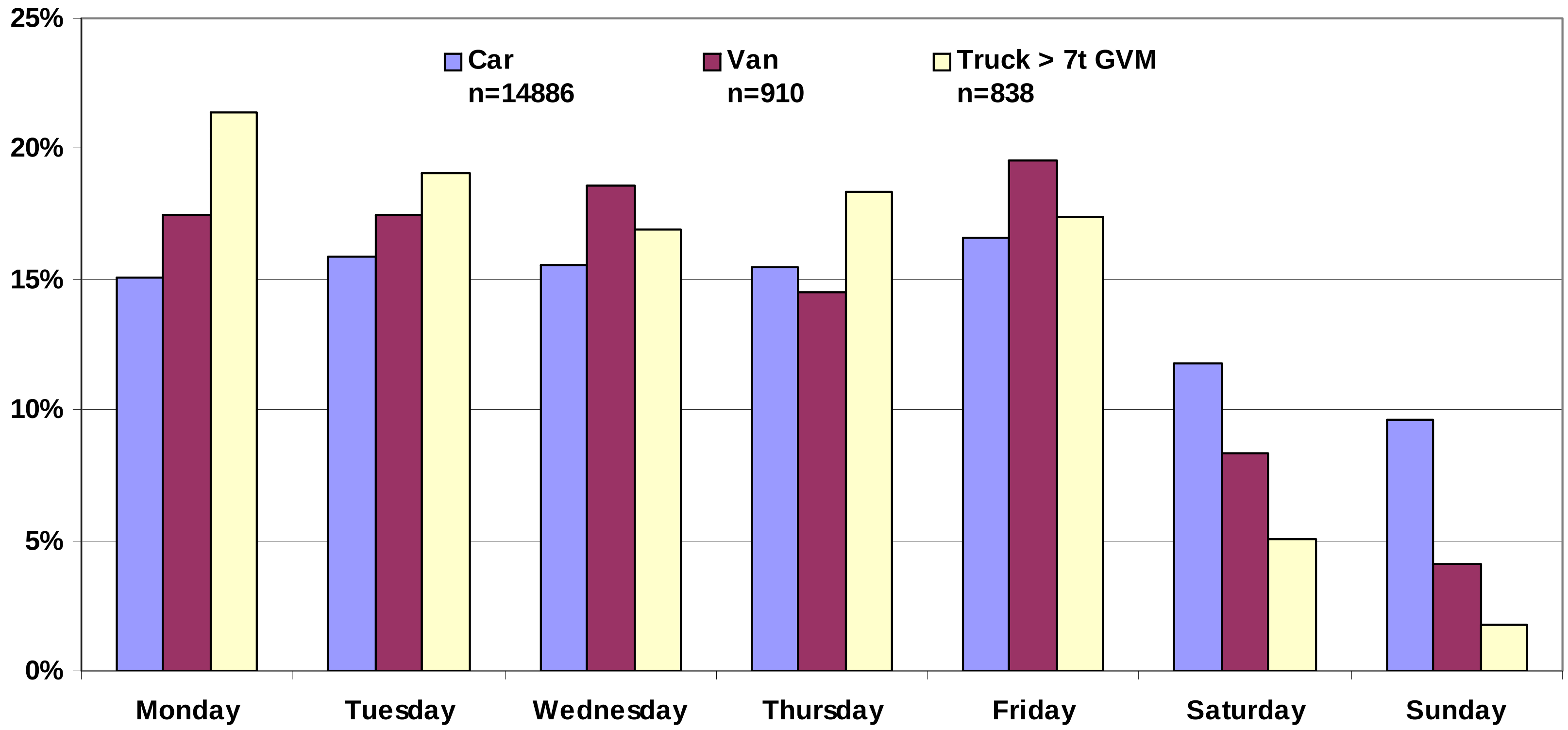
Accident Site





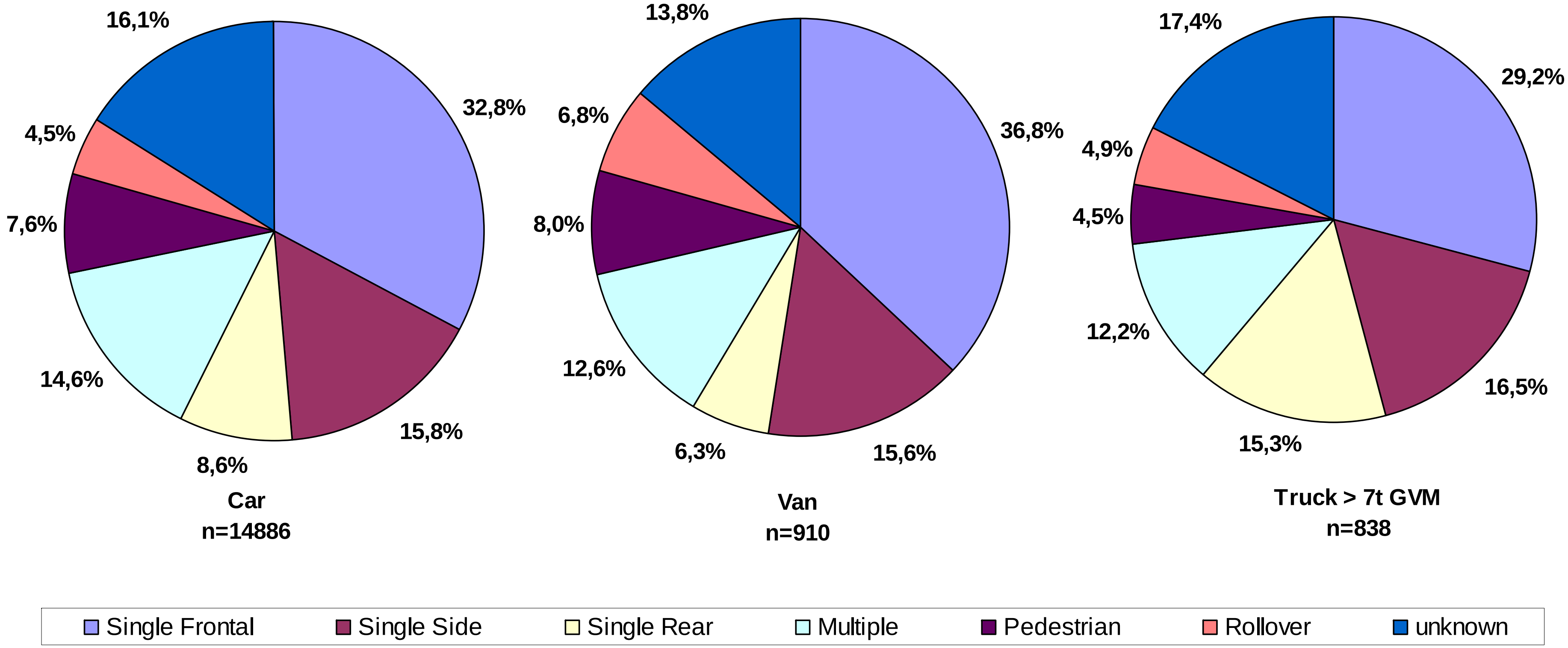
- Above 70 % of the car accidents happen inside urban areas
- Van accidents occur more often in rural areas
- Truck accidents predominate on motorways

Day of the Week



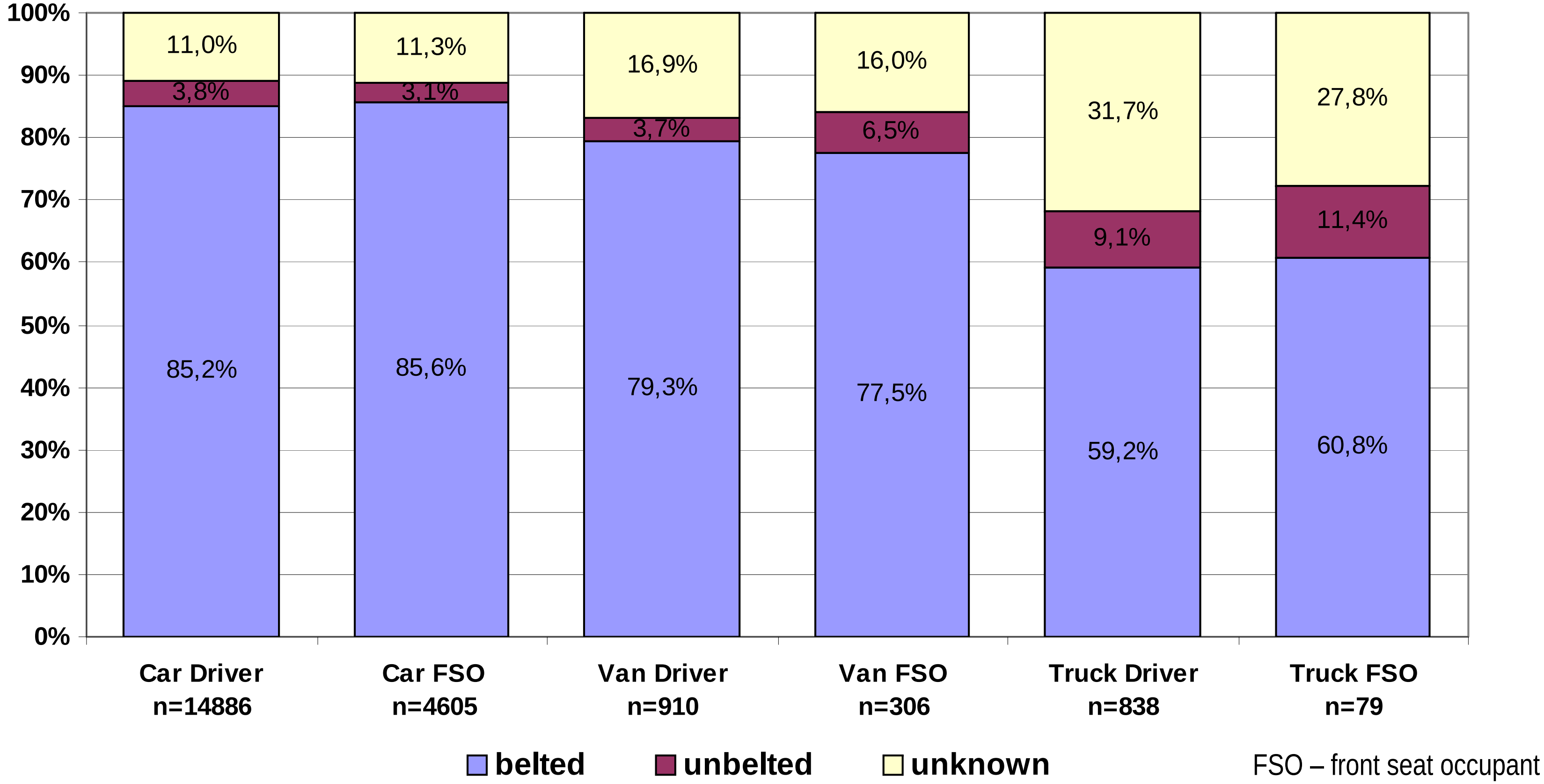
• Van and truck accidents happen predominantly during the week

Impact Type



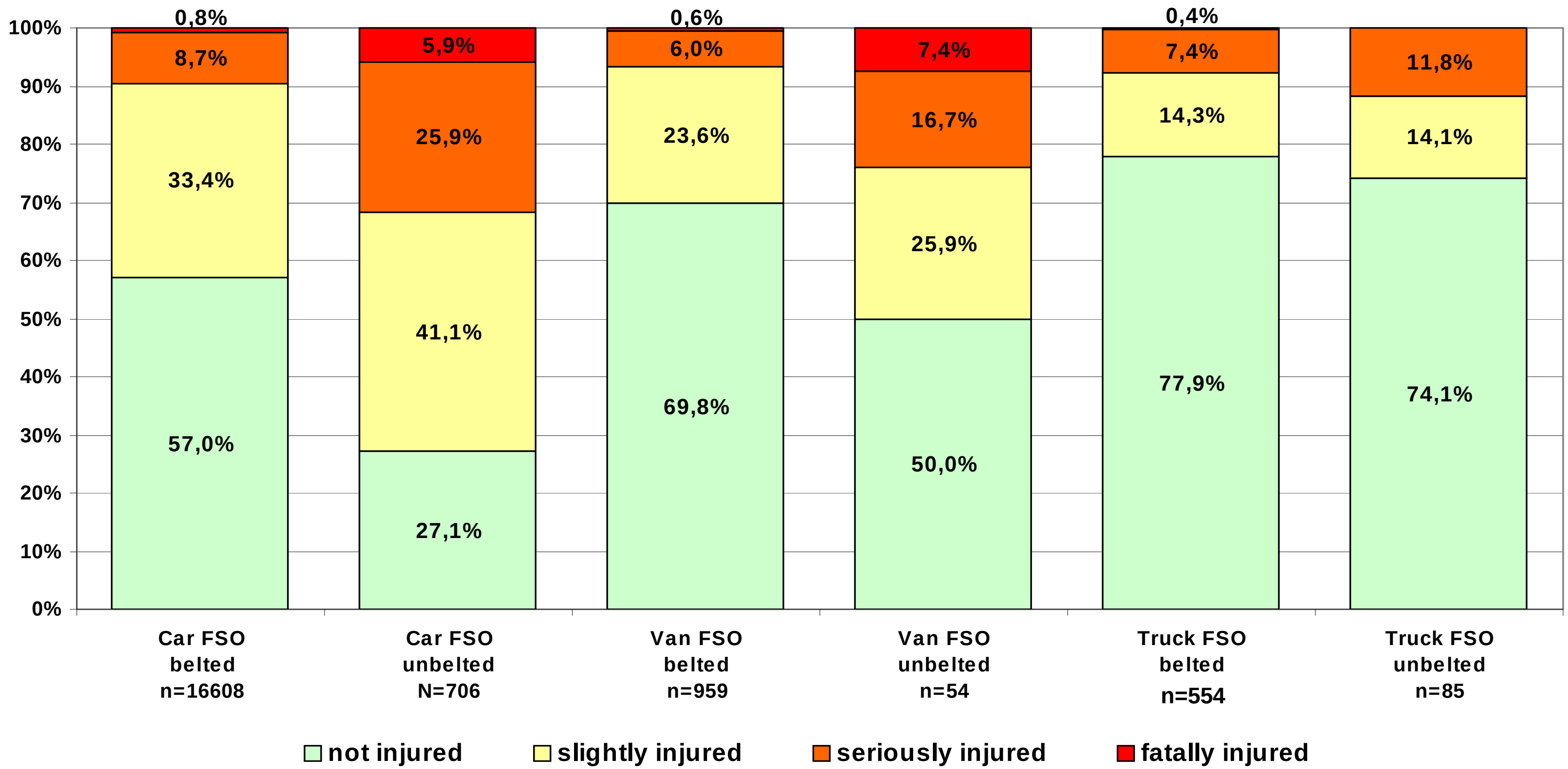
- Similar scenario for all the three groups
- The share of rear impacts is higher for heavy trucks

Safety Belt Usage of Front Seat Occupants



- The share of belted occupants in vans is significantly lower than in cars
- The share of unknown belt usage is higher in commercial vehicles

Injury Severity by Safety Belt Usage if Known



FSO – front seat occupant

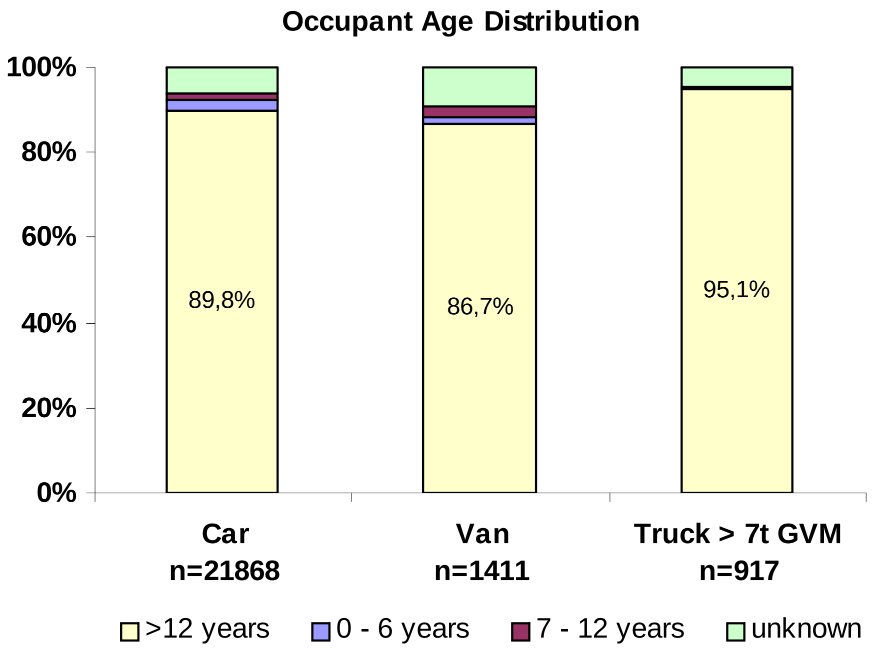
- Belt usage significantly influences the injury severity

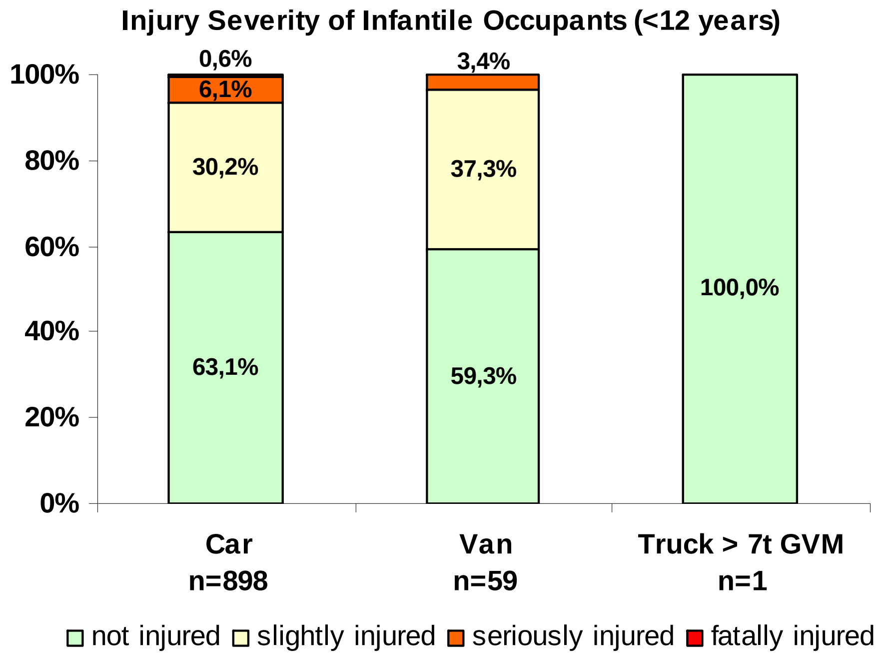
Occupants in Cars, Vans and Trucks

Occupants	Cars		Vans (incl. Minibuses)		Trucks > 7t GVM	
	n	%	n	%	n	%
Driver	14866	68,0%	910	64,5%	838	91,4%
Front Passenger	4605	21,1%	306	21,7%	79	8,6%
Rear Passenger	2397	11,0%	195	13,8%		0,0%
Total	21868	100,0%	1411	100,0%	917	100,0%

• Very similar distribution of the seating positions in cars and vans

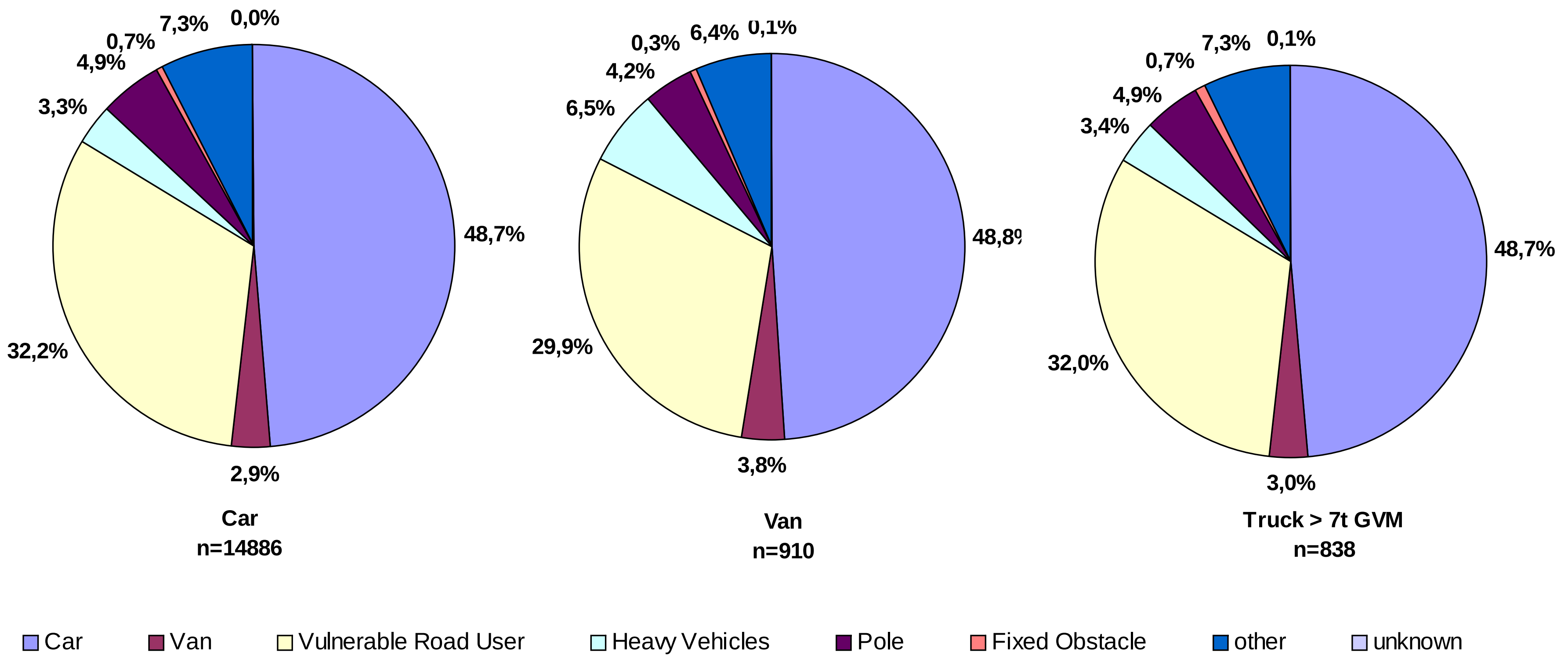
Child Occupants





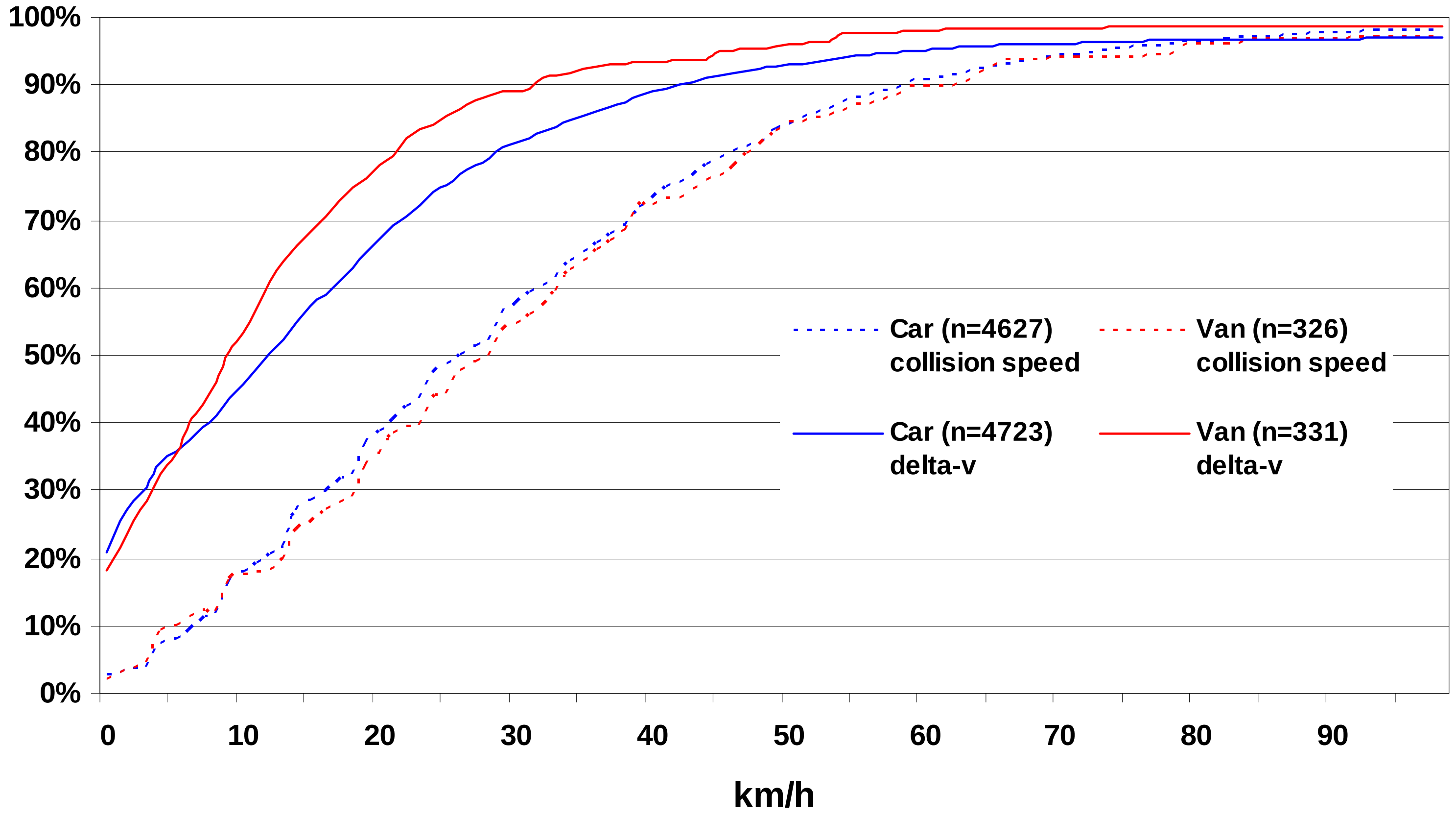
- The share of child occupants is with approx. 4% similar for cars and vans
- 60% of the children are not injured (lower than in passenger cars)
- 3.4% of the children suffer severe injuries in vans (50 % less than in cars)
- No reported child fatalities in vans

Impact Opponents



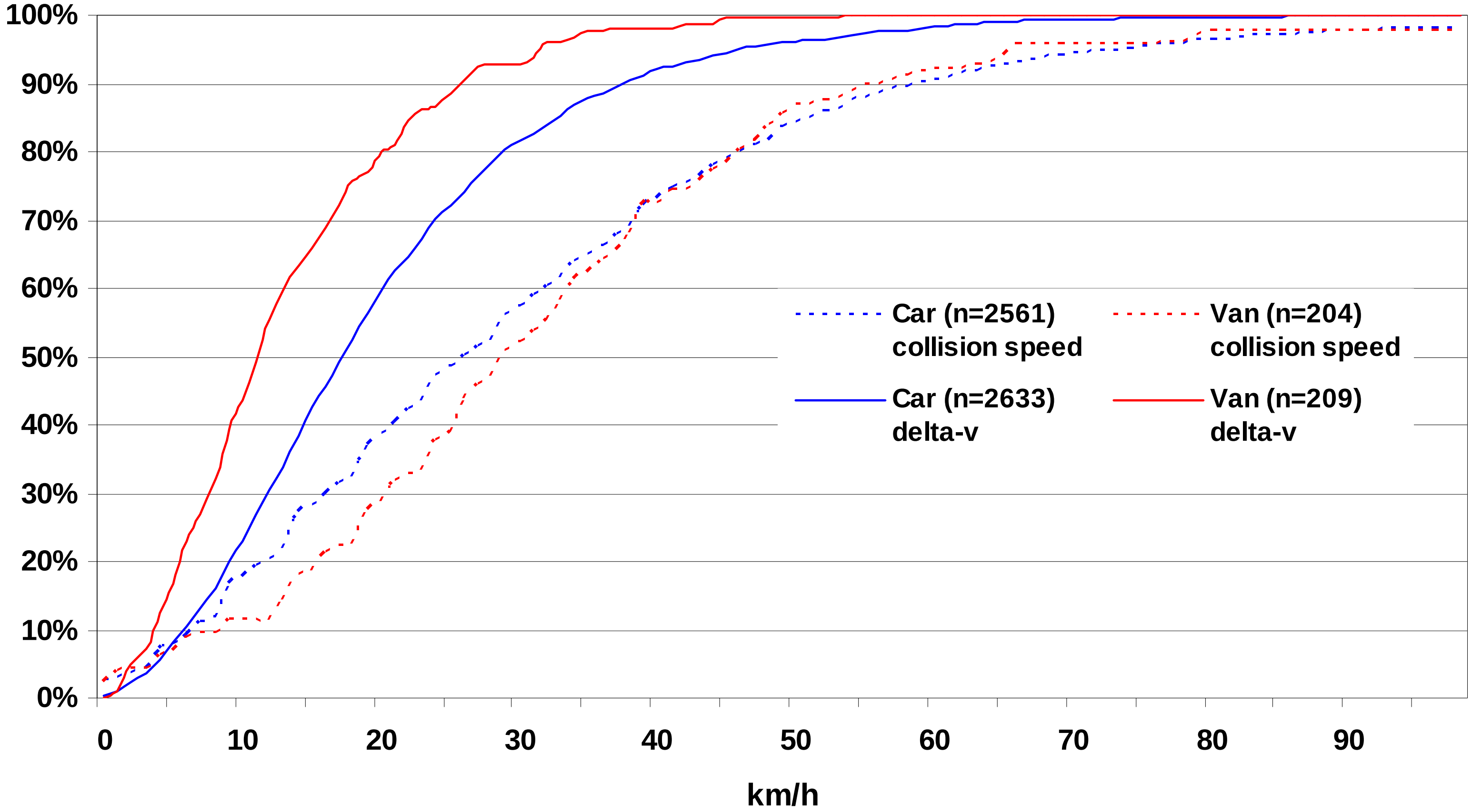
- Very similar scenario for all three groups
- Half of the impacts of all three groups happen to cars

