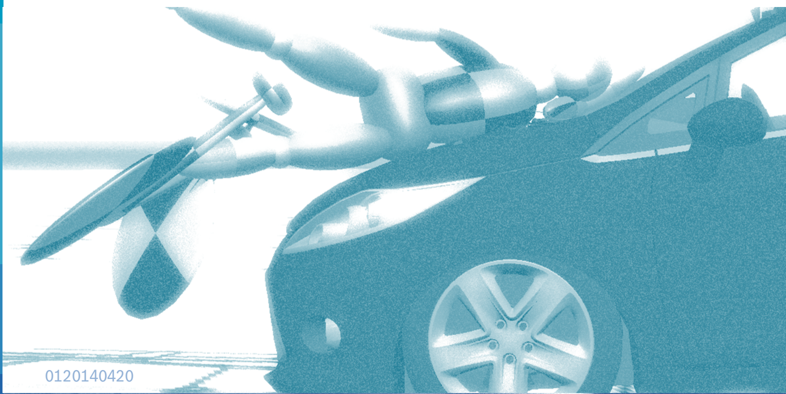
Report 2016/17

BOSCH Accident Research



VM-064

BOSCH

From	Our Reference	Tel	Renningen
CR/AEV1	AEV064-Staff	+49(711)811-34831	31-Jan-18

Topic **Bosch Accident Research Report 2016-17 (AEV064)**

**OCP = Oncoming Collision Prevention*
*** HCV = Heavy Commercial Vehicles (>12t)*
**** German language available only*

Executive Summary Results 2016/17

Bosch Accident Research (AEV-064)

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Executive Summary Results 2016/17

Chapter 02

06. Evaluation of Integrated Safety System portfolio

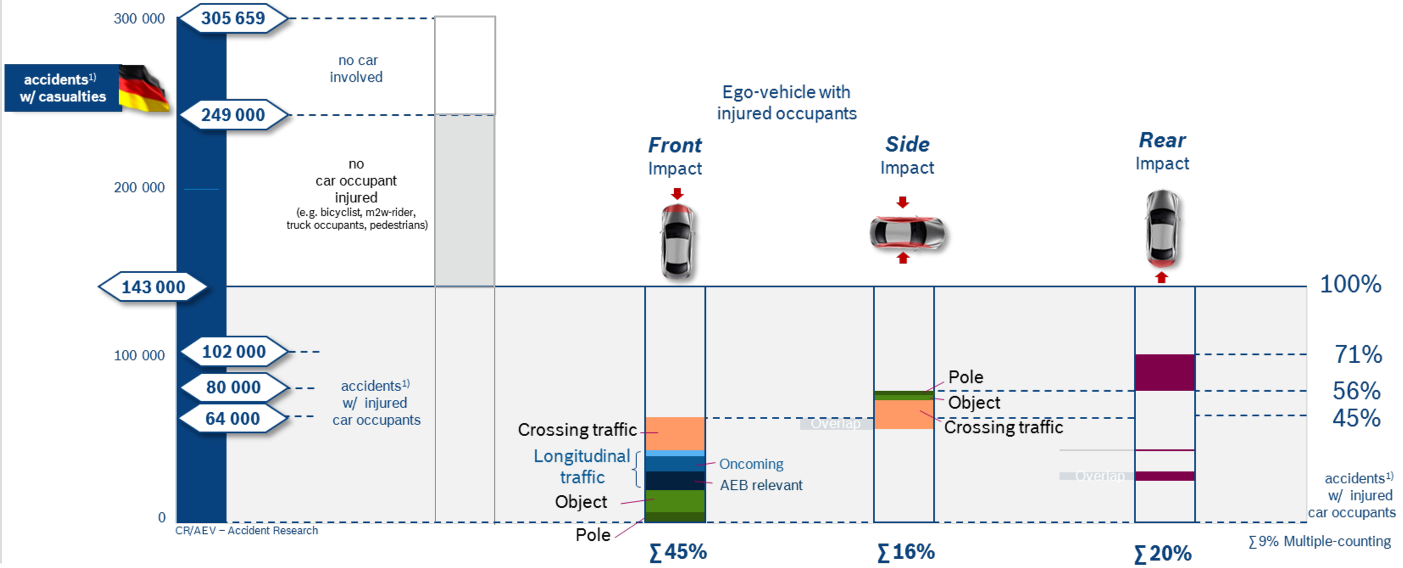
Aim: Evaluation of field of effect for ISS function portfolio: Focus on Integrated Detection Side (IDS)

Methodology

- Using updated GIDAS version and official statistics (2015)
- Advanced case selection criteria applied (considering crash information i.e. v_{rel} =20..140kph and collision speed Δv: >15kph)
- Different weighting methodology applied to get more detailed information on severity at occupant level

Results:

- In every 2nd crash w/ casualties (143.000) a car occupant is injured.
- Thereof 64.000 crashes are IDF (45%), 16.000 crashes IDS (16%) and 22.000 crashes (rear-impact) relevant.
- Focus for ISS: Oncoming crashes, Object/Pole impacts and crossing traffic.
- Confirmation: Most severe crashes are still front and side impacts



▶ Results supports the benefit of various ISS functionalities for customer acquisition

Executive Summary Results 2016/17

07. Highway Pilot Safe Stop Function

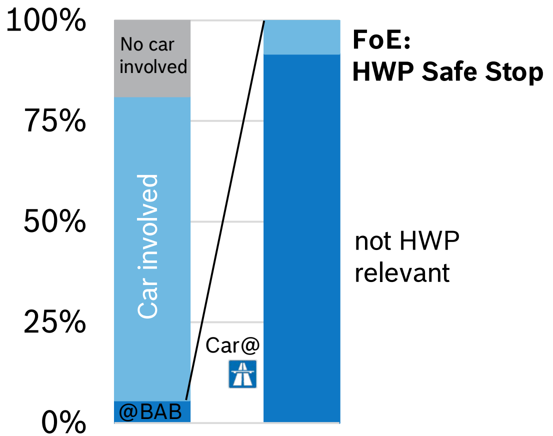
Aim: Assessment of Highway Pilot "Safe Stop"-function in Germany (CC/EYB)

Methodology

- Determination of relevant accidents out of official statistics (DESTATIS) and GIDAS database
- Determination of relevant breakdowns w/ official and requested data from ADAC
- Linking breakdowns and accidents at German highways involving cars
- Estimation of impact of HWP Safe Stop function to current accident situation

Results:

- Relevant car accidents for HWP Safe Stop Function (BAB): 17,000 accidents w/ injuries, thereof are 243 fatal- and 13,419 severe crashes in Germany.
- **Field of Effect** determined to ~1,400 accidents due to disability of driver (details see study)
- Note: Calculation also considers additional accidents caused by "Safe Stop" Function → ~<140 additional rear end crash
- Recommendations:
- Clearly perceivable warning of following traffic highly when system is active i.e. C2X communications / eCall ....
- Deceleration should not exceed 4 m/s^2



▶ Further support on behalf of future AD functions currently under investigation

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08. Injury severity estimation in oncoming collisions (→ OCP)

Aim: Severity estimation to support system- and sensor requirements for Oncoming Collision Prevention function (→ CC/ENA)

Methodology & History

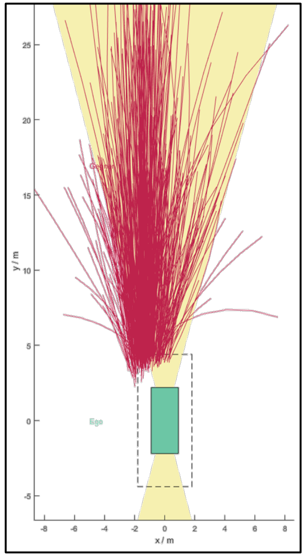
- Analysis against oncoming traffic finished in 2013/14 leads to several function ideas
- Functional limitation: Track angle +/- 30° & relevant accident types (overtaking, oncoming)
- Prioritization of Oncoming Collision functionality in 2015 together with CC/ENA
- Continuous analysis on updated GIDAS database
- **In 2017:** Injury severity estimation by using 1st simulation or reconstructed crashes and 2nd Data Mining i.e. Neural Networks

Status & interim results:

- Field of Effect for OCP: 1.2% of all accidents w/ casualties in Germany
- Trajectories of collision opponent generated for relevant accidents w/ 50% offset and left side impact only
- Driver reaction in OCP relevant crashes (Frontal collision w/ <50% overlap, driver side):

Driver action	No action	Braking only	Braking & Steering	Steering only	Accelerating
Share	37%	22%	33%	6%	3%

- In brake interventions every 2nd driver applies full braking & every 5th minimal braking
- In 80% of relevant crashes the relative initial speed is determined to 130 kph of both vehicles.
- **Injury severity estimation:** Less overlap & higher collision angle results in reduced injury levels on generic cases estimated



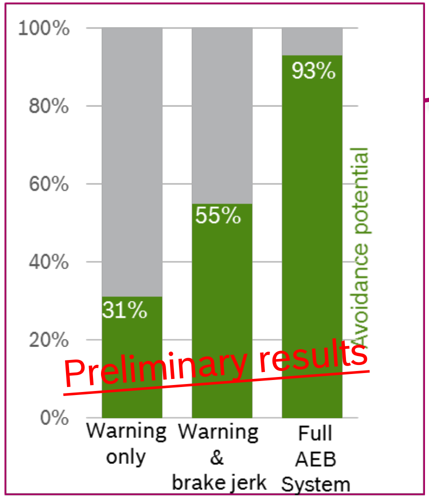
Executive Summary Results 2016/17

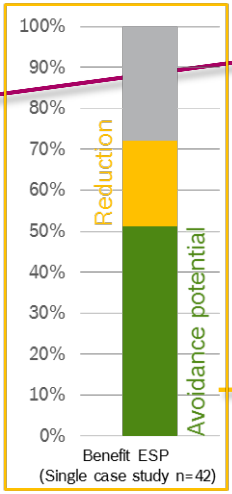
09. Heavy Commercial Vehicle – AEBS & ESC benefits (Status)

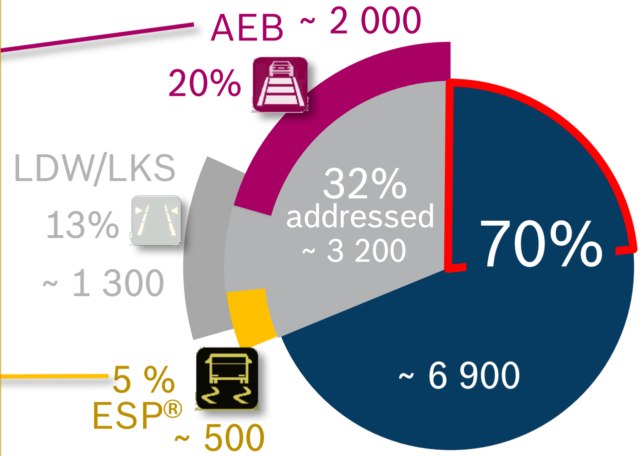
Aim: Evaluation of AS/DAS for HCV (>12t) and support of CC-DA/CVO

Methodology
- Reconstruction of GIDAS database cases for AEB simulation
- AEB requirements implemented in simulation framework → Stochastically simulation of cases (~4 Mio.)
- Single case assessment for ESC benefit estimation

Status & Preliminary results:
- Simulation of LDW function not yet assessed
- ~2.5% of all HCV crashes w/ casualties (~250) could be avoided or at least mitigated if each CV would be equipped w/ ESC in Germany
- 1st estimation: ~18% of all HCV crashes w/ casualties (~1,800) could be avoided in Germany if full AEB system assumed







▶ Next step: Improvement of truck driver model and system requirements to finalize AEBS simulation results along with first evaluation of LKS system by extended simulation methodologies

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10. Correlation between emissions and accidents

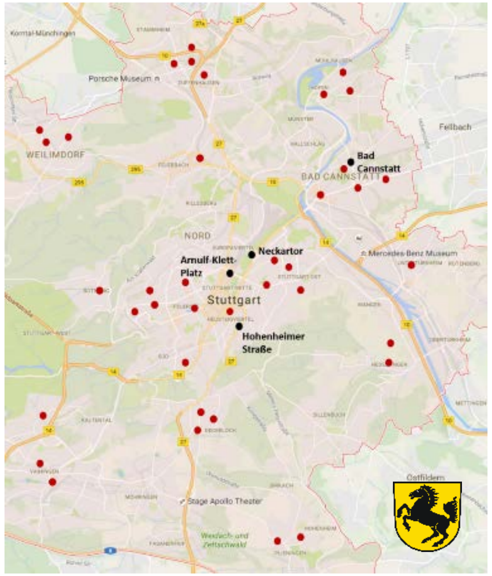
Aim: Proof of correlation between fatal road crashes and NO_2-concentration

Methodology

- Analysis is limited to the city of Stuttgart
- Police reported accidents and environmental data was used for the analysis in between 2011-2015
- Internet based information on contact data was evaluated and incorporated to assess the correlation between emissions and crashes

Results:

- At weekdays 2.1 fatal accidents/100 days whereas a mean NO_2 concentration of 72.5 μm/m^3 occurred. During weekend or bank holiday 2.5 fatal crashes/100 days occurred but with a reduced NO_2 concentration of 55.3 μm/m3 (valid for city of Stuttgart only)
- A high NO_2-concentration doesn't necessarily result in a higher share of fatal road traffic crashes with respect to the observed time frame of 4 years.
- Interactions between road traffic and traffic flow with resulting NO_2 concentration avoid an independent root cause analysis towards fatal crashes. Hence an independent correlation between fatal crashes and NO_2 concentration with given sample size cannot be determined clearly.



Executive Summary Results 2016/17

12. Traffic accident situation on selected Middle East Countries

Aim: Accumulation of statistical crash data on six selected middle east countries to support ESC promotion

Methodology

- Pre-defined countries aligned w/ CC-MBC: *Iran, Jordan, Saudi-Arabia, Qatar, Kuwait, United Arab Emirates (UAE)*
- Research for official published reports on traffic accidents along with requests to traffic authorities and other references
- Calculation of accident risk indicators in order to have reference points for comparison against industrialized countries

Results:

- Report available on current status (~120 pages)
- Road safety is gradually improving in all the studied middle eastern countries, except for the *Kingdom of Saudi Arabia*
- Different behavior is substantial share of drivers in comparison to industrialized countries this includes:
  - Aggressive driving style
  - Lack of respect for other road users
  - No/less safety awareness
  - Violation of traffic laws

Country	Population [Mio]	Registered Vehicles [Mio]	Reported Accidents	Casualties	Fatalities	New Vehicles Registered 2012
Iran	79	27.5	452 630	414 161[1,3]	16 584	860 000
KSA	32	19.8	533 380	47 151	9 031	530 000
UAE	9.3	3.4	4 788	7 406	725	211 500
Kuwait	3.9	1.9	80 827	9 602	429	164 485
Qatar	2.6	1.3	314 591	9 097	178	85 019
Jordan	9.5	1.4	111 057	16 747	608	66 624
Germany	81	61.5	2 516 831	396 891	3 459	3 082 054
USA	321	269	6 296 000	2 478 092	35 092	14 310 000
Japan	127	77	536 899[2]	670 140	4 117	5 369 720
India	1 311	210	501 423[2]	646 412	146 133	17 625 000
EU28	508	322	1 090 300[2]	1 474 200	26 100	14 366 049

[1] Casualties number is based on 2010 data
[2] Reported accident numbers are for accidents with casualties only
[3] Definitions for fatalities and casualties unavailable for Middle Eastern countries, except for Iran (fatalities on the spot) and Jordan (fatalities within 30 days of accident)

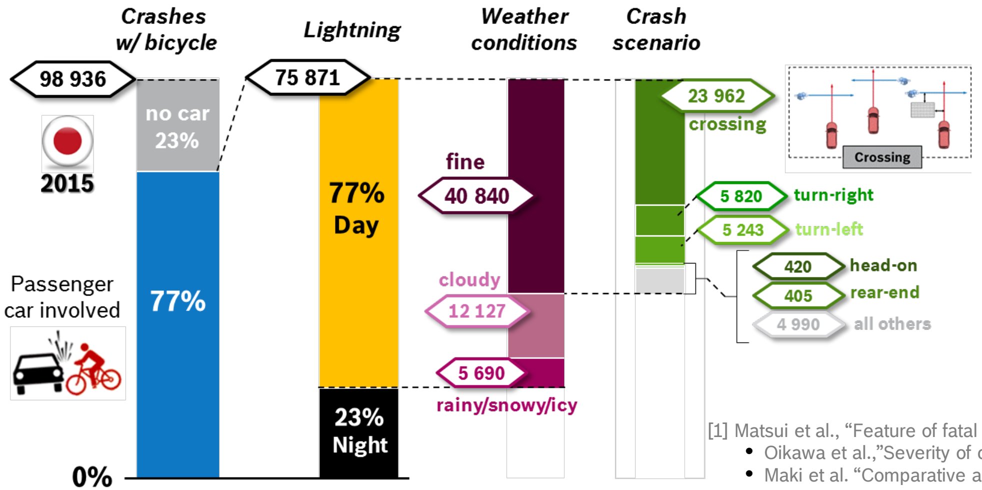
Executive Summary Results 2016/17

13. Analysis of car-bicycle crashes and impacts to J-NCAP

Aim: Evaluation of car-bicyle crashes in Japan to assess sensor requirements settings along with J-NCAP proposal

Methodology

- ITARDA database (2016) used to assess national accident situation
- No access to in-depth data hence EDR data (2009/11 Tokyo University) assessed to identify further crash parameters
- Comparison against EuroNCAP test setup in order to identify possible changes of sensor requirements
- Publication on FastZero 2017 conference held in Sep. 2017, Nara



Source	Condition	TOP 3 scenarios	Cyclist	Cyclist speed kph	Vehicle Speed kph	Impact point
EDR analysis by Bosch Accident Research	▪ Daylight ▪ Fine (dry)	1. Crossing 2. Turning 3. Rear-end	Adult[1]	1. ≤10 2. ≤15 3. ≤15	1. ≤50 2. ≤40 3. ≤45	1. 50% [1] 2. n/a 3. n/a
1. EuroNCAP[1] 2. CATS[1] 3. CATS	▪ Daylight ▪ Fine (dry)	1. Crossing 2. Rear-end 3. Head-on	Adult	1. ≤20 2. ≤20 3. n/a	1. ≤55 2. ≤80 3. n/a	1. 50% 2. 25%/50% 3. n/a

[1] Matsui et al., “Feature of fatal cyclist injuries in vehicle vs. cyclist accidents in Japan”,SAE 2015-01-1415 (2015)
- Oikawa et al.,”Severity of cyclists head injuries caused by impacts with vehicle structure and road surface”, Biomechanical Science & Eng., No.15-00613, Vol 11, No. 2 (2016)
- Maki et al. “Comparative analysis of vehicle-bicyclist and vehicle-pedestrian accidents in Japan”, Acc. Analysis and Prevention 35, pp 927-940 (2003)
- Assessment Protocol Pedestrian Protection V.9, 03/2017, www.euroncap.com; CATS: Cyclist-AEB Testing System, www.tno.nl ,2016

▶ No change of sensor requirements expected but challenges especially on narrow streets w/ obstruction

Executive Summary Results 2016/17

14. HCV: Transfer AEBS & ESC benefits to US

Aim: Evaluation of relevant crashes for AS/DAS involving HCV (>12t) and benefit estimation of ESC and AEBS

Methodology

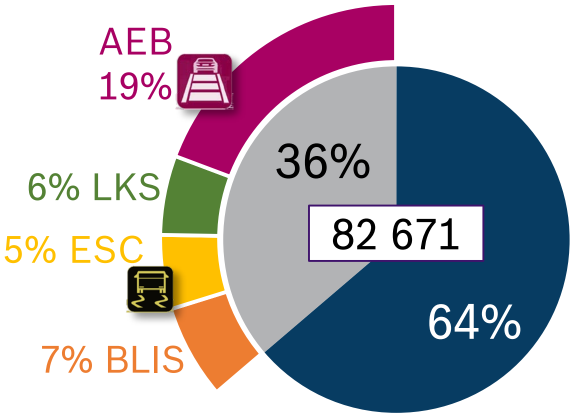
- Determination of relevant accidents w/ casualties using US database FARS and GES
- Benefit of ESC and AEBS was transferred out of results of studies from Germany using GIDAS database (→ see Chapter 09)
- Comparison of available reports to confirm findings

Results:

- Large trucks (>10 000 lbs) are involved in 3% of all injury crashes but in 8% of all fatal crashes within the US but their share of registered vehicles is ~4% only.
- Approximately every 3rd crash involving a large truck could be addressed by state-of the art technologies hence still high potential for other safety technologies.

System	Advanced Emergency Braking System	Lane Keeping Support	Electronic Stability Control	Blind Spot Information System
Field of effect	~16 200 crashes (19%)	~4 900 crashes (6%)	~4 400 crashes (5%)	5 300 crashes (6%)
Est. benefit	~13 300 crashes	n/a	~3 600 crashes	n/a

FoE for selected technologies in large truck crashes w/ injuries in US



Sources: FARS and GES 2015

▶ Results will be used for promotion of HCV safety technologies in US

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Executive Summary Results 2016/17

15. Benefit estimation of LDW/LDP for cars and trucks in China

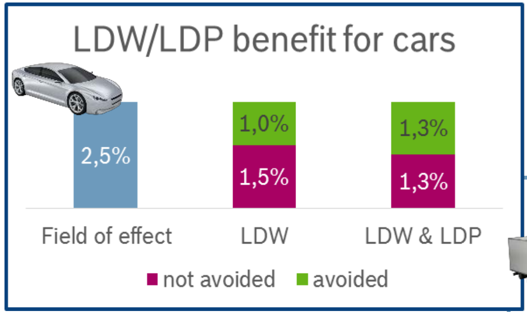
Aim: Estimate the benefit of LDW/LDP for cars and trucks in China

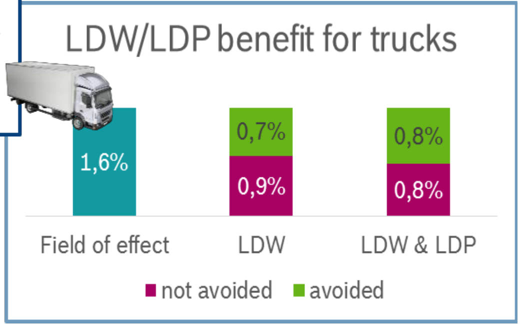
Methodology

- Analysis based on CIDAS (China in depth accident study) data (2014-2016). Data used as input for effectiveness simulation.
- Overall 88 severe crashes out of ~2,000 crashes were identified as being relevant for LDW/LDP simulation
- Driver model stochastically built up and varied results in ~88,000 accidents.
- Reconstruction and variation of accidents with different system settings to assess LDW/LDP effectiveness (~250,000 simulations)

Results:

- In every 2nd severe accident a car is the main responsible party. Field of effect for car LDW/LDP was determined to ~2.5%.
- In every 5th severe accident a truck is the main responsible party. Field of effect for CV LDW/LDP was determined to ~1.6%.
- **Estimated avoidance benefit:** *(100% installation rate)*
  - LDW: ~1.0% cars, ~0.7% trucks
  - LDW+LDP: ~1.3% cars, ~0.8% trucks
- Compared to Germany similar results obtained for FoE & benefit





▶ Next step: Improve quality of reconstruction and enabling stochastic simulation

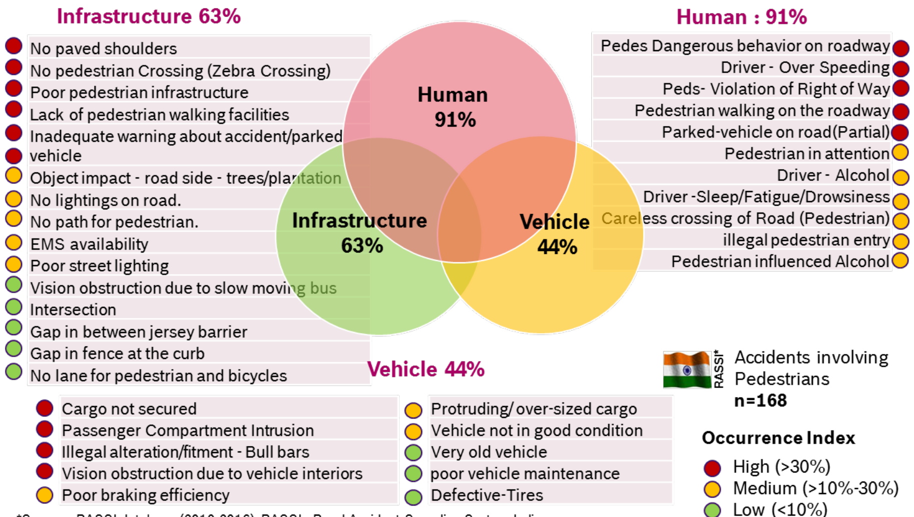
Executive Summary Results 2016/17

16. Overview of pedestrian crashes and AEB assessment in India

Aim: First study on pedestrian crashes along with evaluation of possible benefit for Active Pedestrian Protection in India

Methodology
- RASSI database (2010-2016); total: 1779 crashes thereof 168 against pedestrian (~10%)
- Setup of scripted analysis for easier and more efficient update on behalf of Field of Effect and Benefit
- First steps towards effectiveness and crash avoidance potential

Results:
- Contributing factors mainly due to lack of safety awareness
- Field of effect of car-AEB pedestrian crashes is determined to 26% in RASSI (valid for highway only)
- Crossing pedestrian covers more than 70% of all car-pedestrian crashes (including obstruction) → urban area not considered yet!
- 2 out of 3 crashes occur during daylight conditions
- Simulation based benefit assessment reveals every 10th crash would be avoided if each car was equipped w/ car-AEB Pedestrian



*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

▶ Results presented and published on Delhi Summit Safe Roads (Oct. 17)

▶ Results contribute essentially to develop Bosch ADAS strategy in India

Executive Summary Results 2016/17

17. Setup of on-spot investigation in Campinas, Brazil

Aim: Setup of long term on-spot crash investigation and database

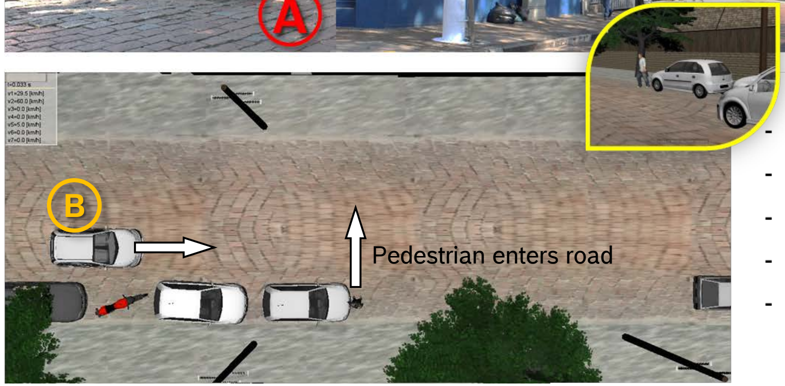
Approach

- Pilot study in 2016 finished
- Continuing initial activity w/ increased member funding (Bosch, Daimler, Takata, Idiada, EMDEC)
- Aim: Contract setup with duration of 4 years; Results published at ESAR conference 2016 and IRTAD conference 2017

IAAT Investigação Avançada de Acidentes de Trânsito

Results:

- Overall 90 crashes investigated and available for 1st analysis (not all cases fully reconstructed)
- Typical urban crash scenarios i.e. crossing accidents and high share of motorcycles involved especially in longitudinal traffic
- High share of these accidents caused by disregarding the traffic rules like e.g. give way
- Example case reconstructed and simulated for car AEB system
- Setup consortium and official project name IAAT



- Pedestrian was crossing the road
- Braking maneuver of vehicle “B”
- Late braking maneuver of vehicle “A”
- Rear-End collision between “A” and “B”
- Vehicle “B” hits the pedestrian

▶ No data collection in 2017 done, investigation re-starts in 2018

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Bosch Accident Research (AEV-064)

Annual Report 2016/17 - Overview and Strategy

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Bosch Accident Research

“Hic locus est, ubi mors gaudet succurrere vitae.”

„This is the place where death delights in helping life.”

„Hier ist der Ort, an dem der Tod sich freut, dem Leben zu helfen.“

Our aim is to derive **local needs** out of **accidents** to ensure highest **benefit** and **quality** of our **products** to improve road **traffic safety** and safe our **environment**

Approaches towards traffic safety

Road safety requires interaction of all pillars

United Nations World Health Organisation

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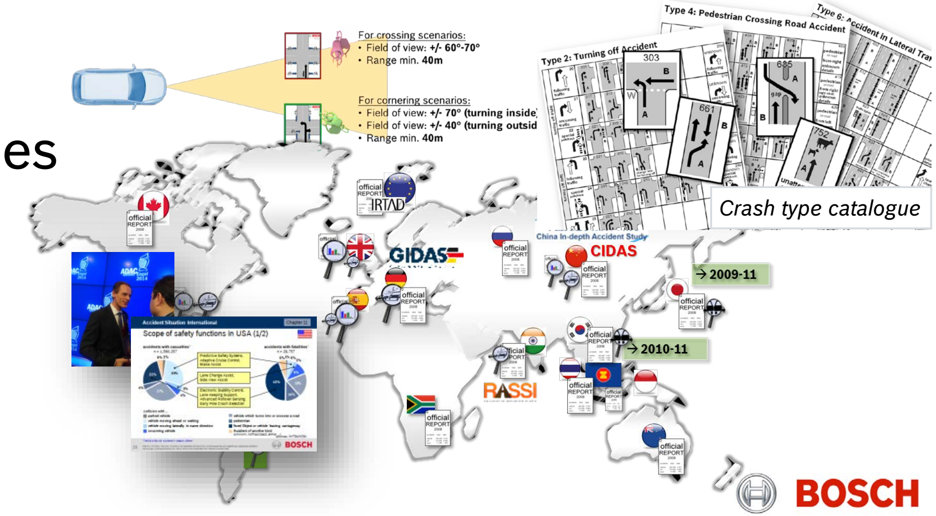
Bosch Accident Research

Scientific crash analysis helps to identify road safety measures

- Integrated in Bosch's Corporate Research
- **Since 2005** crash & vehicle safety research
- Interdisciplinary team w/ 7 employees

  (Mathematicians, Physicians, Automobile- and Mechanical Engineers)

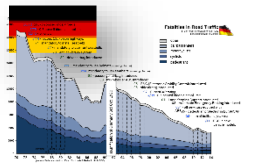
- **Analysis** and **simulation** of real world crash data
- **Benefit assessment** of **all** vehicle safety technologies
- **Product strategy** and **sensor** requirements
- **International** expansion to establish **road safety**



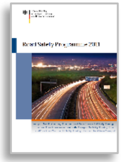
Bosch Accident Research
Business Search Fields & Customers

Market-Pull from real world demands

Accidents



Targets



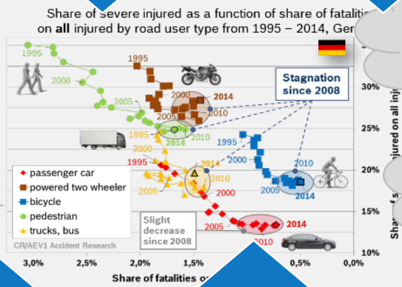
Road safety program

Consumer tests

EURO NCAP
GLOBAL NCAP
www.globalncap.org
C-NCAP

Legislation

§



Future mobility

Vehicle safety

Autonomous Driving

Sensor requirements

Connected vehicles

Market-Push from customer and OEMs

BU Strategies
KAM process
GB+CR support

Trend foresight
Future demands on safety

Globalization
Regional interests

CC-AS

2WP

AE-EB

CVO

ReGe

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Bosch Accident Research

Funding – 2017

Total budget: 1.114 Mio. EUR thereof are…

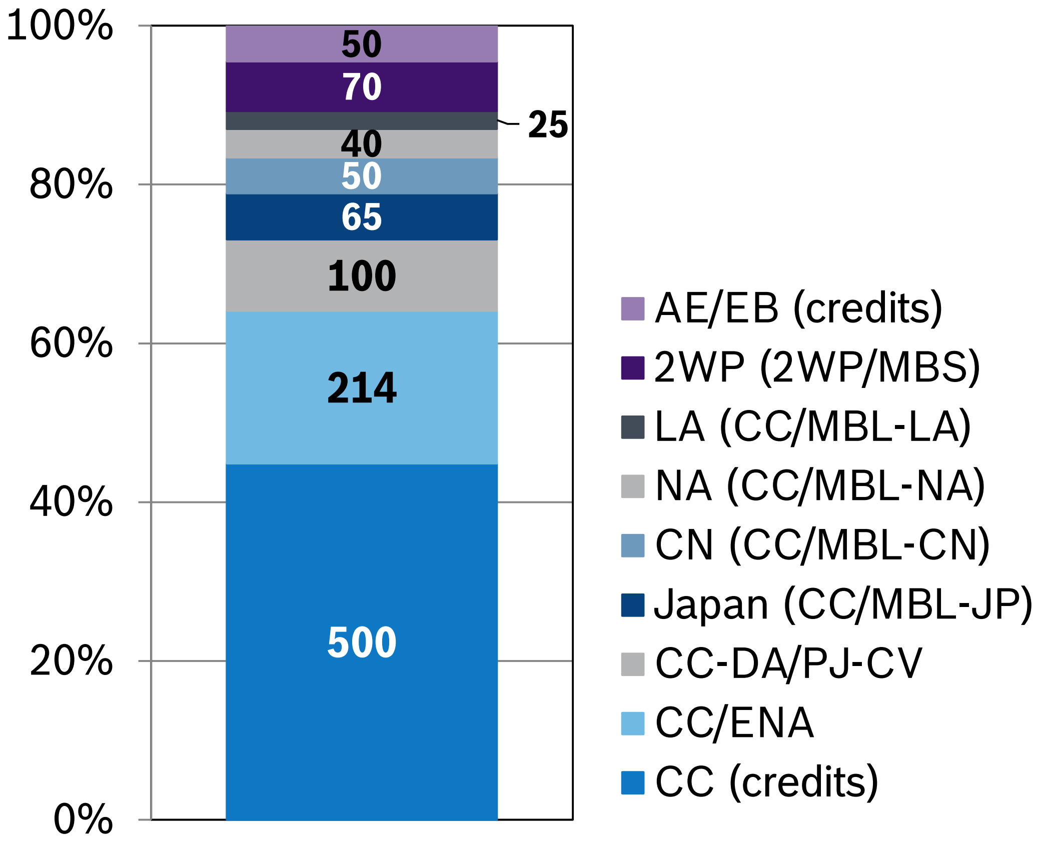
- 550.000 EUR credits
- 564.000 EUR directs

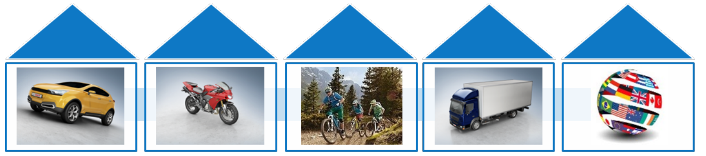
and

- 1 local HC (India) funded by CC/MBL-IN

including material costs of minimum

- 100.000 EUR





Note: Since 2013 regional funding established hence each regions runs its Accident Research activities by direct funding

Accident Research Review

Chapter 03

Strategic goals for Accident Research out of CC

CC strategy	CR strategy
1 Access and turnover in new markets →	Efficiency & benefit estimation of **current safety systems** in **emerging markets** (India, China, Brazil, Russia)
2 Safety- and Driver Assistance System growth for new products →	Efficiency & benefit estimation of **Integrated Safety Systems**, **Connectivity** and **Future Driver Assistant** and designed for **collision avoidance**[1] (EU, NA, JP)
3 Enabling future products → Safety of automated vehicles [2] →	**Situation-** and **Risk assessment** for **future mobility** solutions derived out of current road (& vehicle) safety and assessment of system requirements

- Bosch long-term goal Vision Zero: “no fatalities–no injuries–no accidents”
- Baseline: Access to various accident data sources and simulation based generated data

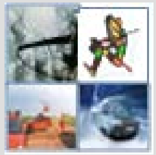
[1] Safety systems for pre-crash phase
[2] Definition of automated driving according to BASt

Bosch Accident Research

Organization of Accident Research within Vehicle Motion

Vehicle Safety and Assistance Systems
CR/AEV A. Schaumann

CR/AEV1 A. Georgi	CR/AEV2 A. Stamm	CR/AEV3 A. Verhagen
Safety Systems	Driver Assistance	Vehicle Mechatronic



Accident Research (AEV-064)

Thomas Lich (Project management)
Lisa Sulzberger
Jörg Mönnich
Thomas Schlender
Alexander Skiera
Girikumar K (India fct. assigned)
Daniel Schmidt (not on picture)

Renningen, Germany
Location of Corporate Research
Bosch Accident Research

Suzhou, China (NN, 2017/18)

Coimbatore / Bangalore, India

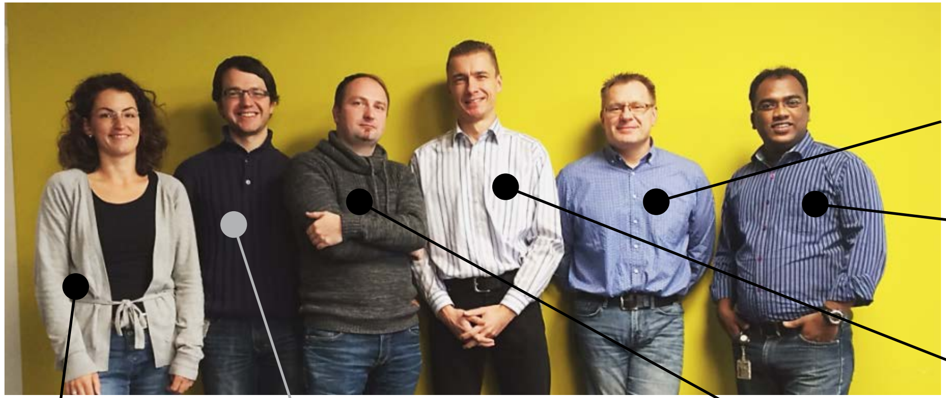
CR: Corporate Research

Bosch Accident Research
The "Crash Detectives"

CR/AEV1 (Section manager)
Georgi Andreas (FAT/AK3)

Bosch Accident Research (VM-064)

Thomas Lich, *Senior Expert / Project Management*



Thomas Lich [Team Lead]
Team lead, Accident analysis, International activities Bosch AR, representative RASSI, CIDAS, TASB Brazil, IRTAD, KOTI

Girikumar K. (India, functional assigned)
Accident analysis and studies, local representative India, RASSI expert group

Thomas Schlender
Accident analysis and studies, driver assistance and automated driving, representative GIDAS, ADAC/AK3

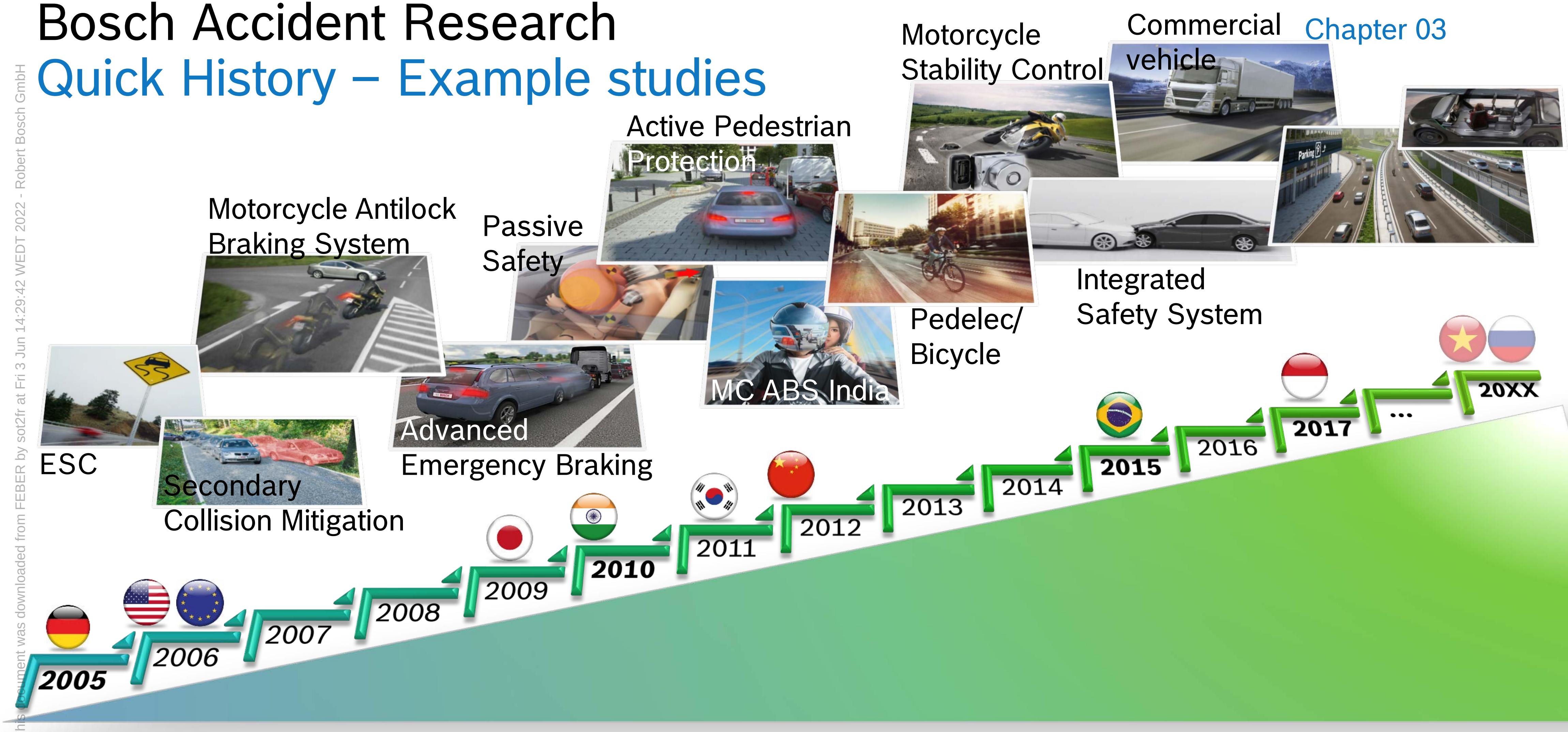
Jörg Mönnich
Accident analysis -studies, on-spot investigation and reconstruction, database, representative GIDAS, RASSI expert groups, TASB Brazil

Alexander Skiera
Accident analysis and studies, simulation, representative GIDAS, CIDAS expert groups

Lisa Sulzberger
Accident analysis and studies, statistical methods, forecast, extrapolation methods, NASS

Daniel Schmidt *(since 03/2017)*
Simulation, Data Mining, representative OPENPass

Bosch Accident Research
Quick History – Example studies



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Bosch Accident Research

International collaborations and sub-contracting

- **Germany:** VDA FAT AK3
  - RB is partner in GIDAS[1] consortium, access to on-spot crashes [**status:** running]
- **China:** China Automotive Traffic Research Centre (CATARC)
  - RB is partner in CIDAS[2] consortium, access to on-spot crashes [**status:** running]
- **India:** JP Research India PVT.
  - RB is partner in RASSI [3] consortium, access to on-spot crashes [**status:** running]
- **Brazil:** Hosted by Bosch
  - RB is partner in IAAT [4] consortium, access to on-spot crashes [**status:** contract re-signed]
- **External collaborations and funded projects:**
  - EU funded project I_HeERO [**status:** finished in 12/2017]
  - External collaboration with University of Jakarta [**status:** running till 03/2018]

[1] German in-depth accident study – www.gidas.org
[2] China in-depth accident study – www.catarc.ac.cn
[3] Road Accident Sampling System India – www.rassi.org.in
[4] Investigacao Avancade de Accidente do Transito Brazil

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Chapter 04

Status of data sources & activities accessed by Bosch Accident Research

Accident Research
CR/AEV1

Bosch Accident Research

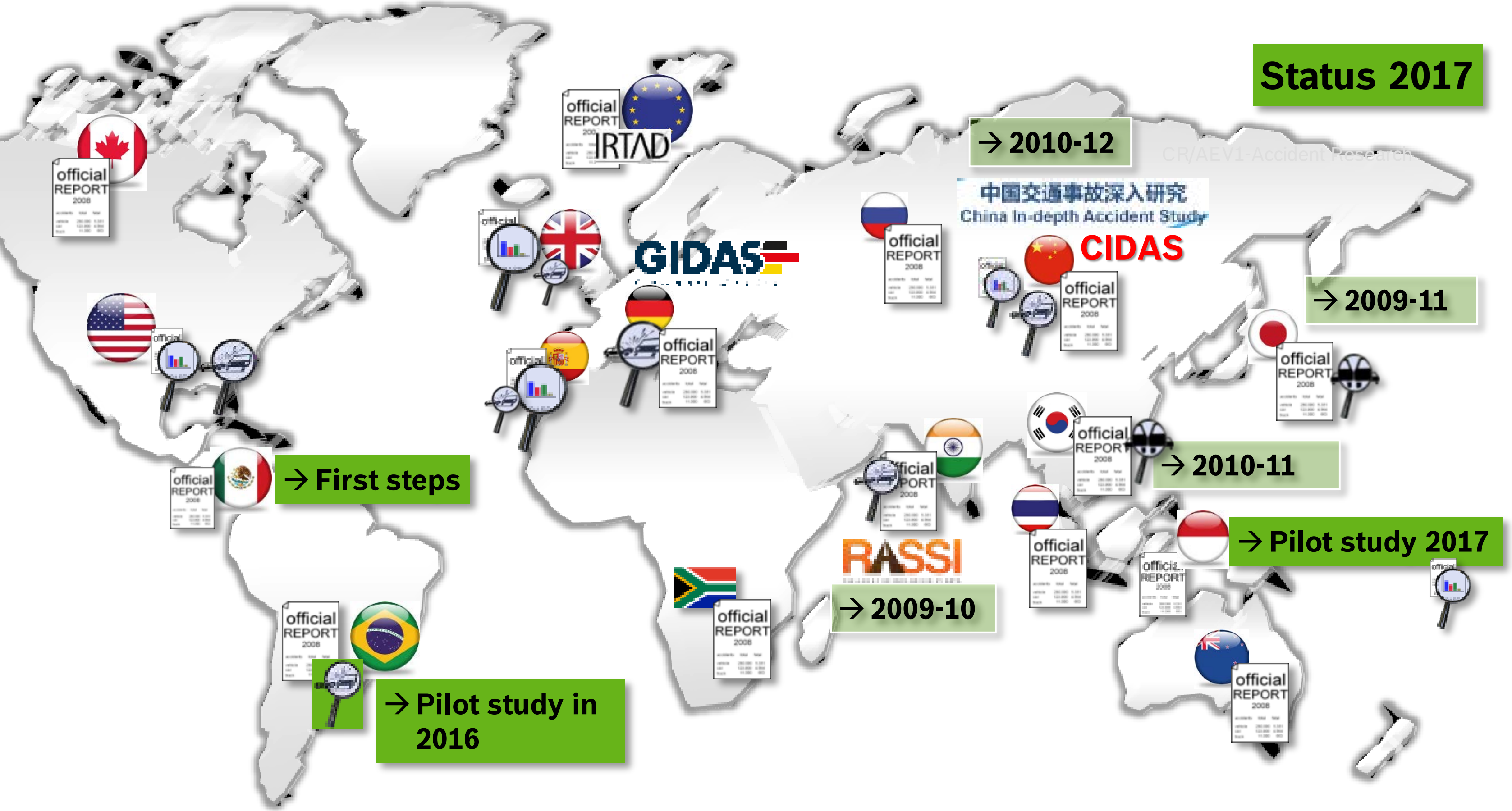
Worldwide activities and data sources by level of information

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

Event recorder data
- Near miss incident and accident data from driving studies
- Video & event recorder data



Note: Not all sources listed here

Status data sources

In-depth accident database - membership required

	GIDAS[1]	RASSI[2]	CIDAS[3]	IAAT[4]
Project start	July 1999	May 2011	July 2011	Pilot study – Jan 2016
Survey areas	Dresden, Hanover	Coimbatore, Mumbai-Pune Expr./Ahmedabad, Kolkata	Changchun, Beijing, Weihai, Ningbo, Chengdu, Foshan	Campinas city (urban only)
Contractor	VUFO, MHH	JPR[5]	CATARC[6]	EMDEC[7]
Target cases per year	2 000	400	800	100
Cases total (Dec. 17)	31 751	2 336	3 600 (incl. 1 300 old DB)	88 coded / 98 investigated
Parameter per case	3 500	750	2 500	~400
Investigators on spot	3	4 (1 for safety)	2 (together w/ police)	3
Members	www.gidas.org	www.rassi.org	www.catarc.co.cn	Bosch, Takata, McKenzie, EMDEC, IDIADA, Honda → **See Chapter 17**

[1] German In depth accident study [2] Road Accident Sampling System India [3] China In-depth Accident Study [4] Investigato Avancada de Acidentes de Transito [5] Jeya Padmanaba Research India [6] China Traffic and Research Center [7] Empresa Municipal do Desenevolvimento de Campinas

Status data sources
Event Drive Recorder data

	Korea – KOTI[1]	Japan - JSAE[2] / TUAT[3]
Project duration	July 2011 – July 2013	Nov. 2009- Dec. 2012
Survey areas	Incheon city, Seoul	Japan
Collaboration	Korean Transport Institute & Taxi Association	JSAE[2], Tokyo University of Agriculture & Technology
Aim	Taxi accidents w/ injuries and sever property damage	Taxi Near-miss accidents (Incidents), slight accidents
Cases total (Dec. 17)	6 800 (2010 & 2011)	> 30 000 (Japanese only)
Parameter per case	~70 parameter including video, x/y/z acceleration, GPS	~50 parameter including video, x/y/z acceleration, GPS
Investigators	Hosted by Korean Taxi Association	Selected Japanese cities hosted by JSAE/TUAT
Members	Bosch only	JOEM, Continental

[1] Korean Transport Institute [2] Japan Society of Automotive Engineering [3] Tokyo University of Agriculture and Technology

Status data sources
Accidents with property damage only

	Bosch / Allianz
Project	2008 → no update possible
Investigation	Allianz customers from south-east Germany
Collaboration	Bosch and Allianz Zentrum für Technik
Data sampling	• Documents provided to Allianz by costumers and experts • Car accidents with property damage only
Cases total	3 986 (2004 & 2007, 2 years)
Parameter per case	up to 107 information coded
Supplementray available for RB	• Expert photos of damaged car for own damage claims only, 1.356 cases • Expert's estimation of damage cost

[1] Korean Transport Institute [2] Japan Society of Automotive Engineering [3] Tokyo University of Agriculture and Technology

Chapter 05

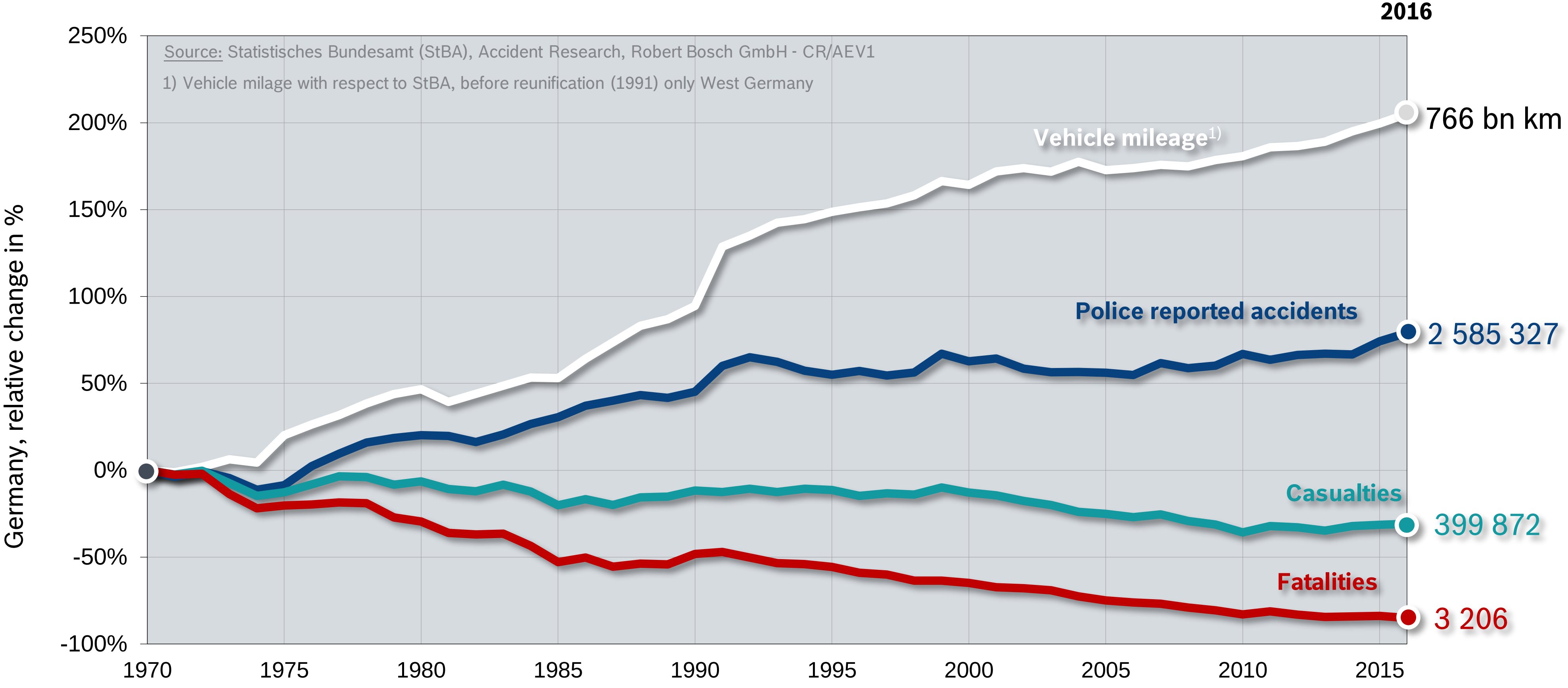
Accident situation – National
- Standard slides / Overview -

Accident Research
CR/AEV1

BOSCH

Accident Situation - National

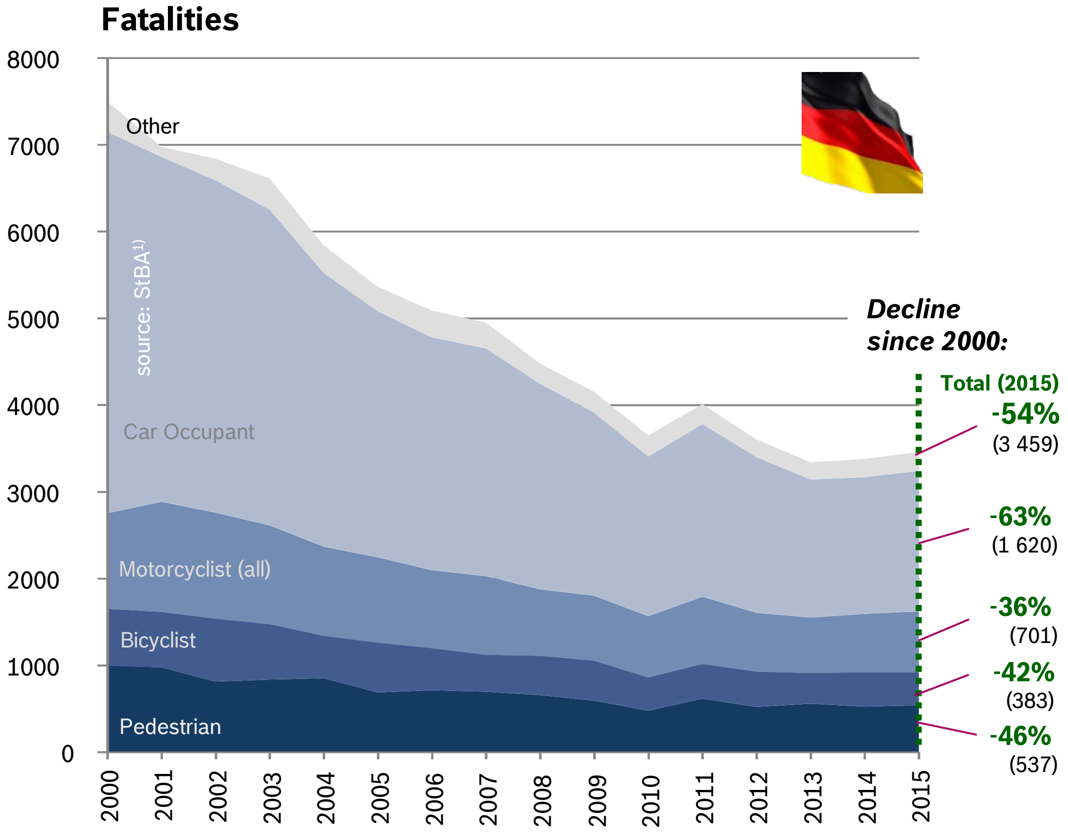
Accident details since 1970 in Germany

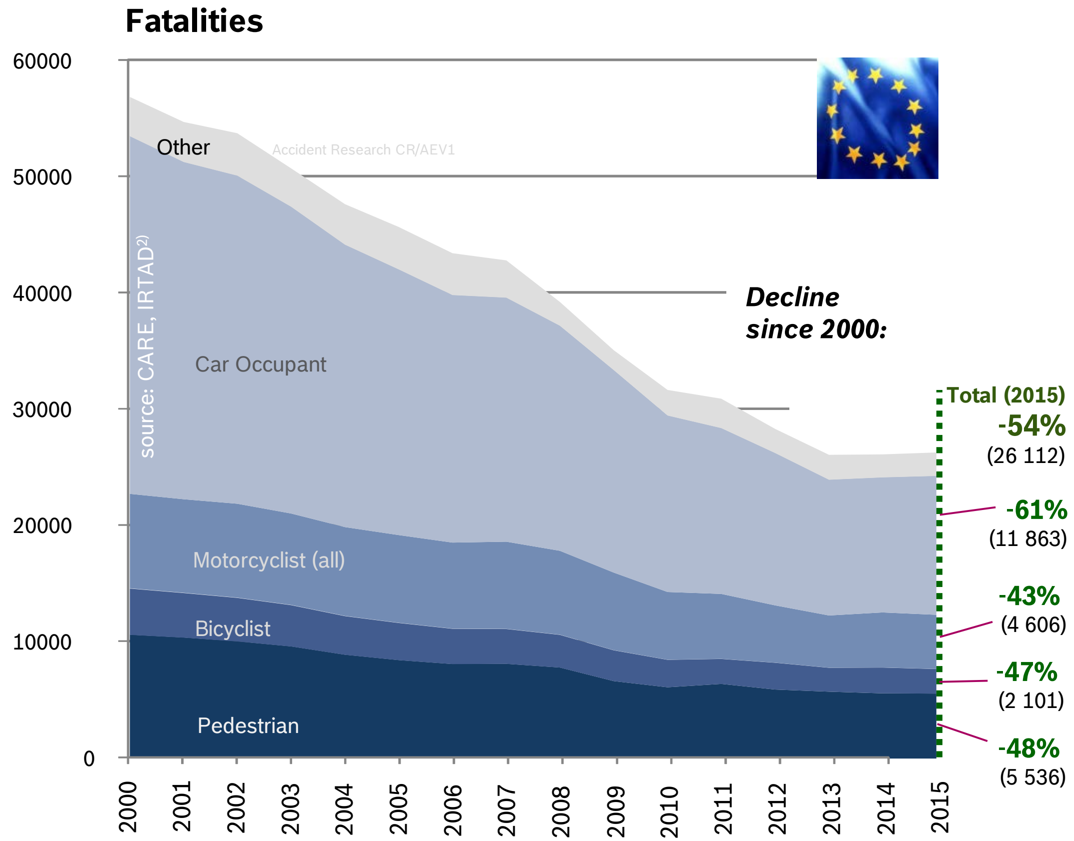


▶ Since 1970: Mileage plus 205% and Reduction of fatalities 85%

Accident Situation - National

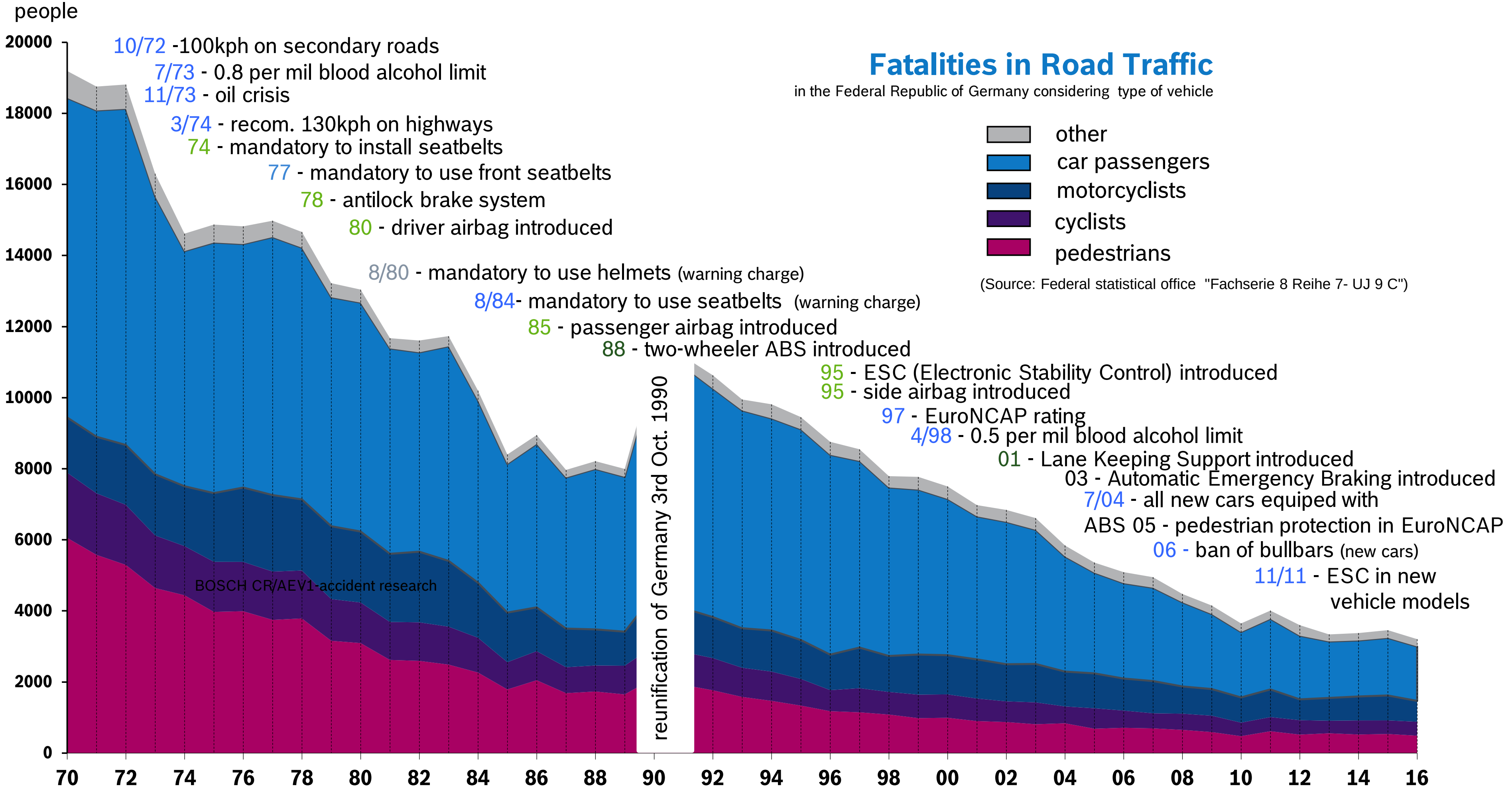
Fatality distribution in Germany vs. EU28 since 2000





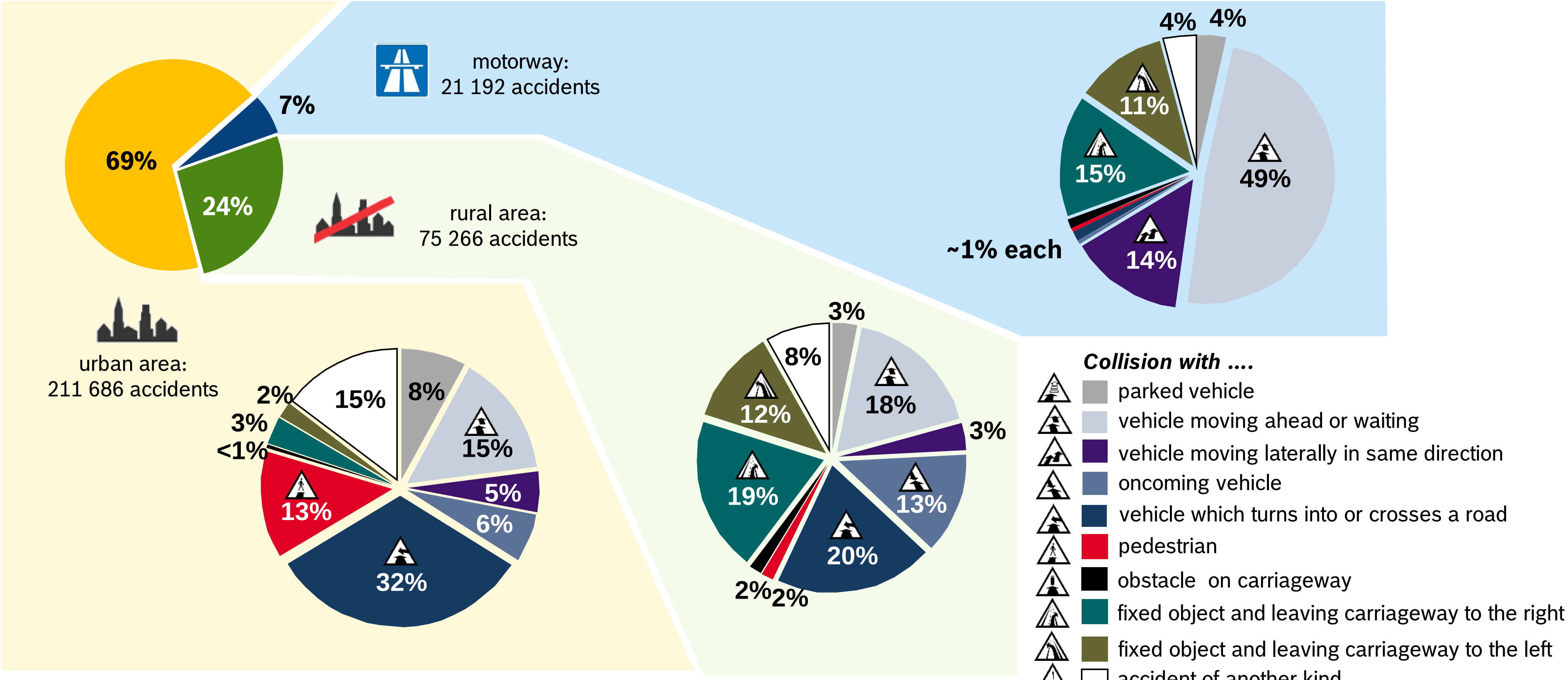
1) StBA: Fachserie 8 Reihe 7, Data from 2000 to 2003 approximated with IRTAD[2)]
2) IRTAD: Road Safety Annual Report, CARE (EU road accidents database), other

Accident Situation - National



Accident Situation - National

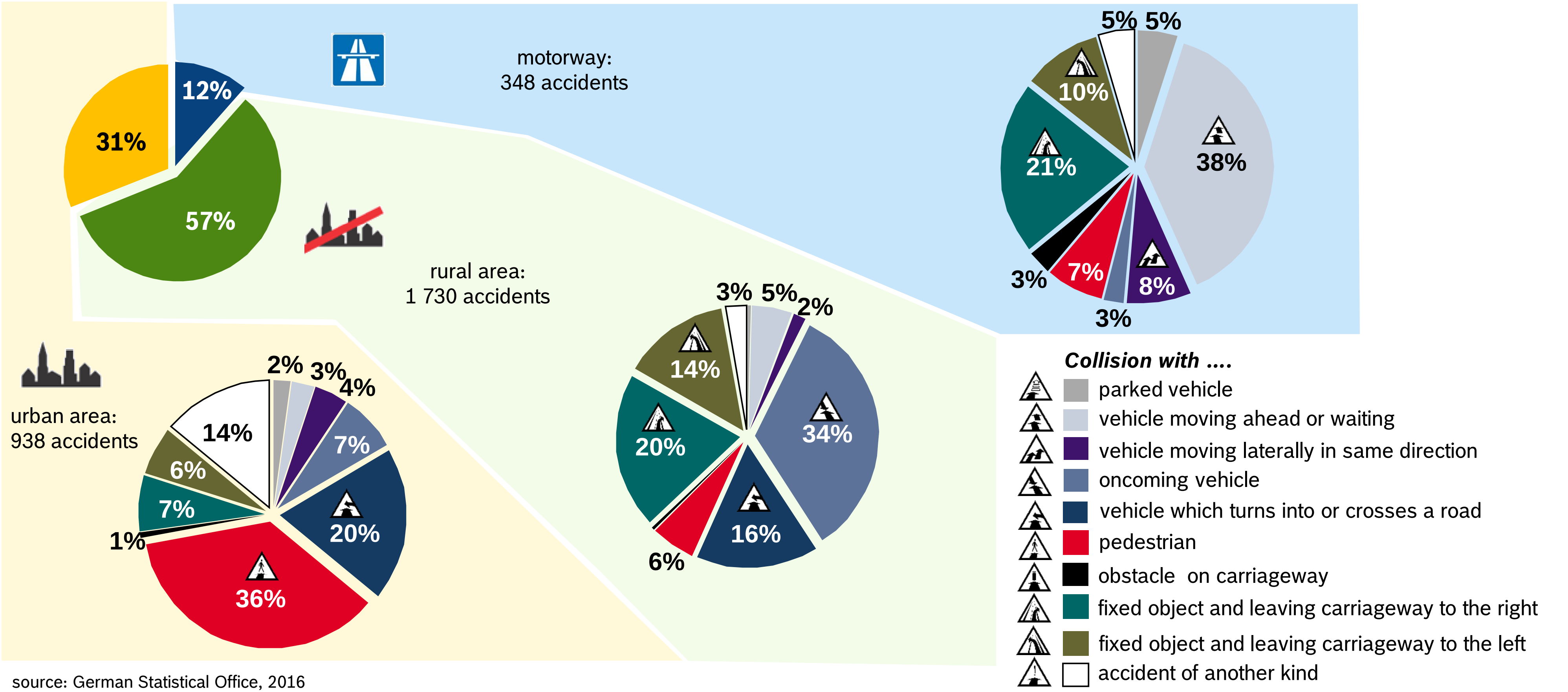
Accidents with casualties by kinds of accident and location



source: German Statistical Office, 2016

Accident Situation - National

Fatal accidents by kinds of accident and location

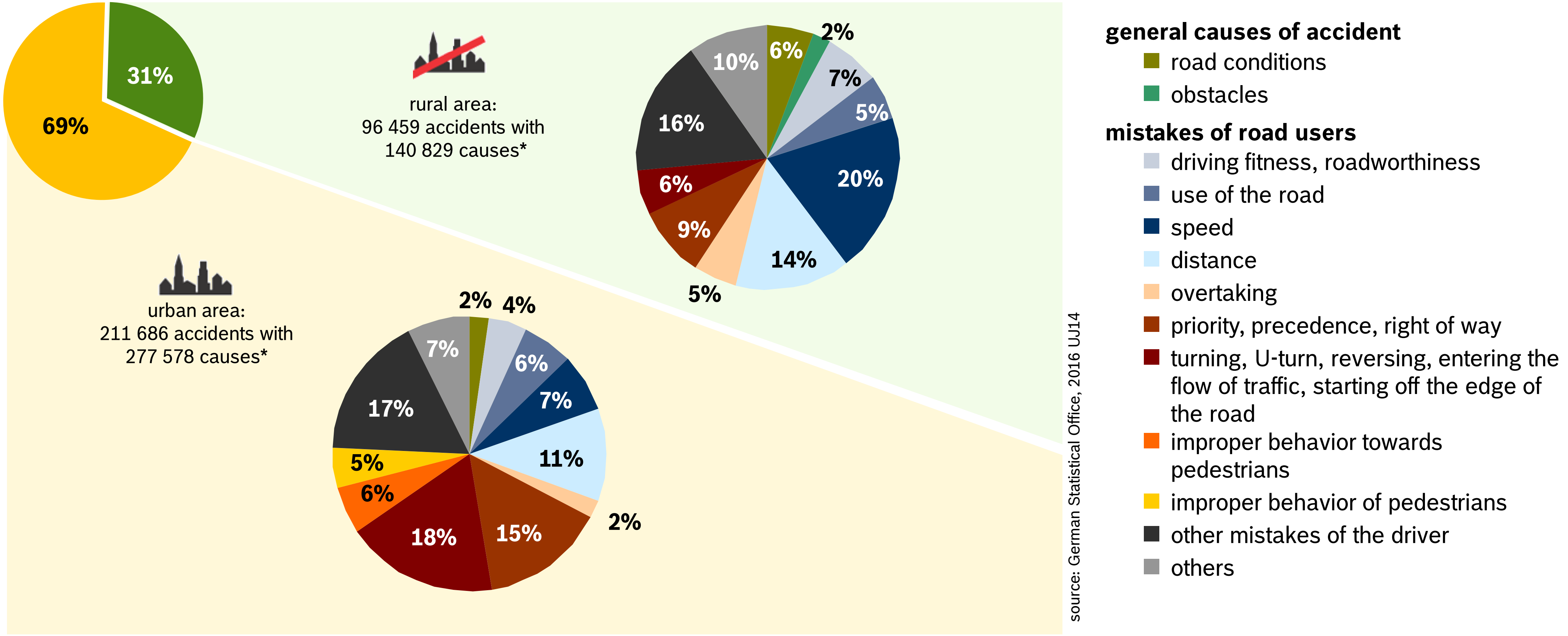


source: German Statistical Office, 2016

Accident Situation - National

Causes for road accidents w/ casualties by location

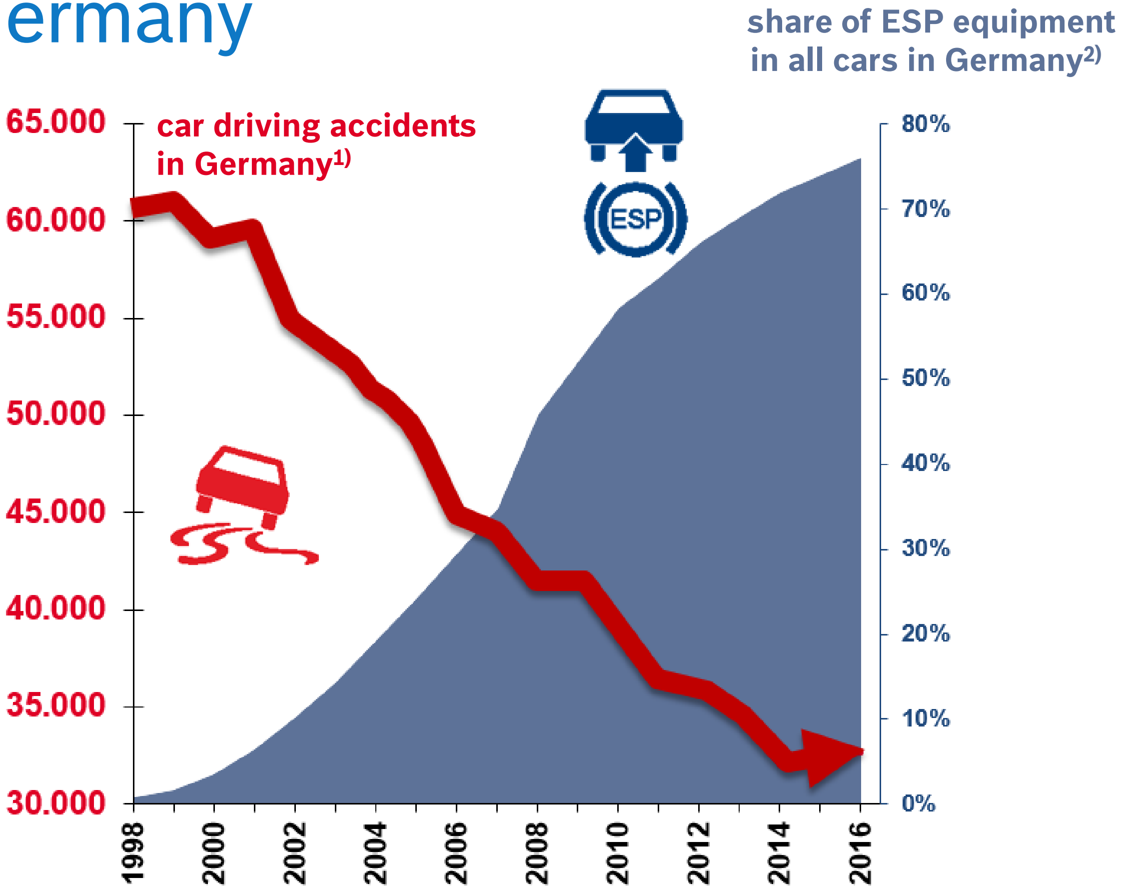
Analysis is based on 308 145 accidents with casualties in 2016



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

Accident Situation - National
Trend of driving accidents in Germany

- Skidding precedes more than 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) Data from CC/MKC, DAT report

Accident Situation - National

Socio-economic costs of German police reported accidents

2016

Accidents ...