Accident Severity – Impact Speeds in Single Frontal Impacts, All Opponents



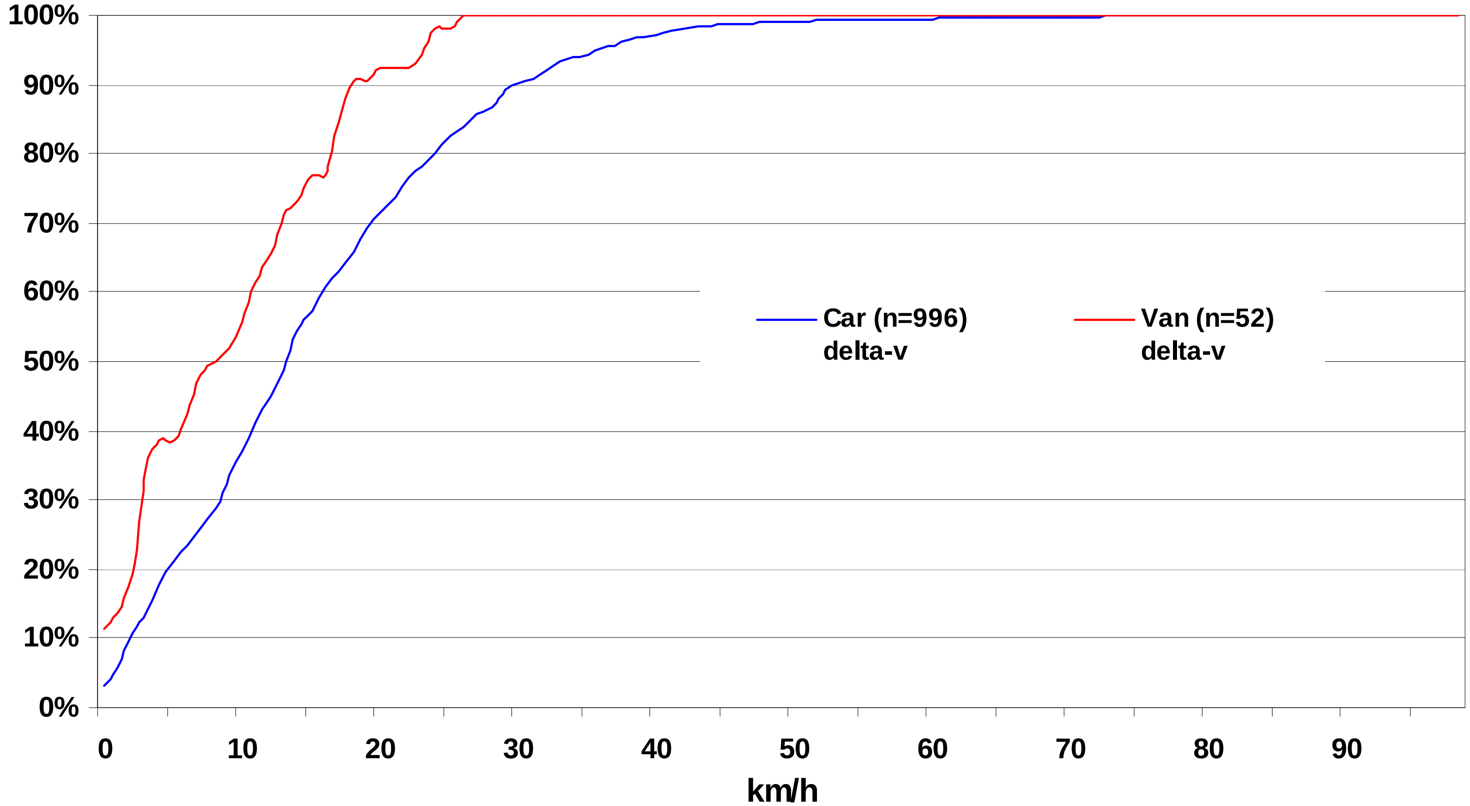
- Collision speeds are very similar for cars and vans
- Delta-v values for vans are lower due to their mass advantage

Accident Severity – Impact Speeds in Single Frontal Impacts against Cars or Vans



- Significant difference in delta-v values of cars and vans when looking at vehicle to vehicle front crashes only

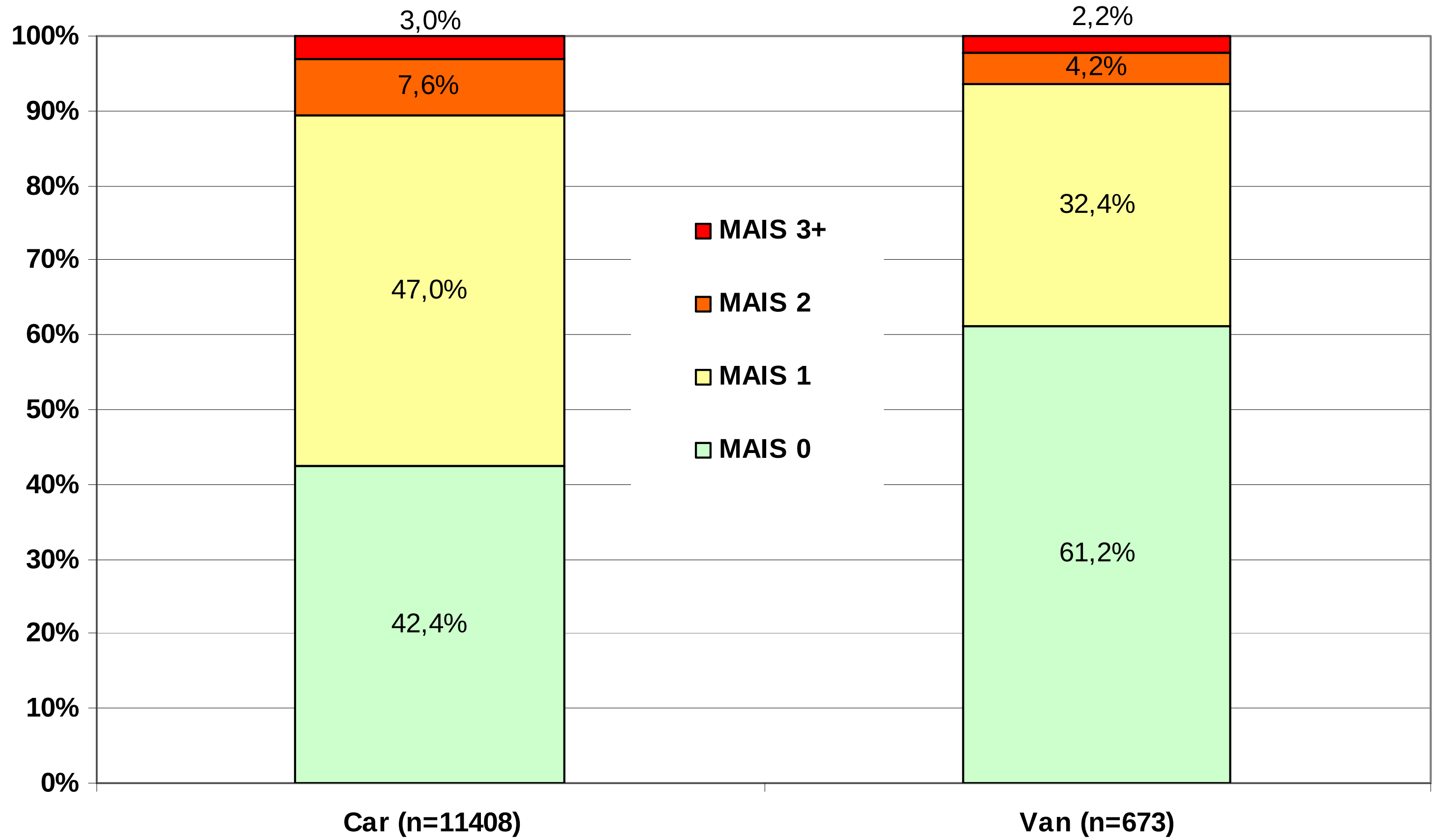
Accident Severity – Delta-v of Target Vehicle in Single Side Impacts with Cars or Vans



- Significant difference in delta-v values of cars and vans when looking at vehicle to vehicle side crashes
- 50% of the vans have a delta v below 10 km/h

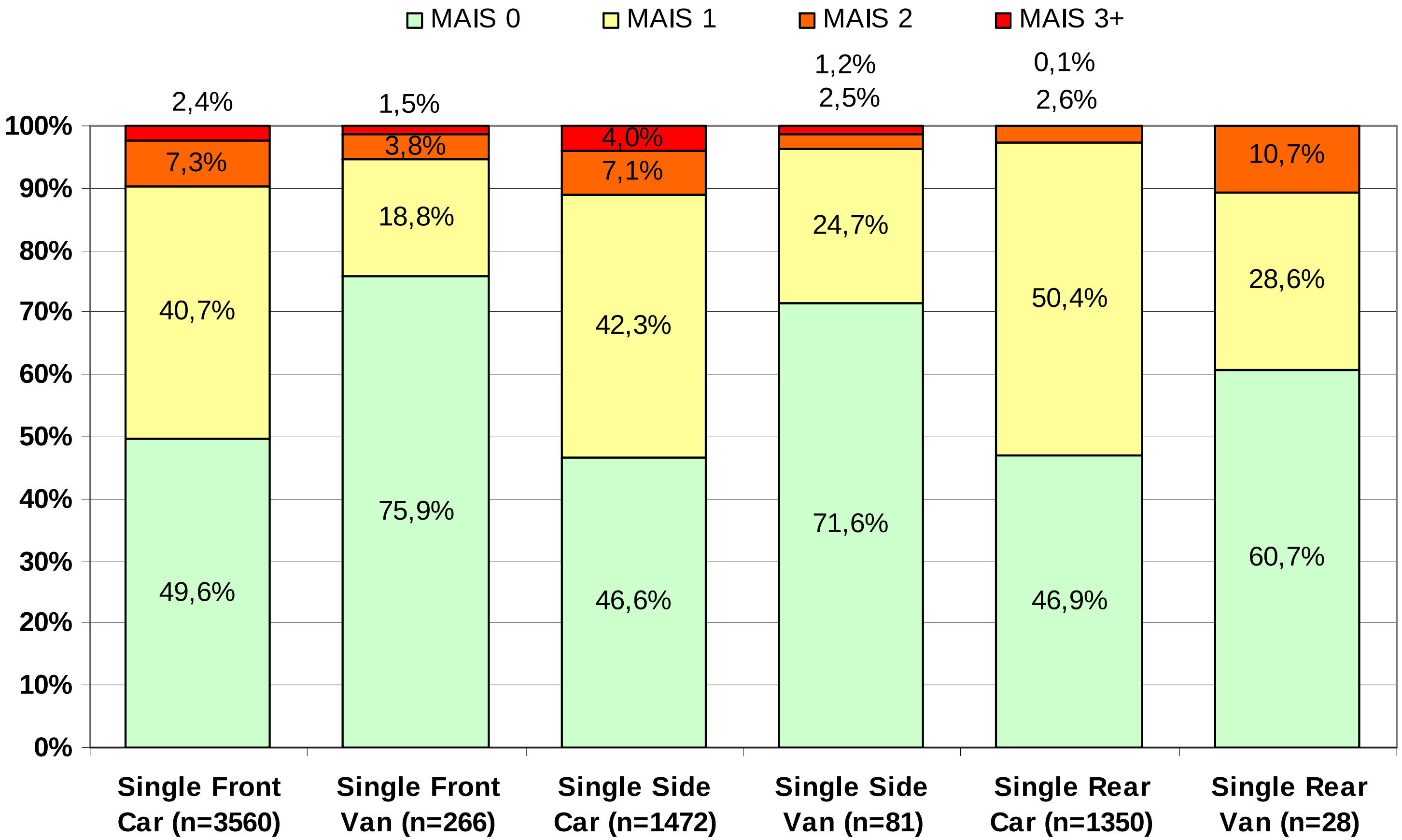
Injury Severity of Belted Front Seat Occupants

Accidents to Vulnerable Road Users exempted



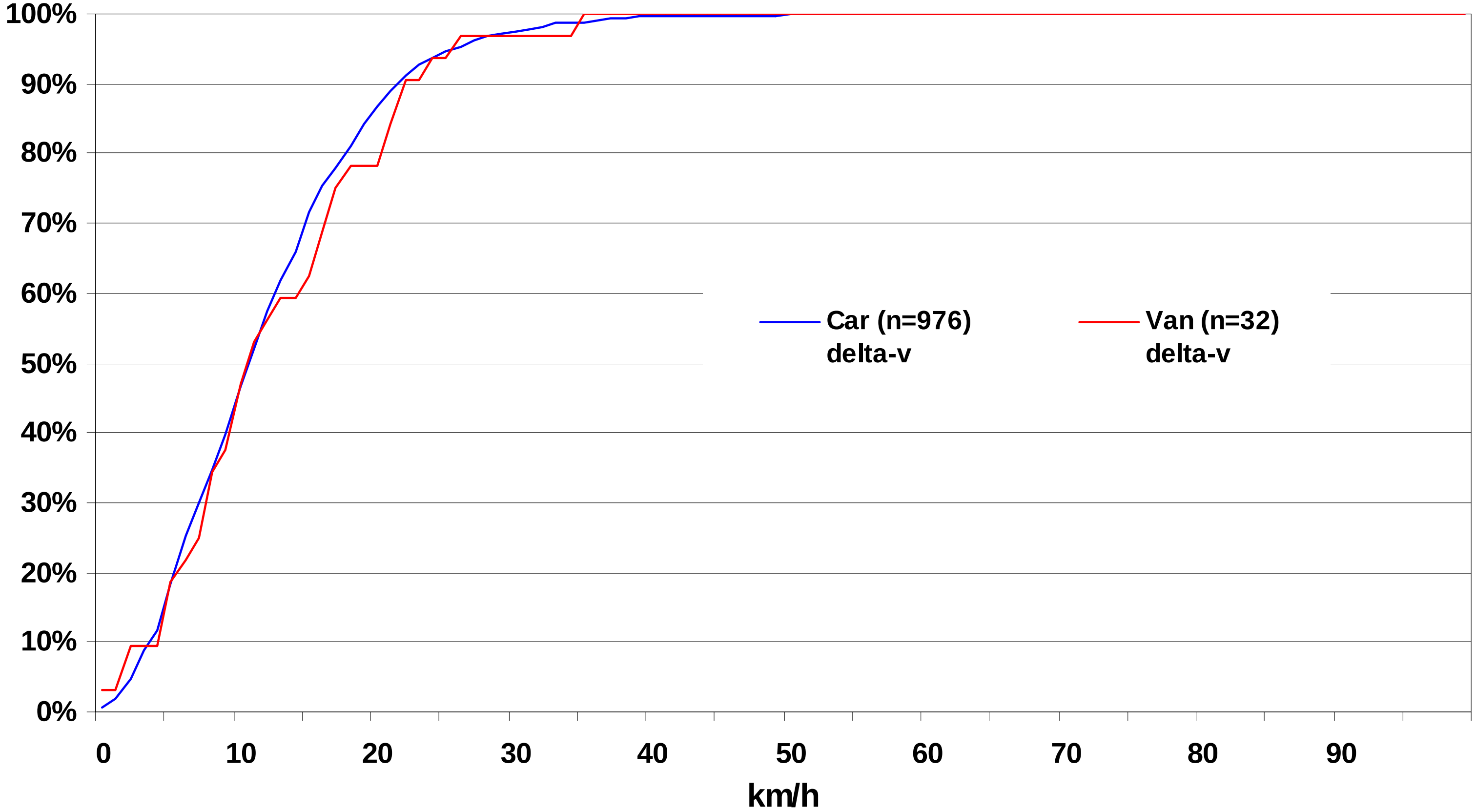
• More than 60% of the belted van occupants suffering no injuries at all

Injury Severity of Belted Front Seat Occupants by Type of Impact - Accidents to Vulnerable Road Users exempted



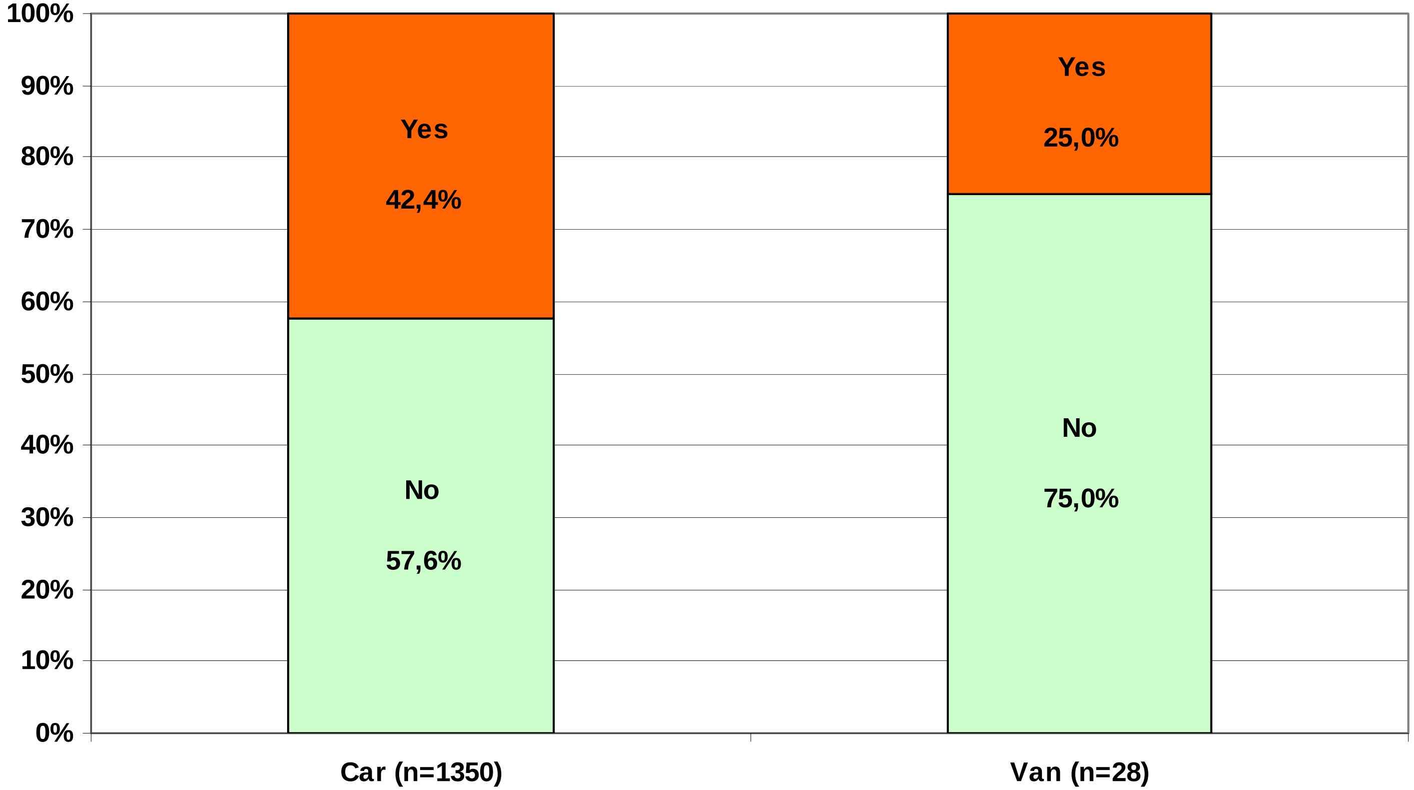
- Looking only at impact types addressable by crash tests, the share of van occupants suffering no injuries is between 60% and 75%

Accident Severity – Delta-v in Single Rear Impacts with Cars or Vans



- Very similar distribution of delta-v in rear impacts for both groups

Soft Tissue Neck injuries of Belted Front Seat Occupants in Single Rear Impacts - Accidents to Vulnerable Road Users exempted



- Just one quarter of the occupants in vans suffer soft tissue neck injuries in single rear impacts

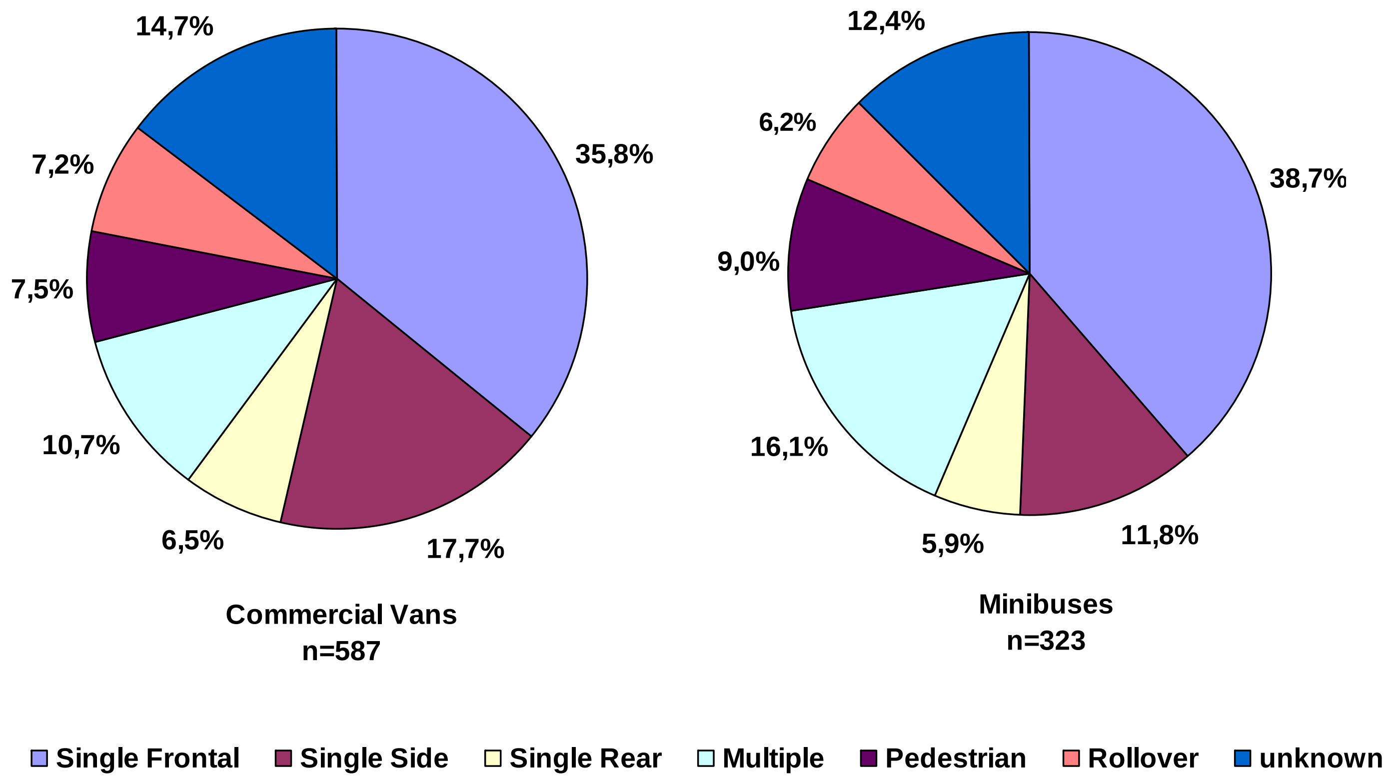
Soft Tissue Neck Injuries of Front Seat Occupants by Type of Impact - Accidents to Vulnerable Road Users exempted

Type of Impact	Car Occupants (n=21868)		Van Occupants (n=1411)	
	n	%	n	%
Single Frontal	654	25.7%	23	26.7%
Single Side	287	11.3%	10	11.6%
Single Rear	655	25.7%	9	10.5%
Multiple	745	29.3%	30	34.9%
Rollover	205	8.1%	14	16.3%
Total	2546	100.0%	86	100.0%

- 6% (86 / 1411) of all FSO in Vans suffer an STNI.
  Car FSO do so in 12% of the cases (2546 / 21868)
- Soft tissue neck injuries in vans occur more often in multiple impacts and rollovers (and less in rear end crashes)

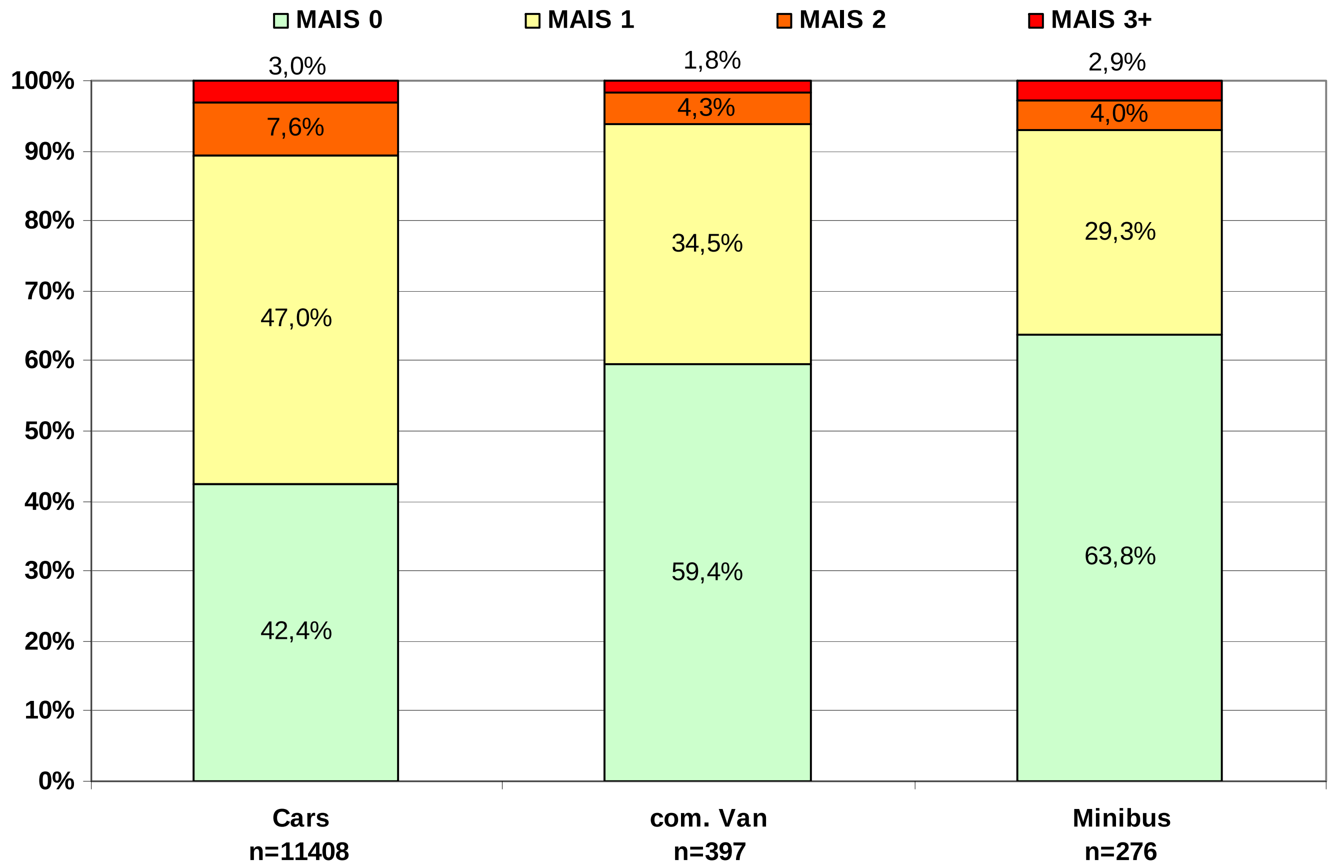
FSO – front seat occupant

Impact Types of Commercial Vans and Minibuses



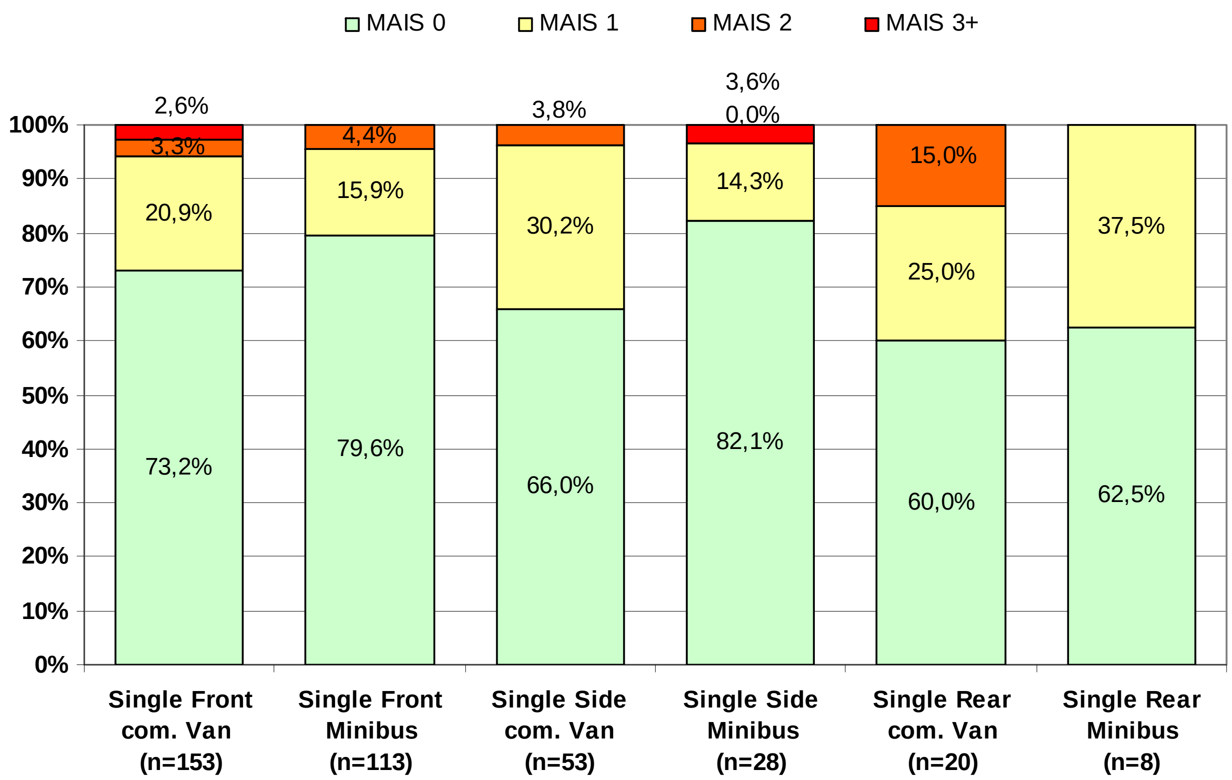
- The share of single side impacts is higher for commercial vans
- The share of multiple impacts is higher for minibuses

Injury Severity of Belted Front Seat Occupants of Cars, Commercial Vans and Minibuses - Accidents to Vulnerable Road Users exempted



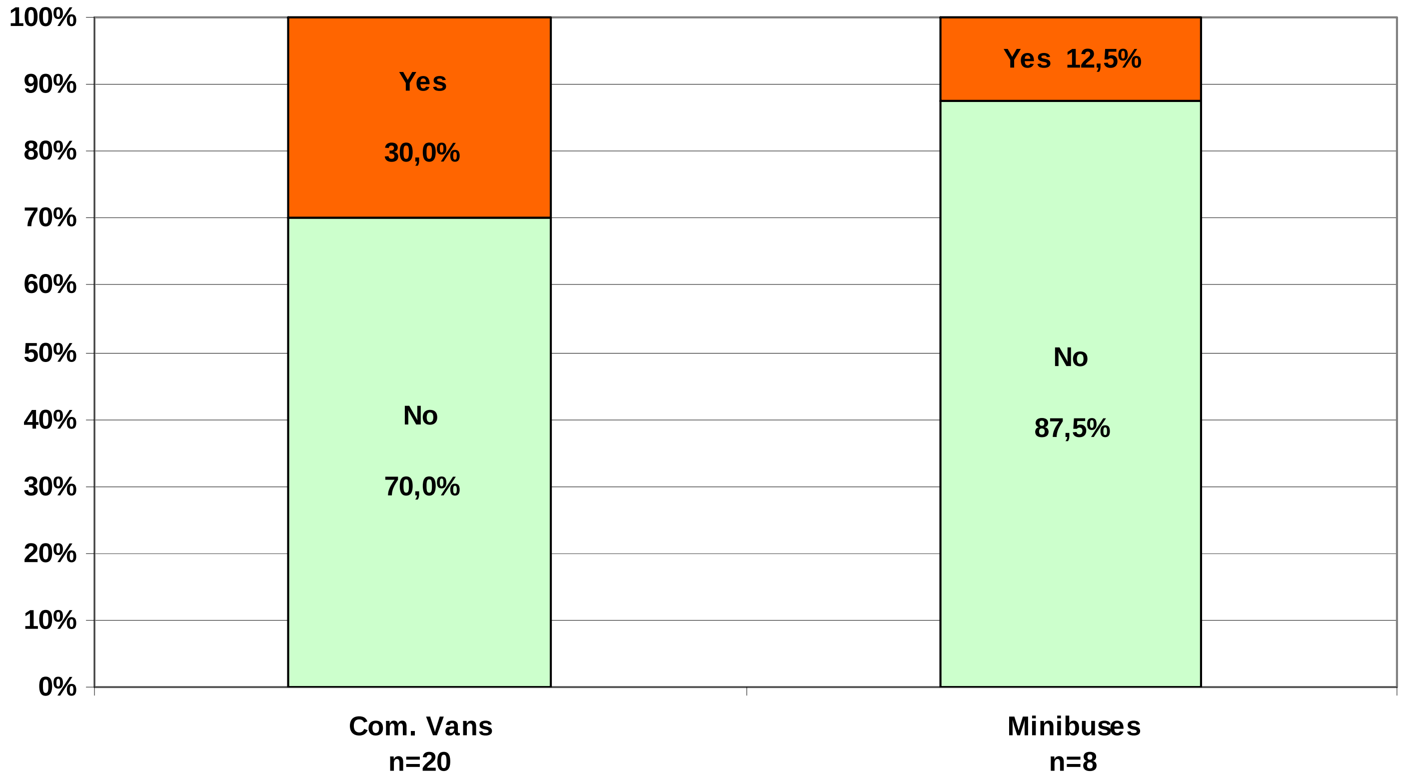
- In general minibus occupants are less frequent injured

Injury Severity of Belted Front Seat Occupants of Commercial Vans and Minibuses by Type of Impact - Accidents to Vulnerable Road Users exempted



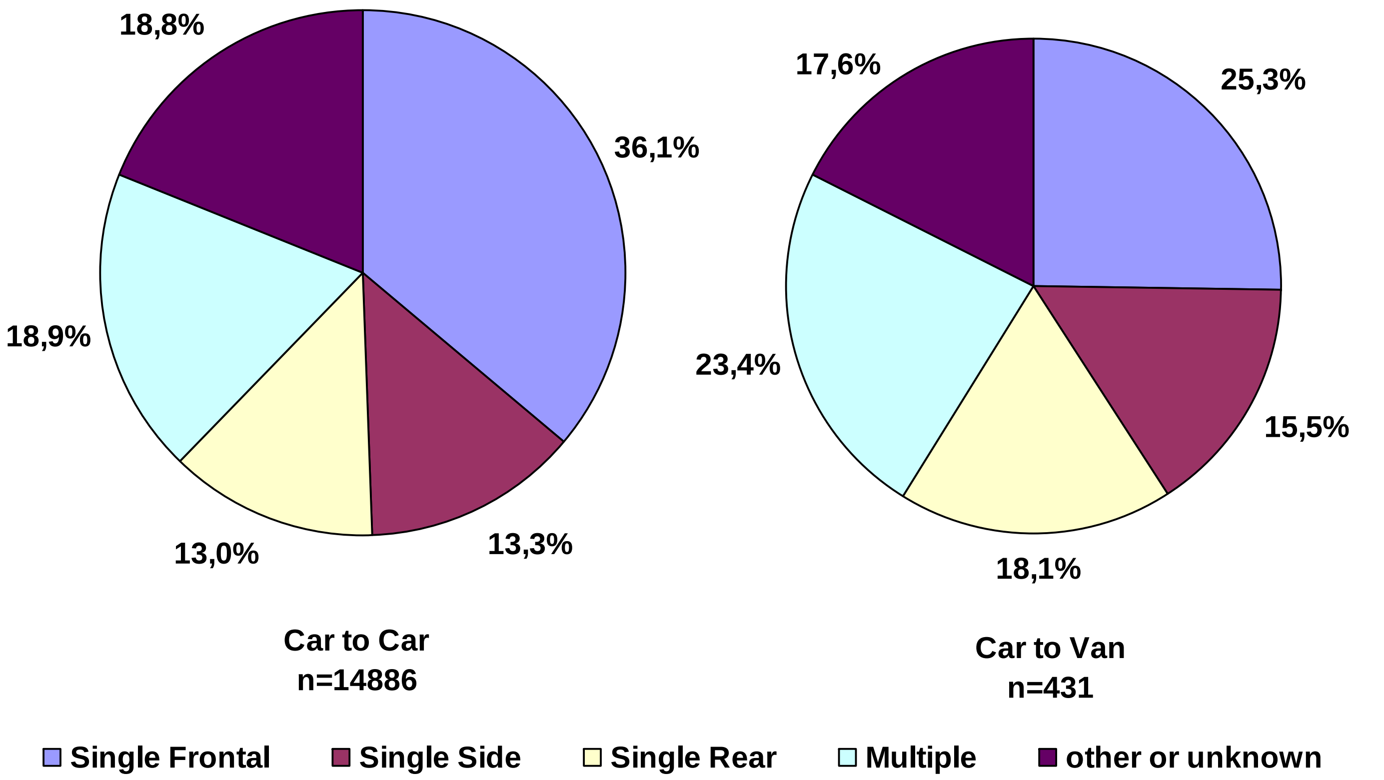
- 80% of the minibus occ. are not injured in accident scenarios covered by front or side impact crash tests, severe injuries in rear impacts were not recorded for minibus occupants.

Soft Tissue Neck Injuries of Belted Front Seat Occupants of Commercial Vans and Minibuses - Accidents to Vulnerable Road Users exempted



- Soft tissue neck injuries are an issue of minor importance for commercial vans and minibuses

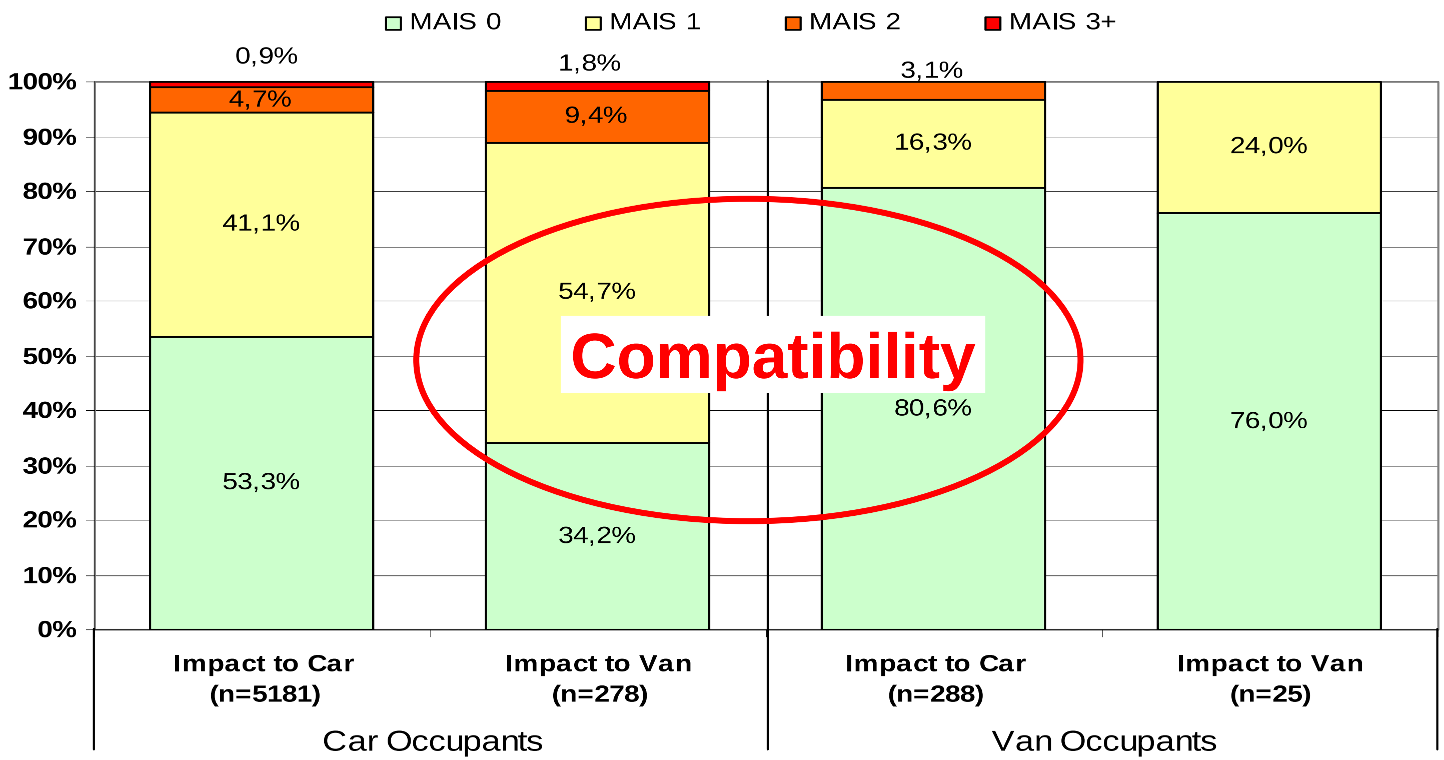
Impact Type in Car to Car and Car to Van Impacts (based on car deformation)



- The share of single frontal impacts is higher for cars
- Single Side, single rear and multiple impacts occur more often with vans

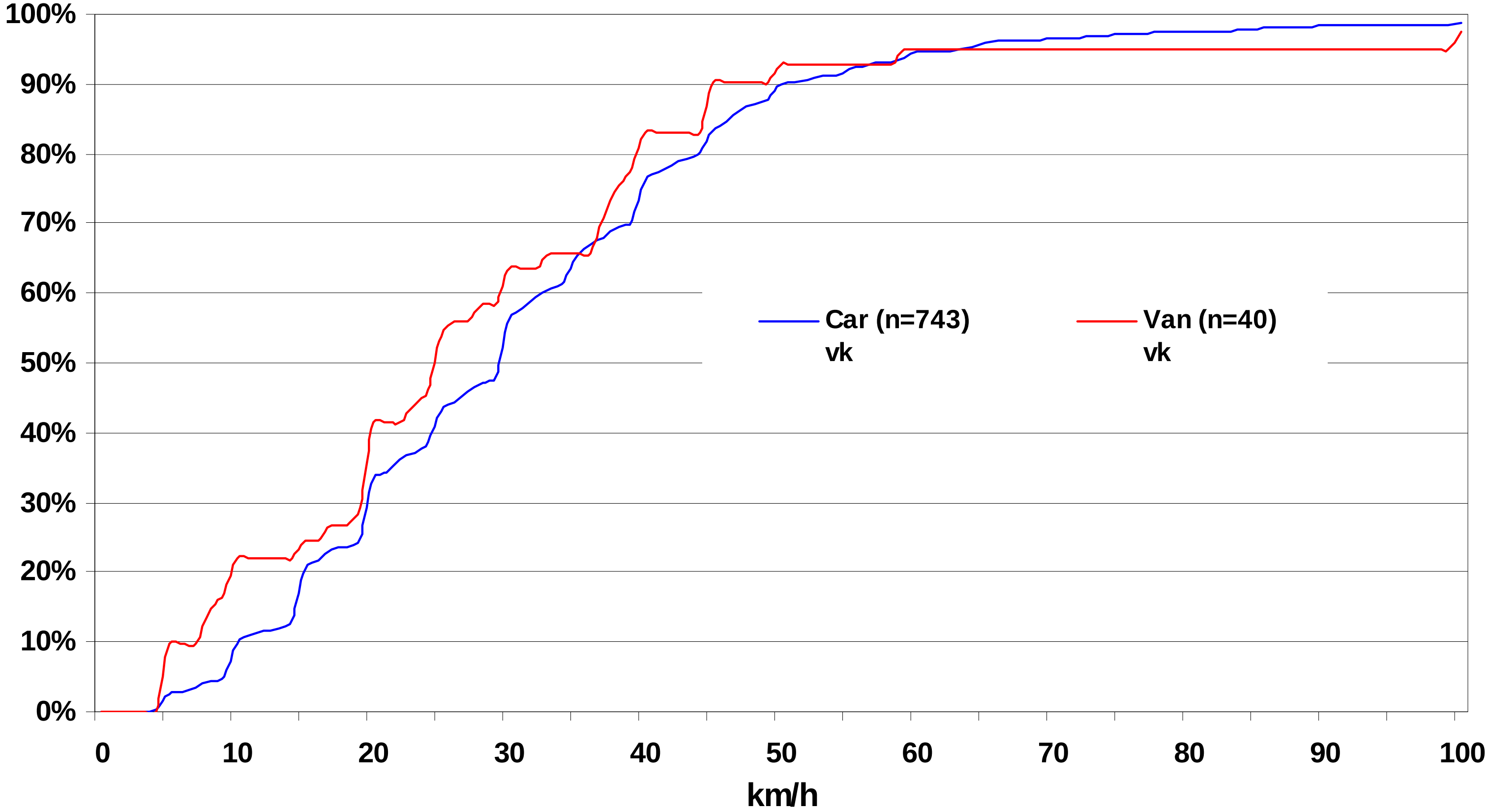
Injury Severity of Belted Front Seat Occupants

in Single Impacts between Cars and Vans



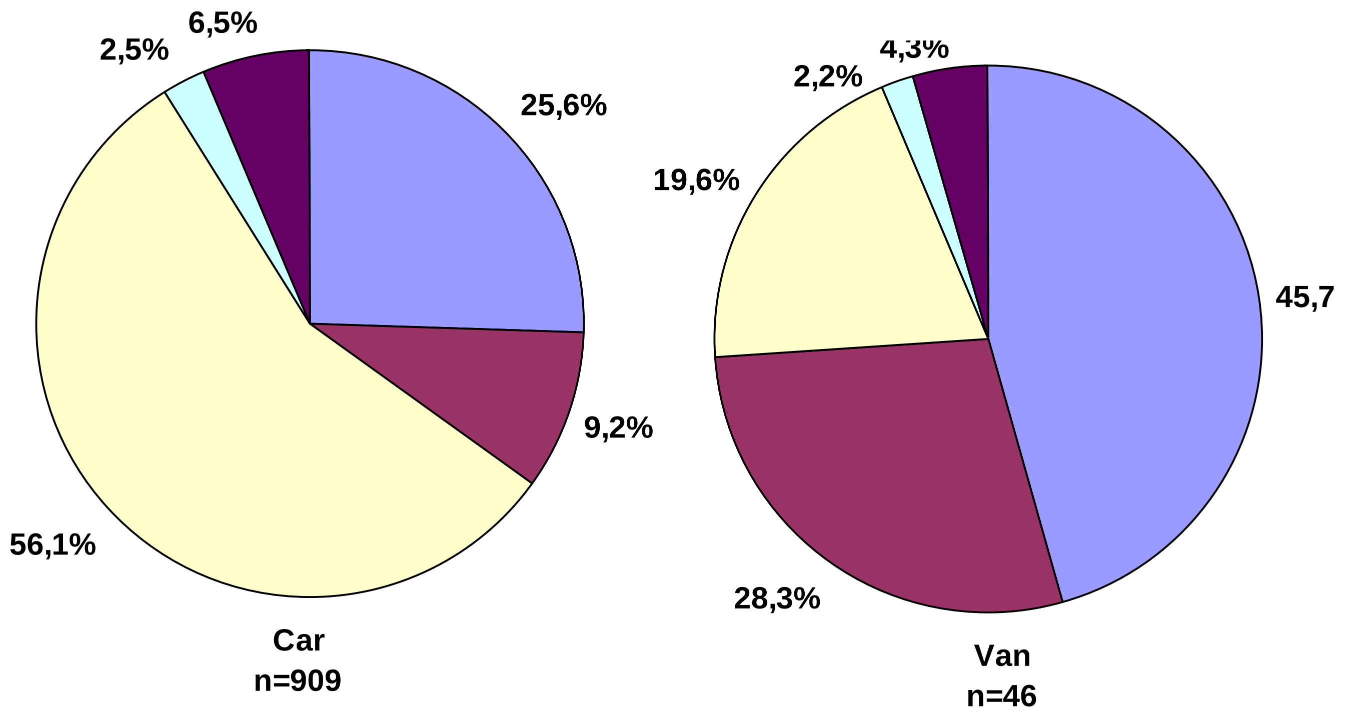
- 80% of the van occupants are not injured in car to van accidents, while 2/3 of the car occupants suffer injuries
- More than 50% of the car occupants are not injured after impacting another car

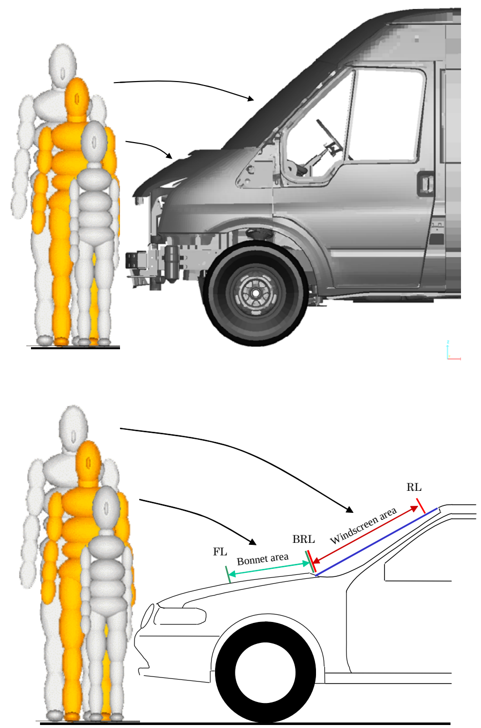
Impact Speeds in Frontal Collisions with Pedestrians



- Slightly lower impact speeds are observed in van to pedestrian accidents

Pedestrian Kinematics in Frontal Collisions



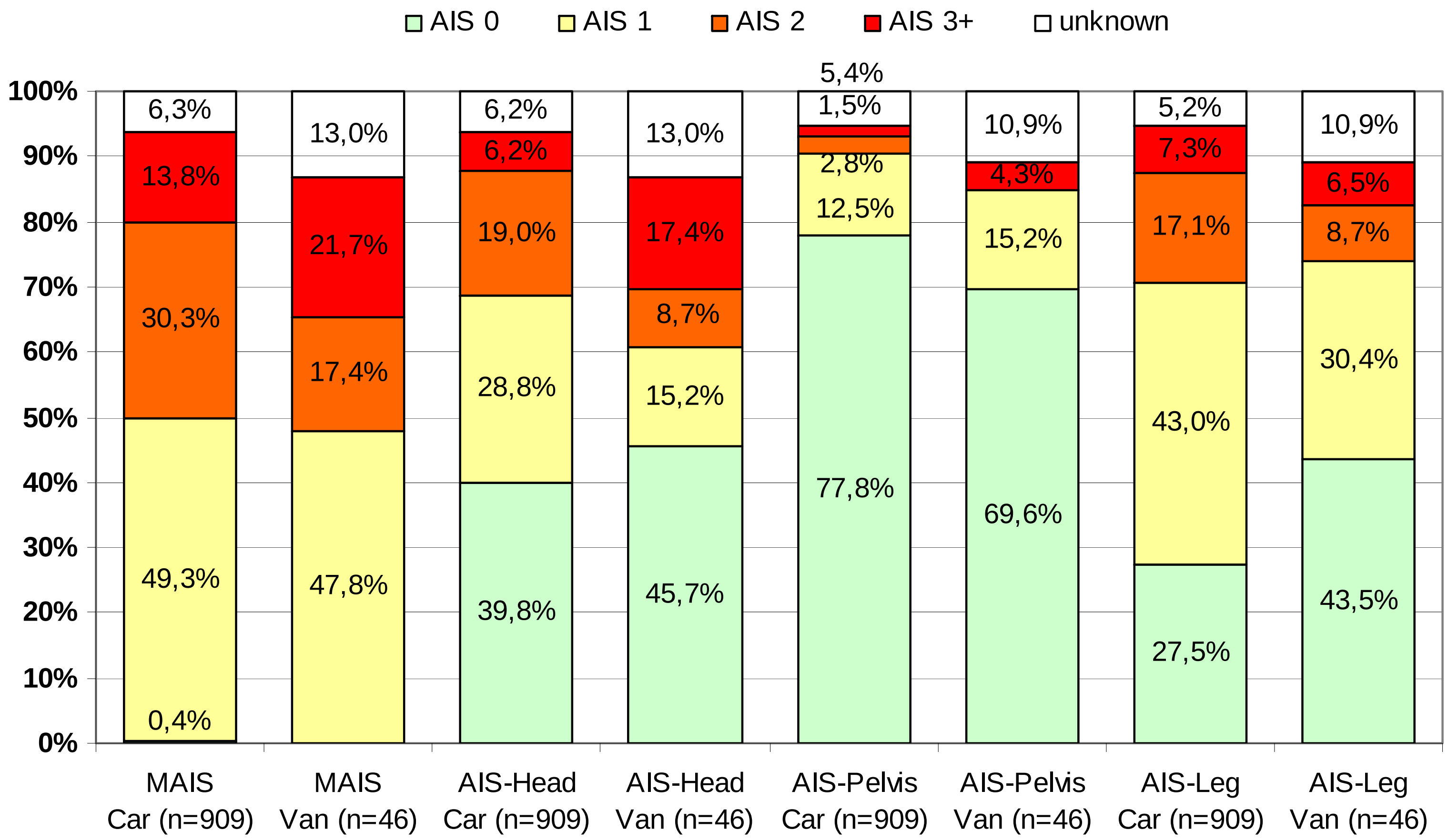


struck **thrown away** **picked up** **run over** **other or unknown**

„Struck“ means that unlike „thrown away“ the pedestrian does not change significantly the direction of motion

- In 56% of the cases the pedestrian is picked up by the car (rotation around front)
- In 75% of the cases the pedestrian is struck or thrown away by the van

Injury Severity of Pedestrians in Car or Van Impacts

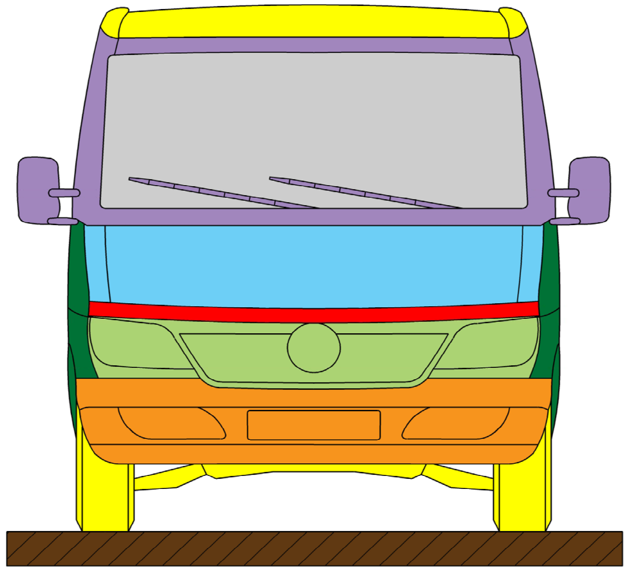


- In general the injury severity of pedestrians is higher in van accidents
- Severe lower leg injuries occur significantly more often in car accidents

Injury Causing Parts in Pedestrian Impacts with Commercial Vans (Source: VUFO Study on Scope Extension on Pedestrian Legislation)

	head	neck	thorax	abdomen	spine	upper extremities	lower extremities	TOTAL
window frame	2	-	-	-	1	-	-	**3**
windscreen	8	-	1	-	-	3	-	**12**
bonnet	1	-	1	-	-	1	1	**4**
BLE	-	-	2	-	1	1	1	**5**
wing	1	-	-	-	-	-	-	**1**
grill & headlamps	-	-	3	2	-	-	-	**5**
bumper	-	-	-	1	-	-	1	**2**
other veh. parts	-	-	-	-	-	1	4	**5**
front, n.f.s.	-	-	-	-	-	-	2	**2**
ground impact	11	-	3	-	-	7	6	**27**
body motion	-	-	-	2	1	-	-	**3**
unknown	1	-	-	-	-	-	1	**2**

$\sum$ 71



N1 vehicles with Gross Vehicle Weight above 2,500kg

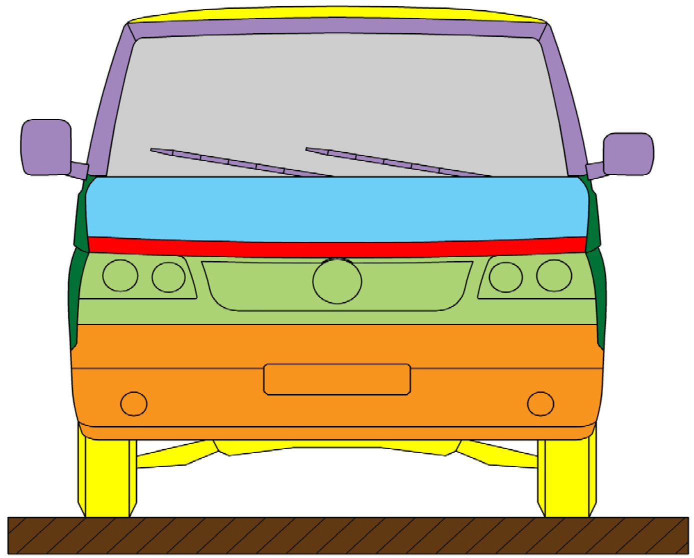
- 50% of the head injuries occur due to ground impact (secondary impact)
- The share of injuries due to bonnet contact is below 6%

Injury Causing Parts in Pedestrian Impacts with Minibuses

(Source: VUFO Study on Scope Extension on Pedestrian Legislation)

	head	*neck*	*thorax*	*abdomen*	*spine*	*upper extremities*	*lower extremities*	*TOTAL*
window frame	-	-	-	-	-	1	-	**1**
windscreen	4	-	-	-	-	-	-	**4**
bonnet	1	-	-	1	-	1	-	**3**
BLE	-	-	-	-	-	-	-	**-**
wing	-	-	-	-	-	-	-	**-**
grill & headlamps	-	-	-	-	-	-	2	**2**
bumper	-	-	-	-	-	-	3	**3**
other veh. parts	-	-	-	-	-	-	-	**-**
front, n.f.s.	-	-	-	-	-	2	1	**3**
ground impact	5	-	-	-	-	5	1	**11**
body motion	-	-	-	-	-	-	-	**-**
unknown	2	-	1	-	-	1	2	**6**

$\sum$ 33



M1 vehicles with Gross Vehicle Weight above 2,500kg

- Ground impact causes one third of all injuries
- Head injuries occur exclusively due to windscreen or ground impact

Next steps:

- Determination of countermeasures based on showed results
- Assessment of countermeasures regarding safety potentials
- Creation final report of phase I
- Decision to start phase II

Overview of Crash Box Deformations in Frontal Collisions of Cars

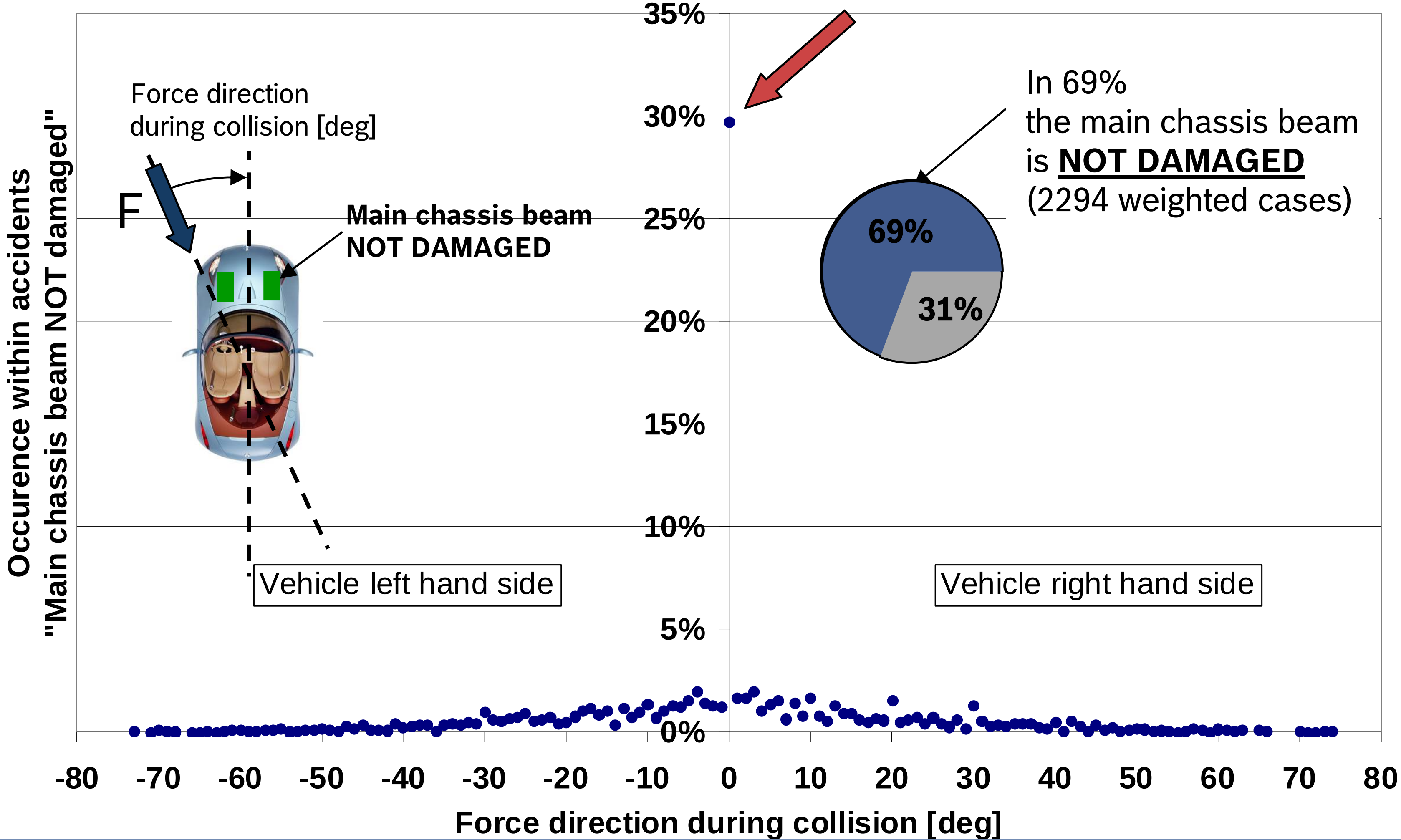
Results of Accident Analysis

Accident Research CR/AEV1

BOSCH

Frontal collisions **NOT damaging** the main chassis beam: Force angle distribution

(Only frontal collisions of passenger cars with personal injury[1])

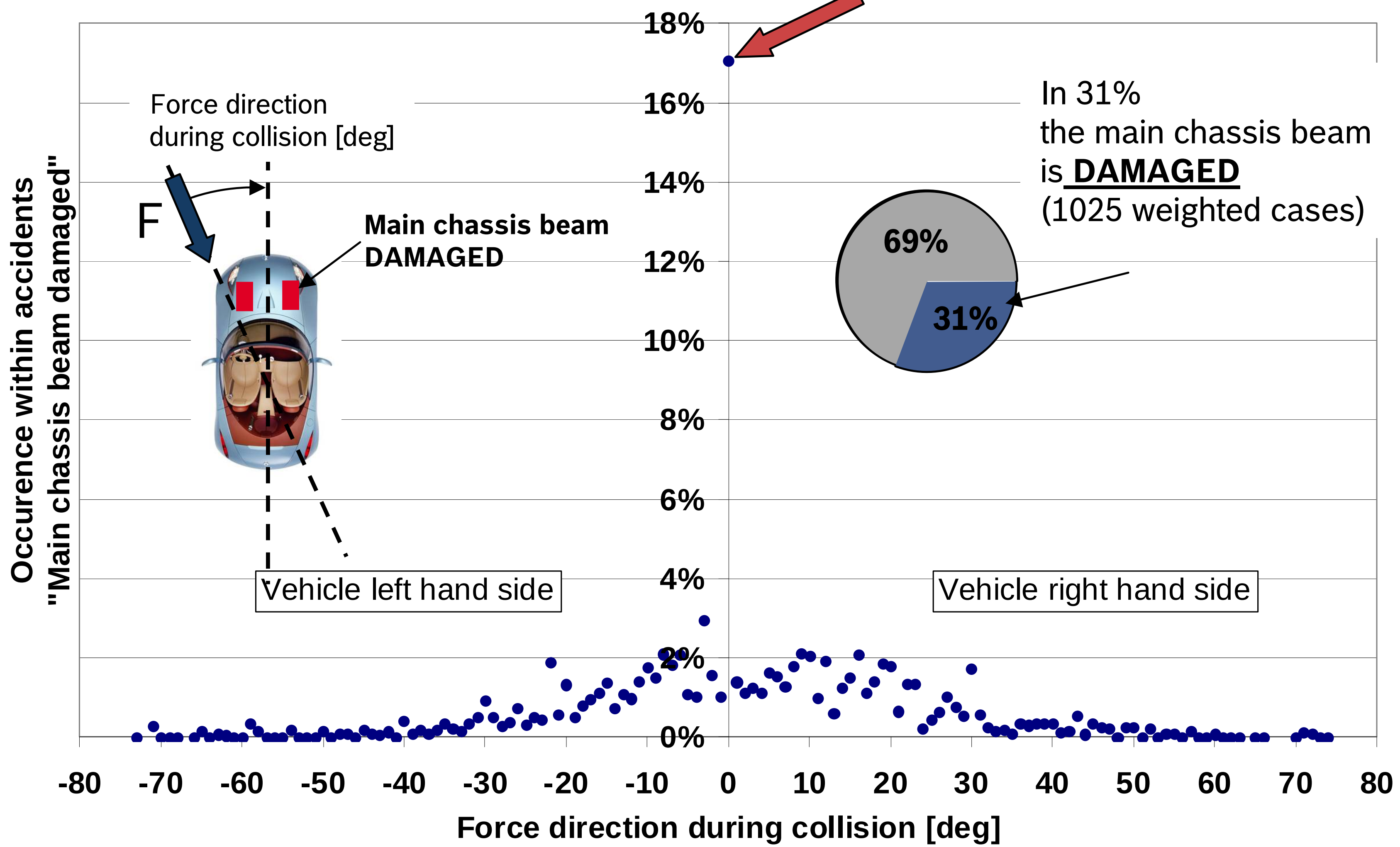


In about one third (30%) of the frontal collisions where the main chassis beam is not damaged, the force direction during collision is (about) longitudinal i.e. aligned with the main chassis beam.