3,016
w/ fatalities

305,129
w/ injured
out of them:

58,385 serious	246,744 slight

2,277,185
w/ Property Damage Only
out of them:

71,638 major damage	2,205,547 minor damage

Source: Federal Statistical Office, Germany – Volume 8, Part 7
Accidents in 2016

➔ approx. 2.6 million police reported crashes for Germany

Socio-economic costs ...

4.13 bn. € **for fatalities**

14.89 bn. € **for injured**
out of them:

9.65 bn. € serious	5.24 bn. € slight

15.29 bn. € **for Property Damage Only**
out of them:

1.60 bn. € major damage	13.69 bn. € minor damage

Source: BASt, Scientific information 11/16; GIDAS 2005-2017

➔ approx. 34.32 billion Euro socio-economic costs due to road traffic accidents

Germany: Integrated Safety System Update Field of Effect

Accident Research
CR/AEV1

BOSCH

Aim of study: Update of field of effect of future Integrated Safety System in several traffic scenarios:

- *ISS function for frontal impact (longitudinal traffic, oncoming, crossing, frontal object collision)*
- *ISS function for side impact (crossing traffic, side object collision)*
- *ISS function for rear impact (longitudinal traffic)*

Method: Analysis is based on real accidents from GIDAS database (2005-2016) and results are mapped to current accident situation in Germany. The estimation of accident severity (occupant injury level) is based on all relevant vehicles equipped with airbags and belted occupants only.

Results: In every 2nd accident w/ casualties in Germany a car occupant was injured. *ISS for frontal impact* addresses about 45% of these cases. This function would have a positive influence on about 19,800 severely injured car occupants and about 1,200 fatalities in maximum if all cars were equipped with this ISS functionality.

ISS function for side impact can help in 16% of all accidents with injured car occupants. A reduction of injury level in further 6,100 severely and about 400 fatally injured car occupants is possible.

The highest safety potential is seen in oncoming traffic scenarios and collisions with objects or hard pole.

BOSCH

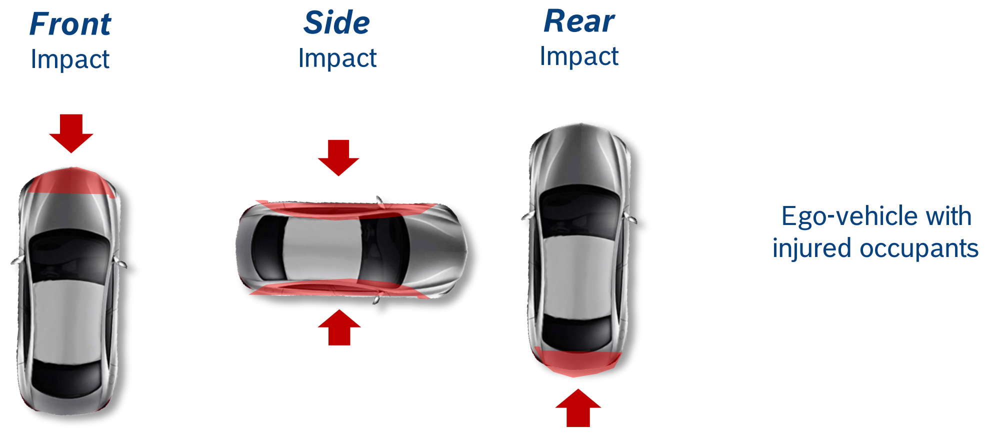
Accident Research: ISS evaluation (Germany)

Methodology

- **305 659** Accident with casualties in Germany (Status 2015)
- **249 000** ... with involved passenger cars
- **143 000** ... with injured car occupants → Potential for ***I***ntegrated ***S***afety ***S***ystem

Field of effect is defined by:

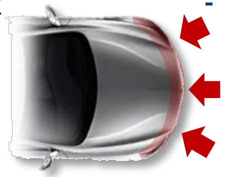
- impact direction / impact area
- collision opponent
- relative track angle (ego vs. opponent)
- relative collision speed
- delta V



Accident Research: ISS evaluation (Germany)

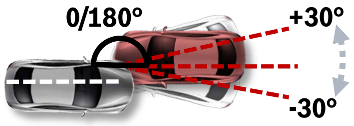
Definition Field of Effect

Front Impact
- Frontal Impact (Ego Car)
- longitudinal traffic sc. with relevant track angle
- relevant collision object



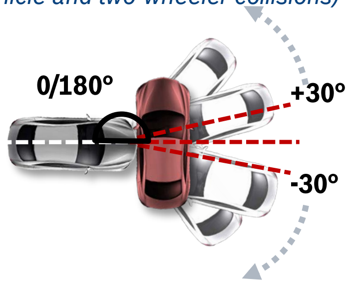
- relative collision speed: 20 ... 140 kph
- collision Δv: > 20 kph

relevant track angle:
(vehicle and two-wheeler collisions)

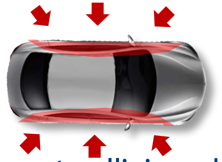


Front Impact (crossing)
- Frontal Impact (Ego Car)
- crossing traffic sc. with relevant track angle
- Vehicle collision

relevant track angle:
(vehicle and two-wheeler collisions)

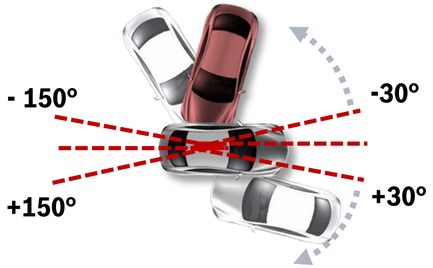


Side Impact
- Side Impact (Ego Car)

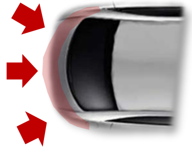


- relevant collision object
- rel. coll. speed: 20 ... 140 kph
- collision Δv: > 15 kph

relevant track angle:
(vehicle and two-wheeler collisions)

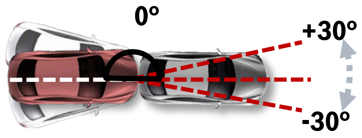


Rear Impact
- Rear Impact (Ego Car)
- longitudinal traffic sc. with relevant track angle
- Vehicle collision



- rel. coll. speed: 20 ... 140 kph
- collision Δv: > 15 kph

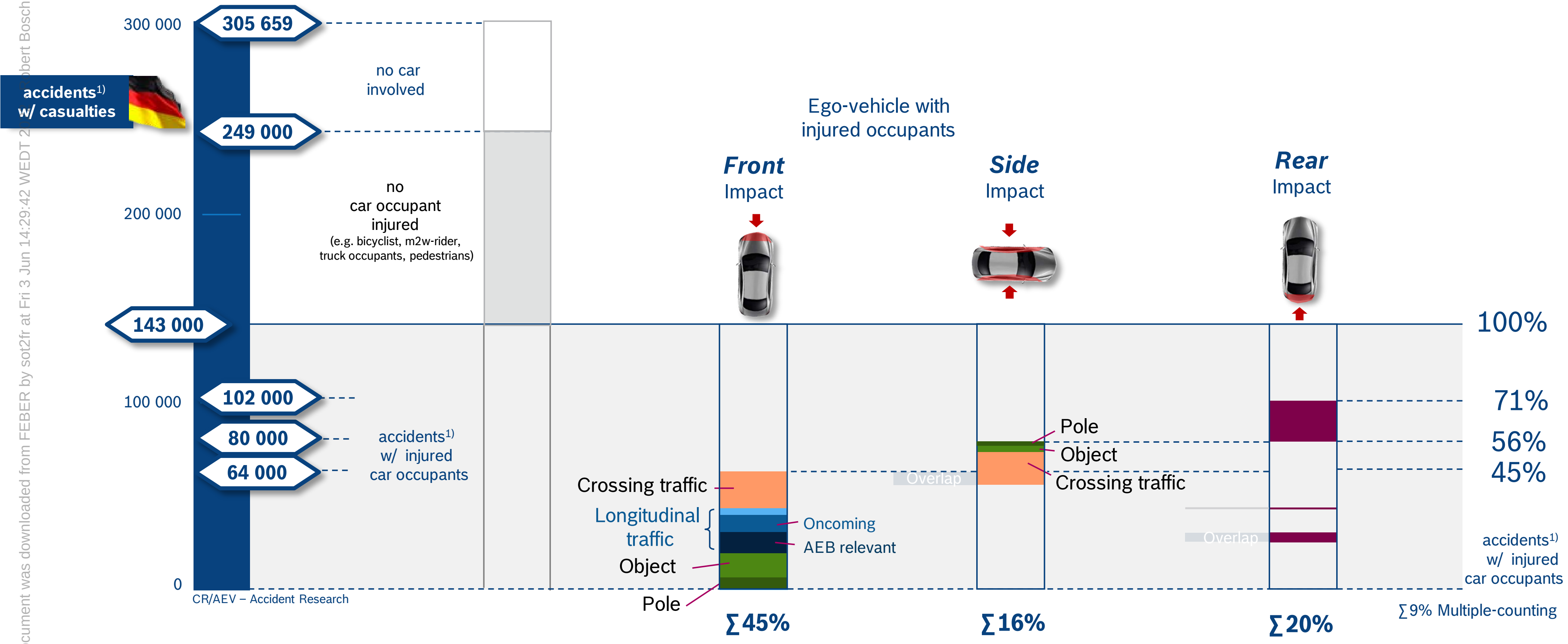
relevant track angle:
(vehicle and two-wheeler collisions)



Field of Effect describes the maximum number of accidents which are addressed under the given boundary conditions. System characteristics (e.g. sensor) are not considered.

Accident Research: ISS evaluation (Germany)

Field of Effect: ISS Front / Side / Rear



All ISS functions address about 71% of all accidents with injured car occupants

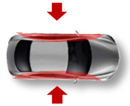
 Internal | Bosch Accident Research (CR/AEV1-Mö) | Jan/31/2018
AEV-064 annual report 2016/17

1) Accidents with casualties, based on DESTATIS published 2016, GIDAS05+ (n=21 512) analysis weighted and mapped to Germany

Accident Research: ISS evaluation (Germany)

Field of Effect: Accidents - ISS Front / Side /Rear

Ego-vehicle with
Injured occupants


Accidents per Year in Germany (relevant car with injured occupants)		**Front Impact**	**Side Impact**	**Rear Impact**
Pole Collision		7 300 (5%)	2 300 (2%)	
Object Collision		13 200 (9%)	2 500 (2%)	
Longitudinal Traffic	*AEB relevant scenario*	11 200 (8%)*		
	Other longitudinal scenario	4 600 (3%)*		28 300 (20%)*
Oncoming Situation		8 800 (6%)		
Crossing Situation		19 300 (13%)*	18 000 (13%)*	

*Multiple scenarios in in 9%
(counting in each scenario)

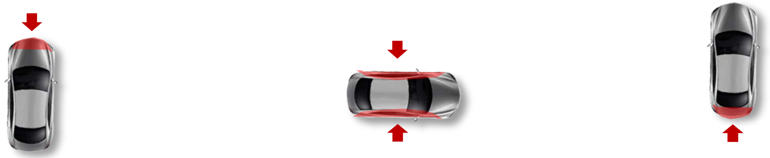
ISS functions regarding front impact cover a field of effect of 45% of all accidents with injured car occupants in Germany. Side impact scenarios 16% of all accidents with injured car occupants.

Accidents with casualties, based on DESTATIS published 2016, GIDAS05+ (n=21 512) analysis weighted and mapped to Germany

Accident Research: ISS evaluation (Germany)

Field of Effect: Occupants hospitalized >24h

Ego-vehicle with hospitalized occupants



Persons per Year in Germany (relevant car with hospitalized occupant)		Front Impact	Side Impact	Rear Impact
Pole Collision		3 800	1 500	
Object Collision		4 500	1 100	
Longitudinal Traffic	*AEB relevant scenario*	1 900		
	Other longitudinal scenario	1 000		2 500
Oncoming Situation		4 900		
Crossing Situation		3 700	3 500	

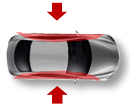
Safety potential regarding injury severity (person) is determined by analyzing vehicles with airbag systems and belted occupants only. The results are mapped to the field of effect in Germany in 2015.

Hospitalized Occupants, based on DESTATIS published 2016, GIDAS05+ (n=21 512) analysis weighted and mapped to Germany

Accident Research: ISS evaluation (Germany)

Field of Effect: Occupants fatal within 30 days

Ego-vehicle with
fatal occupants



Persons per Year in Germany (relevant car with fatal occupants)		Front Impact	Side Impact	Rear Impact
Pole Collision		400	200	
Object Collision		300	~50	
Longitudinal Traffic	*AEB relevant scenario*	~40		
	Other longitudinal scenario	100		100
Oncoming Situation		300		
Crossing Situation		~70	100	

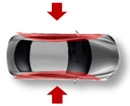
Safety potential regarding injury severity (person) is determined by analyzing vehicles with airbag systems and belted occupants only. The results are mapped to the field of effect in Germany in 2015.

Fatalities, based on DESTATIS published 2016, GIDAS05+ (n=21 512) analysis weighted and mapped to Germany

Accident Research: ISS evaluation (Germany)

Field of Effect: AIS3+ injured Occupants

Ego-vehicle with
AIS3+ injured occupants

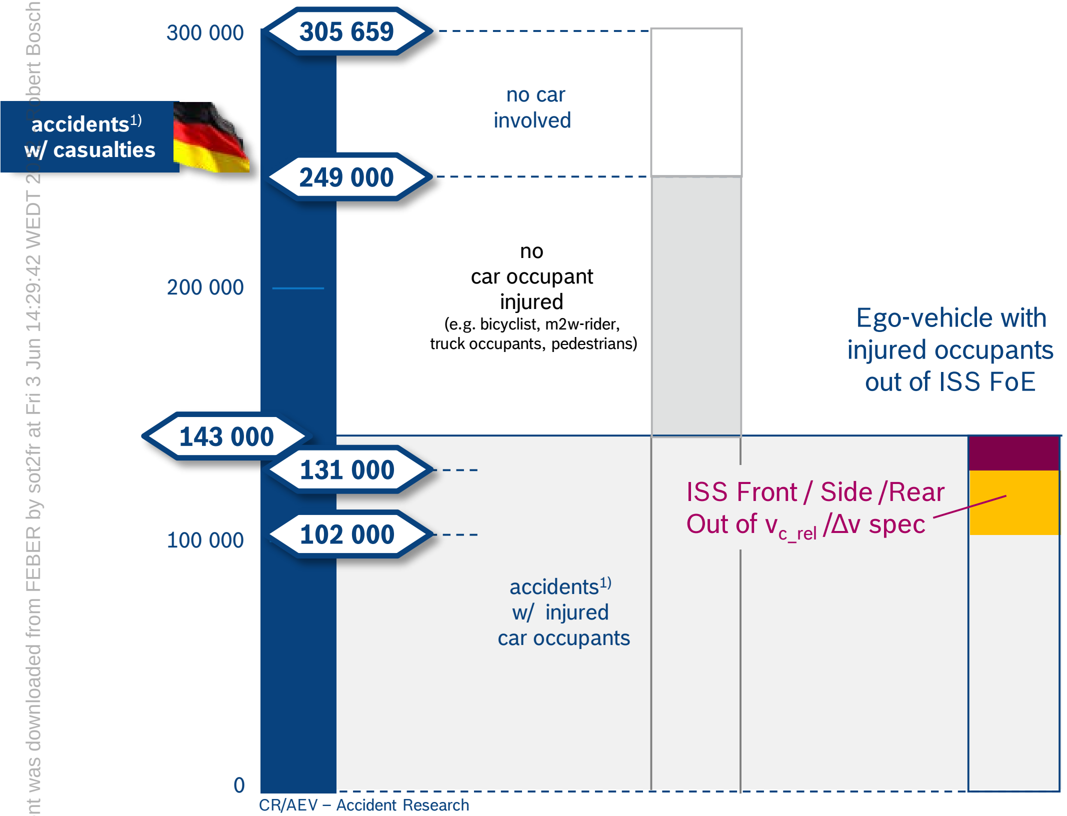

Persons per Year in Germany (relevant car with AIS3+ injured occupants)		Front Impact	Side Impact	Rear Impact
Pole Collision		1 200	600	
Object Collision		700	400	
Longitudinal Traffic	*AEB relevant scenario*	200		
	Other longitudinal scenario	600		300
Oncoming Situation		1 000		
Crossing Situation		400	500	

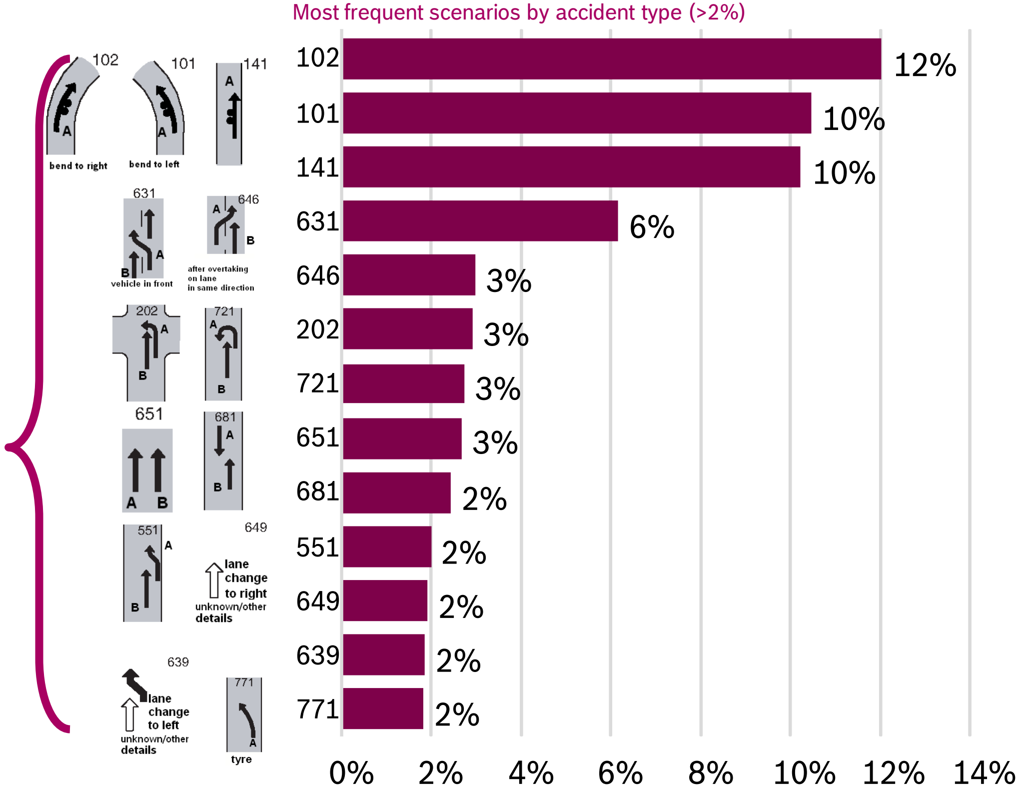
Safety potential regarding injury severity (person) is determined by analyzing vehicles with airbag systems and belted occupants only. The results are mapped to the field of effect in Germany in 2015.

Accident Research: ISS evaluation (Germany)

Chapter 06

Non addressed accidents with injured car occupants





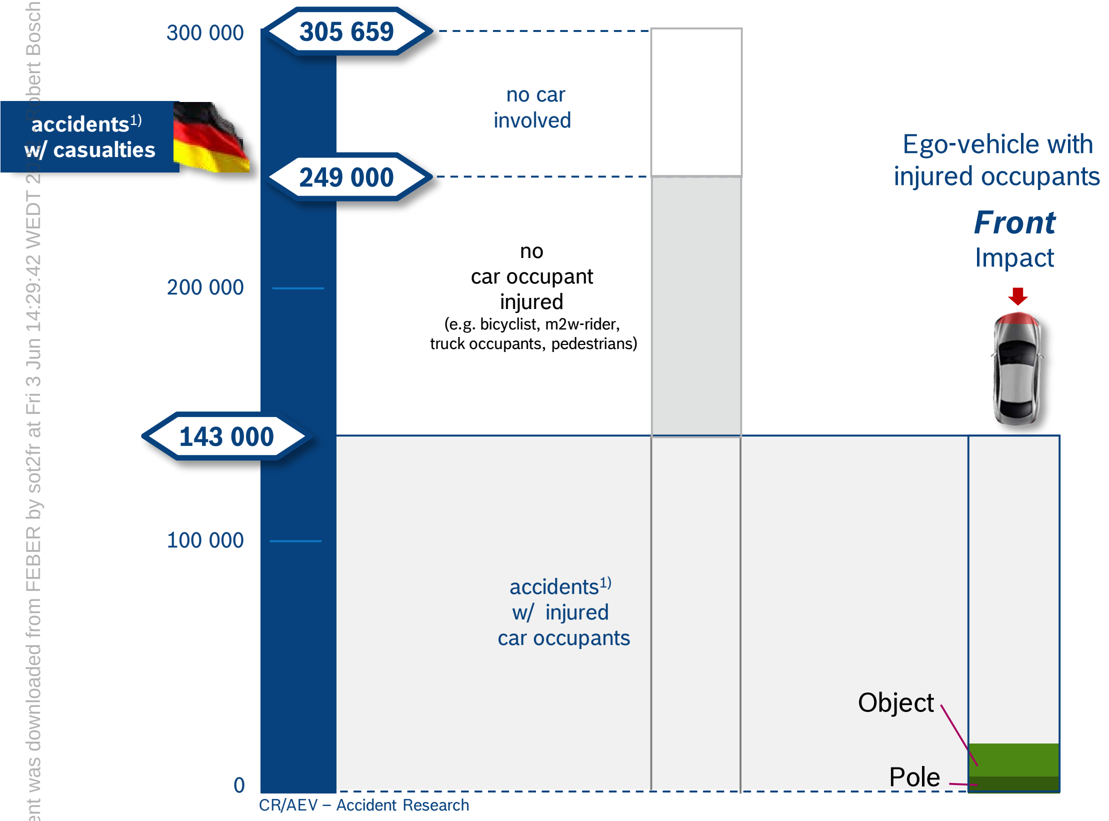
About 8 % of all accidents with injured car occupants are not ISS relevant.
Further 21% are out of relevant crash parameter (Δv and relative collision speed)

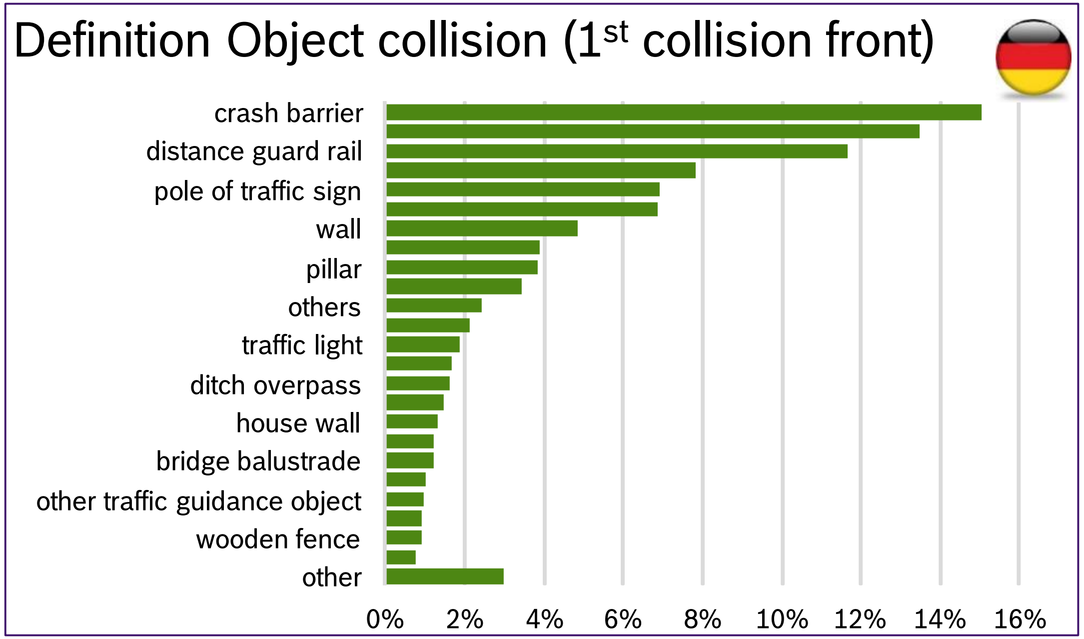
Internal | Bosch Accident Research (CR/AEV1-Mö) | Jan/31/2018

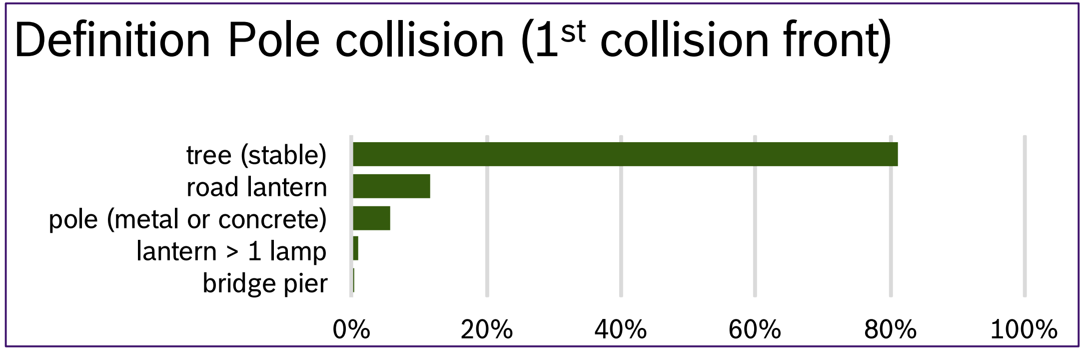
1) Accidents with casualties, based on DESTATIS published 2016, GIDAS (n=27 528) analysis weighted and mapped to Germany

AEV-064 annual report 2016/17

Accident Research: ISS
Field of Effect: ISS Front







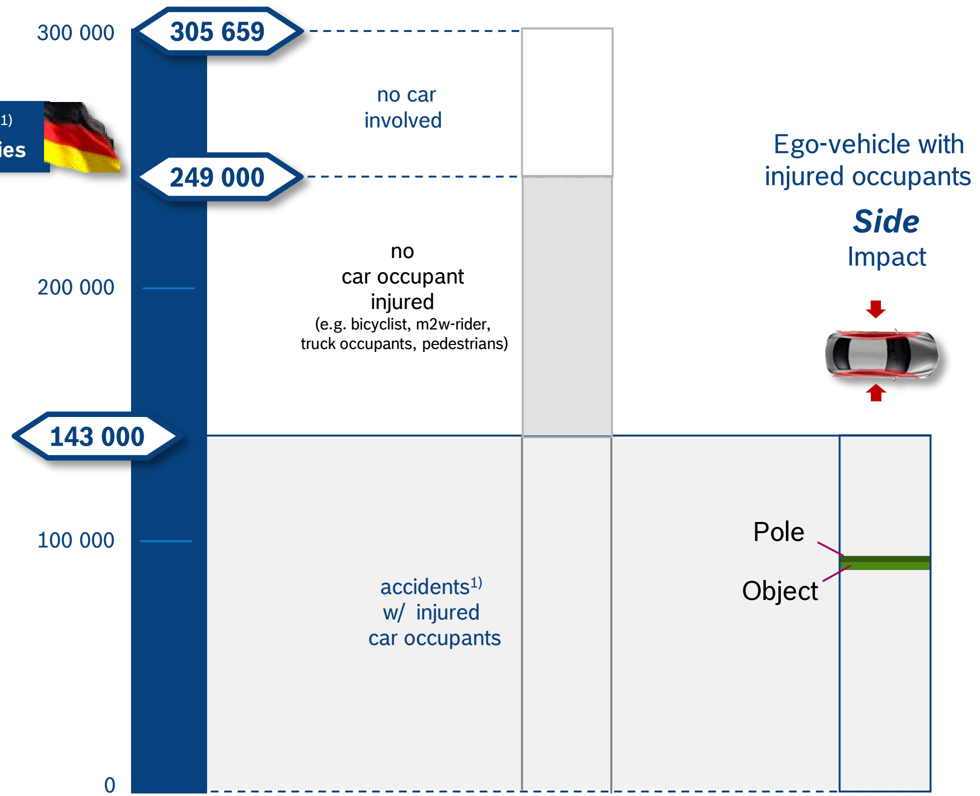
5% of all accidents w/ injured car occupants are front pole collisions. Further 9% are front collisions w/ other objects. These accidents are characterized by higher injury severity.

 Internal | Bosch Accident Research (CR/AEV1-Mö) | Jan/31/2018 1) Accidents with casualties, based on DESTATIS published 2016, GIDAS (n=27 528) analysis weighted and mapped to Germany

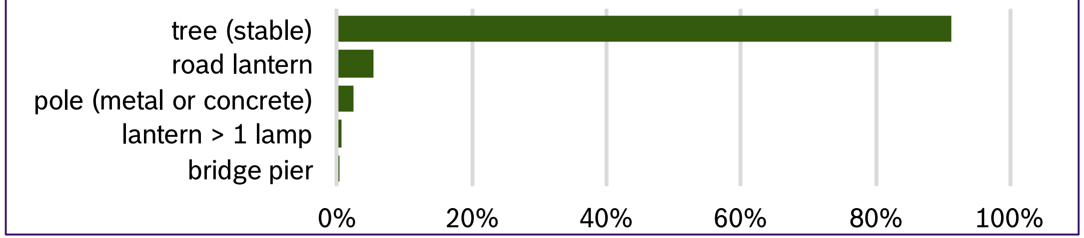
AEV-064 annual report 2016/17

Accident Research: ISS

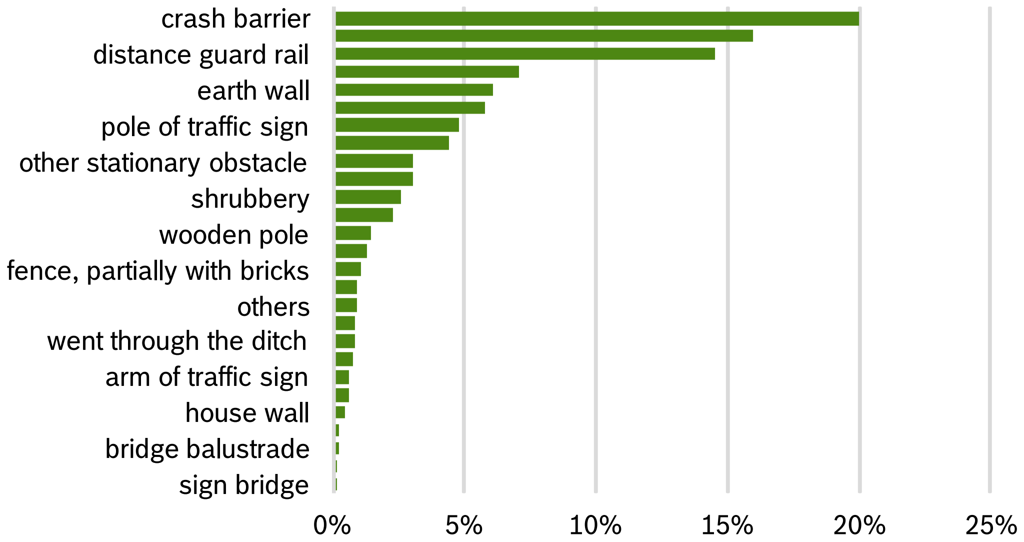
Field of Effect: ISS Side



Definition Pole collision (1st collision side)



Definition Object collision (1st collision side)



In side collisions both pole and other object collisions have high relevance to reduce the number of severely and fatally injured car occupants. Potential of 4% of accidents w/ injured car occupants.

1) Accidents with casualties, based on DESTATIS published 2016, GIDAS (n=27 528) analysis weighted and mapped to Germany

Accident Research: ISS evaluation (Germany)

Summary

- Field of Effect describes the maximum number of accidents which are addressed under the given boundary conditions. System characteristics (e.g. sensor) are not considered. It is defined by relevant track angle, impact area, collision Δv and relative collision speed.
- Results are mapped to Germany by using Official Statistics with parameters: vehicle type, injury severity, accident location and accident type.
- ISS functions regarding front impact cover a field of effect of 45% of all accidents with injured car occupants in Germany. Side impact scenarios 16% of all accidents with injured car occupants.
- ISS for frontal impact addresses about 45% of all accidents with injured car occupants with a possible safety potential by reducing injury level in 19,800 severely injured car occupants and in ~1,200 fatalities
- ISS for side impact can help in 16% of all accidents with injured car occupants by having the potential to reduce the injury level in 6,100 severely and in ~400 fatally injured car occupants
- Highest safety potential expected in oncoming traffic scenarios and collision with objects/hard pole.

Chapter 07

Germany: Highway Pilot Safe Stop

Accident Research
CR/AEV1

Summary

Aim of study:

(1) Estimating influence of HWP Safe Stop in accident situation
(2) Estimating current accident rate due to broken cars on German motorways

Method:

- Determination of relevant accidents with following databases: DESTATIS, GIDAS and several State statistical offices (evaluated by Fraunhofer IVI)
- Detailed analyses of ADAC breakdown statistics

Results:

- HWP Safe Stop **net** benefit estimation: ~5.5 – 7.5% less car accidents w/ casualties on German motorways (Autobahn) → this corresponds to a reduction of accidents w/ casualties in Germany up to **~0.4%** (~1280)

  Note: Net benefit given assuming driver disability
- Clearly perceivable warning of following traffic highly recommended when Safe Stop becomes active

BOSCH

Accident Research: HWP Safe Stop

Content

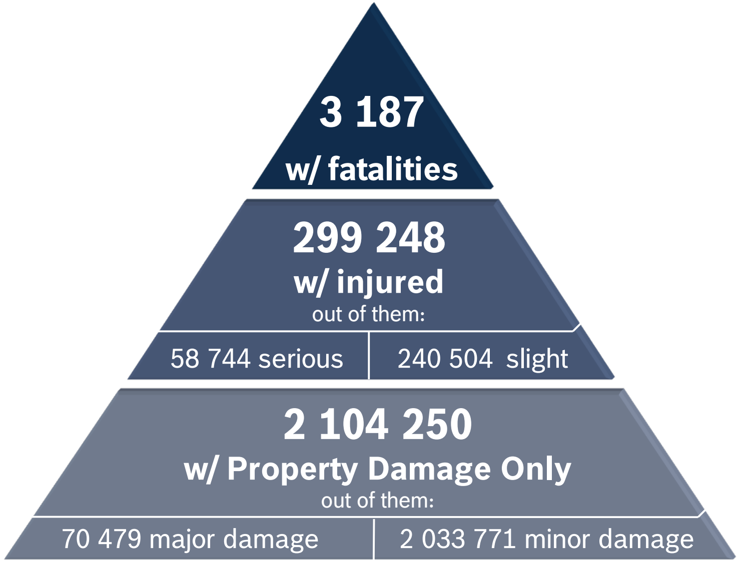
- Overview of accident situation and mileage of passenger cars
- Determination of relevant accidents with DESTATIS and GIDAS database
- Determination of relevant breakdowns w/ official and requested data from ADAC
- Determination of probability that a Safe Stop on German motorways (BAB) turns into an accident
- Estimation of influence of HWP Safe Stop in accident situation
- Conclusion, Recommendation and Next Steps
- Annex

BOSCH

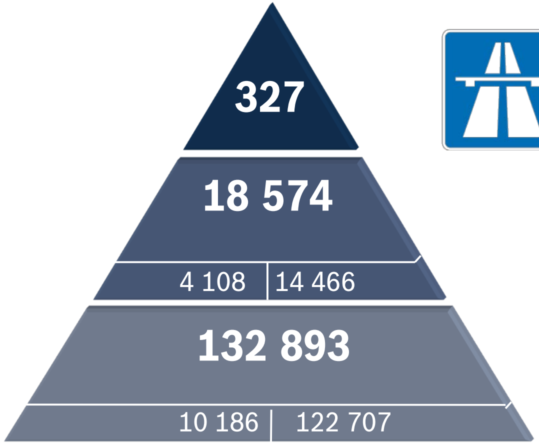
Accident Research: HWP Safe Stop

Overview of Accident Situation

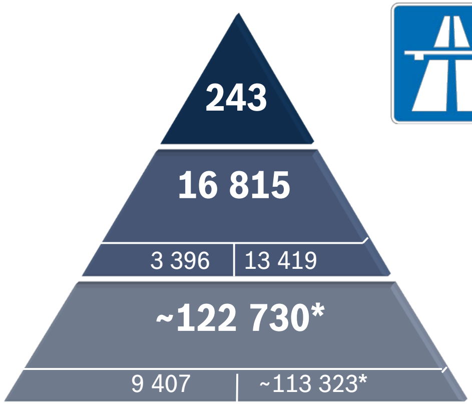
Accidents in Germany 2014:



...on German motorways (BAB):



... on German motorways w/ passenger cars involved:



- Distribution within accidents: higher fatality rate @BAB in comparison to all accidents in Germany.
- In spite of higher speeds other severity distribution similar → this is due to much less VRU on BAB**

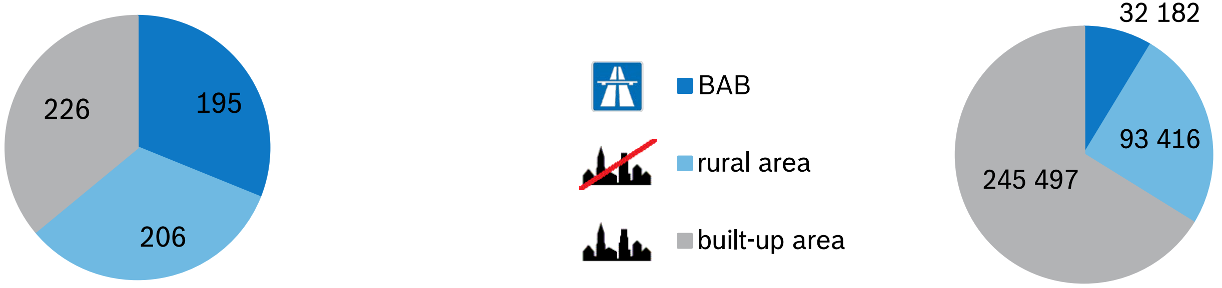
Source: DESTATIS 2014 FS8R7 (UJ 47; time series); * projection of BAB numbers of all vehicles **no pedestrians and cyclists, only PTW (VRU…Vulnerable Road Users; PTW… Powered Two Wheeler)

Accident Research: HWP Safe Stop

Mileage of passenger cars vs. accidents

Passenger car mileage [bn km]

Cars involved in accidents w/ casualties



2014	km / accident	
	with injury	fatal
Motorway	6 070 000	468 386 000
Rural	2 210 000	98 939 000
Urban	920 000	322 560 000
All scenarios	1 690 000	196 000 000

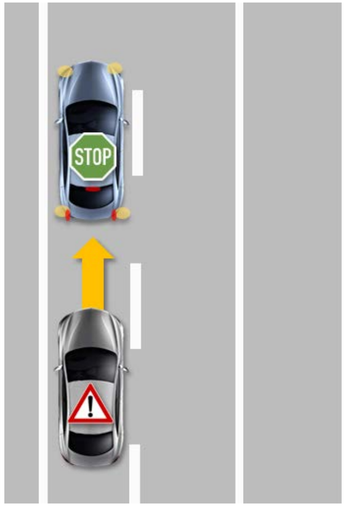
▶ **@BAB:** ~31% of total mileage but less than 10% of car involvement*

Sources: DESTATIS 2014 FS8R7; BASt

* related to involvement of passenger cars on all accidents w/ casualties

Internal | Bosch Accident Research (CR/AEV1-Sd) | Jan/31/2018
AEV-064 annual report 2016/2017

Accident Research: HWP Safe Stop
System description



- **Relevant for HWP:** only roads with structurally separated lanes for each direction
- **Intervention of HWP Safe Stop:** System gently decelerates car in current lane until standstill
- **Intention behind:** *On average higher traffic safety due to stopped car at lane compared to a driverless car which is moving w/o control.*

Level 3/4 vehicles:

- HWP Safe Stop becomes active only if driver is not available when needed as primary operator

Examples: 1) AD mode: in case of relevant technical defect → take over request (TOR) to driver
2) Manual driving mode: monitoring of drivers state, if disability of driver detected → TOR to driver

→ **Safe Stop becomes active *only if there is no response of driver after TOR within given timeframe***

- Following analyses based on system description above

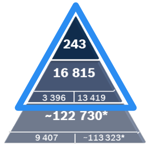
- Level 5 vehicles: In case of relevant technical defect the car has to be able to reach safely at least shoulder respectively exit of BAB automatically via appropriate fallback level → not focus of this study

Accident Research: HWP Safe Stop

Accidents w/ casualties

DESTATIS Statistisches Bundesamt

302 435	Accidents with casualties	100%
245 412	Accidents involving passenger cars	81%
17 058	... on German motorways (BAB)	~6%



Accidents on BAB due to car breakdown: ?

Current rate of accidents due to car breakdown

Accidents caused by disability of driver ?

Field of effect (FoE) of HWP Safe Stop

- **~6%** of all accidents w/ casualties and passenger car involved take place on motorways
- GIDAS database needed for further analyses

Sources: DESTATIS 2014 FS8R7

BOSCH

Accident Research: HWP Safe Stop

Accidents due to car breakdown & disability of driver (1)

DESTATIS Statistisches Bundesamt → 17 058 ⇨ GIDAS GERMAN IN-DEPTH ACCIDENT STUDY → 1 686

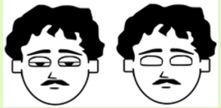
Accidents w/ casualties involving passenger cars on German motorways (BAB) → **set to 100%**

Accidents on BAB due to car breakdown: ~7% (117)

- ~5.5% (93)
  collision w/ other vehicle due to unstable driving conditions (e.g. tire blow-out) OR single vehicle accident
  → cases not relevant
- **~1.4%** (24)
  Evaluation by single case analysis:
  Case is only relevant if following traffic collide w/ broken car which slowed down or stopped before
  → current rate due to breakdown

Accidents caused by disability of driver... **~8.3%** (140)

- **~5.7%** (95)
  ... due to (micro) sleep



- **~2.6%**[1] (45)
  ... due to health issues

~85%
Others

- Very detailed information available in GIDAS database but small number of relevant cases.
- Useful supplement w/ higher number of cases is provided by Fraunhofer IVI and evaluated in the following.

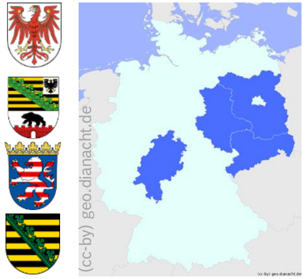
Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12

[1] share certainly higher due to considerable share of accidents caused by unreported health problems of driver

BOSCH

Accident Research: HWP Safe Stop

Accidents due to car breakdown & disability of driver (2)



Fraunhofer IVI

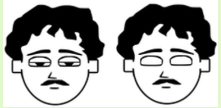
17 599 — Accidents w/ casualties involving passenger cars at motorways (BAB) of 4 German states (2010-2015) → **set to 100%**

Accidents on BAB due to car breakdown: ~8.4% (1 486)

- ~7.5% (1 324): collision w/ other vehicle due to unstable driving conditions (e.g. tire blow-out) OR single vehicle accident → cases not relevant
- **~0.9%** (162): cases only relevant if following traffic collide w/ broken car which slowed down or stopped before **→ current rate due to breakdown**

Accidents caused by disability of driver… **~5.8%** (1 013)

- **~3.8%** (662): … due to (micro) sleep



- **~2.0%**[1] (351): … due to health issues

~86%: Others

- Evaluation based on analysis of 257 719 accidents w/ casualties
- Detailed accident type (3-digit) was determined by evaluation of accident cause and semantic analyses of police accident report (method developed by Fraunhofer IVI).

Sources: DESTATIS 2014 FS8R7; Evaluation by Fraunhofer IVI 11/2016, based on accidents w/ casualties involving passenger cars of 4 German states (2010-2015); Picture: geo.dianacht.de

[1] share certainly higher due to considerable share of accidents caused by unreported health problems of driver

BOSCH

Accident Research: HWP Safe Stop

Accidents due to car breakdown & disability of driver (3)

Fraunhofer IVI

GIDAS – GERMAN IN-DEPTH ACCIDENT STUDY

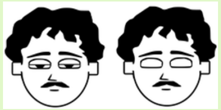
Evaluation of... ...accidents w/ casualties involving passenger cars at motorways (BAB)

Accidents at BAB due to car breakdown: ~7.0 - 8.4%

- ~5.5 - 7.5%: collision w/ other vehicle due to unstable driving conditions (e.g. tyre blow-out) OR single vehicle accident → cases not relevant
- **~0.9 – 1.4%**: cases only relevant if following traffic collide w/ broken car which slowed down or stopped before **→ current rate due to breakdown**

Accidents caused by disability of driver... **~5.8 – 8.3%**

- **~3.8 – 5,7%**: ... due to (micro) sleep



- **~2.0 – 2.6%**[1)]: ... due to health issues

~85% Others

- Current rate of accidents due to car breakdown @BAB which result in collision of following traffic is between **~0.9 – 1.4%** of accidents w/ casualties involving passenger cars @BAB
- Rate of accidents due to disability of driver is between **~5.8 – 8.3%** → **FoE** for HWP Safe Stop[1)]

Sources: DESTATIS 2014 FS8R7; Evaluation of Fraunhofer IVI 11/2016

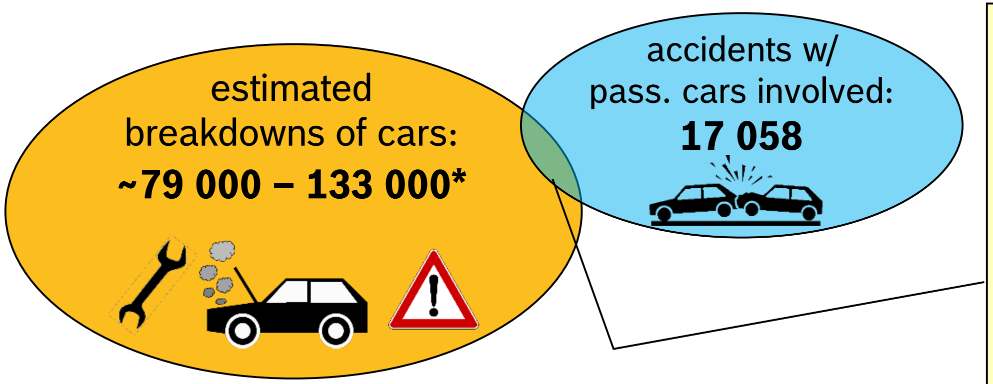
[1)] share certainly higher due to considerable share of accidents caused by unreported health problems of driver

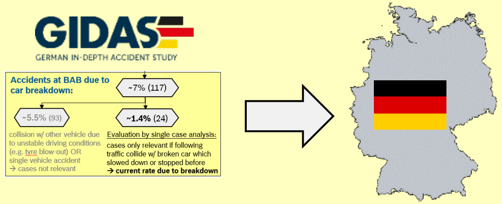
BOSCH

Accident Research: HWP Safe Stop

Overlap of breakdowns and accidents @BAB

- Database: ADAC breakdown statistics
- Estimations necessary to determine all breakdowns of cars in Germany @BAB
  (for details: see annex slide 24)





GIDAS **projection to Germany** results in…

… accidents due to breakdowns:

~1 180 *(overlap of illustrated sets)*

… thereof relevant**: **~240**

- Probability that a breakdown @BAB leads to a relevant accident due to following traffic is estimated with 0.25% (~0.18% - ~0.32%)*

Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12

* Bosch estimation, for details see annex ** cases only relevant if following traffic collide w/ broken car which slowed down or stopped before, NO collision w/ other vehicle due to unstable driving conditions (e.g. tire blow-out) NOR single vehicle accident

Accident Research: HWP Safe Stop
Probability that a Safe Stop turns into an accident

- Probability that breakdown turns into a relevant accident due to following traffic is ~0.25%*
  → BUT for almost all breakdowns car is stopping at shoulder
- **Challenge:** no figures available if car is stopping in traffic lane
- **Approach:** selection of rear end crashes (UTYP 60/61) @BAB out of GIDAS and distinction of cases w/ and w/o relevant further rear end collision:

1 686 — Accidents w/ casualties involving passenger cars at German motorways (BAB)

552 — rear end crashes (UTYP=60x/61x) → **set to 100%**

rear end crashes ...

~7% (39) — ... w/ relevant further rear end collision**

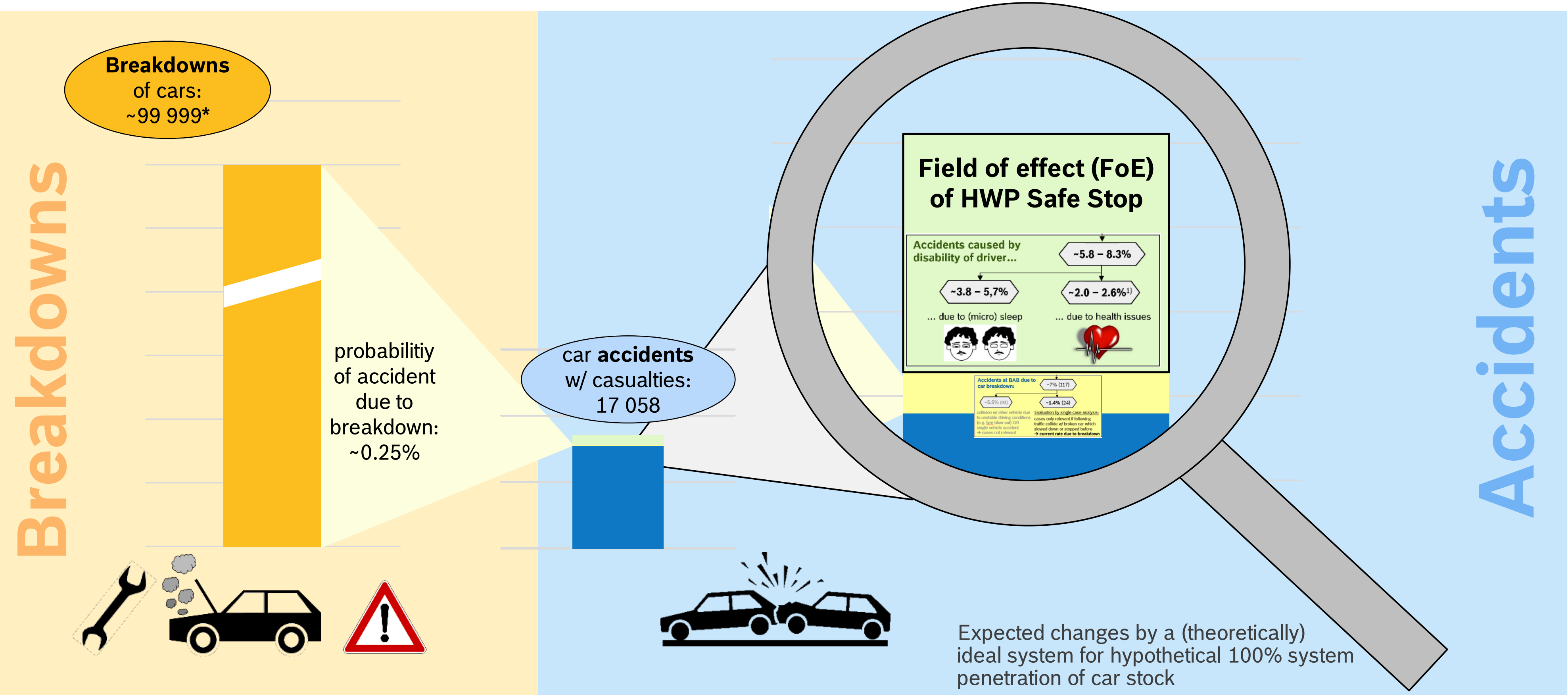
~93% (513) — ... w/o relevant further rear end collision**

- AR estimation for share of safe stops in current lane @BAB which will probably result in car accidents w/ casualties due to following traffic: **5% ... 10%*****

Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12 * estimation out of ADAC breakdown statistics and GIDAS analyses ** for details see annex
*** 95% confidence interval: 5.2 - 9.7% (binomial distribution, Agresti-Coull-Intervall)

Accident Research: HWP Safe Stop

Visualization - Effect on accidents due to disability of driver (1/4)

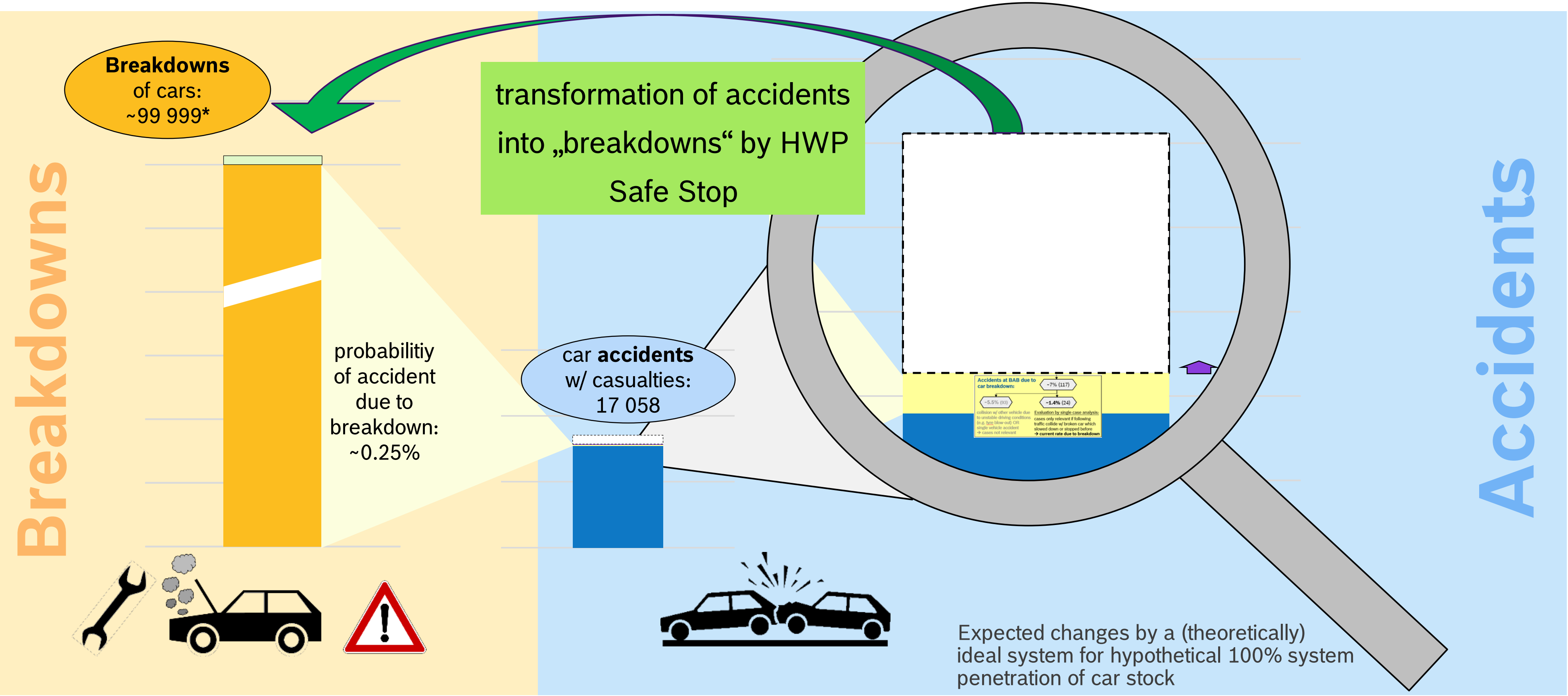


Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12; Evaluation of Fraunhofer IVI 11/2016

* estimation out of ADAC breakdown statistics

Accident Research: HWP Safe Stop

Visualization - Effect on accidents due to disability of driver (2/4)



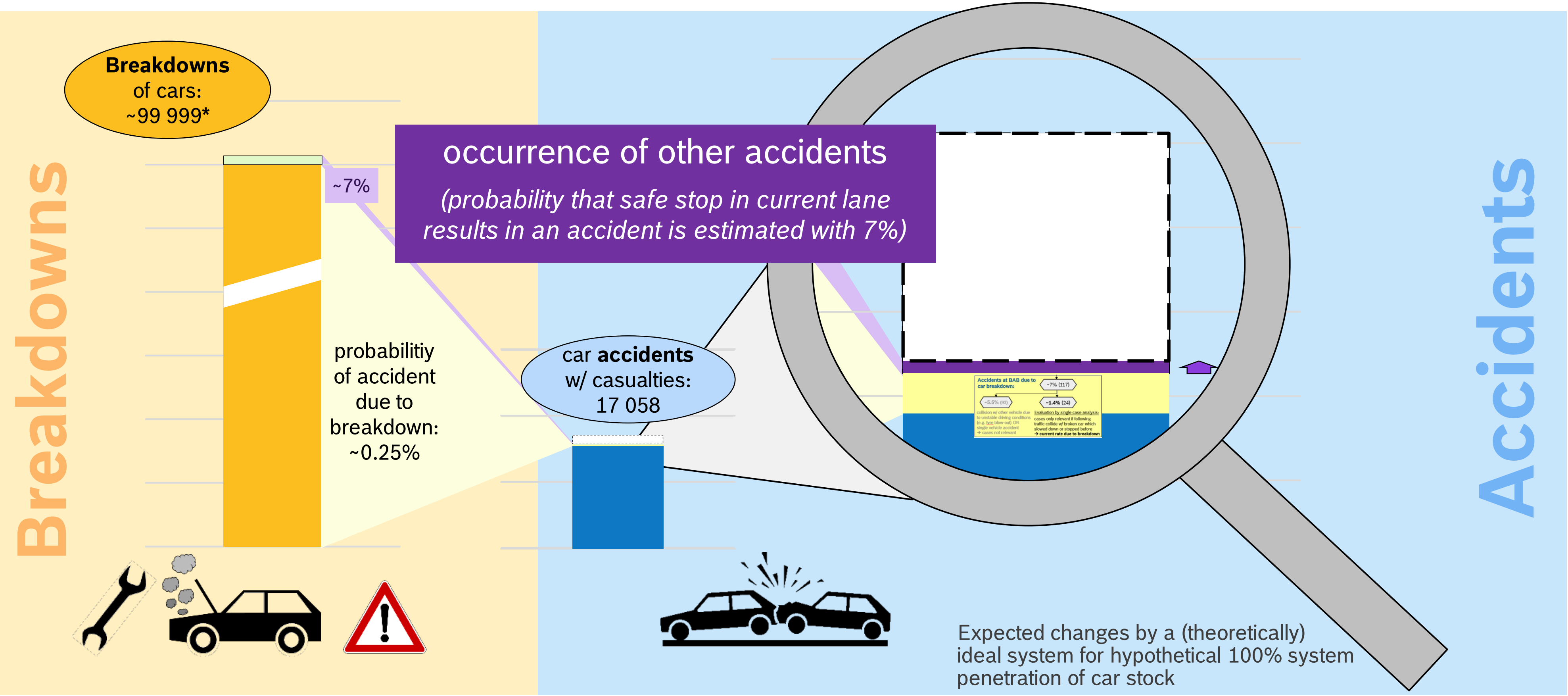
Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12; Evaluation of Fraunhofer IVI 11/2016

* estimation out of ADAC breakdown statistics

Accident Research: HWP Safe Stop

Chapter 07

Visualization - Effect on accidents due to disability of driver (3/4)

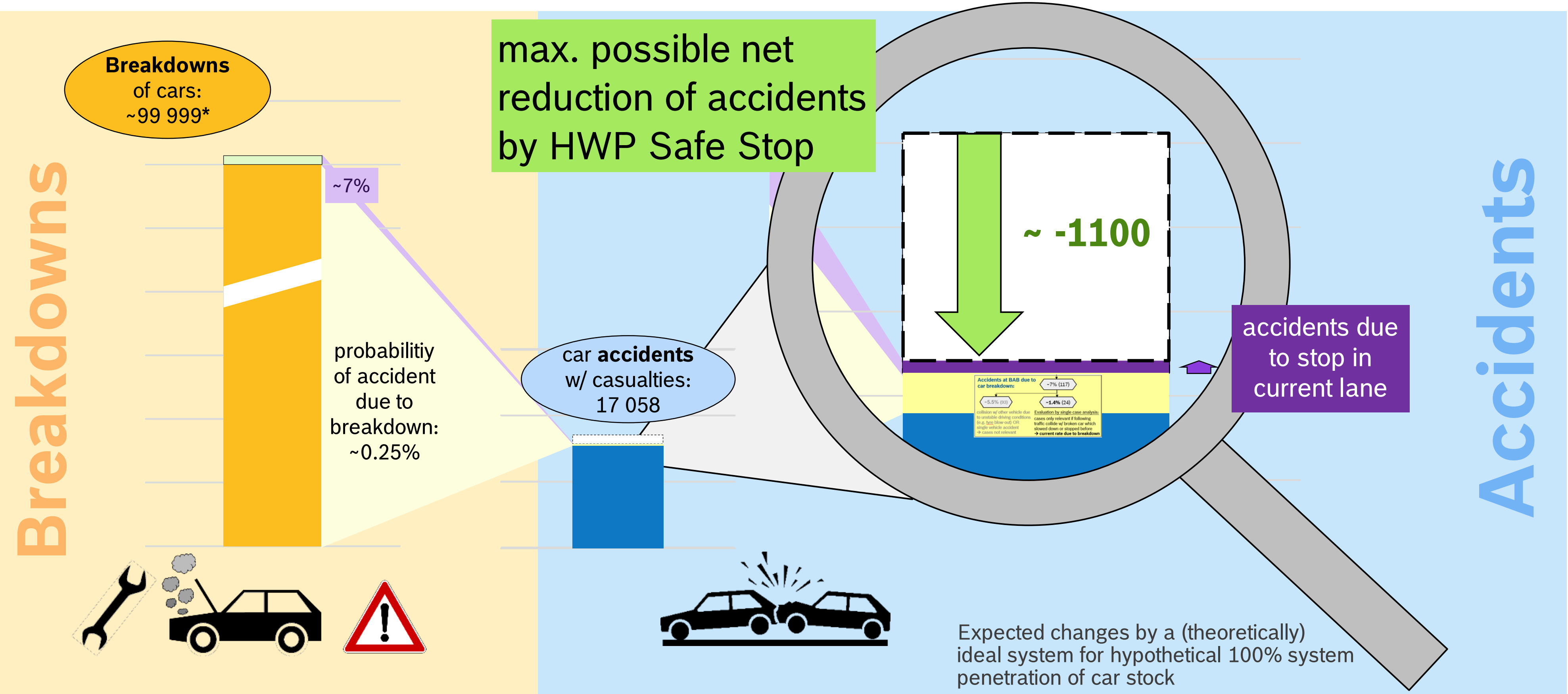


Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12; Evaluation of Fraunhofer IVI 11/2016

* estimation out of ADAC breakdown statistics

Accident Research: HWP Safe Stop

Visualization - Effect on accidents due to disability of driver (4/4)



Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12; Evaluation of Fraunhofer IVI 11/2016

* estimation out of ADAC breakdown statistics

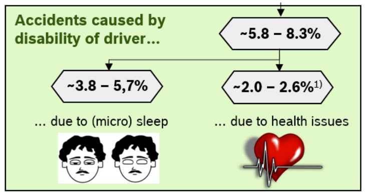
Accident Research: HWP Safe Stop

Expected change due to HWP Safe Stop (ideal system)

- Slightly more accidents due to additional cars stopping in lane
- Estimation of accidents @BAB due to HWP Safe Stop
  - in case of disability of driver: ~75-105 [2)]
  - in case of technical defects of HWP System: currently not determinable

accidents due to stop in current lane

- Much less accidents caused by disability of driver
- With a **theoretical ideal system** accidents caused by disability of driver could be completely avoided
  → max. ~1 280 less car accidents @BAB[1)]



Sources: DESTATIS 2014 FS8R7; GIDAS 2015.12; Evaluation of Fraunhofer IVI 11/2016

- HWP Safe Stop benefit **estimation**: ~5.5 – 7.5% less car accidents w/ casualties @BAB[1)2)]
- This corresponds to a **reduction of accidents w/ casualties** up to ~0.4% (~930 - 1280)

[1)] Figures for hypothetical 100% system penetration of car stock and a (theoretically) ideal system; fault rate of HWP not considered
[2)] Based on AR estimation that 5-10% of HWP Safe Stops will result in an accident with following traffic, derived from mean lower and upper limits of GIDAS and Fraunhofer evaluation

BOSCH

Accident Research: HWP Safe Stop

Summary and next steps

Conclusion:

- If HWP Safe Stop addresses main part of cases with disability of driver
  → then net benefit will be much higher than possible accidents due to stop in current lane

Recommendation:

- Clearly perceivable warning of following traffic highly recommended when Safe Stop becomes active, e.g. by:
  - hazard lights
  - flashing lights w/ higher intensity than current hazard lights (regulatory approvals necessary!)
  - *eCall* and other C2X communication possibilities
- Deceleration should not exceed $4m/s^2$

Germany: Injury severity estimation in oncoming collisions → Oncoming Collision Prevention

Accident Research
CR/AEV1

BOSCH

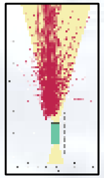
Accident Research: Injury severity estimation

Wrap up

2013/2014: Analysis against oncoming traffic leads to several function ideas

2015: Oncoming collisions prioritized by CR and CC/ENA

2016: System and function specification of Oncoming Collision Prevention (OCP) by continuous analysis and trajectory identification



▶ Research question:

Which injury severity can be expected in case of an OCP intervention?

Note: To assess the injury severity more precisely, crash simulation is needed. This requires more advanced vehicle models which are not available at the time being. Therefore a generic approach was chosen by evaluation of crash parameters out from reconstruction. Hence it is not the aim to have an on-board vehicle injury severity estimation afterwards.

Accident Research: Injury severity estimation

Overview studies

▶ Goal:

To assess the impact of the OCP-functionality the change of injury severity has to be evaluated. System requirements were not available at the time being there for a hypothetical OCP functionality is used. Based on two methods (independent approach) the injury severity is estimated and compared afterwards.

▶ Two approaches:

- **Study 1:** Master Thesis S. Müller, **“*Injury severity estimation by using statistical methods*”**, German only
  Aim is to use statistical methods to establish a baseline model for an injury severity estimation using various reconstructed crash parameters. Afterwards the model is assessed with “*new*” simulated cases.
- **Study 2: Multibody model simulation of reconstructed oncoming crashes w/ baseline and OCP function**
  Aim is a simulation based assessment by using acceleration values from a multibody model. To estimate the injury severity the Head Injury Criteria is used. Afterwards the model was applied on re-simulated “new” cases assuming an OCP intervention. Finally compared with results from study 1.

▶ Results:

Both methods show that less overlap (offset) and higher collision angle result in a reduced injury level. Therefore a higher confidence is given on the results.

STUDY 1 (GERMAN):

ABSCHÄTZUNG DER INSASSENVERLETZUNGS-SCHWERE MIT STATISTISCHEN METHODEN

Übersicht

1. Motivation / Aufgabenstellung
2. Datengrundlage
3. Modell
4. Ergebnisse
5. Anwendung auf OCP
6. Fazit

Accident Research: Injury severity estimation

Chapter 08


Aus ungeklärter Ursache kommt Beteiligte 1 nach links in den Gegenverkehr und kollidiert mit entgegenkommenden Beteiligten 2. Die Fahrerin des Bet. 1 erlitt dabei tödliche Verletzungen, wohingegen der Fahrer von 2 unverletzt bleibt.

Endlage Audi

Bet. 1 Mitsubishi – Lancer (1991); *v0=69km/h, dv=60km/h*

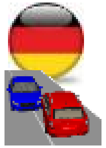
Endlage Mitsubishi

Bet. 2 Audi Q7 (2006); *v0=98km/h dV=27km/h*


<u>Überdeckungsgrad:</u>
Mitsubishi 33% vs. Audi 18%

GIDAS
#0120110403


BOSCH



Accident Research: Injury severity estimation

Relevanz von Begegnungsunfällen

- CR/AEV1 Studie (2012) – Amtliche Unfallstatistik

Unfälle	mit Personenschaden	mit Getöteten
gesamt	299.637 (100%)	3.375 (100%)
mit entgegenkommendem Fahrzeug	22.295 (7,4%)	719 (21,3%)
...davon außerorts	9.889 (3,3%)	648 (19,2%)

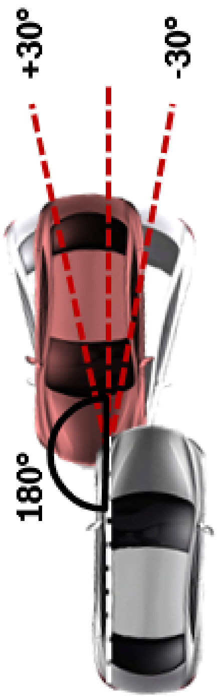
- Jeder 5. tödliche Unfall ist mit entgegenkommendem Fahrzeug

▶ **Maßnahme:** Aktiver Fahrzeugeingriff um Unfälle zu vermeiden oder deren Schwere zu reduzieren

Quelle: CR/AEV1 Interne Studie (GIDAS, 2012) und amtliche Statistik DESTATIS F8 R7, 2013

Accident Research: Injury severity estimation
Oncoming Collision Prevention (OCP) Funktion

- OCP soll Unfälle mit entgegenkommenden Fahrzeugen und geringer Überdeckung verhindern
- Für den aktiven Eingriff werden dabei folgende Fälle (Unfallfahrzeug) betrachtet
  - Unfallfahrzeug ist PKW
  - Unfallgegner ist Fahrzeug (keine Zweiräder)
  - Hauptschadenseinwirkung ist an Fahrerseite
  - Überlappung der Fahrzeuge ist maximal 50%
  - Kollisionswinkel ist 180° +/- 30°



▶ Aktiver Eingriff verändert die Unfallkonstellation z.B. Winkel, Überdeckung, ...