[1]Evaluation based on GIDAS (german in depth accident study), year 2001-08

Frontal collisions **WITH damage** to the main chassis beam : Force angle distribution

(Only frontal collisions of passenger cars with personal injury[1])

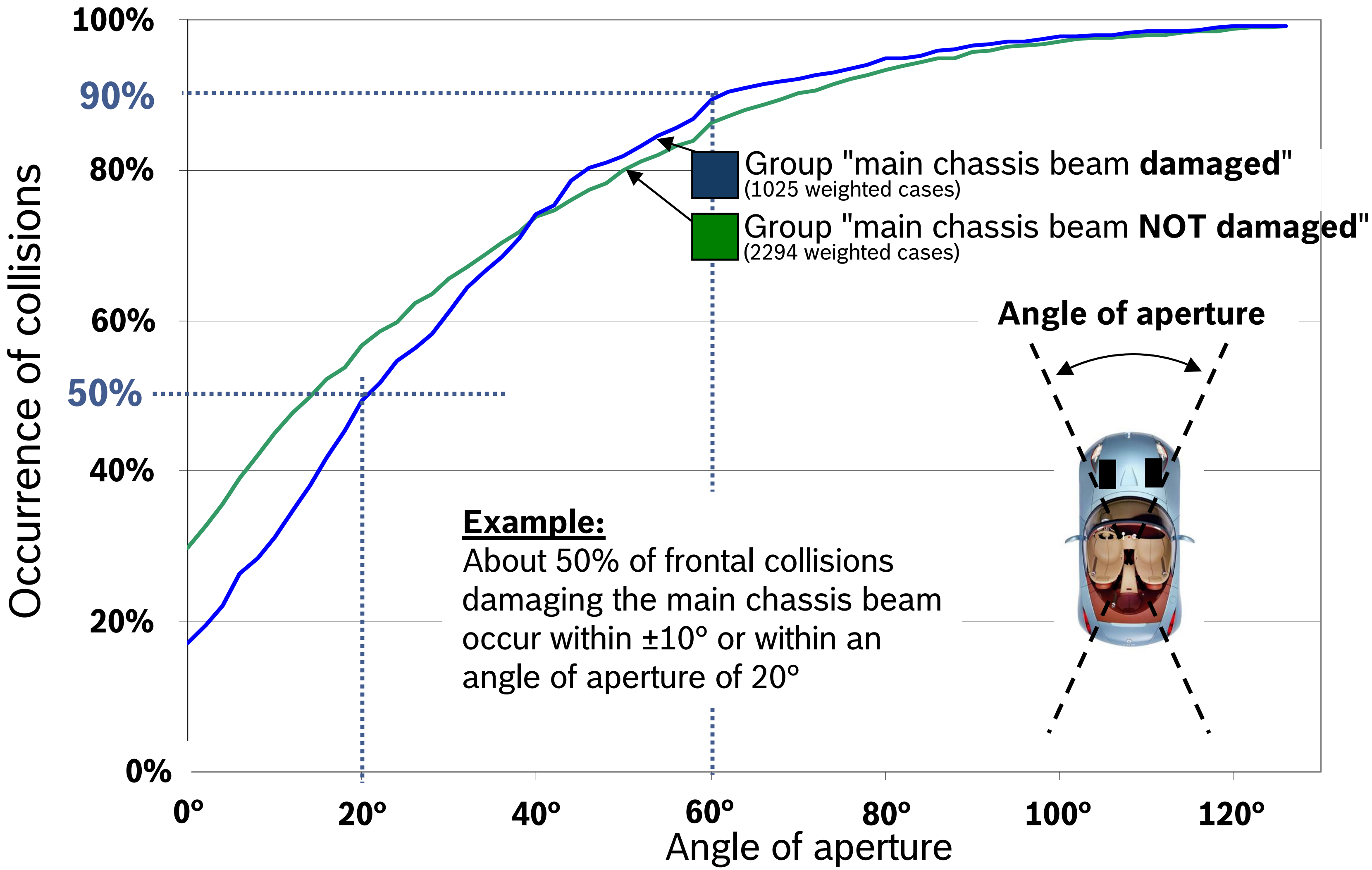


In about one of six (17%) frontal collisions, where the main chassis beam is damaged, the force direction during collision is (about) longitudinal i.e. aligned with the main chassis beam.

[1]Evaluation based on GIDAS (german in depth accident study), year 2001-08

Frontal collisions: Occurrence of collisions in dependence of the aperture angle

(Only frontal collisions of cars with personal injury[1])



About 50% of frontal collisions damaging the main chassis beam occur within an aperture angle of 20°

[1]Evaluation based on GIDAS (german in depth accident study), year 2001-08

Case selection in GIDAS (numbers below present weighted cases)

Accidents

11713
reconstructed accidents
(GIDAS 2001-2008
Status = 4)

→

Vehicles

20476 vehicles

↓

14156 passenger cars
FART = 3

↓

6975 frontal collisions
(VDI2 = 1 and VDI1 = 10,11,12,1,2)

↓

6545 cases with known force direction
(IMP ≠ 777, 888, 9999, 999)

↓

4629 cars damaged in area of bumper
(BRPX < 15 and VDI7 > 1)

↓

4061 cars damaged in area of main chassis beam
(VDI3 ≠ 20, 30, 40)

↓

2294 cars	1025 cars	741 cars
main chassis beam NOT damaged (LONGDEF = 2 or LONGDEF = 1, 3 and LONGCM = 0, 1)	**main chassis beam damaged** (LONGDEF =1,3 and LONGCM > 1 and not 999 and not empty)	**not assigned to left groups** (LONGDEF = 8,9 or LONGDEF = 1, 3 and LONGCM = 999 or empty)

Evaluation based on GIDAS (german in depth accident study), years 2001-08

Accidents in Germany Involving Wild Animals

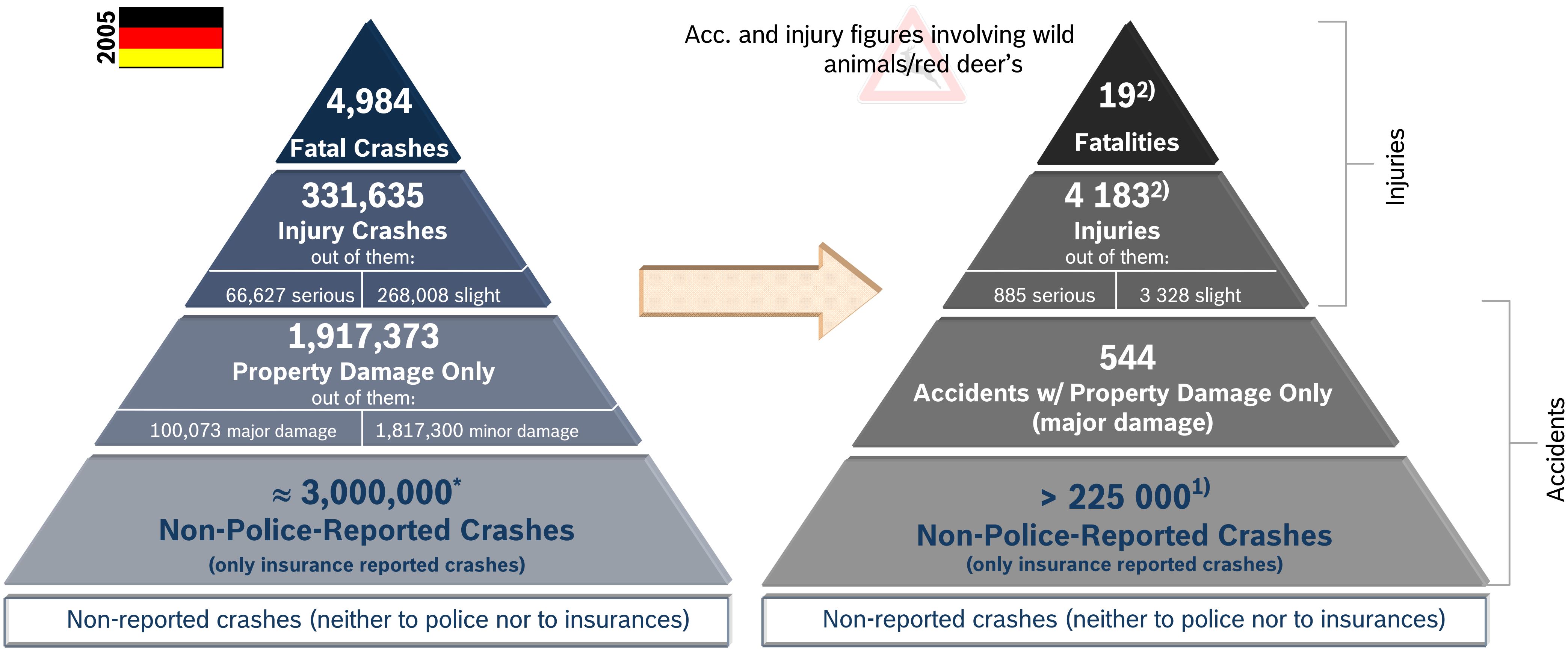
GIDAS case: 30030520

Results of Accident Analysis

Accident Research CR/AEV1

BOSCH

Accident figures Germany compared to acc. w/ wild animals



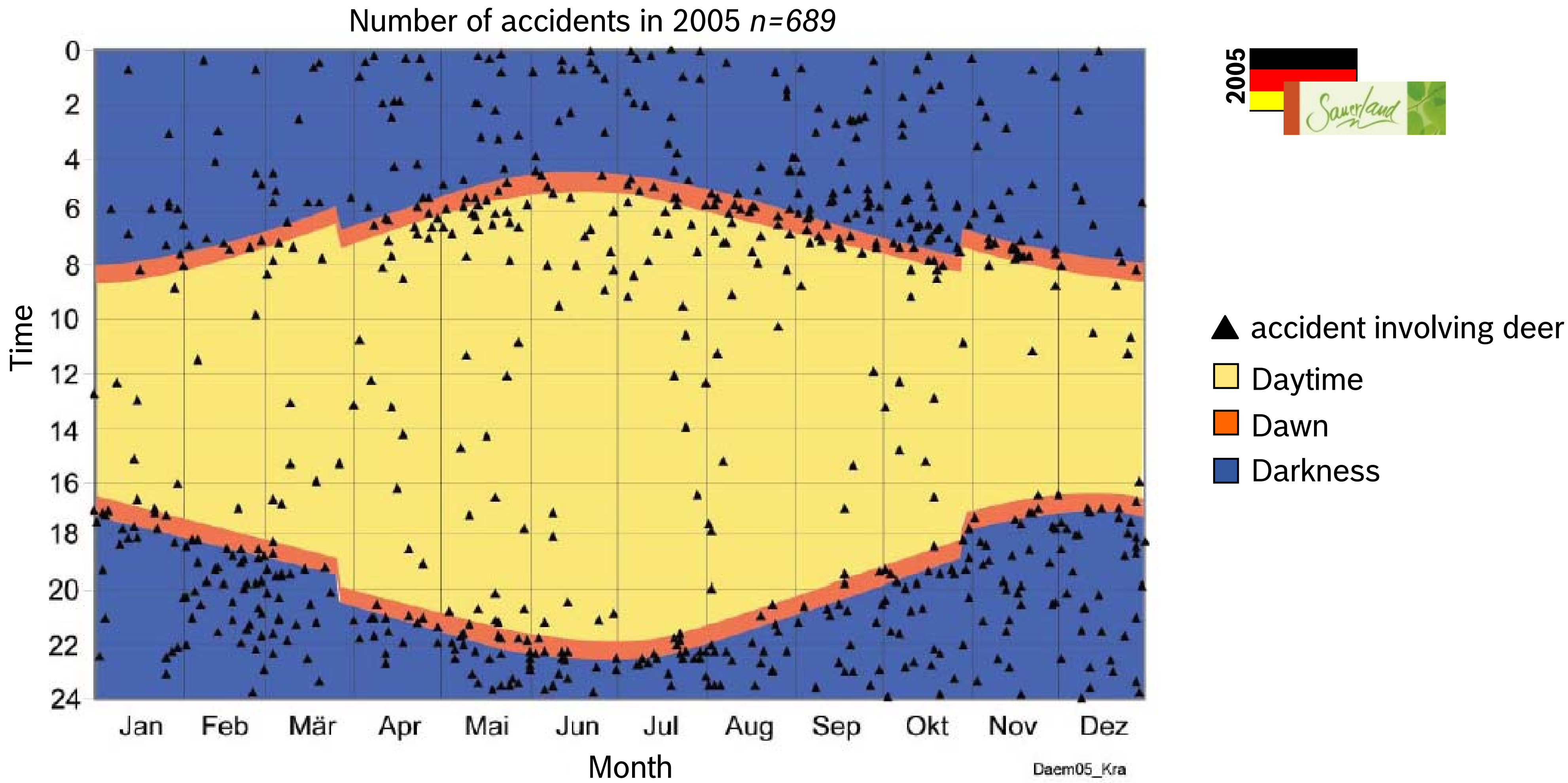
sources: Federal Statistical Office, Germany
* GDV-yearbook (estimation)

sources: Federal Statistical Office, Germany
1) GDV-research report

➔ A share of approx. 4,5% are accidents involving wild animals resulting in property damage only crashes in Germany (2005)

1) Source: "Unfallhäufungen mit Wildunfällen", Research report of GDV, 2007, H.Voß
2) In total 3597 accidents w/ personal injuries involving wild animals occurred in Germany 2005

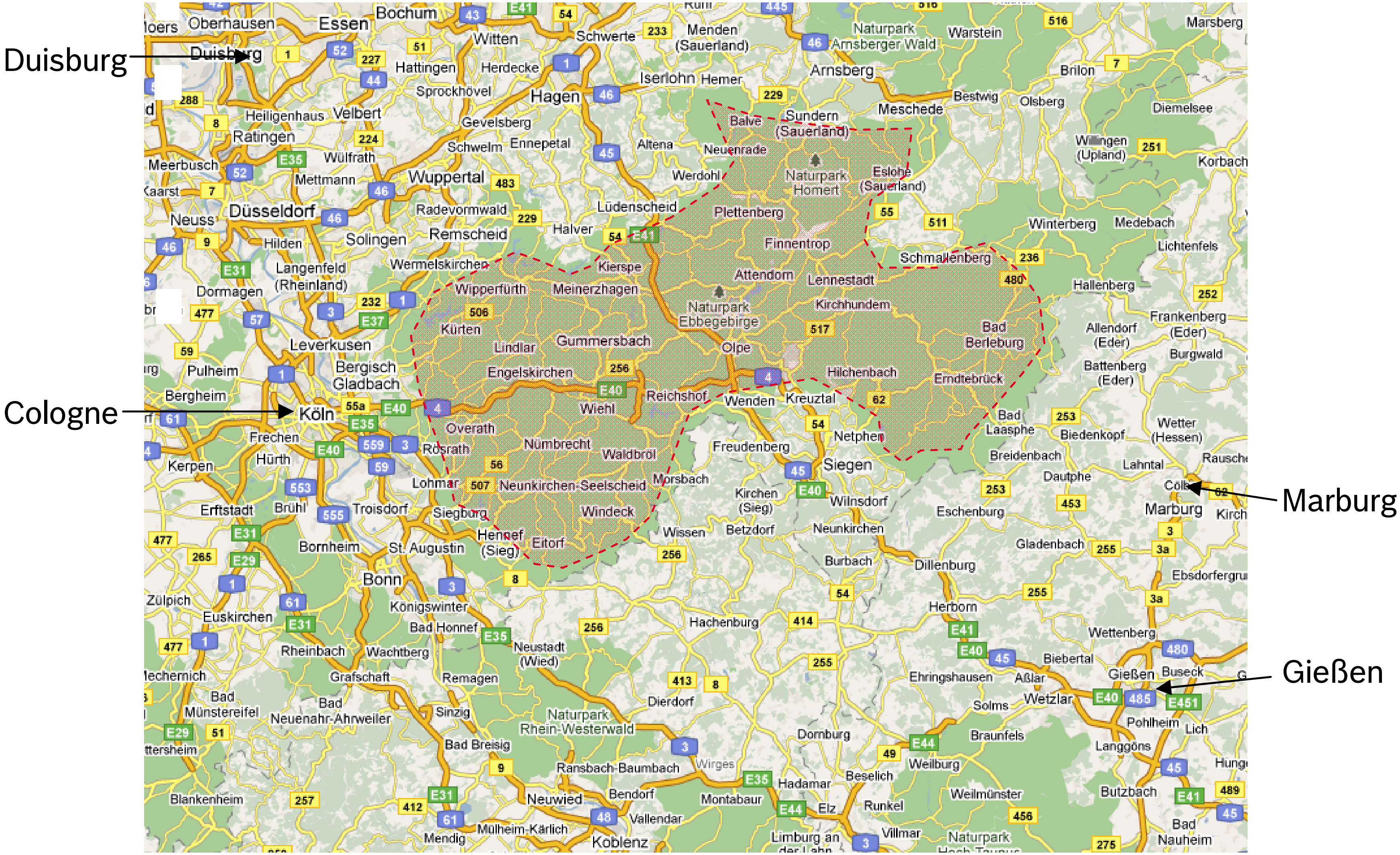
Distribution of accidents involving wild animals/deer's by month and daytime in observation area "Oberbergischen Kreis", 2005[1)]



Note: Frequency of accidents shown in the diagram are only seen for 2005 and not for the other years, in other words distribution seemed to be not representative over time

1) Source: "Unfallhäufungen mit Wildunfällen", Forschungsbericht des GDV 2007, H.Voß

Observation area “Oberbergischen Kreis” for accident study involving deer’s and other animals

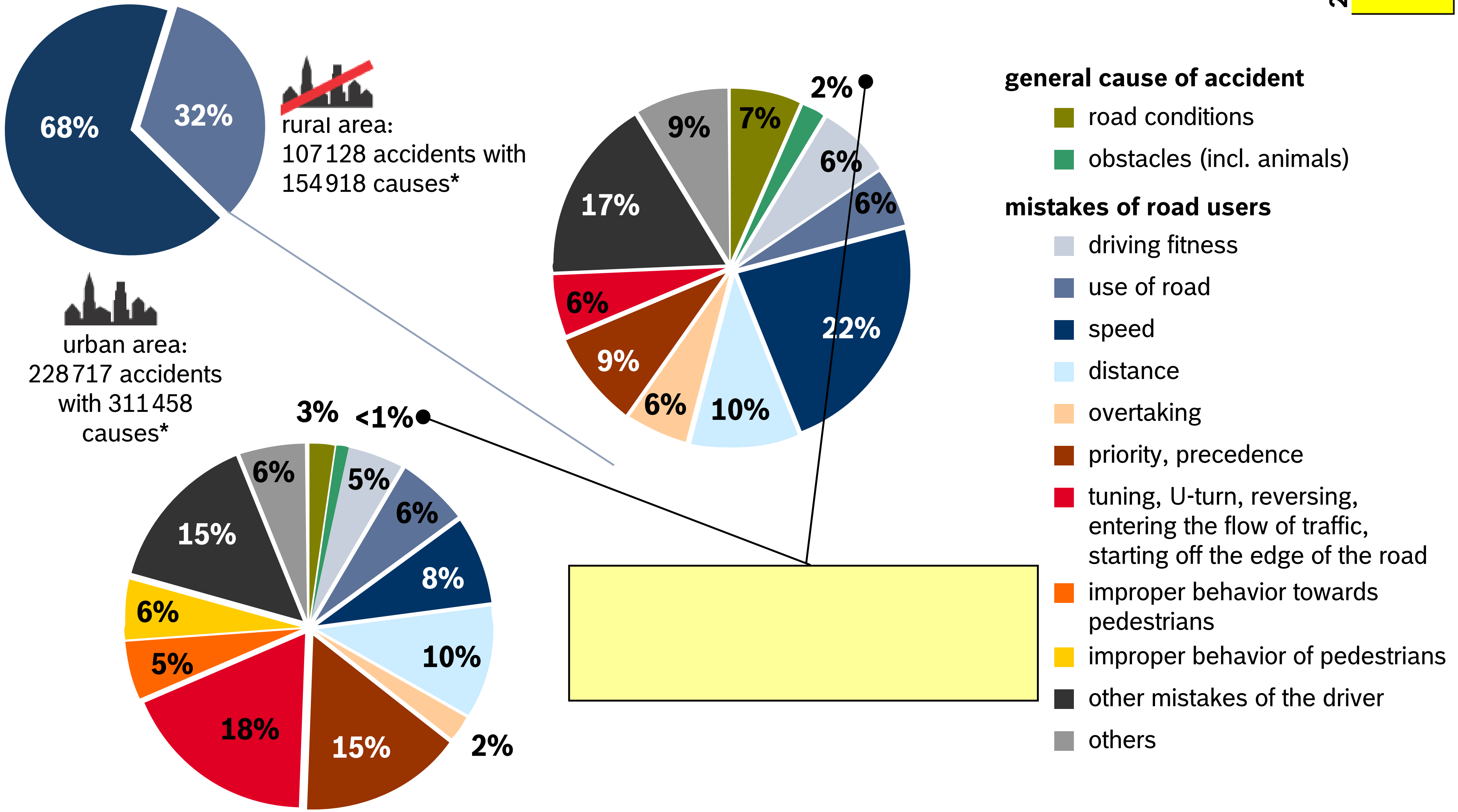


[1)] Source: “Unfallhäufungen mit Wildunfällen”, Forschungsbericht des GDV 2007, H.Voß

Causes for accidents with injuries in Germany

2007

Analysis is based on 335 845 accidents in 2007



Source: Federal Statistical Office 2007

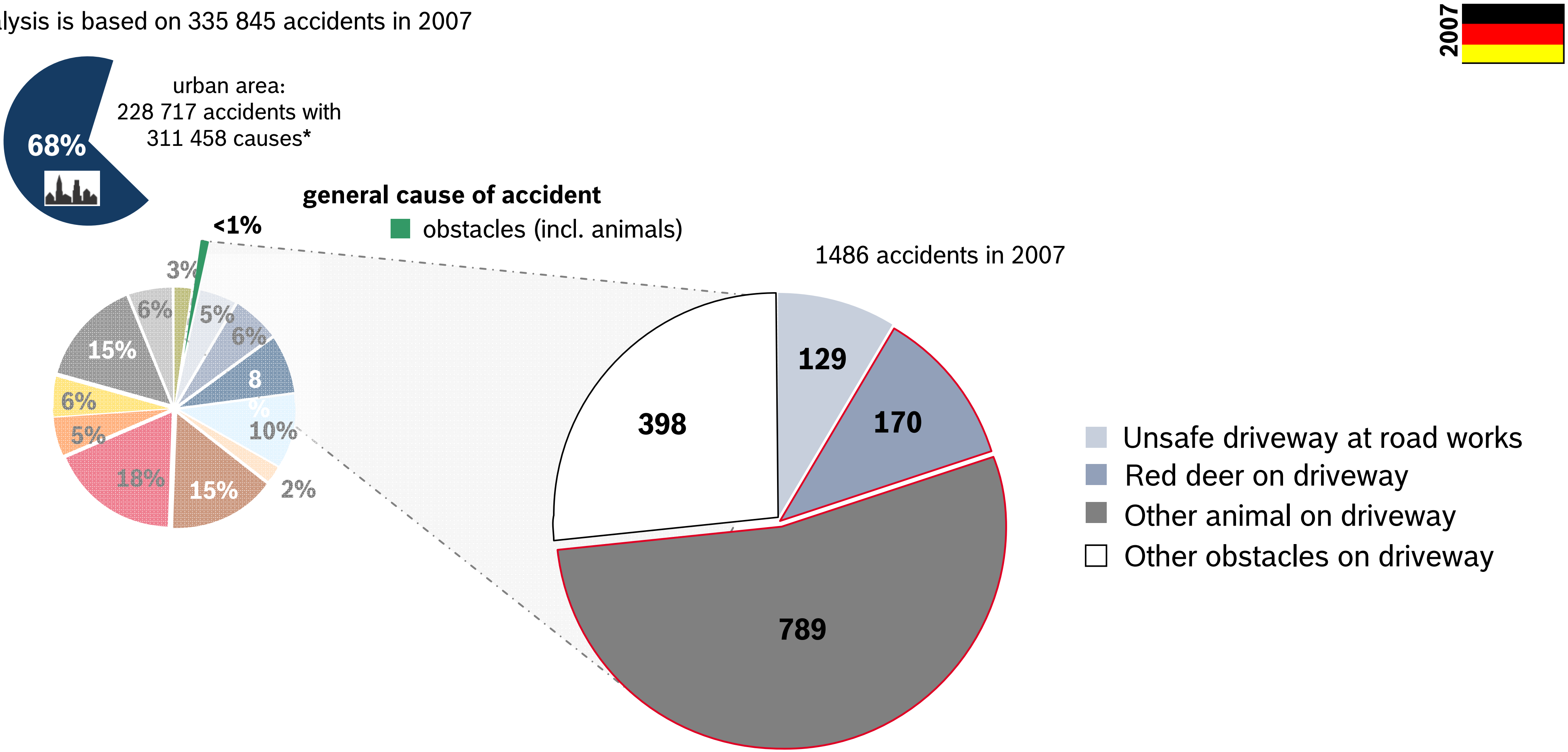
* In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.

This slide is a Standard Slide of the Accident Research therefore annually available

BOSCH

Causes for accidents with injuries in Germany

Analysis is based on 335 845 accidents in 2007

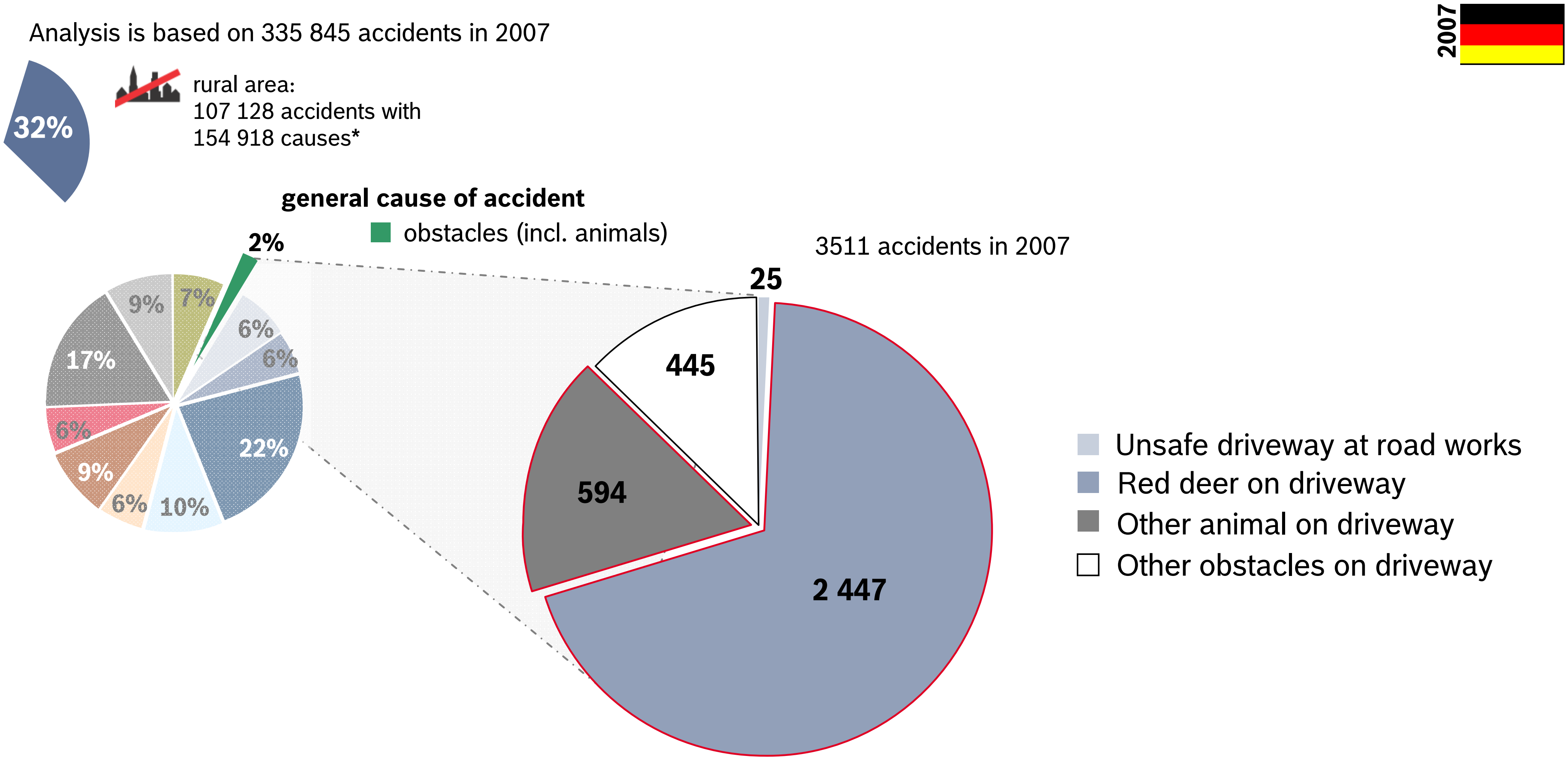


Source: Federal Statistical Office 2007

* In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.

Causes for accidents with injuries in Germany

Analysis is based on 335 845 accidents in 2007



Source: Federal Statistical Office 2007

* In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.

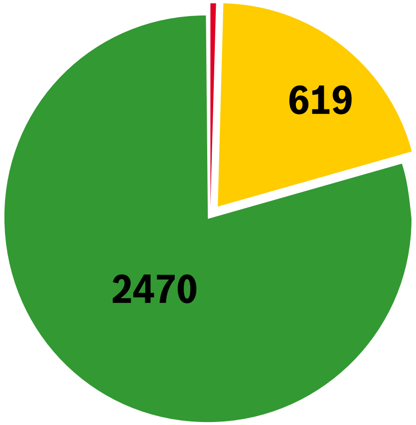
Injuries caused by accidents against obstacles

urban and rural area

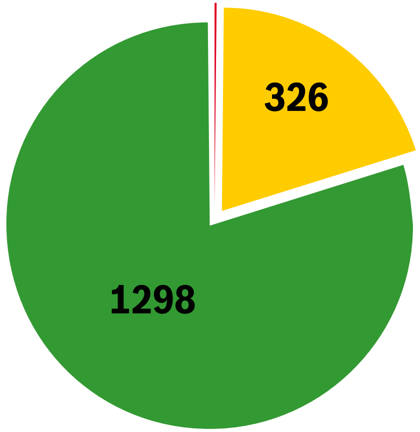
2007

Red deer on driveway

20[1)]



3[1)]



Other animal on driveway

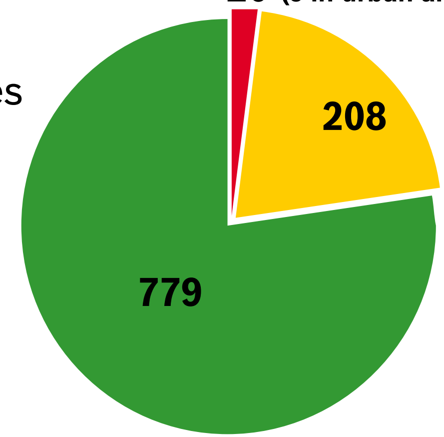
Fatal injured

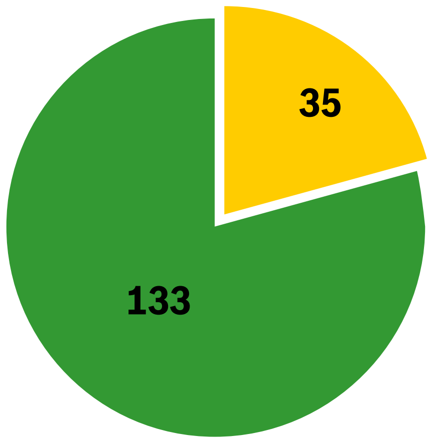
Severe Injured

Slight Injured

Other obstacles on driveway

20 (5 in urban area)





Unsafe driveway at road works

Source: Federal Statistical Office 2007

[1)] Fatalities only in rural area

Appendix – Damages of accidents involving wild animals reported from insurances in Germany[1)]

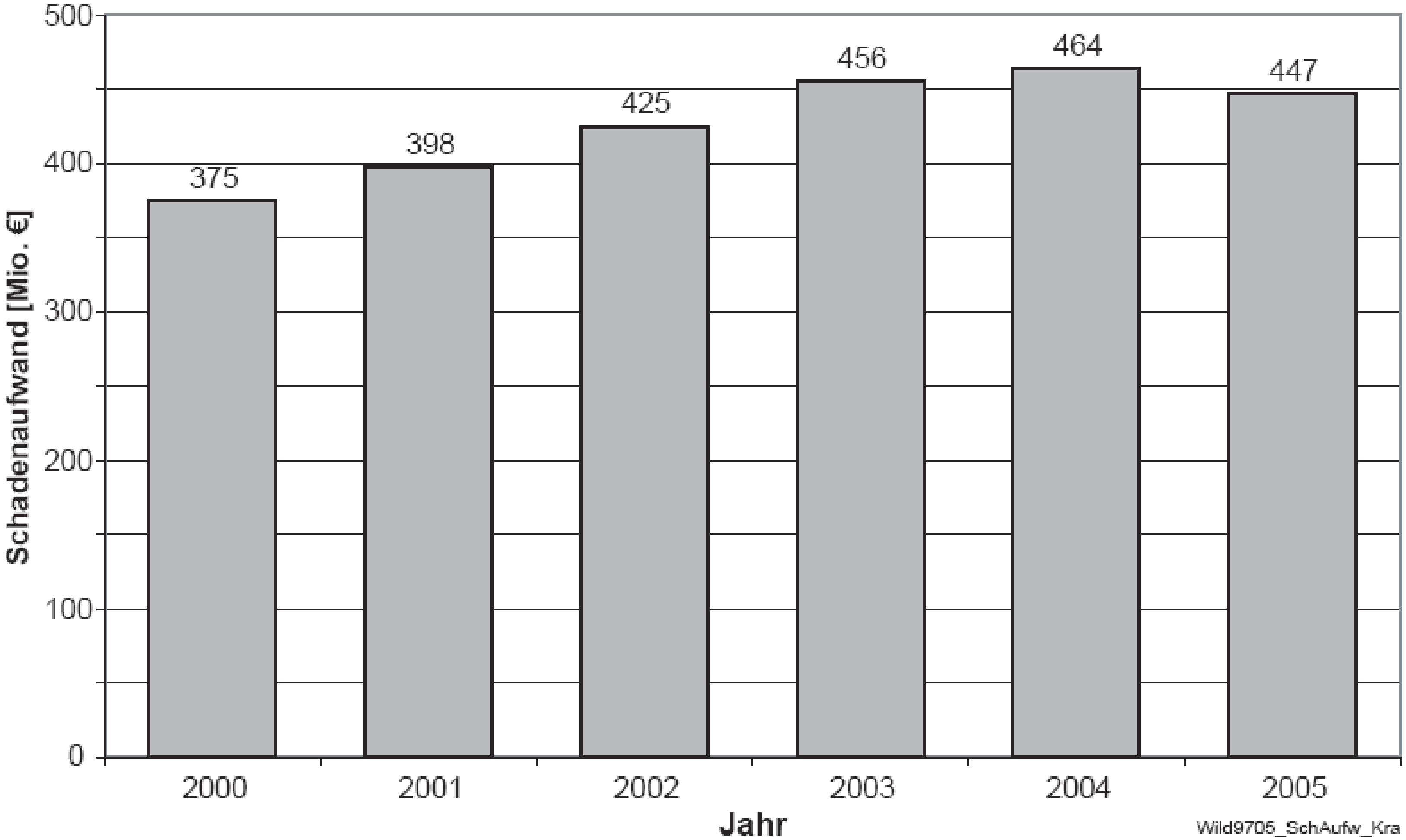


Bild 1: Schadenaufwand in der Fahrzeugversicherung insgesamt (Vollkasko und Teilkasko) bei Unfällen mit Wildbeteiligung in Deutschland

[1)] Source: "Unfallhäufungen mit Wildunfällen", Forschungsbericht des GDV 2007, H.Voß

Appendix – Accidents involving wild animals reported to insurances in Germany[1)]

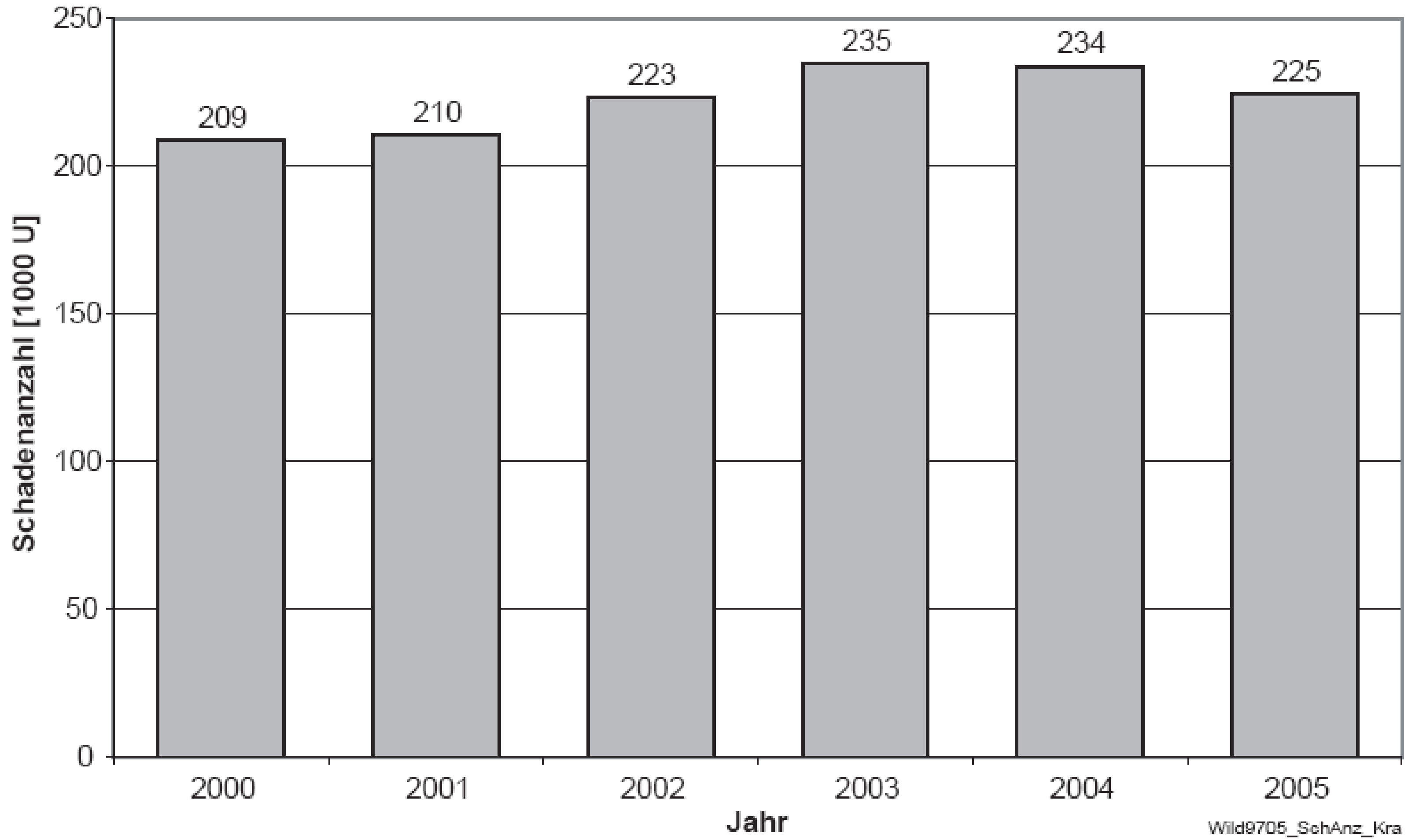
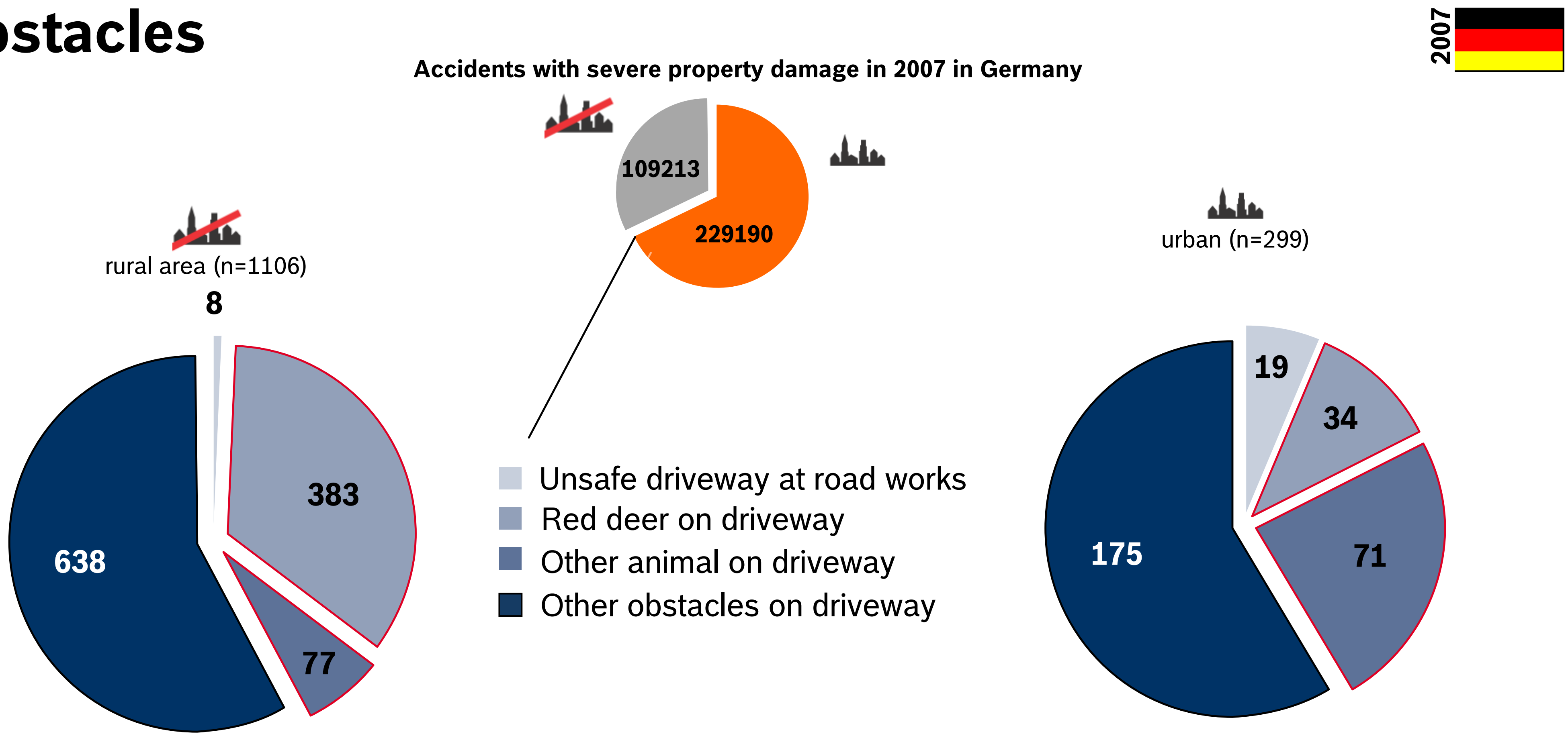


Bild 2: Schadenanzahl in der Fahrzeugversicherung insgesamt (Vollkasko und Teilkasko) bei Unfällen mit Wildbeteiligung in Deutschland

[1)] Source: “Unfallhäufungen mit Wildunfällen”, Forschungsbericht des GDV 2007, H.Voß

Appendix - Severe property accidents caused by obstacles



Source: Federal Statistical Office 2007

[1)] Fatalities only in rural area

Preset – Road leaving and High Relative Impact Speed

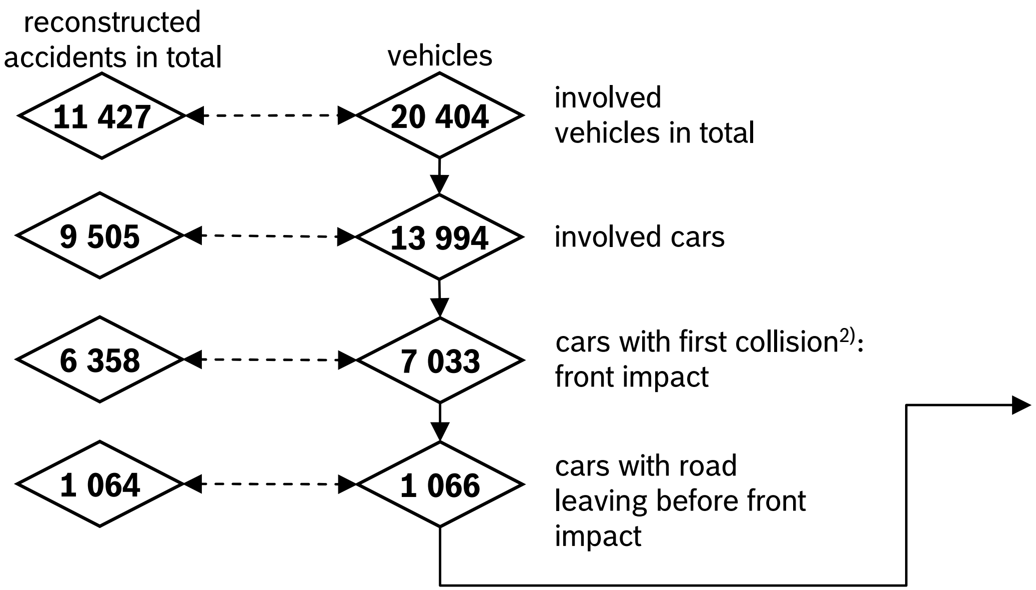
GIDAS: #1070719

Results of Accident Analysis

Accident Research CR/AEV1

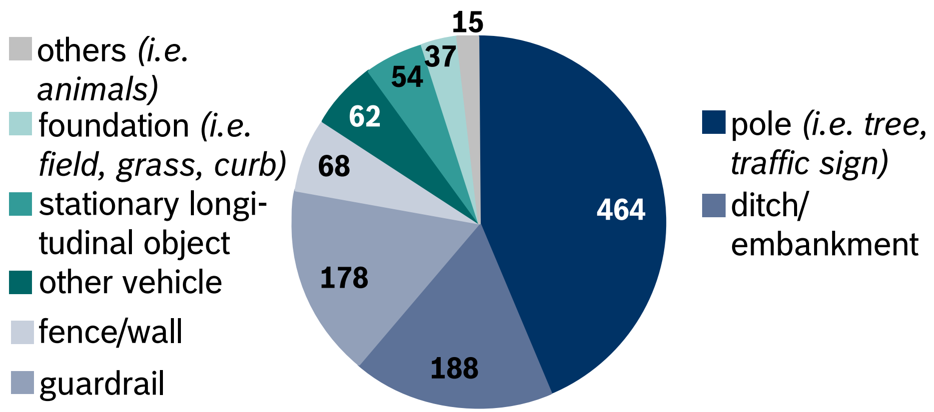
BOSCH

Data selection[1)] of cars with road leaving followed by a front impact



➔ In 1064 accidents 1066 cars leave the road at least once before a front impact

collision opponents in front impact



➔ In 464 accidents 464 cars crash into a pole after road leaving

➔ Referred to all accidents involving cars this is a share of almost 5%

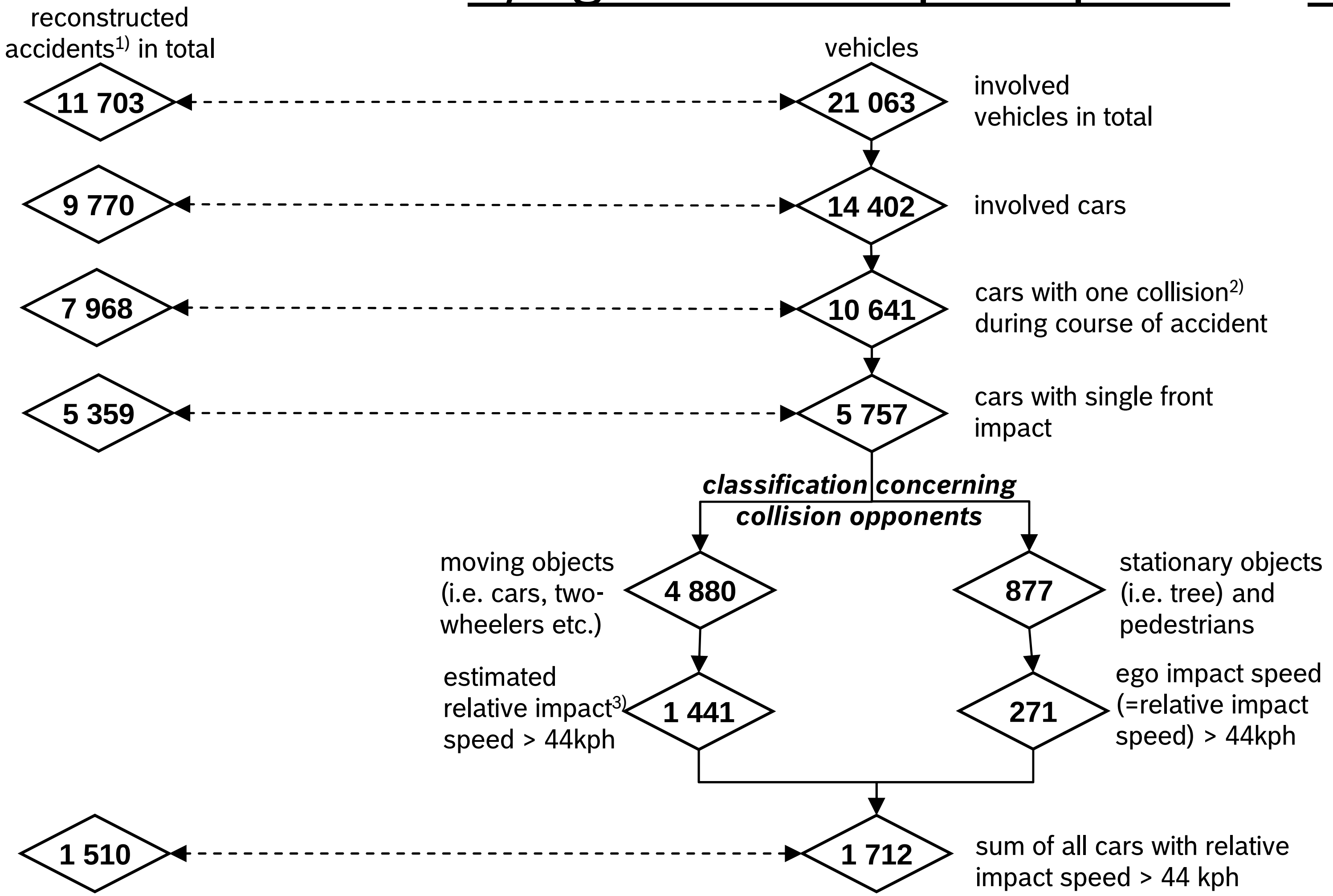
➔ Referred to all accidents involving cars with an initial front impact this is a share of about 7%

1) Source: GIDAS 2001-2008 *(weighted data for Germany)*, different data extract compared to extract on slide 3 is used

2) This is an impact with a change in speed with about more than 3 kph or an impact causing a change in moving direction or damages. Small collisions are not determined in this analysis

BOSCH

Selection of cars w/high relative impact speeds in single front impacts



➔ In about 15% of all accidents with casualties in Germany involving cars there is at least one car involved with a single front impact and a relative collision speed higher than 44kph

➔ Referred to all accidents with casualties involving cars with single front impact this a share of about 28%

1) Source: GIDAS 2001-2008 *(weighted data for Germany)* - only accidents with at least one vehicle involved are considered, different data extract compared to extract on slide 2 is used
2) Impact with delta-V appr.>3 kph or impact causing change in moving direction or damages (no determination of small collisions)
3) For information to determined relative impact speeds and necessary formulas, please see: slide 4 and slide 5

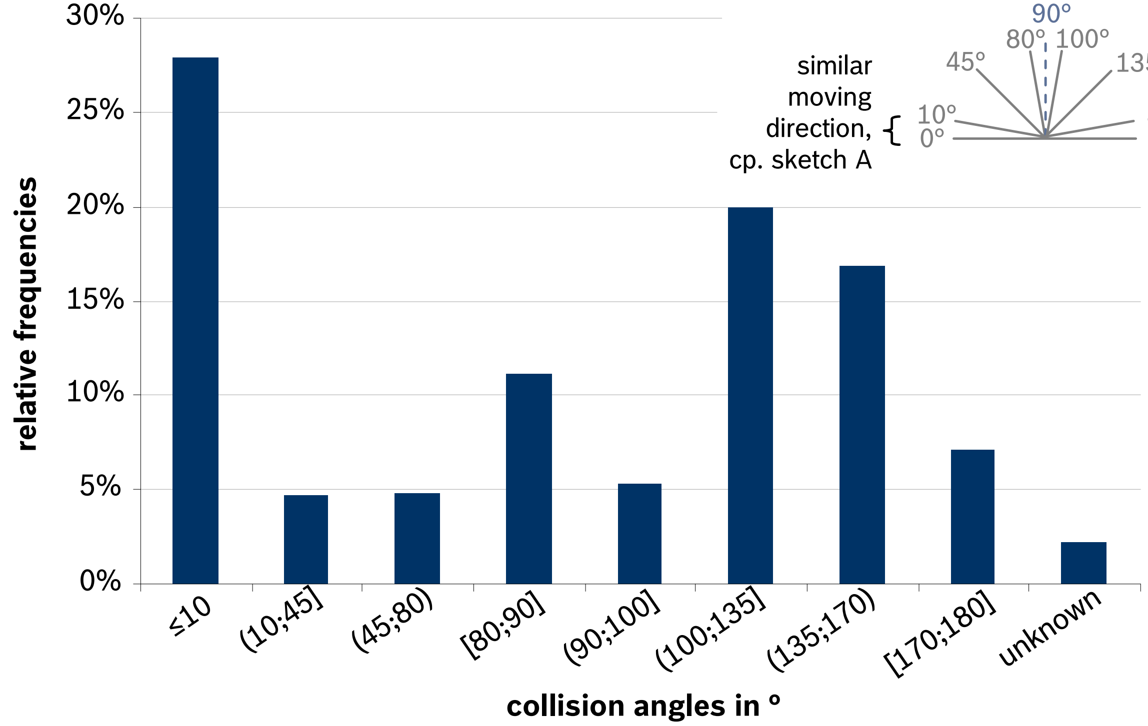
Preset – Road leaving & High Relative Impact Speed

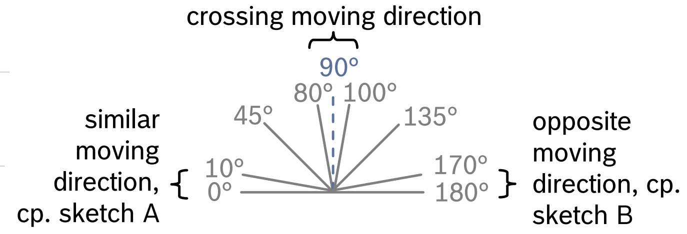
Chapter 17

BACKUP

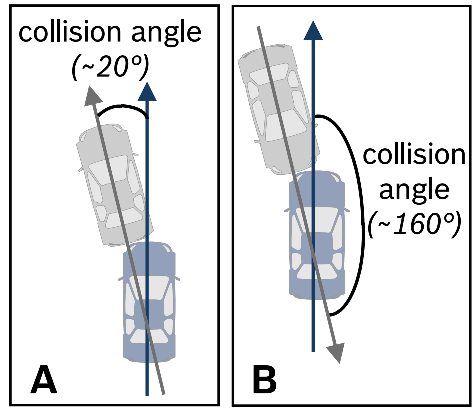
cars1) colliding with moving objects

4 880 → Distribution of collision angles





sketches to collision angles



Formulas used for determining relative collision speed

For 0° ≤ |collision angle| ≤ 90°:

relative collision speed = *ego's collision speed* - cos(|*collision angle*|) • *opponent's collision speed*

For 90° < |collision angle| ≤ 180°:

relative collision speed = *ego's collision speed* + sin(|*collision angle*| - 90°) • *opponent's collision speed*

1) Source: GIDAS 2001-2008 *(weighted data for Germany)* - only accidents with at least one vehicle involved are considered

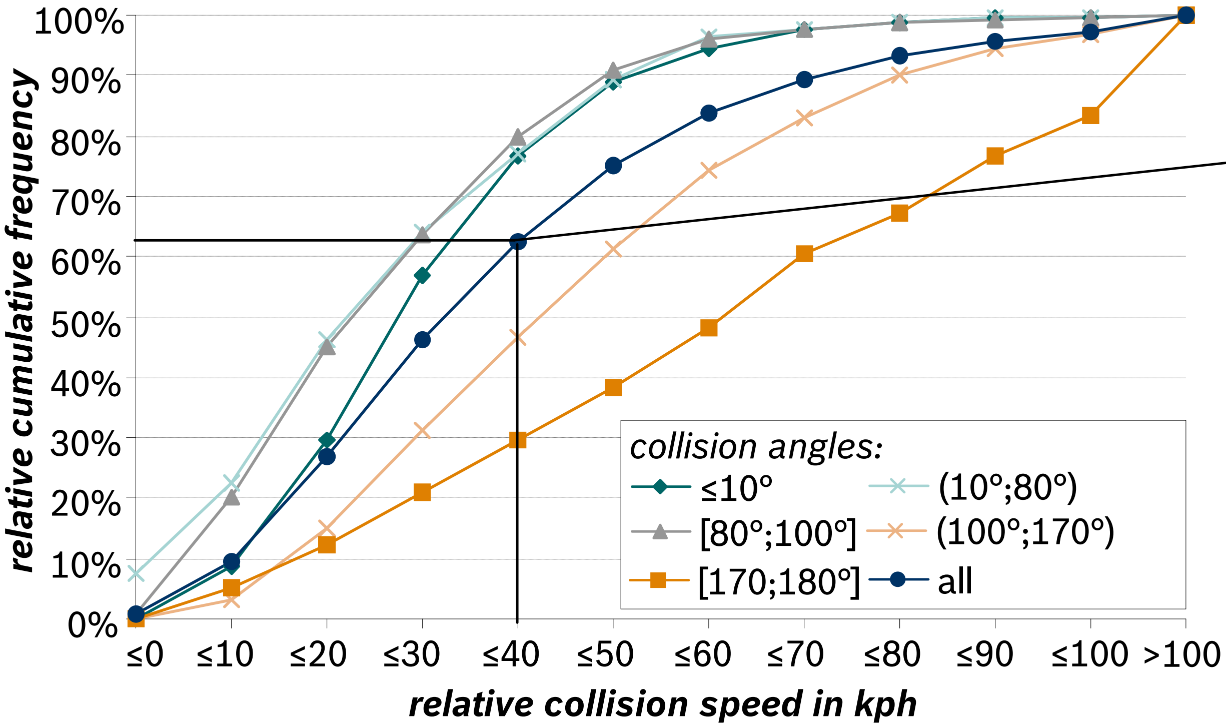
BOSCH

Preset – Road leaving & High Relative Impact Speed

BACKUP

cars[1)] colliding with moving objects + known coll. angle and speeds

4 430 → Cumulative frequency of relative collision speeds for specified collision angles

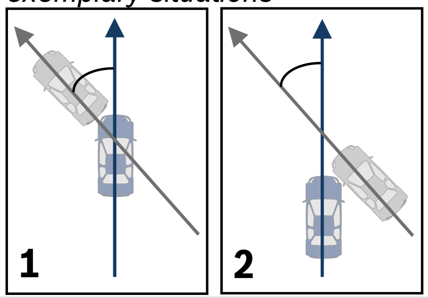


More than 60% of the cars have a single front impact with a relative speed ≤ 40 kph

➔ This diagram provides only the information about the relative speed in the collision between two vehicles. The moving directions before the crash are not considered.