Accident Research: Injury severity estimation

Aufgabenstellung / Ziel des Modells

- **Aufgabenstellung:**
  - Auswirkungen auf die Verletzungsschwere bei „neuer Unfallkonstellation“ abschätzen

- **Betrachtung mit statistischen & „neuen“ Methoden:**

1. *Modell erstellen*
   - Ziel: Verletzungsschwere realer Unfälle bestmöglich voraussagen
2. *Schätzung*
   - Geänderte Kollisionsstellung mit Modell bewerten

▶ Vorselektion der Daten notwendig

2. DATENGRUNDLAGE

Accident Research: Injury severity estimation

GIDAS Datenbank

GERMAN IN-DEPTH ACCIDENT STUDY

www.gidas.org

- Daten von Unfällen mit Personenschaden in Dresden und Hannover
- Seit 1999 ca. 2000 Unfälle pro Jahr
- Datenerhebung:
  - Fahrzeug
  - Umwelt
  - Unfall
  - Informationen über beteiligte Personen

▶ Auswahl der Datengrundlage

Accident Research: Injury severity estimation
Übersicht - Auswahl und Vorgehen

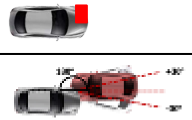
GIDAS
GERMAN IN-DEPTH ACCIDENT STUDY

Unfallfahrzeuge — **53 016**

... davon PKW — 64% — **33 769**

... relevante PKW (Hauptschaden Front) — 19% — **9 822**

... relevante PKW in Begegnungsunfällen (OCP: Winkel & Überdeckung) — 0,5% — **267**



9 822 → erstellen → Modell

267 → **Simulation** → Veränderte OCP Fälle → Bewertung

Modell → **Anwendung** → Bewertung

Bosch-Abzug Jahrgang 2001-2017 V160808, Fahrzeugebene, Daten nicht gewichtet oder hochgerechnet

BOSCH

Accident Research: Injury severity estimation

Verletzungsschwere / Selektion

- **Insassenverletzungsschwere über amtliche Definition:**
  - Getötete — An Unfallfolgen verstorben; innerhalb von 30 Tagen
  - Schwerverletzte — Stationärer Krankenhausaufenthalt min. 24h
  - Leichtverletzte — Alle übrigen Verletzten
  - Unverletzte — Keine Verletzung

- **Betrachtung:**
  - Verletzungsschwere des Fahrers
  - Alle Unfallfahrzeuge mit Hauptschadenseinwirkung an der Front – 9822 Fälle

Accident Research: Injury severity estimation

Verteilung der Verletzungsschwere

Chapter 08

- **Beobachtung:** 1 Unfallfahrzeug und Informationen über Fahrer / Unfall
  → Aus einem Unfall potentiell mehrere Beobachtungen

- Verteilung der Verletzungsschwere (9822 Fälle):

Verletzungsschwere	PVERL	Codierung	Anzahl	Prozent
Unverletzt	*UV*	1	6989	71.16%
Leichtverletzt	*LV*	2	2228	22.68%
Schwerverletzt	*SV*	3	570	5.80%
Getötet	*GT*	4	35	0.36%

Accident Research: Injury severity estimation
Signifikante Einflussfaktoren

- **Ermittlung mit Schrittweiser Regression**

• *Insasse*	Alter, Statur, Geschlecht, Vorerkrankungen
• *Fahrzeug*	Erstzulassung, Deformation, Fahrzeugklasse, VDI, Kollisionsgeschwindigkeit, Ausgangsgeschwindigkeit
• *Sicherheitssysteme*	Status Front Airbag, Belastung Rückenlehne, Gurt benutzt, Nutzungsfehler Gurt
• *Unfallgegner*	Art, Kollisionsgeschwindigkeit
• *Unfall*	EES, Relativmasse, Delta-V, Kollisionswinkel, Schwimmwinkel, Berührpunkt in Y
• *Umwelt*	Ortslage, Straßenart

3. MODELL

Accident Research: Injury severity estimation

Problemstellung / Methoden

Function Fitting

- Lineare Regression:

$$\hat{y} = \beta_0 + \beta_1 x_1 + \ldots + \beta_k x_k = \beta^T x$$

- Neuronales Netz
- Support Vector Machine (SVM) Regression

$$\hat{y} = \beta^T x + \alpha$$

- Random Forest mit Regression Trees

Klassifizierung (4 Klassen)

- Logistische Regression

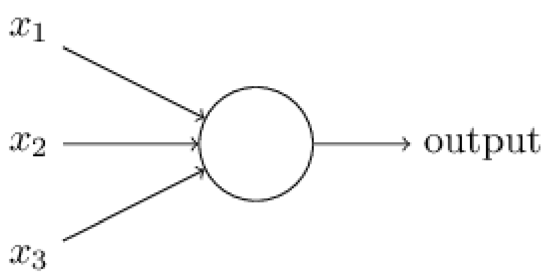
$$\pi_j = \frac{1}{1 + e^{-\beta^T x}}$$

- Neuronales Netz

Accident Research: Injury severity estimation
Neuronales Netz

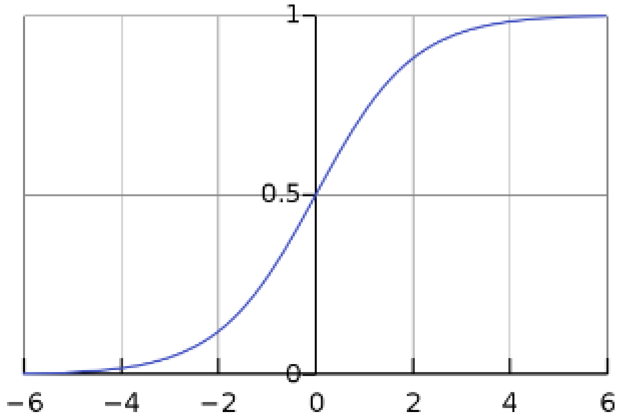
- Inputs werden mit Gewichten multipliziert und durch eine Aktivierungsfunktion transformiert

$$output = f(w_1x_1 + w_2x_2 + w_3x_3 - b)$$



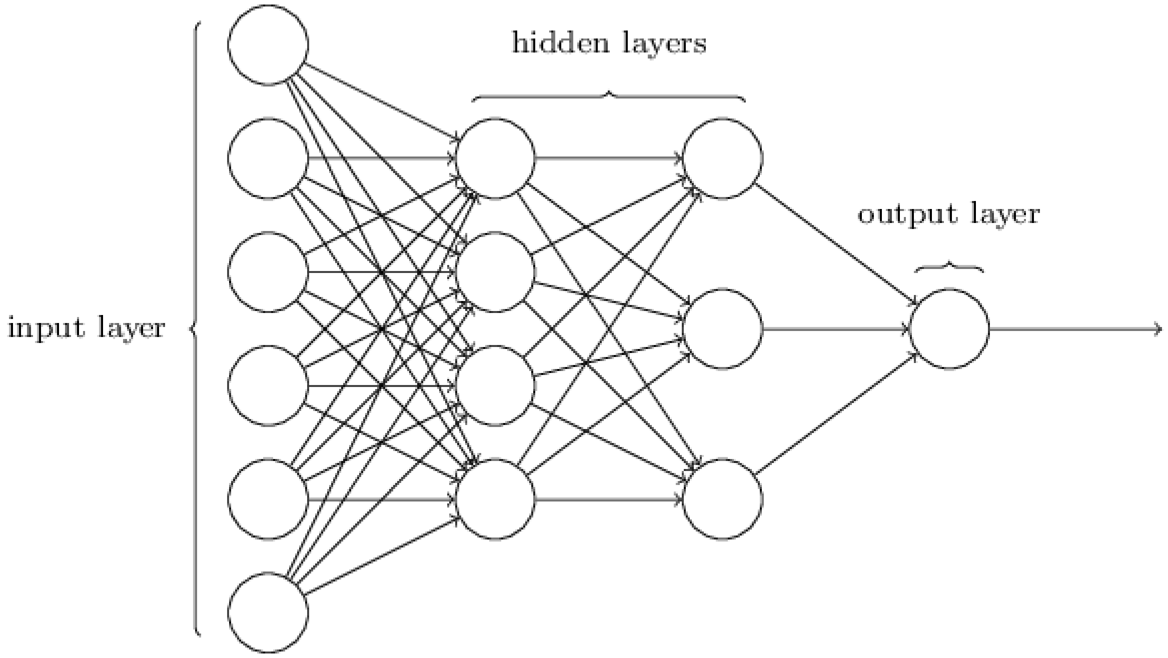
- Beispiel für Aktivierungsfunktion – Logistische Funktion:

$$f(x) = \frac{1}{1 + e^{-x}}$$



Accident Research: Injury severity estimation
Neuronales Netz

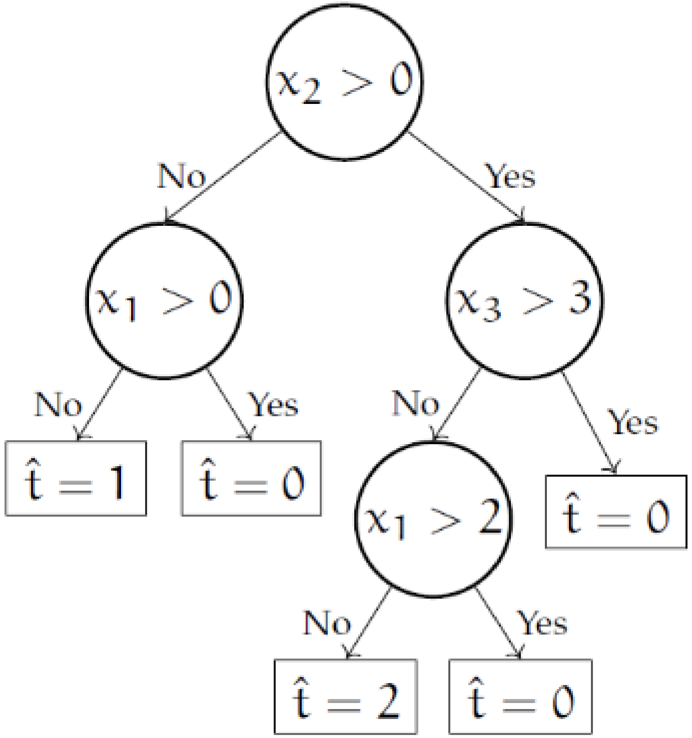
- Aus Neuronen wird ein Netz mit mehreren Schichten aufgebaut
- Fehler zwischen Output und Zielgröße wird bestimmt
- Ableitung des Outputs nach den Gewichten wird bestimmt
- Gewichte werden angepasst, um den Fehler zu verringern



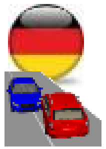
Accident Research: Injury severity estimation
Random Forest / Decision Trees

- Regression / Klassifizierung über einen Entscheidungsbaum

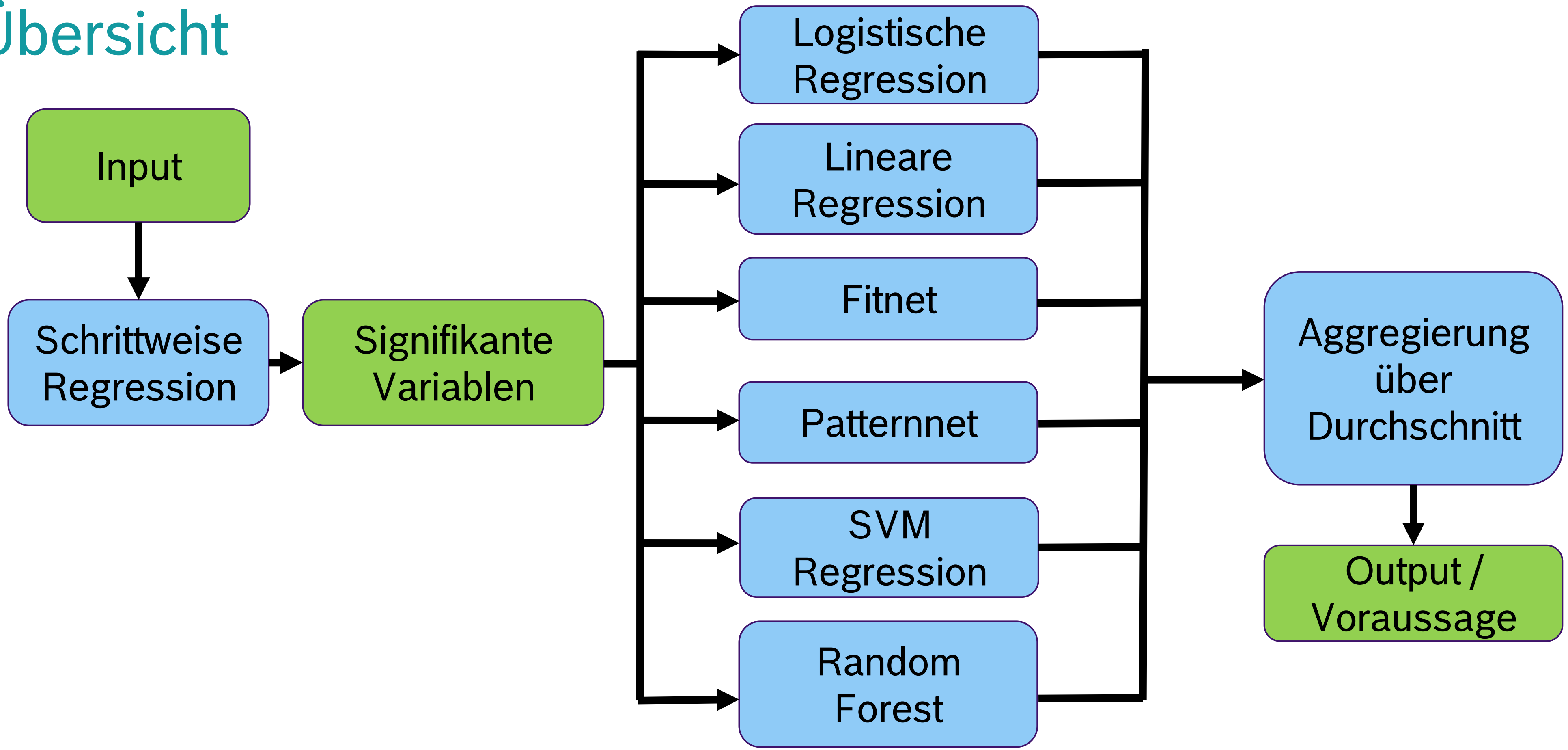
- Random Forest: Mehrere Bäume werden erstellt und aggregiert



Accident Research: Injury severity estimation



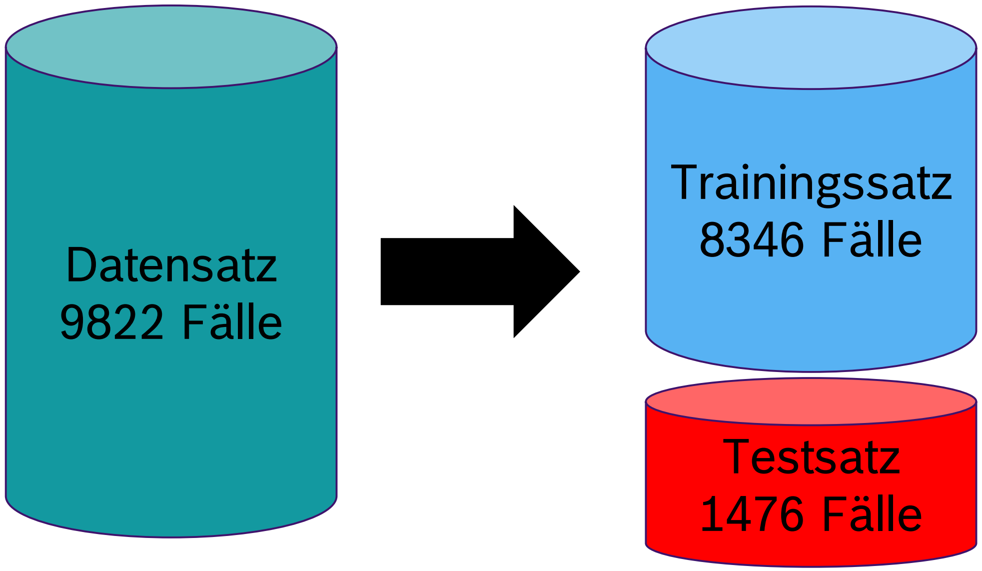
Übersicht



▶ Aggregieren der Methoden führt zu den besten Vorhersageergebnissen

Accident Research: Injury severity estimation
Methodik

- Datensatz wird unterteilt in
  - Trainingsdaten, um Methoden zu trainieren
  - Testdaten, um Methoden zu validieren



4. ERGEBNISSE

Accident Research: Injury severity estimation

Vergleich der Methoden

- Testsatz 1476 Fälle
- Vergleichskriterium: PVERL=UV mit 1050 Fällen (Nullmodell)

	Gesamt	Fitnet	Logistische Regression	Patternnet	Lineare Regression	Random Forest	SVM Regression
Anzahl	1226	1223	1221	1220	1213	1209	1207
Prozent	**83,06%**	82,86	82,72	82,66	82,18	81,91	81,78

- Bei anderen Testsätzen variiert Vorhersagegüte zwischen 81%-85%

Accident Research: Injury severity estimation

Gesamtschätzer

- Klassifizierung für alle Klassen in mehr als 50% richtig
- Mehrzahl an UV und LV richtig eingeordnet
- Probleme bei SV und GT

Confusion Matrix

Vorhersage \ Zielklasse	UV	LV	SV	GT	
UV	950 64.4%	77 5.2%	4 0.3%	0 0.0%	92.1% 7.9%
LV	100 6.8%	246 16.7%	51 3.5%	1 0.1%	61.8% 38.2%
SV	0 0.0%	15 1.0%	28 1.9%	2 0.1%	62.2% 37.8%
GT	0 0.0%	0 0.0%	0 0.0%	2 0.1%	100% 0.0%
	90.5% 9.5%	72.8% 27.2%	33.7% 66.3%	40.0% 60.0%	83.1% 16.9%

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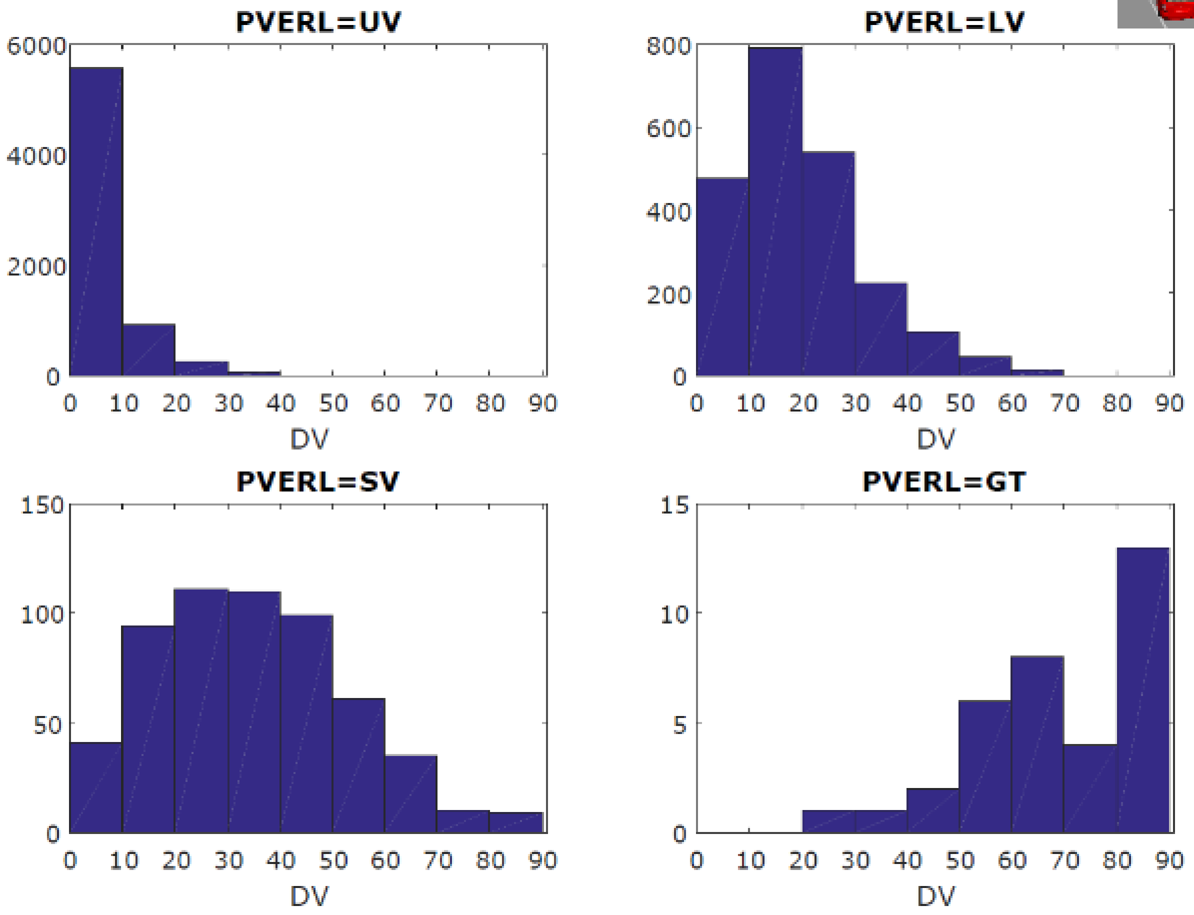
Accident Research: Injury severity estimation

Fehlklassifizierungen

<u>Mögliche Ursachen:</u>

- Unfall kann durch vorhandene Daten nie vollständig beschrieben werden
- Übergang von LV/SV ist fließend
- Viele ähnliche Unfälle mit unterschiedlicher Verletzungsschwere



→ Delta V bei schweren Unfällen höher, jedoch starke Überlappungen

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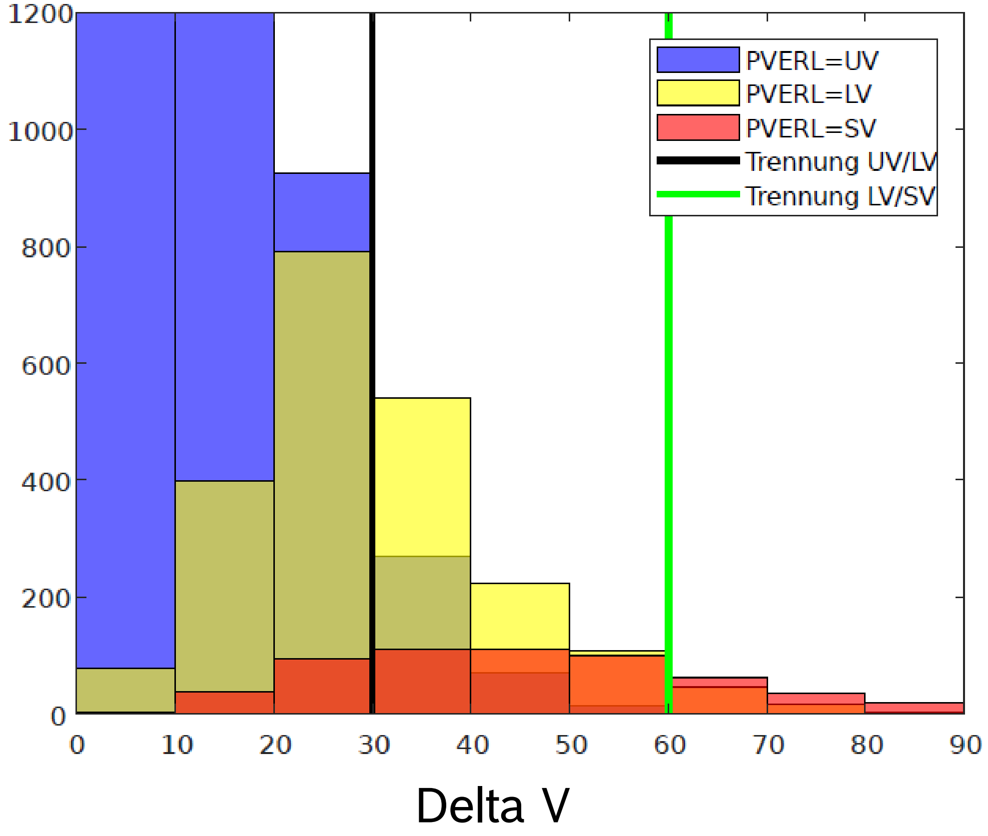
Accident Research: Injury severity estimation

Fehlklassifizierungen



- Trennlinien zeigen mögliche Klassifizierung
- Verschiebung der Trennlinien führt zu höherem Fehler

Accident Research: Injury severity estimation

Bedingte Wahrscheinlichkeiten

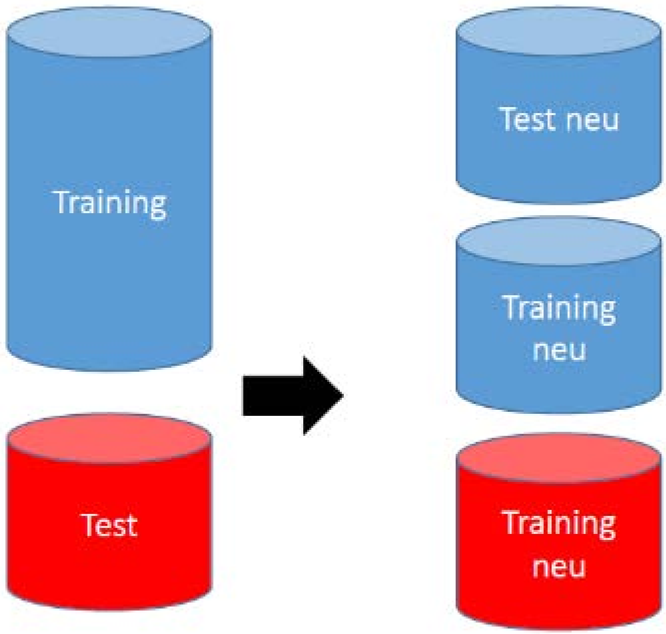
- Geben an, wie zuverlässig eine Klassifizierung ist
- Diagonalelemente geben Wahrscheinlichkeit einer richtigen Klassifizierung an

	y=1	*y=2*	*y=3*	*y=4*
P(UV|y)	92,1%	25,1%	0%	0%
P(LV|y)	7,5%	61,8%	33,3%	0%
P(SV|y)	0,4%	12,8%	62,2%	0%
P(GT|y)	0%	0,3%	4,4%	100%

▶ Kann genutzt werden, um die Gesamtverteilung der Vorhersage anzupassen

Accident Research: Injury severity estimation
Bedingte Wahrscheinlichkeiten - Anwendung

- Neuer unabhängiger Testsatz wird erstellt und Modell neu trainiert



Accident Research: Injury severity estimation

Beispielfall

- Regressionsschätzer (Betas) werden benutzt, um den Unterschied in PVERL zu analysieren

- **Größte Faktoren:**
  - Delta V
  - Geschwindigkeit Gegner
  - Relatives Crashgewicht
  - EES
  - Geschlecht
  - Fahrzeugklasse

▶ Interpretation nur sehr eingeschränkt

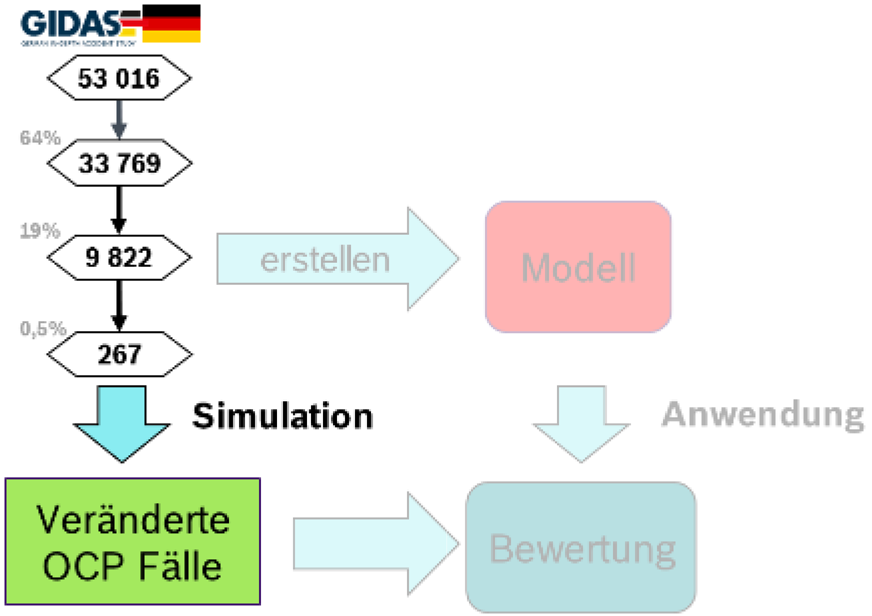

Bet01 Variable	*Wert*	*Bet02 Variable*	*Wert*	*Unterschied*
DV_80	0,88	*DV_40*	0,31	0,57
VK_Gegner_110	0,48	*VK_Gegner_60*	0,00	0,48
GEWGESrel_0_5	0,21	*GEWGESrel_3*	0,00	0,21
EES_80	0,29	*EES_60*	0,11	0,18
GESCHL_4	0,05	*GESCHL_3*	-0,06	0,11
FZGKLASS_6	0,01	*FZGKLASS_10*	-0,05	0,07
TDEZJ_1990	0,05	*TDEZJ_2005*	-0,01	0,06
AIRBF_0	0,02	*AIRBF_2*	-0,02	0,04
STATUR_5	0,03	*STATUR_4*	0,00	0,03
VDI3_21	-0,05	*VDI3_20*	-0,06	0,01
RLWER_3	0,04	*RLWER_2*	0,03	0,01
RHSBEN_1	0,04	*RHSBEN_1*	0,04	0,00
KONBETEIKONOBJ_3	-0,09	*KONBETEIKONOBJ_3*	-0,09	0,00
ORTSL_4	0,04	*ORTSL_4*	0,04	0,00
STRART_5	0,16	*STRART_5*	0,16	0,00
RHSFEHL_2	-0,12	*RHSFEHL_2*	-0,12	0,00
KWINKS_0	0,10	*KWINKS_0*	0,10	0,00
MAXDEFB_50	0,23	*MAXDEFB_50*	0,23	0,00
(Intercept)	1,09	*(Intercept)*	1,09	0,00
ALTER1_50	0,07	*ALTER1_60*	0,08	-0,01
V0_70	0,05	*V0_100*	0,06	-0,01
VK_60	0,07	*VK_100*	0,09	-0,03
KWINK_180	0,13	*KWINK_m180*	0,17	-0,04
BRPY_m50	0,01	*BRPY_m60*	0,05	-0,04
VEALLG_250000	0,00	*VEALLG_1*	0,05	-0,05
Summe	3,77		2,18	

5. ANWENDUNG AUF OCP FÄLLE

Accident Research: Injury severity estimation

Simulation

- **<u>Annahme:</u>** OCP Funktion ist „aktiv“ → Variation der Unfallkonfiguration
- OCP Fälle werden mittels PC Crash simuliert, dabei werden folgende Werte generiert:
  - *Kollisionsgeschwindigkeit*
  - *Kollisionswinkel*
  - *Delta-v*
  - *Berührpunkt in Y*
  - *EES*
  - *Maximale Deformation*
- Ergänzung der restlichen Daten aus GIDAS



▶ Neu generierte OCP Fälle sind unabhängige Testfälle

Accident Research: Injury severity estimation

Verteilung der Verletzungsschwere

- Die Verletzungsschwere der 267 Fälle ist folgendermaßen verteilt

PVERL	Anzahl OCP	Prozent OCP	Anzahl gesamt	Prozent gesamt
UV	80	29,96%	6989	71.16%
LV	130	48,69%	2228	22.68%
SV	53	19,85%	570	5.80%
GT	4	1,50%	35	0.36%

▶ Hypothese: Höherere Verletzungsschwere → schlechteres Klassifizierungsergebnis

Accident Research: Injury severity estimation
Ergebnisse der Klassifizierung

- Klassifizierung für alle Klassen in mehr als 50% richtig
- 173 von 267 Beobachtungen richtig klassifiziert (~65%)
- <u>Vergleichskriterium:</u>
  PVERL=LV mit 130 Beobachtungen

Confusion Matrix

Vorhersage \ Zielklasse	UV	LV	SV	GT	
UV	47 17.6%	12 4.5%	1 0.4%	0 0.0%	78.3% 21.7%
LV	33 12.4%	110 41.2%	36 13.5%	0 0.0%	61.5% 38.5%
SV	0 0.0%	8 3.0%	15 5.6%	3 1.1%	57.7% 42.3%
GT	0 0.0%	0 0.0%	1 0.4%	1 0.4%	50.0% 50.0%
	58.8% 41.3%	84.6% 15.4%	28.3% 71.7%	25.0% 75.0%	64.8% 35.2%

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Bedingte Wahrscheinlichkeiten bei OCP

- Werden zur Bewertung der geänderten Konstellation gebraucht

	y=1	y=2	y=3	y=4
P(UV|y)	78,3%	18,4%	0%	0%
P(LV|y)	20,0%	61,5%	30,8%	0%
P(SV|y)	1,7%	20,1%	57,7%	50,0%
P(GT|y)	0%	0%	11,5%	50,0%

- Alle Vorhersagen sind zu mehr als 50% richtig (siehe Diagonalelemente)

▶ Abschätzung der Verletzungsschwere durch Anwendung auf variierte OCP-Begegnungsunfälle

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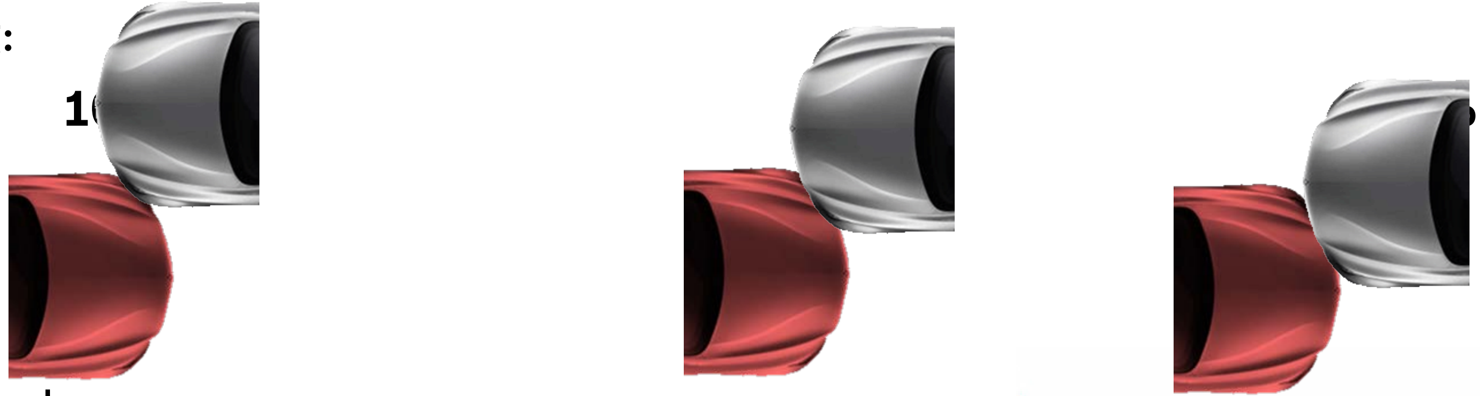
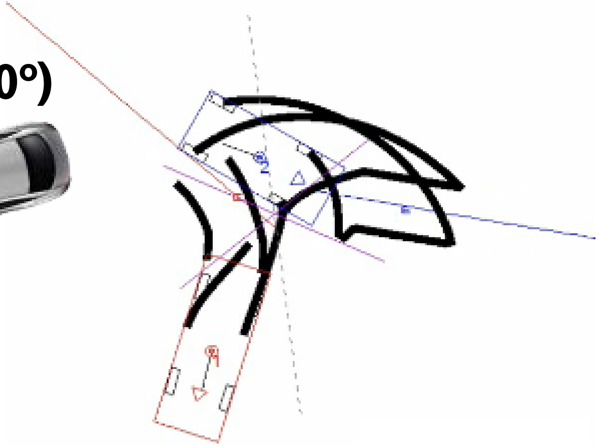
Variation der Fälle

- Unfallkonfiguration wird verändert → Rekonstruktion durch Simulation mit PC Crash
- Variation Überdeckung:



- Variation Kollisionswinkel:

-160° 180° 200° (-160°)



▶ Jeder Fall wird dabei 9 mal variiert

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Variationen Beispielfall

Variation	Overlap	Winkel	PVERL Bet 01	PVERL Bet 02
Original Bet 01	33	173	3,6045	–
Original Bet 02	18	−173	–	2,1437
Variation 1	10	160	3,108	1,4093
Variation 2	10	180	2,9896	1,7054
Variation 3	10	−160	2,7431	1,5787
Variation 4	30	160	3,6551	1,6998
Variation 5	30	180	3,6302	2,1437
Variation 6	30	−160	3,3751	2,0746
Variation 7	50	160	3,6479	2,2585
Variation 8	50	180	3,7403	2,184
Variation 9	50	−160	3,7243	2,1437

- Reale Verletzungsschwere:
  - Bet. 01 Getötet (4)
  - Bet. 02 Unverletzt (1)
- Geringerer Overlap führt zu geringerer Verletzungsschwere
- Winkel am Beispiel ohne Einfluss (Ablenkung von -173° auf 160° unrealistisch)

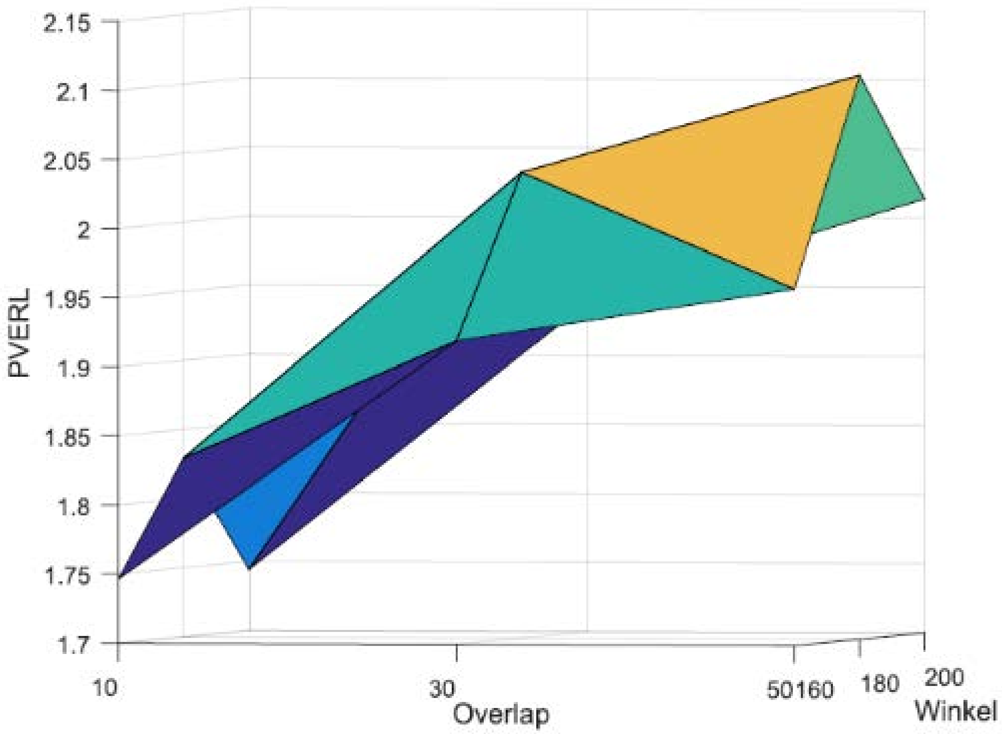
GIDAS Fall #0120110403

Accident Research: Injury severity estimation

Ergebnisse Variation - Schaubild

- Variation wird auf alle Fälle angewendet
- Gesamtverteilung wird mittels bedingter Wahrscheinlichkeiten angepasst
- Für jede Konstellation wird dann der Durchschnitt gebildet

Durchschnittliche geschätzte Verletzungsschwere als Funktion der Überdeckung und des Kollisionswinkels



▶ Geringerer Overlap und Abweichung von 180° reduziert die Verletzungsschwere

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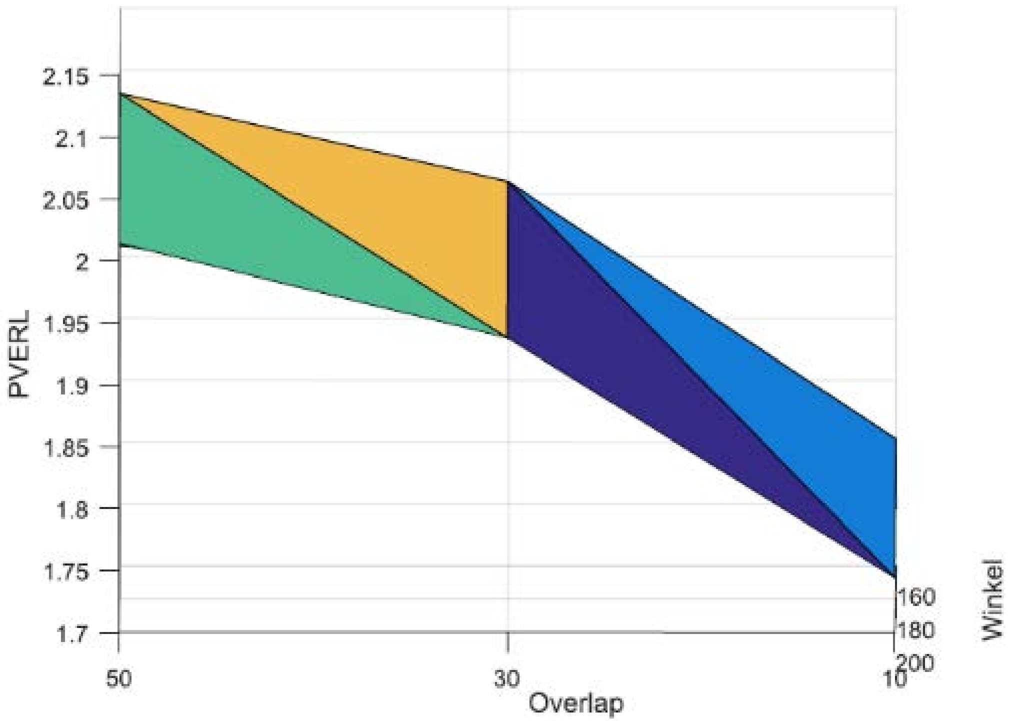
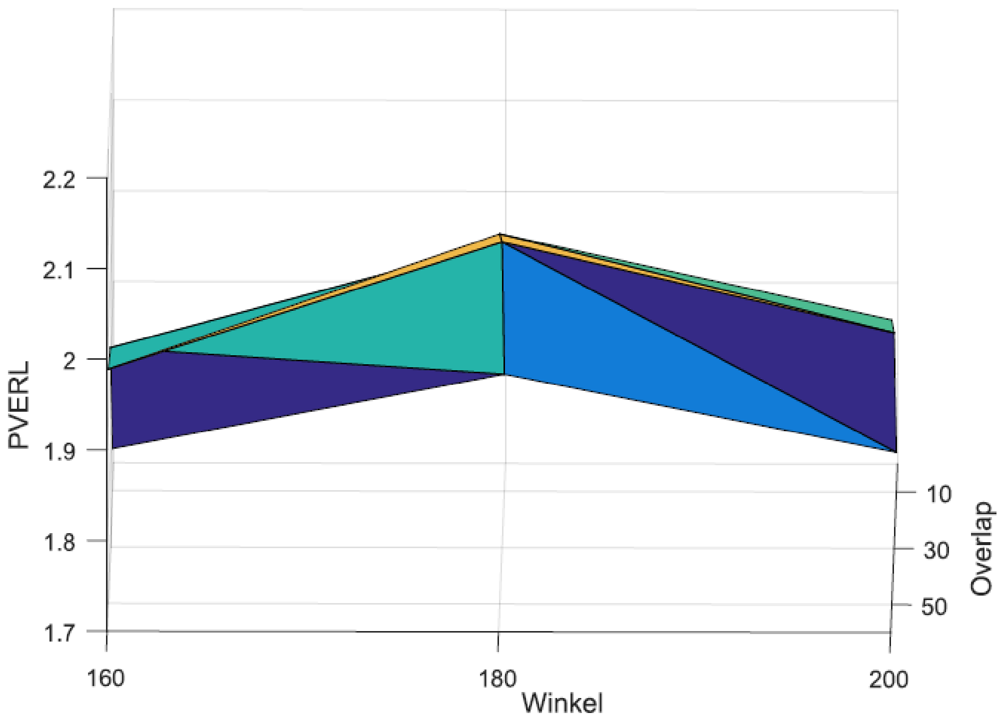
Ergebnisse Variation - Schaubild

Durchschnittliche geschätzte Verletzungsschwere als Funktion der Überdeckung und des Kollisionswinkels



Durchschnittliche geschätzte Verletzungsschwere als Funktion der Überdeckung und des Kollisionswinkels



▶ Geringerer Overlap und Abweichung von 180° reduziert die Verletzungsschwere

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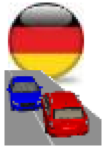
6. FAZIT / AUSBLICK

Accident Research: Injury severity estimation



- Verletzungsschwere lässt sich mit verschiedenen Modellen schätzen
- Bei Unfällen mit Hauptschaden (Front) lässt sich die Verletzungsschwere mit einer Güte von 81% - 85% sehr gut klassifizieren
- Anwendung auf OCP Fälle führt zur einer reduzierten Klassifizierungsgüte auf ca. 65% → Grund andere Verletzungsschwereverteilung
- Über bedingte Wahrscheinlichkeiten lassen sich Folgerungen für die Änderung in Overlap / Kollisionswinkel ableiten
- Mit mehr Beobachtungen und weiteren Variablen lässt sich die Güte insbesondere für höhere Verletzungsgrade steigern
- Aufbau eines Modells nur für OCP Fälle möglich allerdings derzeit nicht leistbar, aufgrund fehlender Stichprobenanzahl

STUDY 2:

MULTIBODY MODEL SIMULATION OF RECONSTRUCTED ONCOMING CRASHES

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Accident Research: Injury severity estimation
Introduction

▶ Oncoming Collision Prevention

Avoidance of car-to-car oncoming collisions w/ small overlap by ESC brake intervention (1st) / supported by steering (2nd)
→ Focus of EuroNCAP 2020

▶ Aim of the study

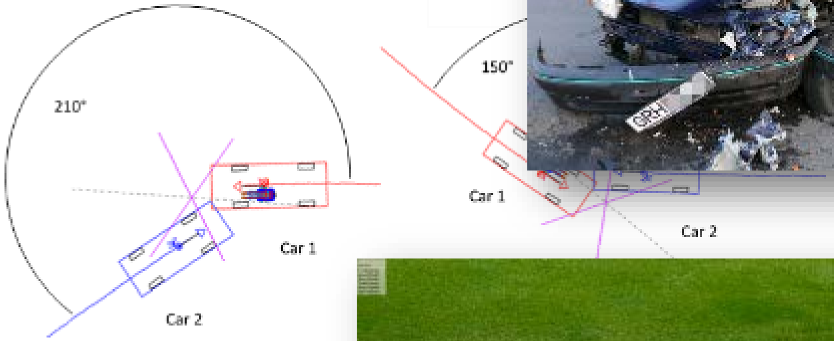
(1) Proof of concept to estimate the injury severity in case of oncoming car-to-car front impact w/ variations of collision parameters

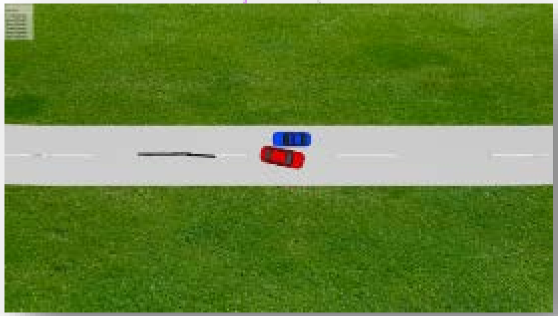
(2) Rough generic effectiveness estimation of the Oncoming Collision Prevention function (OCP) via simulation

Accident Research: Injury severity estimation

Approach

1. Validate PC-Crash output by comparing against real crash tests
2. Choose appropriate oncoming collision accidents from GIDAS database
3. Simulate the chosen cases in various scenarios
4. Process simulation output data in order to assess effect of changing scenario on occupant injury level
5. Simulate OCP system actions in an oncoming collision scenario to evaluate effectiveness and benefit





Accident Research: Injury severity estimation

Limitations

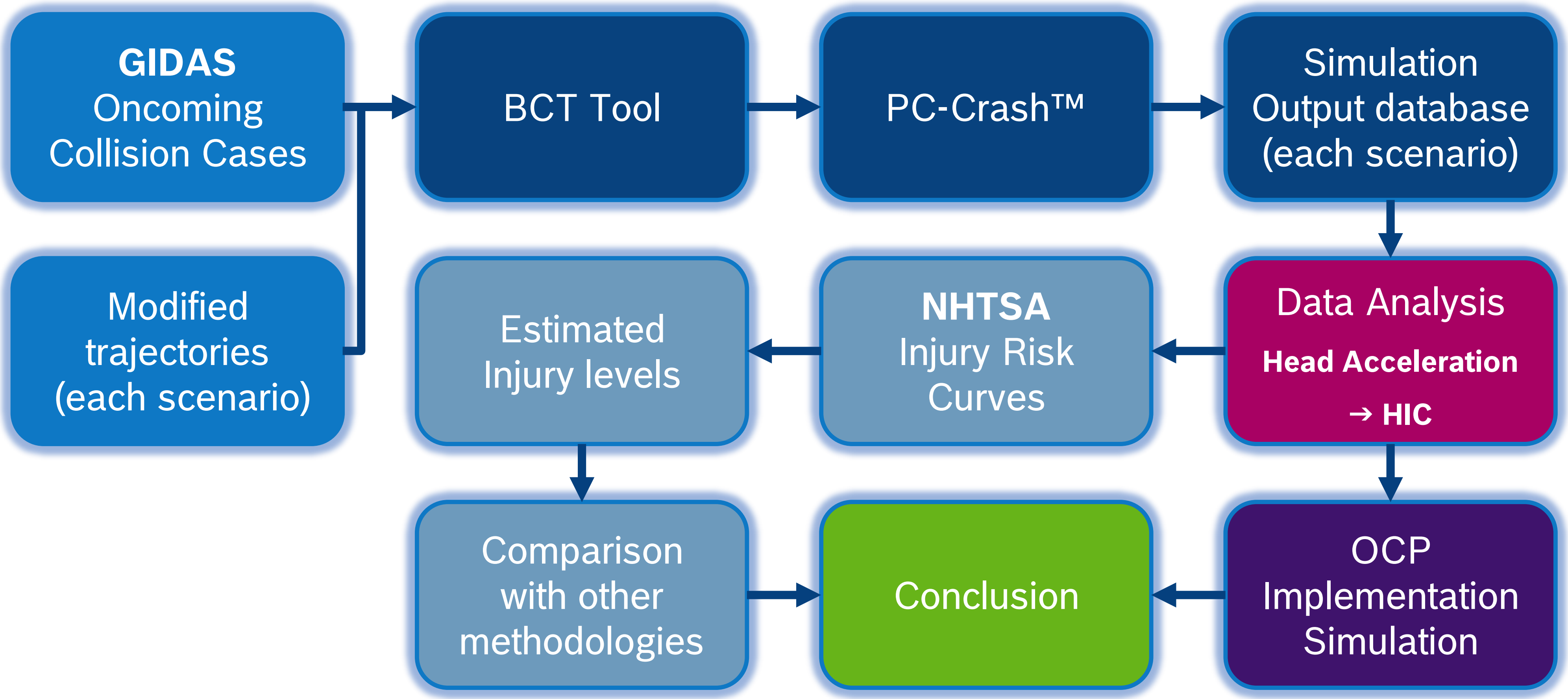
- Built in multibody occupant simulation used (PC-Crash) therefore
  - No airbag simulated
  - No cockpit to collide with
  - Generally overestimated measurements
  - Occupant needed positioning for every case

	Simulation Max Acceleration				Real Crash Test Max Acceleration			
Body Part	Head	Torso	Left Foot	Right Foot	Head	Torso	Left Foot	Right Foot
Accord (g)	63.25	125.18	159.45	147.76	41	40	156	72
Fit (g)	79.60	155.71	211.09	201.86	84	65	134	200

- Rectangular template shapes used for simulation vehicles
- OCP functionality not integrated or modeled hence realization to be proven independently

Simulation results serve as an indicator of what to expect rather than an absolute outcome

Accident Research: Injury severity estimation
Process Flowchart



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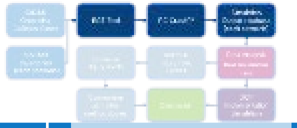
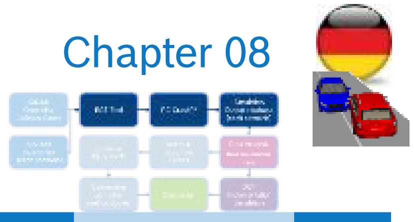
Accident Research: Injury severity estimation
Chosen Accidents Overview



ID	Accident	GIDAS Car 1	GIDAS Car 2	Coll. V1	Coll. V2	Weight 1	Weight 2	GIDAS MAIS08
1	1050889	Kleinwagen	LKW/ Bus	34	33	900	1700	1
2	1060835	untere Mittelklasse	untere Mittelklasse	34	33	1010	1142	1
3	1070270	untere Mittelklasse	Mittelklasse	39	27	1400	1470	0
4	1070274	Mittelklasse	Mittelklasse	19	13	1480	1360	0
5	1070704	untere Mittelklasse	Mittelklasse	23	20	1300	1550	0
6	1110403	untere Mittelklasse	Geländewagen	60	104	1100	2400	6
7	1120608	Geländewagen	LKW/ Bus	18	18	2250	33500	5
8	1120731	Kleinwagen	Minis	45	65	1255	1311	3
9	1130019	Minis	Kleinwagen	37	37	1180	1166	4
10	1140475	Kleinwagen	LKW/ Bus	50	50	900	10700	3
11	30080464	Mittelklasse	LKW/ Bus	85	100	1385	7226	6
12	30120538	untere Mittelklasse	untere Mittelklasse	75	85	1193	1250	3

Accident Research: Injury severity estimation

Chosen Accidents Overview



ID	Accident	x1	y1	z1	x2	y2	z2	Start Time	End Time	Depth Simulated
1	1050889	1.9	0.375	0.37	1.05	0.375	1	4.25	5.75	15 ms only
2	1060835	2	0.375	0.4	2	0.375	0.4	4.5	5.5	15 ms only
3	1070270	2	0.375	0.55	2.3	0.375	0.45	4.5	5.5	15 ms only
4	1070274	2.3	0.375	0.45	2.3	0.375	0.45	4.5	5.5	15 ms only
5	1070704	2	0.375	0.4	2	0.375	0.55	4.5	5.5	15 ms only
6	1110403	2.2	0.375	0.4	2.3	0.375	0.65	4.5	5.5	0 ms and 15 ms
7	1120608	2.3	0.375	0.6	2	0.375	1.5	4.75	5.75	0 ms and 15 ms
8	1120731	2.1	0.375	0.5	1.9	0.375	0.4	4.5	5.5	0 ms and 15 ms
9	1130019	1.7	0.375	0.4	2	0.375	0.4	4.5	5.5	0 ms and 15 ms
10	1140475	2	0.375	0.35	2	0.375	1.5	4.5	5.5	0 ms and 15 ms
11	30080464	2.2	0.375	0.3	2	0.375	1.5	4.5	5.5	0 ms only
12	30120538	2	0.375	0.35	2	0.375	0.4	4.5	5.5	0 ms only

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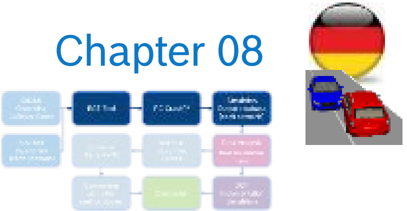
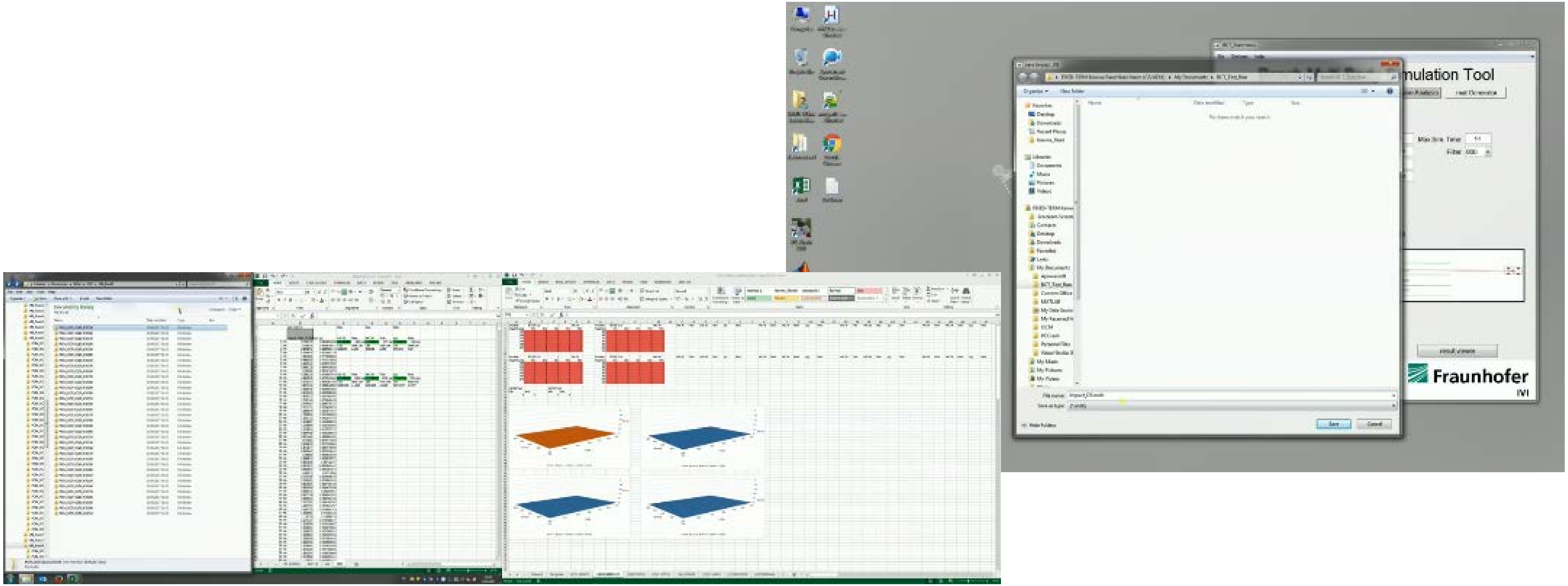
Accident Research: Injury severity estimation
Simulation Procedure and automation

Chapter 08



- GUI based macro to automatically generate and process the data



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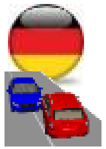
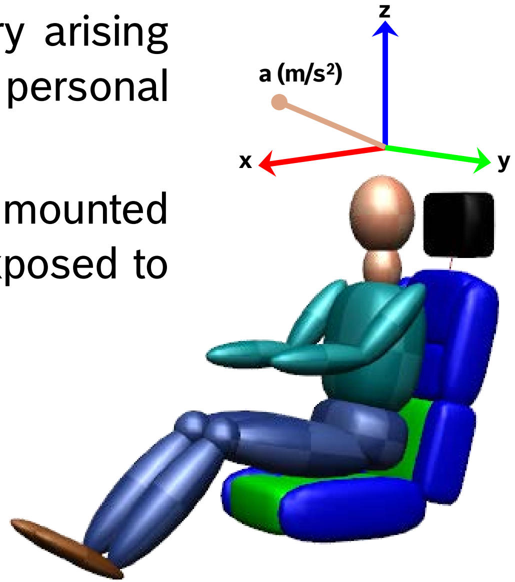
Accident Research: Injury severity estimation

Definitions: Head Injury Criteria (HIC)



- The Head Injury Criterion (HIC) is a measure of the likelihood of head injury arising from an impact. The HIC can be used to assess safety related to vehicles, personal protective gear, and sport equipment.
- Normally the variable is derived from the measurements of an accelerometer mounted at the center of gravity of a crash test dummy's head, when the dummy is exposed to crash forces.

$$HIC = \left\{ \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t)dt \right]^{2.5} (t_2 - t_1) \right\}_{max}$$



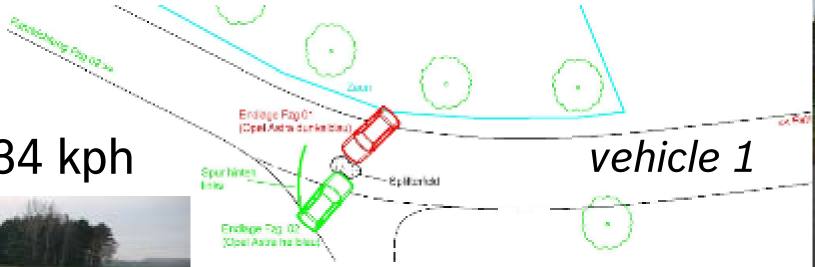
- t_1 and t_2 are the initial and final times (in seconds) of the interval during which HIC attains a maximum value, and acceleration a is measured in gs (standard gravity acceleration). The maximum time duration of HIC, $t_2 - t_1$, is limited to a specific value between 3 and 36 ms, usually 15 ms.

Accident Research: Injury severity estimation

Example: GIDAS case 1060835

vehicle 2

Collision speed =34 kph



vehicle 1

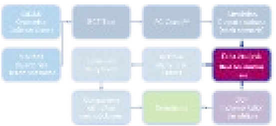
Collision speed =33 kph

Beschreibung des Unfallablaufes:

Bet. 01 befährt die Ortsverbindung von Cunnersdorf/Freitelsdorf in Richtung Schönfeld. Kurz vor dem Ortseingang Schönfeld fährt sie in einer Rechtskurve nicht weit genug rechts und stößt mit dem im Gegenverkehr befindlichen Bet. 02 zusammen. Dabei werden sowohl 01, als auch Fahrer und Beifahrer von 02 leicht verletzt..

- Both participants received minor injuries

Accident Research: Injury severity estimation
Example results



Accident 1060835 Vehícle 1 — HIC-15

Angle/Overlap	10%	20%	30%	40%	50%
150	2.4	117.3	177.4	17.4	[illegible]
160	2.5	198.8	215.5	[illegible]	230.6
170	1.0	103.5	[illegible]	[illegible]	219.1
180	0.7	[illegible]	[illegible]	201.1	205.2
190	1.1	[illegible]	150.5	157.0	162.7
200	[illegible]	9.2	95.8	102.8	112.6
210	2.2	12.3	62.8	60.4	66.4

Reduced injury

Angle

Overlap

HIC15 vehicle 1

Min	Max
0.73	230.62

Accident 1060835 Vehicle 2 — HIC-15

Angle/Overlap	10%	20%	30%	40%	50%
150	1.4	21.1	33.0	107.4	43.7
160	1.4	49.9	56.0	60.4	65.8
170	1.0	39.8	88.8	93.9	98.1
180	0.9	9.4	68.8	120.6	123.8
190	1.3	24.4	129.3	133.3	136.4
200	1.0	11.7	123.4	128.4	132.5
210	1.5	19.0	73.9	106.2	112.6

HIC15 vehicle 2

Min	Max
0.89	136.4

- Less overlap and higher angles result in lower HIC

GIDAS case 1060835

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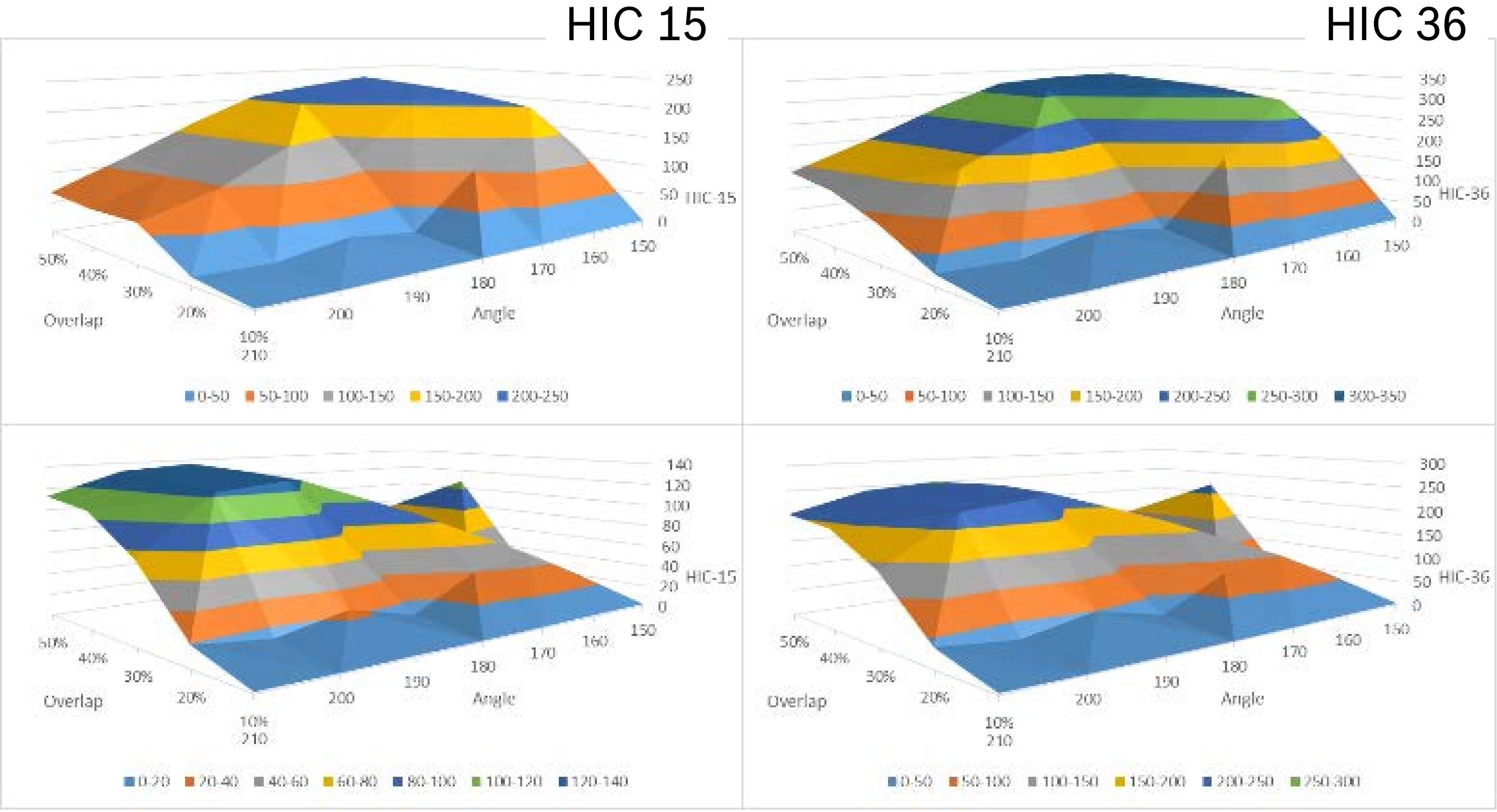
Accident Research: Injury severity estimation
Example results

Chapter 08

Vehicle 1

Vehicle 2



▶ Less overlap and higher angles result in lower HIC values

GIDAS case 1060835

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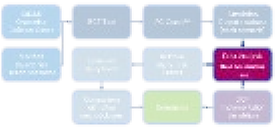
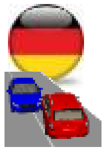
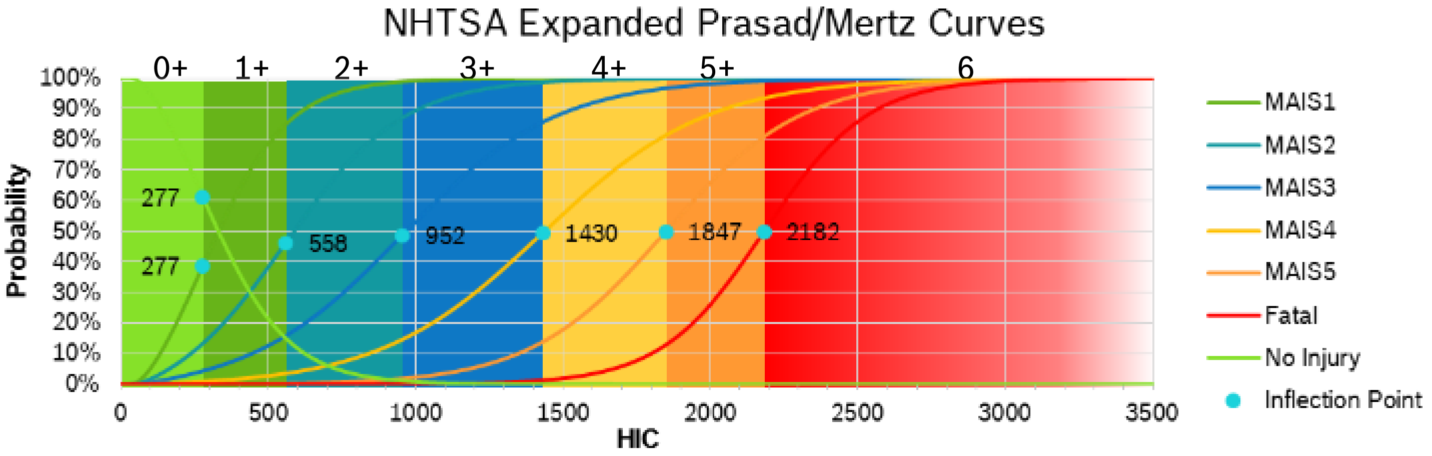
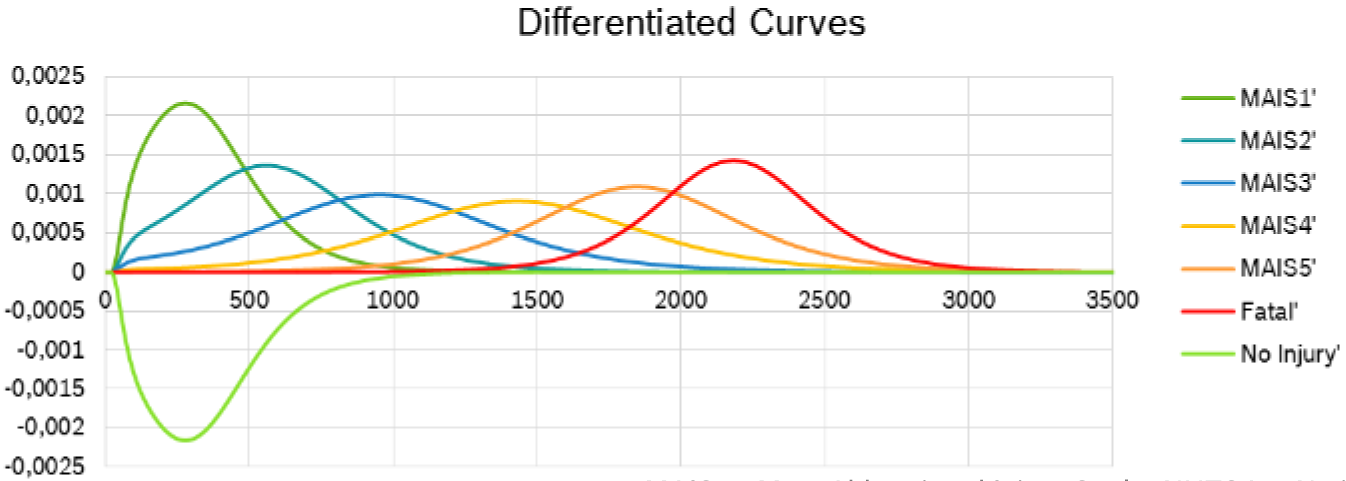




Accident Research: Injury severity estimation

Conversion from HIC to MAIS





$$P(MAIS\ 1) = \left[1 + e^{\left(1.54 + \frac{200}{HIC}\right) - 0.0065 HIC}\right]^{-1}$$

$$P(MAIS\ 2) = \left[1 + e^{\left(2.49 + \frac{200}{HIC}\right) - 0.00483 HIC}\right]^{-1}$$

$$P(MAIS\ 3) = \left[1 + e^{\left(3.39 + \frac{200}{HIC}\right) - 0.00372 HIC}\right]^{-1}$$

$$P(MAIS\ 4) = \left[1 + e^{\left(4.9 + \frac{200}{HIC}\right) - 0.00351 HIC}\right]^{-1}$$

$$P(MAIS\ 5) = \left[1 + e^{\left(7.82 + \frac{200}{HIC}\right) - 0.00429 HIC}\right]^{-1}$$

$$P(Fatal) = \left[1 + e^{\left(12.24 + \frac{200}{HIC}\right) - 0.00565 HIC}\right]^{-1}$$

MAIS := Max. Abbreviated Injury Scale; NHTSA = National Highway Safety Administration

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Accident Research: Injury severity estimation
Conversion results

▶ GIDAS case 30120538 used to explain methodology – real world severity: MAIS 3

Accident 30120538		Car	1		HIC-15
Angle/Overlap	10%	20%	30%	40%	50%
150	471	1213	1292	1447	1501
160	8	1511	1570	1623	1673
170	1	365	1692	1716	1726
180	1	315	1535	1566	1587
190	0	74	1151	1210	1273
200	5	622	684	751	809
210	115	111	415	492	576

Accident 30120538		Car	1		MAIS
Angle/Overlap	10%	20%	30%	40%	50%
150	1+	3+	3+	4+	4+
160	0+	4+	4+	4+	4+
170	0+	1+	4+	4+	4+
180	0+	1+	4+	4+	4+
190	0+	0+	3+	3+	3+
200	0+	2+	2+	2+	2+
210	0+	0+	1+	1+	2+

HIC → MAIS

Accident 30120538		Car	2		HIC-15
Angle/Overlap	10%	20%	30%	40%	50%
150	134	325	345	498	568
160	11	552	631	695	1011
170	2	165	1000	1057	1116
180	1	275	1316	1345	1363
190	0	102	1425	1447	1458
200	2	1273	1317	1356	1387
210	31	153	1052	1145	1200

Accident 30120538		Car	2		MAIS
Angle/Overlap	10%	20%	30%	40%	50%
150	0+	1+	1+	1+	2+
160	0+	1+	2+	2+	3+
170	0+	0+	3+	3+	3+
180	0+	0+	3+	3+	3+
190	0+	0+	3+	4+	4+
200	0+	3+	3+	3+	3+
210	0+	0+	3+	3+	3+

HIC15 PKW1

Min	Max
0	1726

HIC15 PKW2

Min	Max
0	1458

MAIS PKW1

Min	Max
0+	4+

MAIS PKW2

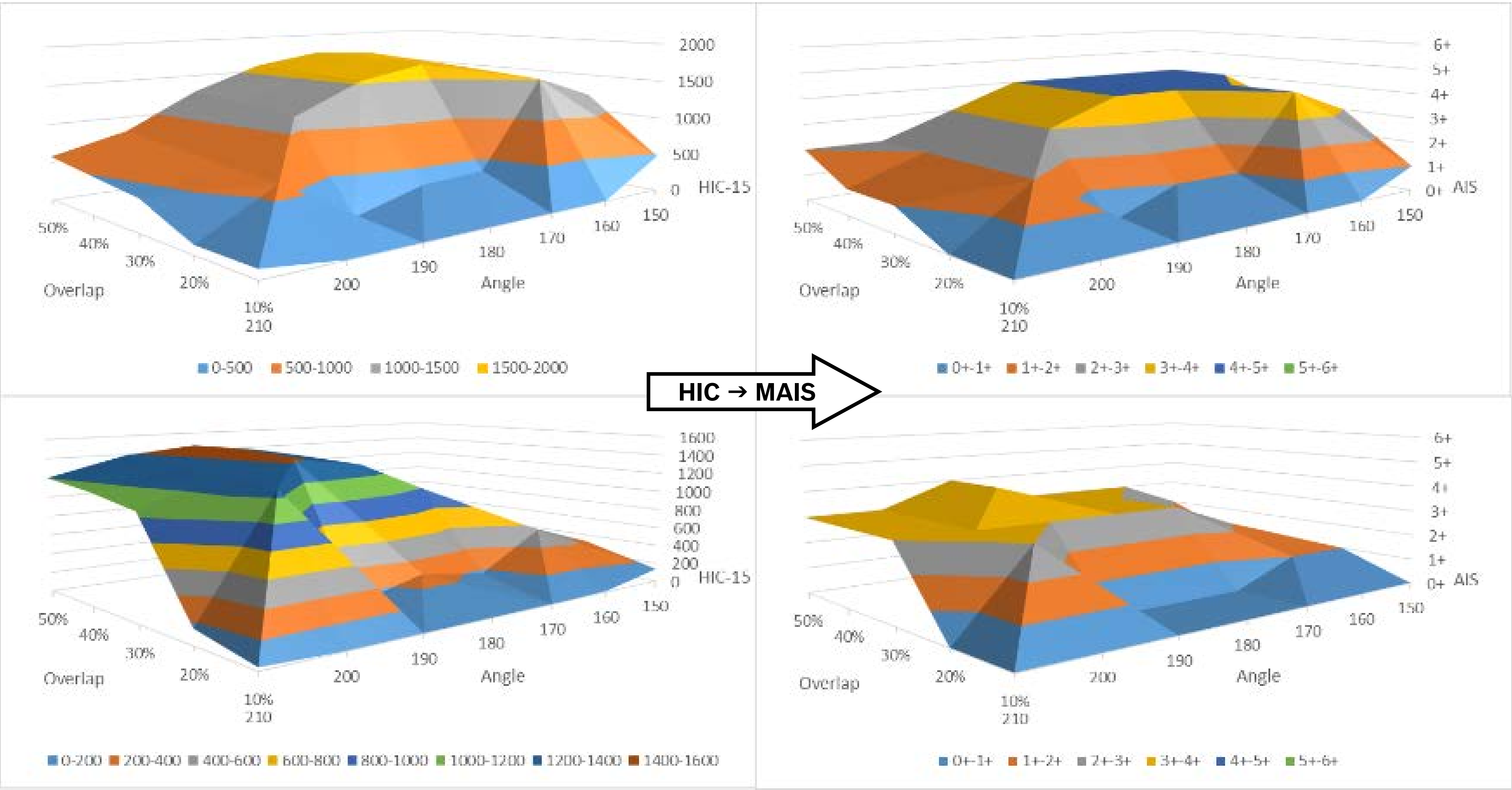
Min	Max
0+	4+

Accident Research: Injury severity estimation

Conversion results based on GIDAS case #30120538

Vehicle 1

Vehicle 2



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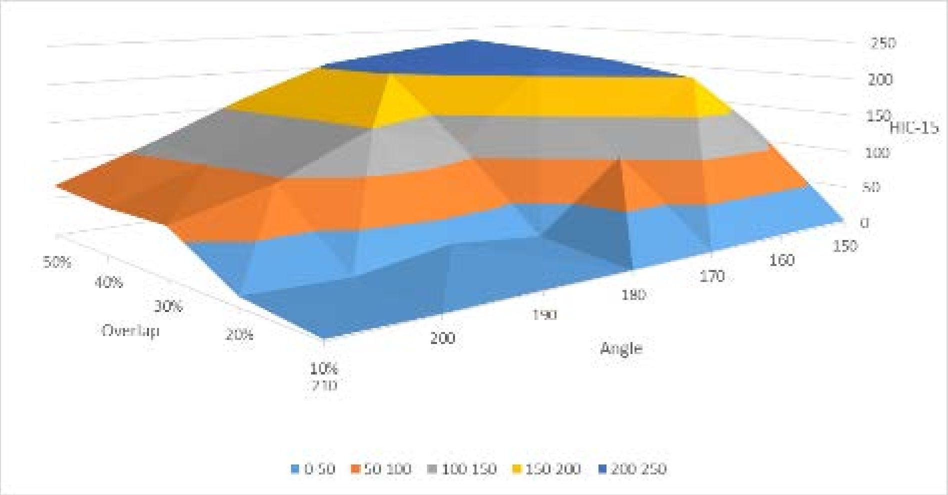
AEV-064 annual report 2016/17