➔ It is not considered if the LRR-sensor can detect the collision opponent. I.e. the two visualized situations on the right-hand side are the same concerning the considered parameters (*here: collision angle=40°, relative collision speed=50kph*) but the probability for detecting the opponent is expected to be different.

exemplary situations



1) Source: GIDAS 2001-2008 *(weighted data for Germany)* - only accidents with at least one vehicle involved are considered

Rollover Accidents:
- Overview (USA, Japan)
- Truck rollover accidents (USA)

Results of Accident Analysis

Accident Research CR/AEV1

BOSCH

Accident figures

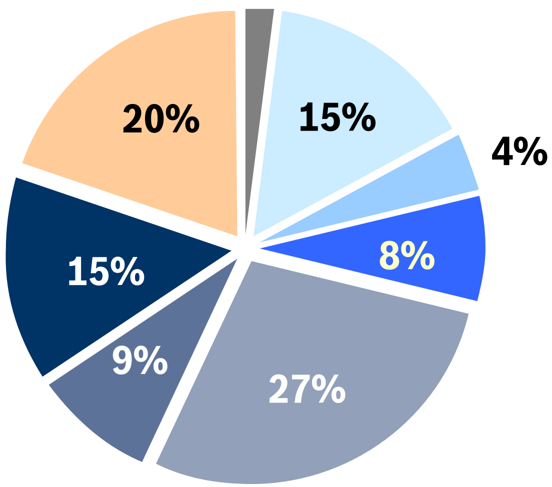
	Resident population [Mio]	Registered motor vehicles [Mio]	Injury accidents [Mio]	Fatal Accidents*	Share of Fatal accidents in injury accidents	Fatalities*
	82,4	56,7	0,33	**4717**	**1,46 %**	**5091**
	299,4	251,8	1,78	**38588**	**2,16 %**	**42642**
	127,8	91,4	0,89	**7007**	**0,79 %**	**7272**

sources: StBA, NHTSA, IATSS, IRTAD, Year 2006

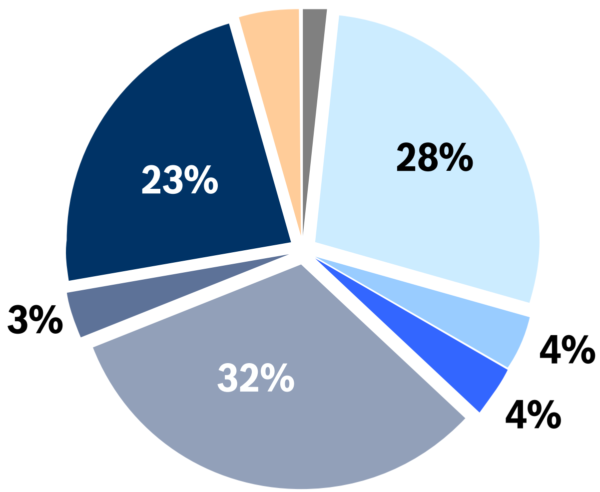
* for fatalities that occur within 30 days

Accidents with casualties by kinds of accidents

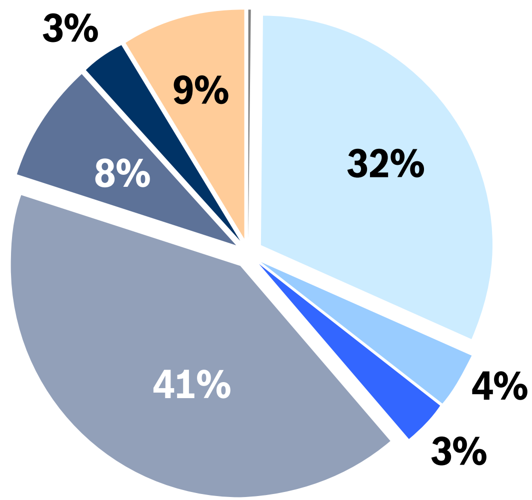
327,984
accidents with casualties



1,784,588 [1]
accidents with casualties



886,864 [2]
accidents with casualties



collision with …

- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object (vehicle leaving carriageway required)**
- **Accident of another kind**
  (unknown, not fixed object, animal …)

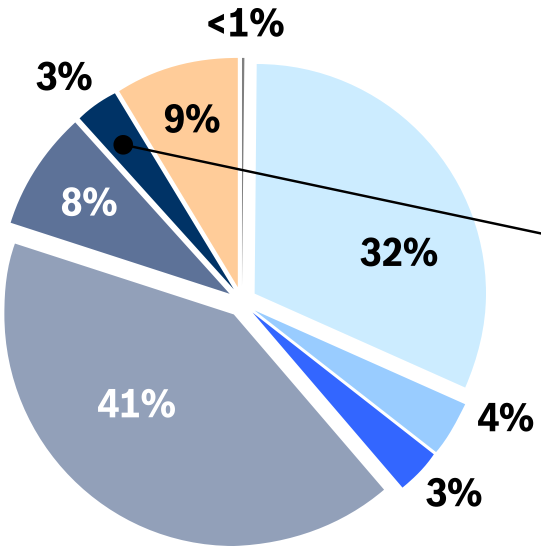
sources: StBA, GIDAS, NHTSA, IATSS, Year 2006

[1] USA: Vehicle to Bicycle - accidents in category „Others"
[2] Japan: Accidents without automobile involvement in category "Others"

Scope of safety functions in Japan

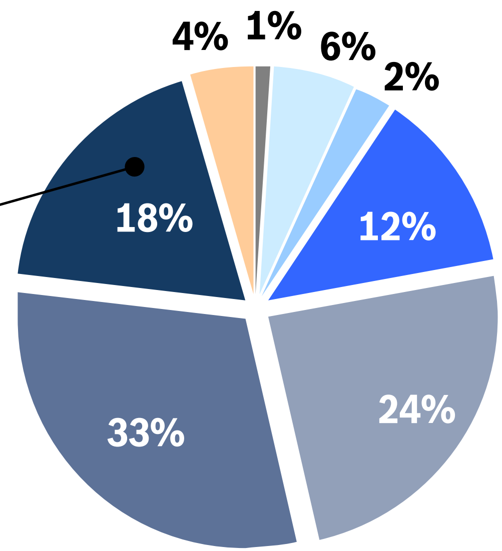
2006

accidents with casualties[1]
n = 886,864



Electronic Stability Control,
Lane Keeping Support,
Advanced Rollover Sensing,
Early Pole Crash Detection

accidents with fatalities[1]
n = 6,147[2]



collision with …

- **parked vehicle**
- **vehicle moving ahead or waiting**
- **vehicle moving laterally in same direction**
- **oncoming vehicle**
- **vehicle which turns into or crosses a road**
- **pedestrian**
- **fixed Object or vehicle leaving carriageway**
- **Accident of another kind** (unknown, not fixed object, animal …)

sources: IATSS 2006

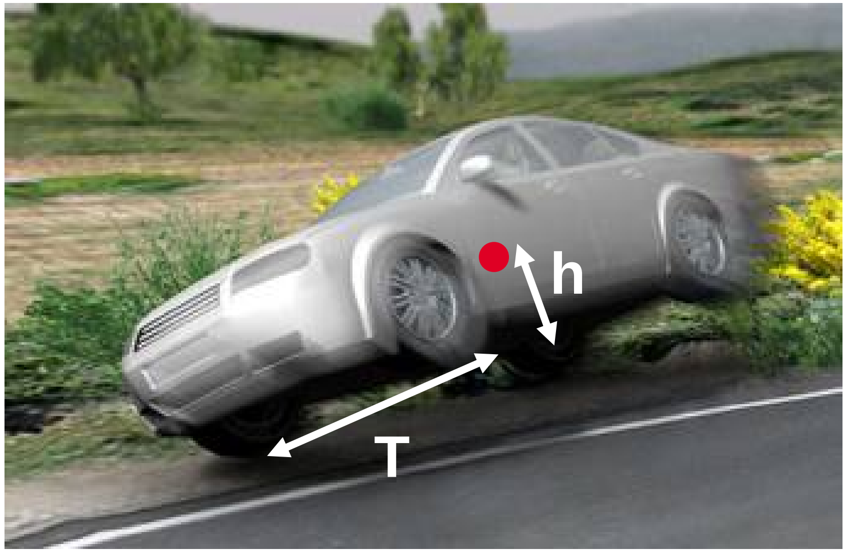
[1] accidents without automobile involvement in category "Others"
[2] only fatalities that occur within 24 hours

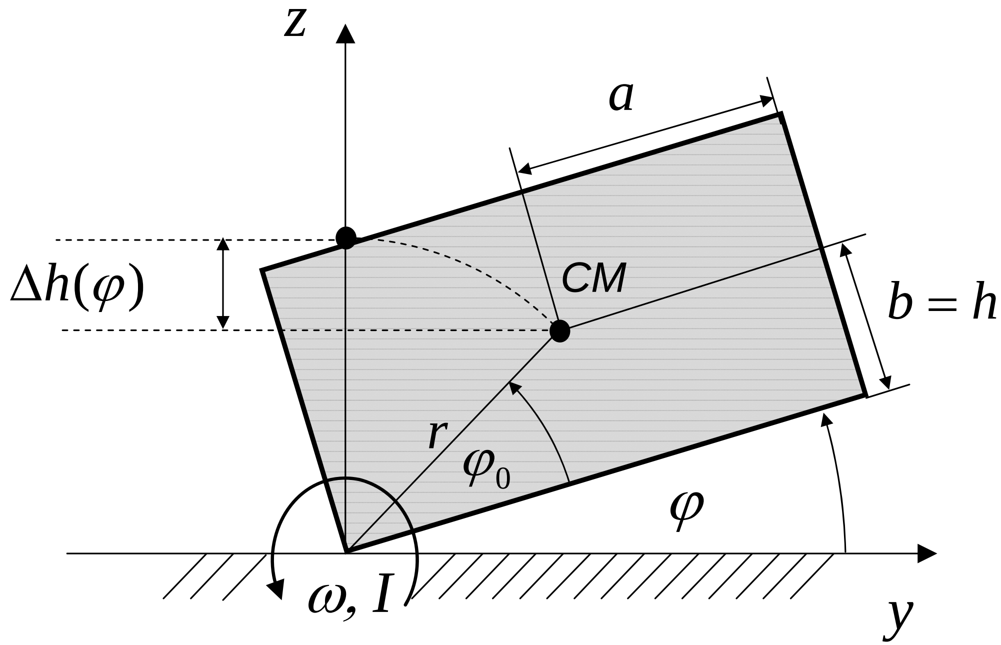
BOSCH

The physics behind a rollover event

The Static Stability Factor (SSF) of a vehicle is an at-rest calculation of its rollover resistance based on its most important geometric properties. The SSF is a number that relates the height of the center of gravity *h* of a vehicle to its track width *T*. In general, SUVs and vans have lower SSF values than passenger cars.

➔ *Therefore the probability for a rollover is higher for SUVs compared to ordinary passenger cars.*

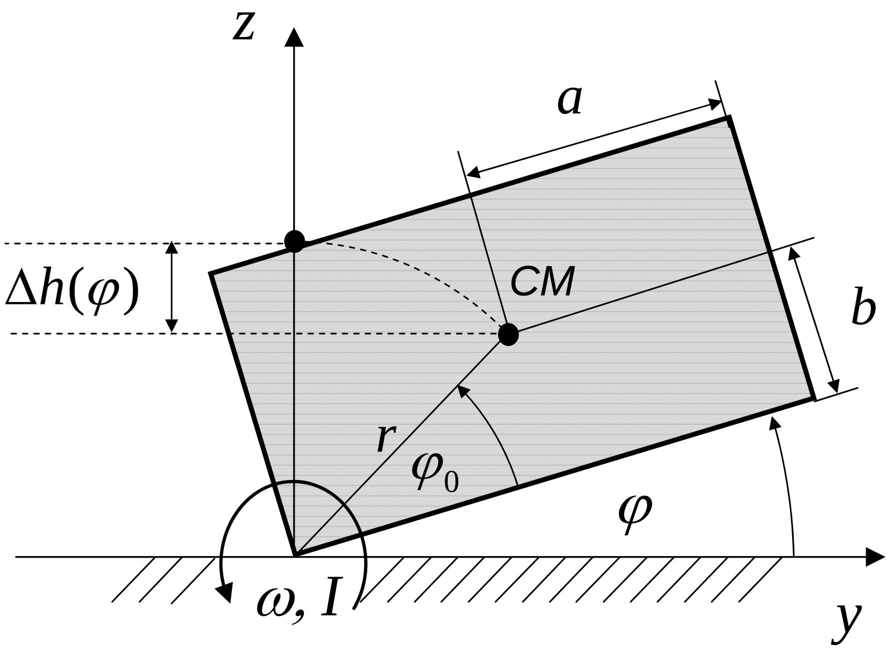




Static Stability Factor (SSF): $$\boxed{SSF \equiv \sigma = \frac{T}{2h}}$$

The physics behind a rollover event

A vehicle is supposed to roll, if its roll rate ω at a given roll angle φ exceeds a critical threshold ω_{crit}:



φ	roll angle of vehicle
CM	center of mass m
ω	angular rate
I	moment of inertia

e.g. energy criterion:

$$\Delta E_{rot} \geq \Delta E_{pot}$$

critical angular rate:

$$\omega_{crit}^{Mode\,1}(\varphi) = \sqrt{\frac{2mg}{I}\Delta h(\varphi)}$$

with

$$\Delta h(\varphi) = r(1 - \sin(\varphi + \varphi_0))$$

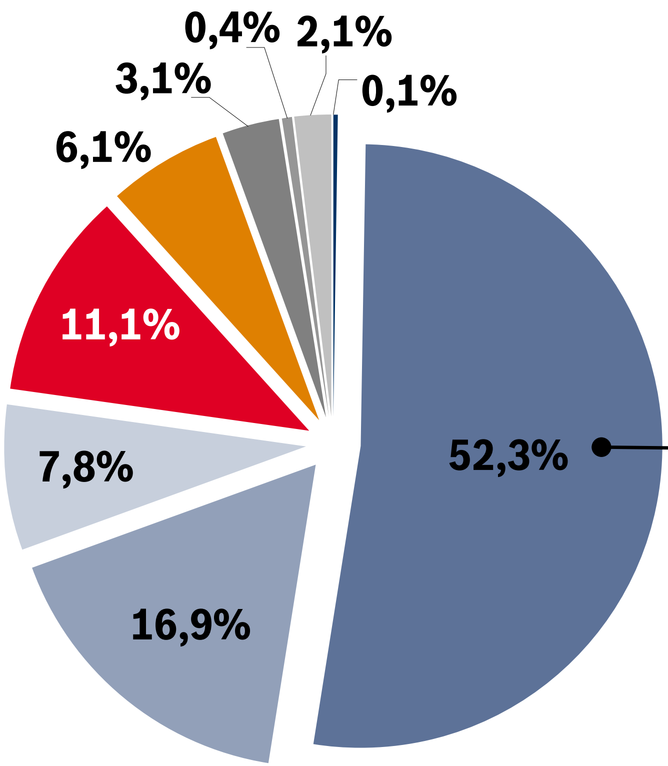
and $r = \sqrt{a^2 + b^2}$

Traffic accidents involving primary parties

2006

accidents with casualties[1)]
n = 886,864

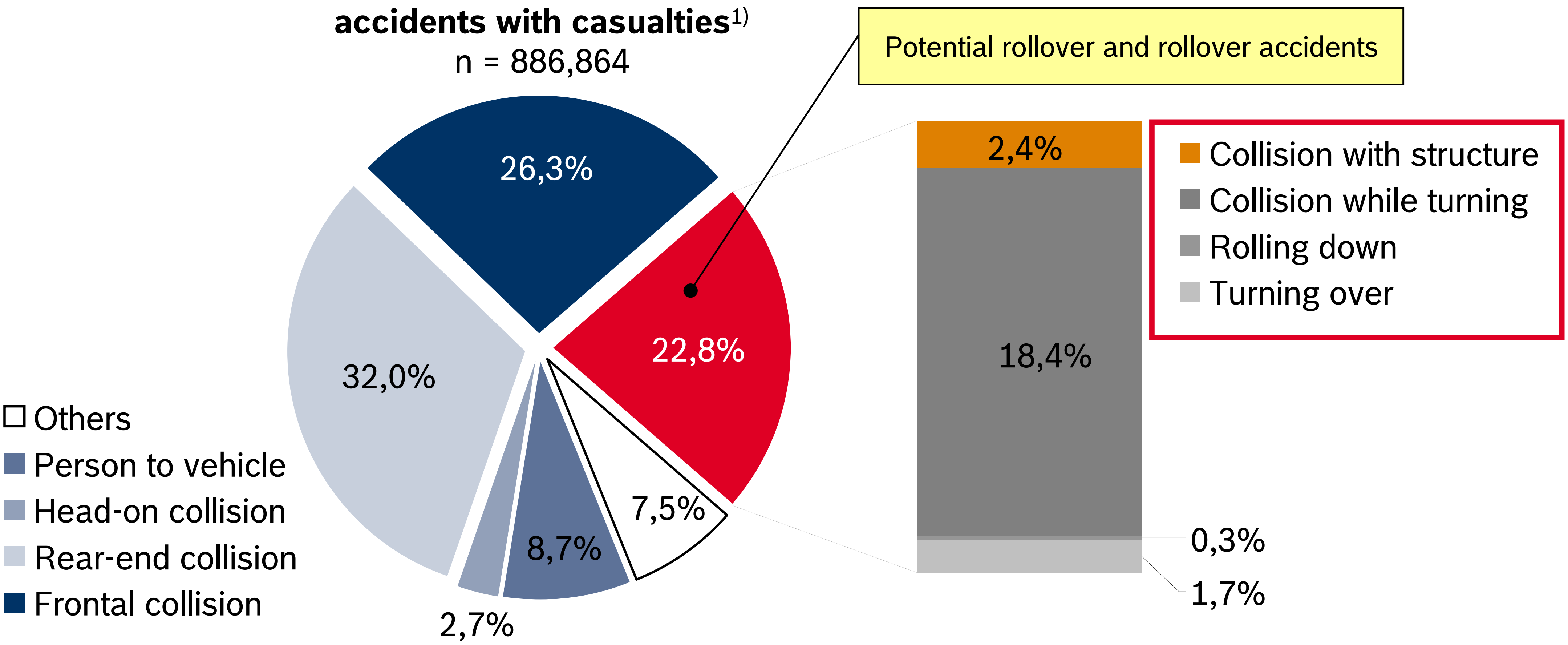
Minivan & MPV included in ordinary passenger cars



[1)] accidents without automobile involvement in category "Others"

Traffic accidents by type of accident

2006



➔ In a share of approx. 23% of all accidents w/ casualties a rollover occurrence is possible or occurred during the accident

[1)] accidents without automobile involvement in category "Others"

Rollover accident situation in the USA*

2006

- In 2006 approximately 6 million police reported traffic accidents with over 42 000 fatalities and 2,5 million injuries occurred in the US.
- The proportion of vehicles that rolled over in fatal crashes (21.6%) was 4 times higher than the proportion of injury crashes (5.3%) and 15 times as high as the proportion in property-damage-only crashes (1.4%).
- Compared with other vehicle types, utility vehicles experienced the highest rollover rates in fatal crashes (35.1%) and in injury crashes (9.8%).
- Large trucks experienced the highest rollover rate in property-damage-only crashes (2.6%)

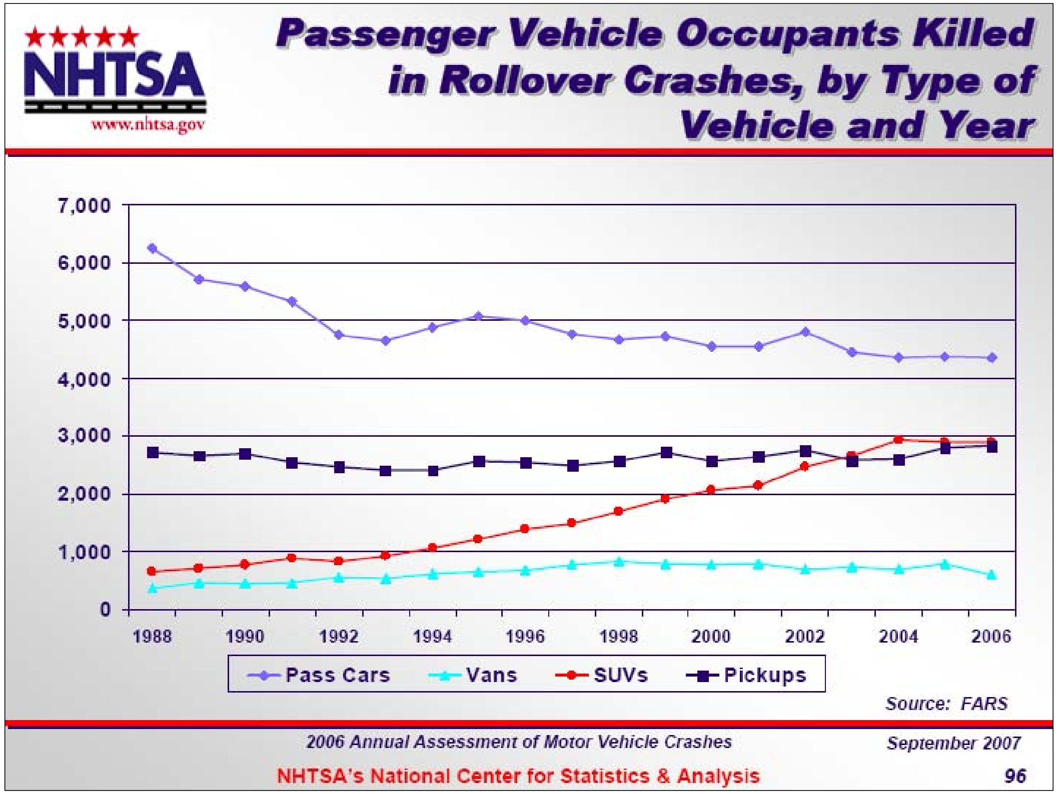
*NHTSA‘s National Center for Statistics & Analysis (Traffic Safety Report /Annual Assessment of Motor Vehicle Crashes), 2006

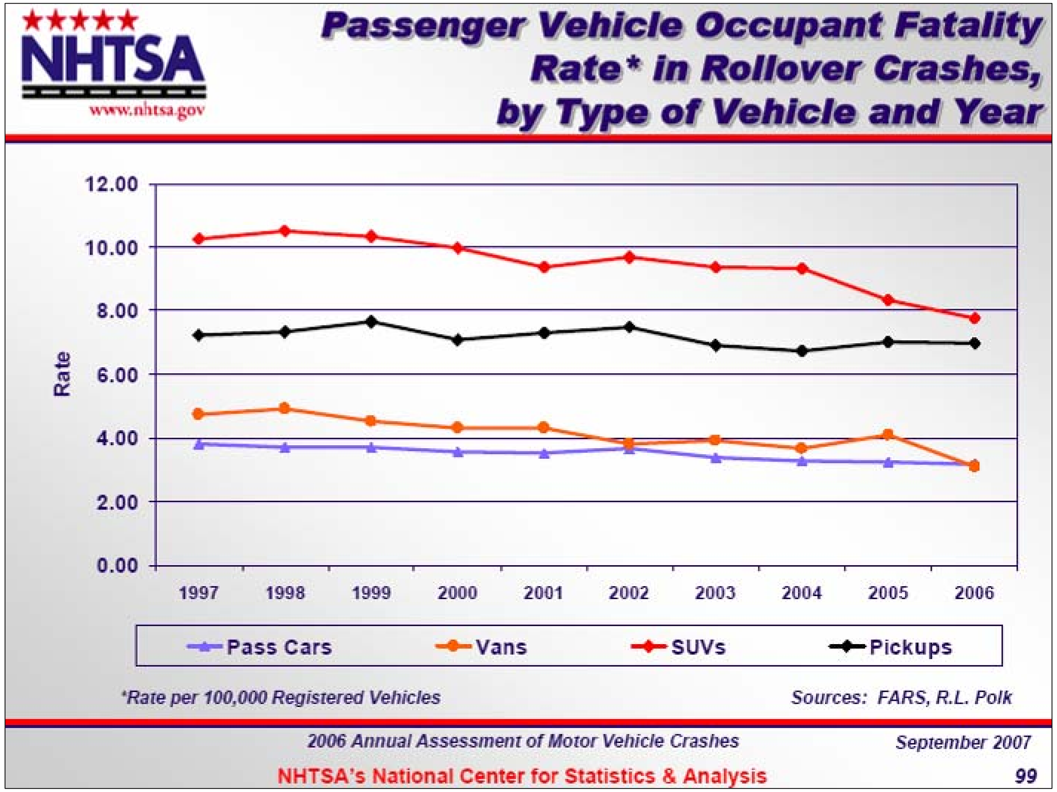
Rollover accident situation in the USA*

2006

Fatalities in rollover crashes by type of vehicle

Fatality rate per 100 000 registered vehicles in rollover crashes by type of vehicle





➔The share of fatalities increased by vehicle type SUV continuously!

➔The increased death rate for SUV‘s are caused by the higher penetration of this vehicle type!