Accident Research: Injury severity estimation
Preliminary Outlook

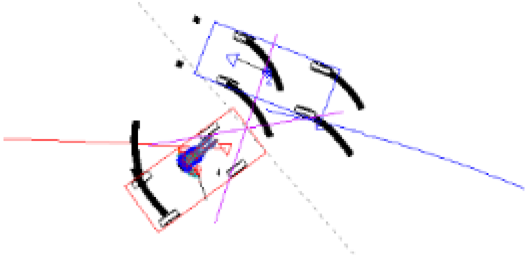
- HIC-15 much lower at overlap ≤ 20% and angles ≥ 180°

- 20% overlap and 180° angle (center)
  → 20% overlap and 170° angle (left)
  → 30% overlap and 180° angle (right)

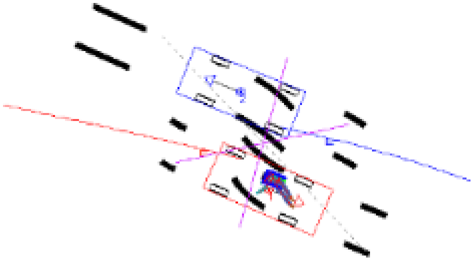
- Post collision trajectory analysis indicates causes for higher values



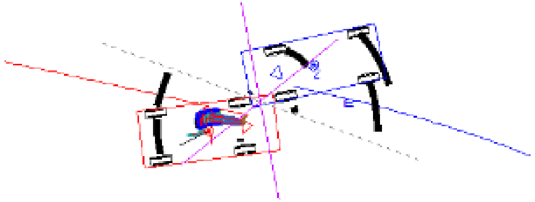
OL20 KW170



OL20 KW180



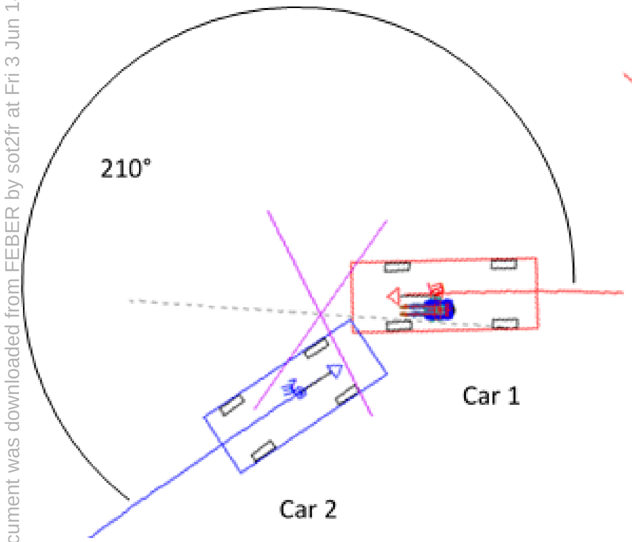
OL30 KW180

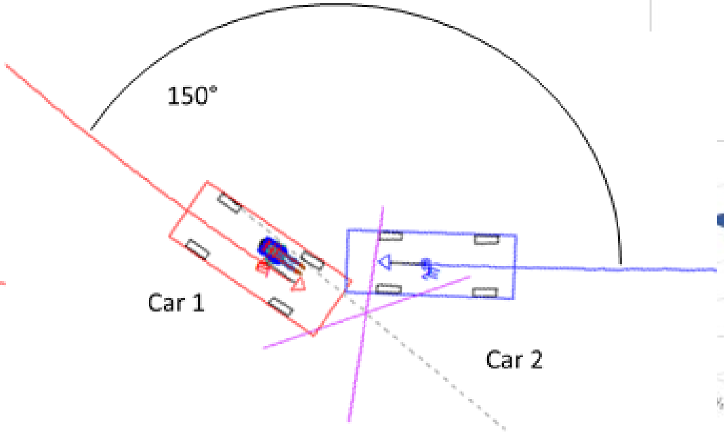


Accident Research: Injury severity estimation
Impact of angle and overlap

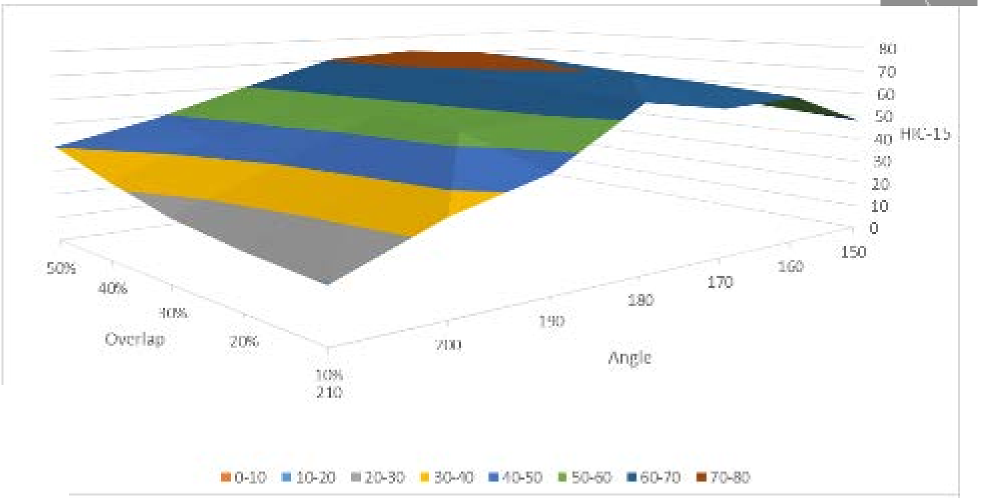
▶ Angle and overlap are a matter of perspective

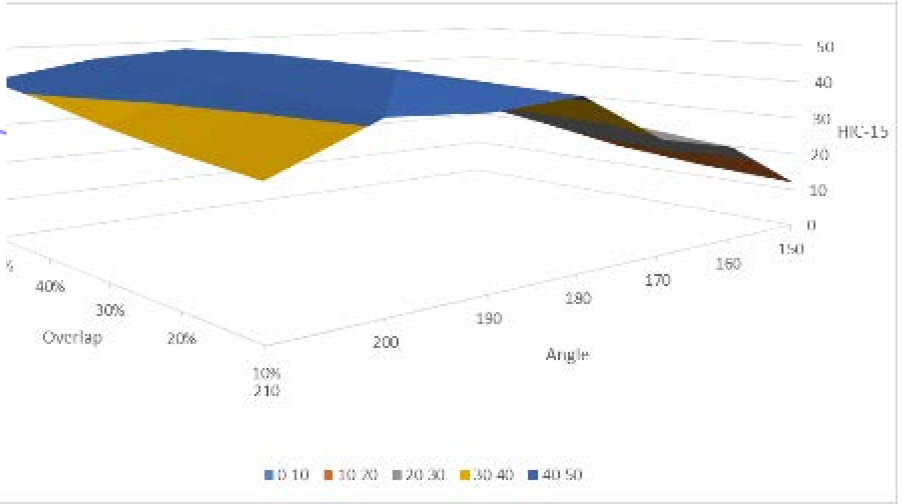
Vehicle 1's perspective





Vehicle 2's perspective





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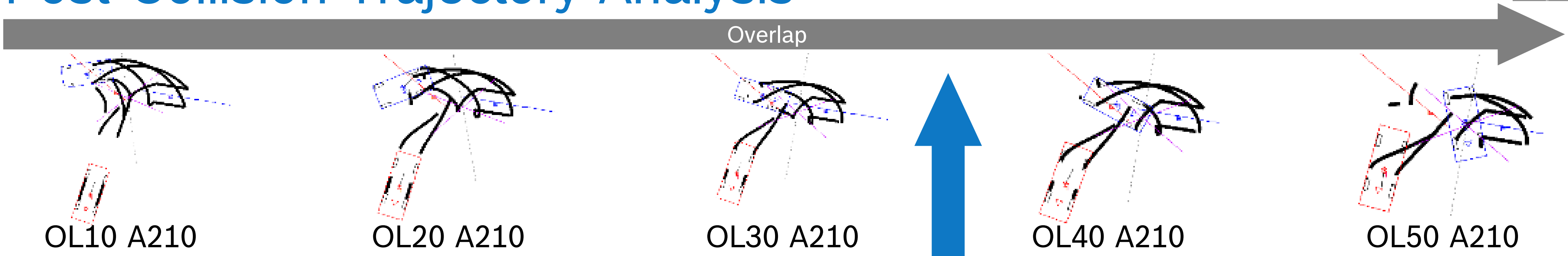
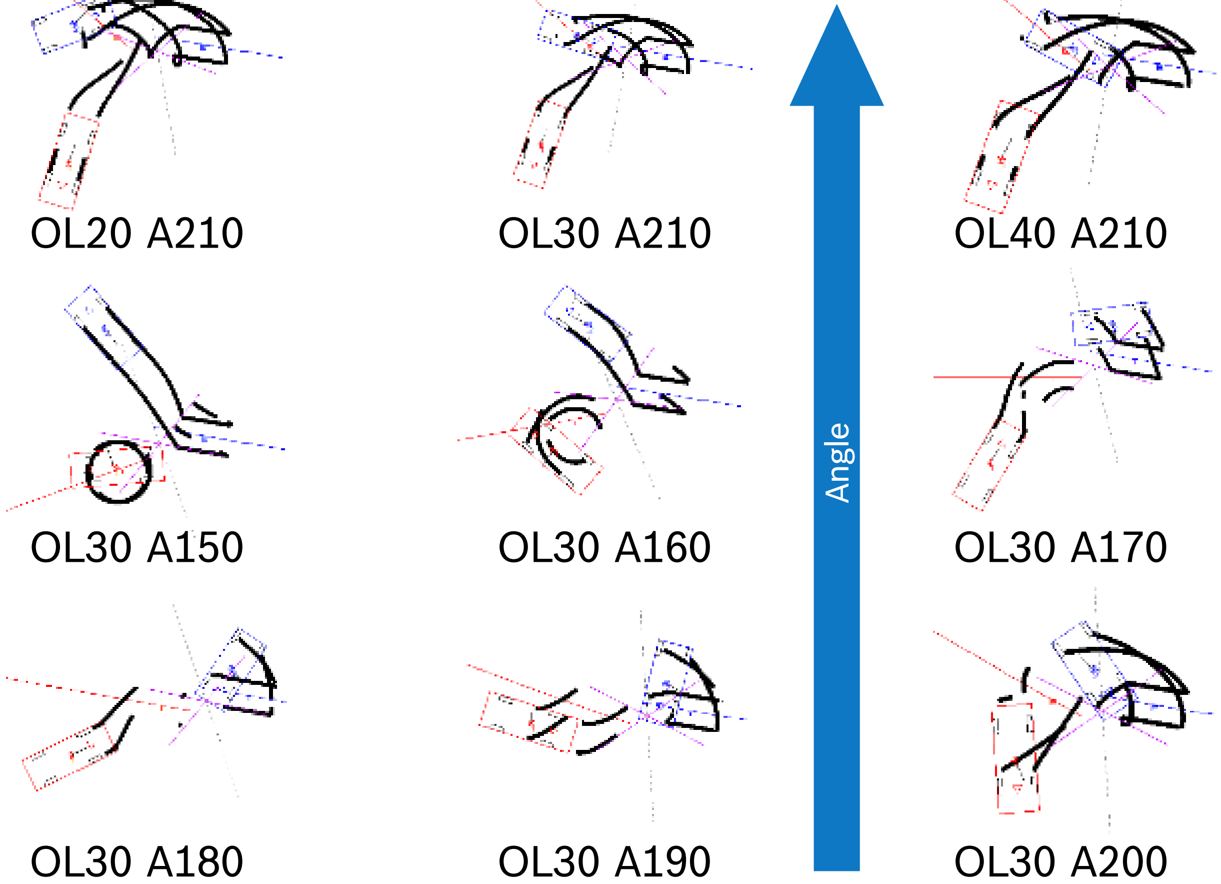
Accident Research: Injury severity estimation

Post-Collision Trajectory Analysis



Increasing overlap raises amount of momentum exchanged and as a result lowers post-collision velocity



The angle determines the direction of the resultant momentum and how much momentum is converted to angular momentum

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Accident Research: Injury severity estimation
OCP implementation for simulation

- **Baseline:** GIDAS case #1120731 (Offset 50%, Angle 180°)
- **OCP intervention:** TTC = 500ms; steer to right
- Results shows potential to avoid the collision entirely → further system design to be evaluated again

Accident	1120731	Car	1		HIC-36
Angle /Overlap	**0.6%**	**8.5%**	**20%**	**30%**	**50%**
180					644.26
183				618.43	
185.5			608.39		
189		175.51			
190	2.09				

Accident	1120731	Car	2		HIC-36
Angle /Overlap	**0.6%**	**8.5%**	**20%**	**30%**	**50%**
180					603.05
183				627.81	
185.5			614.67		
189		216.80			
190	0.66				

Accident Research: Injury severity estimation

Simulation demonstration

GIDAS case #1120731

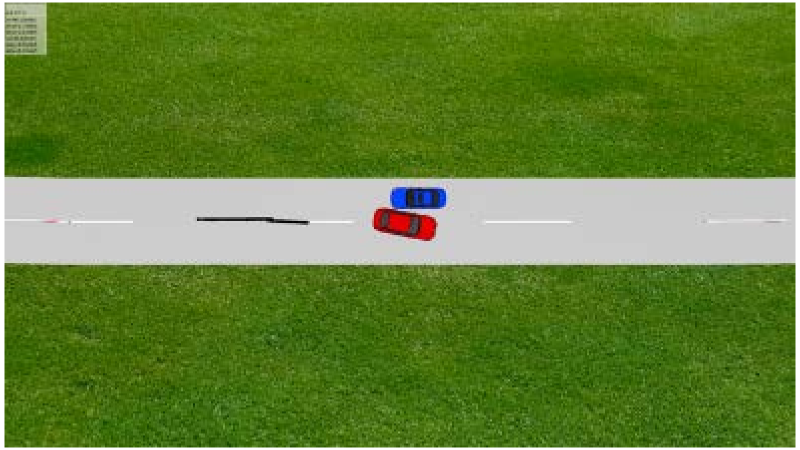
Scenario	Collision?	Collision Angle	Collision Overlap	HIC-15	Time	HIC-36	Max Head Acc.	Time	MAIS	P(No Injury)	P(MAIS 3+)
Baseline: No OCP	**Yes**	**180°**	**50%**	**539.106**	**5,003 ms**	**770.670**	**73.93 g**	**5,009 ms**	**1+**	**16.89%**	**14.74%**
Braking/Steering 200ms before collision	Yes	186°	18%	31.949	5,023 ms	52.983	25.54 g	5,095 ms	0+	99.95%	0.01%
Braking/Steering 300ms before collision	Side Front Collision	188°	-	1.078	4,175 ms	2.374	5.62 g	4,180 ms	0+	100.00%	0.00%
Braking/Steering 500ms before collision	Side Rear Collision	189°	-	3.118	5,095 ms	6.199	9.96 g	5,217 ms	0+	100.00%	0.00%
Braking/Steering 800ms before collision	No	-	-	0.016	4,714 ms	0.037	1.18 g	2 ms	0+	100.00%	0.00%
Steering 800ms before collision	No	-	-	0.022	4,821 ms	0.046	1.19 g	4,833 ms	0+	100.00%	0.00%
Braking 900ms before collision	No	-	-	0.008	0 ms	0.015	1.18 g	2 ms	0+	100.00%	0.00%

Example:

Braking/Steering 200ms before coll.

HIC-15: 31 << 1.000

P(No Injury): 99.95%



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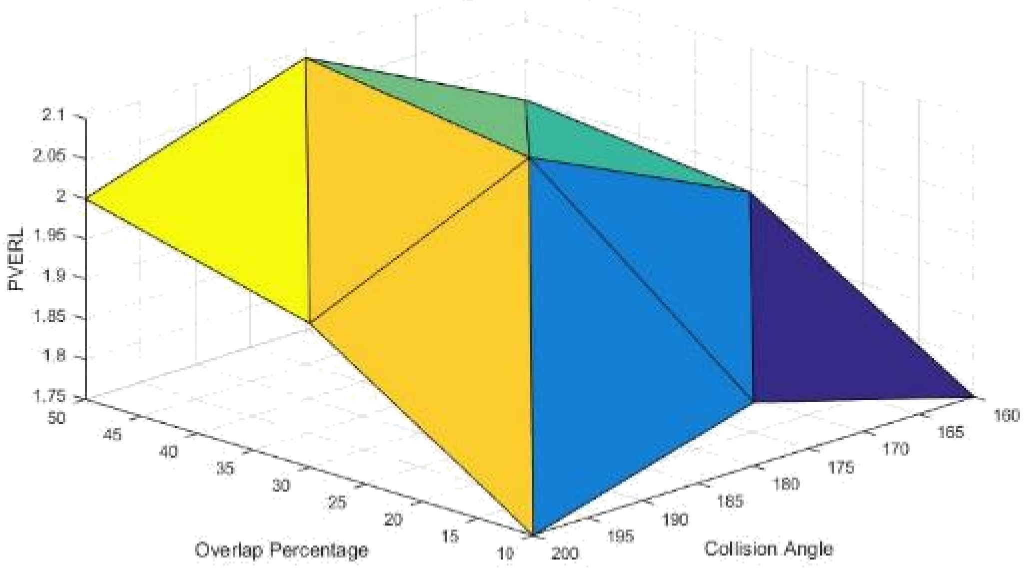
Accident Research: Injury severity estimation

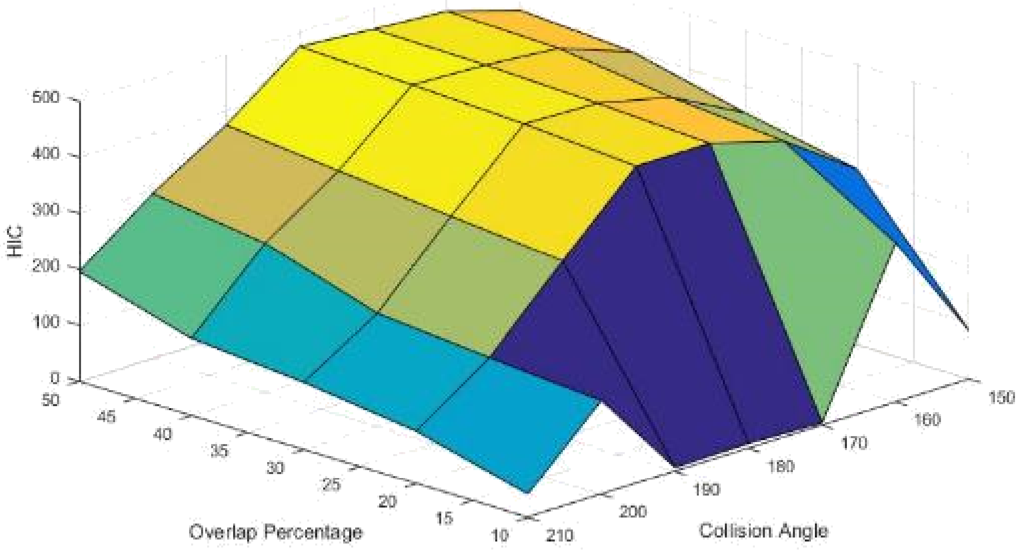
Comparison against study 1: Statistical Model & Data Mining

- **Result:** Both methodologies seem to indicate a similar result
- Data mining results are more symmetrical in terms of angle

Study 1: Statistical model



Study 2: Simulation based approach



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Accident Research: Injury severity estimation
Summary & Conclusion

- Independent approach of study 1 and 2 leads to similar results
- Less overlap and higher collision angle results in reduced injury levels
  - Less overlap leads to less momentum being exchanged, thus a higher post-collision velocity
  - Higher angles lead to more post-collision angular momentum
  - After point of collision, the OCP system should control the path of the vehicle by counter steering
- Results indicate that even if the system fails to avoid collision, it could still mitigate head injury levels by effectively lowering the overlap and increasing the collision angle
- System trigger >~600ms before a potential collision for safety and comfort purposes should be targeted
- Both methodologies applicable to assess the impact of an OCP function ones the system is designed anyhow the obtained result give an indication of the effectiveness and can be used for promotion purposes. For real effectiveness evaluation customer specific models should be considered.

Chapter 09

Germany: Benefit estimation of AEBS for heavy trucks

Accident Research
CR/AEV1

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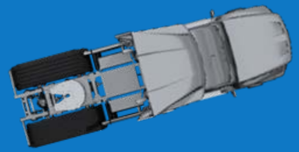
Accident Research – CVO
Overview Results Accident Analysis

	 **N1** (Results all to N2 related crashes)	 **N2** (Results all to N2 related crashes)	**N3** (Results all to N3 related accidents) (100% installation rate assumed) 
ESC	Field of effect: **6%** Benefit: n/a	Field of effect: **5%** Benefit: n/a	Field of effect: **5%** Benefit: **3% - 4%** Status: Exchange w/ M.Horn on skidding accidents ongoing
LDW/LKS	Field of effect: **13%** Benefit: n/a	Field of effect: **7%** Benefit: n/a	Field of effect: **13%** 1st estimation: **~4%** Status: Simulation in validation process Exchange w/ CC-DA/EPC1 Sascha Siegmund needed
AEBS	Field of effect: **20%** Benefit: n/a	Field of effect: **16%** Benefit: n/a	Field of effect: **20%** Benefit EU conform system: **~14%** Benefit for variant 1 (real): **~11%** Communicated

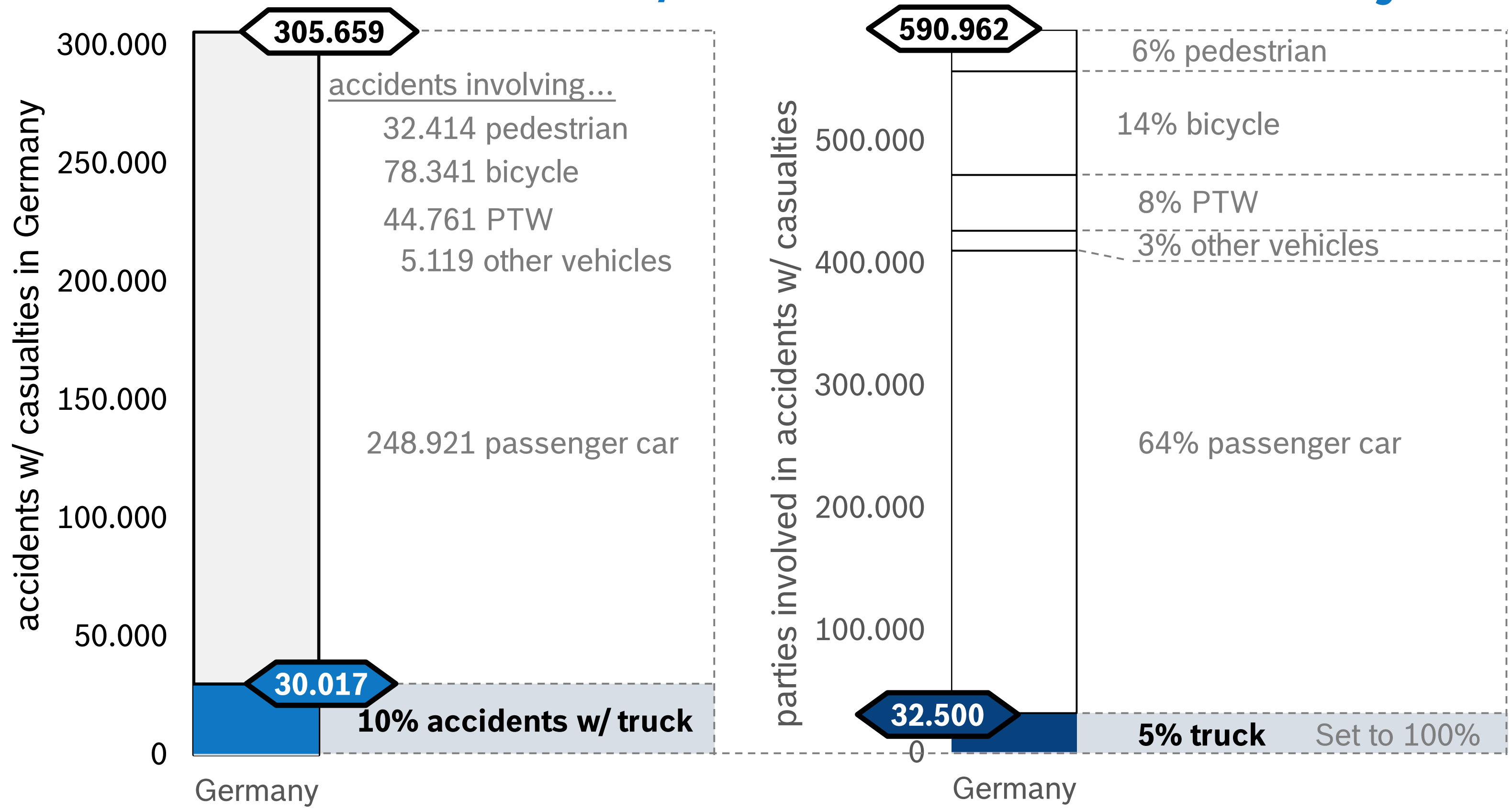
▶ **Next steps:** Incorporation of driver behavior required in 2018

Accident Research: Heavy Commerical Vehicles

Overview truck accidents w/ casualties in Germany

Chapter 09

2015



- In 10% of all accidents w/ casualties in Germany involve trucks
- Overall 32.500 trucks (5%) involved in all accidents w/ casualties in Germany

Internal | Bosch Accident Research (CR/AEV1-Sk) | Jan/31/2018
AEV-064 annual report 2016/17

Source: DeSTATIS Yearbook 2015, "Unfälle von Güterkraftfahrzeugen im Straßenverkehr"

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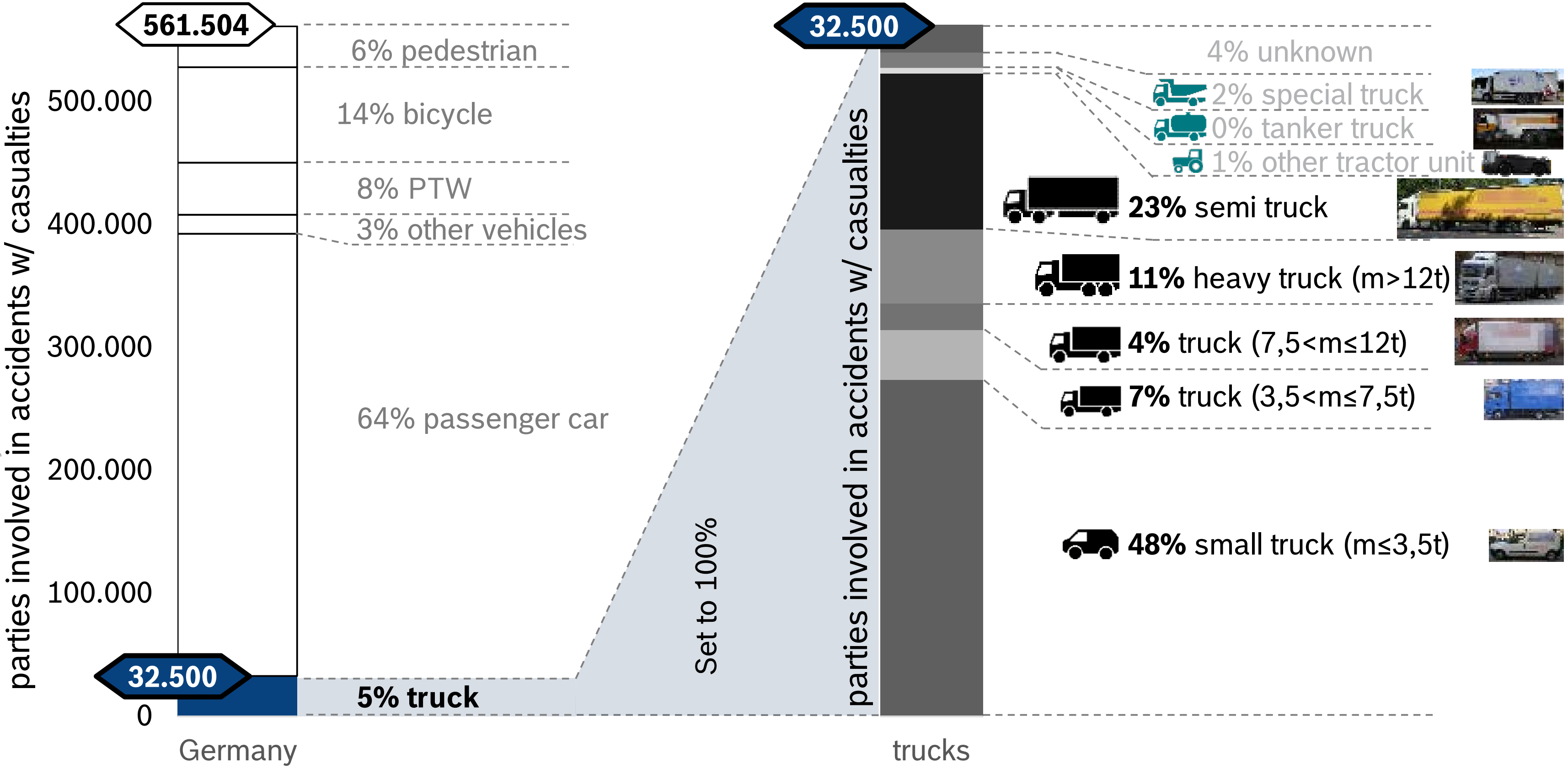
Accident Research: Heavy Commerical Vehicles

Chapter 09

Truck involvement in accidents w/ casualties in Germany

2015



- Trucks are seldom involved in accidents on German roads.
- Reasonable share of semi trucks within truck accidents.
- High share of small trucks within truck accidents.

▶ Truck safety required for all classes hence evaluation of current accident situation required for N1, N2 and N3 vehicles

Internal | Bosch Accident Research (CR/AEV1-Sk) | Jan/31/2018
AEV-064 annual report 2016/17

Source: DeSTATIS Yearbook 2015, “Unfälle von Güterkraftfahrzeugen im Straßenverkehr“

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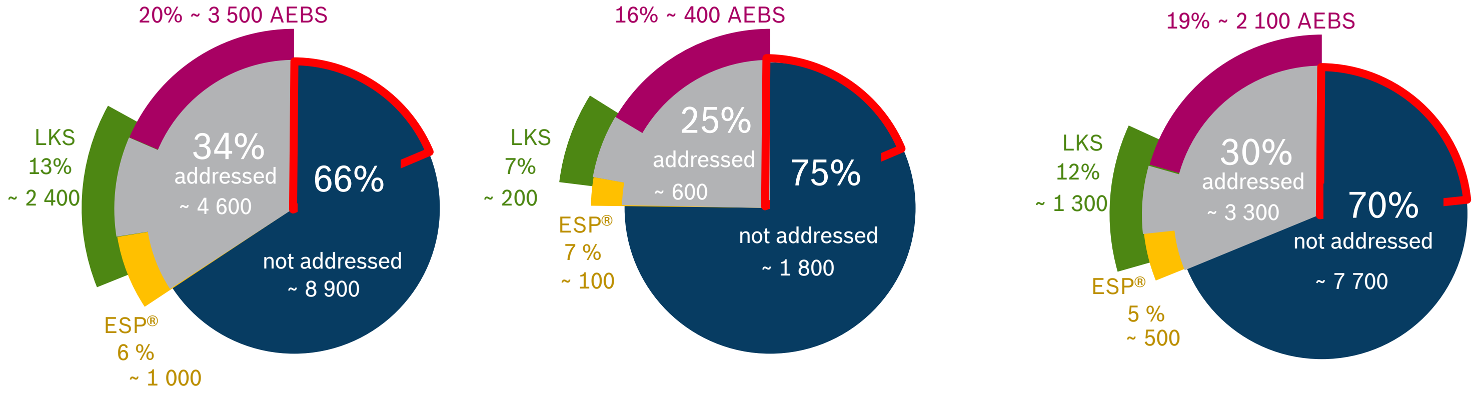
Accident Research: Heavy Commerical Vehicles
Field of Effect - AEBS, LKS ESP® (CV)

Truck as primary party / responsible (not addressed crashes by AEBS, LDW/LKS, ESP)



17 600 Accidents w/ trucks ≤7,5t | **2 400 Accidents w/ trucks 7,5t to 12t** | **11 000 Accidents w/ trucks >12t**

AEBS: Truck as main causer of a rear-end crash
LDW/LKS: Truck with lane change manoeuvre before first collision
ESP®: Loss of control before first collision

- High share of truck crashes w/ casualties not addressed by state-of-the art system (AEBS, LKS,ESP®)
- For all classes further potential seen for either Assistance, Active- or Passive Safety
- **Focus:** N3 (>12t)

Source: GIDAS database (2001-2015) weighted and representative for Germany; N2 analysis includes also special vehicle sizes i.e. construction vehicles etc.

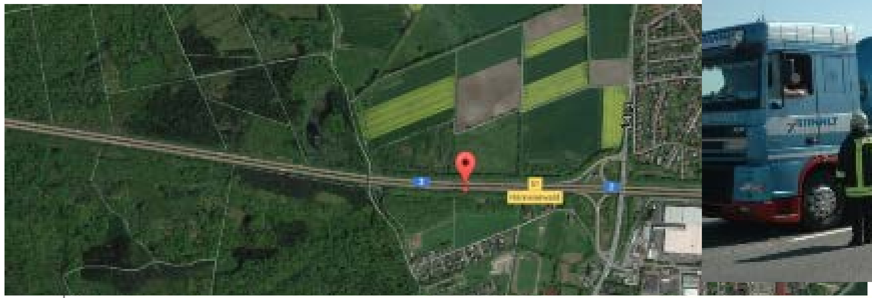
1 - GENERAL OVERVIEW

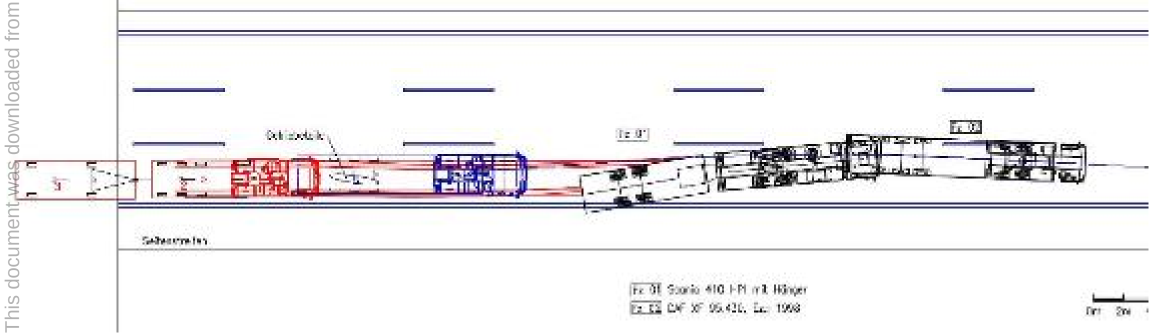
AEBS RELEVANT ACCIDENTS FOR TRUCKS >12T & FIELD OF EFFECT

Accident Research: Heavy Commerical Vehicles

Typical accident situation

- GIDAS case 30080299:
  truck on German highway (85 kph) crashes into other truck (0 kph)
  at end of traffic jam (collision speed 75 kph)





GIDAS
GERMAN IN-DEPTH ACCIDENT STUDY

21 431 — Accidents with casualties

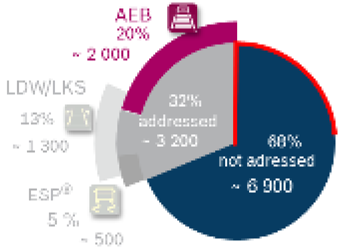
100%

796 — ... incl. N3 vehicles

147 — ... AEBS scenario

Statistical analysis based on

- 147 AEBS relevant accidents w/ casualties
- involving heavy trucks (N3)
- weighted for Germany



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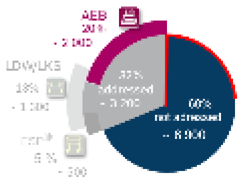
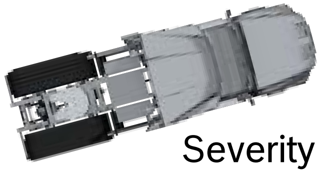
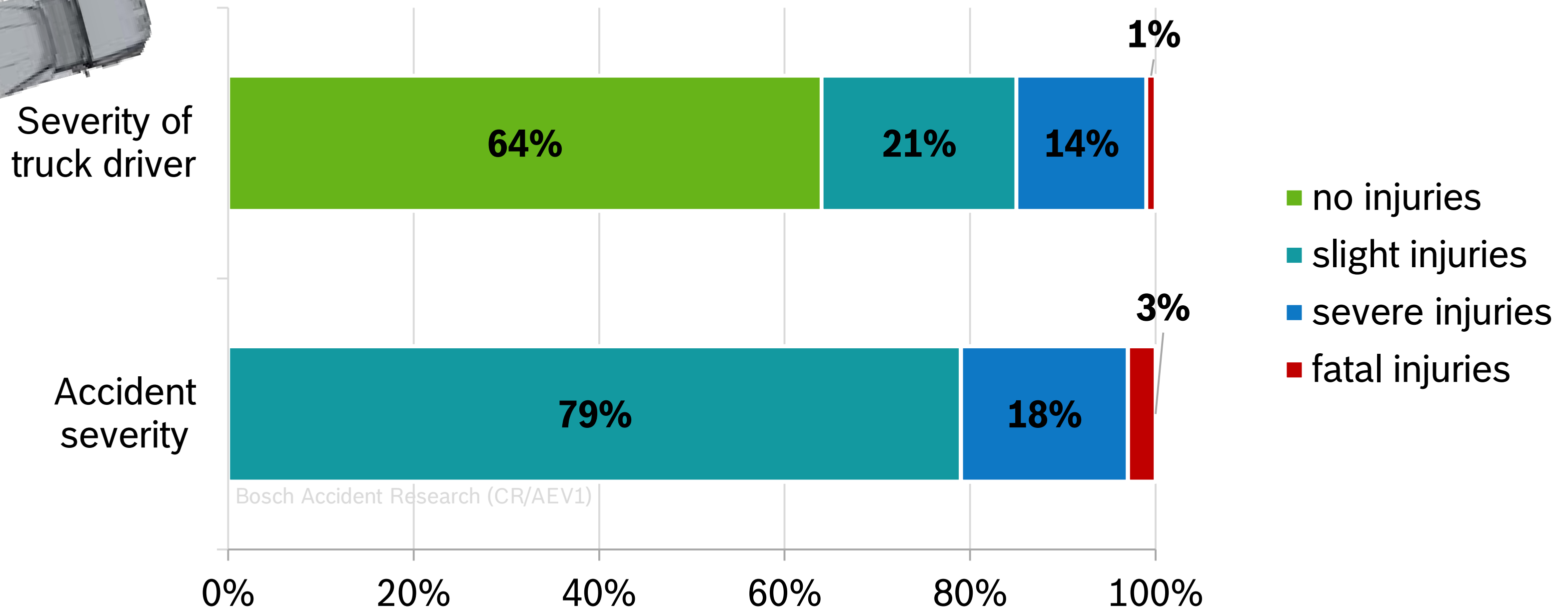
Severity for AEBS relevant N3-vehicle rear-end crashes







- Benefit of AEBS mainly given for opponent nevertheless in nearly every 2nd collision the truck driver was also injured

Internal | Bosch Accident Research (CR/AEV1-Lh, Si) | Jan/31/2018 Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

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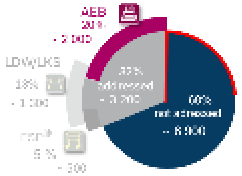
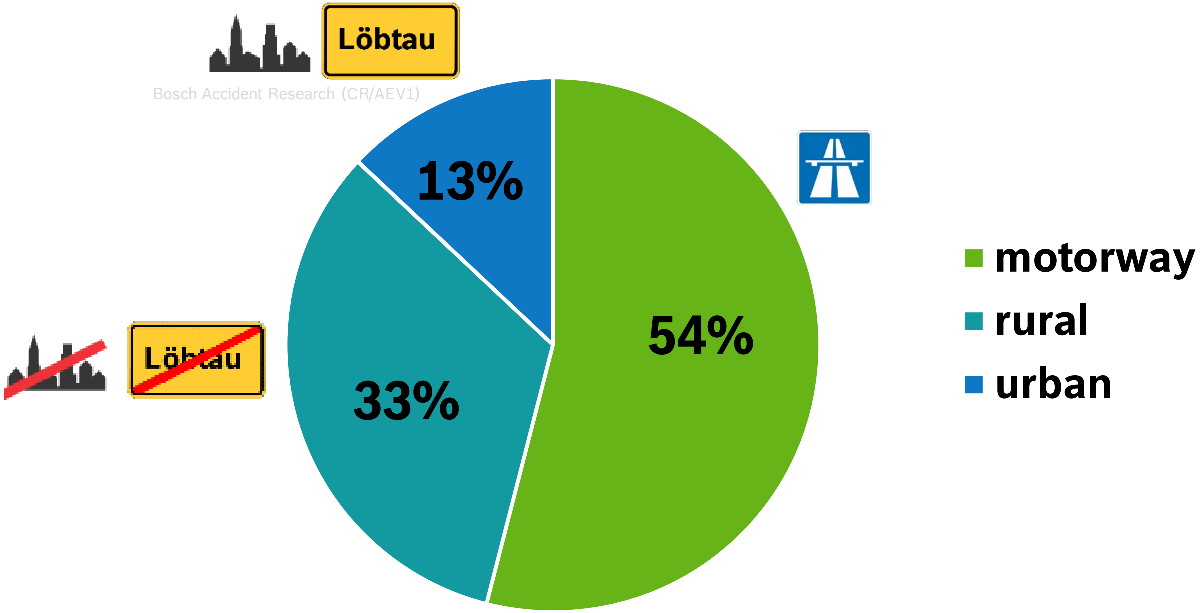
Chapter 09

Location for AEBS relevant N3-vehicle rear-end crashes





▶ Half of all AEBS relevant collisions w/ casualties are on motorway

Internal | Bosch Accident Research (CR/AEV1-Lh, Si) | Jan/31/2018
AEV-064 annual report 2016/17

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

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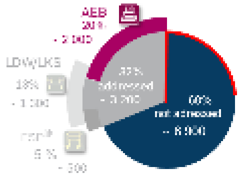
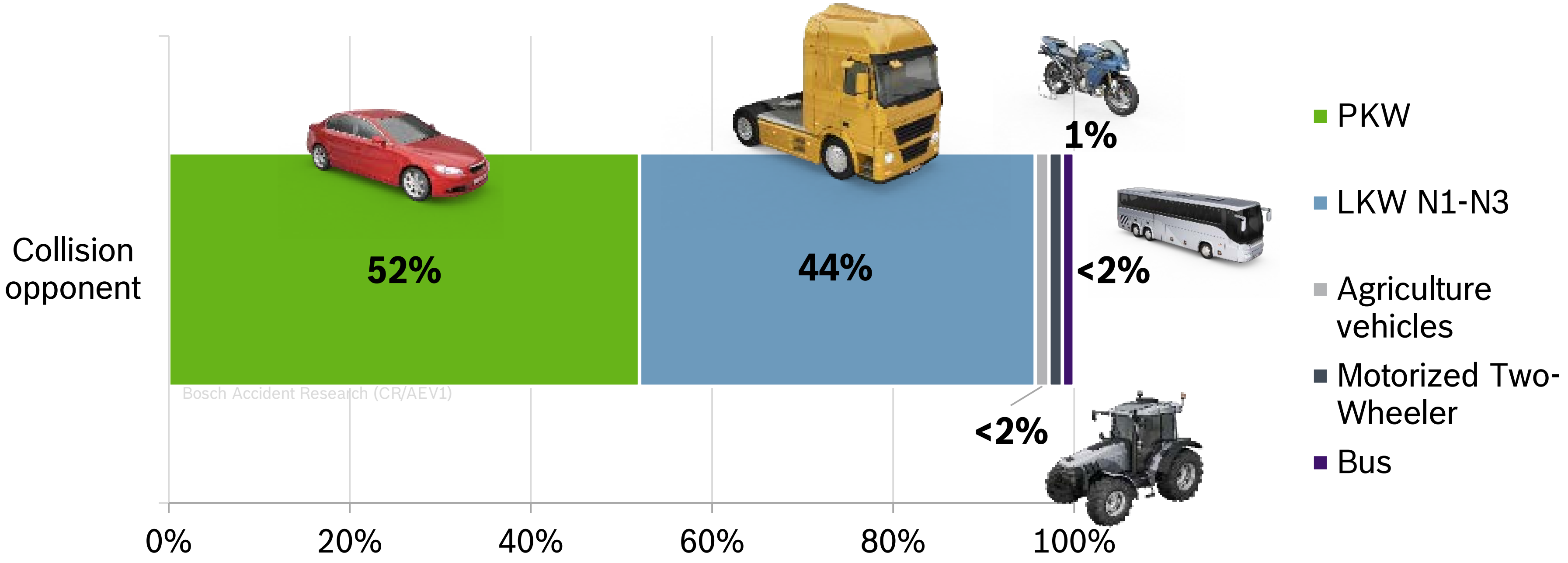
Opponent for AEBS relevant N3-vehicle rear-end crashes





- Main collision opponent are either trucks or passenger cars therefore no sensor detection problems assumed

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

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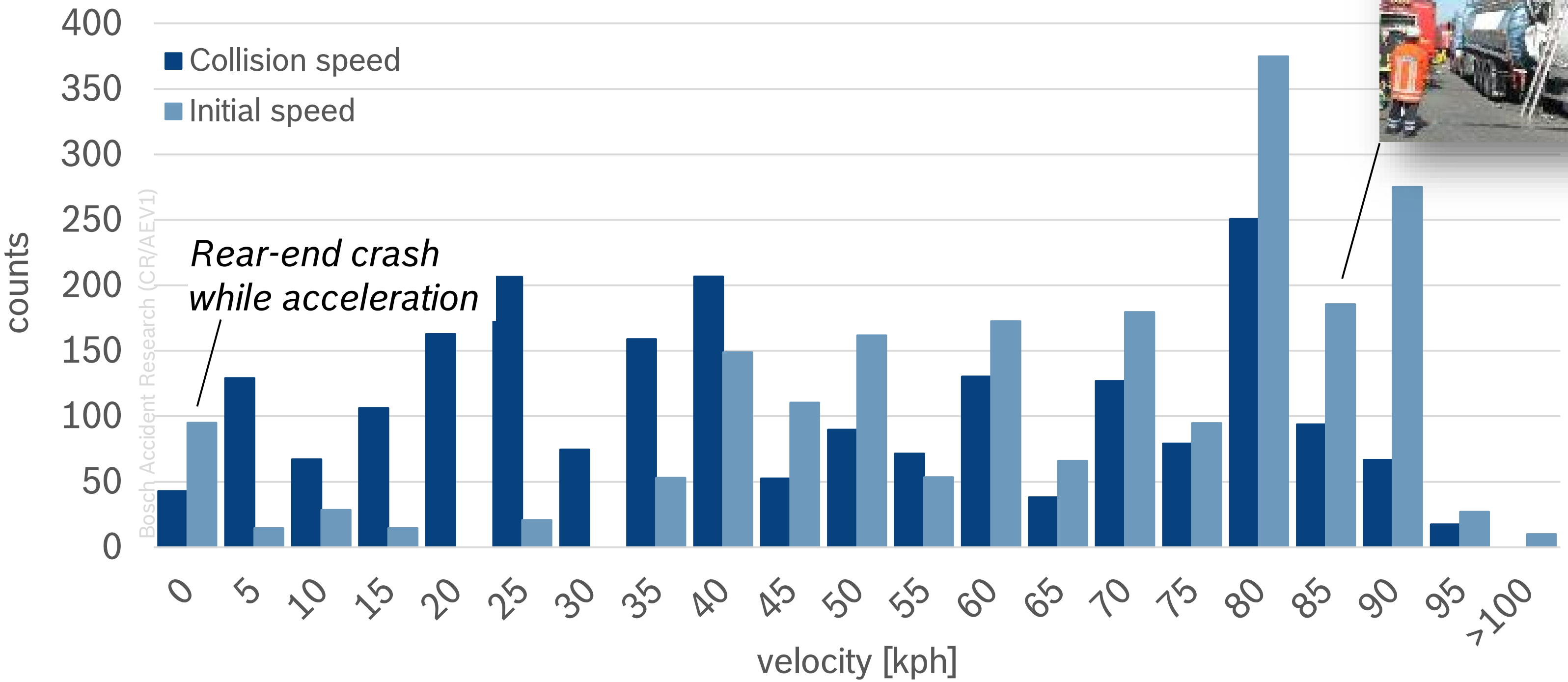
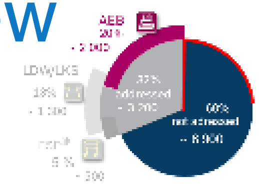
Accident Research: Heavy Commerical Vehicles

Init. & coll. speed in AEBS relevant crashes (N3) – Overview





initial speed:
Ø 64 kph

collision speed:
Ø 45.7 kph

- Bosch considers AEBS from initial speed >0 kph, hence more benefits achieved compared to EU approach which considers >15 kph

Internal | Bosch Accident Research (CR/AEV1-Lh, Si) | Jan/31/2018
AEV-064 annual report 2016/17

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

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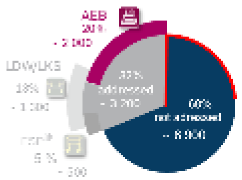
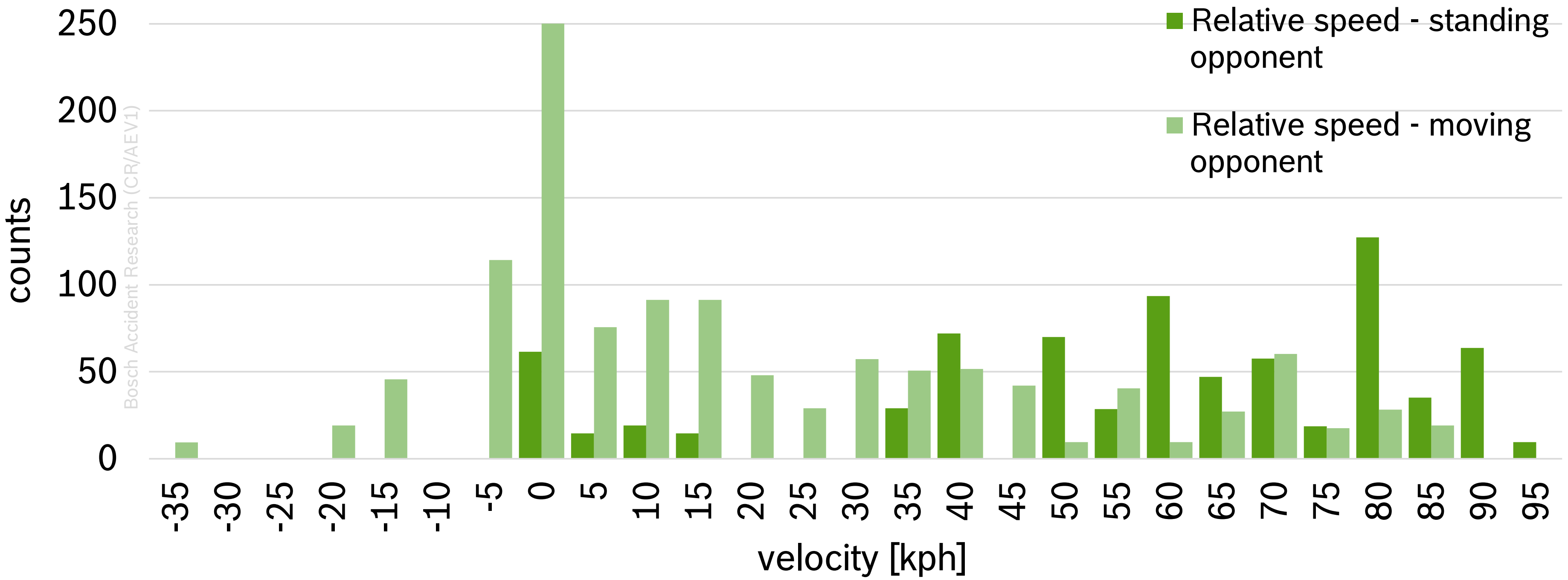
Accident Research: Heavy Commerical Vehicles

Chapter 09

Relative initial speed in AEBS relevant crashes (N3)





- Relative initial speed for standing opponent ($\varnothing v_{rel}$ = 57 kph) reasonable larger compared to moving opponent ($\varnothing v_{rel}$ = 32 kph)

Internal | Bosch Accident Research (CR/AEV1-Lh, Si) | Jan/31/2018
AEV-064 annual report 2016/17

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

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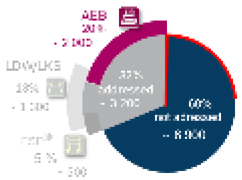
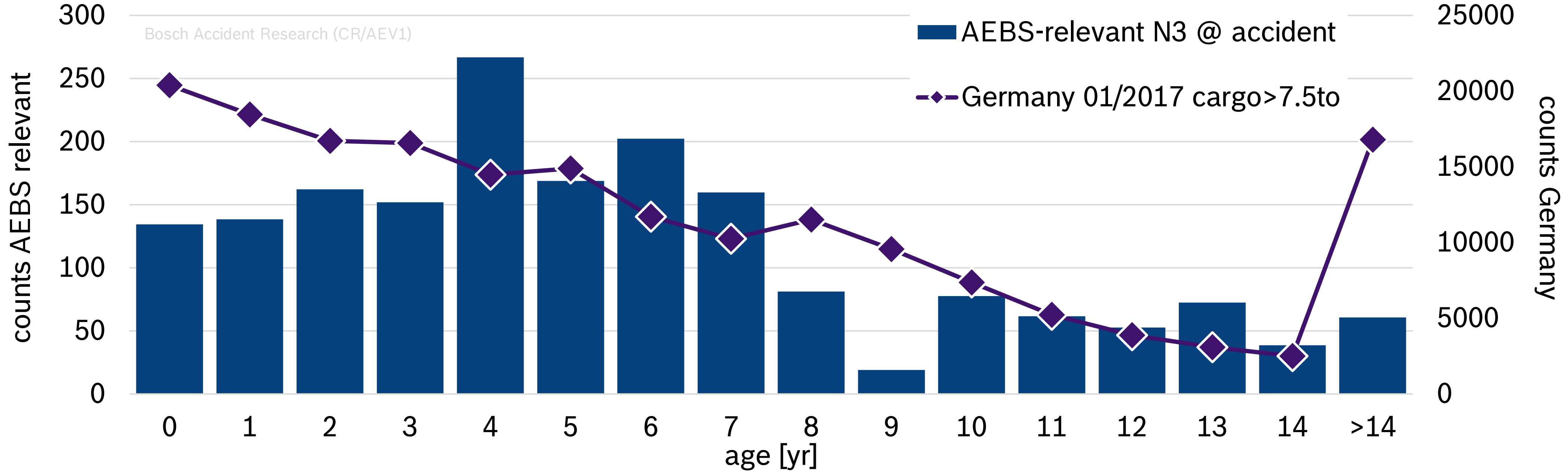
Accident Research: Heavy Commerical Vehicles

Chapter 09

Age of trucks in AEBS relevant crashes (N3)



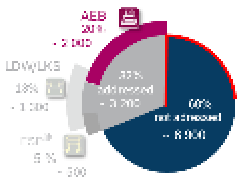


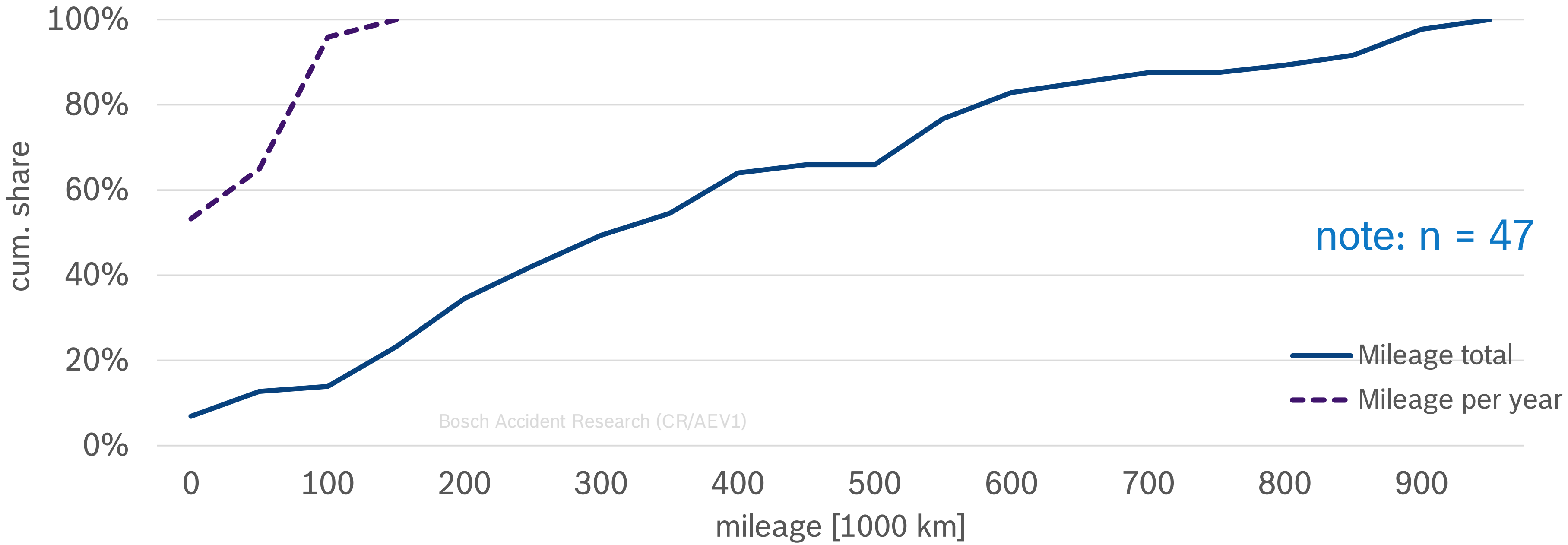
▶ Most trucks involved in AEBS relevant accidents younger than 8 years

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=121 N3 caused rear-end collisions w/ casualties in Germany
Kraftfahrtbundesamt, Fahrzeugzulassungen FZ15

Accident Research: Heavy Commerical Vehicles

Mileage of trucks in AEBS relevant crashes (N3)





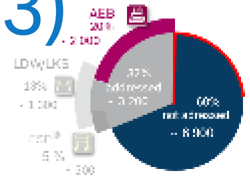
- 2 of 3 trucks drive up to 100 000 km per year
- 2 of 3 trucks drove < 500 000 km before crash - mileage mainly unknown (n = 100)

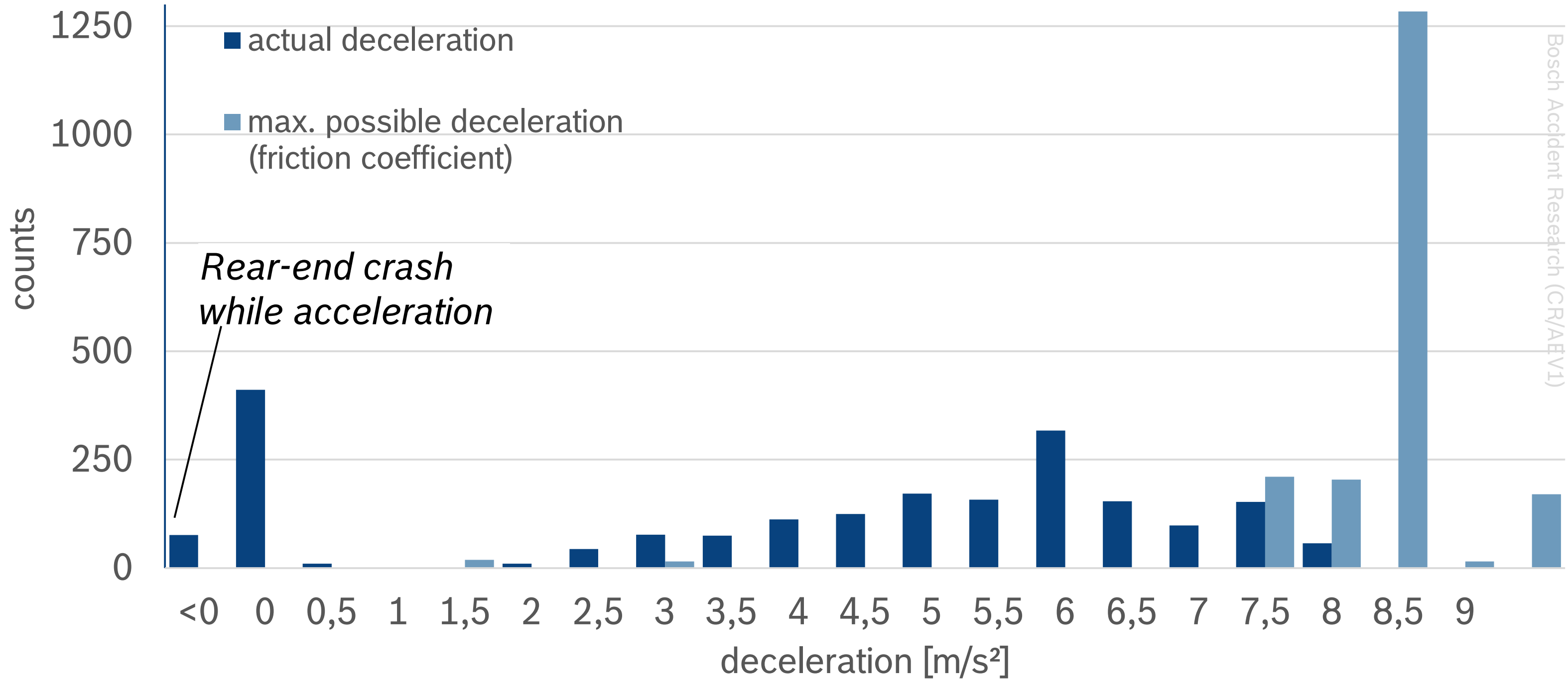
Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=47 N3 caused rear-end collisions w/ casualties in Germany

Accident Research: Heavy Commerical Vehicles

Chapter 09

Deceleration and frict. coeffic. in AEBS relevant crashes (N3)





friction coefficient estimated by Bosch accident research based on road condition (dry, wet, snow, ...) and type of road surface (concrete, asphalt, ...)

e.g. Asphalt

dry	moist	wet	snow
8.8 m/s²	8.0 m/s²	7.5 m/s²	3.0 m/s²

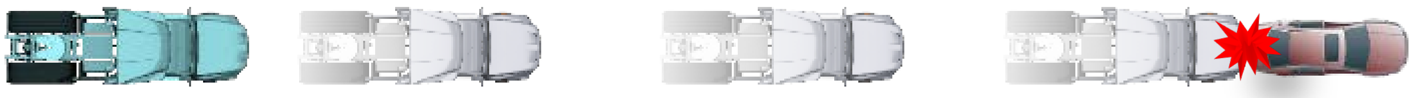
- Most AEBS relevant accidents on good road conditions (friction coefficient ≥ 8.0 m/s²)
- Deceleration applied by driver typically reasonably smaller than max. possible deceleration

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

Accident Research: Heavy Commerical Vehicles

Vehicle deceleration prior to rear-end collision

Accident situation



Evaluation based on reconstructed averaged deceleration taking street conditions into account

Driver behaviour Prior to rear-end crashes	Full braking 10%	Partial braking 66%	No braking 20%	Accelerating 4%
Assistance System	PCW Predictive Collision Warning	EBA Emergency Braking Assist	AEB Automatic Emergency Braking	

- **PCW** **Warning** by visual, acoustic and/or brake jerk
- **EBA** **Target braking** with driver brake input
- **AEB** **Automatic braking** to reduce speed of the vehicle and mitigate collision

▶ In every 5th rear-end accident caused by N3-vehicles the driver didn't apply the brakes

Internal | Bosch Accident Research (CR/AEV1-Lh, Si) | Jan/31/2018
AEV-064 annual report 2016/17

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=147 N3 caused rear-end collisions w/ casualties in Germany

2 - AEB SYSTEM

BENEFIT ESTIMATION BY STOCHASTIC SIMULATIONS

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Accident Research: Heavy Commerical Vehicles

Methodology via Simulation

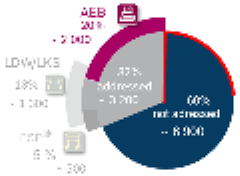
GIDAS database

Reconstructed accident data only

Field of effect

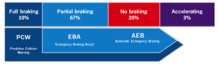
Select relevant crashes

- Primary truck impact w/ another vehicle at rear-end



Function & system characteristic

- Sensor model
- Braking performance wrt to accident situation

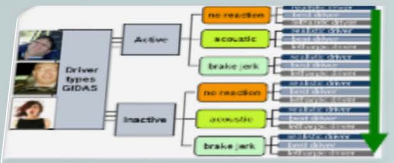


- System parameters
  → EU regulation /
  → Variants

Driver model

$\sum$ cases

Estimated effectiveness



Driver model

- *Combination of different driver characteristics*
- *Degree of attention*
- *Reaction to warning types*
- *Reaction times*

Automatic calculation

- Deceleration
- Street conditions
- **Stochastical** re-calculation for each driver combination

Note:
- Sensor model not considered yet → could be implemented
- Degree of attention – As of now no driver reaction / characteristics known

▶ For each driver scenario multiple simulations done and summed up

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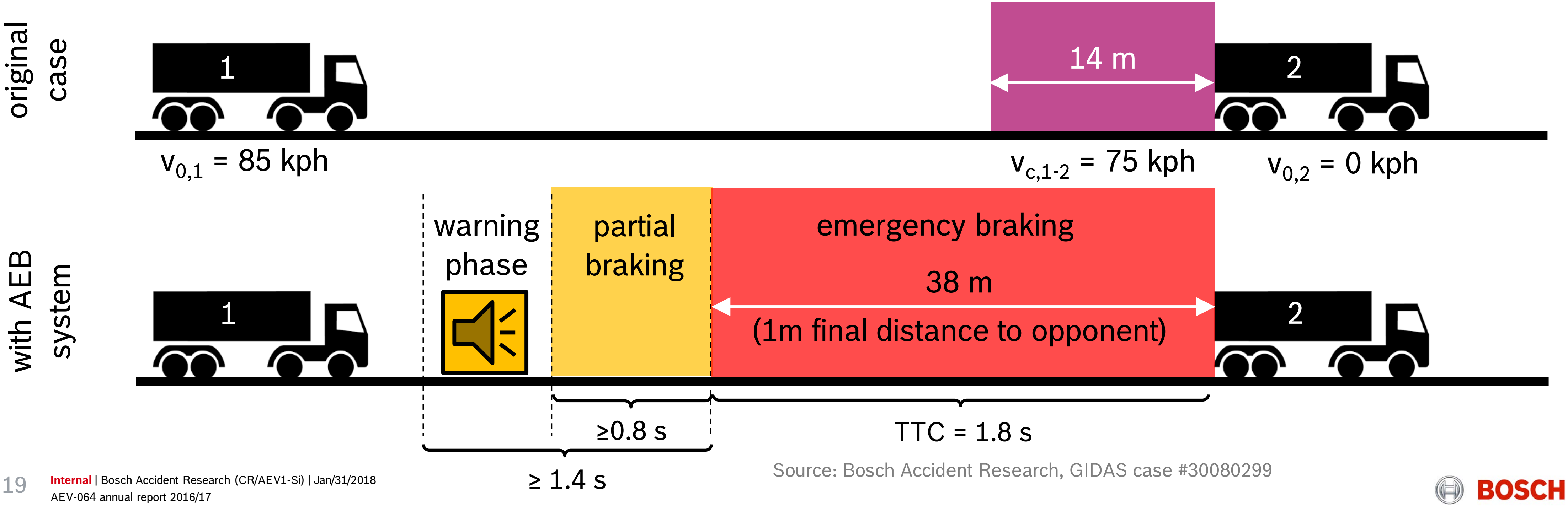
Accident Research: Heavy Commerical Vehicles

System specifications on example case

- Initial truck running w/ 85kph on motorway crashed w/ collision speed of 75kph into other truck (0kph) at the end of traffic jam
- Driver of perpetrator died where as other truck driver was not injured

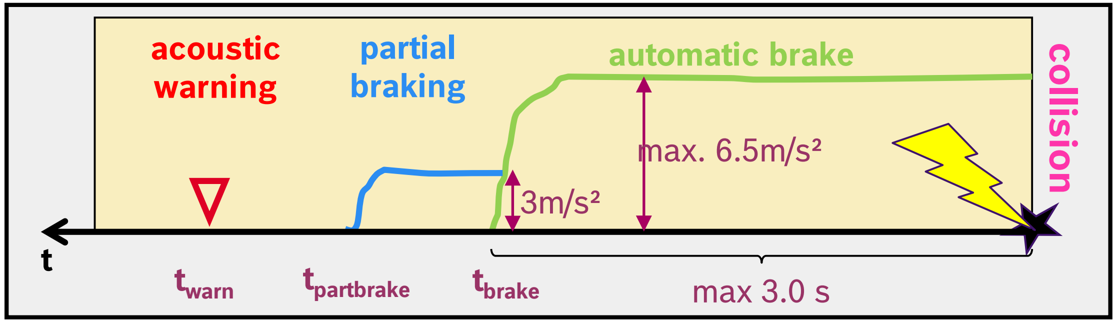


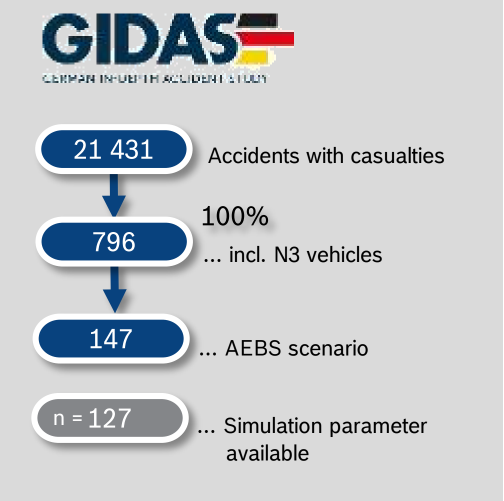
Source: Bosch Accident Research, GIDAS case #30080299

Accident Research: Heavy Commerical Vehicles

Variant: EU conform system (regulation no. 347/2012)

- **Warn strategy:**
  - 1st acoustic warning (min 1.4s before emergency braking)
  - 2nd partial braking with a=3m/s² (min 0.8s before emergency braking)
- **Emergency braking:**
  - target braking: 1m distance to opponent
  - taking constant deceleration of opponent into account
  - max. deceleration set to 6.5 m/s² (or lower given by road conditions)
- **Assumptions:**
  - EGO trajectories out of reconstruction used (n=127 with simulation parameter available)
  - partial braking does **NOT** overrule driver
  - in emergency braking phase w/ brake support for driver (i.e. max. deceleration)





	EU conform
t_{warn}	t_{brake} - 1.4s
$t_{partbrake}$	t_{brake} - 0.8s
t_{brake}	depends on situation

Internal | Bosch Accident Research (CR/AEV1-Si) | Jan/31/2018
AEV-064 annual report 2016/17

Accident Research: Heavy Commerical Vehicles

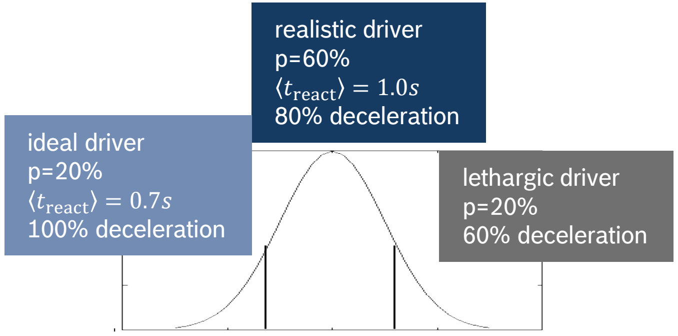
Truck driver model

Warning → reaction driver → reaction time → max. deceleration

yes/no | distribution | distribution

Assumptions:

- 50% of drivers react after acoustic warning
- driver reaction time stochastically distributed



- driver brakes with
  - 60% (lethargic),
  - 80% (realistic),
  - 100% (ideal)

  of full deceleration (given by μ_{max}, max 6.5m/²)

- **Status:**
  Currently no detailed information available for truck driver characteristics(e.g. reaction time)

Accident Research: Heavy Commerical Vehicles

Stochastic simulation

- Simulation flow

GIDAS

calculate original trajectory

simulate trajectories acoustic warning

simulate trajectories full AEB system

loop all 127 cases

draw histograms / calculate avoidance potential

- reconstruct original trajectories from GIDAS
- simulate each case in two scenarios

Scenario 1	Scenario 2
detect critical situation	detect critical situation
acoustic warning	acoustic warning
partial braking	partial braking
emergency brake	emergency brake

- Each trajectory describes vehicle positions for 7s in 10ms steps (5s pre-crash & 2s post-crash on original time scale)
- Statistical stability due to 127 x 2 x 10 000 = 2.54 Mio simulations