* NHTSA‘s National Center for Statistics & Analysis (Traffic Safety Report /Annual Assessment of Motor Vehicle Crashes)

Rollover accident situation in the USA*

2006

Passenger Vehicle Occupants Killed and Injured in Rollover Crashes, by Type of Vehicle

NHTSA www.nhtsa.gov

Type of Vehicle	Year 2005	Year 2006	% Change
Occupants Killed*	10,870	10,698	-1.6%
Passenger Cars	4,371	4,352	-0.4%
Vans	794	604	-24%
SUVs	2,895	2,888	-0.2%
Pickup Trucks	2,796	2,840	+1.6%
Occupants Injured*	222,000	207,000	-6.8%
Passenger Cars	89,000	81,000	-9.0%
Vans	17,000	15,000	-12%
SUVs	68,000	70,000	+2.9%
Pickup Trucks	47,000	40,000	-15%

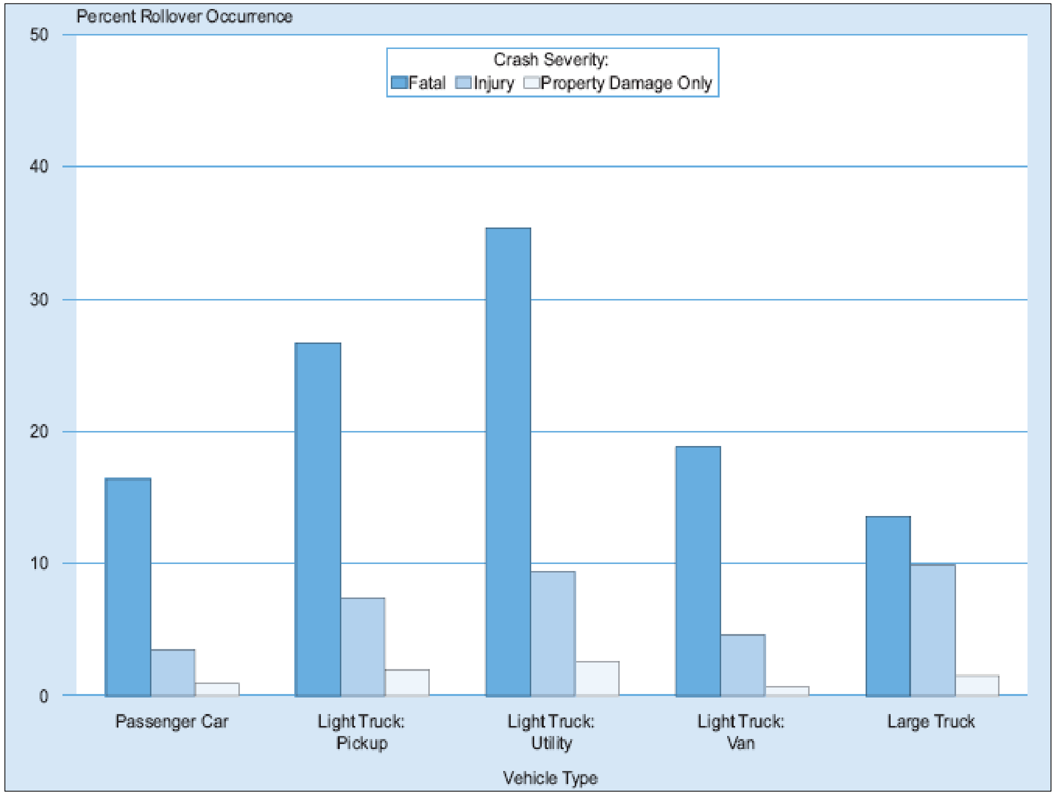
Totals for injured may not add due to rounding. Percentages computed after rounding.
**Total Killed and Injured includes Occupants of Other Light Trucks*

Sources: FARS, NASS GES

2006 Annual Assessment of Motor Vehicle Crashes — *September 2007*

NHTSA's National Center for Statistics & Analysis — 95

Share of rollovers by vehicle type

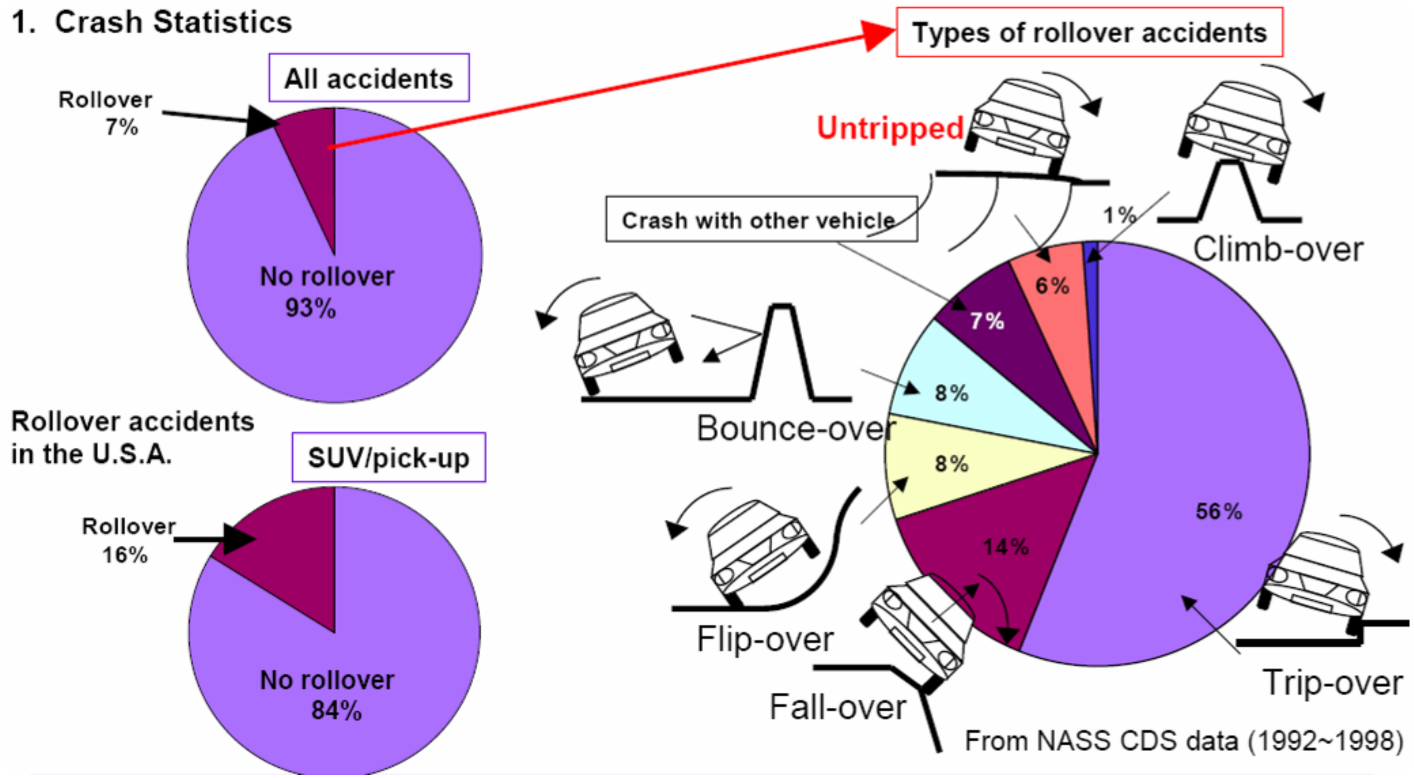


- ➔ **The number of fatalities in rollover crashes decreased to ~10 700 in 2006!**
- ➔ **Compared to other vehicle types SUV's have the highest share of rollover rates in accidents with fatalities (35%).**

* NHTSA's National Center for Statistics & Analysis (Traffic Safety Report /Annual Assessment of Motor Vehicle Crashes)

Kind of rollover*

2006



→More than half of the rollover accidents are tripped-rollover accidents (1992-1998). It is assumed that the share of tripped rollover will increase due to the fact that in the last recent years SUVs have a higher penetration rate (higher center of gravity)!

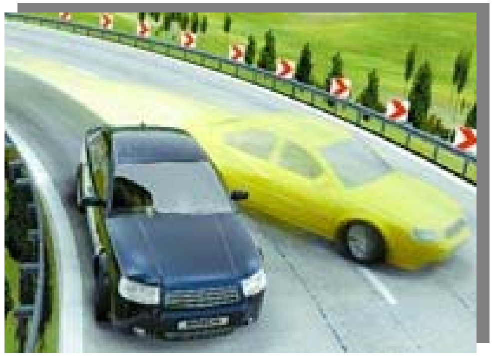
→The share of bounce-rollovers are smaller compared to Germany (~28%). This could be due to the less longitudinal barriers in the US.

* Honda Rollover Study – Recommended Rollover Test Procedures 2002

Estimated influence of an ESC in rollover accidents*

ESC: Automatic and selected braking intervention on single wheels to avoid over-and under steering of the vehicle in critical driving situations.

☒ Vehicle stays stable in critical driving maneuver
☒ Rollover mitigation due to avoided accidents while the vehicle leaving the carriageway



Rollover frequency of passenger vehicles equipped with ESC compared to non ESC equipped passenger vehicles

Passenger vehicle w/ ESC	Rollover		
	yes	no	**total**
yes	15	608	623
no	309	5938	6247
total	324	6546	6870

$$Odds_{ESC} = \left(\frac{Rollover_{ESC_{yes}}}{Rollover_{ESC_{no}}}\right) / \left(\frac{Rollover_{yes}}{Rollover_{no}}\right) = 0{,}47$$

Confidence level 95%: 0,28 – 0,79

$$Benefit_{ESC} = 1 - Odds_{ESC} = 53\%$$

➔ Result statistically significant !
➔ The benefit can be seen as a trend for the positive influence given from an ESC system for rollover mitigation!

➔ **Trend: With an ESC-system the rollover occurancy is reduced to more than 50%.**

* Analysis based on single case analysis of 389 rollover accidents w/ injuries from GIDAS database (2001-2004)

Accident analysis on truck rollovers in NA

Picture from http://truckaccidents360.com

Results of Accident Analysis

Accident Research CR/AEV1

Objectives and database sources

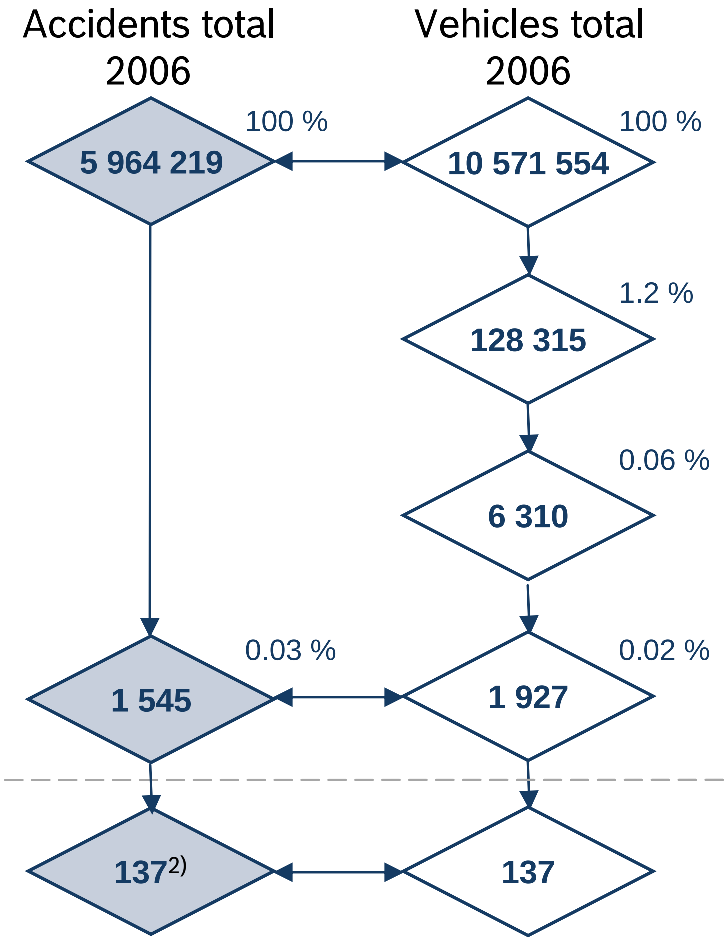
1. Database source
   - General Estimation Sampling 2006 (GES)
   - Data includes police reported accidents with property damage only and injured persons in the US
   - Data weighted for the US

2. Questionnaires
   - Rollover of medium /heavy trucks within vehicle segment 5-7
   - Special focus on ramp/exit rollover, i.e. highway exit

3. Analysis
   - includes medium/heavy trucks above 4,536kg GVWR and busses
   - include all rollover occurred in a curve
   - Examples from CDS not available, instead GIDAS accidents used

Rollovers of medium/heavy trucks[1)]

Source: GES 2006 (**weighted** for US)



Transition to vehicles

Selection of medium- or heavy trucks, busses (>4 536 kg GVWR)

Selection of truck/bus with rollover

Selection of truck/bus with rollover in a <u>curve</u>

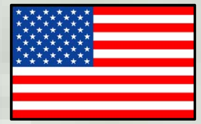
Selection of truck/bus with rollover in a <u>curve on entrance or exit ramps</u>

➔ In approximately 0.3‰ of all accidents in US there is a medium/heavy truck or a bus involved in a rollover event, whether tripped or untripped rollover.
➔ Focusing on entrance/exit ramp rollover with medium/heavy trucks a share of approx. 137 accidents[2)] occur.

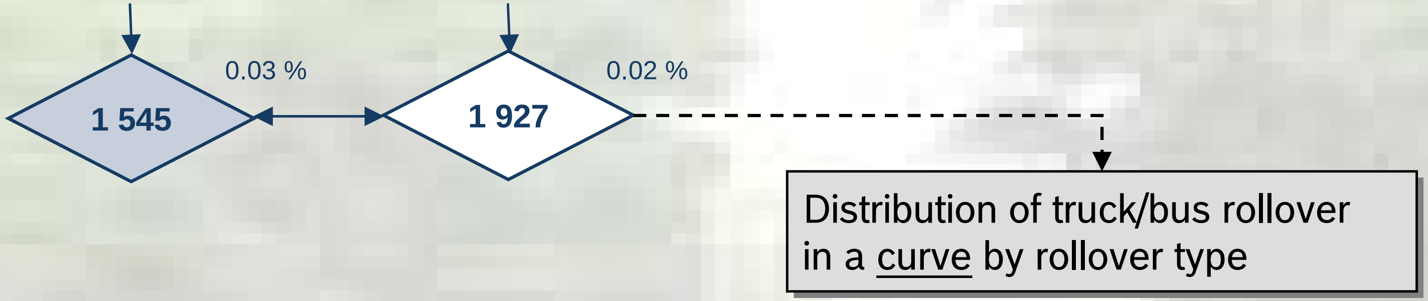
1) Medium/Heavy trucks defined : > 4,536 kg GVWR
2) This is represented by 24 unweighted accidents in the US

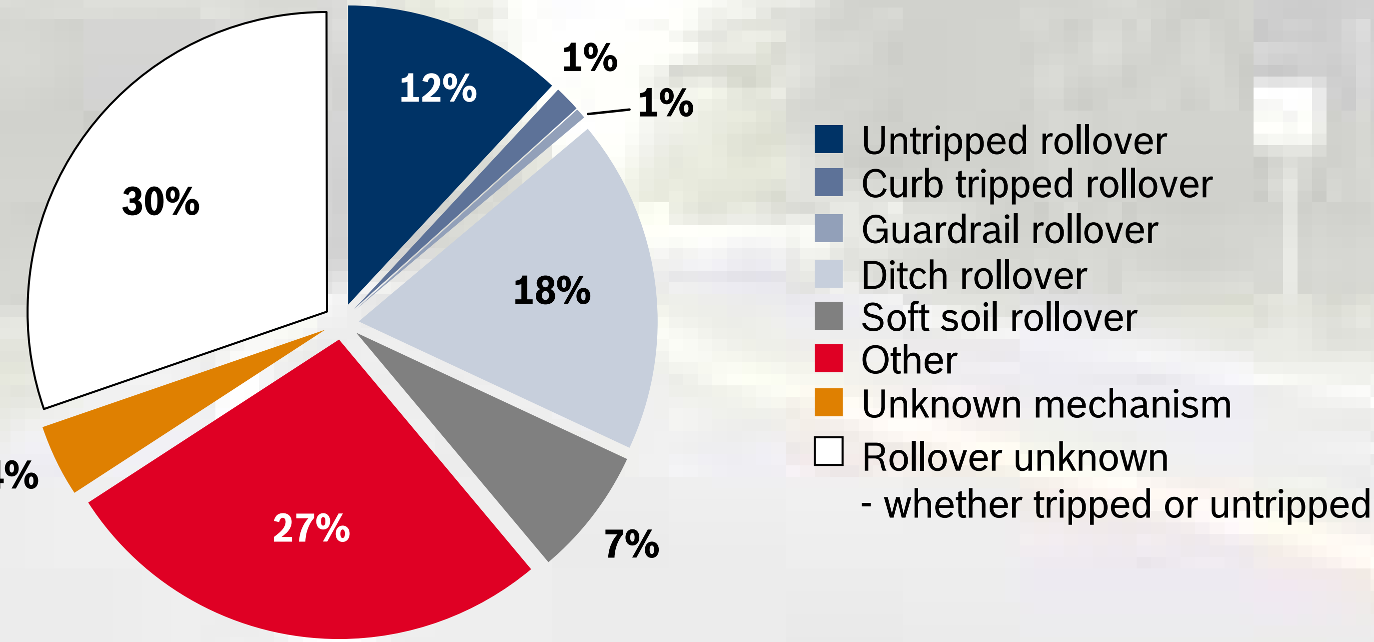
BOSCH

Rollover distribution of medium/heavy trucks[1)]



Source: GES 2006 (**weighted** for NAFTA)





➔ A minimum share of 12% are untripped rollovers from medium/heavy trucks or busses.
➔ Accumulated a minimum share of 27% are tripped rollovers.

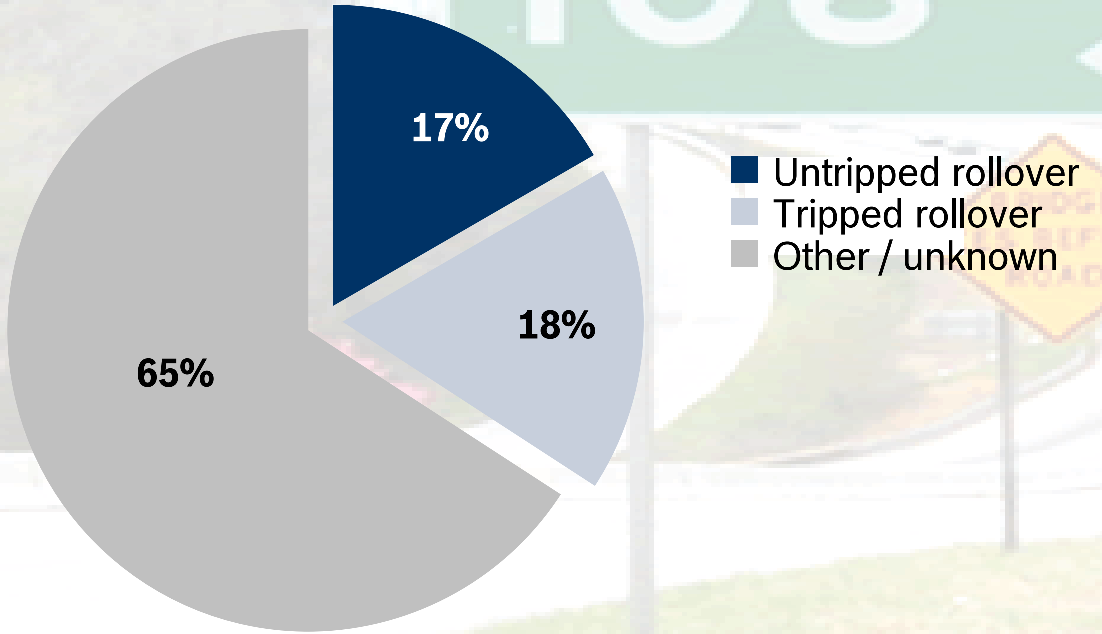
1) Medium/Heavy trucks defined : > 4,536 kg GVWR

Rollover distribution of medium/heavy trucks[1)]

Source: GES 2006 (**weighted** for NAFTA)

137 ⟷ 137

Distribution of rollovers of medium/heavy trucks and busses on entrance / exit ramps[2)] by rollover type

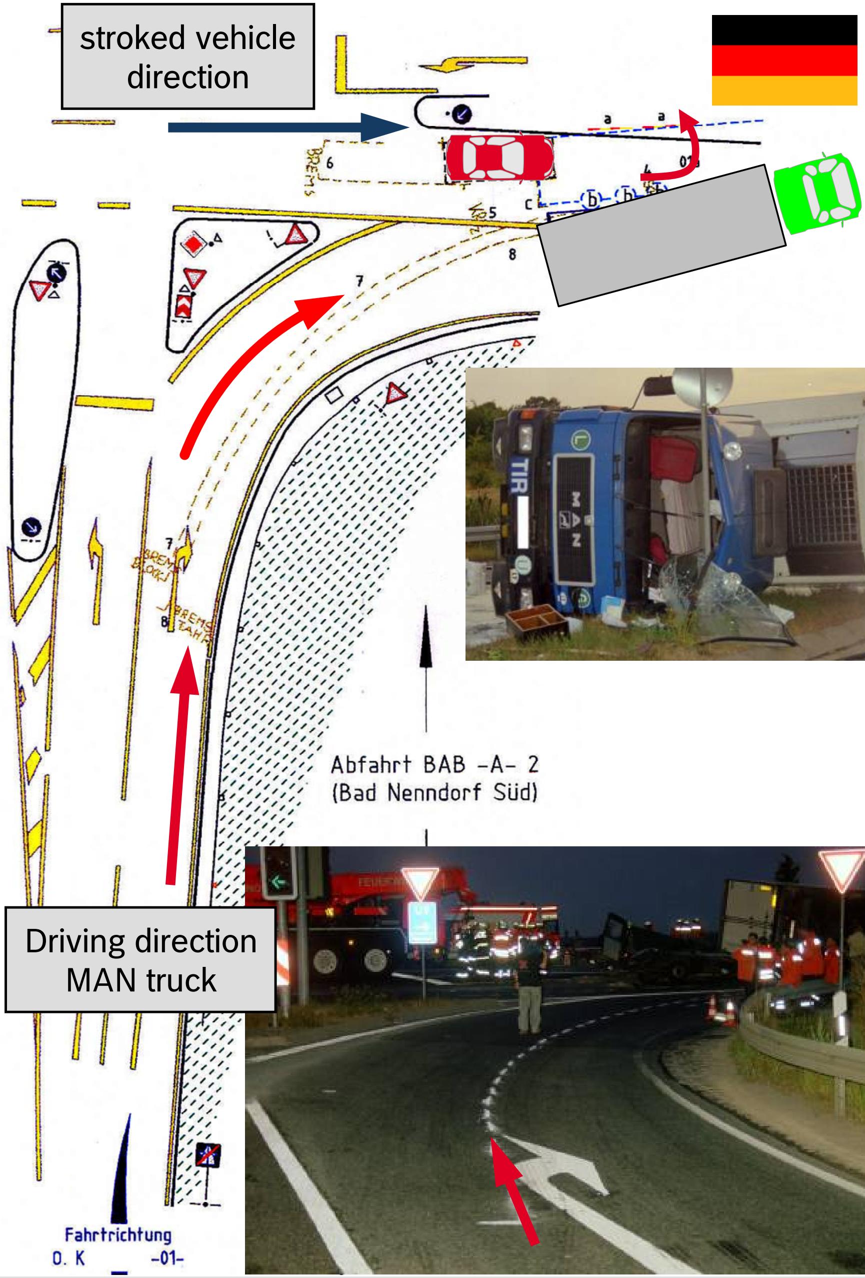


➔ The share of untripped and tripped truck/bus rollovers on entrance/exit ramps are approximately 18% respectively.

1) Medium/Heavy trucks defined : > 4,536 kg GVWR
2) This is represented by 24 unweighted accidents in the US

GIDAS case #3030634[1)]

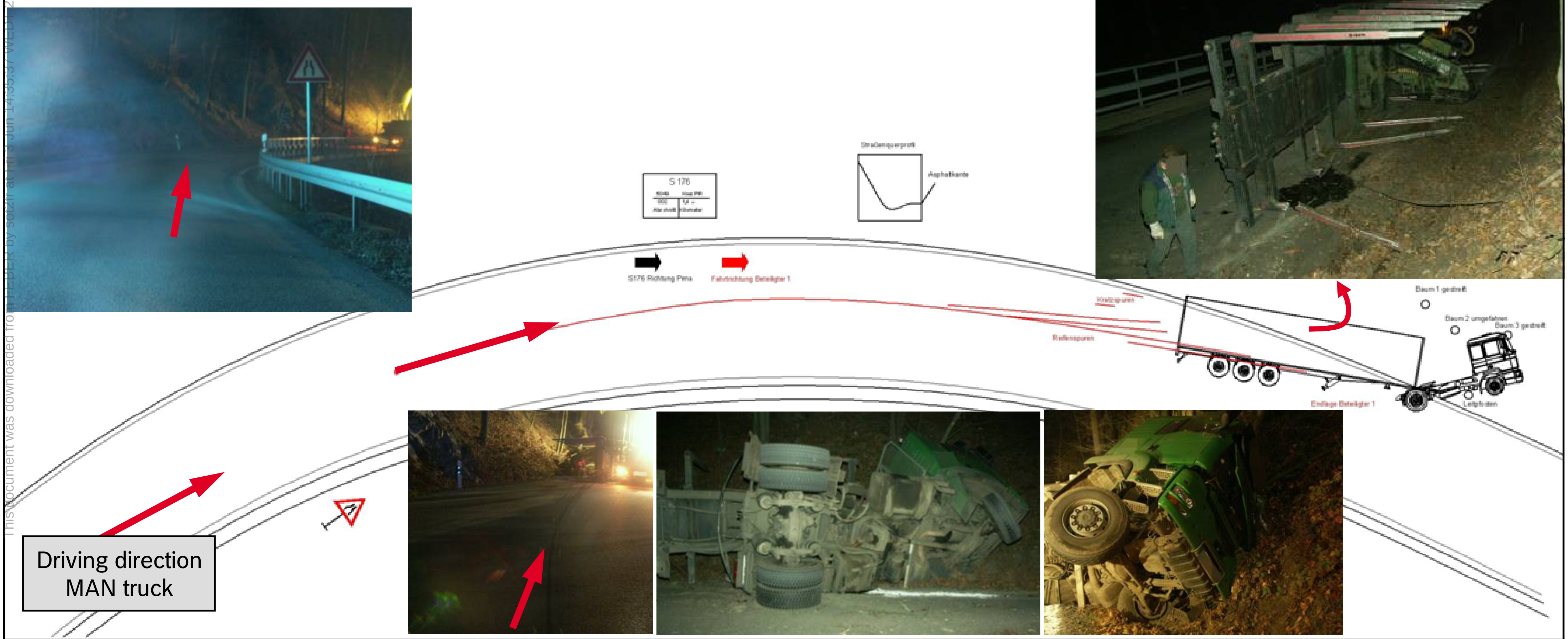
- Example case for truck rollover in exit ramp
- The truck (Type MAN) wanted to leave the motorway and turn into a federal highway. After passing the right curve (~70kph) the truck tipped over and hit the oncoming vehicle (curve radius not coded).



[1)] CDS case not available, GIDAS accident used instead

GIDAS case #1050868[1)]

- Example case for truck rollover in curve
- Due to speeding (70kph) the truck (MAN TGA12) with trailer left the road in a right curve and tipped over. The radius of the curve is 57 m. Taking a maximum lateral acceleration of $6 m/s^2$ into account results this in a max. speed of 67kph.



[1)] CDS case not available, GIDAS accident used instead

Relevance Of Technical Defects In Accidents

- Technical Defects of Vehicles
- Analysis of Defects in Fuel Pipes
- Analysis of Stranded Vehicles (D, USA, J)

Results of Accident Analysis

Accident Research CR/AEV1

Technical Defects of Vehicles

Results of Accident Analysis

Accident Research CR/AEV1

Outline

1. Information to Technical Defects in Cars from DEKRA

   Diagrams with Information about Technical Defects Taken from "VERKEHRSSICHERHEITSREPORT 2008"

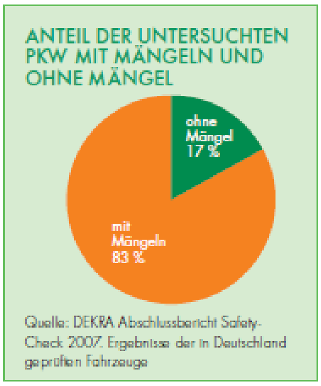
2. Technical Defects as Cause for Traffic Accidents Based on Official Statistics, Germany

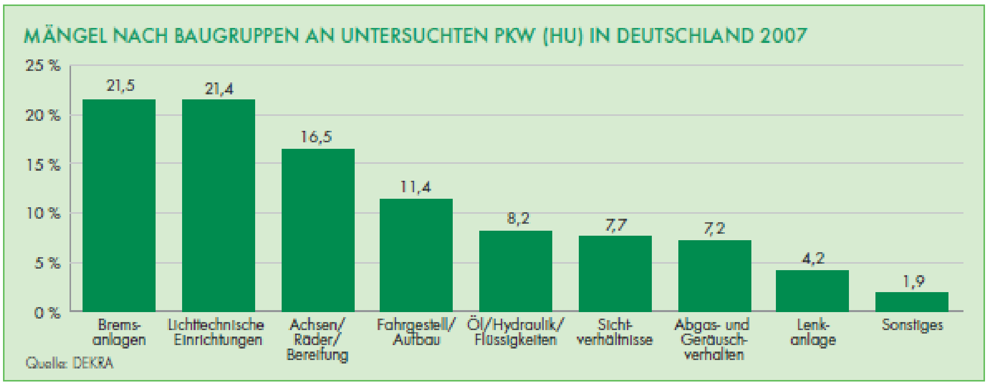
   Causes for Road accidents with Injured in Germany – "Other" Causes for Road Accidents in Detail – Technical Defects as Causes for Road Accidents

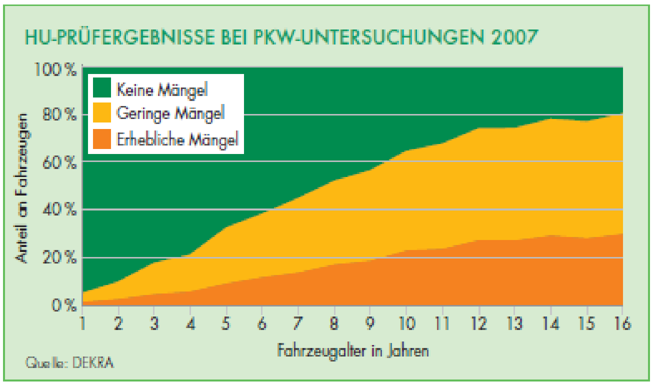
3. Technical Defects in Accidents based on Data from German In-Depth Accident Study

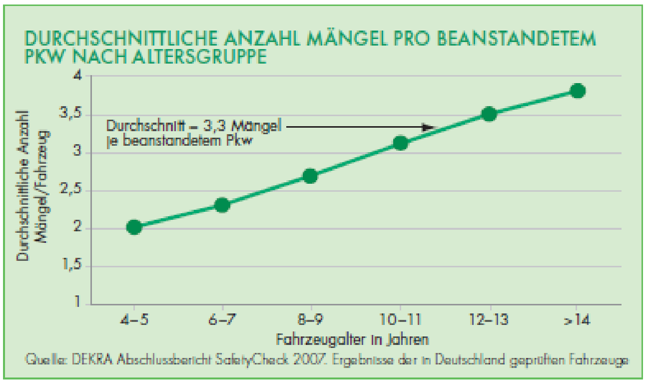
   Technical Defects in Cars Involved in Accidents with Injuries – Distribution of Kinds of Technical Defects in Cars

Diagrams[1] with information about Technical Defects (1/2)



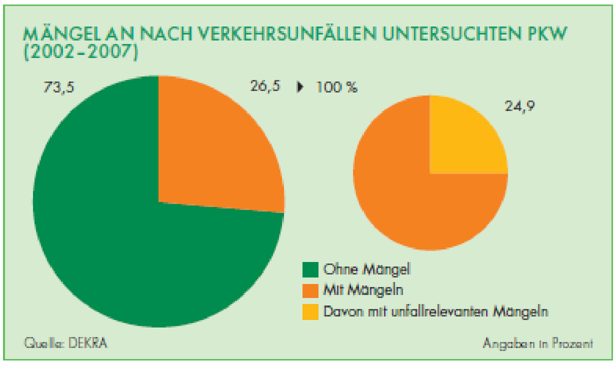


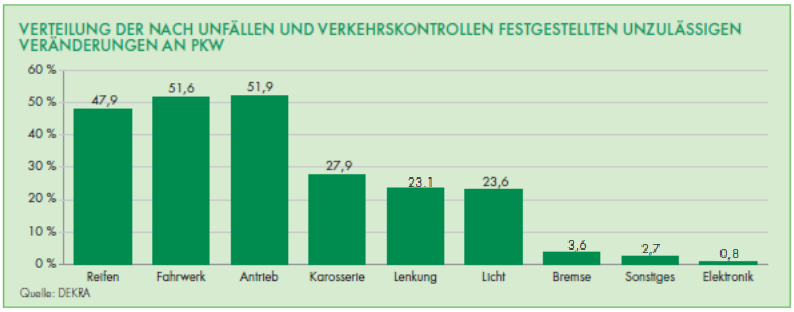


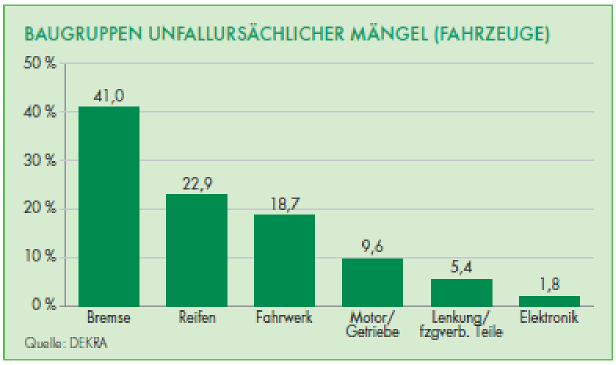


1) source: 3 828 cars checked in traffic controls, VERKEHRSSICHERHEITSREPORT 2008 from DEKRA (p. 18 ff.)