GIDAS
GERMAN IN-DEPTH ACCIDENT STUDY

21 431 Accidents with casualties

100%

796 ... incl. N3 vehicles

147 ... AEBS scenario

n = 127 ... Simulation parameter available

x 10 000 ... trajectories for each system and case

- **For each scenario 10 000 trajectories simulated → overall 2.54 million simulations**

Internal | Bosch Accident Research (CR/AEV1-Si) | Jan/31/2018
AEV-064 annual report 2016/17

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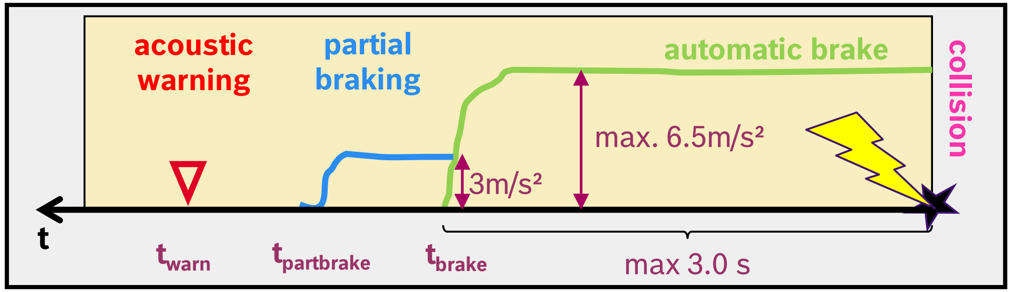
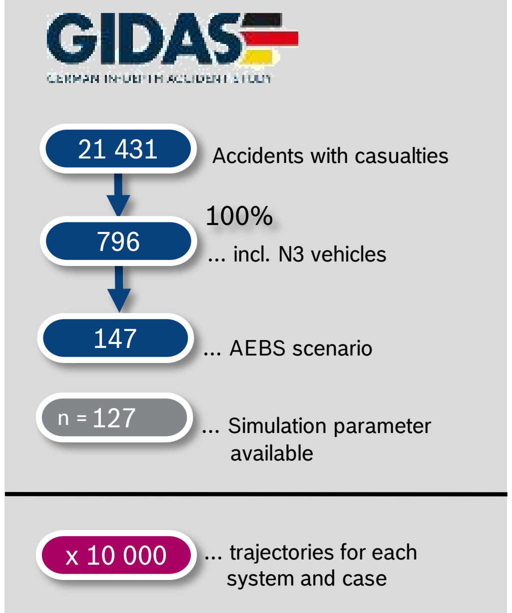
Accident Research: Heavy Commerical Vehicles

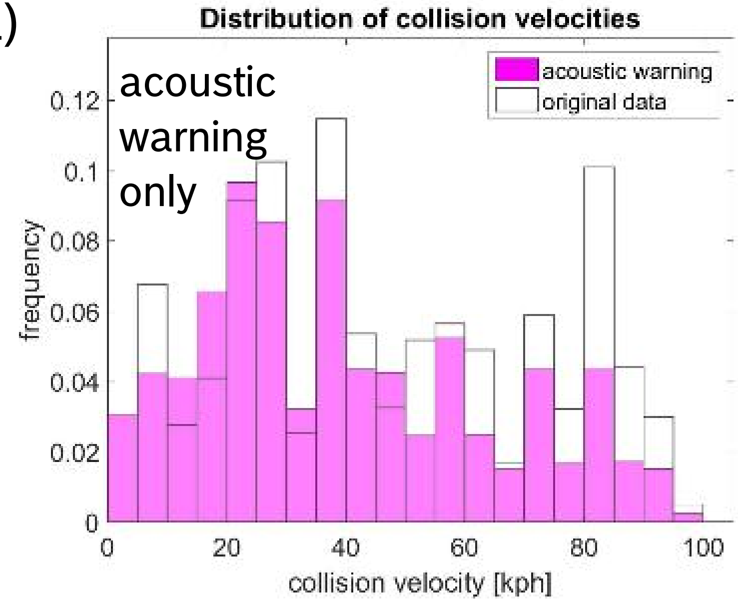
Results: EU conform system (1/2)

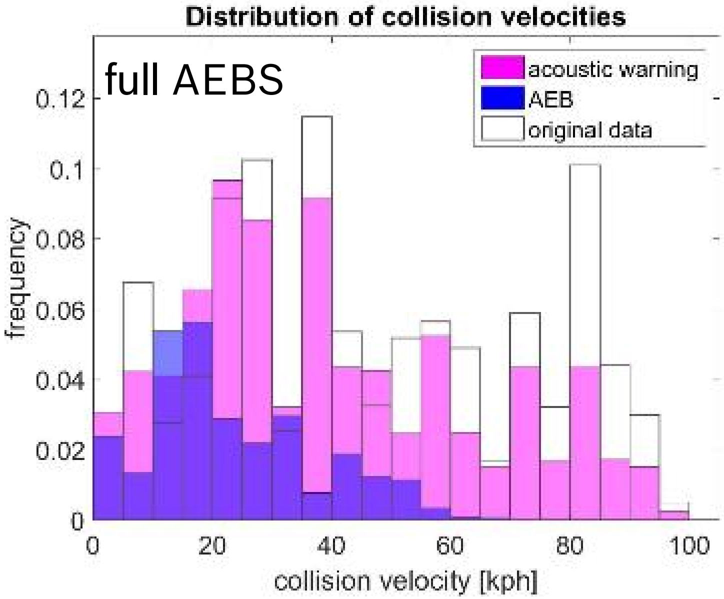
- braking to 1m distance to opponent
- taking constant deceleration of opponent into account
- trajectories follows original trajectory





1)

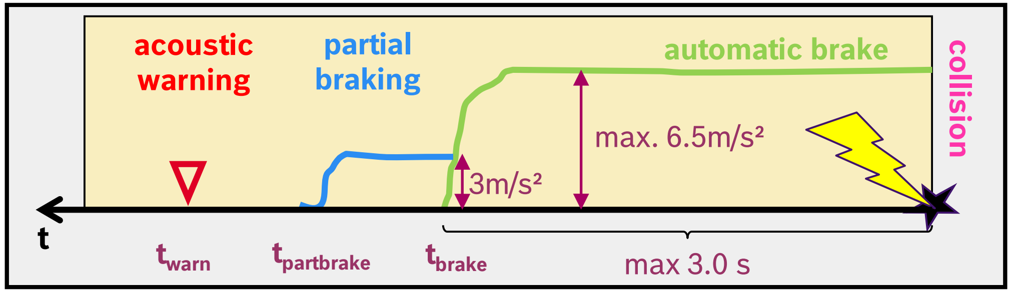


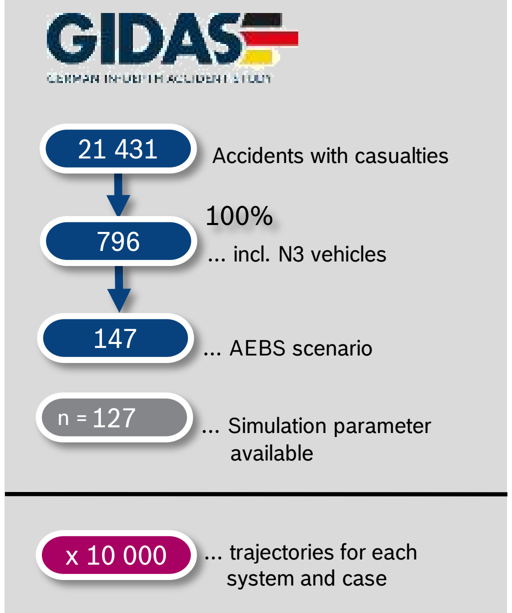


	avoidance potential
acoustic warning	17%
full AEB system	72%

Accident Research: Heavy Commerical Vehicles
Results: EU conform system (2/2)

- braking to 1m distance to opponent
- taking constant deceleration of opponent into account
- trajectories follows original trajectory





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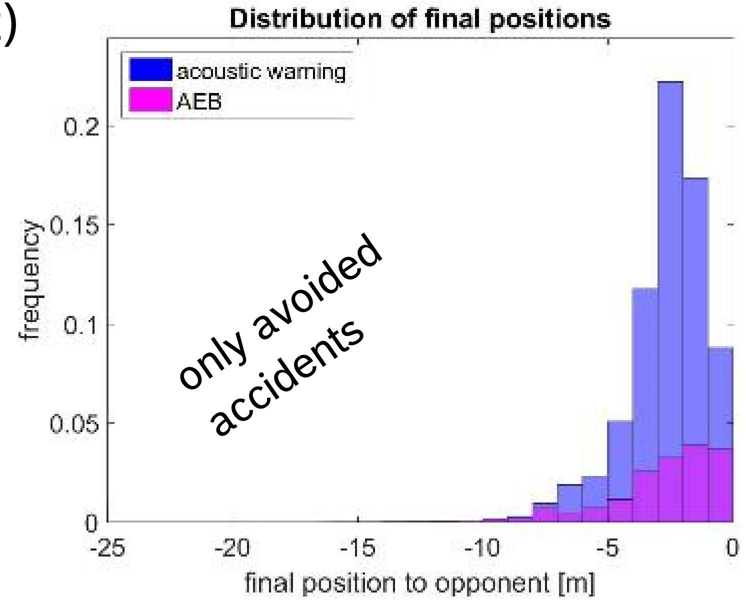

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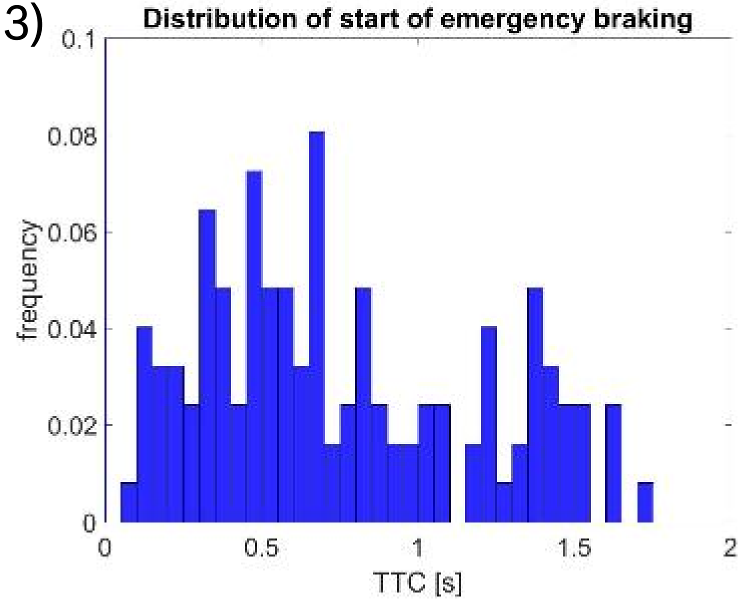

	avoidance potential
acoustic warning	17%
full AEB system	72%

SUMMARY

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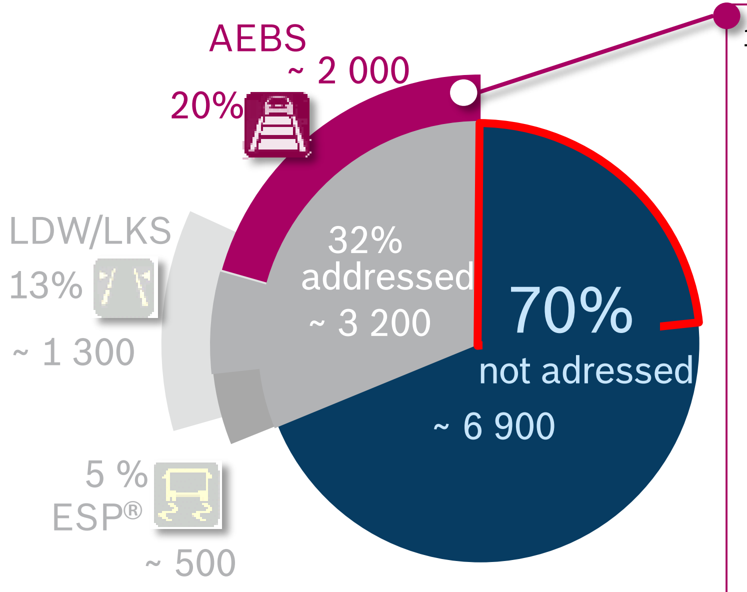
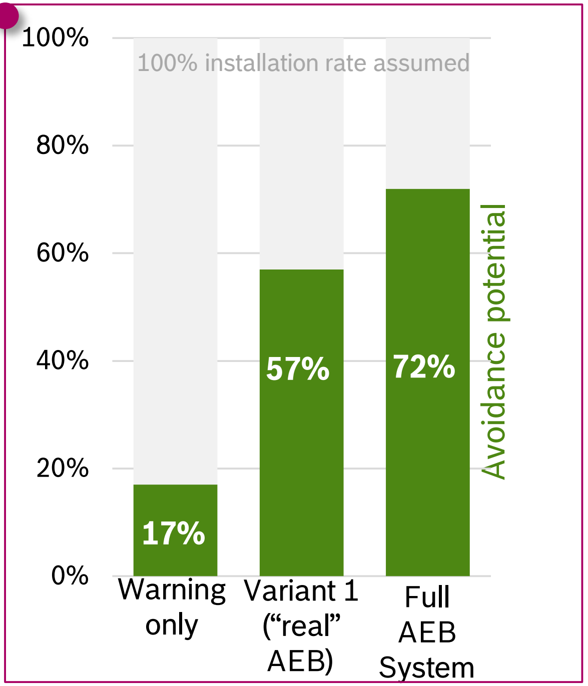
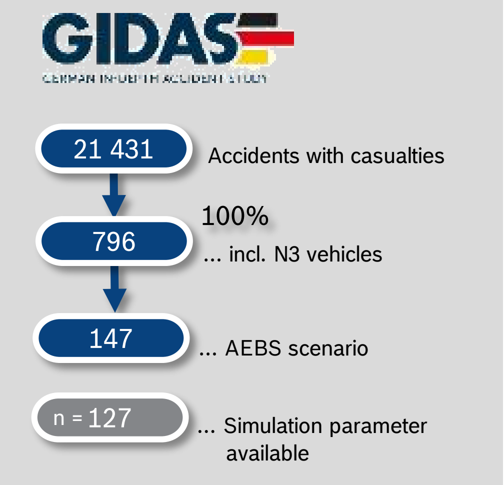
Accident Research: Heavy Commerical Vehicles

Benefit estimation of Truck AEBS - N3 (>12t)

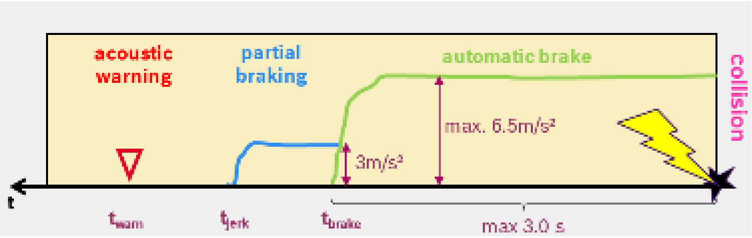
- **Field of effect for N3 AEBS:** ~2.000 accidents w/ casualties in Germany p.a.
- Benefit estimated based on stochastic simulation







AEBS:



Method:

- reconstruct original trajectory
- implement driver model w/ stochastically normal-distributed reaction times
- simulate trajectories w/ driver model and AEB system (in total ~2.5 Mio. simulations)

- If all N3 vehicles were equipped w/ AEBS it is estimated that nearly 3 out of 4 relevant truck crashes w/ casualties would be avoided with an EU-conform full AEBS in Germany

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Germany: Correlation between emissions and accidents (Study in German only)

Accident Research
CR/AEV1

Accident Research: Emissions and Accidents
Executive Summary

- **Aim:** Proof of correlation between fatal road traffic crashes and NO_2-concentration
- **Result:**
  1. At weekdays **2,1** fatal accidents/100 days whereas a mean NO_2 concentration of 72,5 µm/m³ occurred. During weekend or bank holiday **2,5** fatal crashes/100 days occurred but with a reduced NO_2 concentration of 55,3 µm/m³.*
  2. A high NO_2-concentration doesn’t necessarily results in a higher share of fatal road traffic crashes with respect to the observed time frame of 4 years.
  3. Interactions between road traffic and traffic flow with resulting NO_2 concentration avoid an independent root cause analysis towards fatal crashes. Hence an independent correlation between fatal crashes and NO_2 concentration with given sample size cannot be determined clearly.

*Conclusions valid for city of Stuttgart only (2011-2015)

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Unfallforschung: Emissionen und Unfallgeschehen

Sache

- **Aufgabe:** Korrelation von Verkehrsunfällen mit Todesfolge und NO_2-Konzentration prüfen
- **Ergebnis:**
  1. An Werktagen ereigneten sich **2,1** tödliche Unfälle/100 Tage bei einer gemittelten NO_2-Konzentration von 72,5 µm/m³, an Wochenenden bzw. Feiertagen **2,5** tödliche Unfälle obwohl geringerer NO_2-Konzentration von 55,3 µm/m³.*
  2. Eine hohe NO_2-Konzentration führt somit nicht zu einer Erhöhung von tödlichen Unfällen im Straßenverkehr, in dem ausgewertetem Zeitraum.
  3. Die Wechselwirkungen zwischen Verkehr, dem damit bedingten Verkehrsstrom und der NO_2-Konzentration verhindern eine unabhängige Ursachenzuordnung zu tödlichen Unfällen. Damit lässt sich der Zusammenhang zwischen Verkehrsunfällen mit Todesfolge und NO_2-Konzentration bei gegebener Stichprobe nicht eineindeutig ermitteln.

*Aussage gültig für die Stadt Stuttgart (2011-2015)

Unfallforschung: Emissionen und Unfallgeschehen

Überblick

- Prüfung der Datengrundlage und Status Umwelt- und Unfalldaten
- Prüfung der Nullhypothese
- Ermittlung der Wirkzusammenhänge
- Ermittlung Beitrag Verkehr an NO_X-Konzentration
- Verkehrsstrom und –dichte
- Ermittlung des Verkehrsstrom nach Wochentag und Uhrzeit
- Korrelation Verkehrsstrom und NO_2-Konzentration
- Zuordnung der Unfälle mit Todesfolge nach Wochentag und Uhrzeit
- Bezugskennzahl: Tödliche Unfälle pro 100 Tage in Abhängigkeit des Wochentags und der NO_2-Konzentration (Stuttgart)

Unfallforschung: Emissionen und Unfallgeschehen

Prüfung der Datengrundlage

- Daten zum Unfallgeschehen mit Personenschaden inklusive Verkehrstoten für Deutschland
  - Polizeilich gemeldete Unfälle über das Jahrbuch 2015 (DESTATIS F8R7) in aggregierter Form verfügbar. Information zum exakten Unfallort sind aus Datenschutzgründen nicht verfügbar. Daher kann diese Datenquelle für diese Analyse herangezogen werden.
  - Rohdaten der polizeilich gemeldeten Unfälle der Stadt Stuttgart (2011-2015, Polizeidirektion Stuttgart) wurden einmalig für Forschungszwecke RB zur Verfügung gestellt → Verwendete Datenbasis.
- Umweltdaten Deutschland
  - 514 Messstationen, davon 214 in Baden-Württemberg. Messung von NO_2 und PM10* verfügbar. Daten sind in aggregierter Form in einem Onlineportal kostenlos abrufbar. 4 Messstationen der Stadt Stuttgart wurden detailliert analysiert.
- Daten zum Verkehrsstrom (Schleifendaten)
  - Daten zum Verkehrsfluss der Stadt Stuttgart aus Berichten (2011-2014) extrahiert und aufbereitet.

- Die Hypothese wird für die Stadt Stuttgart geprüft

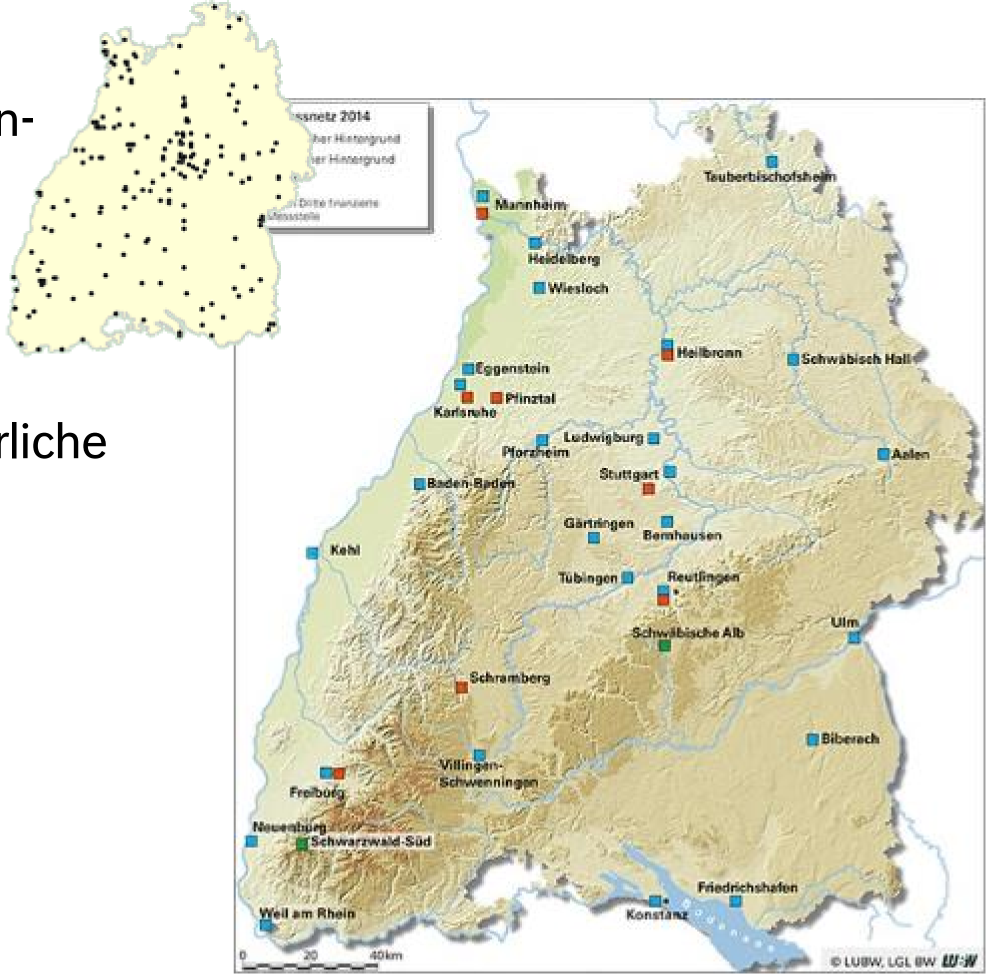
*PM10: Emission von Feinstaub der Partikelgröße 10µm; NO_2: Stickstoffdioxid

Unfallforschung: Emissionen und Unfallgeschehen
Status Datengrundlage Umweltdaten

- 514 Messstationen in Deutschland, davon 214 in Baden-Württemberg (2015) mit 3 Kategorien:
  - Ländliche & städtische Wohngebiete
  - Industrie
  - Verkehr

- Stuttgart (Zentrum) mit 4 Luft-Messstationen, kontinuierliche NO_2 und PM10-Messungen
  - Bad Canstatt
  - Neckartor
  - Arnulf-Klett-Platz
  - Hohenheimer Straße

- Zulässige Grenzwerte NO_2
  - im Jahresmittel: 40 µg/m³ (ab 1.1.2010)
  - im 1h-Wert: 200 µg/m³ (ab 1.1.2010)
  - im 1h-Wert: 18 Überschreitungen p.a.



Quellen: Umweltbundestamt – www.env-it.de;
Landesanstalt für Umwelt, Messungen und Naturschutz, Baden Württemberg - www.lubw.baden-wuerttemberg.de/lubw

Unfallforschung: Emissionen und Unfallgeschehen

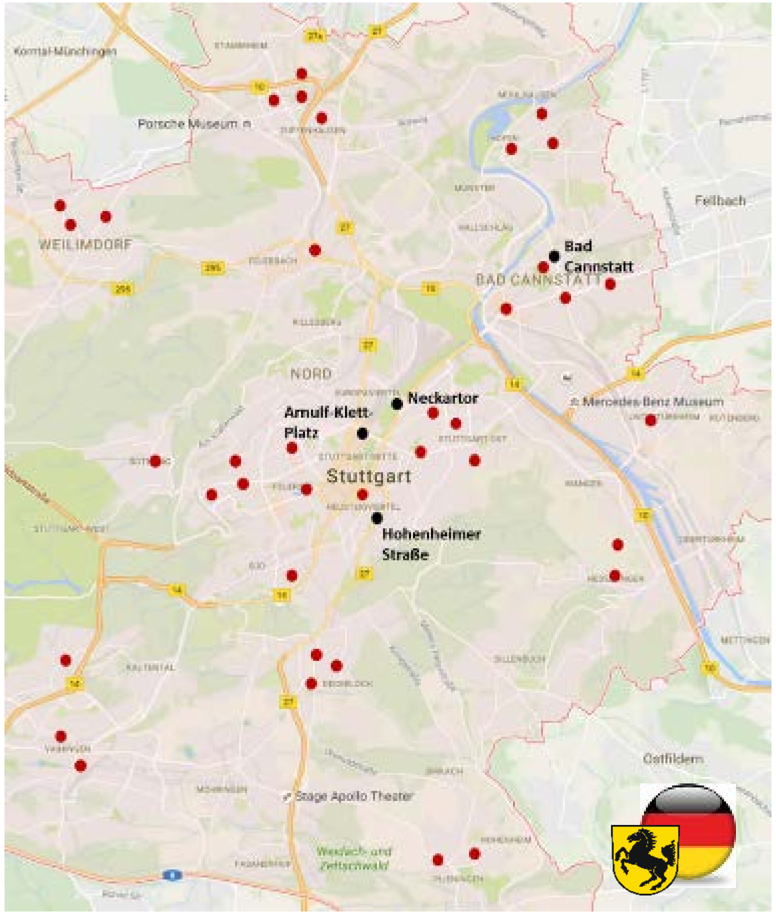
Status Unfallgeschehen Stadt Stuttgart

- 10.829 Unfälle mit Personenschaden (2011-2015) davon...
  - 40 Unfälle mit Getöteten (0,4%) dabei starben 41 Personen
  - 1.351 Unfälle mit Schwerverletzten (12,6%)
  - 9.319 Unfälle mit Leichtverletzten (87%)
  - 119 Unfälle mit unbekanntem Personenschaden

- Unfälle mit Getöteten nach Jahr

Jahr	Anzahl
2011	10
2012	10
2013	7
2014	5
2015	8

Unfallort Unfälle mit Getöteten (n=38) und Lage der 4 Messstationen im Großraum Stuttgart



Unfallort ●
Messstation ●

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Unfallforschung: Emissionen und Unfallgeschehen

Prüfung Nullhypothese Chi²-Unabhängigkeitstest

- Hypothese H_0: Auftreten tödlicher Verkehrsunfälle stochastisch unabhängig von der NO_2-Belastung.
- Vorgehen: Berechnung der Mittelwerte der NO_2-Konzentration (4 Messstationen) und der Zuordnung zu den tödlichen Unfällen.

	Ø NO_2-Messwert 1 bis 60 µg/m³	**Ø NO_2-Messwert 61 bis 80 µg/m³**	**Ø NO_2-Messwert 81 bis 140 µg/m³**
Anzahl Stunden **mit** Ereignis tdl. Unfall	11	13	14
Anzahl Stunden **ohne** Ereignis tdl. Unfall	18 778	11 992	11 992

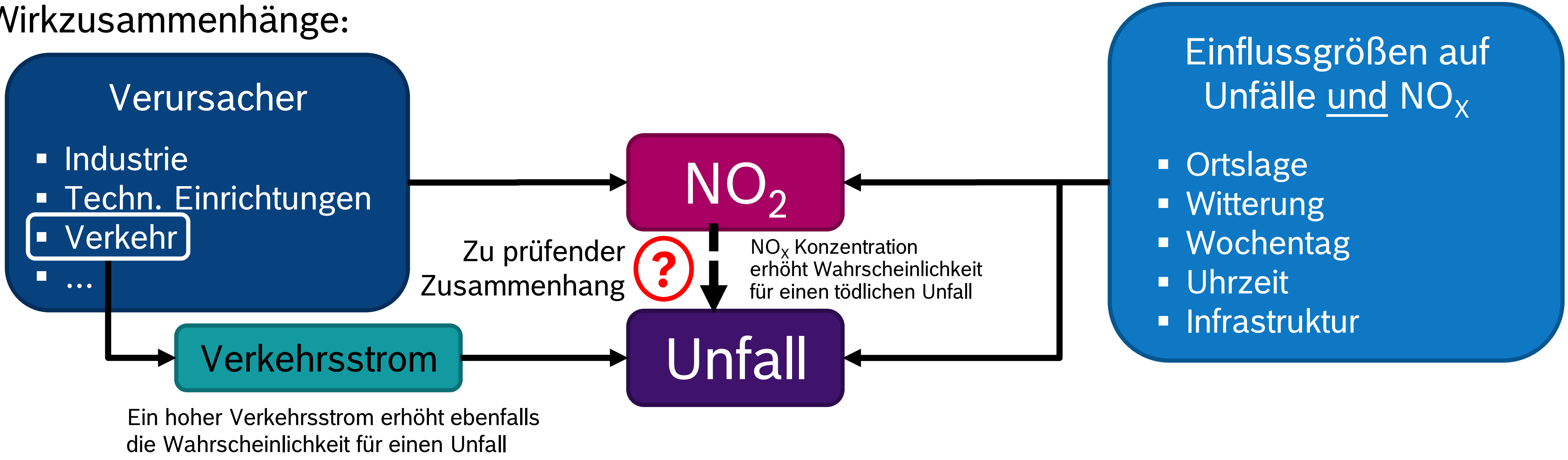
- Ergebnis (p-Wert): 0,17 > 0,05 (95%tile Signifikanz) → Nullhypothese kann nicht bestätigt werden
- Test zeigt Tendenz zur Unabhängigkeit
- Weitere Untersuchung zur Unabhängigkeit von NO_2 und Unfällen mit Todesfolge notwendig

Bemerkung: $\chi 2$ liefert ein Wert unabhängig von der Anzahl der Klassen der Merkmale X (Unfall ja/nein) und Y (NO_2)

Unfallforschung: Emissionen und Unfallgeschehen

Schritt 1: Ermittlung der Wirkzusammenhänge

- Wirkzusammenhänge:



- Einflussgrößen auf NO_X-Konzentration u.a. durch weitere Verursacher (Industrie, Verkehr,...)
- Sowohl Unfälle als auch NO_X-Konzentration durch Verkehrsstrom beeinflusst, aber auch durch Orts- und Wetterlage, Wochentag und Uhrzeit → Problem: Stau verursacht durch Unfall erhöht NO_X
- Folge: Wechselwirkungen verhindern eine unabhängige Ursachenzuordnung
- Ziel: Eliminierung der Größen zur Abschätzung der Korrelation zwischen NO_2 und Unfällen

Unfallforschung: Emissionen und Unfallgeschehen

Schritt 2: Prüfung Beitrag Verkehr an No_x-Konzentration

- Verursacher Emissionen in Stuttgart 2012 in t pro Jahr

Gruppe	CO	NO_x	SO_2	NMVOC	Staub	PM10	CH_4	CO_2	N_2O	NH_3
Biogene Systeme	n.v.	30	n.v.	44	7	3	116	n.v.	48	196
Kleine und Mittlere Feuerungsanlagen	4.993	551	29	216	173	168	179	1.071.274	8	n.v.
Industrie und Gewerbe	181	430	164	1.050	31	17	34	942.370	13	1
Sonstige Technische Einrichtungen	805	403	n.v.	1.634	22	20	1.643	46.814	65	n.v.
Verkehr	**4.298**	**1.538**	**4**	**537**	**435**	**173**	**31**	**674.416**	**15**	**85**
Summe	10.278	2.952	196	3.482	668	381	2.004	2.734.874	148	283

CO = Kohlenstoffmonoxid
NOx = Stickoxide
SO_2 = Schwefeldioxid
NMVOC= Flüchtige Organische Verbindungen ohne Methan
PM10 = Feinstaub Partikelgröße 10µm
CH_4 = Methan
CO_2 = Kohlendioxid
N_2O = Distickstoffmonoxid
NH_3 = Ammoniak

- Der durch den Verkehr entstehende NO_X Ausstoß wird maßgeblich durch den Verkehrsfluss bzw. der Verkehrsdichte in Stuttgart bestimmt z.B. Stau.
- NO_X-Ausstoß zu 50% durch Verkehr verursacht, dadurch sind NO_2 Messungen verzerrt.
  → Ansatz: Eliminierung durch Berücksichtigung der Verkehrsdichte und des Wochentages

Quelle: Landesanstalt für Umwelt, Messungen und Naturschutz Baden Württemberg – Region Stuttgart

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Unfallforschung: Emissionen und Unfallgeschehen

Schritt 2b: Prüfung Beitrag Verkehr an NO_x- Belastung

- Verursacher Verkehr nach Fahrzeugart in Stuttgart 2012 in t pro Jahr

Stoff	*PKW*	*LNFZ ≤3,5t*	*SNFZ >3,5t*	*KRAD*	*Summe*
Fahrleistung km/Jahr	2.938.386.688	87.384.800	163.335.536	52.449.964	3.241.556.992
CO	3.520	43	211	467	4.241
NO_x	861	84	549	9	1.503
SO_2	3	n.v.	1	n.v.	3
NMVOC	429	4	9	91	533
Staub	269	16	114	3	402
PM10	101	7	31	2	140
CO_2	523.136	18.315	125.181	4.668	671.299
Anteilig NOx	**55%**	**6%**	**37%**	**2%**	**100%**

Quelle: www.ekat.baden-wuerttemberg.de/gkz_strv_v1.php?GKZ=111000
n.v.: nicht nachweisbar, vernachlässigbar. Abweichungen in den Summen sind auf das Runden der Zahlen zurückzuführen

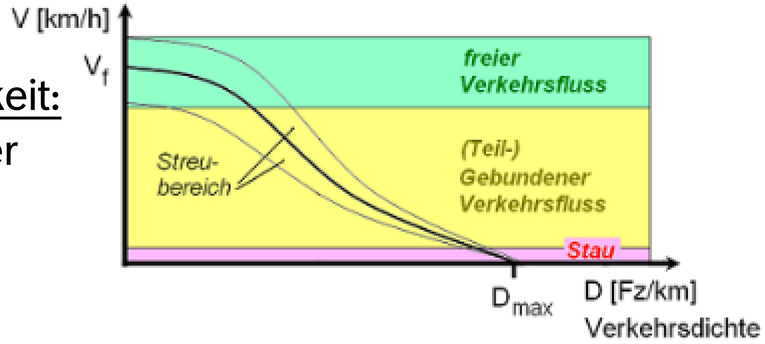
Unfallforschung: Emissionen und Unfallgeschehen

Schritt 3: Verkehrsdichte

- Verkehrsdichte bezeichnet die Anzahl der Verkehrsteilnehmer im Verkehrsstrom je Wegeinheit zu einem Zeitpunkt.
- Zusammenhang zwischen Verkehrsdichte und Fahrzeuggeschwindigkeit: Je mehr Fahrzeuge auf einem Straßenabschnitt fahren, umso geringer wird die Fahrgeschwindigkeit.
- Bei einer kritischen Fahrzeugdichte und einer dazugehörigen Fahrzeuggeschwindigkeit wechselt der Zustand des Verkehrsflusses von stabil nach instabil und führt damit zum Stau.
- Stauursache kann aber auch ein vorausgegangener Unfall sein.

Ansatz: Zustandsgleichung des Verkehrsflusses $\boxed{Q = D \cdot V}$

Abb.: Hendrik Ammoser, Fakultät Verkehrswissenschaften "Friedrich List" Dresden

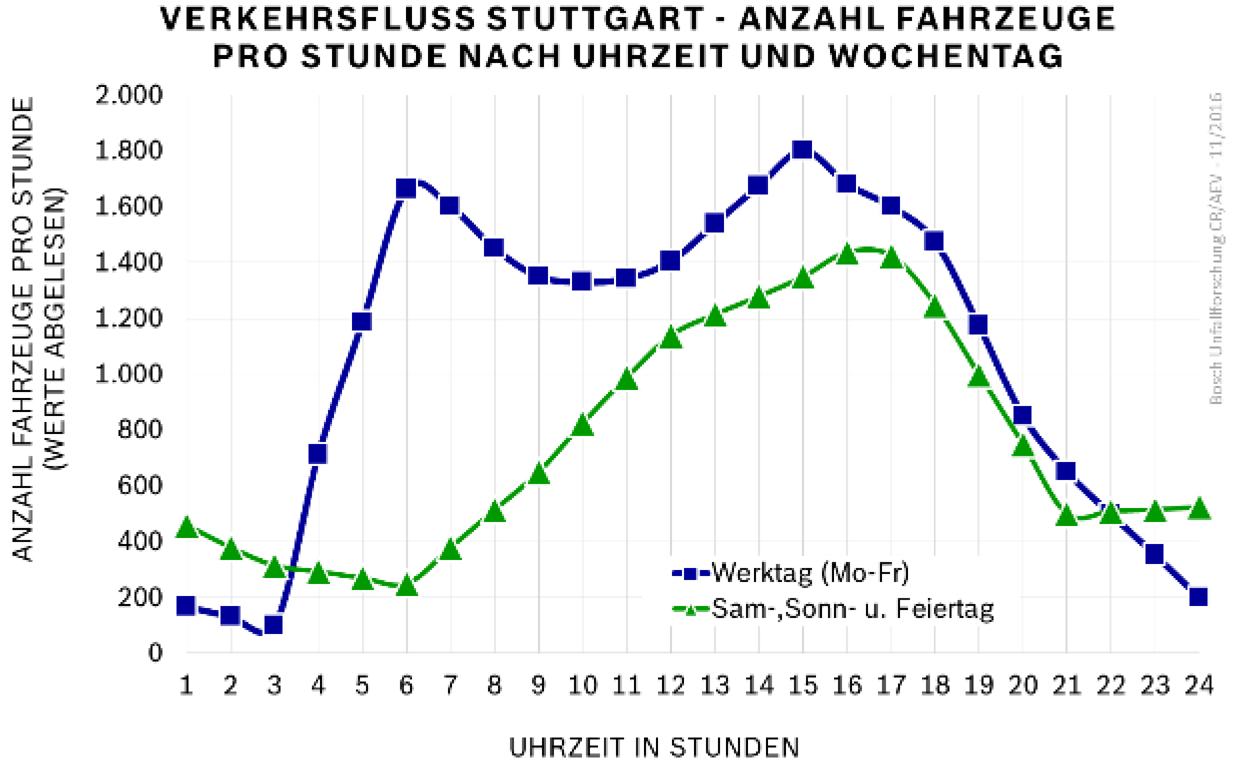


- Bei einem Stau erhöht sich die NO_2 Konzentration und diese ist wiederum abhängig von der im Stau befindlichen Fahrzeugklassen und deren Ausstoß → Ermittlung des Verkehrsstroms nach Wochentag und Uhrzeit

Bildquelle: Wikipedia
Quelle: Forschungsgesellschaft für Straßen- und Verkehrswesen: Begriffsbestimmungen, Teil: Verkehrsplanung, Straßenentwurf und Straßenbetrieb. FGSV Verlag, Köln 2000, S. 37

Unfallforschung: Emissionen und Unfallgeschehen

Schritt 4: Ermittlung des Verkehrsstroms nach Wochentag



Datengrundlage:
Verkehrsstromdaten nur aggregiert verfügbar. Gemittelte Werte aus den Jahren 2011-2014 nach Wochentag und Uhrzeit verwendet.

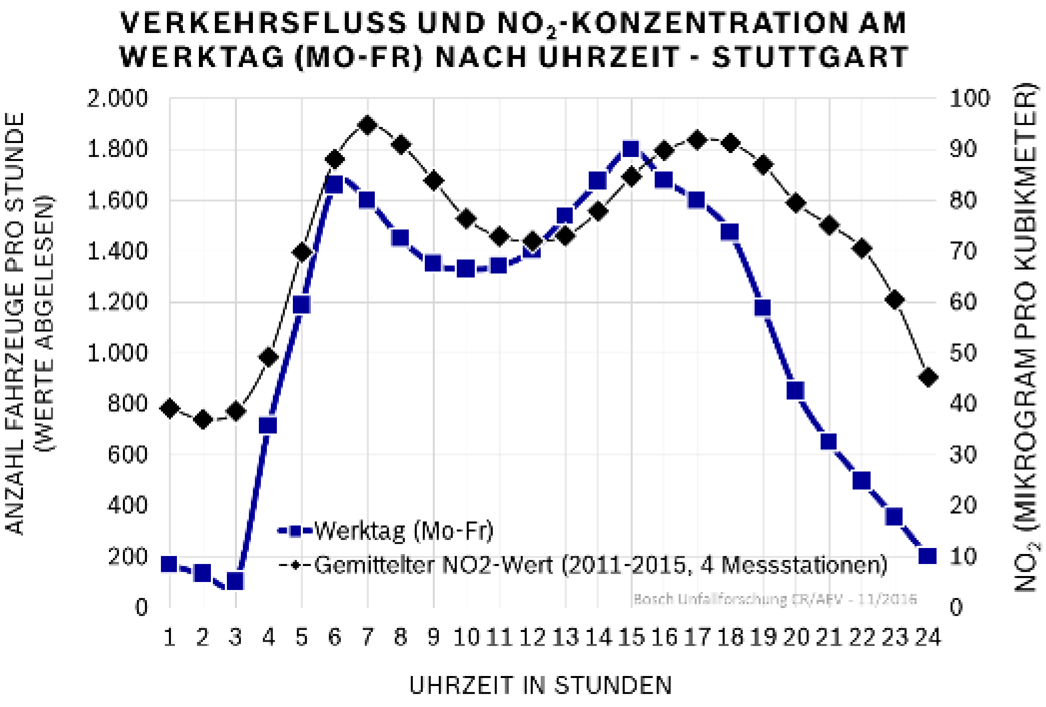
Ø Anzahl Fahrzeuge/h
- **Werktag (Mo-Fr) : 1.081**
- **Sa,So,Feiertag : 759**

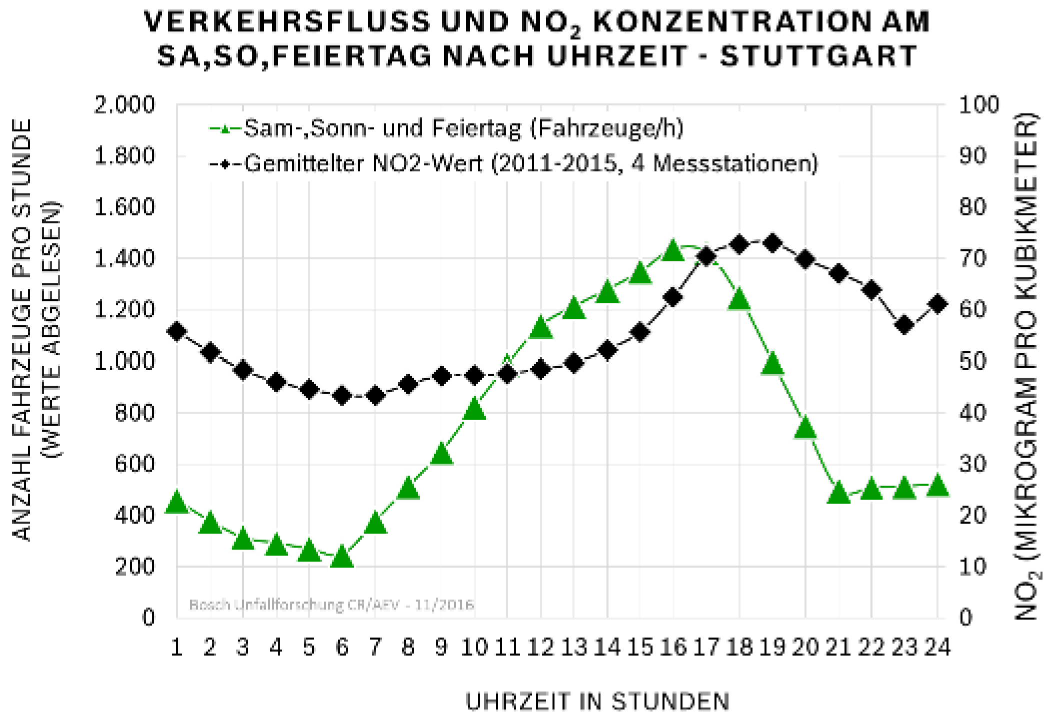
- Unterschiedlicher Verkehrsstrom an Werktagen (Berufsverkehr) und an Wochenenden (Nachtverkehr mangels ÖPNV) führt zu anderen NO_2-Konzentration → Zuordnung der NO_2 Messungen (Elimination der Verursacher)

Quelle: Landesanstalt für Umwelt, Messungen und Naturschutz Baden Württemberg – Region Stuttgart

Unfallforschung: Emissionen und Unfallgeschehen

Schritt 4: Korrelation Verkehrsstrom und NO_2





- Ermittlung des Korrelationskoeffizienten zwischen Verkehrsstrom und NO_2 liefert an
  - Werktagen (Mo-Fr) = 0,87 → NO_2-Konzentration in starkem linearen Zusammenhang mit Verkehrsstrom
  - Wochenenden (Sa-So,Fei.) = 0,42 → NO_2-Konzentration verteilt sich über den Tageszyklus weniger korreliert

Quelle: Landesanstalt für Umwelt, Messungen und Naturschutz Baden Württemberg – Region Stuttgart

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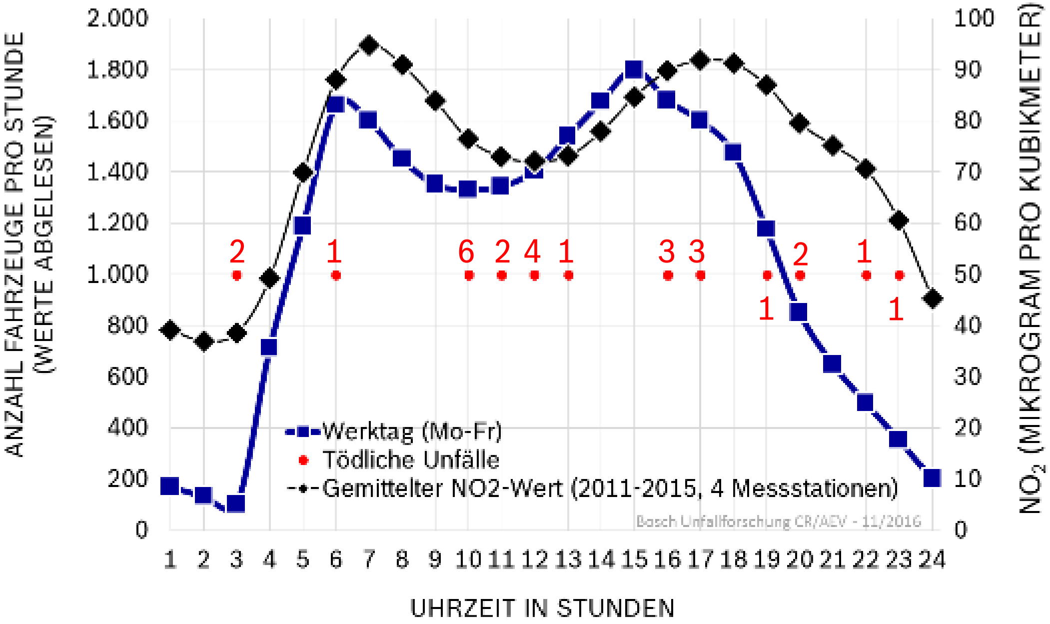
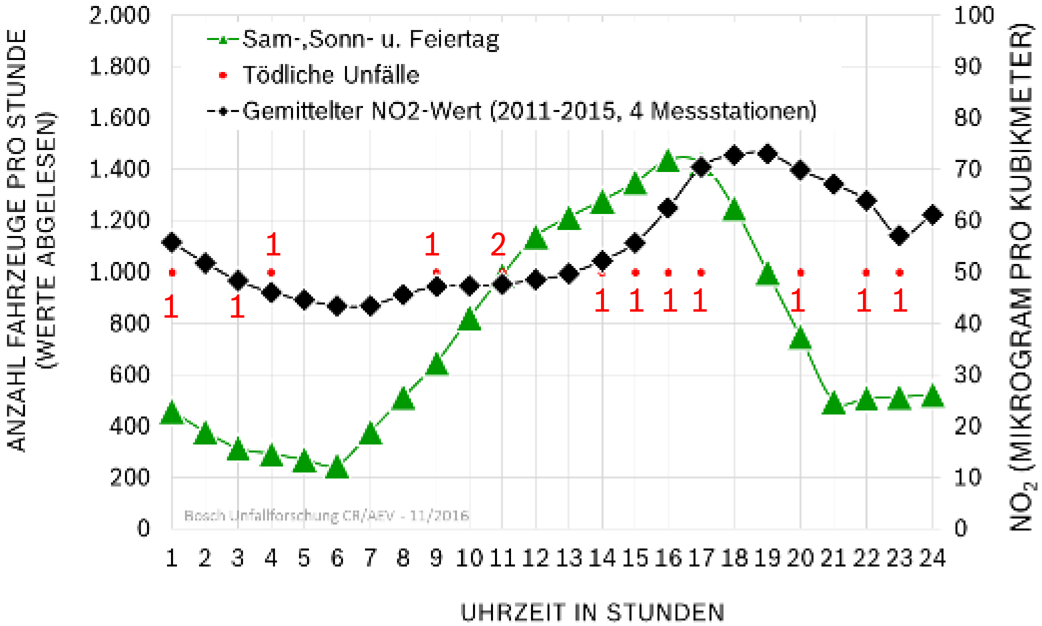
Unfallforschung: Emissionen und Unfallgeschehen

Schritt 5: Zuordnung Unfälle mit Todesfolge

VERKEHRSFLUSS, NO_2-KONZENTRATION UND TDL. UNFÄLLE WERKTAG (MO-FR) - STUTTGART



VERKEHRSFLUSS, NO_2 KONZENTRATION UND TDL. UNFÄLLE AM SA,SO,FEIERTAG - STUTTGART



- Im Analysezeitraum ereigneten sich an Werktagen 27 tödliche Unfälle und an Wochenenden bzw. Feiertagen 13 tödliche Unfälle → Verteilung zeigt Unabhängigkeit von der NO_2 Konzentration
- Berechnung einer Bezugskennzahl für Unfälle mit Todesfolge (Basis 100 Tage) unter Berücksichtigung des Verkehrsstroms und der NO_2-Konzentration

Quelle: Landesanstalt für Umwelt, Messungen und Naturschutz Baden Württemberg – Region Stuttgart, Unfallzahlen der Polizeidirektion Stuttgart für ausschließlich Forschungszwecken zur Verfügung gestellt (2011-2015)

Unfallforschung: Emissionen und Unfallgeschehen

Schritt 6: Ermittlung Bezugskennzahl - Stuttgart

Zeitraum	**Anzahl Unfälle mit Todesfolge** (2011-2015)	**Unfälle mit Todesfolge pro 100 Tage**	**Mittlerer Verkehrsstrom (Fzg./h)**	**Mittlere NO_2 Konzentration mg/m^3 (24h)**
Mo-Fr (5 Tage)	27	**2,1**	1.081	72,5
Sa-So (2 Tage)	13	**2,5**	759	55,3

- An Werktagen ereigneten sich 2,1 tödliche Unfälle/100 Tage bei einer gemittelten NO2-Konzentration von 72,5 µm/m3, an Wochenenden bzw. Feiertagen 2,5 tödliche Unfälle obwohl geringerer NO2-Konzentration von 55,3 µm/m3.
- Fazit: Bei dem verfügbaren Stichprobenumfang zeigt sich, dass eine hohe NO_2 Konzentration nicht zu einer Erhöhung von tödlichen Unfälle im Straßenverkehr führt.
- Anmerkung: Datenschutzgründe verhindern derzeit das Prüfen der These für eine größere Region.

Quelle: Landesanstalt für Umwelt, Messungen und Naturschutz Baden Württemberg – Region Stuttgart, Unfallzahlen der Polizeidirektion Stuttgart für ausschließlich Forschungszwecken zur Verfügung gestellt (2011-2015)

Accident situation – International
- Standard slides / Overview -

Accident Research
CR/AEV1

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Bosch Accident Research - International statistics

Content

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Road safety in 2015 – a public health issue

	Registered motor vehicles [Mio]	Road accidents involving injuries [Mio]	Fatalities (fatalities within 30 days after accident)	Fatality risk per vehicle
	91.3	0.54	4 867	1 : 18 700
	327.1	1.09	26 134	1 : 12 500
	281.3	1.72	35 092	1 : 8 000
	279.0	1.28	58 022	1 : 4 800
	23.9	0.23	4 621	1 : 5 200
	51.3	0.18	23 114	1 : 2 200
	54.5*	0.43*	33 996*	1 : 1 600*
	210.0	0.50	146 133	1 : 1 400

* 2008

Sources: IRTAD; Statistics 2015, EU transport statistical pocketbook 2017,Road accidents Japan; NPA Accident Statistics; Global Health Observatory Data Repository, WHO; Traffic safety facts 2015; Road accident Statistics China, Yearbook 2015; Anuário estatísticodo DENATRAN - RENAEST 2008, Brazil; Information on road safety 2015, Traffic Police of Russia (www.gibdd.ru/stat/); Road Transport Yearbook, Ministry of Road Transport & Highways, Govt. of India 2015; Data portal India: (http://data.gov.in)

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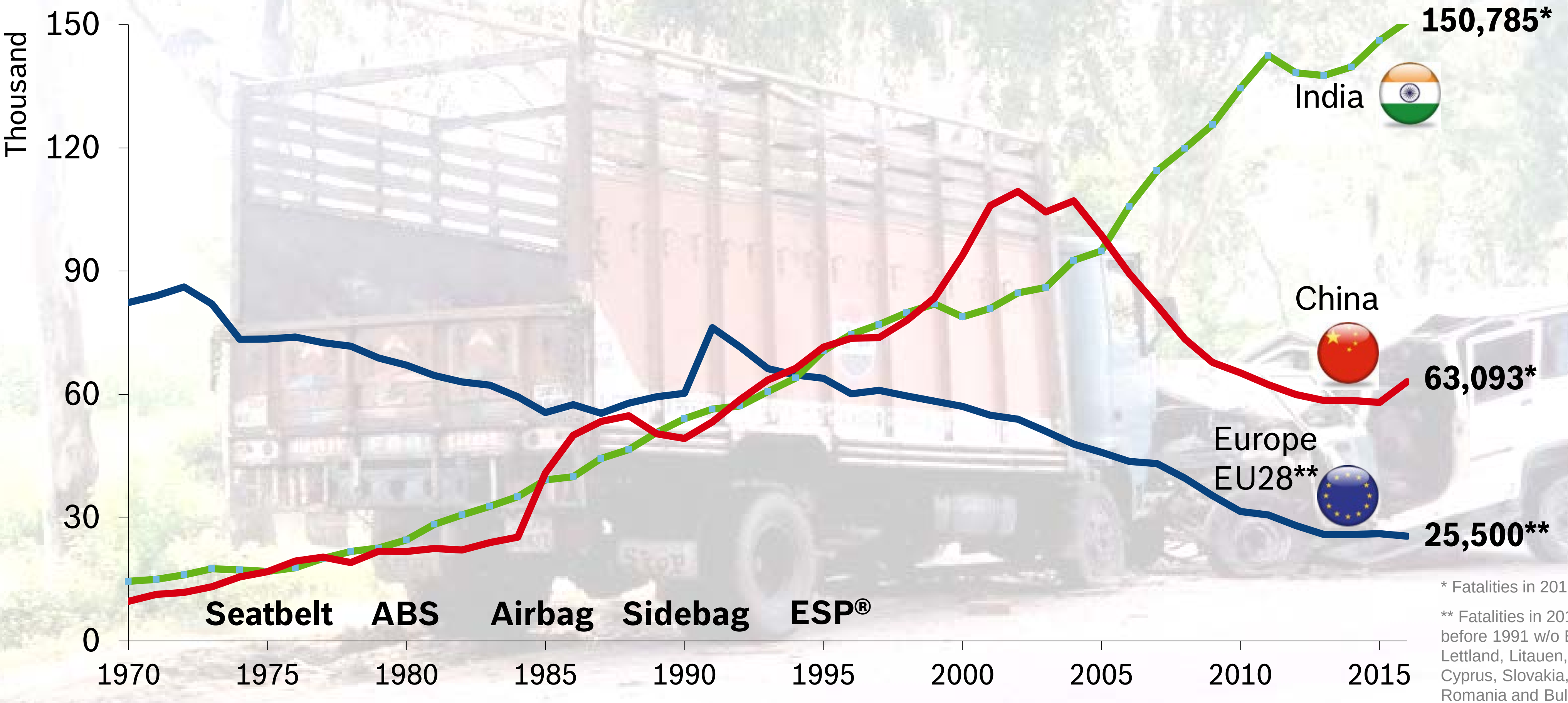
Road traffic fatalities in Europe, India and China



* Fatalities in 2016

** Fatalities in 2016, before 1991 w/o Estland, Lettland, Litauen, Malta, Cyprus, Slovakia, Poland, Romania and Bulgaria

Source: Bosch Accident Research (CR/AEV), Road Safety Annual Report 2017 (IRTAD) (EU28); MORTH report 2017, China Annual year book 2017

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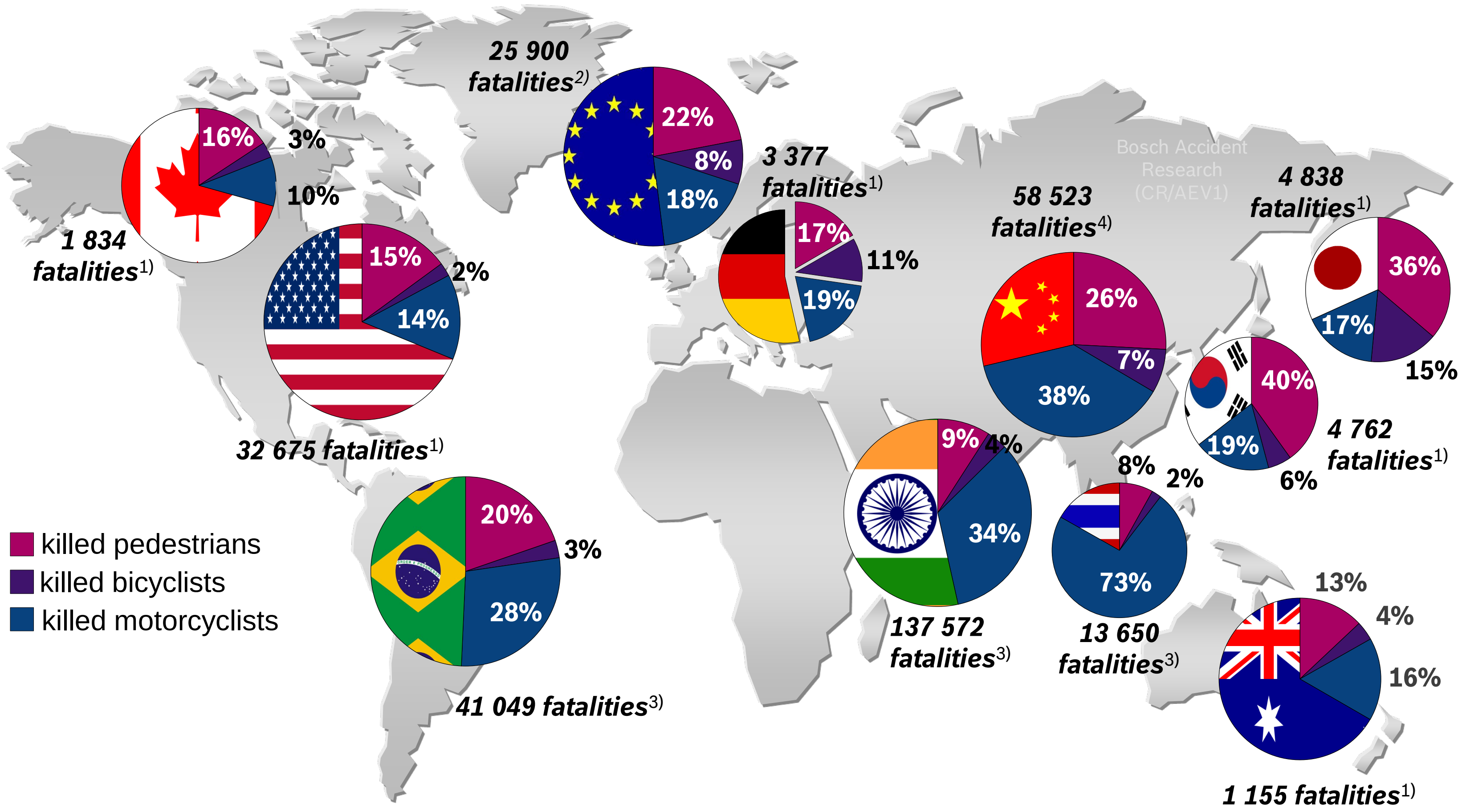
Chapter 11

Fatalities in road traffic 2014 – share of vulnerable road users (VRU)



Sources:
1) IRTAD 2016
2) ERF
3) WHO report 2015, reported road traffic fatalities from 2013
4) Traffic Accidents China, Annual yearbook 2014, share of motorcyclists includes Ebikes

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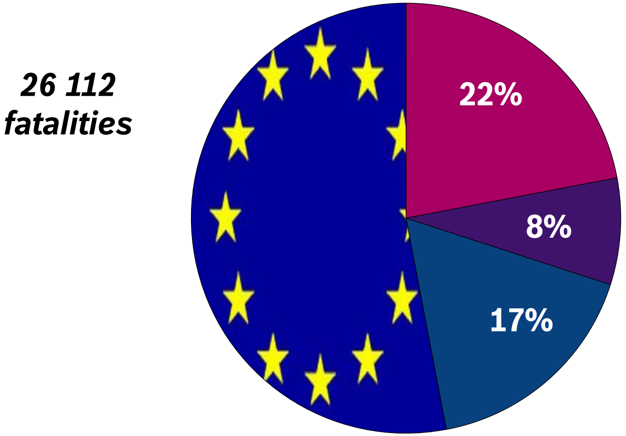
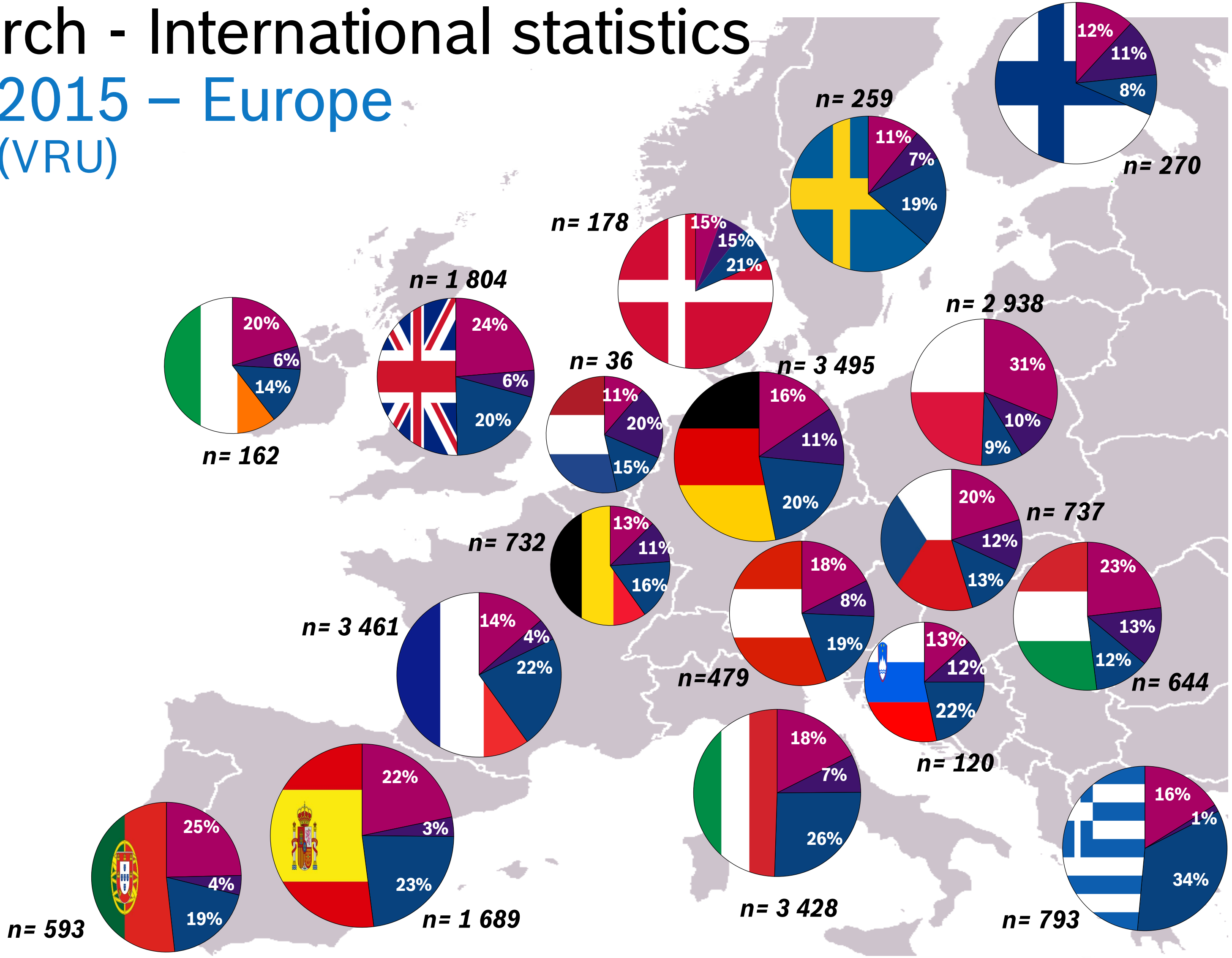
Fatalities in road traffic 2015 – Europe

Share of vulnerable road users (VRU)





- killed pedestrians
- killed bicyclists
- killed motorcyclists

Source: IRTAD 2016

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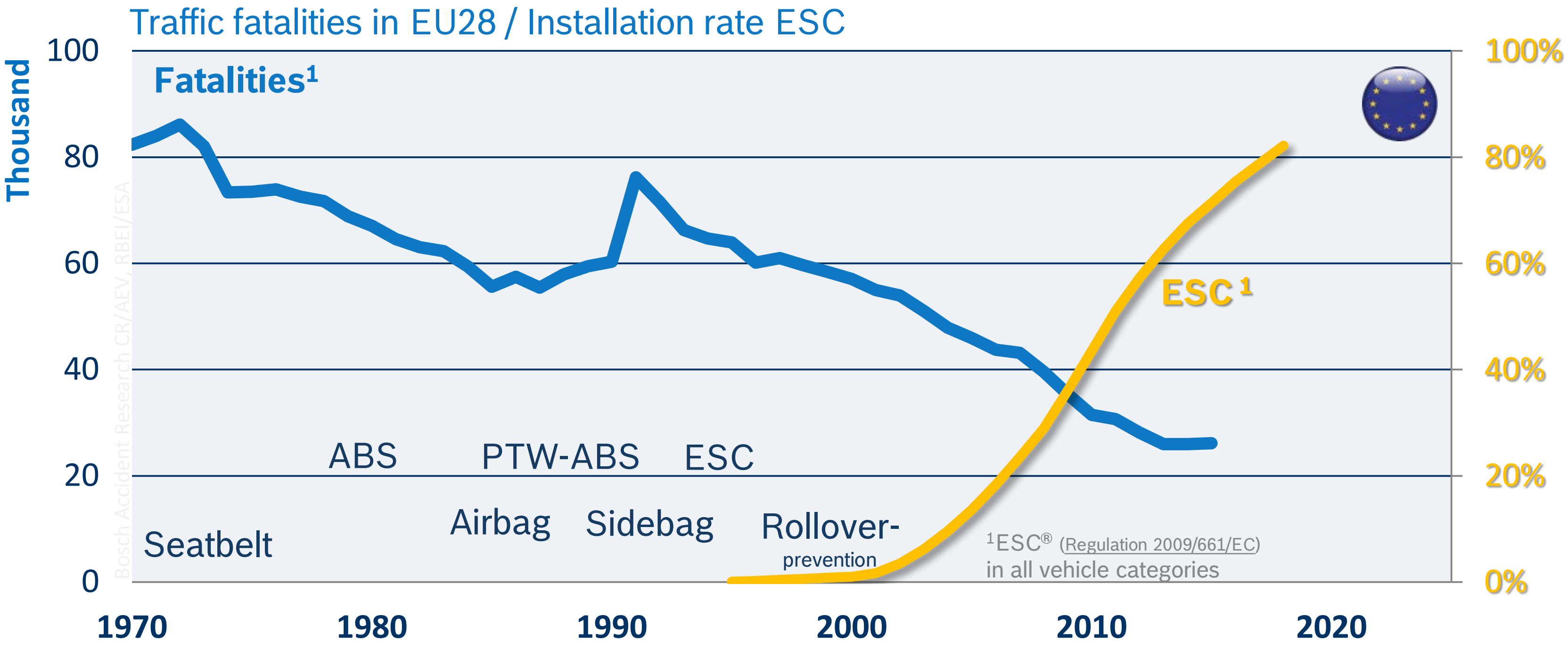
Vehicle safety safes live



Source: Bosch Accident Research CR/AEV, Road Safety Annual Report 2015 (irtad) (EU28); ESC installation rate estimated based on new car production level

- Besides other measures vehicle safety safes live
- Safety effectiveness supported by legislation i.e. ESC

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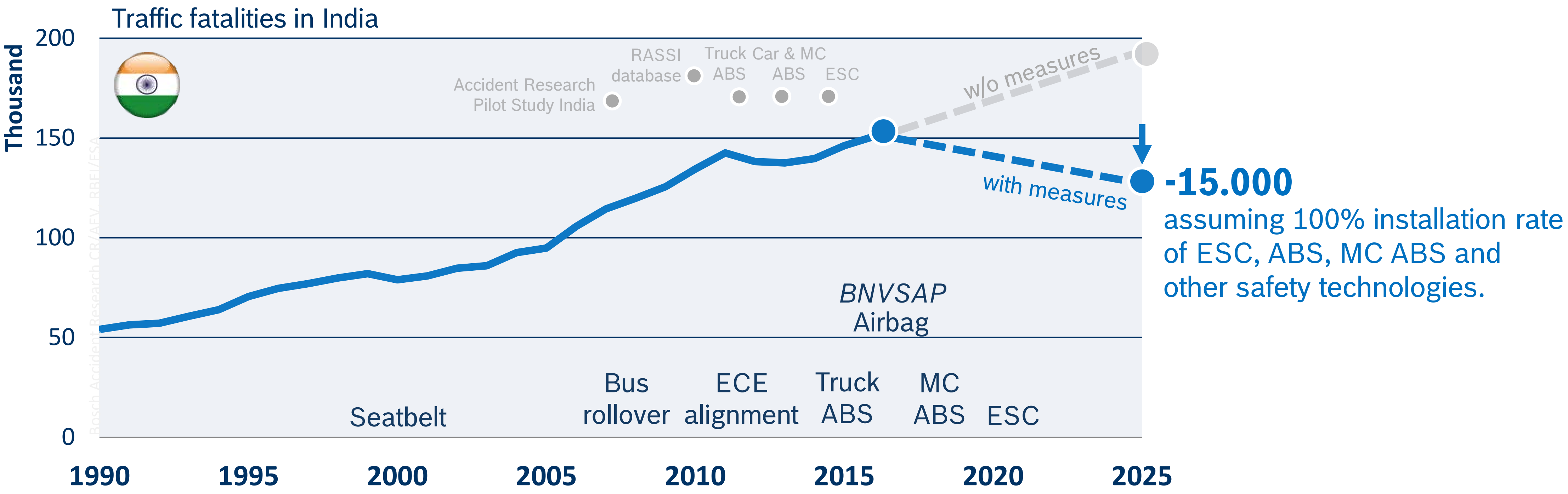
Milestones for traffic safety in India



- Besides other measures vehicle safety safes live
- Safety effectiveness supported by legislation i.e. ESC

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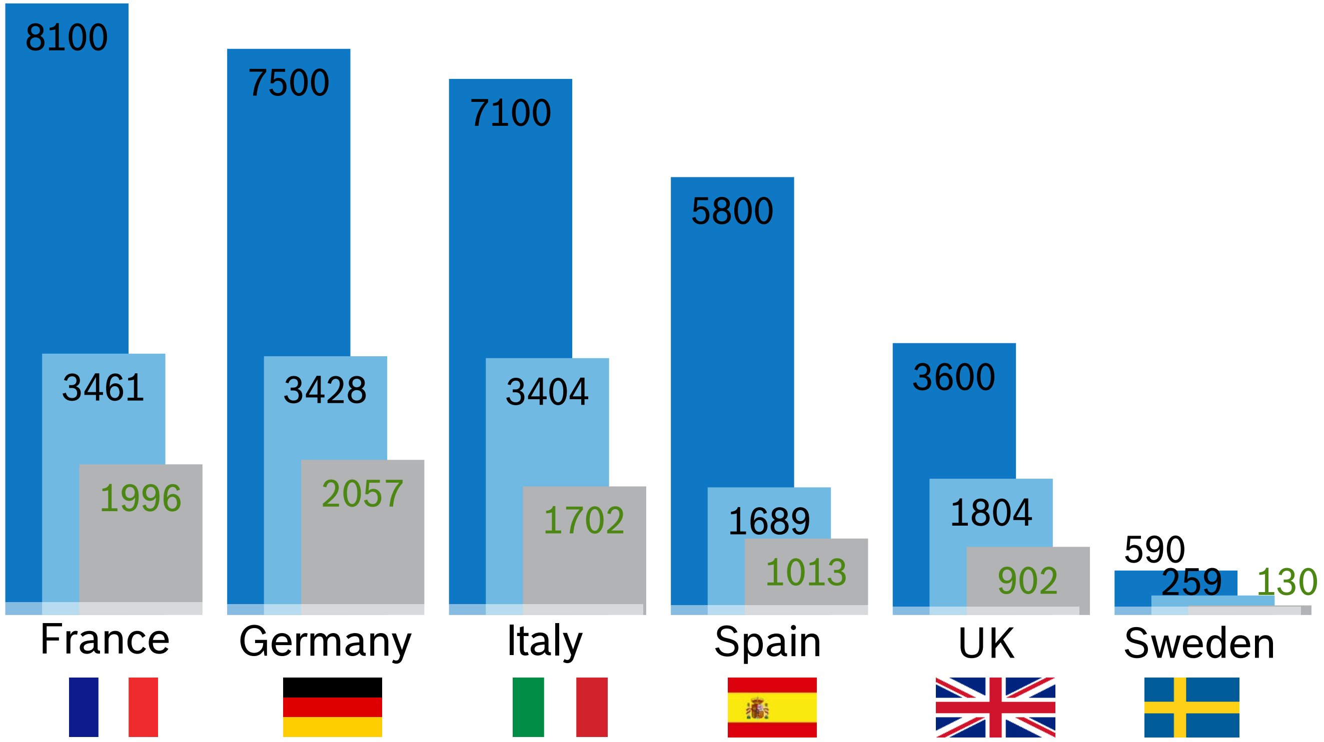
Chapter 11

Initiatives in road safety – Europe

- Vision: accident-free driving; status 2015



Fatalities EU 28:

Status 2000: 55 000

Status 2010: 31 500
(-40% rel. to 2000)

Status 2015: 26 100
(-15% rel. to 2010)

Target 2020: 16 000
(-50% rel. to 2010)

2000 | 2015 | Target 2020

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Accident figures 2015

	Resident population [Mio]	Registered motor vehicles [Mio]	Accidents with casualties [Mio]	Fatal Accidents*	Share of Fatal accidents (in casualty accidents)	Fatalities*
	82.2	53.7	0.31	**3 277**	**1.05 %**	**3 377**
	322.7	260.3	1.72	**32 166**	**1.82 %**	**35 092**
	127.1	91.0	0.63	**n.a.**	**0.80 %**	**4 867**

Sources: KBA, DESTATIS, NHTSA, FHWA, IRTAD, NPA Japan

* for fatalities that occur within 30 days (for Japan: extrapolated from data of fatalities who occur within 24 hours)

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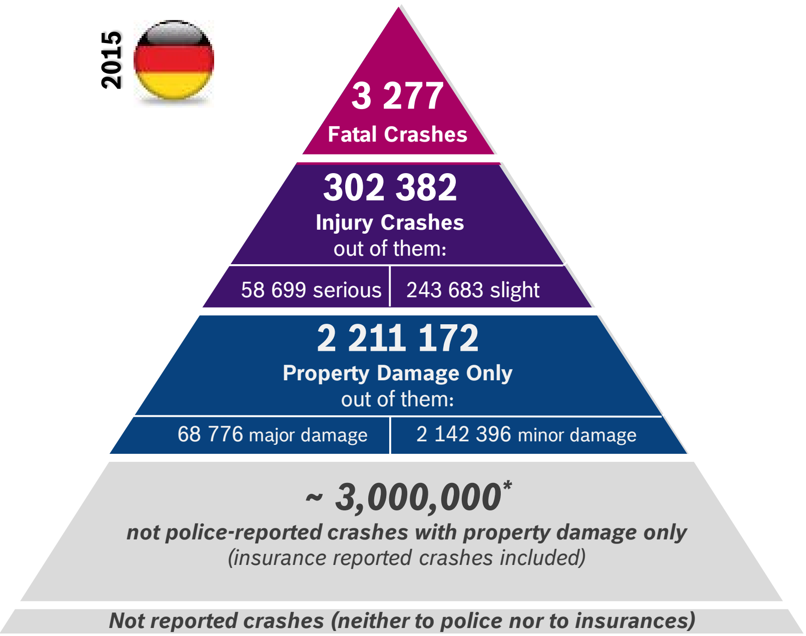
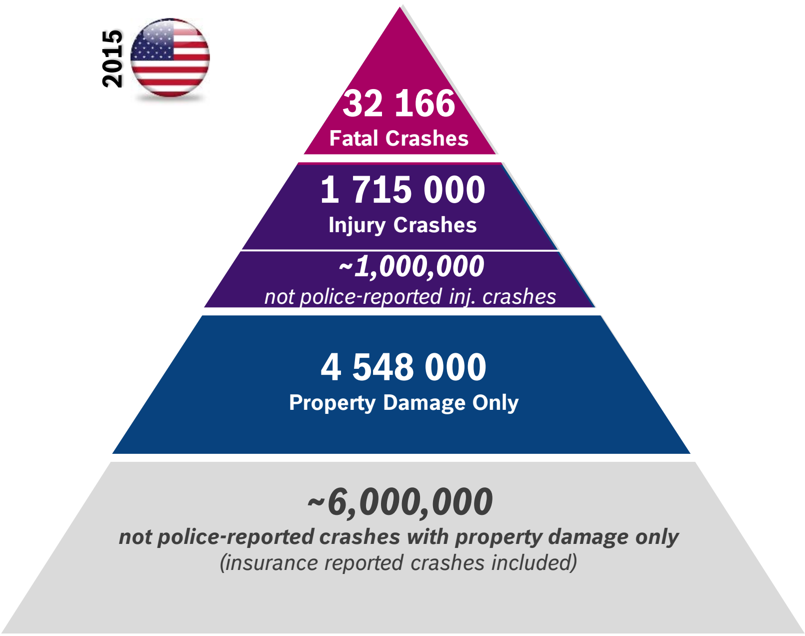
Accident figures Germany – USA (2015)



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



source: NHTSA Traffic Safety Facts 2015, DOT HS 812 384

- ~5.5 million police or insurance reported crashes in Germany

→ ~6.2 million police reported crashes and ~13 million crashes in US totally

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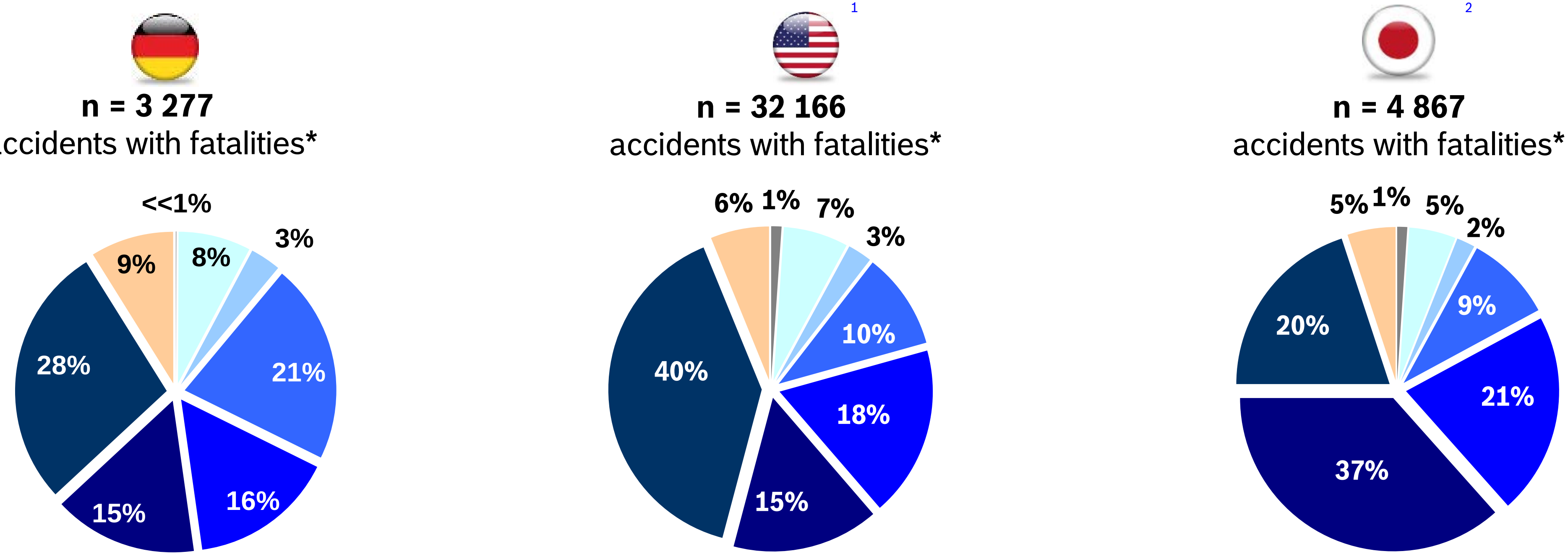
Fatal accidents by kinds of accidents



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

sources: DESTATIS, GIDAS, NHTSA, NPA Japan, Year 2015

[1] USA: motorized vehicle to Bicycle - accidents in category „Others“
[2] Japan: Accidents without automobile involvement in category “Others”
* for fatalities that occur within 30 days (for Japan: extrapolated from data of fatalities which occur within 24 hours)

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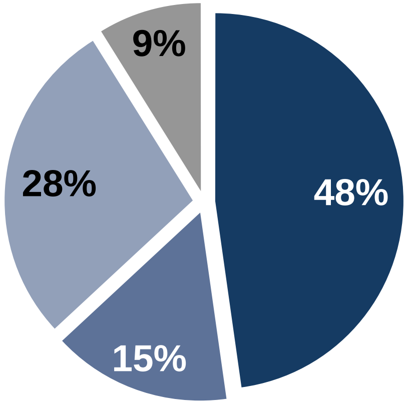
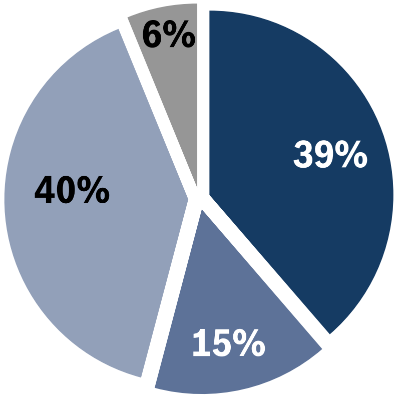
Chapter 11

Fatal accidents divided in main categories

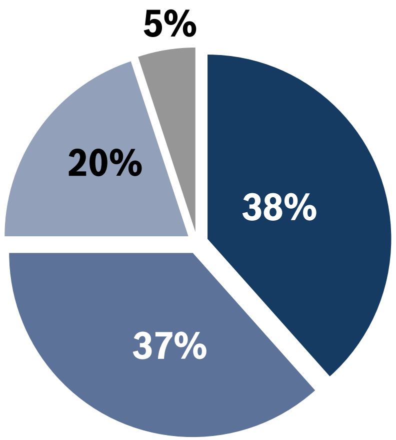
n = 3 277
accidents with fatalities*



[1]
n = 32 166
accidents with fatalities*



[2]
n = 4 867
accidents with fatalities*



main categories:

- **motorized vehicle – any vehicle** [1]
- **motorized vehicle - fixed object (off road)**
- **motorized vehicle - pedestrian**
- **others (object on road, animal…)**

sources: DESTATIS, GIDAS, NHTSA, NPA Japan, Year 2015

[1] USA: motorized vehicle to Bicycle - accidents in category „Others“
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* for fatalities that occur within 30 days (for Japan: extrapolated from data of fatalities which occur within 24 hours)

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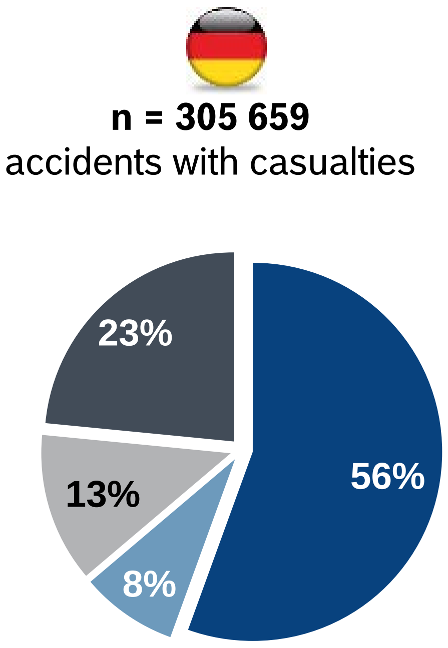
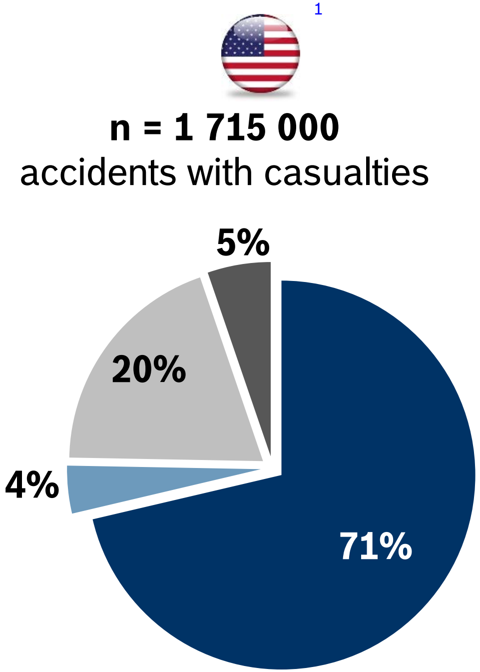
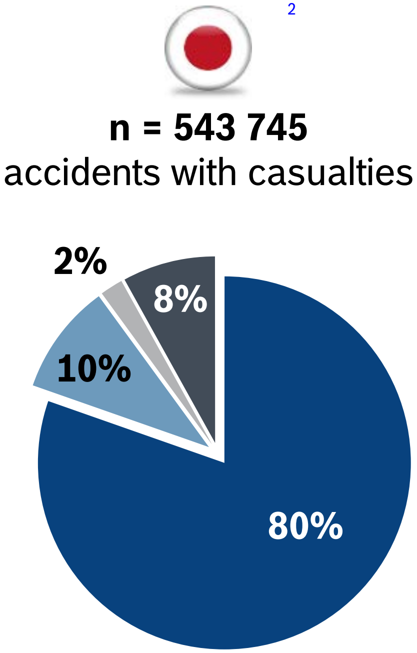
Accidents with casualties divided in main categories







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sources: DESTATIS, GIDAS, NHTSA, NPA Japan, Year 2015

[1] USA: motorized vehicle to Bicycle - accidents in category „Others“
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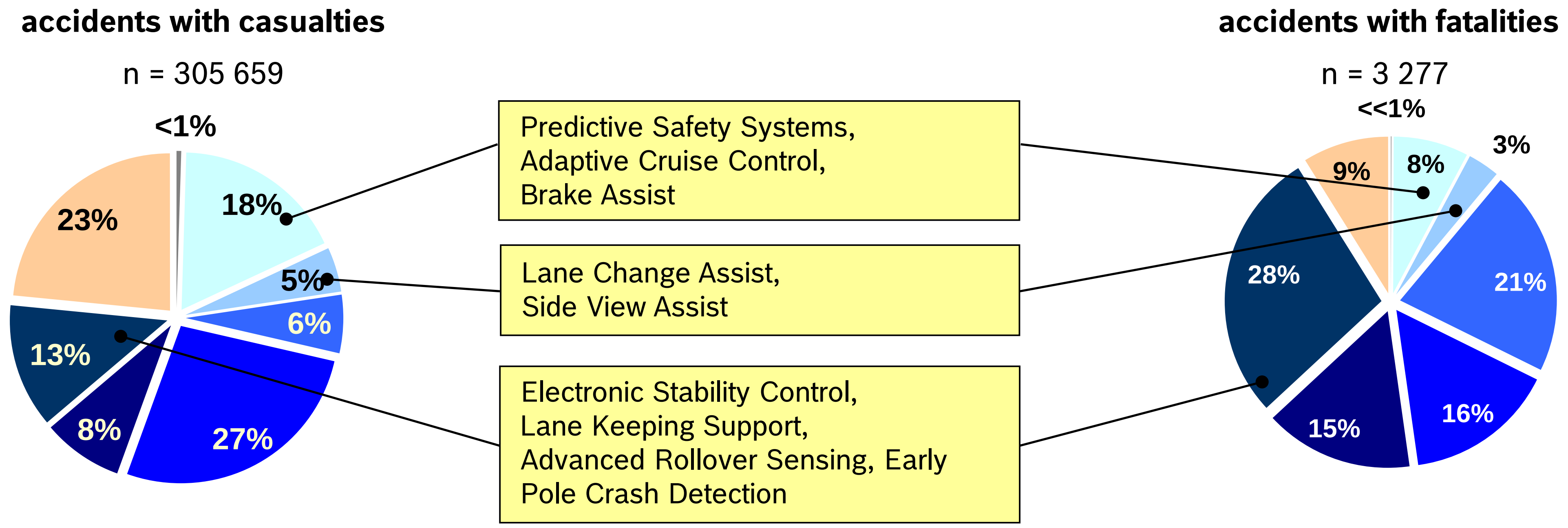
Bosch Accident Research - International statistics
Scope of safety functions in Germany (1/2)



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

Source: DESTATIS 2015

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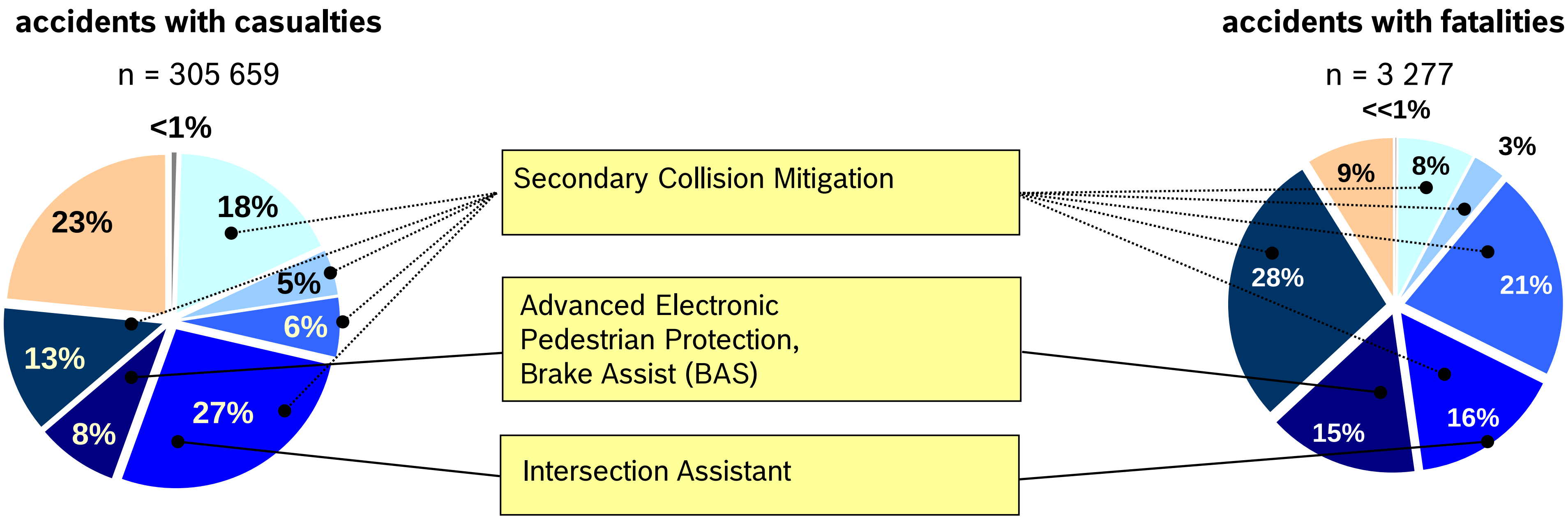
Scope of safety functions in Germany (2/2)



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

Source: DESTATIS 2015

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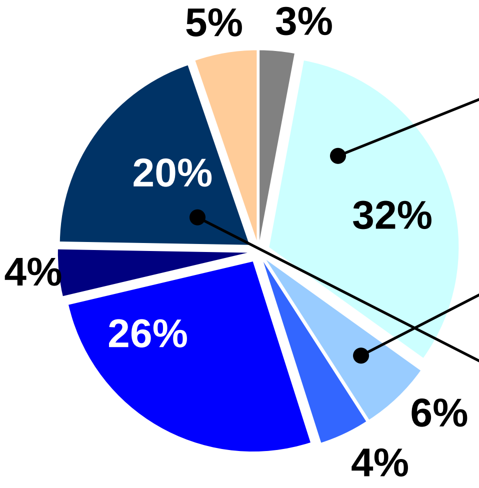
Scope of safety functions in USA (1/2)

accidents with casualties

n = 1 747 166



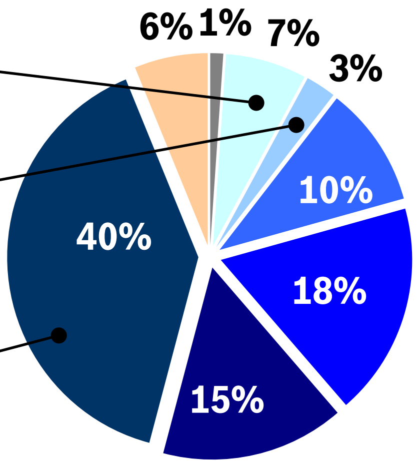
Predictive Safety Systems,
Adaptive Cruise Control,
Brake Assist

Lane Change Assist,
Side View Assist

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

accidents with fatalities

n = 32 166



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source: NHTSA Traffic Safety Facts 2015, DOT HS 812 384

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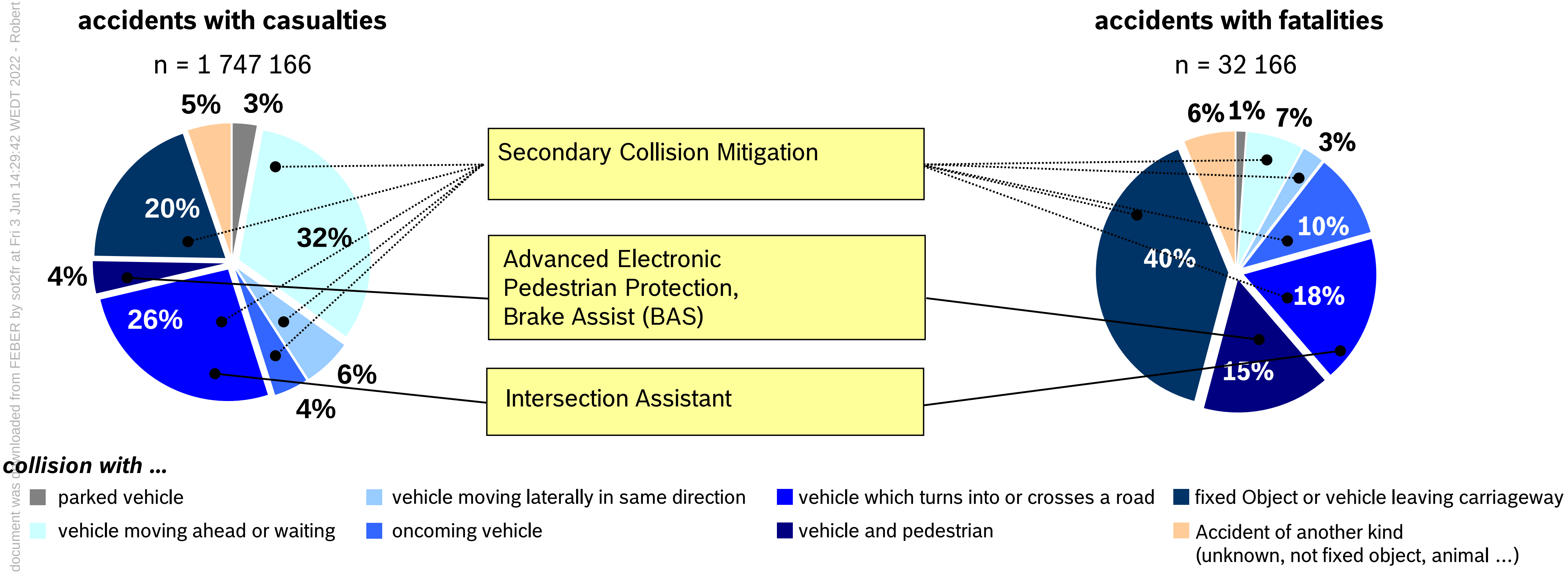
Scope of safety functions in USA (2/2)



source: NHTSA Traffic Safety Facts 2015, DOT HS 812 384

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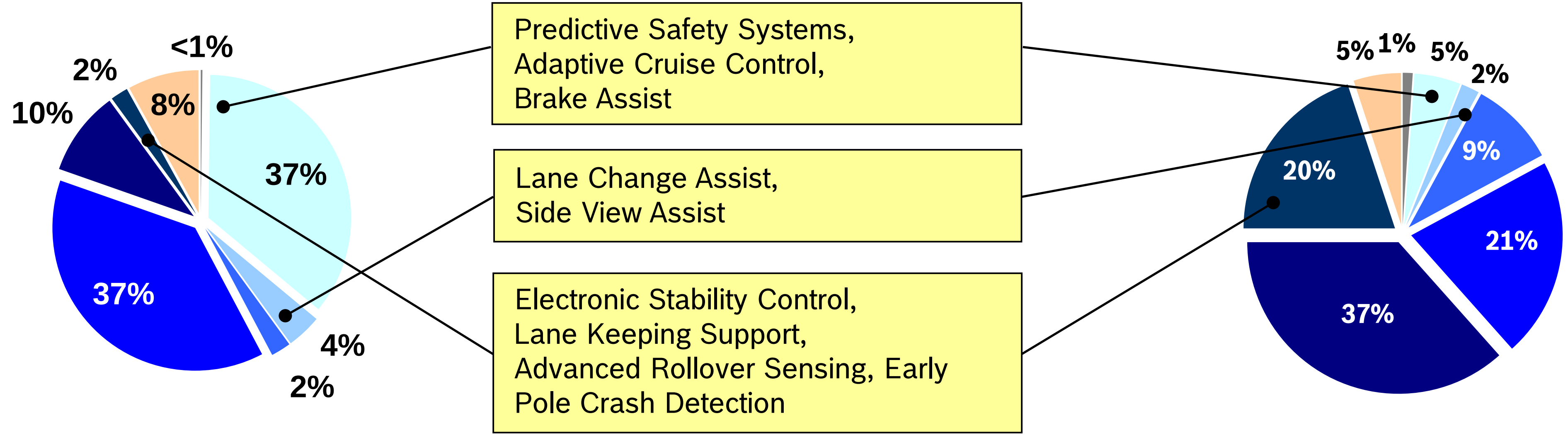
Scope of safety functions in Japan (1/2)

accidents with casualties

n = 543 745

accidents with fatalities

n = 4 867



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Source: Mame 2015

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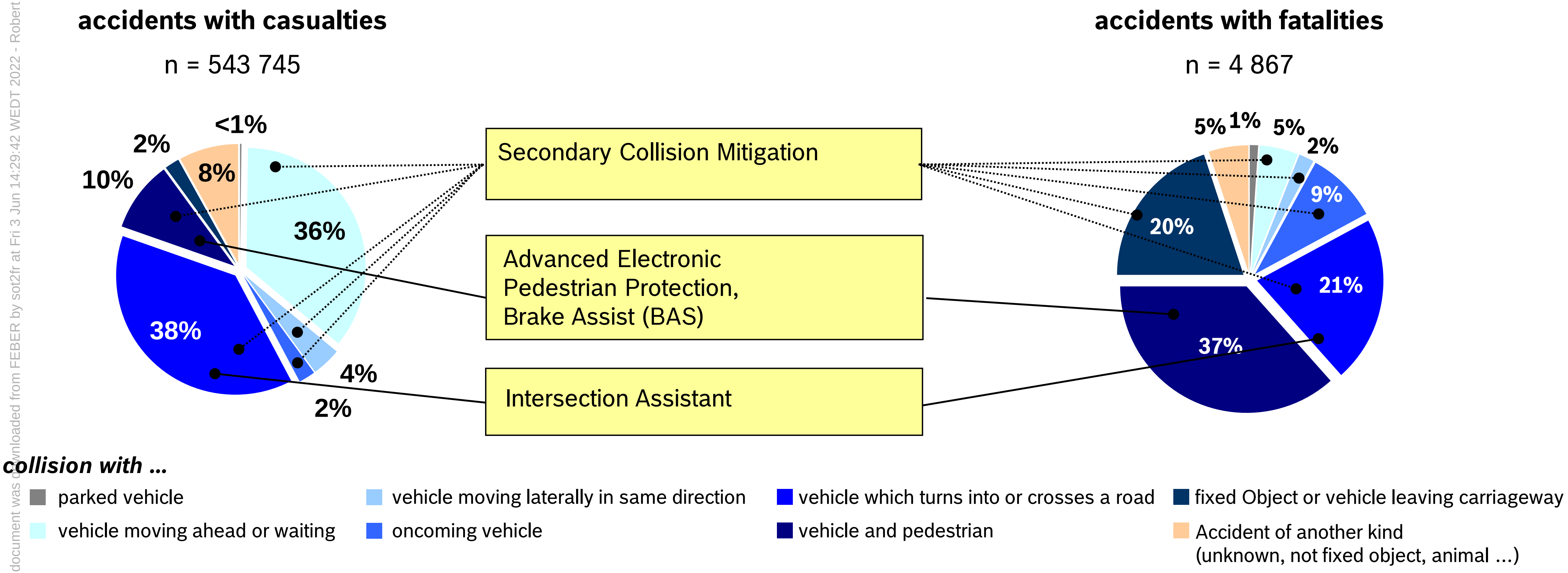
Scope of safety functions in Japan (2/2)



Source: Mame 2015

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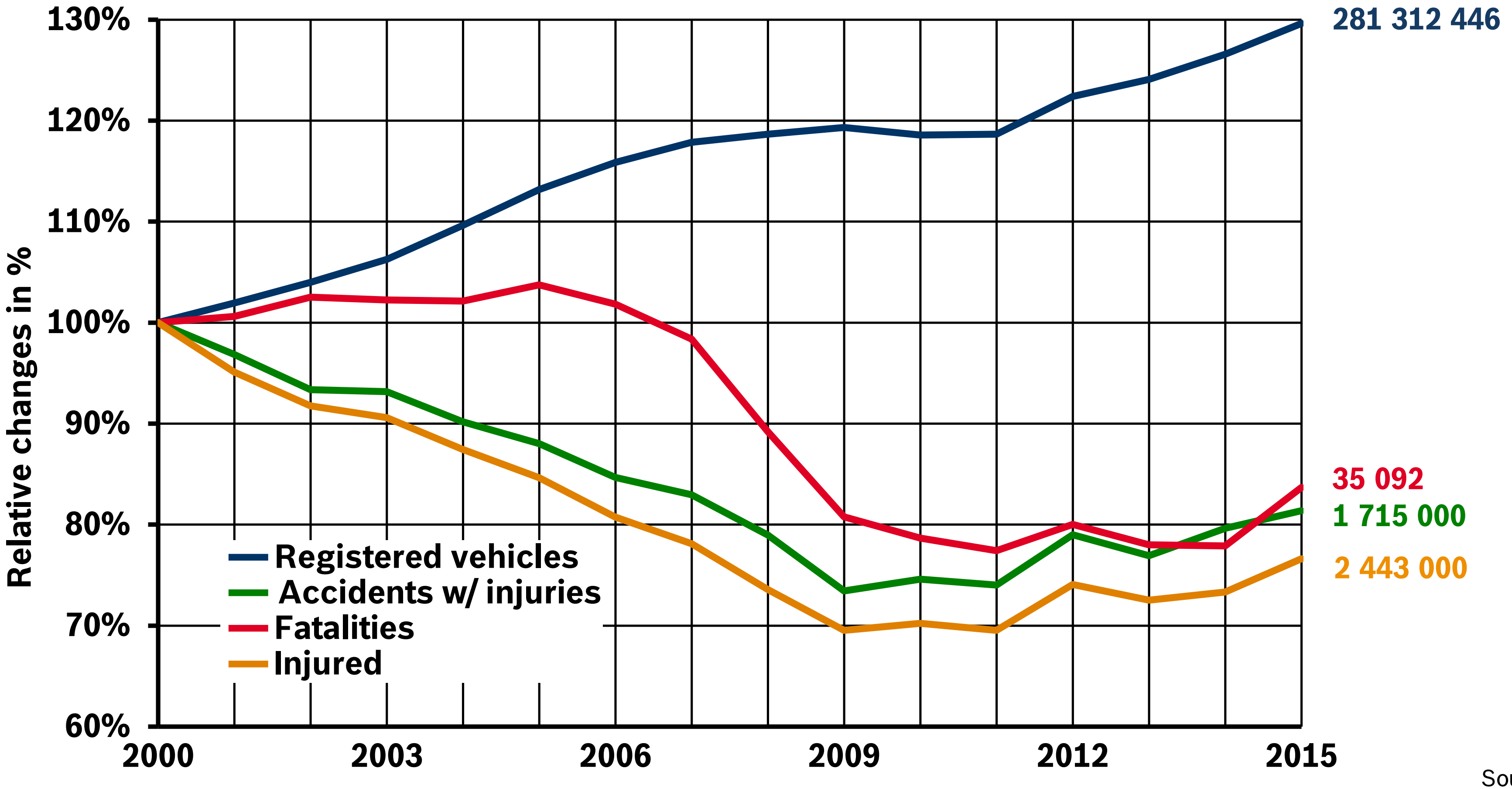
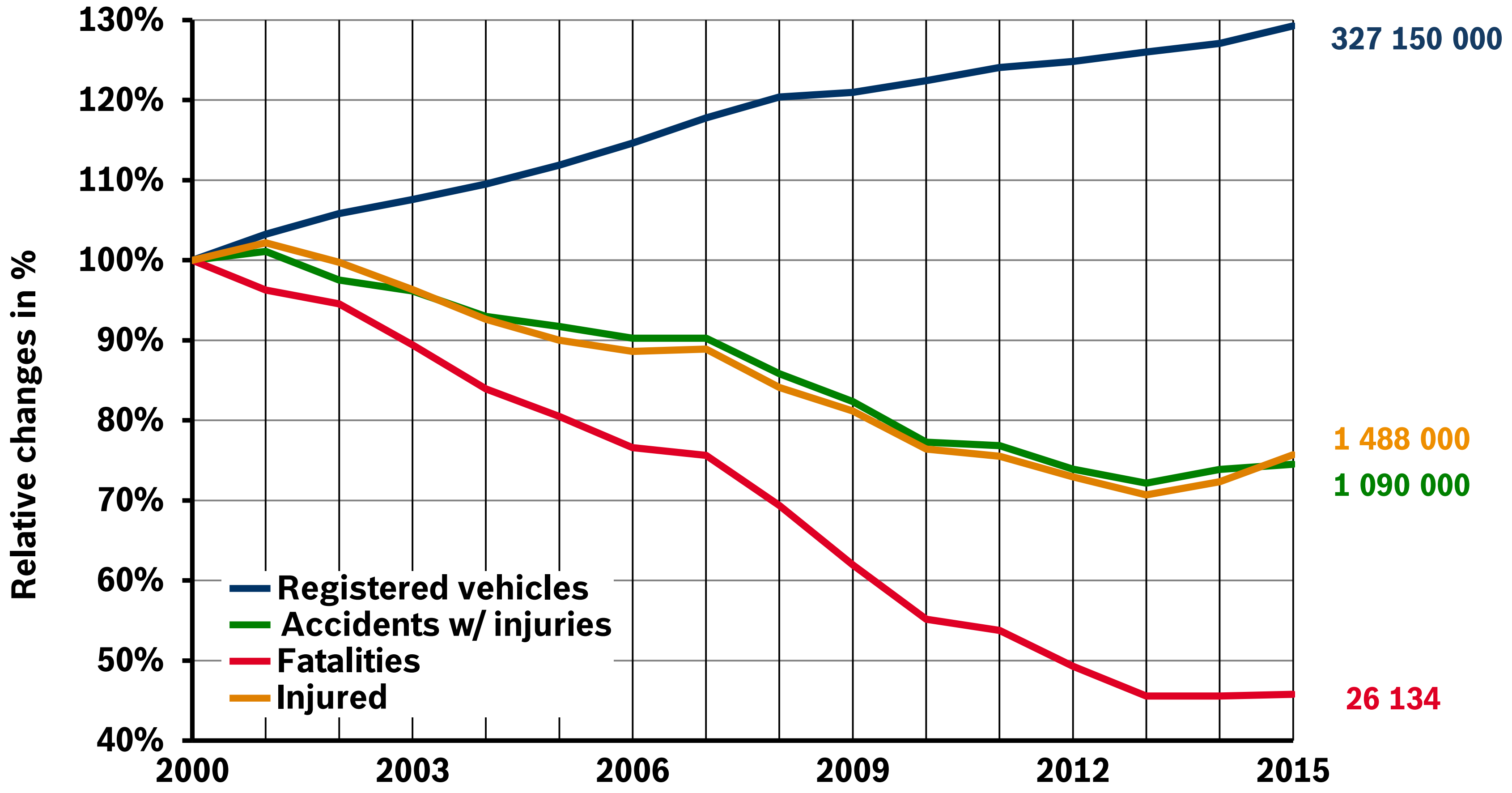
Bosch Accident Research - International statistics
Road Traffic Accidents USA



Source: Traffic safety facts 2017

Bosch Accident Research - International statistics

Road Traffic Accidents EU28



Source: Eurostat

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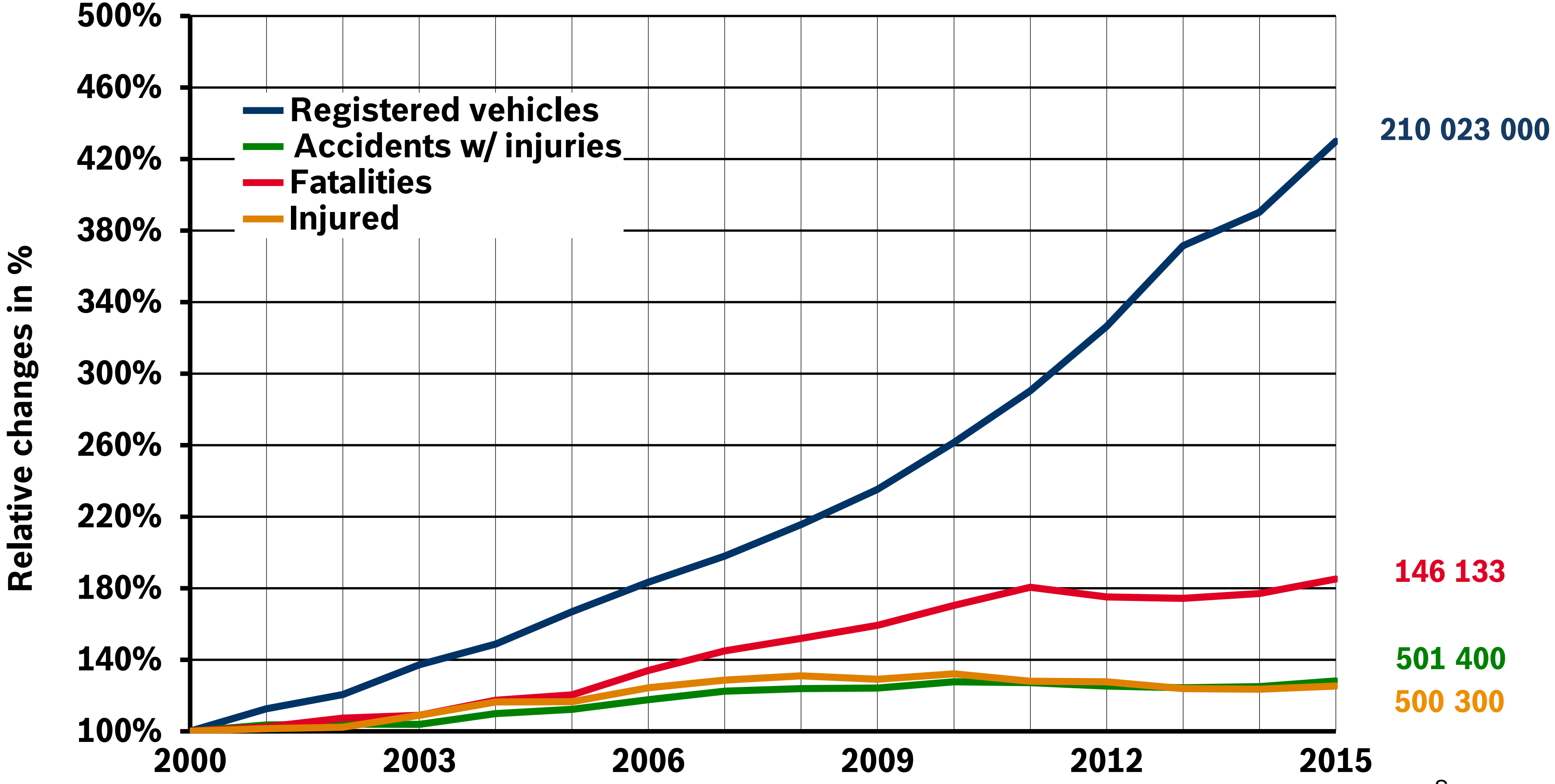
Road Traffic Accidents India

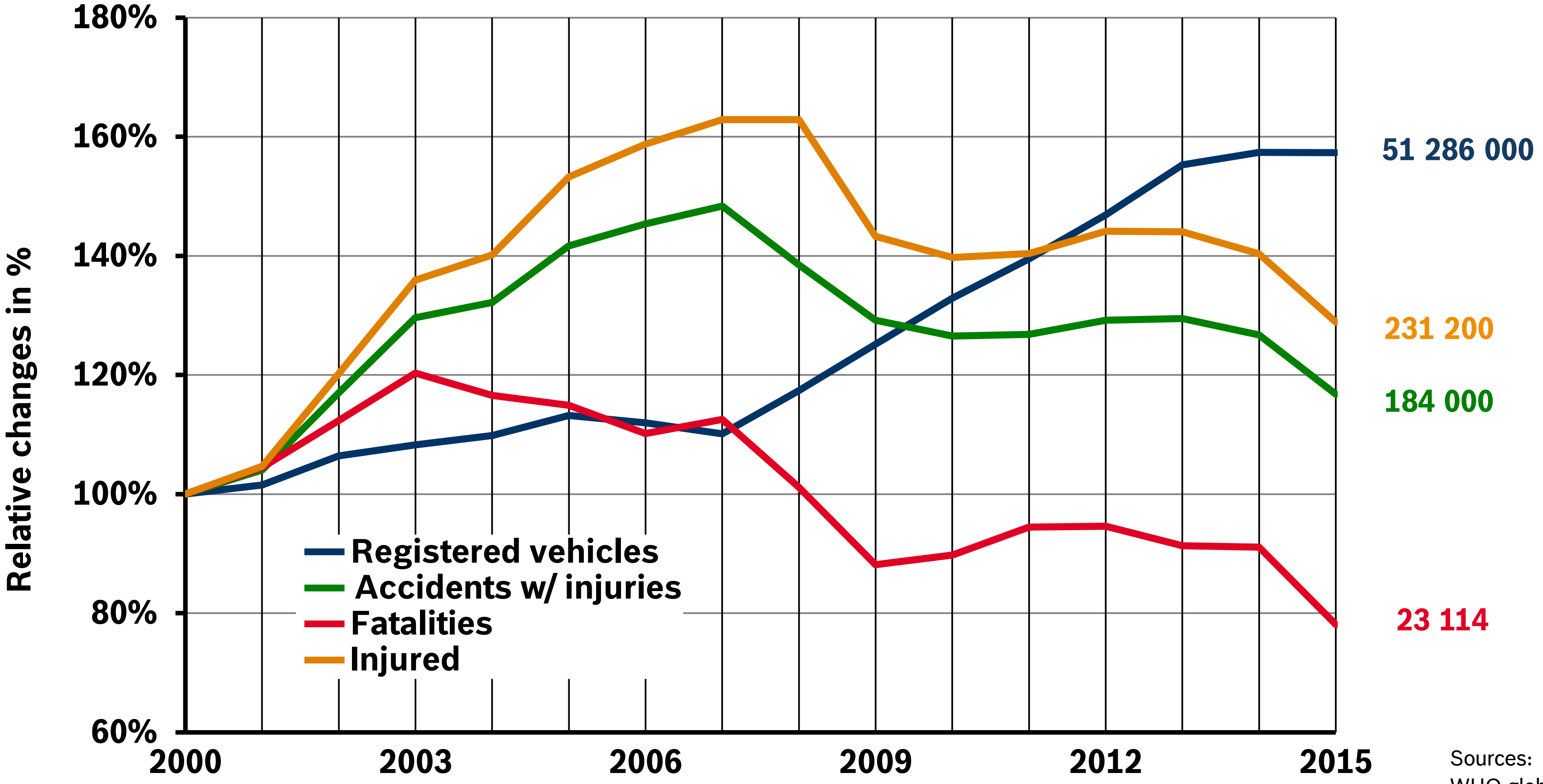


Source: road accidens in India 2015

Internal | Bosch Accident Research (CR/AEV1) | Jan/31/2018
AEV-064 annual report 2016/17

Bosch Accident Research - International statistics
Road Traffic Accidents Russia

Chapter 11



Sources:
WHO global status report on road safety
http://stat.gibdd.ru/

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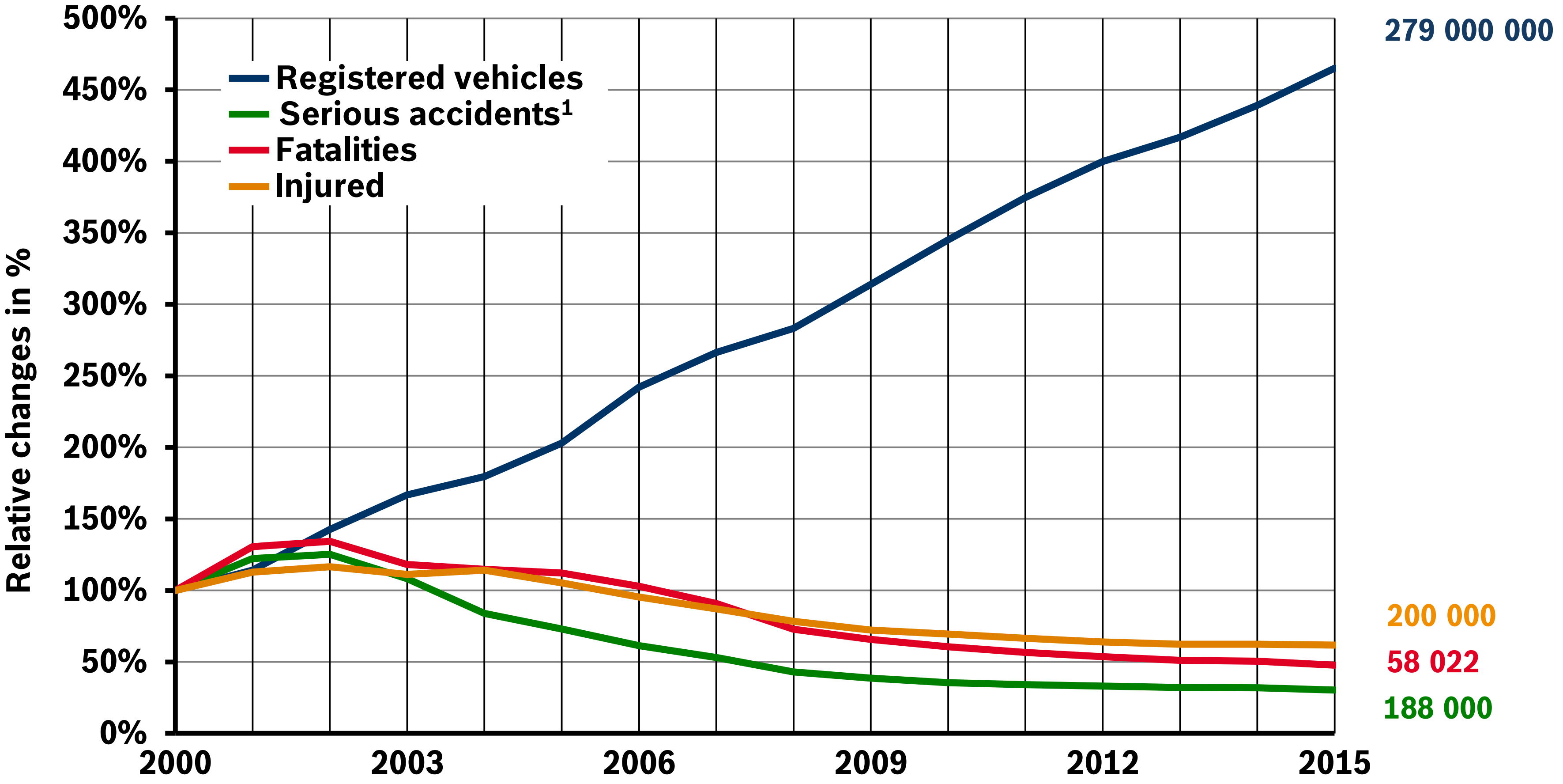
Bosch Accident Research - International statistics
Road Traffic Accidents China



Source: Chinas annual report

[1] Serious accidents: At least 3 persons slightly injured or 1 person seriously+ injured or property damage more than 1 000 RMB

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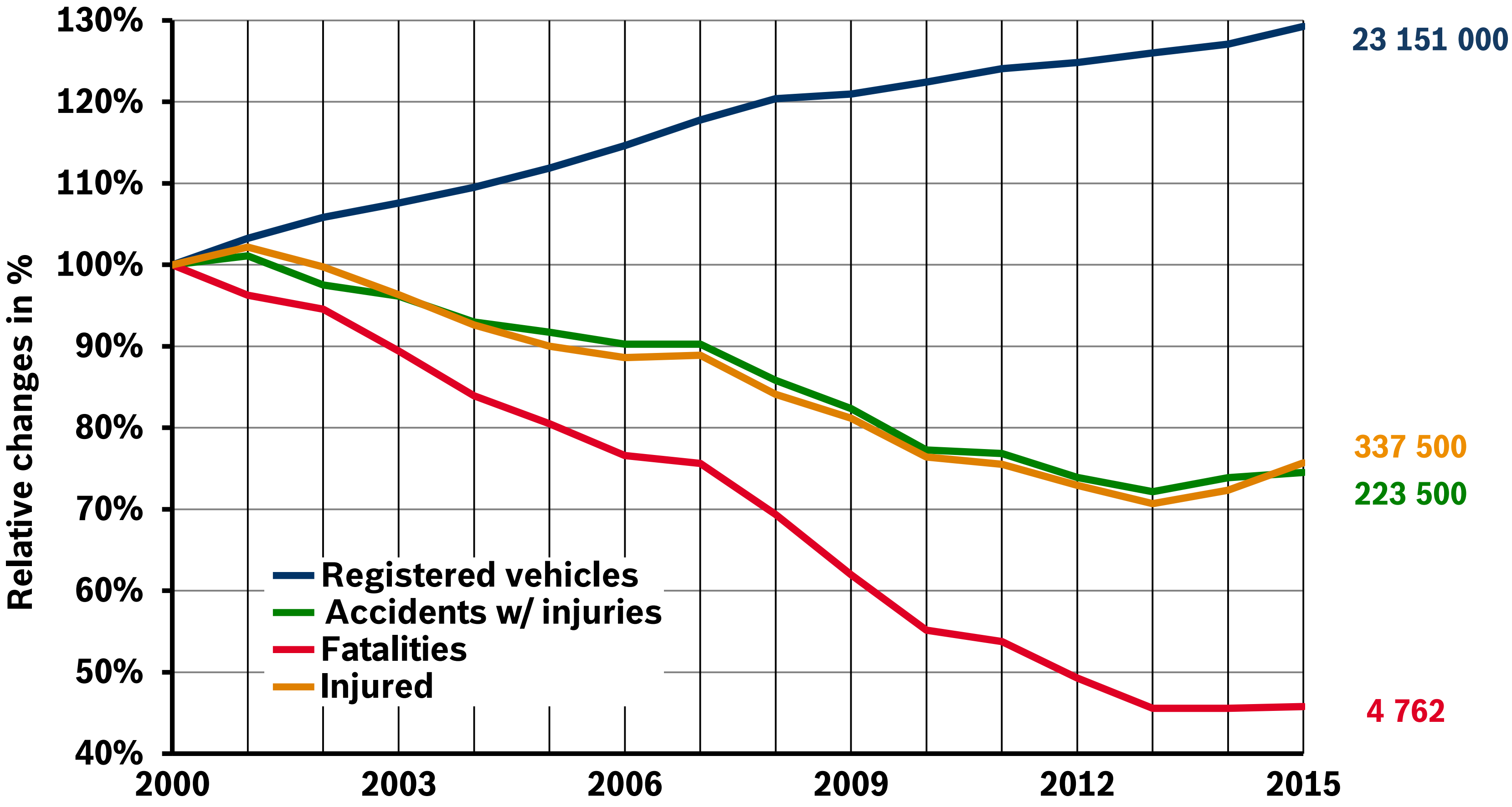
Chapter 11

Road Traffic Accidents South Korea

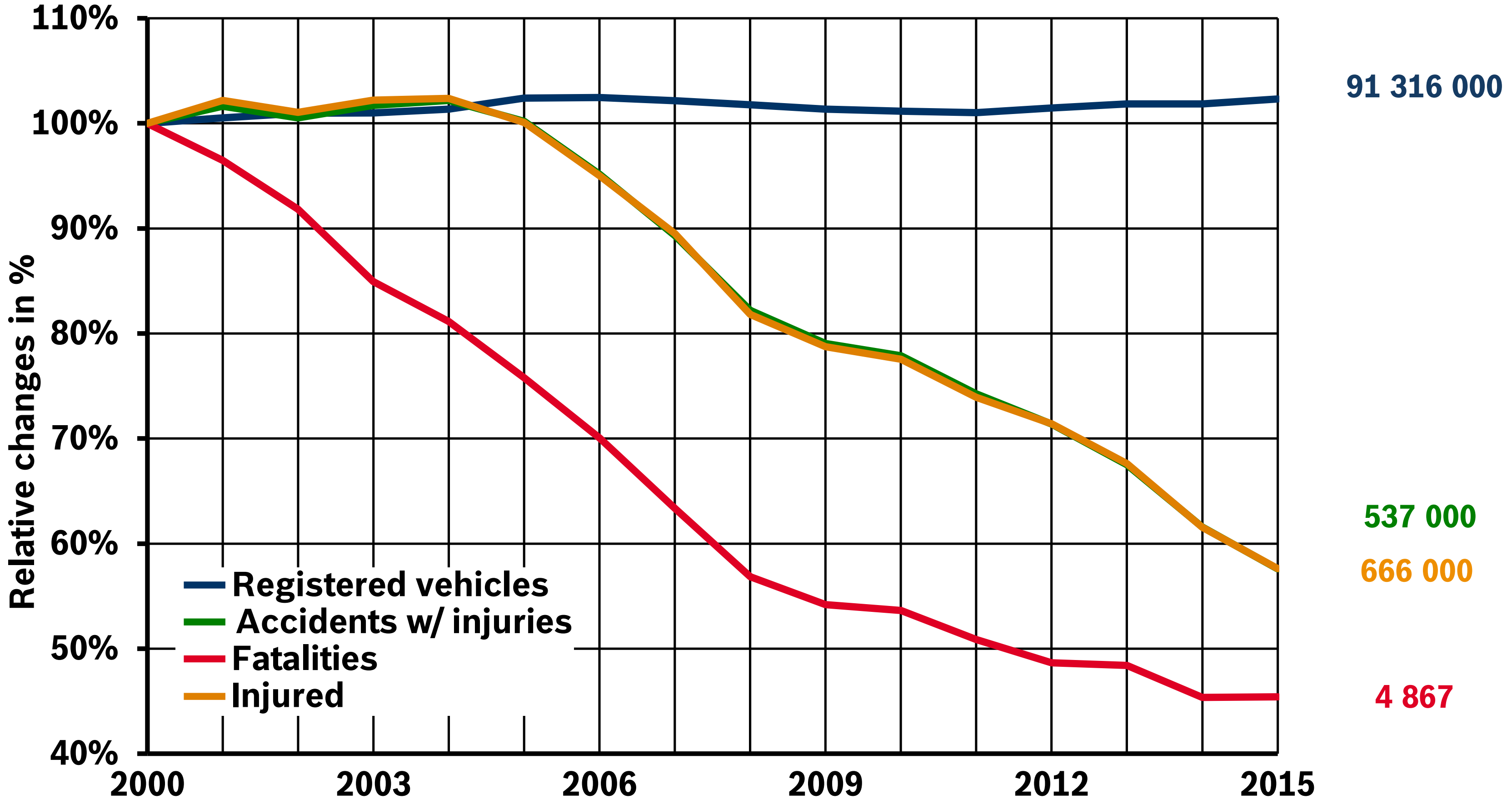


Source: koroad

Bosch Accident Research - International statistics

Chapter 11

Road Traffic Accidents Japan



Source: Mame 2015

Internal | Bosch Accident Research (CR/AEV1) | Jan/31/2018
AEV-064 annual report 2016/17

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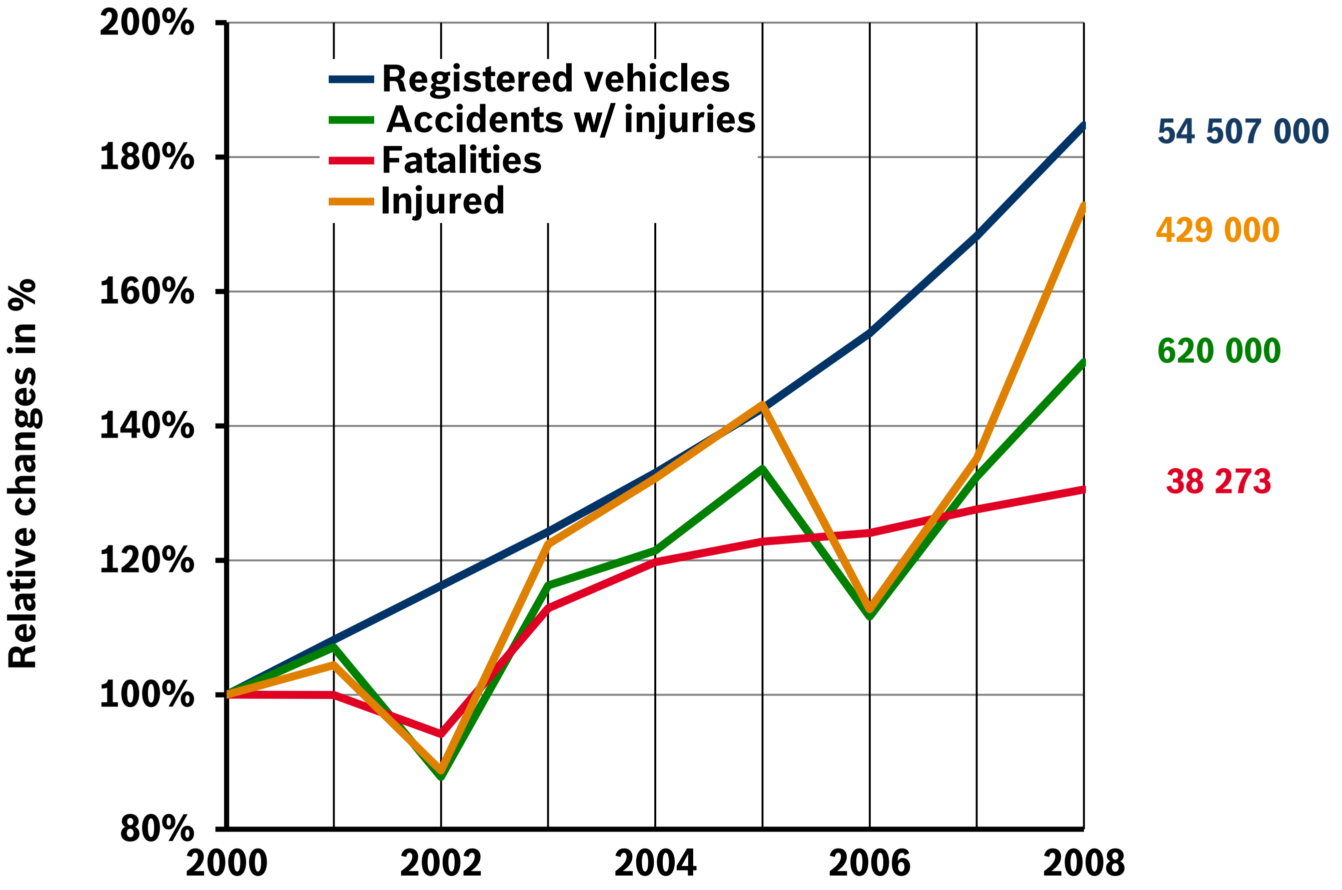
Bosch Accident Research - International statistics

Road Traffic Accidents Brazil

Chapter 11



Source: Anuário estatísticodo DENATRAN - RENAEST 2008, Brazil

Chapter 12

Arabic countries:
Middle East Road Safety Situation Report

Accident Research
CR/AEV1

Source of image: https://www.youtube.com/watch?v=xLd5IDjlOXU

Summary

Chapter 12

Aim of study: (1) Accumulation of statistical accident data on Middle Eastern countries from various sources for a better understanding of the road safety situation in the Middle East

(2) Calculation of accident risk indicators in order to have reference points for comparison

Method:
- Using official statistical databases
- Requesting information directly from relevant authorities
- Referring to published journals or news reports

Results:
- Road safety is gradually improving in all the studied Middle Eastern countries, except for the Kingdom of Saudi Arabia
- Different behavior of a substantial share of drivers in comparison to western countries:
  - Aggressive driving style
  - Lack of respect for other road users and their safety
  - Violation of traffic laws

Source of background image: https://www.youtube.com/watch?v=xLd5IDjlOXU

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Contents

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- Middle Eastern Countries Overview
- Global Road Safety Situation
- Middle Eastern National Road Safety Strategy Overview
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- Accident Videos
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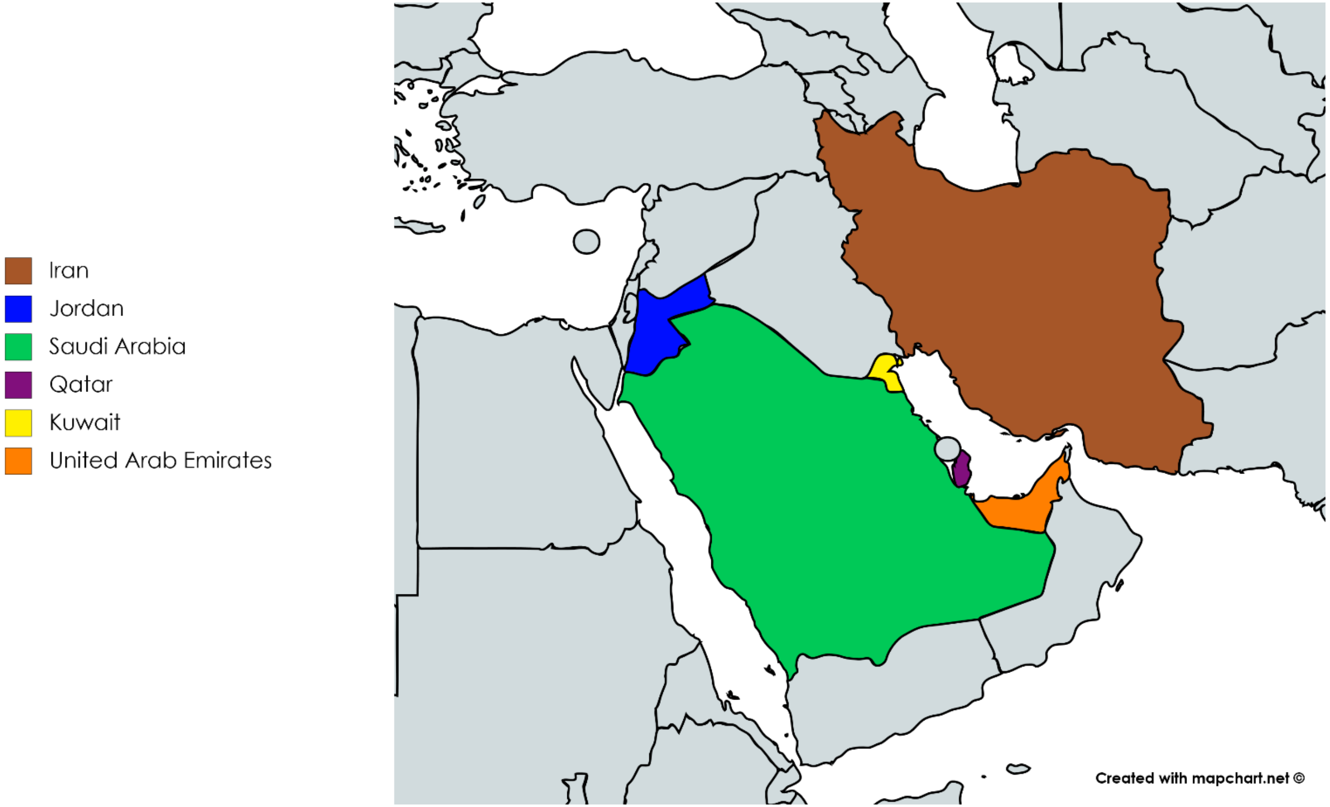
- Summary & Conclusion
- Annex

Accident Research: ReGe - Middle East Countries

Map of the Middle East and Selected Countries for this Report

Source: https://upload.wikimedia.org/wikipedia/commons/7/72/Map_of_Middle_East.png



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Middle Eastern Countries Overview

Country	Population 2016 [Mio]	% of Pop. Foreign	GDP (PPP) per Capita [Int$]	Car Import Customs		Fuel Price [$/L]	Quality of Data [1-10]	Special Characteristics
				Cost	Age			
Iran	80.0	-	18 100	High	1	0.36	5	• Motorcycles restricted to 250cc • Women not allowed to drive motorcycles
KSA[1]	32.2	37%	54 100	Low	5	0.24	3	• Women not allowed to drive (only country globally*) • Alcohol prohibited
UAE[2]	9.3	89%	67 700	Low	10	0.50	2	• Starting May 2017, safety regulations enforced on vehicle imports • Good public transportation systems
Kuwait	4.0	70%	71 300	Low	5	0.34	5	• Kuwaiti dinar is the world's highest-valued currency
Qatar	2.6	88%	129 700	Low	5	0.45	8	• Illegal for garages to repair accident damage without official paperwork
Jordan	9.8	~33.3% (Refugees)	11 100	High	5	1.24	7	• Diesel passenger cars not allowed • Motorcycles allowed for public since 2010 • 1.4 Mio registered vehicles in 2015, 4.5 Mio foreign vehicles entered that year • Only country on the list with non-oil based economy

[1] Kingdom of Saudi Arabia
[2] United Arab Emirates

* KSA's King issued a royal order on Sep. 26th 2017 to lift ban and allow women to drive by June 2018

Accident Research: ReGe - Middle East Countries

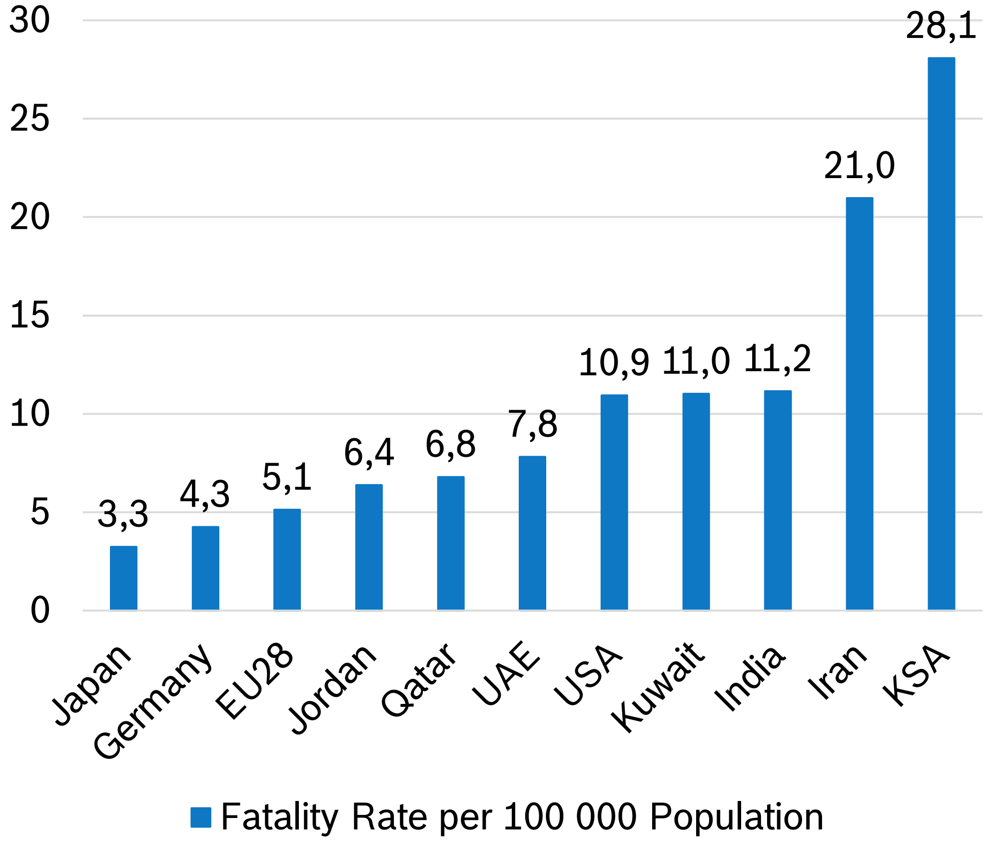
Global Road Safety Situation

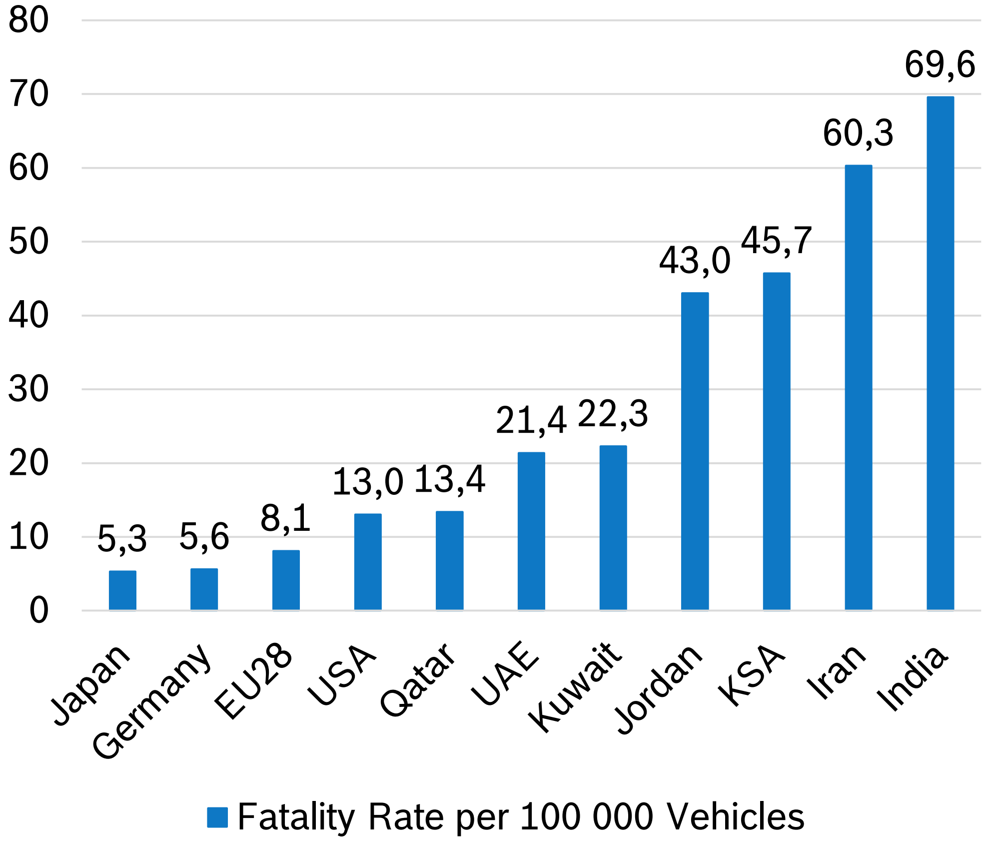
Country	Population [Mio]	Registered Vehicles [Mio]	Reported Accidents	Casualties	Fatalities	New Vehicles Registered 2012	Year
Iran	79	27.5	452 630	414 161[1,3]	16 584	860 000	2015
KSA	32	19.8	533 380	47 151	9 031	530 000	2016
UAE	9.3	3.4	4 788	7 406	725	211 500	2016
Kuwait	3.9	1.9	80 827	9 602	429	164 485	2015
Qatar	2.6	1.3	314 591	9 097	178	85 019	2016
Jordan	9.5	1.4	111 057	16 747	608	66 624	2015
Germany	81	61.5	2 516 831	396 891	3 459	3 082 054	2015
USA	321	269	6 296 000	2 478 092	35 092	14 310 000	2015
Japan	127	77	536 899[2]	670 140	4 117	5 369 720	2015
India	1 311	210	501 423[2]	646 412	146 133	17 625 000	2015
EU28	508	322	1 090 300[2]	1 474 200	26 100	14 366 049	2015

[1] Casualties number is based on 2010 data
[2] Reported accident numbers are for accidents with casualties only
[3] Definitions for fatalities and casualties unavailable for Middle Eastern countries, except for Iran (fatalities on the spot) and Jordan (fatalities within 30 days of accident)

Accident Research: ReGe - Middle East Countries

Global Road Safety Situation in Figures





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Chapter 12

Red Light Crossing Accident in Saudi Arabia

Source: https://www.youtube.com/watch?v=XSIBDhLJes0

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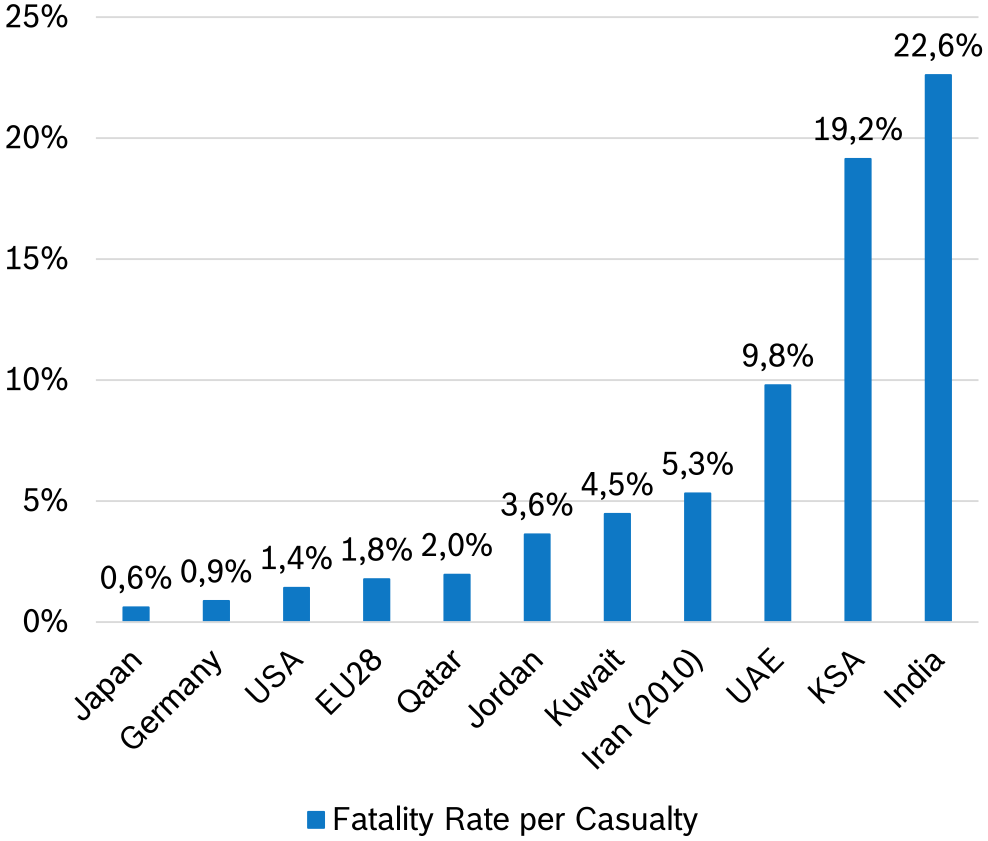
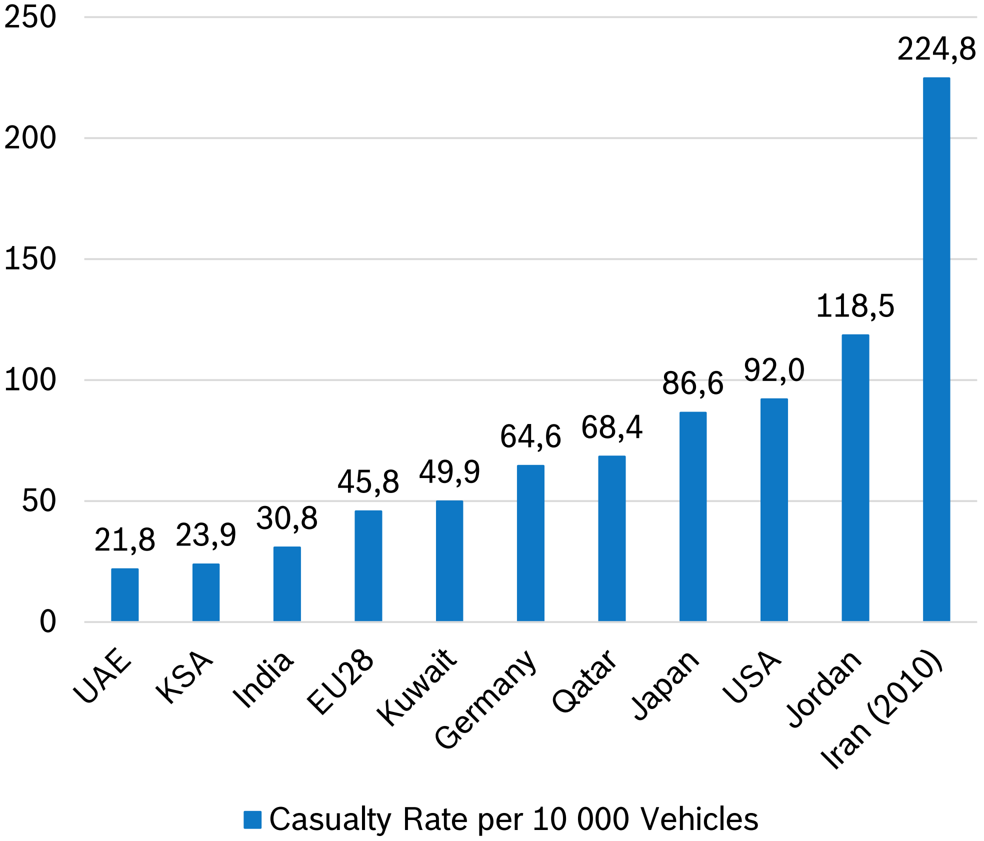
Global Road Safety Situation in Figures