Diagrams[1)] with information about Technical Defects (2/2)



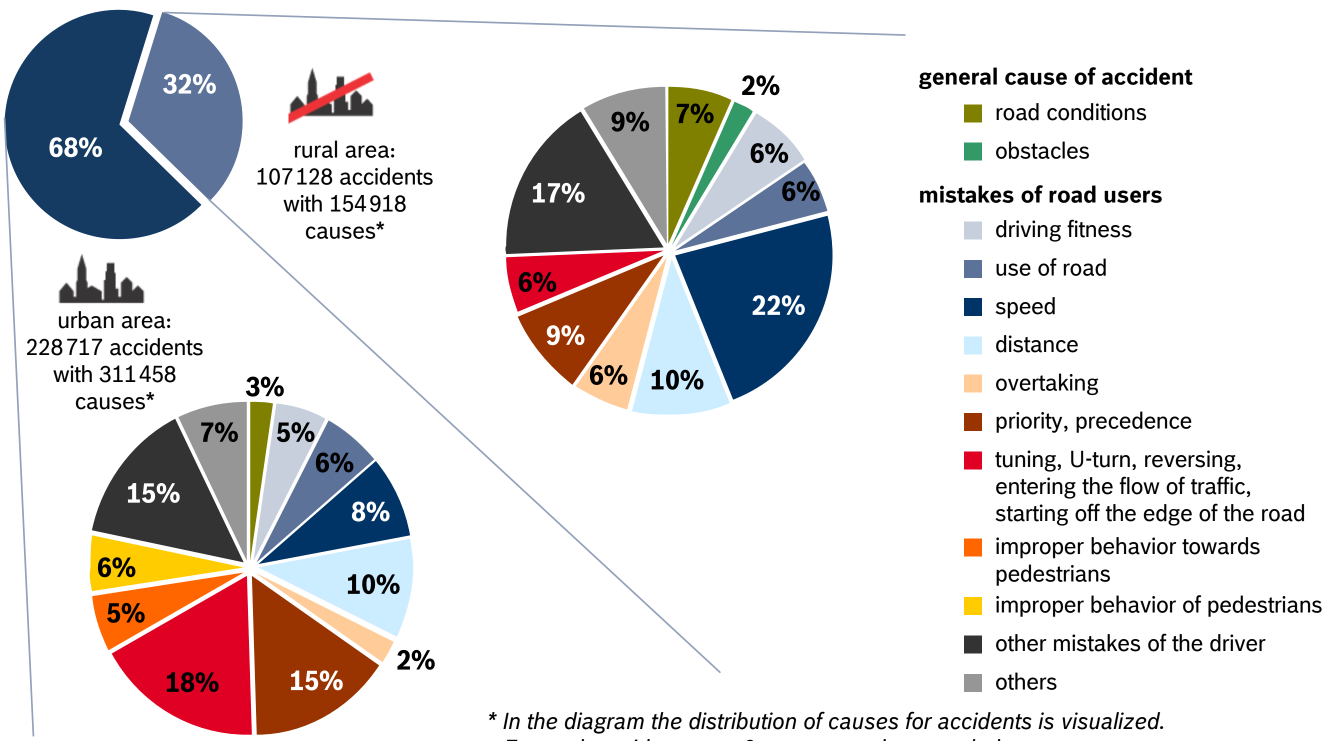




1) source: 3 828 cars checked in traffic controls / 5 394 cars checked after having an accident, VERKEHRSSICHERHEITSREPORT 2008 from DEKRA (p. 18 ff.)

Causes[2)] for Road Accidents with Injured in Germany

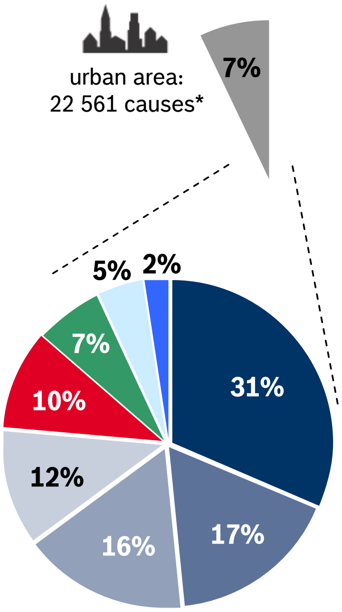
Analysis is based on 335 845 accidents in 2007



** In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.*

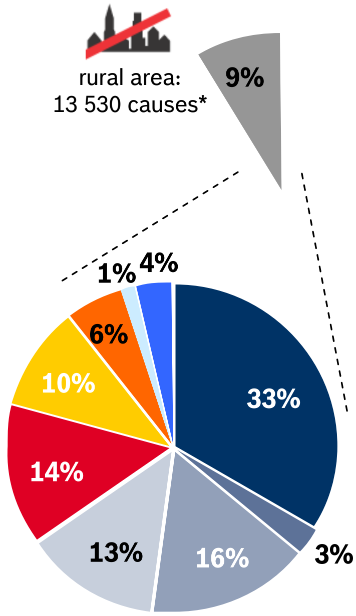
1) source: German Statistical Office, 2007
2) This information is taken from standard slide no. 13

"Other" Causes for Road Accidents in Detail



"other" causes of accident in detail

- other causes-more detailed allocation impossible
- stationary vehicles
- driving side by side
- technical defects
- weather conditions
- wrong behavior of pedestrians
- wrong behavior towards pedestrians
- obstacles
- passing
- charge

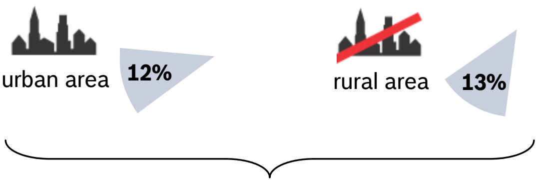


** In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.*

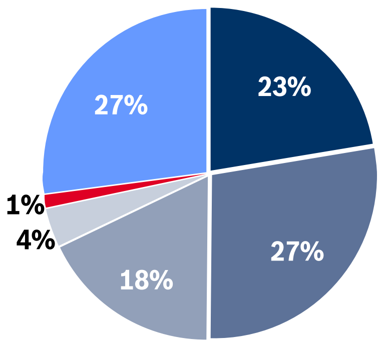
1) source: German Statistical Office, 2007

2. Technical Defects as Cause for Traffic Accidents[1)]
Chapter 19

Technical Defects as Causes for Road Accidents



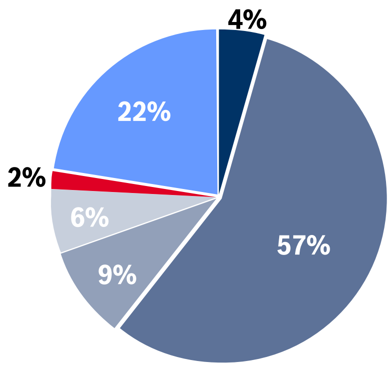
Technical defects of all vehicle types
(4 425 causes*)



technical defects

- lighting
- tires
- brakes
- steering
- towing device
- other defects

As comparison: **Technical defects of passenger cars only**
(1 463 causes*)



** In the diagram the distribution of causes for accidents is visualized. For each accident up to 8 causes can be recorded.*

1) source: German Statistical Office, 2007

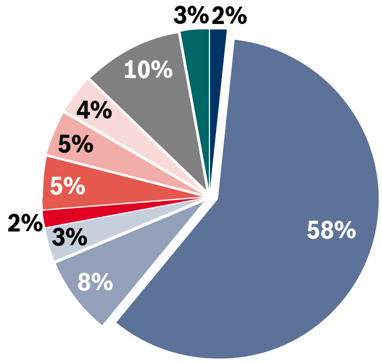
Technical Defects in Cars Involved in Accidents with Injuries

accidents[1] in total	vehicles	
13 799	24 907	involved vehicles in total
11 507	16 939	involved cars
255	255	technical defects

➔ There 255 cars with at least one technical defect. Referred to all cars this is a share of ~1.5%.

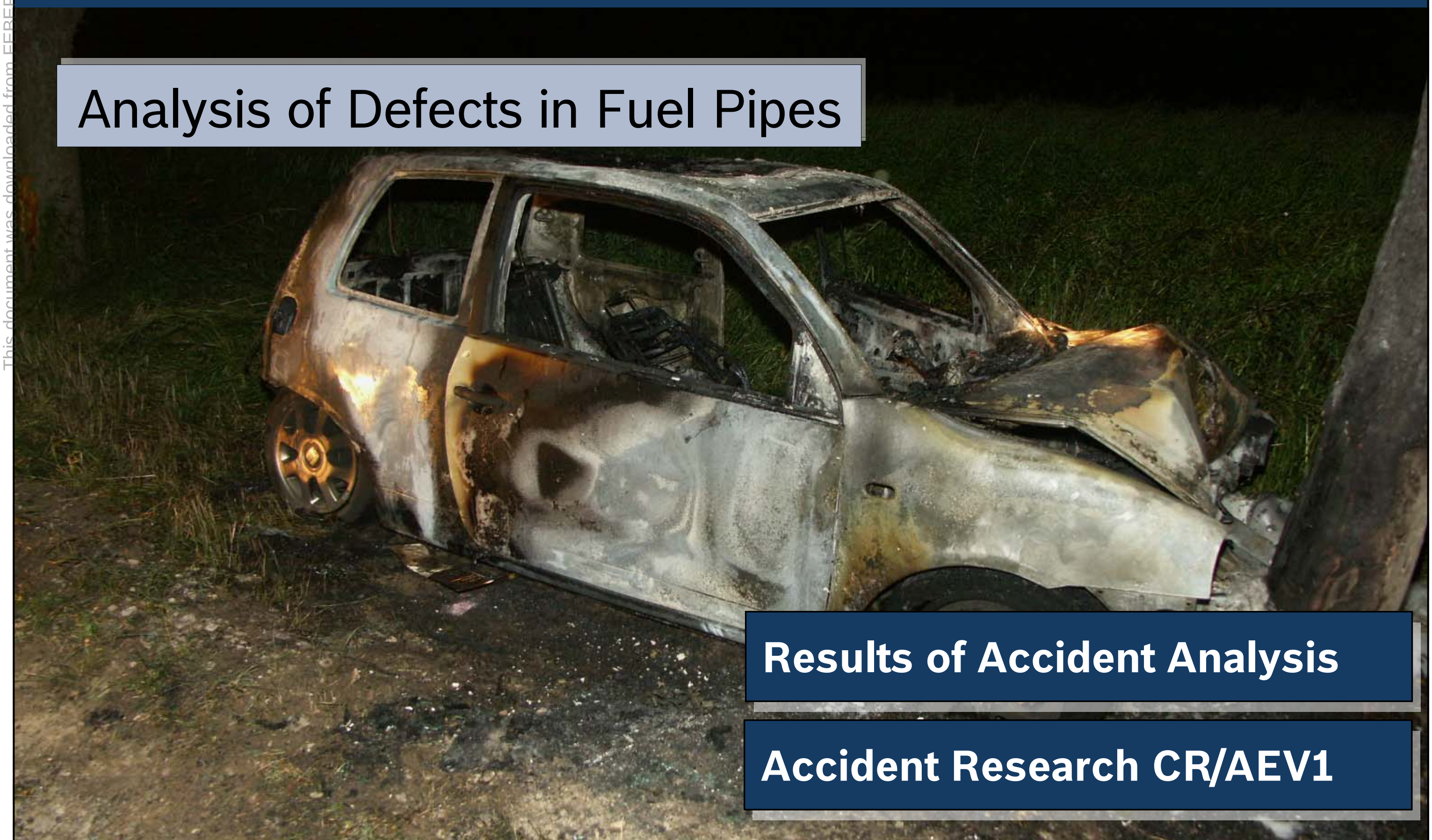
Distribution of Kinds of Technical Defects in Cars

(It is possible to specify more than one technical defect for a car. There are 323 technical defects in 255 cars.)

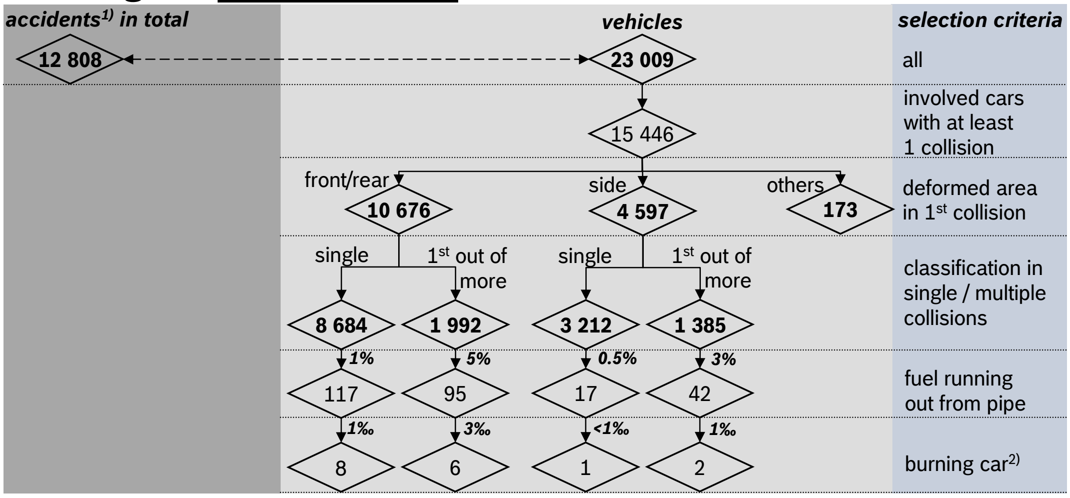


Defective vehicle parts
- lights
- tires
- brakes
- steering
- electronics
- suspension
- engine
- overall view
- others
- unknown

1) Source: GIDAS 2001-2008 *(weighted data for Germany)*



Selection of Accidents Involving Cars with Fuel Running out from Fuel Pipe Based on GIDAS[1] Data



➔ Fuel is **less frequently** running out from pipe **in side than in front/rear** crashes.
➔ The frequency of **fuel running out from pipe and burning** cars is in all cases **less or equal than 3‰.**

1) German In-Depth Accident Study: reconstructed, weighted data from 2001-2008 is used
2) The cause for the fire needs not to be the outrunning fuel, the fire i.e. can be caused by inflamed oil

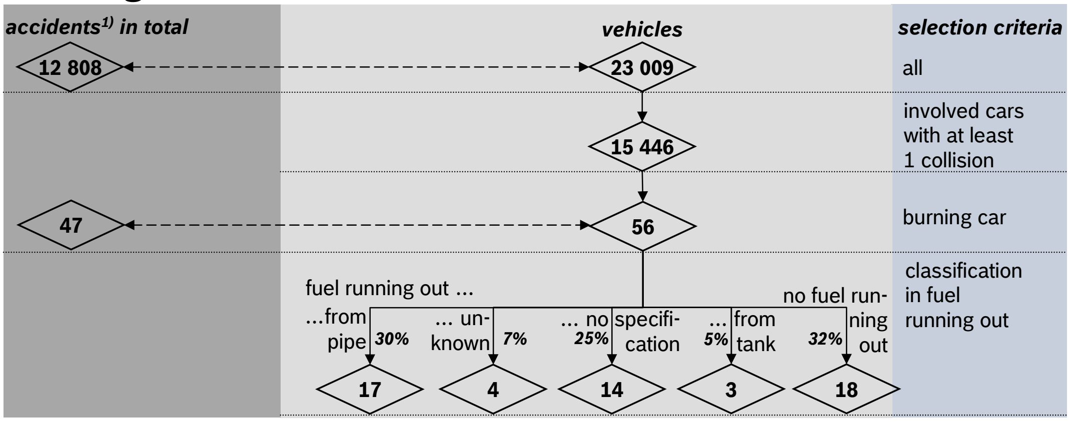
BOSCH

<u>Grenzen der Auswertung:</u>

1. Es lässt sich von ausgelaufenem Kraftstoff aus einer “Leitung” bzw. “Leitung Motorraum” schließen, dass die Spritleitung beschädigt ist. Dieser Schluss gilt jedoch nur in diese eine Richtung. Es muss nicht zwingend gelten, dass aus einer beschädigten Spritleitung Kraftstoff ausläuft. Für die Aussage über die Häufigkeit beschädigter Spritleitung basierend auf dieser Auswertung gilt, dass prinzipiell noch weitere Pkw enthalten sein können deren Spritleitung im Unfall beschädigt wurde ohne das Kraftstoff ausgelaufen ist.
2. Die Ursache für den Brand der Pkw muss obwohl Kraftstoff ausgelaufen ist nicht zwingend der ausgelaufene Kraftstoff sein (vgl. Fußnote 2 auf Folie). Die Ursachen für die Brandentstehung können vielfältig sein. Es könnte ebenfalls sein, dass beispielsweise bei einem Frontanprall zusätzlich zu dem ausgelaufenen Kraftstoff Öl austritt und sich entzündet. Die Ursache für den Brand wäre in diesem Fall, dass ausgelaufene Öl und nicht der ausgetretene Kraftstoff.
3. Die mit dieser Auswertung ermittelten 17 brennenden Pkw mit auslaufendem Kraftstoff aus einer Leitung sind eine Untergrenze. Es ist zu erwarten, dass bei brennenden Pkw das Teil aus dem Kraftstoff ausgelaufen ist nicht immer zu bestimmen ist. Aus den Ergebnissen der Analyse zu brennenden Pkw insgesamt lässt sich jedoch entnehmen (vgl. Folie 3), dass maximal zusätzlich 18 brennende Pkw mit auslaufendem Kraftstoff aus einer Leitung möglich sind. Das sind erstens diejenigen Pkw, bei denen Kraftstoff ausgelaufen ist, jedoch aber nicht genauer spezifiziert wurde aus welchem Teil Kraftstoff ausgetreten ist (n=14). Hinzukommen noch Pkw, bei denen nicht bekannt ist, ob Kraftstoff ausgelaufen ist (n=4). Diese zusätzlichen 18 Pkw sind als Obergrenze zu sehen. Es ist beispielsweise auch denkbar, dass bei einem Teil dieser 18 Pkw ein Kabelbrand die Ursache für die Entzündung des Pkw gewesen ist.
4. Bei Pkw mit Mehrfachkollisionen wurde für die Anprallart (Front/Heck – Seite) jeweils der erste Zusammenstoß betrachtet. Dieser erste Anprall kann beispielsweise sehr leicht gewesen sein und der Schaden an einer Leitung wurde erst durch eine folgende Kollision verursacht. Es ist zwar häufig der Fall, dass die erste Kollision diejenige mit einer großen Geschwindigkeitsänderung ist, aber es gibt auch Unfälle, bei denen die Beschädigungen am Fahrzeug durch eine folgende Kollision verursacht werden. Es kann zu Verschiebungen in den Häufigkeiten der Anprallarten kommen, wenn bei den Mehrfachkollisionen, nicht die erste, sondern z.B. die airbagrelevante Kollisionen bezüglich der Anprallart ausgewertet werden. Für Aussagen, ob es tatsächlich zu signifikanten Verschiebungen bei den Mehrfachkollisionen kommt, sind weitere detaillierte Analysen erforderlich.

→ Insgesamt lässt sich sagen, dass diese Anzahl der brennenden Pkw mit ausgelaufenem Kraftstoff eine grobe Schätzung für den Anteil der zerstörten Spritleitungen darstellt.

Selection of Accidents Involving Burning Cars with Fuel Running out Based on GIDAS[1)] Data



→ In almost **4‰** of all **accidents** with injuries there is at least one **burning car** involved.

→ In about **30%** of the burning cars there is fuel running out **from pipe**, in **25%** it is **not specified** from which part fuel was running and in **7%** it is **unknown** if fuel was running out.

1) German In-Depth Accident Study: reconstructed, weighted data from 2001-2008 is used

<u>Grenzen der Auswertung:</u>

Kleine Fallzahl

Bei dieser Auswertung ist zu berücksichtigen, dass die Aufteilung der 56 Pkw in das Auslaufen von Kraftstoff auf einer kleinen Zahl basiert. Die Verteilung bezüglich des auslaufenden Kraftstoffs ist somit mit einem größeren Unsicherheitsfaktor behaftet. Oder anders ausgedrückt bei dieser kleinen Zahl kann es in der Verteilung zu Verschiebungen im Vergleich zur Grundgesamtheit kommen.

Analysis of Stranded Vehicles (D, USA, J)

Results of Accident Analysis

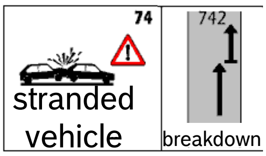
Accident Research CR/AEV1

BOSCH

Accidents <u>with Casualties</u> Involving Stranded Vehicles

12 808 accidents[1] with casualties in total

15 accidents involving a stranded vehicle *(GDV type 742, cp. sketch)*



➔**Less than 2‰** of all accidents with casualties involve **a <u>vehicle</u> with a breakdown**

Kinds of stranded vehicles

Kinds of stranded vehicles	Number[2]
Passenger car	9
Truck	4
other	2

➔**Less than 1‰** of all accidents with casualties involve **a <u>passenger car</u> with a breakdown**

1) source: German In-Depth Accident Study - reconstructed, weighted data from 2001-2008 is used
2) Because of small numbers the distribution must be considered critically *(please cp. slide 6 ff.)*

BOSCH

Accident Severity and Reasons for Breakdowns in Accidents[1)] Involving a Stranded Car

Reasons for being stranded	Number[2)]	Accident Severity
Puncture	2	Slight
Lack of fuel	1	Serious
Technical defect – engine & electronics	2	Slight
Breakdown – no more detailed information	2	Slight and Fatal
unknown	2	Slight

Accident Involving a Car with Technical Defect – Engine & Electronics

(GIDAS case: #1070925 with weighting factor 2)

A Fiat Punto has a technical defect (electronics and motor break down) while driving on a motorway. The car is stopped on the on-ramp. The scene of the accident is not cordoned off well. A truck using the slip road crashes into the Fiat Punto and falls down. Only the driver of the truck suffers slight injuries.

picture of the accident scene

1) source: German In-Depth Accident Study - reconstructed, weighted data from 2001-2008 is used

2) because of small numbers the distribution must be considered critically *(please cp. slide 6 ff.)*

BOSCH

All Accidents with Vehicle Contributing Factor "defect in power-train"

5 801 228 — accidents[1)] in total

↓

115 448 — accidents with a vehicle contributing factor

↓

52 636 — accidents with a vehicle contributing factor of automobiles or automobile derivatives

↓

4 346* — accidents with vehicle contributing factor "Power Train-Universal Joint, Drive Shaft, Transmission, etc." of automobiles or automobile derivatives

→ ***Less than 1‰** of all accidents are contributed by **a car with a technical defect in power-train***

1) Accidents (with casualties and property damage only) in GES 2008 - weighted data is used

* this weighted number is equivalent to 35 real accidents

BOSCH

Severities in Accidents[1] with Vehicle Contributing Factor "defect in power-train" of a Car

Accident severity	frequency	in percent
No injury	2934	67%
Possible injury	856	20%
Non incapacitating injury	276	6%
Incapacitating injury	70	2%
Injured, severity unknown	90	2%
unknown	120	3%

➔ *In more than 2/3 of the relevant accidents no person is injured*

➔ *There is no fatal accident in the relevant accidents*

➔ *But the real number of relevant accidents is with 35 cases quite small, hence the accident severity distribution must be considered critically (please cp. slide 6 ff.)*

1) Accidents (with casualties and property damage only) in GES 2008 - weighted data is used

Analysis of Stranded Vehicles
Chapter 19

Traffic Accidents by Type of Violation "Operating Defective Vehicle"

accidents[1] with casualties

787 139 — accidents involving motor vehicles or 1st moped class as primary parties

↓

138 — accidents with type of violation "operating defective vehicle"

accidents[1] with fatalities[2]

5 189 — accidents involving motor vehicles or 1st moped class as primary parties

↓

2 — accidents with type of Violation "operating defective vehicle"

➔ ***In less than 1‰*** *of all accidents with casualties involving cars as primary parties the type of violation is* ***"operating defective vehicle"***

➔ ***In less than 1‰*** *of all accidents with fatalities involving cars as primary parties the type of violation is* ***"operating defective vehicle"***

➔ ***BUT:*** *the results are an underestimation because only the causer of the accident and not all involved vehicles are considered concerning a defect*

1) IATSS, Year 2007
2) only fatalities that occur within 24 hours

Mindestgröße von Stichprobenumfängen
Grundlagen*

1. Stichprobenumfänge mit 30 Elementen oder weniger gelten allgemein als zu klein für repräsentative Aussagen über die Grundgesamtheit
2. Zur Gewährleistung, dass ein binäres Zielereignis (z.B. Antrieb defekt, Antrieb nicht defekt) mit Eintrittswahrscheinlichkeit *p* in der Stichprobe gleich häufig wie in der Grundgesamtheit auftritt, muss die Stichprobe ausreichend groß sein. Zur Bestimmung des Mindestumfangs einer Stichprobe, um eine vorgegebene Schätzgenauigkeit des Parameters *p* zu erreichen, wird folgende Formel für unendliche Grundgesamtheiten[1)] verwendet:

$$\boxed{n \geq z^2 \cdot \frac{p(1-p)}{\varepsilon^2}} \quad (1)$$

n … minimal erforderlicher Stichprobenumfang

z … aus zentraler Wahrscheinlichkeit der Standardnormalverteilung[2)] berechneter Wert der gewählten Sicherheitswahrscheinlichkeit (z.B. D(z)=95% ➔ z=1,96)

p …prozentualer Anteilswert des zu schätzenden Parameters in der Grundgesamtheit (abgeschätzt mit Vorinformationen), „worst-case“ Abschätzung mit p=0,5

ε …gewählter, tolerierter Fehler (ε=0,05 entsprechen einer Abweichung von +/-5%, somit Breite von 10%)

1) Als unendliche Grundgesamtheit gilt eine Population, die ausreichend groß ist. Die Unfälle mit Personenschaden erfüllen beispielsweise die Kriterien für eine unendliche Grundgesamtheit.
2) Für Informationen zur Standardnormalverteilung siehe Folie 6

* Quellen: Lothar Sachs „Angewandte Statistik“, kleine Formelsammlung von Prof. Koch, Institut für medizinische Informatik und Biometrie, TU Dresden (http://www.imib.med.tu-dresden.de/imib/biometrie/Kompendium_Biometrie_Formelsammlung.pdf)

Mindestgröße von Stichprobenumfängen
Anwendung auf GIDAS-Auswertung am Bsp. MAIS5+ Verletzungen

1. Die GIDAS-Daten gelten aufgrund der angewandten Erhebungsart als repräsentative Stichprobe aller Unfälle mit Personenschaden in Deutschland. Ebenso wie jede aus GIDAS zufällig gezogene Stichprobe.
2. Zur Beantwortung der Frage, wie genau und zuverlässig Aussagen über das nicht Vorhandensein von MAIS5+ Verletzungen sind, wird Formel (1) verwendet. Mit der Formel wird der Mindestumfang einer Stichprobe bestimmt, mit der Aussagen unter vorgegebener Genauigkeit über die Auftretenswahrscheinlichkeit *p* eines Ereignisses (z.B. „MAIS5+ Verletzungen treten im Unfallszenario X auf“) möglich sind.
3. Für die Bestimmung des notwendigen Stichprobenumfangs bei vorgegebener Genauigkeit werden die Parameter wie folgt gewählt:

z=1,96 (entspricht 95%-Konfidenzintervall bei Annahme einer Standardnormalverteilung)

p=827/9331 ≈ 0,09 (Zur Abschätzung wie häufig das Ereignis „MAIS5+ Verletzungen bei ausgewähltem Unfallszenario X“ auftritt, wird das Unfallszenario (Stadt: Unfallszenario 1) mit dem größten Anteil an allen Unfällen mit Personenschaden verwendet. Dieser angenommene Wert für p gilt als konservative Abschätzung, da das Ereignis „MAIS5+Verletzungen“ nicht bei allen Unfällen des ausgewählten Unfallszenarios zu erwarten sind und der größte Anteil eines Unfallszenarios betrachtet wurde.)

ε=0,05 (entspricht einem toleriertem Fehler von p im Bereich von +/-5%)

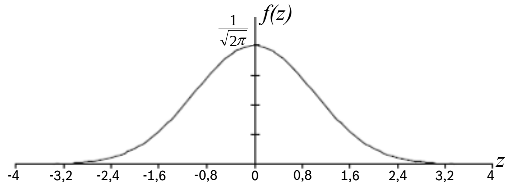
einsetzen in (1): $n \geq 1{,}96^2 \cdot \frac{0{,}09(1-0{,}09)}{0{,}05^2} \approx 125{,}85$ worst-case: $n \geq 1{,}96^2 \cdot \frac{0{,}5(1-0{,}5)}{0{,}05^2} \approx 384{,}16$

➔ **Ein Stichprobenumfang von n=126 Unfällen mit Personenschaden wird mindestens benötigt, um die Auftretenshäufigkeit des Ereignisses „MAIS5+ Verletzungen im Unfallszenario X“ mit einem tolerierten Fehler von +/-5% und einer 95%-igen Eintrittswahrscheinlichkeit zu bestimmen. Maximal werden für das „worst-case“ Szenario n= 385 Unfälle mit Personenschaden benötigt.**

Mindestgröße von Stichprobenumfängen

Die Standardnormalverteilung* $N(0,1)$

Dichtefunktion: $f(z)=\frac{1}{\sqrt{2\pi}}\cdot e^{-\frac{z^2}{2}}$

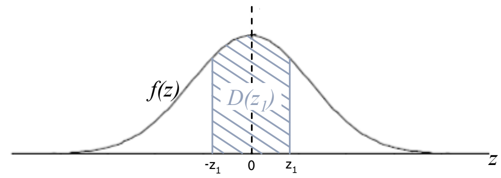


Verteilungsfunktion: $\phi(z)=\int_{-\infty}^{z} f(z)dz$

Da sich das Integral von *f(z)* nicht geschlossen lösen lässt, sondern nur numerische Lösungen für einzelne *z*-Werte berechnet werden können, sind die Werte aus einer Tabelle zu entnehmen (s. unten)

Aufgrund der Symmetrie von $f(z)$ gilt: $\phi(-z)=1-\phi(z)$

zentrale Wahrscheinlichkeit/ Wahrscheinlichkeit für zweiseitige Fragestellungen:



$D(z_1)$ beschreibt mit welcher Wahrscheinlichkeit *P* die Zufallsvariable Z in dem Bereich zwischen $-z_1$ und z_1 liegt:
$D(z_1)=P(-z_1\leq Z\leq z_1)$

Beispiel: Für ein *z*-Wert von 1,96 erhält man folgende Gleichung $D(1{,}96)=P(-1{,}96\leq z\leq 1{,}96)=0{,}95996$
→95% aller Werte einer standardnormal verteilten Zufallsvariablen Z liegen in der Population zwischen -1,96 und 1,96 *(95% Eintritts- bzw. 5% Irrtumswahrscheinlichkeit)*.

Wertetabelle:

α	1- α	*D(z)*
0,1	0,9	1,64485
0,05	0,95	1,95996
0,01	0,99	2,57583
0,001	0,999	3,29053

* Quellen: Lothar Sachs „Angewandte Statistik", kleine Formelsammlung von Prof. Koch, Institut für medizinische Informatik und Biometrie, TU Dresden (http://www.imib.med.tu-dresden.de/imib/biometrie/Kompendium_Biometrie_Formelsammlung.pdf)