Accident Research: ReGe - Middle East Countries

Middle Eastern National Road Safety Strategy Overview

Country	National Road Safety Target	National Road Safety Strategy					Year Introduced
		Legislation	Infrastructure	Post-crash care	Education	Technology	
Iran	Reducing fatalities per 100 000 population to 9 by 2020	☑	☑	☑	☑	☑	2011
KSA	Reducing road traffic fatalities by 50% by 2021	☑	☑	☑	☑	☑	2011
UAE	Reducing fatalities per 100 000 population to 3 by 2021	☑	☑	☑	☑	☑	2014
Kuwait	Reducing fatality rate per 100 000 population to below 16 by 2015	☑	☑	☑	☑	☑	2009
Qatar	Reducing fatalities per 100 000 population to 10 by 2016	☑	☑	☑	☑	☑	2013
Jordan	Reducing road traffic fatalities by 50% by 2022	☑	☑	☑	☑	☑	2010

Accident Research: ReGe - Middle East Countries

Detailed National Road Safety Strategy Overview

Country	National Road Safety Target	National Road Safety Strategy
Iran	Reducing fatalities per 100 000 population to 9 by 2020	Road infrastructure safety, law enforcement and prevention of unsafe road users behavior, public awareness and safety campaigns, post-crash care, public training, health & safety management of commercial drivers, driver training & driving license procedure, vehicle standards improvement, road safety management system, assessment, evaluation and budget allocation, crash data record and analysis
KSA	Reducing road traffic fatalities by 50% by 2021	Improve design of roads and signs, improve driver behavior, mitigate consequences of accidents, enhance coordination between agencies, applied research results, set ambitious targets, ensure appropriate funding, enhance private sector participation
UAE	Reducing fatalities per 100 000 population to 3 by 2021, 0 road traffic accident fatalities by 2030	Assessing the speeding problem, engineering, laws/legislation, education and awareness, enforcement, stakeholder coordination, emergency medical services
Kuwait	Reducing road fatalities 30% by 2015, reducing fatality rate per 100 000 population to below 16 by 2015, reducing fatality rate per 10 000 registered vehicles to below 3.8 by 2015, and reducing the serious road accident injuries number to below 8,600 per year	Awareness, monitoring, institutional reform, sustainable system, enhancement of the information technology, improvement of the road accident investigation system, training of traffic cadres, enforcement, improving traffic signs and signals
Qatar	Reducing fatalities per 100 000 population to 10 by 2016, reducing the annual number of road crash fatalities to 130 by 2022, and reducing the number of serious injuries to 300 by 2022	An update to the Qatar traffic law in 2009 and introduction of a penalty points system, installation of red-light and speed cameras, development of a process and guideline for road safety audit which will improve the safety standard of new roads and assess priorities on existing roads, commencement of pedestrian crossing strategy for Qatar, review of the Qatar highway design and traffic manuals, improvements to processes and standards for workzones, review of speed limits in Qatar, development of materials and guidance for road safety education in schools, introduction of theory and practical components to the driving test, introduction of systems to help with response to road crashes, development of world-class emergency medical services
Jordan	Reducing fatalities per 10 000 vehicles to 1 by 2016, reducing fatalities by 50% by 2022	Conducting studies to make recommendations, planning and managing roads to reduce congestion, focusing on the most dangerous intersections, increasing penalties for the most harmful traffic violations, increasingly monitor traffic on months, days, times, and roads where accidents occur most, increasing stakeholder cooperation, several road safety awareness campaigns, also a Traffic Safety Conference is periodically held in Jordan

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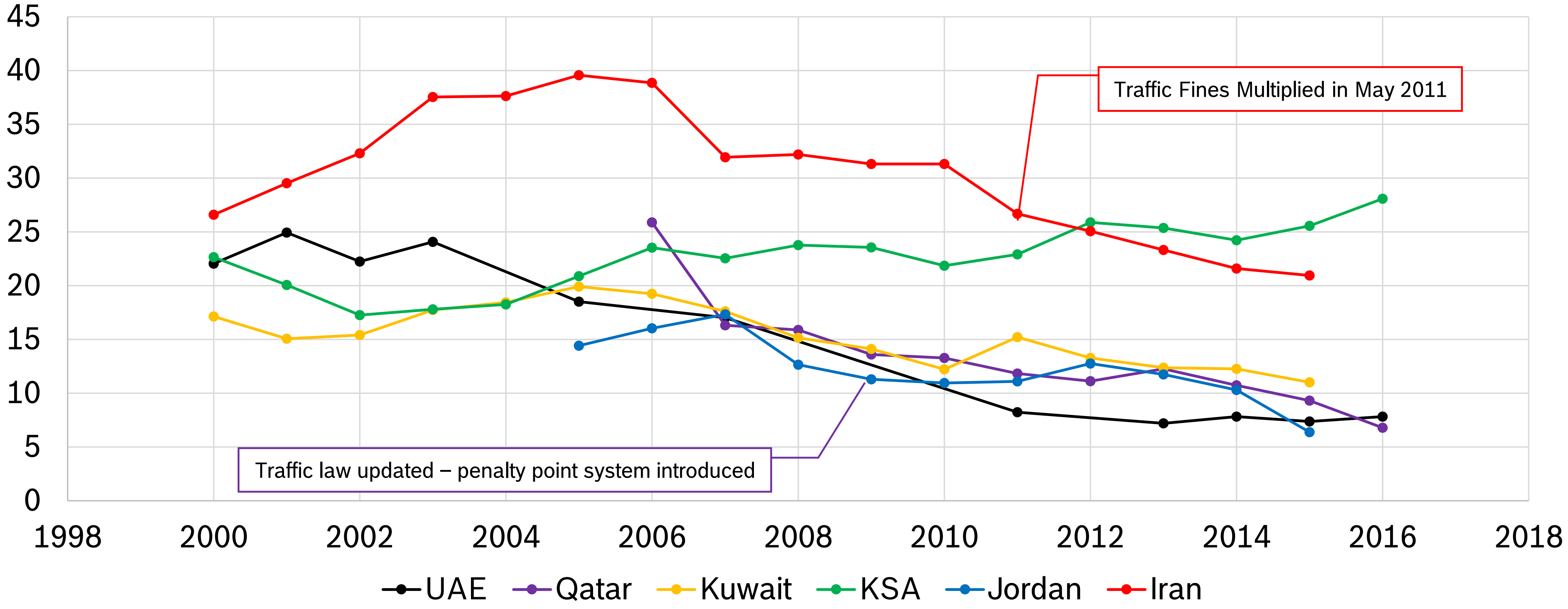
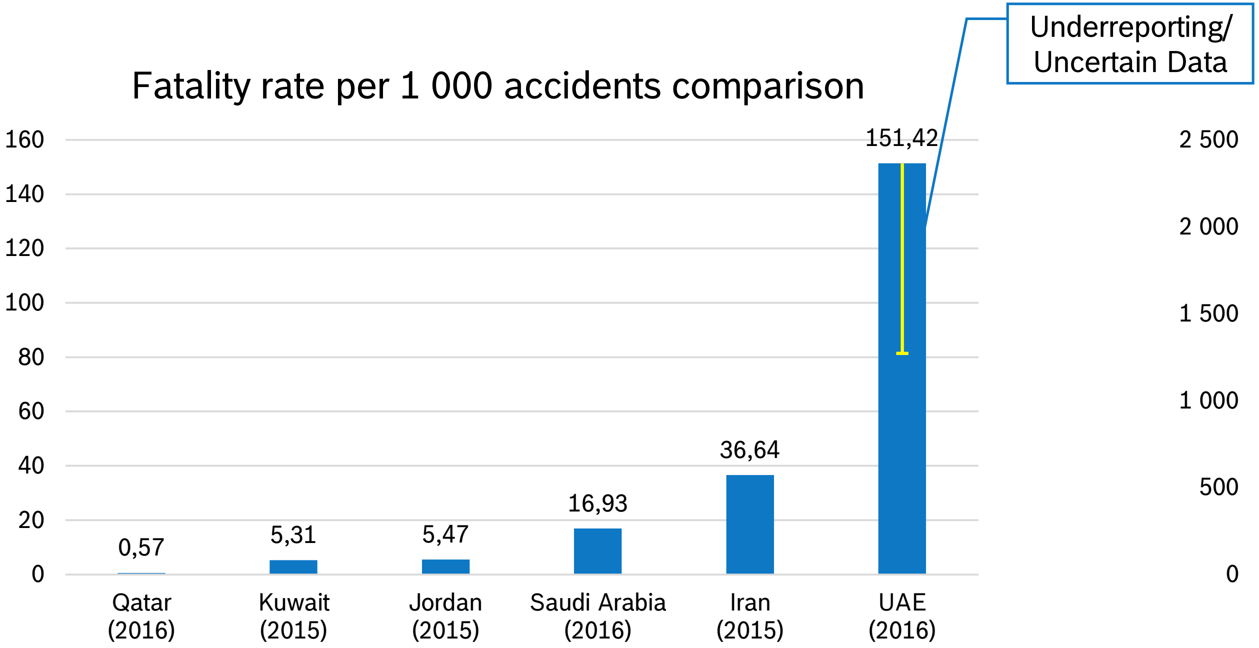
Accident Research: ReGe - Middle East Countries

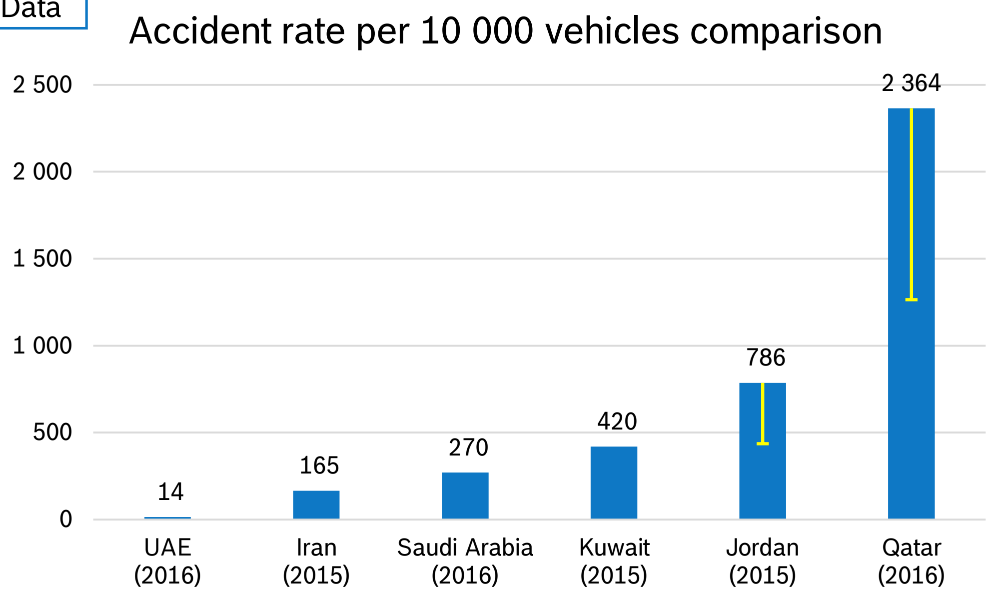
Fatality Rate per 100 000 Population Timeline



Accident Research: ReGe - Middle East Countries

Middle Eastern Road Safety Situation in Figures





- 15.14% of accidents in UAE are fatal
  → This can be explained by the low number of reported accidents (4 788 in 2016)
- Various underreporting rates for each country

- Almost 24% of vehicles in Qatar involved in accidents
  → This can be due to the entry of ~2 Mio people through the land border connecting to Saudi Arabia combined with the high reporting rate due law's requirement for repairs
- Jordan had an influx of 4.5 Mio foreign vehicles in 2015

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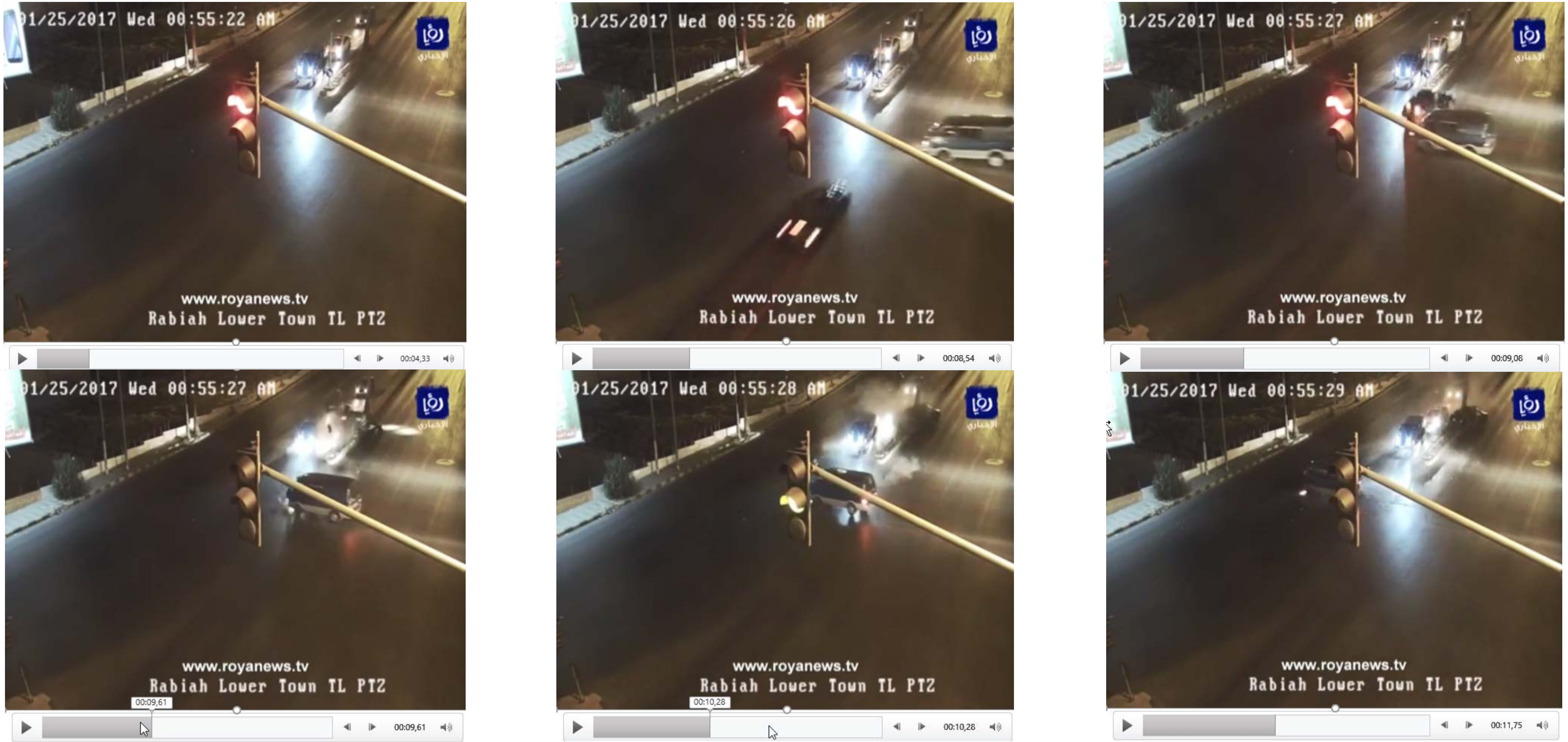
Accident Research: ReGe - Middle East Countries

Red Light Crossing Accident in Jordan 



Source: https://www.youtube.com/watch?v=XGxDhe1vJfw

Accident Research: ReGe - Middle East Countries

Saudi Drift Video – Inside View

Saudi Drifting: an illegal street racing-like phenomenon believed to have started in the late 1970s that involves trying to "drift" cars; to drive cars that are generally non-modified factory-setup rental cars at very high speeds, around **160–260 km/h**, across wide highways throwing the car left and right.

https://en.wikipedia.org/wiki/Tafheet

Source: https://www.youtube.com/watch?v=W-8CsawAAXw

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Saudi Drift Video – In Public with Traffic

Source: https://www.youtube.com/watch?v=HVrBh71PzDw

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Chapter 12

Saudi Drift Video – Fatal Accidents

Source: https://www.youtube.com/watch?v=XhKkwMr1Ac8

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Accident Research: ReGe - Middle East Countries

Chapter 12

Saudi Drift Video – Fatal Accidents

Source: https://www.youtube.com/watch?v=TR07YLs-LeI

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Chapter 12

Saudi Drift Video – Fatal Accidents

Source: https://www.youtube.com/watch?v=TR07YLs-LeI

Accident Research: ReGe - Middle East Countries

Recommended Measures

Car:

- Anti-drift functionality to avoid misuse
- EDR with video, even while vehicle is parked
- Seat belt reminder with protection from manipulation

Legislative / Infrastructure:

- Seat belt legislation including rear seat passengers
- Section control against speeding
- Implementing traffic calming measures (speed bumps, reducing lanes, etc...)
- Improve infrastructure and planning for sidewalks and roads

Education:

- Raising road safety awareness in both pedestrians & drivers, especially young adults
- Provide activities for young adults to be involved in to avoid boredom[1], e.g. fund dedicated local race tracks to offer a safe place for drivers to show off their skills

[1] Particularly intended for KSA, but also applicable for other countries to a certain extent

Accident Research: ReGe - Middle East Countries

Summary & Conclusion

- Different behavior of a substantial share of drivers in comparison to western countries:
  - Aggressive driving style (tailgating, improper overtaking, frequent lane changes w/ near misses…)
  - Lack of respect for other road users and their safety
  - Relatively more frequent violation of traffic laws
- Very low rate of seat belt use in spite of law (example: 2.5% for accidents w/ casualties in Qatar)
- Traffic laws need to be enforced more strictly
- Road safety awareness needs to be raised, especially among young adults
- Reckless driving and drifting in public needs to be eliminated
- The situation in all of the Middle Eastern countries being studied is gradually improving (except KSA)

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Chapter 13

Japan: Analysis of car-bicycle crashes and impact towards J-NCAP test scenario conditions

Accident Research
CR/AEV1

Aim of study:

(1) Evaluation of current accident situation of car-bicycle accidents w/ casualties in Japan
(2) Determination of probable J-NCAP test scenarios for a car-AEB Cyclists system and comparison with Euro NCAP test scenarios

Method:

- Literature survey especially on car-bicycle crashes in Japan
- Analysis of ITARDA database 2016 (Inquiry to ITARDA)
- Detailed single case analysis of ~200 incidents including 39 car-bicycle crashes from Event Drive Recorder data (2009-2011)

Result:

- Major car-bicycle accident situations are crossing bicycle w/ and w/o obstruction during daylight and fine weather conditions (~5% of all accidents w/ casualties in Japan)
- Slight differences between Japan and Europe wrt scenarios, vehicle speeds
- Similar test scenarios assumed hence no impacts towards car sensor system requirements assumed in order to detect bicycles.

For details: Ask for publication @ Fast Zero 2016 conference, Nara, Japan

Accident Research: ReGe Japan

Bicycle safety required worldwide

	Bicycle crash 2015	Share on all crashes w/ casualties
	98 900	18%
	198 200*	19%
	78 300	25%
	45 000	3%
	12 400	6%

Status: ~70% up to ~80% a passenger car involved → Measure: Car AEB-Cyclist

Source: Statistical Bureau (JP), * Estimation out of CARE DB (EU/OECD), DESTATIS F8R7 (GER), Traffic Safety Facts (US), Road Traffic Authority (Korea, 2013); Video: Bosch/KOTI database 2010/11

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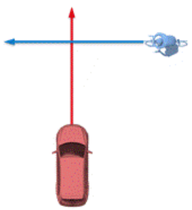
Accident Research: ReGe Japan

Euro NCAP: Car AEB-Cyclist protocol 2018

	CBAN	CBAL	
VUT speed	20-60 kph	25-60 kph	50-80 kph
Cyclist speed	15 kph	15 kph	20 kph
Obstruction	No	No	No
Impact point	50%	50%	25%
System	AEB	AEB	FCW
Assessed test scenario			

VUT: Vehicle under test; AEB: Advanced Emergency Braking; FCW: Forward Collision Warning; CBAN: Collision Bicycle Adult Near Side, CBAL: Collision Bicycle Adult Longitudinal (rear-end); Source: www.euroncap.com

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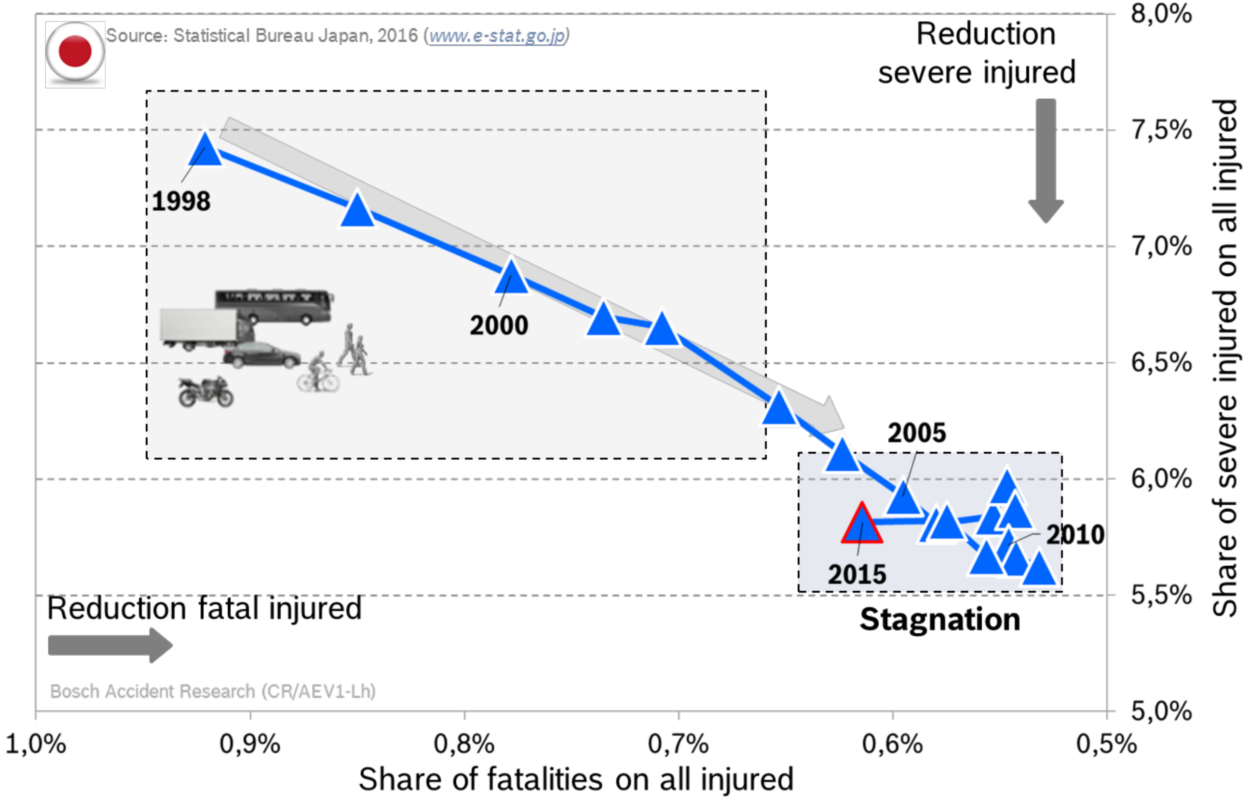
Euro NCAP: Car AEB-Cyclist applied on crossing scenario

Source: news.thatcham.org/latest_media/tag/vehicle-safety#filter-list-items 07/04/2017 downloaded

Accident Research: ReGe Japan

Evolution of road traffic safety in Japan since 1998



- Very high safety standard achieved since 1998 nevertheless also stagnation observed since a decade → Root cause analysis required

Source: Statistical Bureau Japan, 2016 (www.e-stat.go.jp)

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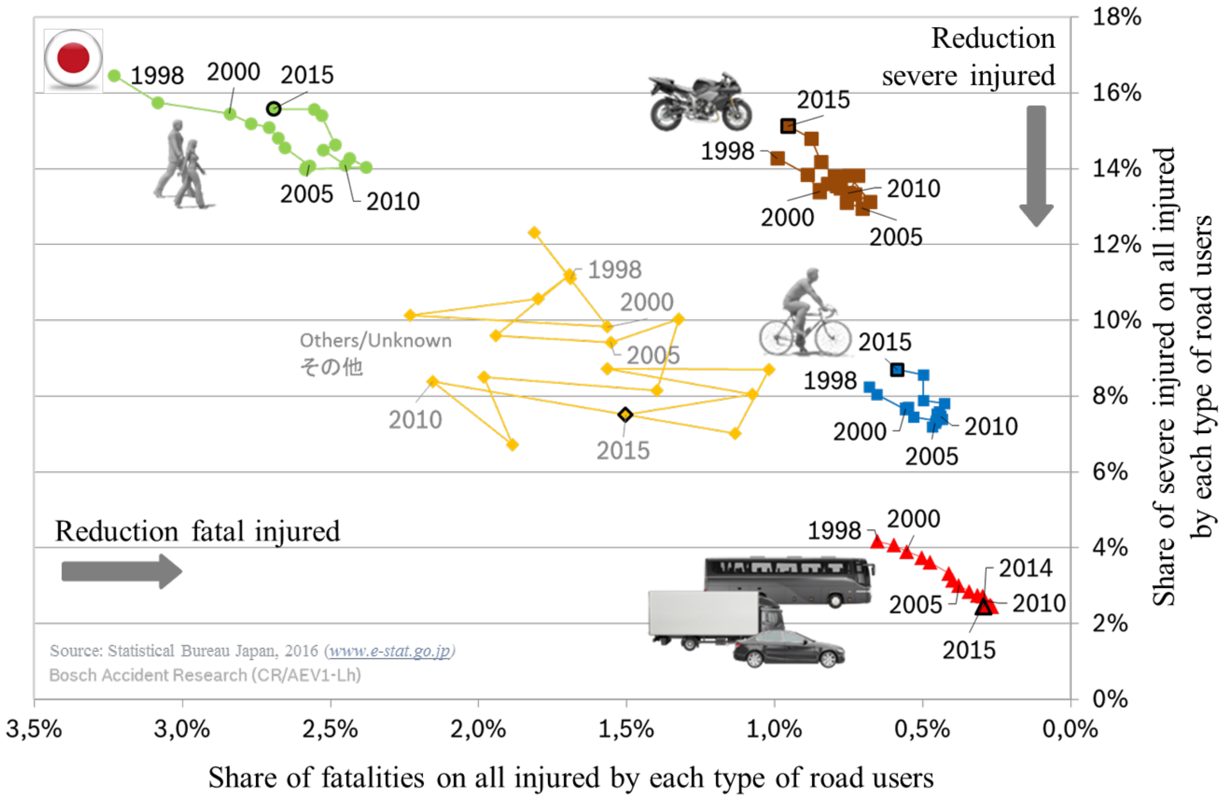
Accident Research: ReGe Japan

Evolution of road traffic safety in Japan by type of road user

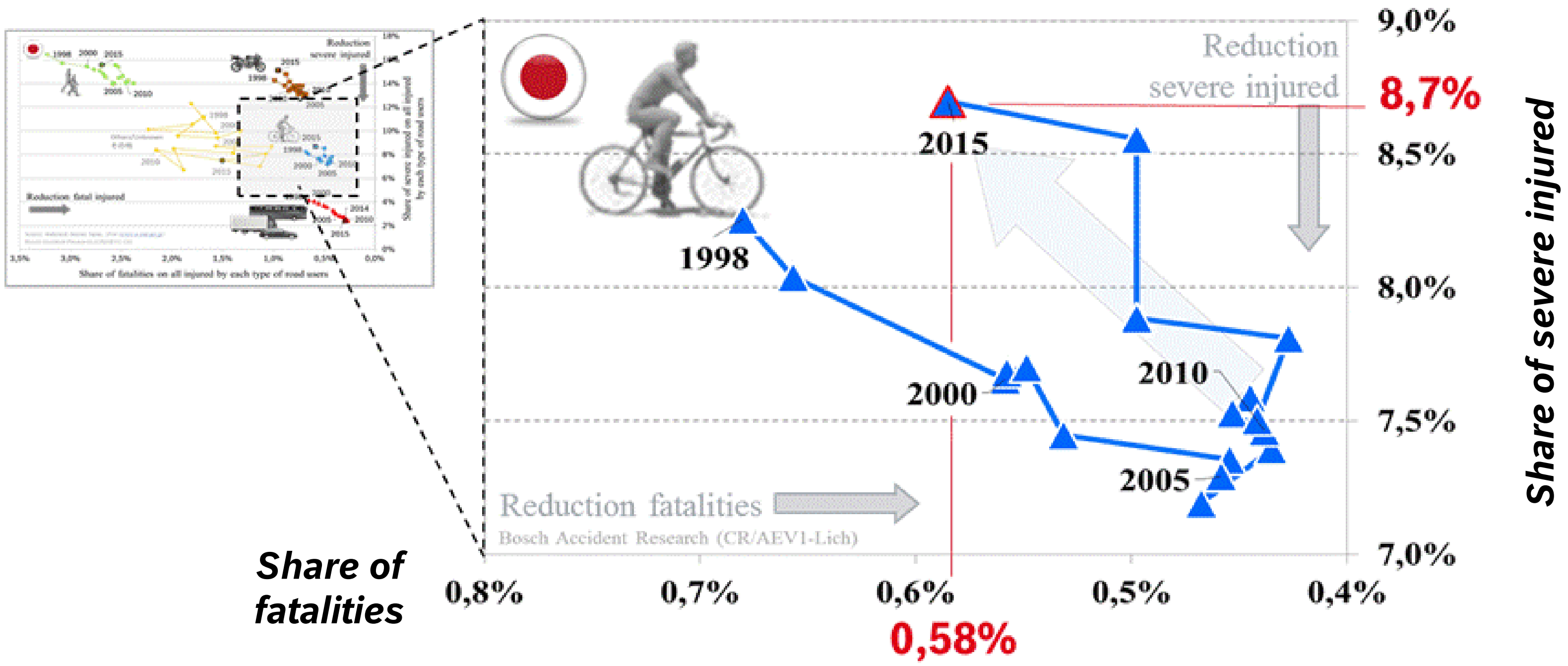


- Stagnation especially for Vulnerable Road User observed hence to improve road safety in Japan countermeasures for VRU required.

Source: Statistical Bureau Japan, 2016 (www.e-stat.go.jp)

Accident Research: ReGe Japan

Stagnation of bicycle safety and reversing trend observed

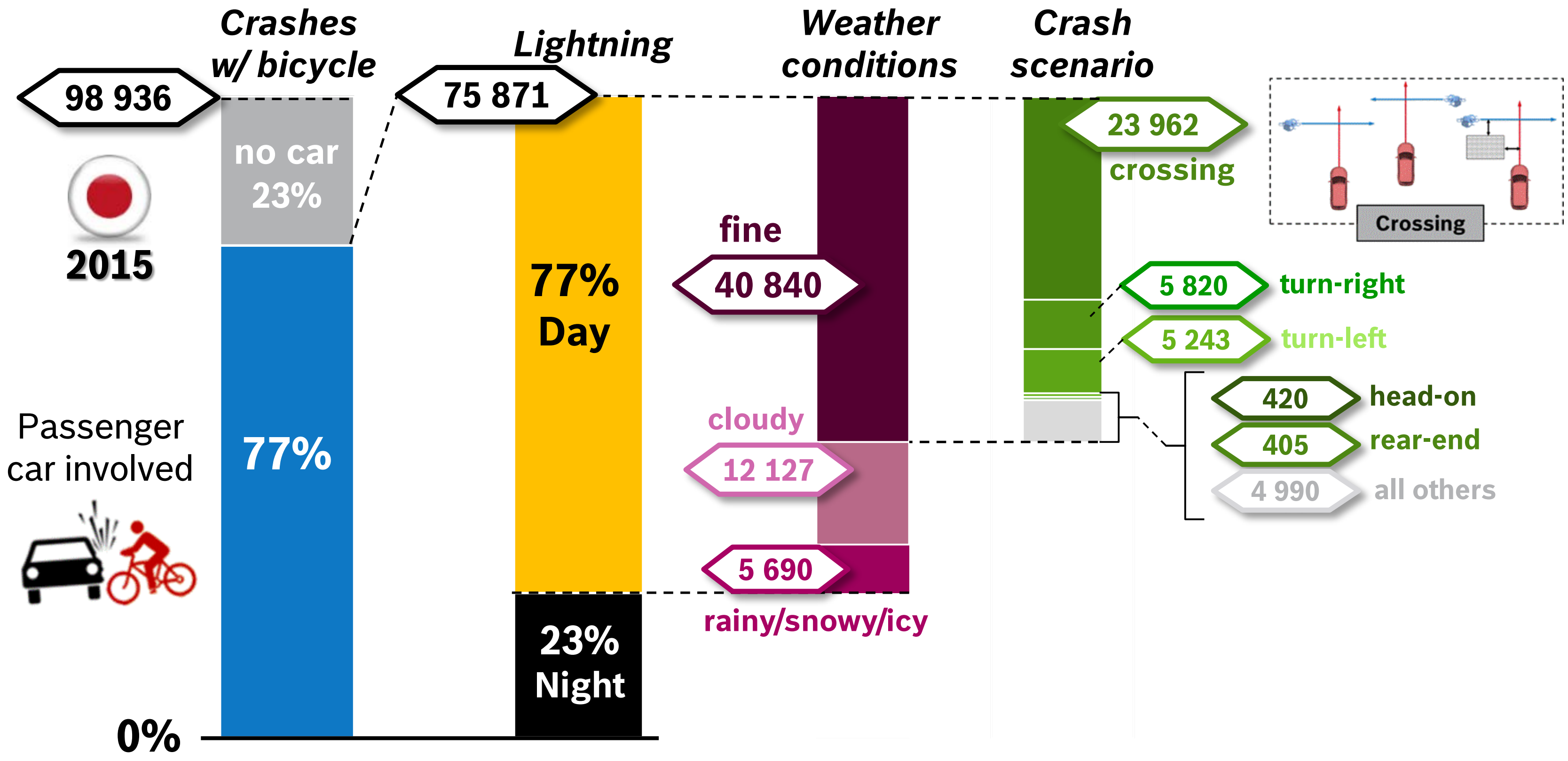


- **Aim:** Analysis of car-bicycle events using Event-Drive Recorder data to identify possible test scenarios for a car AEB-Cyclist system.

Source: Statistical Bureau Japan, 2016 (*www.e-stat.go.jp*)

Accident Research: ReGe Japan

Accident situation involving cyclists



- **Majority:** Crossing at intersection during daylight in fine conditions
- How do such crashes look like → Further analysis required

Source: ITARDA data, 2015

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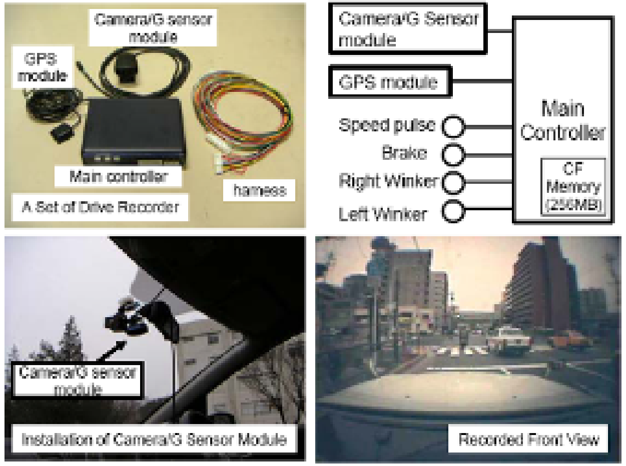
Accident Research: ReGe Japan

Analysis of Event-Drive Recorder data as in-depth source

- **194 bicycle events** thereof 39 crashes
- 3-digit accident type classification
- Image post-processing to estimate speed, distance, ...



Incident database JSAE / Tokyo University (2009-2013)

図 1：データベース画面の例

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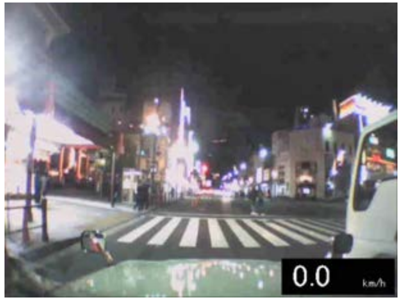
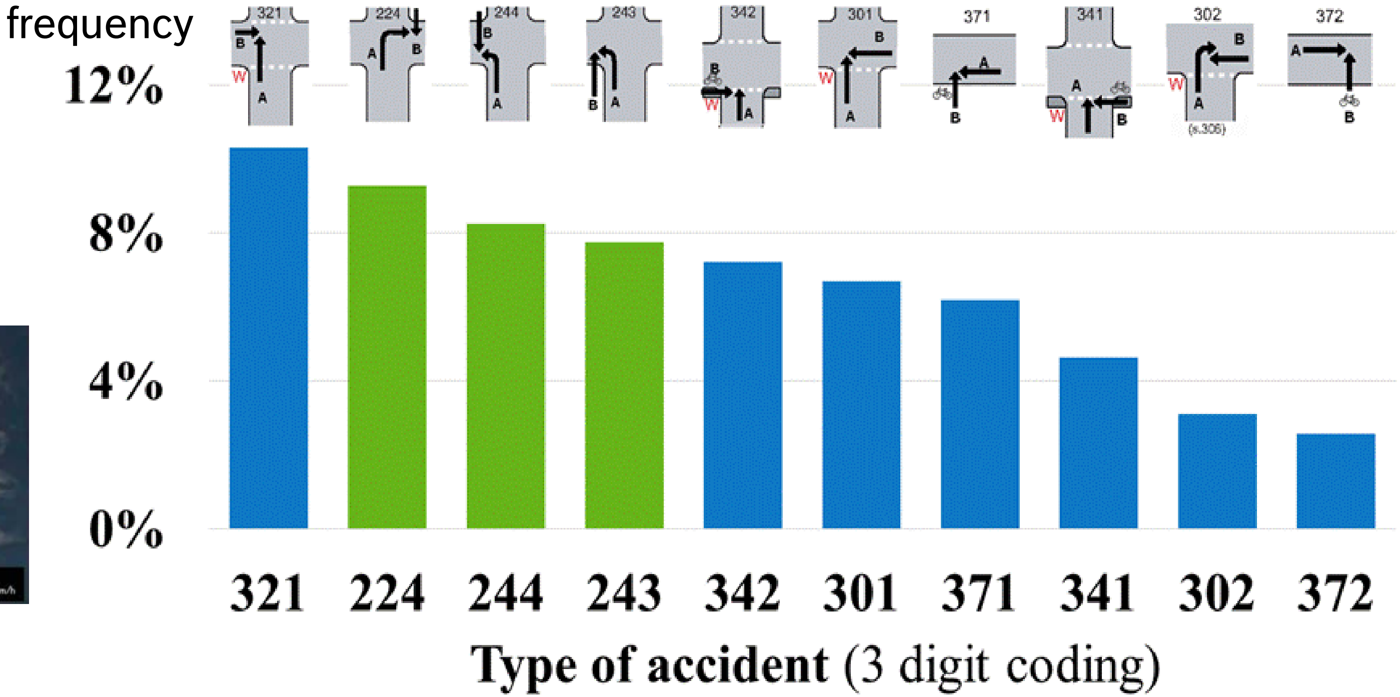
Accident Research: ReGe Japan
Crossing from left side at intersection

1. What is the most common collision/incident scenario ?





Source: Event Drive Recorder data, TUAT/JSAE (2009-2013); n=194 incidents (39 crashes, 155 high level incidents)

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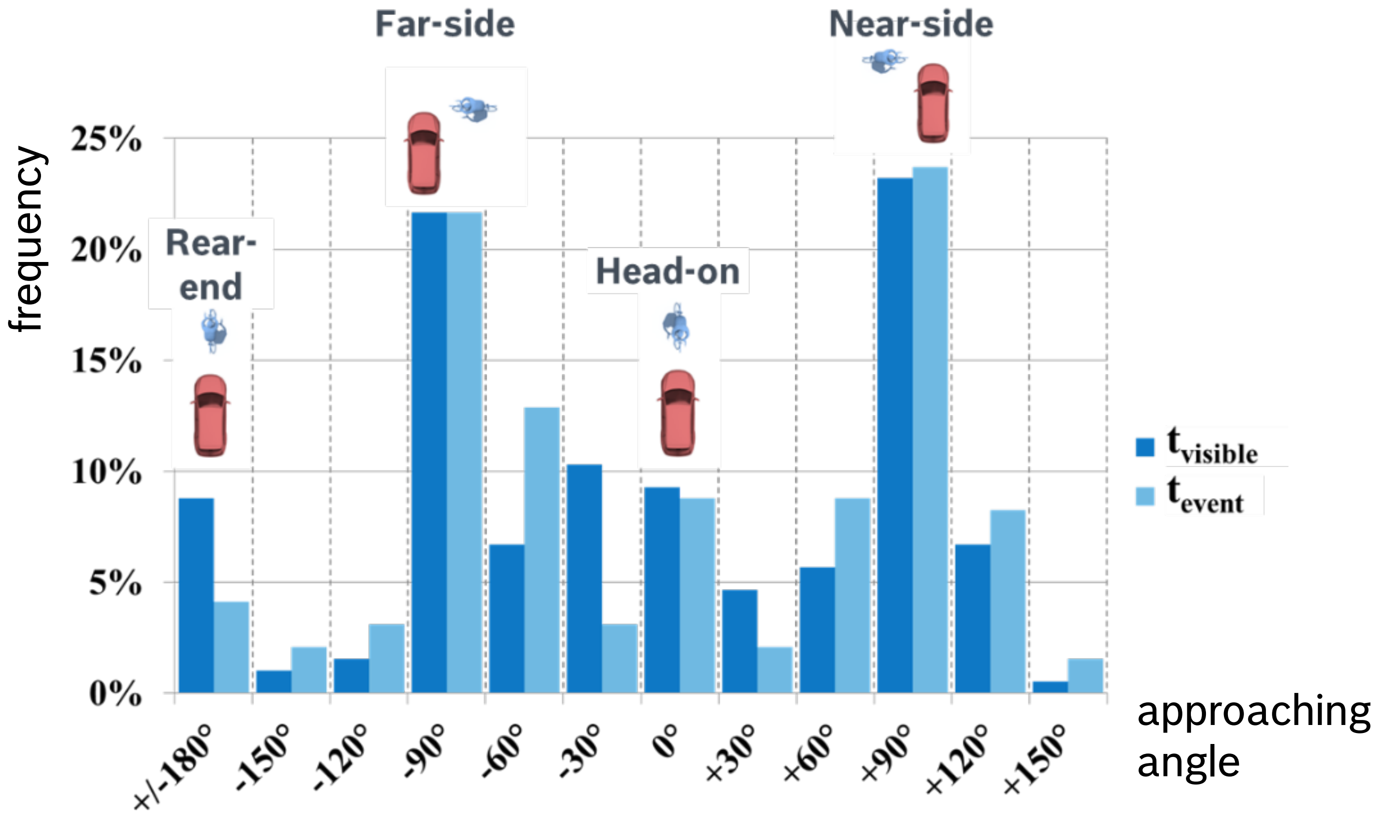
Mainly perpendicular approaching angle

2. Which “collision angle” will be more likely ?



Source: Event Drive Recorder data, TUAT/JSAE (2009-2013); n=194 incidents (39 crashes, 155 high level incidents)

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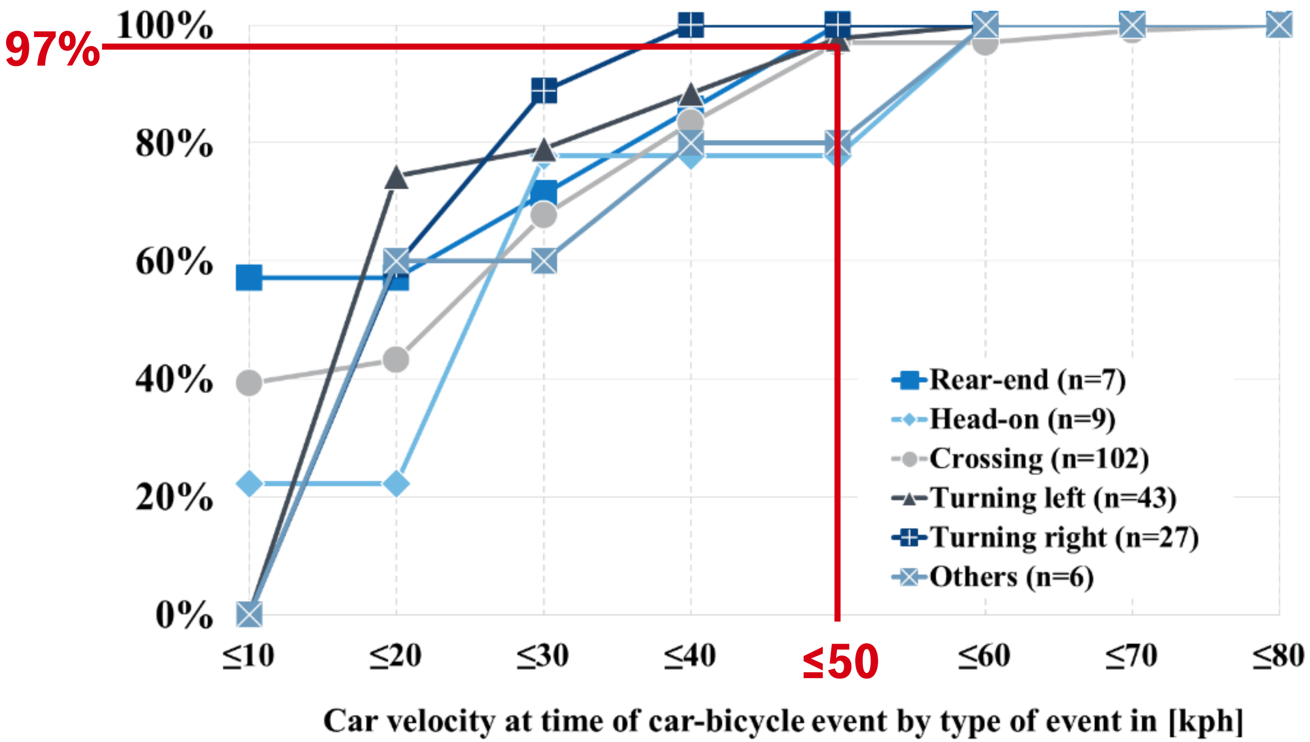
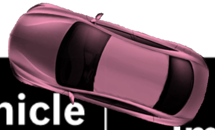
Crossing: ~100% @ vehicle speed ≤ 50kph

3. Which vehicle speed is required ?



Source: Event Drive Recorder data, TUAT/JSAE (2009-2013); n=194 incidents (39 crashes, 155 high level incidents)

Accident Research: ReGe Japan
Comparison between Japan and Europe

Source	Condition	TOP 3 scenarios	Cyclist	Cyclist speed kph	Vehicle Speed kph	Impact point
EDR analysis by Bosch Accident Research	▪ Daylight ▪ Fine (dry)	1. Crossing 2. Turning 3. Rear-end	Adult[1]	1. ≤10 2. ≤15 3. ≤15	1. ≤50 2. ≤40 3. ≤45	1. 50% [1] 2. n/a 3. n/a
1. EuroNCAP[1] 2. CATS[1] 3. CATS	▪ Daylight ▪ Fine (dry)	1. Crossing 2. Rear-end 3. Head-on	Adult	1. ≤20 2. ≤20 3. n/a	1. ≤55 2. ≤80 3. n/a	1. 50% 2. 25%/50% 3. n/a

[1]
- Matsui et al., “Feature of fatal cyclist injuries in vehicle vs. cyclist accidents in Japan”,SAE 2015-01-1415 (2015)
- Oikawa et al.,”Severity of cyclists head injuries caused by impacts with vehicle structure and road surface”, Journal of Biomechanical Science and Engineering, No.15-00613, Vol 11, No. 2 (2016)
- Maki et al. “Comparative analysis of vehicle-bicyclist and vehicle-pedestrian accidents in Japan”, Acc. Analysis and Prevention 35, pp 927-940 (2003)
- Assessment Protocol Pedestrian Protection V.9, 03/2017, www.euroncap.com; CATS: Cyclist-AEB Testing System, www.tno.nl ,2016

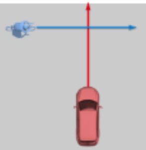
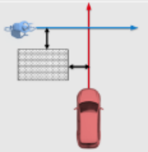
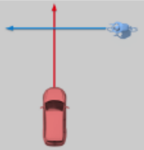
▶ Situation rather similar between Europe and Japan except “Turning scenario” and participant’s speed therefore more investigation required.

Note: Turning scenario mainly covered by turning vehicle

Accident Research: ReGe Japan

Crossing scenario in daylight and fine conditions

▶ Car AEB-Cyclists test scenarios proposed by Bosch Accident Research

Conditions	Assessed scenario	Vehicle speed kph	Cyclist speed kph	Relative angle	Obstruction
▪ Daylight, ▪ Fine (dry)	C1 	≤50	≤10	90°	No
	C2 	≤35	≤10	90°	Yes
	C3 	≤50	≤15	- 90°	No

Field of Effect: Car AEB-Cyclist system in Japan could address 24 367 crashes thereof 2.125 fatal & severe crashes and no change of sensor characteristics assumed

Source: ITARDA 2015, EDR data, TUAT/JSAE (2009-2013)

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Accident Research: ReGe Japan

Summary and Discussion

- Measure: Car AEB-Cyclist to improve traffic safety in Japan
- Differences observed between Japan & Europe
- Test setup proposal: Crossing cyclists at daylight and in fine (dry) street conditions
- No change of sensor characteristics assumed
- Further investigations required to confirm findings and to assess bicycle speed / impact points and dummy size

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US: ESC, LKS, AEBS and BLIS – Field of Effect (FoE) and Estimated benefit for Large Trucks in the US

Accident Research
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Summary:

Aim of study:

(1) Identify Field of Effect of Automated Emergency Braking System (AEBS), Lane Keeping System (LKS), Electronic Stability Control (ESC) and Blind Spot Information System (BLIS) for large trucks in the US

(2) Benefit Estimation of ESC and AEBS for large trucks in the US

Method:

- Determination of relevant accidents w/ casualties with databases FARS and GES
- ESC and AEBS: Transfer of benefit estimation from results of studies based on German accidents w/ casualties to US

Results:

- **Field of Effect** of…

AEBS:	19%	(~16 200)
LKS:	6%	(~4 900)
ESC:	5%	(~4 400)
BLIS:	6%	(~5 300)

- **Estimated avoided accidents** by…

ESC:	~ 3 600
AEBS:	~ 13 300

Annual Report - ReGe US: Large Trucks

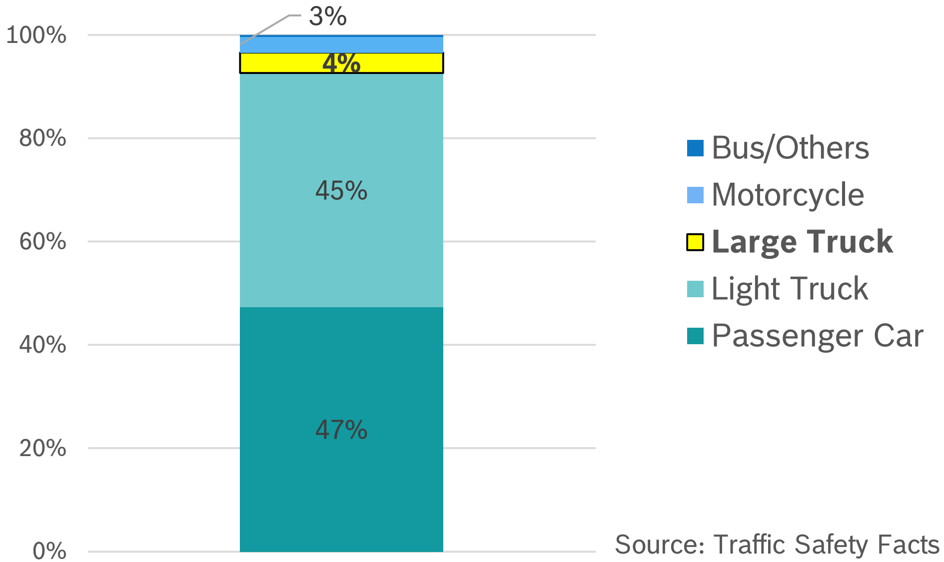
Content

- Overview of large truck crashes in the US
- Field of Effect of AEBS / LKS / ESC / BLIS
- Estimation of efficiency of ESC and AEBS for large trucks
- Summary & Conclusion
- Annex: list of literature

OVERVIEW OF LARGE TRUCK CRASHES IN THE US

Annual Report - ReGe US: Large Trucks
Crashes in the US - Overview

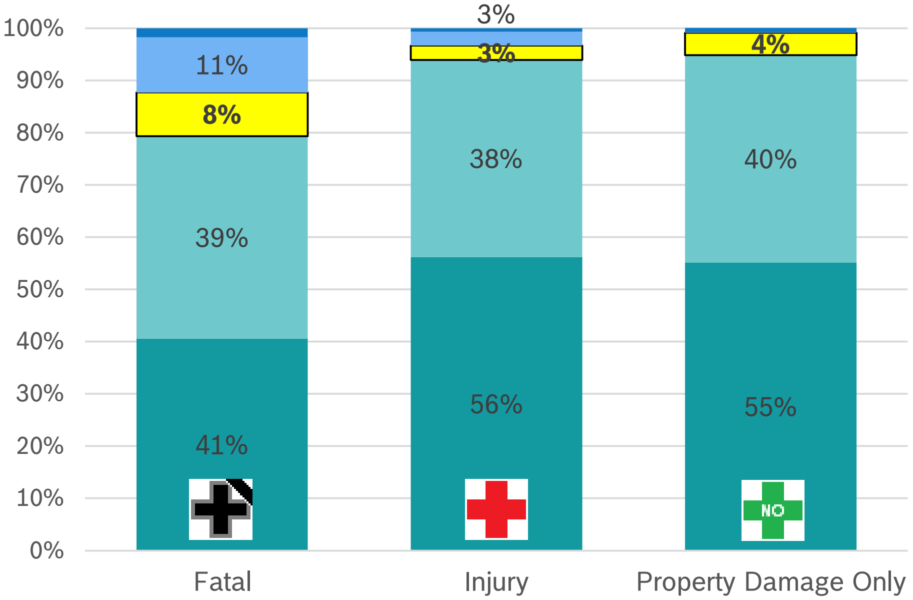
Registered Vehicles in US 2015:



281 312 446

Source: Traffic Safety Facts 2015

Crashes: vehicle involvement by severity:



48 923 | 3 176 000 | 8 049 000

▶ Large trucks[1)] are involved in 8% of fatal crashes but their share of registered vehicles is ~4% only.

[1)] Large truck is defined by GVWR > 10 000 lbs (~4 500 kg)

Internal | Bosch Accident Research (AEV1-Sd) | Jan/31/2018
AEV-064 annual report 2016/17

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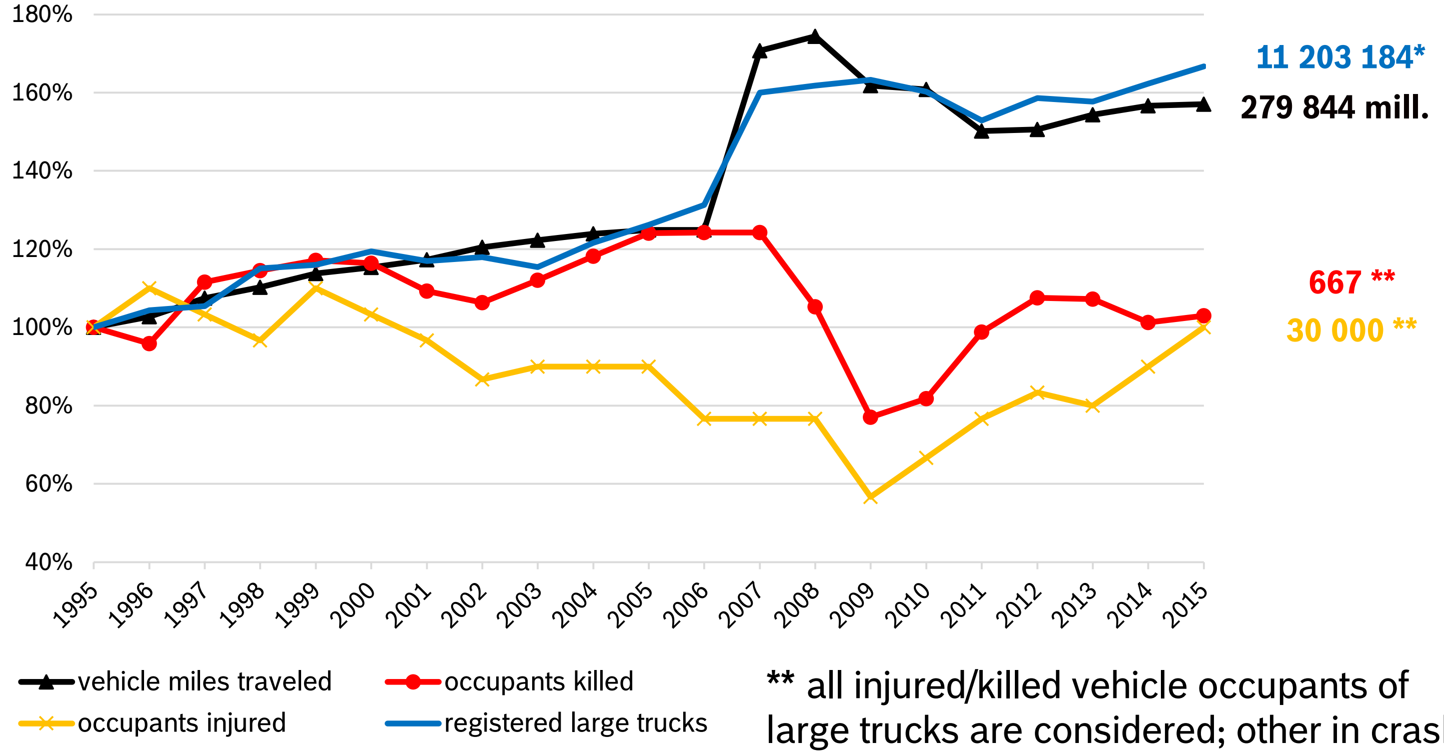
Various trends for large trucks over the last two decades



- Number of killed or injured occupants of large trucks on 1995-level
- **Potential of safety systems for large trucks remaining**

** all injured/killed vehicle occupants of large trucks are considered; other in crash involved casualties not considered

* *Data since 2007 were calculated using a new methodology developed by FHWA. Data for these years are based on new categories and are not comparable to previous years*

Source: Traffic Safety Facts 2015

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FIELD OF EFFECT OF AEBS / LKS / ESC / BLIS FOR LARGE TRUCKS

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Crash selection criteria for assignment to AS and DAS

AEBS	Automated Emergency Brake System
ESC	Electronic Stability Control
LKS	Lane Keep System
BLIS	Blind Spot Information System

- 1st: Crashes w/ casualties w/ at least one large truck involved; following criteria:

AEBS
- Front-to-Rear collision w/ vehicle travelling in same direction

ESC
- Loss of Control or preceding skidding
- Rollover

only cases w/o relevance for LKS

- Jackknife

only cases w/o relevance for AEBS

LKS
- Truck is traveling off the edge off the road
- Ran off roadway
- Cross lane line / median / centerline

only cases w/o relevance for ESC

BLIS
- Truck is traveling over the lane and collides w/ another vehicle in transport w/ relevant crash type[1)]

1) ACC_TYPE = (>43 AND <50) OR (>70 AND <80); intention of lane change not always clearly determinable , therefore some overlap to LKS possible

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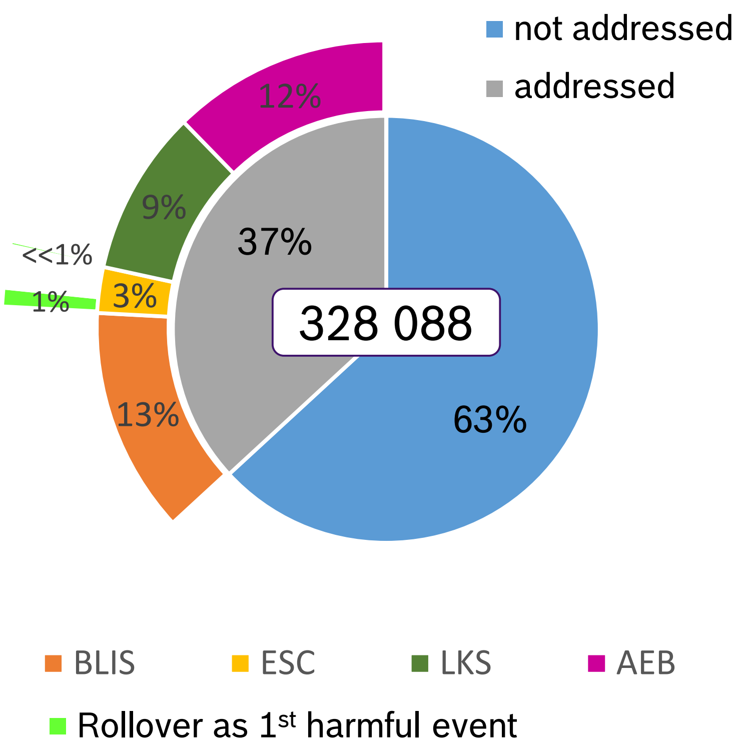
Field of Effect – BLIS, ESC, LKS and AEBS (property damage only)



Crashes w/ property damage only:

- Highest potential for BLIS (Blind Spot Information System)
- AEBS with second highest FoE followed by LKS
- FoE of ESC contains only crashes w/ loss of control or preceding skidding as first event of crash
  → skidding after drive off the edge of the road is allocated to LKS
- Share of Rollover almost not relevant (~1%)

Sources: GES 2015

Imputed values were used for calculation of percentages → This approach assumes that the distribution in the unknown cases is the same as in the known cases.

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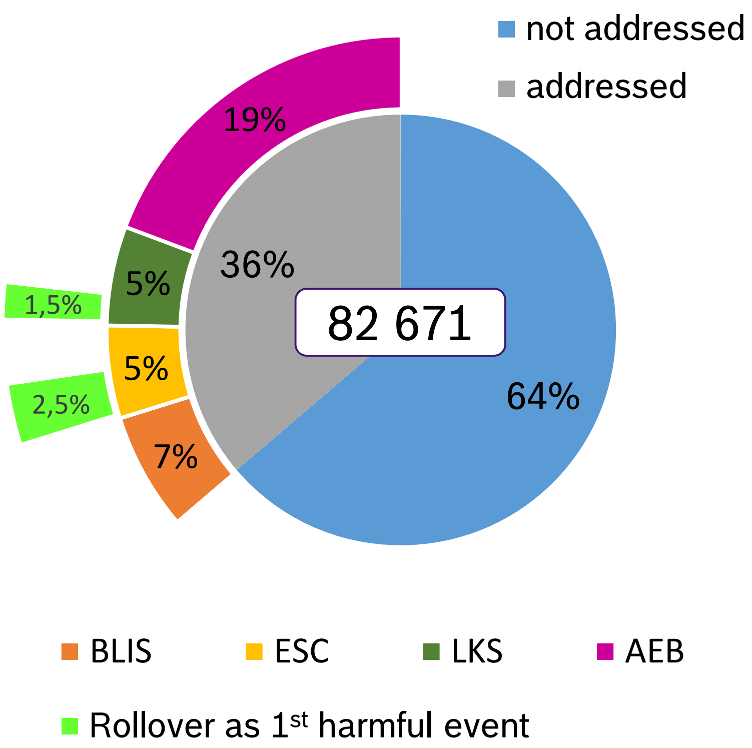
Field of Effect – BLIS, ESC, LKS and AEBS (injury crashes)



Crashes with injuries:

- Highest potential for AEBS (Automated Emergency Brake System)
- BLIS with second highest FoE
- FoE of ESC contains only crashes w/ loss of control or preceding skidding as first event of crash
  → skidding after drive off the edge of the road is allocated to LKS
- Share of Rollover about 4%
  → less than expected out of literature research
  → probable reason: current market penetration of RSC & ESC[1)]

Sources: FARS and GES 2015

Imputed values were used for calculation of percentages
→ This approach assumes that the distribution in the unknown cases is the same as in the known cases.

1) http://www.fleetowner.com/equipment/reaction-positive-stability-control-proposal

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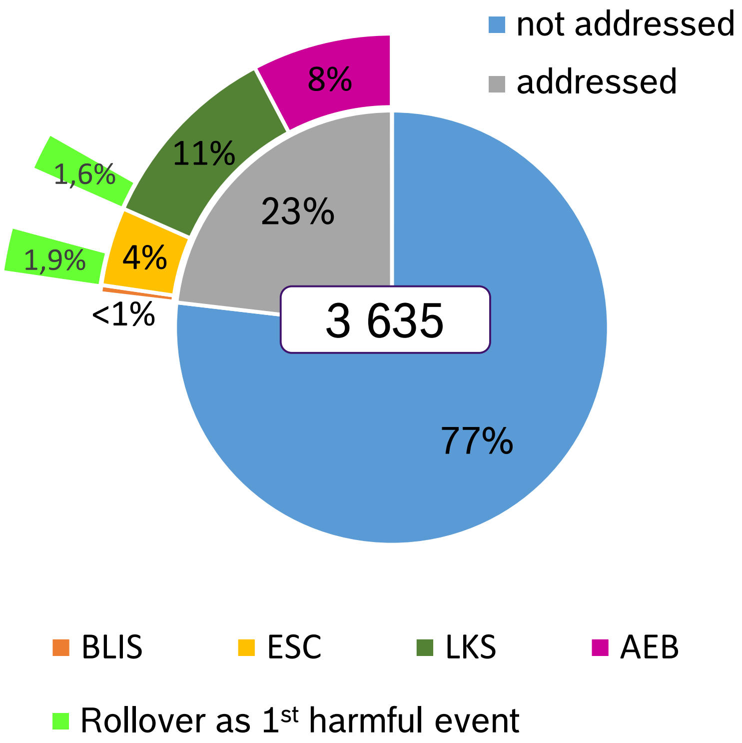
Field of Effect – BLIS, ESC, LKS and AEBS (fatal crashes)



Crashes with fatalities:

- Highest potential for LKS – almost 11% (Lane Keeping System)
- FoE of ESC contains only crashes w/ preceding skidding as first event of crash
  → skidding after drive off the edge of the road is allocated to LKS
- Share of Rollover less than 4%
  → less than expected out of literature research
  → probable reason: current market penetration of RSC & ESC[1)]
- BLIS almost not relevant

Sources: FARS 2015

Imputed values were used for calculation of percentages → This approach assumes that the distribution in the unknown cases is the same as in the known cases.

1) http://www.fleetowner.com/equipment/reaction-positive-stability-control-proposal

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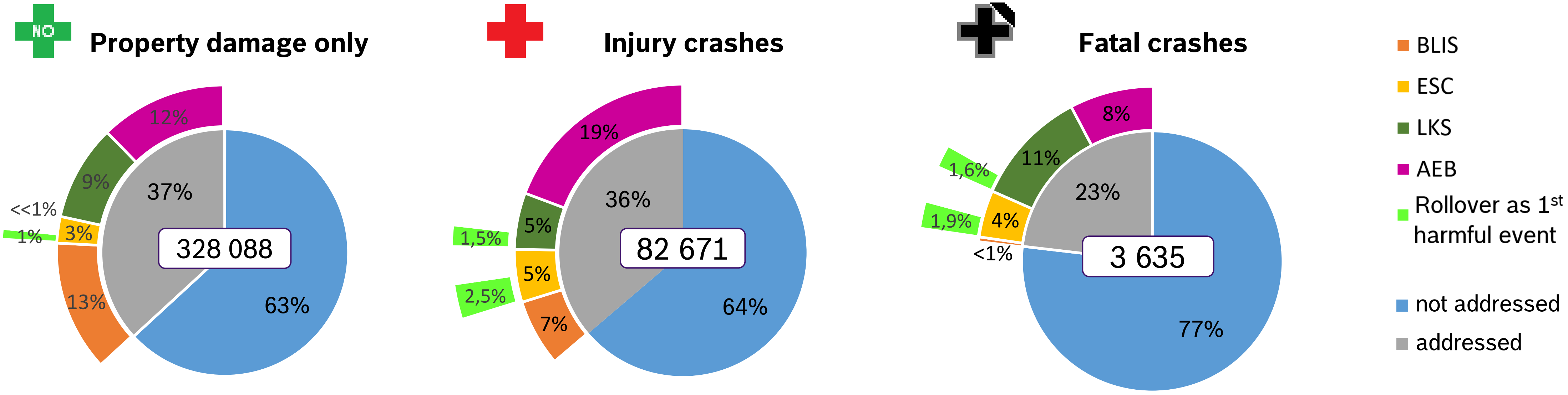
Field of Effect – BLIS, ESC, LKS and AEBS

▶ Comparison of FoE by severity:



Imputed values were used for calculation of percentages → This approach assumes that the distribution in the unknown cases is the same as in the known cases.

▶ Approximately every 3rd crash involving a large truck could be addressed by state-of the art technologies hence still high potential for other safety technologies given in the US

Sources: FARS and GES 2015

BENEFIT ESTIMATION OF ESC AND AEBS FOR LARGE TRUCKS

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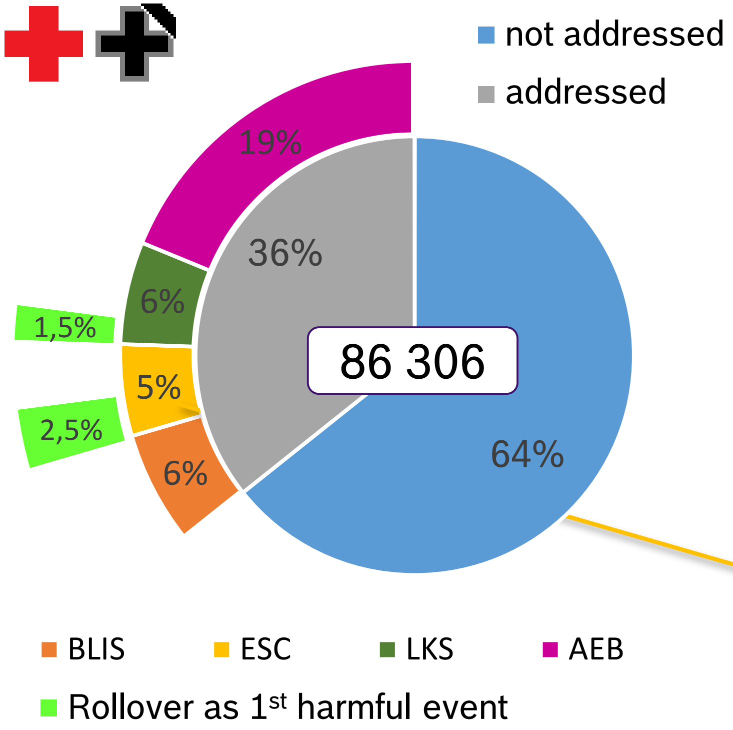
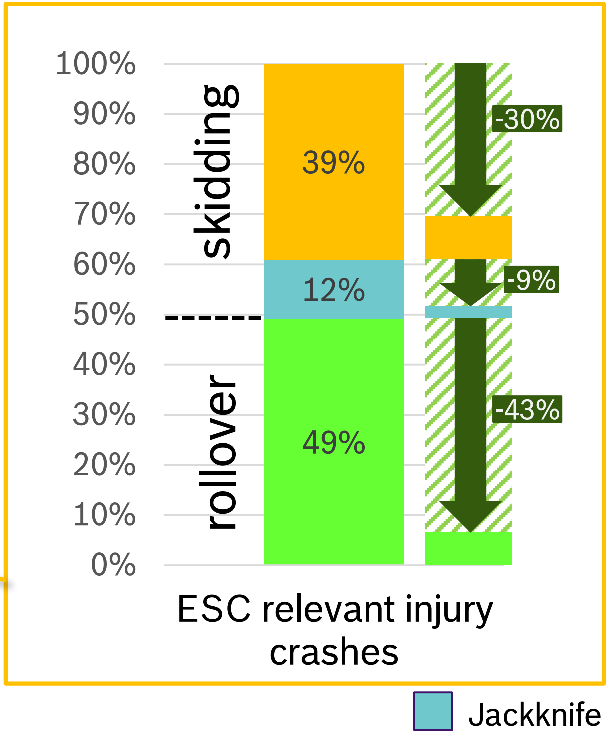
Benefit estimation of ESC for Large Trucks





Estimated reduction potential of ESC for large trucks (100% IR assumed)

- <u>For skidding crashes (incl. jackknife):</u>
  Results of estimation of ESC effectiveness of *passenger cars* in crashes w/ casualties in Germany used[1)] → possible reduction by **78%**
- <u>For Rollover:</u>
  Results of estimation of ESC effectiveness for large trucks in crashes w/ casualties in Germany used[2)] → possible reduction by **87%**

- With 100% installation rate of ESC in large trucks: about 80% of ESC relevant large truck crashes due to loss of control could be avoided. This corresponds to a reduction of almost 3 600 crashes w/ casualties[3)].

Sources: [1)] Average of [VUFO 2014] and [Bosch 2013 - Sd] [2)] [Bosch 2017 - Moe]

[3)] For crashes w/ preceding skidding: assumption of similar efficiency of ESC for trucks compared to ESC of pass. cars

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Comparison of Benefit estimation of ESC for Large Trucks

	Bosch Accident Research (CR/AEV)	NHTSA - John Woodrooffe et al. [DOT HS 811 205]
ESC: Estimated benefit	- **3 600** crashes w/ casualties (related to the year 2015)	- **4 659** crashes w/ casualties (related to the year 2005)
ESC: Estimated efficiency	~ **80%**	**~ 42%**
Field of effect (FoE)	- Only cases relevant w/ preceding skidding or w/ pre-crash instability due to roll - Clear separation for FoE of ESC and LKS *('failure to follow curve' was assigned to LKS only)*	- First event: roll instability or yaw instability - ESC-FoE contains 'failure to follow curve': → for these cases efficiency set to Zero → this results in determination of less efficiency of ESC
Database	- 43 crashes w/ casualties (crashes from **2005-2016**)	- 159 crashes w/ injury severity of killed, or incapacitating injury, or non-incapacitating injury (crashes from **2001-2003**)
Data source & Information depth	- GIDAS - about 3 600 variables for each crash	- Large Truck Crash Causation Study (LTCCS, FARS, GES) - about 1 000 variables for each crash
Evaluation method	For Rollover crashes: - Single case analysis by experts of crash reconstruction and vehicle dynamics - calculation of threshold speed for rollover depending on speed, curve radius and load (full-, medium- and unloaded) Other relevant crashes: ESC efficiency of pass. cars used	- Single case analysis by experts of crash reconstruction and vehicle dynamics (132 cases) and HiL-simulation (22 cases) - For Rollover crashes: calculation of threshold speed for rollover depending on speed, curve radius and load (full-, medium- and unloaded) - ABS as baseline (only add on by ESC included in calculation)
benefit estimates are limited to ...	- N3-trucks (GVW>12t) operating in Germany → electronic speed limiter <90kph by law	- 5-axle tractor-semitrailers operating within the US → max. speed up to 120kph (75mph)

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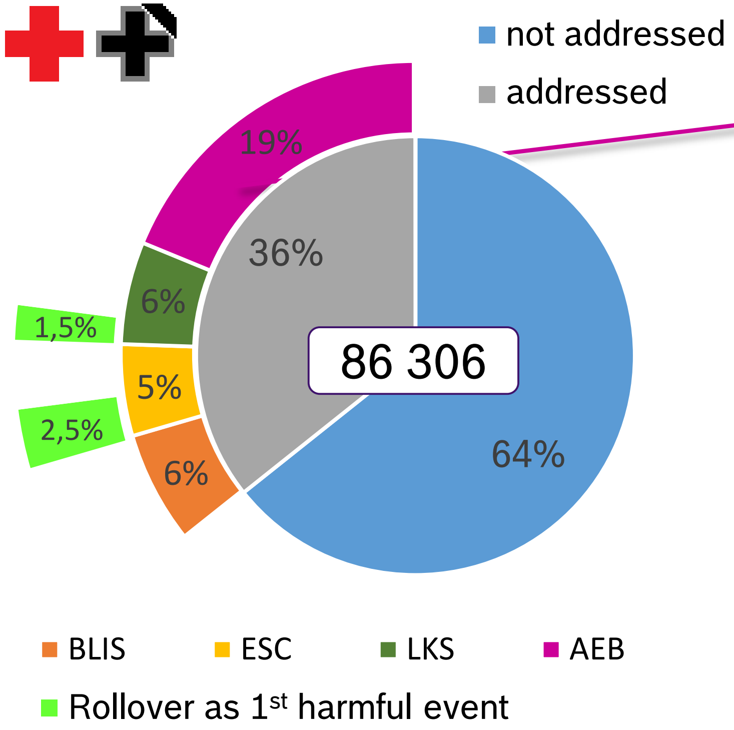
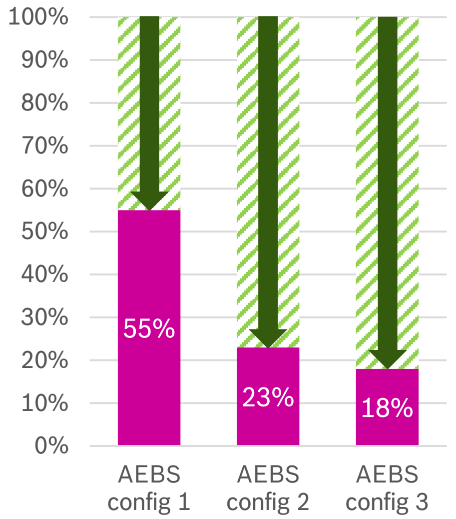
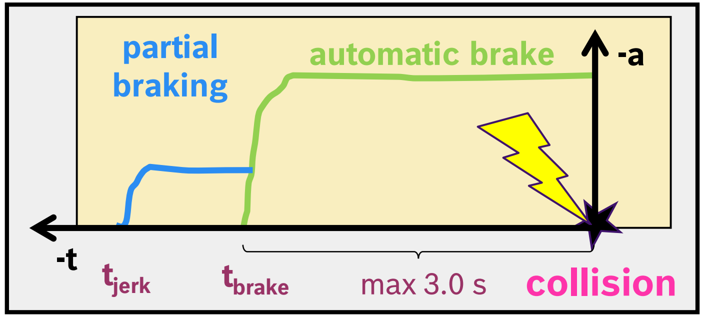
Benefit estimation of AEBS for Large Trucks





Estimated reduction potential of 3 AEBS configurations for large trucks
(IR of 100% assumed; status 2017-12-08)

- Used system configurations based on proposals from CVO given to Bosch Accident Research *(for details see annex)*
- These configurations were used to simulate crashes in Germany w/ large trucks involved (GIDAS) to determine possible reduction potential



- With 100% IR* of AEBS in large trucks: dependent on system configuration 45-82% of rear end collisions of large trucks could be avoided. This corresponds to a reduction of 7 300 – 13 300 crashes w/ casualties.

Sources: FARS and GES 2015; [Bosch 2017]
*IR… installation rate

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SUMMARY & CONCLUSION

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Summary and Comparison

	Acc. w/ casualties w/ N3-trucks (GVW>12t) involved in Germany	Acc. w/ casualties w/ Large Trucks (GVW>4,5t) involved in the US
Field of Effect of... AEBS LKS ESC BLIS	 20% (2 000) 13% (1 300) → overlap w/ ESC and AEBS enclosed 5% (500) n.a.	 19% (~16 200) 6% (~4 900) 5% (~4 400) 6% (~5 300)
ESC: Estimated benefit Estimated efficiency	 ~ **400** crashes w/ casualties ~ **80%**	 ~ **3 600** crashes w/ casualties ~ **80%**
AEBS: Estimated benefit[1)]	 **up to ~1 600** crashes w/ casualties	 **up to ~13 300** crashes w/ casualties
Data source	GIDAS	FARS, GES
Speed limit for relevant trucks	electronic speed limiter <90kph by law	max. speed up to 120kph (75mph)

[1)] assuming full AEBS w/ config3 → Used system configurations based on proposals from CVO given to Bosch Accident Research (for details see annex)

▶ Rather similar field relevance given for large truck safety technologies in Germany and US especially for AEB

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Conclusion

- **Large truck fatal crashes:**
  - highest potential for LKS followed by AEBS
  - further analysis required for the 77% share of fatal crashes not addressed by any of the four systems
- **Large truck injury crashes:** by far highest potential for AEBS
- **Large truck crashes w/ property damage only:** highest potential for BLIS followed by AEBS
- Efficiency of ESC estimated with ~80% → corresponds to a reduction of almost 3 600 crashes w/ casualties
- Efficiency of LKS is dependent on system configuration and estimated with about 45-82% → corresponds to a reduction of 7 300 – 13 300 crashes w/ casualties
- Rather similar results observed wrt to field relevance compared to Germany
- **Still potential for other large truck safety technologies on current crash situation, for identifying those further analysis required**

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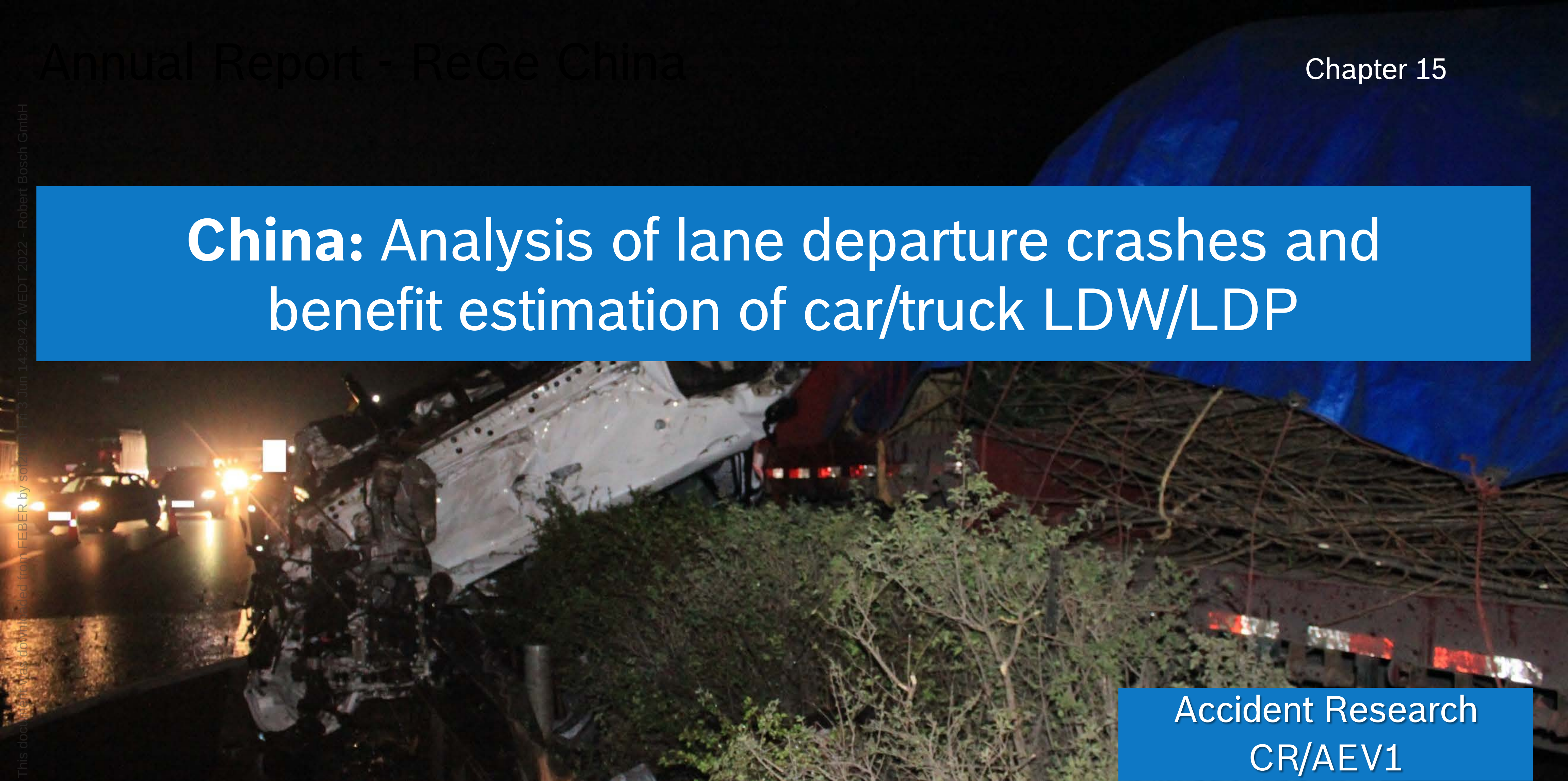
Chapter 15



China: Analysis of lane departure crashes and benefit estimation of car/truck LDW/LDP

Accident Research
CR/AEV1

BOSCH

Aim: Estimate the effectiveness of Lane Departure Warning (LDW) & Lane Departure Prevention (LDP) for trucks and cars in China

Method: Determine relevant accident cases from CIDAS database. To determine effectiveness a near production level based LDW/LDP system was modelled and incorporated in a simulation environment. Furthermore a simplified driver model was integrated. Afterwards crashes were simulated assuming LDW & LDP systems active. Results outlined for China.

Result:

- ~3.3% of all accidents w/ casualties in China are relevant for LDW/LDP system for cars (~2.5%) & trucks (~0.8%)
- ~1.3% of all accidents are avoidable by LDW for cars, ~0.5% by LDW for trucks
  ⇔every second departure accident is avoidable by LDW for cars and 3 out of 5 for trucks
- ~1.5% of all accidents are avoidable by LDW+LDP for cars, ~0.6% by LDW+LDP for trucks
  ⇔3 out of 5 departure accident is avoidable by LDW+LDP for cars and 2 out of 3 for trucks

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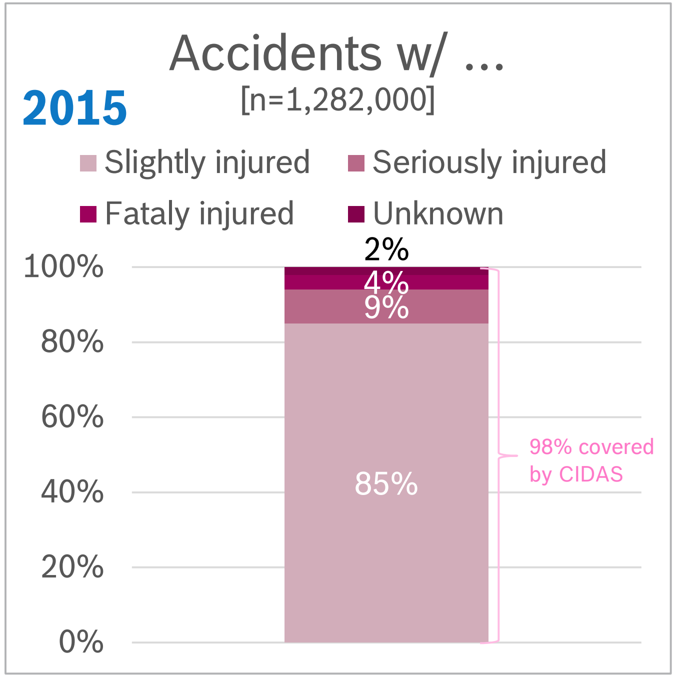
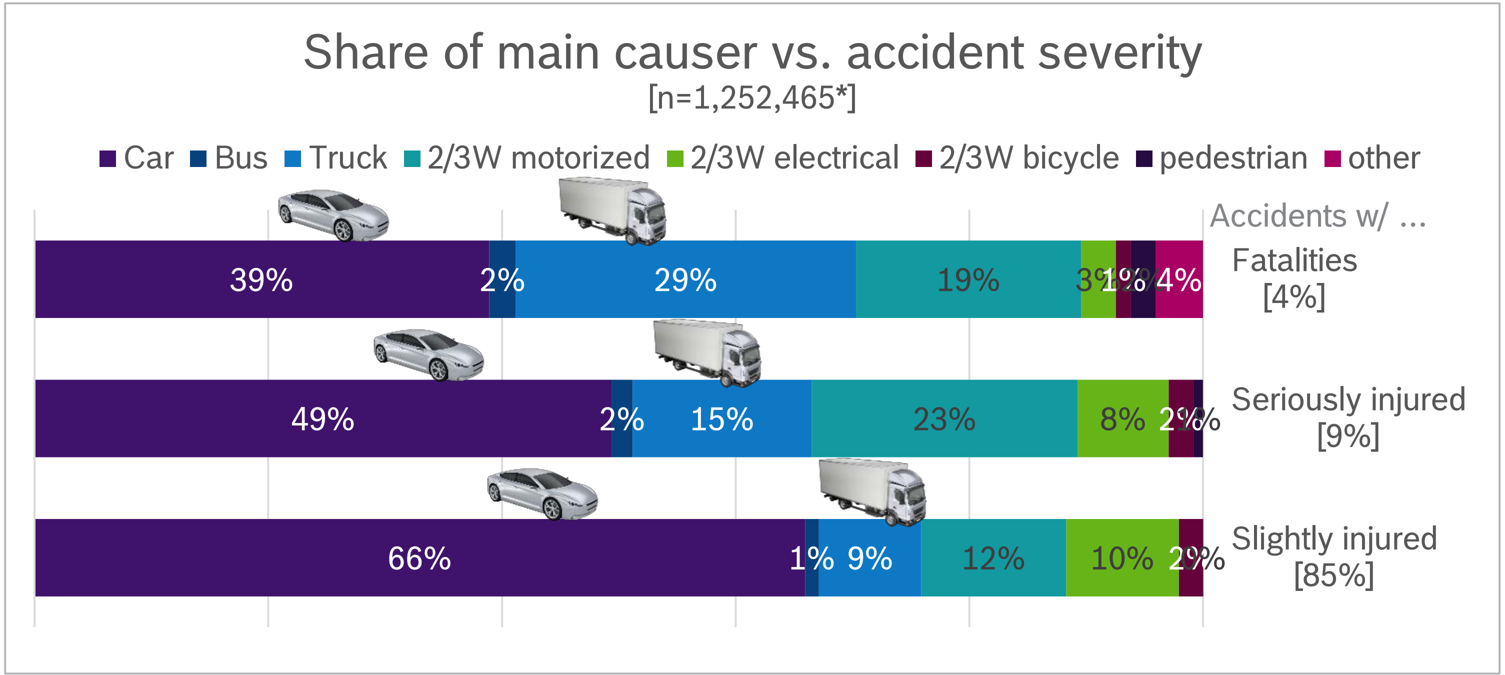
Accident severity in China 2015





- Serious injuries occur in 1 out of 10 accidents w/ casualties and fatalities in 1 out of 20
- Cars cause more often slight accidents, trucks cause more often severe accidents

Analysis based on 2.011 CIDAS accidents (2014-2016); * 29.535 accidents w/ unknown severity excluded

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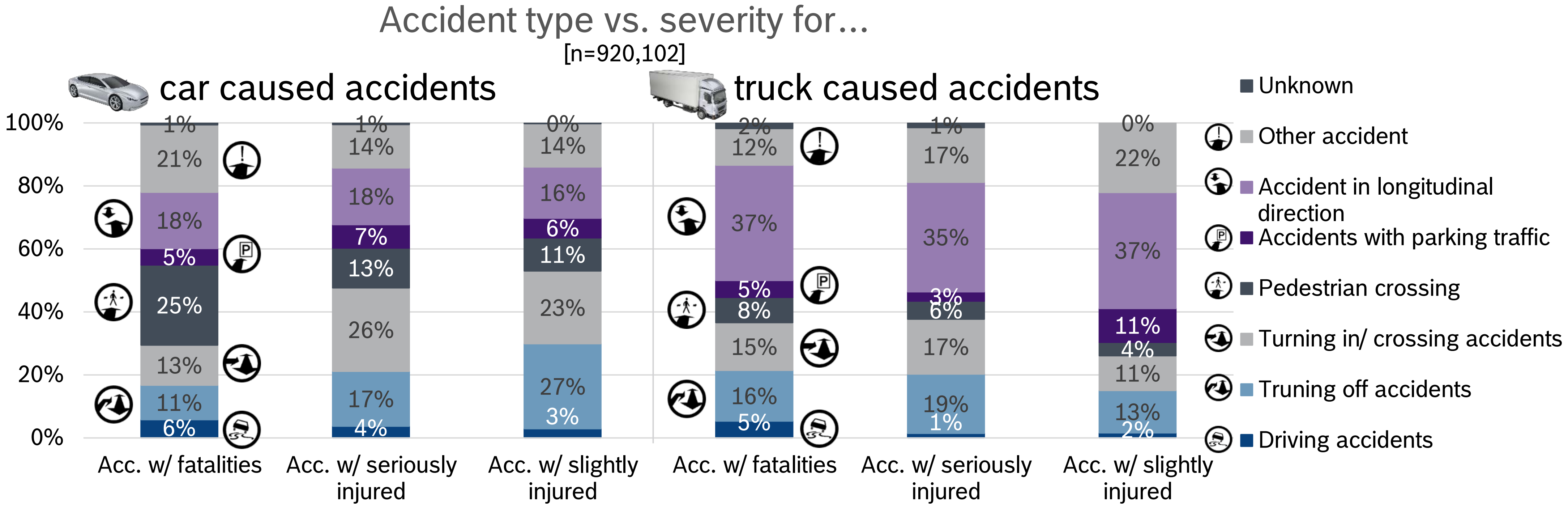
Accident type for car and truck caused accidents



Cars:

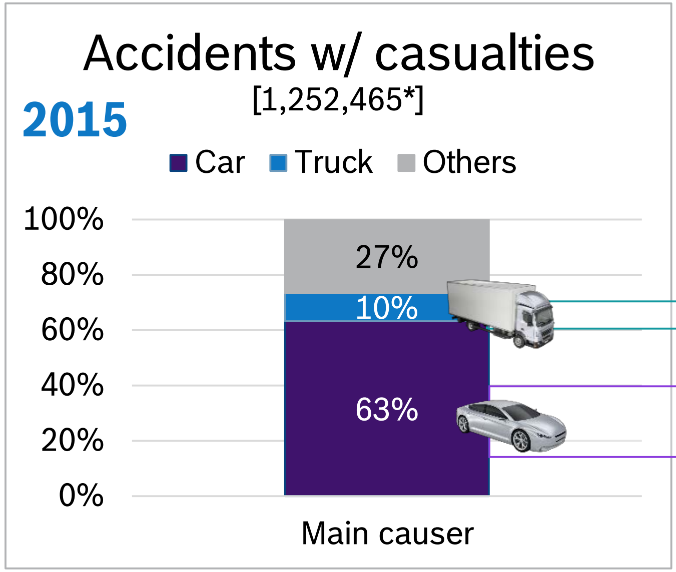
- Main conflict situation for car caused accidents: crossing pedestrian & at crossings

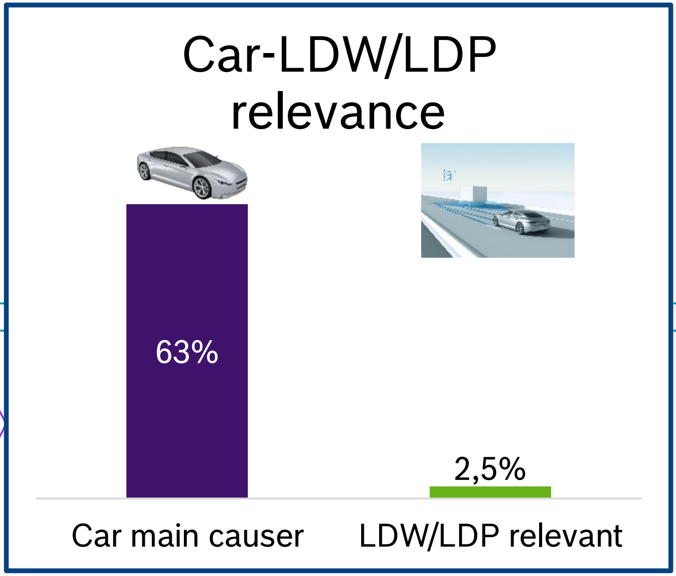
Trucks:

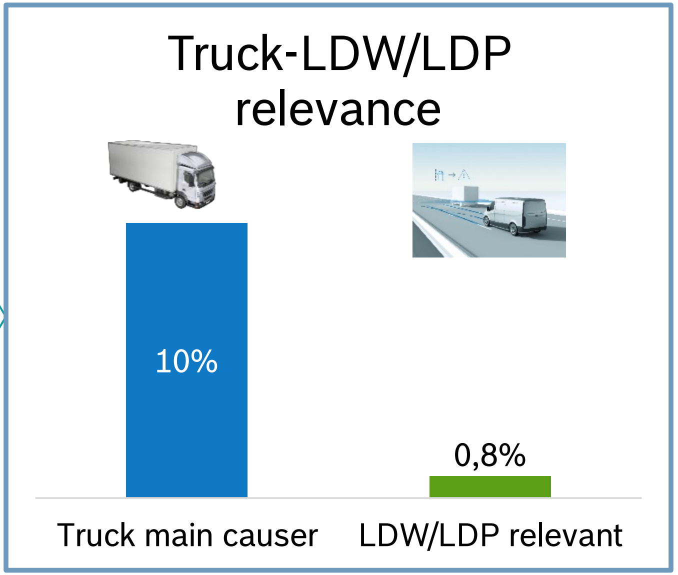
- Main conflict situation for truck caused accidents: longitudinal traffic & at crossings

Analysis based on 2.011 CIDAS accidents (2014-2016)

LDW & LDP: Field of effect







Cars:

- Car caused 3 out of 5 (~63%) accidents w/ casualties, thereof 1 out of 25 relevant for LDW/LDP

Trucks:

- Truck caused 1 out of 10 (~10%) accidents w/ casualties, thereof 1 out of 13 relevant for LDW/LDP

Analysis based on 2.011 CIDAS accidents (2014-2016); LDW=Lane Departure Warning, LDP=Lane Departure Prevention; * 29.535 accidents w/ unknown severity excluded

LDW & LDP: Analysis limitations

Assumptions:

- CIDAS representative within its investigation criteria (only accidents w/ 4+ vehicles) for China
- CIDAS information reflect actual occurred accident
- Distributions of driver reaction representative for Chinese drivers

Limitations and conditions:

- No actual model for vehicle dynamic used
- Road and lane marking conditions not taken into account
- Simplified reconstruction:
  - Vehicle always starts in the middle of its lane
  - Departure angle constant during accident
  - Driver starts his reaction while leaving his lane → some accidents do not happen at all
- LDW/LDP system specification provided by CC-DA/EAV2-CN
- Simplified systems and driver model assumed for simulation

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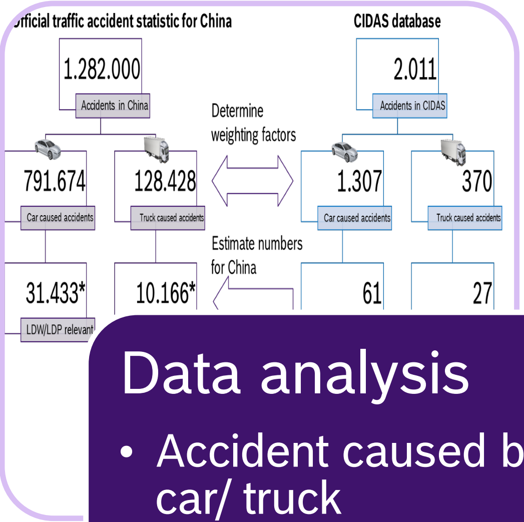
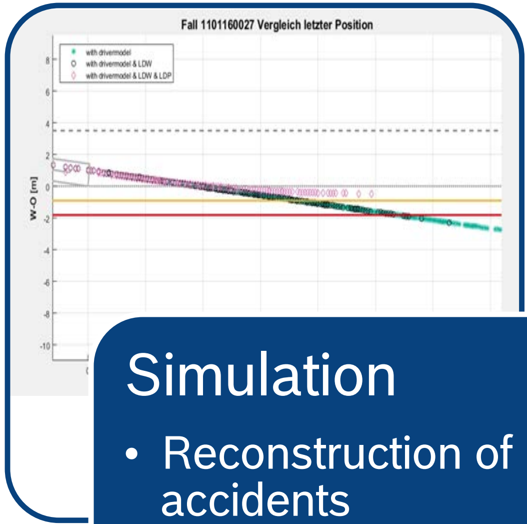
Chapter 15

Analysis approach: Overview



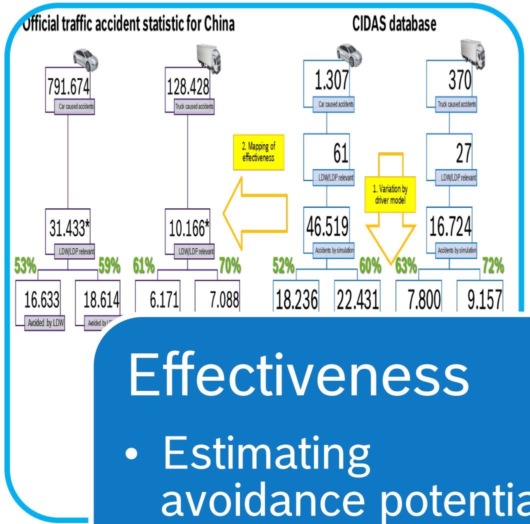
Data analysis

- Accident caused by car/ truck
- Relevant for LDW/ LDP



Simulation

- Reconstruction of accidents
- Simulation of accidents:
  - w/ driver
  - driver+LDW*
  - driver+LDW&LDP*



Effectiveness

- Estimating avoidance potential by extrapolating simulated accidents to China

* System specification provided by CC-DA/EAV2-CN

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Chapter 15

Analysis approach: Data analysis

Official traffic accident statistics for China

1,282,000
Accidents in China

791,674
Car caused accidents

128,428
Truck caused accidents

~31,400*
LDW/LDP relevant

~10,200*
LDW/LDP relevant

Determine weighting factors

Estimate numbers for China

CIDAS database

2,011
Accidents in CIDAS

1,307
Car caused accidents

370
Truck caused accidents

61
LDW/LDP relevant

27
LDW/LDP relevant

* Estimated numbers; LDW=Lane Departure Warning, LDP=Lane Departure Prevention

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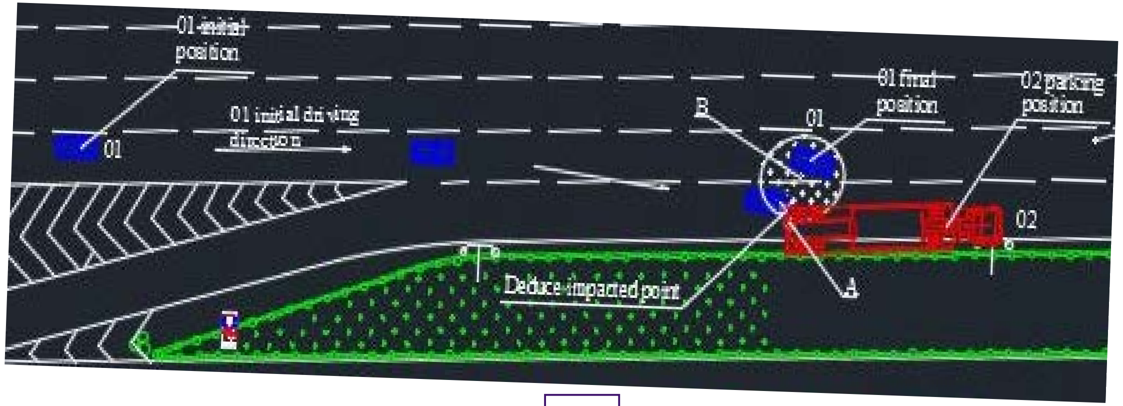
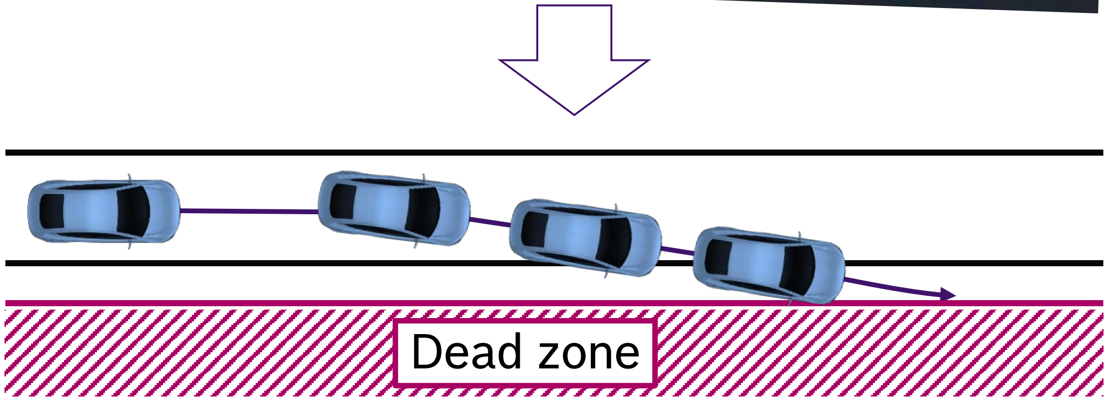
Analysis approach: Simulation: 1st Reconstruction

1. Digital accident sketch & CIDAS information as input
2. Recoding of missing information:
   Dead zone, free space between lane and dead zone
3. Creating simulate able sketch
4. Reconstruct dynamic vehicle information, assumption:
   - Vehicle starts in middle of its lane
   - Departure angle is constant





▶ Reconstructed digital accident sketch ready for simulation

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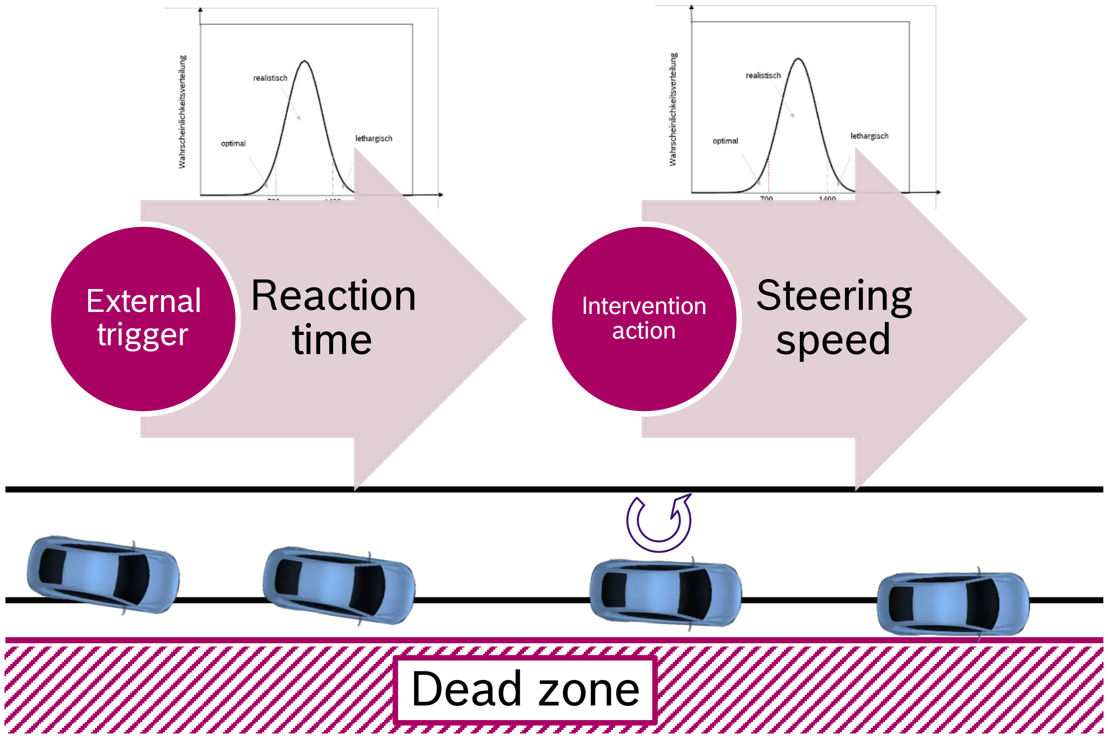
Analysis approach: Simulation: 2nd Driver model

Driver model defined by two attributes:

1. Reaction time
   How fast does the driver react on an external trigger?
2. Steering behaviour
   How fast steers the driver?

Assumption:

1. Driver attributes are normally distributed
2. Values for distributions taken from literature



▶ Huge range of different driver by combining two statistical distributions

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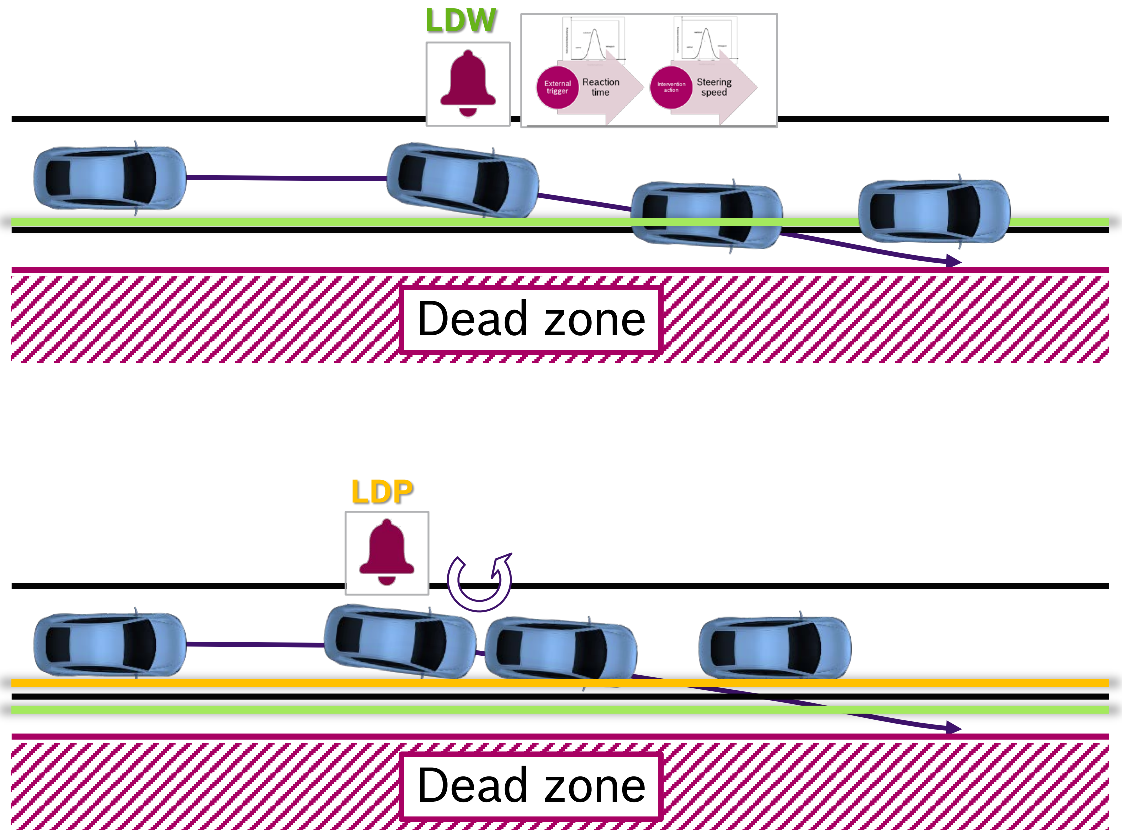
Analysis approach: Simulation: 3rd System model

Two systems defined:

- System specification according to CC-DA/EAV2-CN requirements

1. LDW only:
   LDW-System is triggered by virtual line
   →Triggers driver reaction

2. LDW+LDP:
   LDP-System is triggered by virtual line
   →Automatically steers back to the lane
   LDW-System is triggered by virtual line
   →Triggers driver reaction



▶ System behaviour transferred into simulation environment

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System specification

- Original specification for passenger cars provided by CC-DA/EAV2-CN on the 05/2017, these were simplified for easier simulation and used for cars and trucks hence limitations given for truck results.
- System specification used for simulation:

	Simulation LDW only	Simulation LDW + LDP	
Specification	LDW	LDW	LDP
Operating speed range	60 - 180 kph	60 - 180 kph	60 - 180 kph
Maximum departure angle	< 40°	< 40°	< 40°
Maximum curve radius	> 250 m	> 250 m	> 250 m
LDW-warning time before crossing LDW lane	0.7 s	0.7 s	-
Distance between virtual lane and driving lane	0.2 m	-0.1 m	0.2 m
Change of vehicle orientation by LDP			5 $[grad \cdot s^{-1}]$

Analysis approach: Simulation: 4th Simulation process

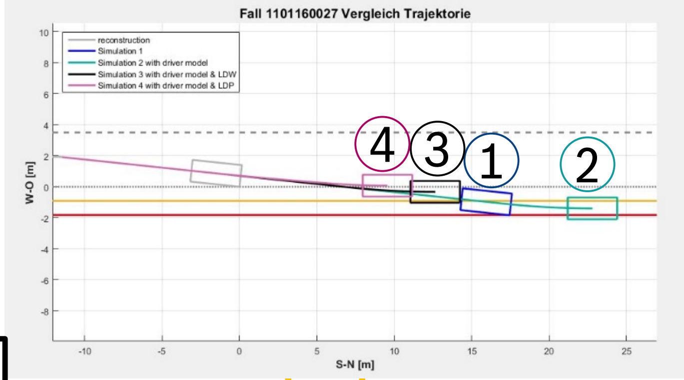
1. Prove of concept simulation:
- No driver model
- No system

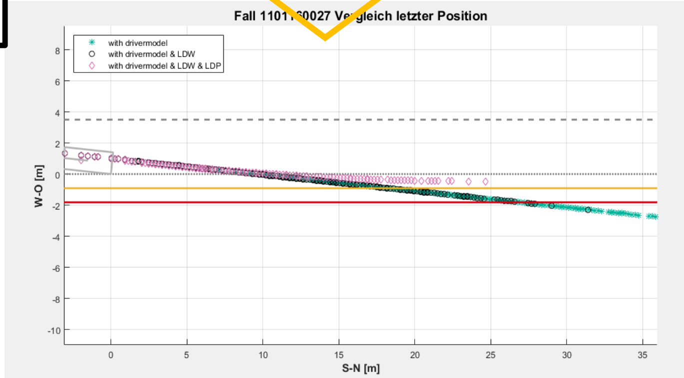
2. Ground truth simulation:
- Driver model
- No system

3. LDW only simulation:
- Driver model
- LDW system

4. LDW+LDP only simulation:
- Driver model
- LDW+LDP system

Stochastically variations of driver attributes





▶ In total 88 accidents each simulated w/ 1,000 driver types results in 88,000 simulations

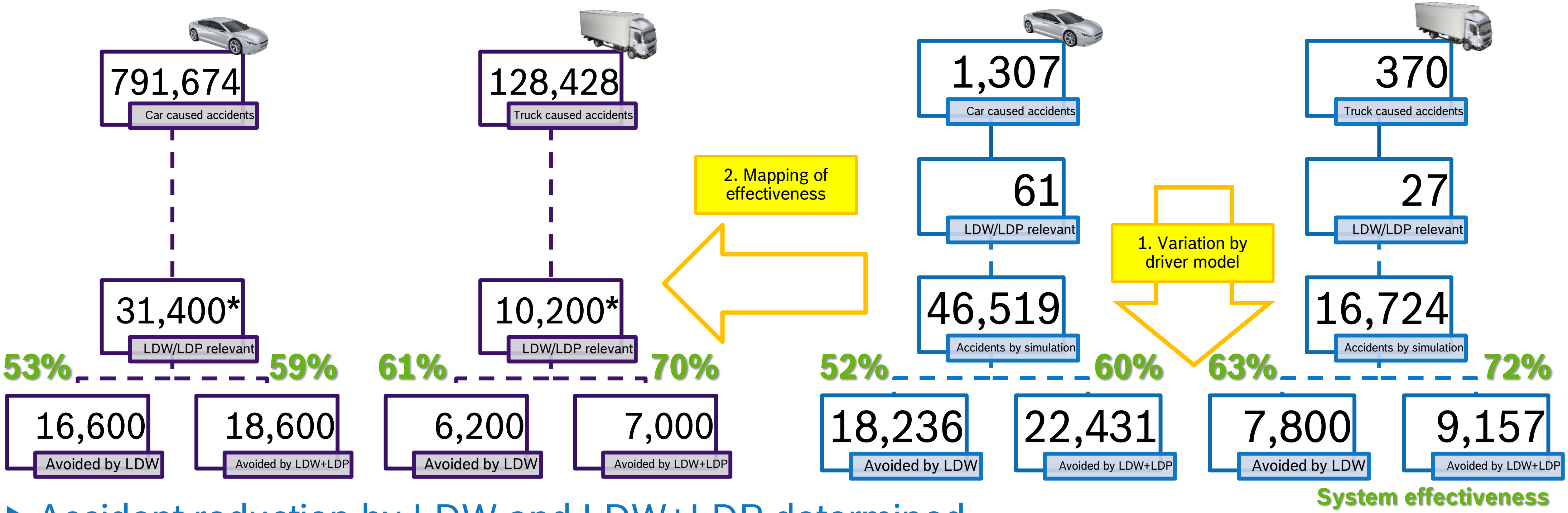
Internal | Bosch Accident Research (CR/AEV1-Sk) | Jan/31/2018
AEV-064 annual report 2016/17

Annual Report - ReGe China

Analysis approach: Effectiveness

Official traffic accident statistics for China

CIDAS database



- Accident reduction by LDW and LDW+LDP determined
- Results mapped to China by additional weighting methodology

Internal | Bosch Accident Research (CR/AEV1-Sk) | Jan/31/2018
AEV-064 annual report 2016/17

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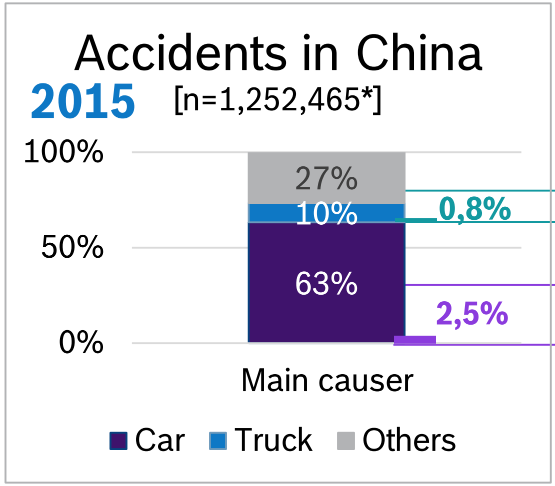
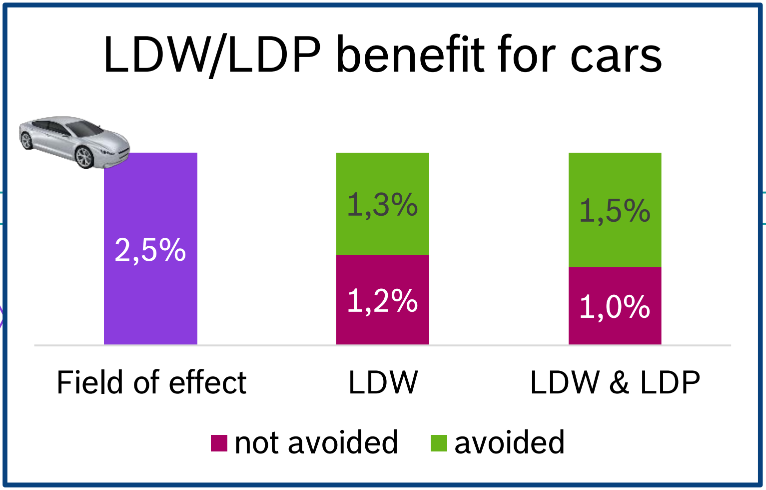
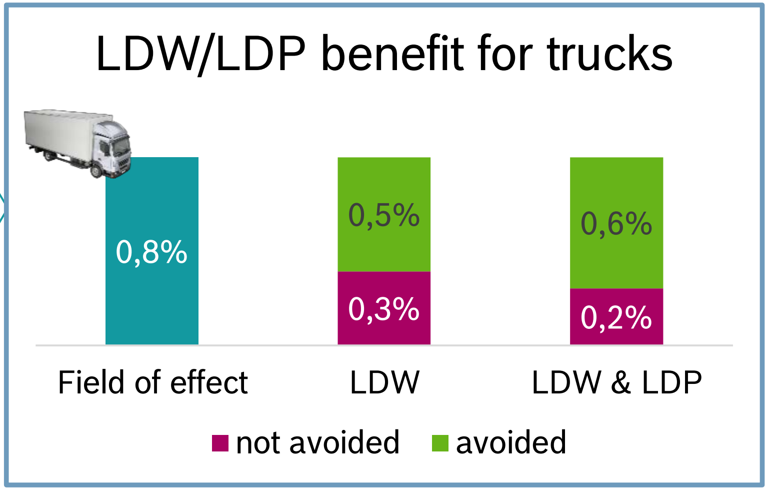
LDW & LDP: Estimated benefit in accidents w/ casualties







Cars:

- 2.5% of all accidents w/ casualties in China are relevant for LDW/LDP system for cars
- ~1.3% of all accidents w/casualties are avoidable by LDW and 1.5% by LDW+LDP for cars

Trucks:

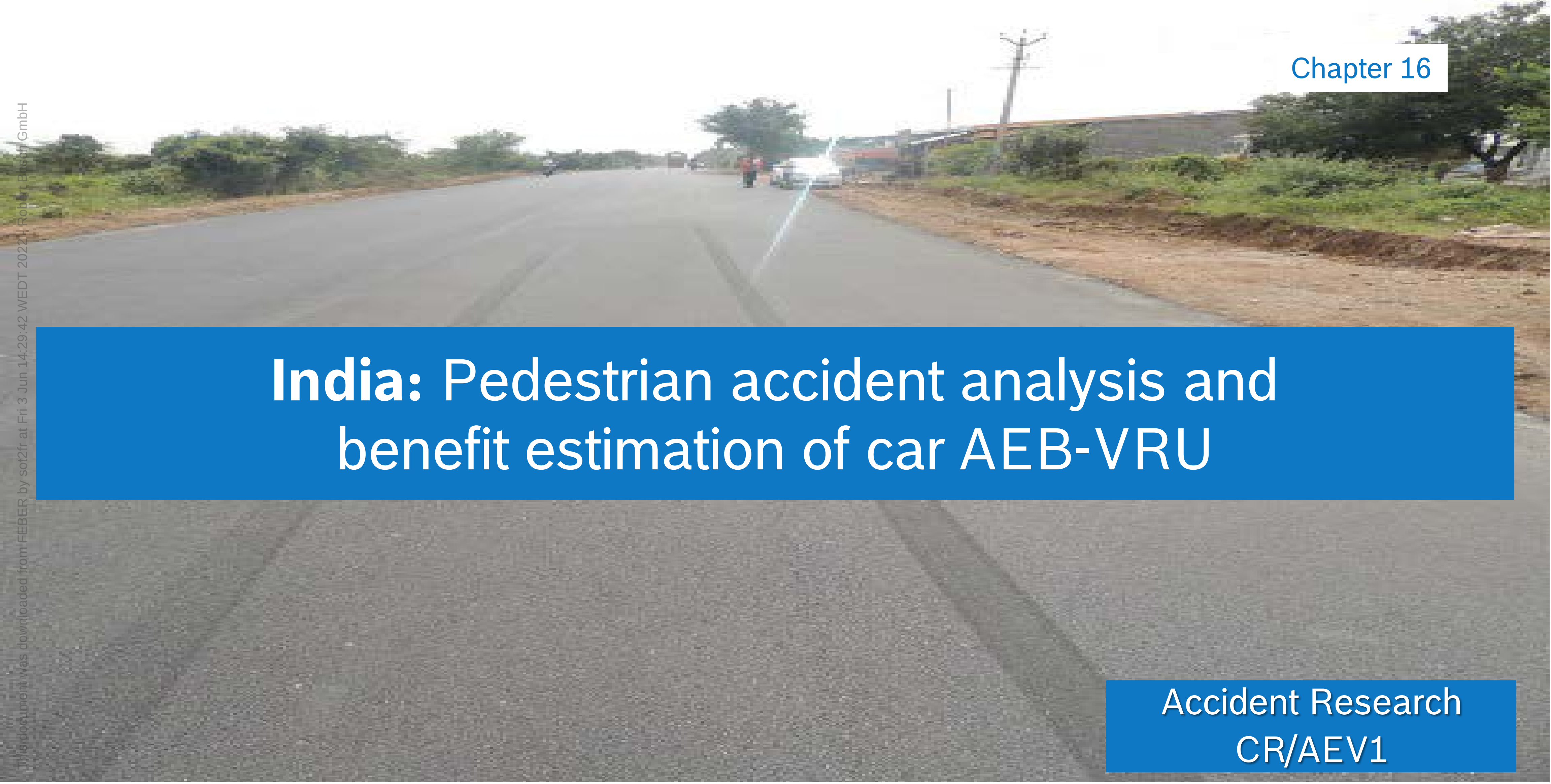
- 0.8% of all accidents w/ casualties in China are relevant for LDW/LDP system for trucks
- ~0.5% of all accidents w/casualties avoidable are by LDW and 0.6% by LDW+LDP for trucks

Analysis based on 2.011 CIDAS accidents (2014-2016); LDW=Lane Departure Warning, LDP=Lane Departure Prevention; * 29.535 accidents w/ unknown severity excluded

Annual Report - ReGe China

Summary

- According to national statistics 1,282,000 accidents w/ casualties occur in China (2015)
- Field of effect for LDW/LDP is determined to ~3.3%, in other words about 41,609 accidents w/ casualties are relevant for a LDW/LDP system (cars ~2.5% and trucks ~0.8%)
- Benefit is estimated by variations of simulations of modeled LDW/LDP system according to system specification provided by CC-DA/EAV2-CN in total 88,000 simulations
- If each car was be equipped with a LDW system 16,633 accidents (~1.3%) could be avoided by LDW in other words every 2nd lane departure is avoidable by a car LDW
- If each car was be equipped with a LDP (including LDW) system 18,614 accidents (~1.5%) could be avoided by LDP in other words every 3rd out of 5 road departure is avoidable by a car LDW
- If each truck was be equipped with a LDW system 6,171 accidents (~0.5%) could be avoided by LDW in other words every 3rd out of 5 departure is avoidable by a truck LDW
- If each truck was be equipped with a LDP (including LDW) system 7,088 accidents (~0.6%) could be avoided by LDP in other words every 2rd out of 3 road departure is avoidable by a truck LDW



Chapter 16

India: Pedestrian accident analysis and benefit estimation of car AEB-VRU

Accident Research
CR/AEV1

BOSCH

Summary

Aim of the study

The current study is aimed to give a status of the pedestrian accident situation in India

Method

Analysis is based on 1779 cases from RASSI database (Status: Jan - 2017). 168 relevant accidents involving 207 pedestrians were analyzed. The analysis covered various accident situations, type and kind of pedestrians accidents, pedestrians accident causation, environmental parameters, potentials field of effect of various advance safety functions and pedestrians' behaviors.

Results

Nearly 10% (13 900) of pedestrians are fatal each year involving in ~5% of overall accidents in India. This study reveals every second pedestrian accident occurred while walking and crossing the road straight. The preliminary study reveals that the field of effect for car-AEB pedestrian is ~26%. In other words every 4th pedestrian crash in this study is relevant for car-AEB pedestrian. One in tenth pedestrian accidents is avoided by Car – AEB pedestrian. In every third pedestrian accident which is not avoided - the collision speed is reduced up to 40- 80% thereby minimizing the severity of the accident.

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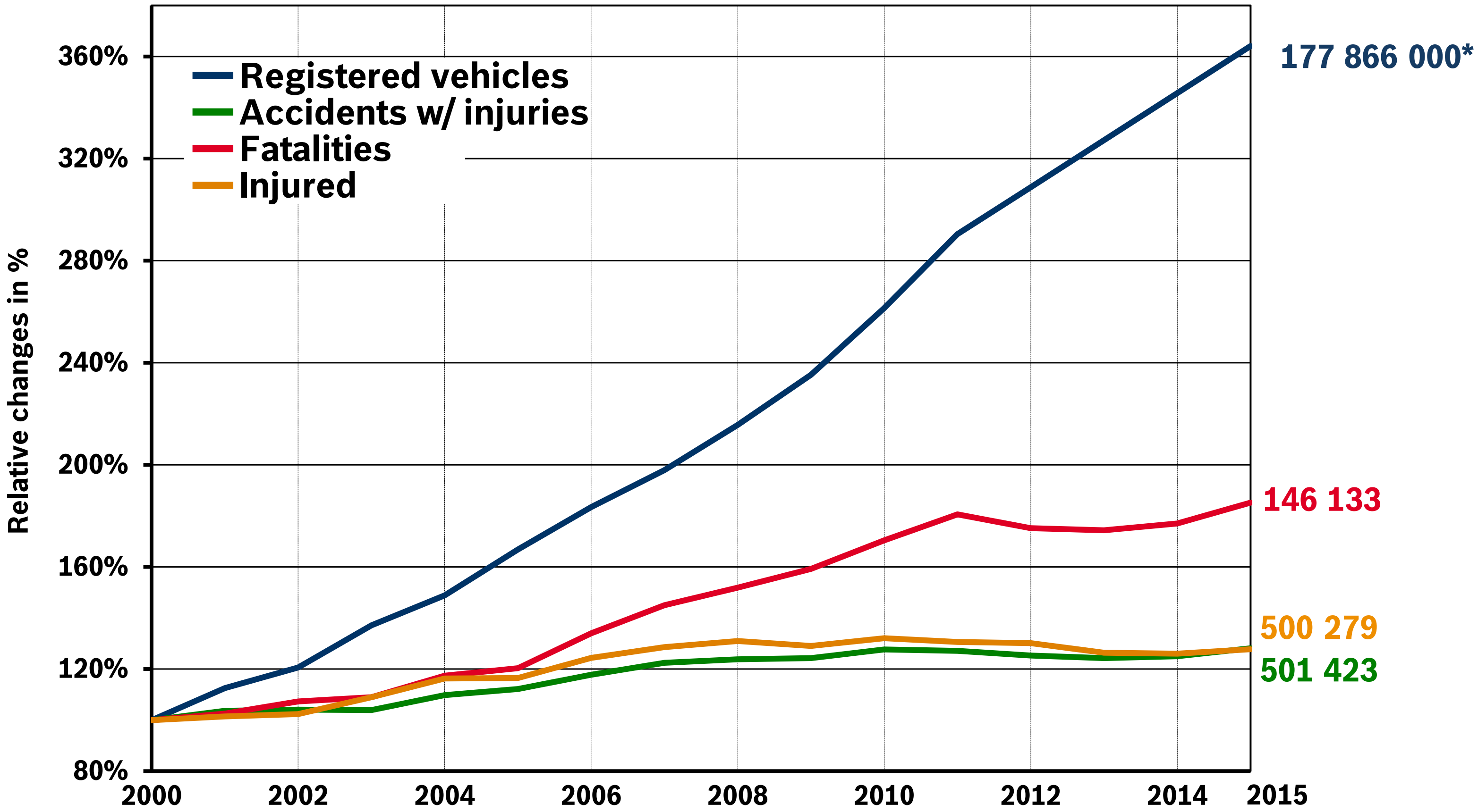
Evolution of road traffic accidents since 2000 in India



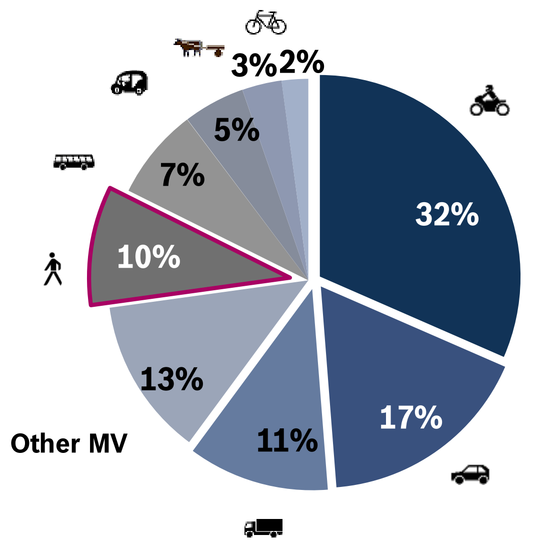
*Source : Road Accident in India 2015, Transport Research Wing, Ministry of Road Transport and Highway Department, GOI,
Figures for registered vehicles for 2012 to 2015 shown here are provisional with projection of 20 % relative increase

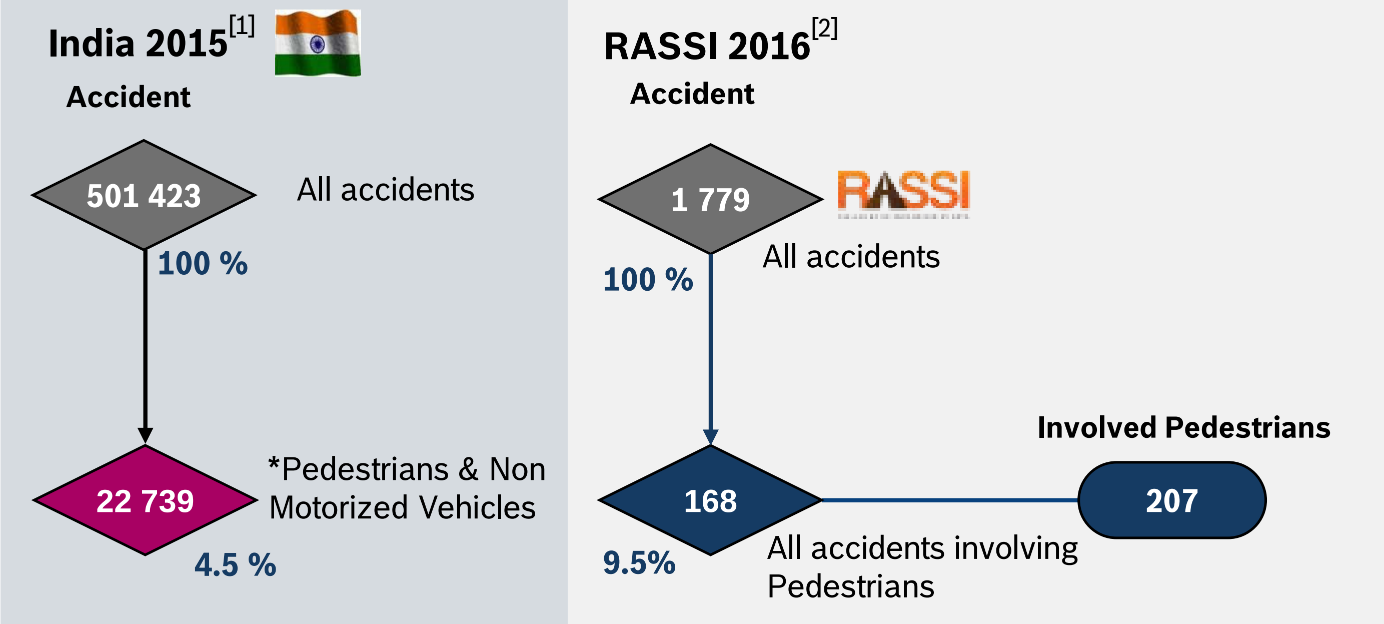
BOSCH

Fatality by type of road user categories 2015 / Data usage

Fatality in road accidents by type of Road User Categories: 2015

n=146 133





[1] Source: Road Accident in India 2015, Transport Research Wing, Ministry of Road Transport and Highway Department, GOI,

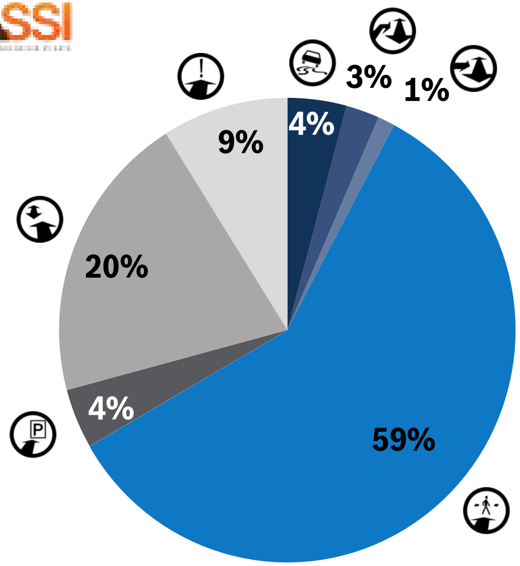
[2] Source: RASSI database (2010-2016), data not representative for complete India, RASSI = Road Accident Sampling System India

*Non-Motorized Vehicles/Objects include cycles, cycle rickshaws, hand-drawn vehicles, pedestrians, animals, trees, level-crossings and other fixed objects.

Every 10th road traffic fatality in India is a pedestrian (~13 900 people)

Annual Report - ReGe India
Accident type

Accidents involving Pedestrians
n=168



Type of accident:
Describes the conflict situation which resulted in the accident.

- **Driving accident**
- **Turning off the road**
- **Turning into or crossing**
- **Pedestrian crossing**
- **Involving stationary vehicles**
- **Accidents in lateral traffic**
- **Other accident**

Nearly 60% of pedestrian involved accidents are during crossing the road, major share of pedestrian involvement is also seen in accidents in lateral traffic.

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

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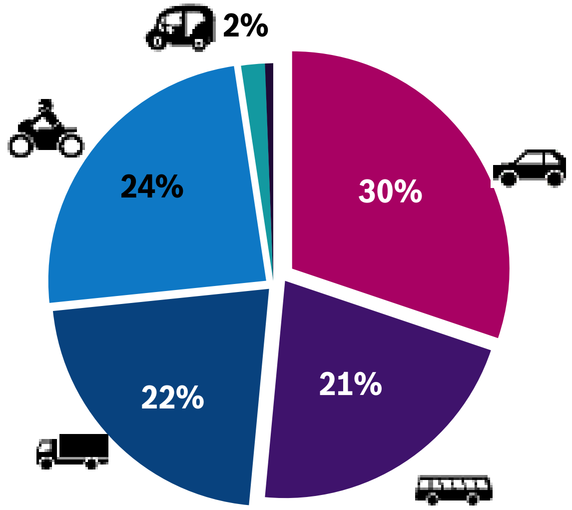
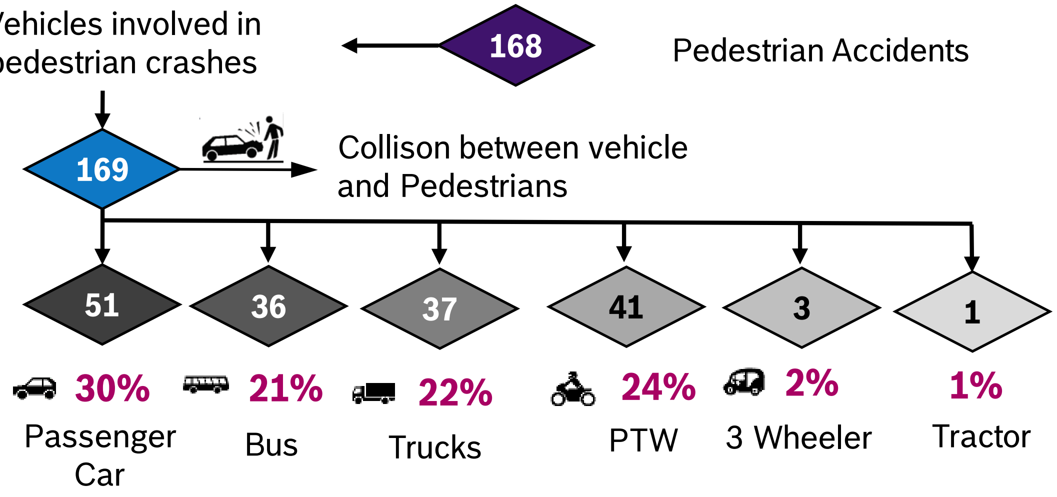
Vehicles involved in pedestrian crashes

Accidents involving Pedestrians
n=168





- Pedestrian accidents **mainly with car as primary collision** opponent (every 3rd accident)
- 85% of car impact happed by **forward moving car**
- PTW, trucks and buses as collision opponent have nearly same shares of 21 – 24% in all pedestrian accidents
- Trucks and Bus collisions contributing to high pedestrian fatality rate

*Source: RASSI database (2010-2016), RASSI = Road Accident Sampling System India

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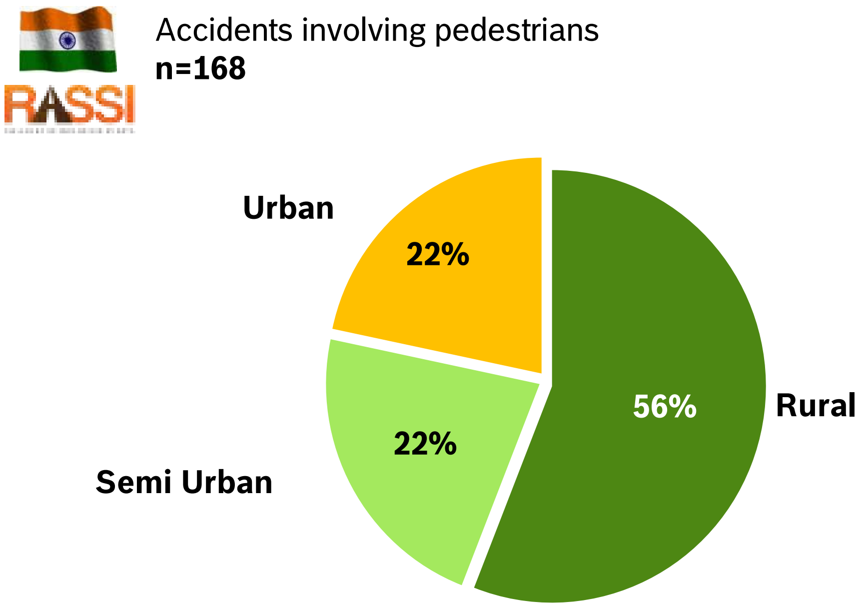
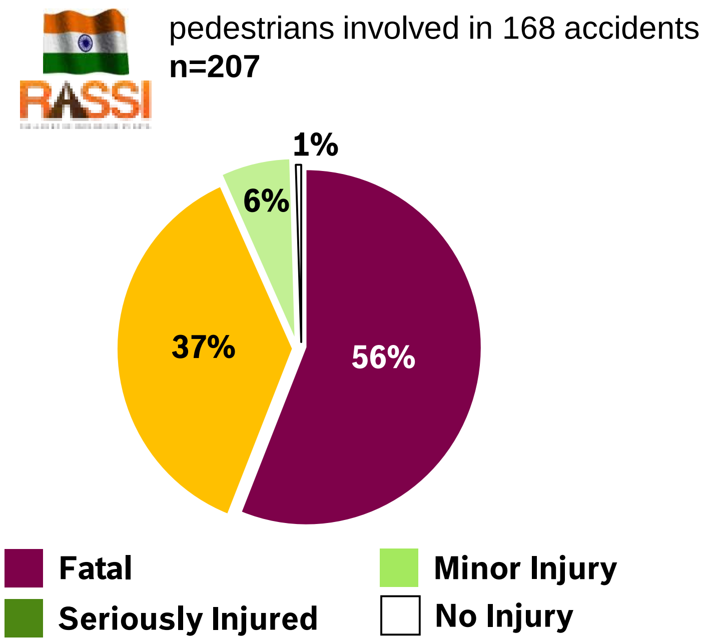
Crash Location - Facts





- Highest pedestrian fatality is recorded in rural roads
- Pedestrian accidents occur mainly during daytime, nearly 28% of pedestrian accidents occur during night with poor visibility

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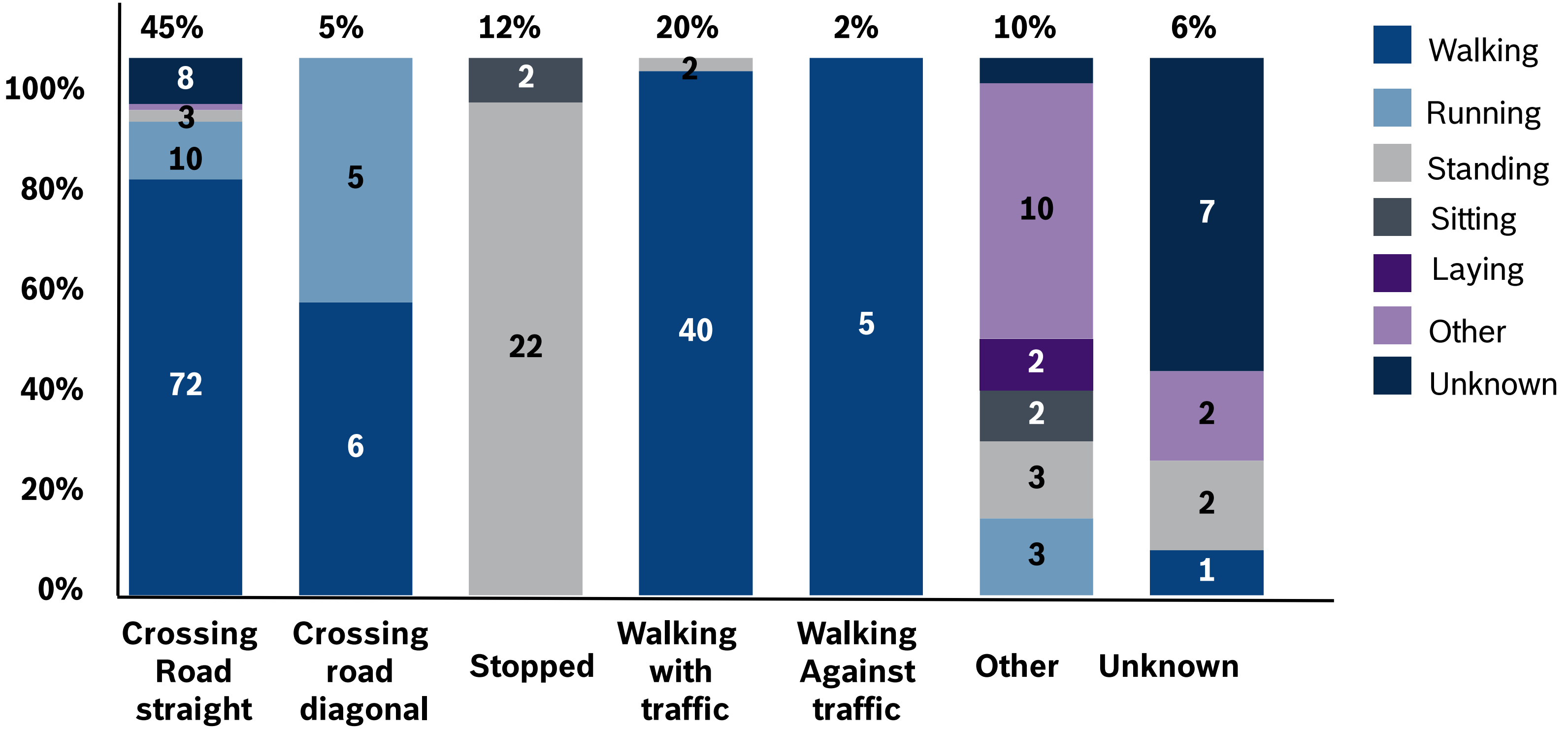
Pedestrians actions during pre crash

All Pedestrians involved in 168 accidents*
n=207



▶ Every 2nd pedestrian accident occurred while walking and crossing the road straight and nearly 12% of pedestrian accident occurred while standing in road

Internal | Bosch Accident Research (CR/AEV1-Mö,Giri) | Jan/31/2018
AEV-064 annual report 2016/17

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

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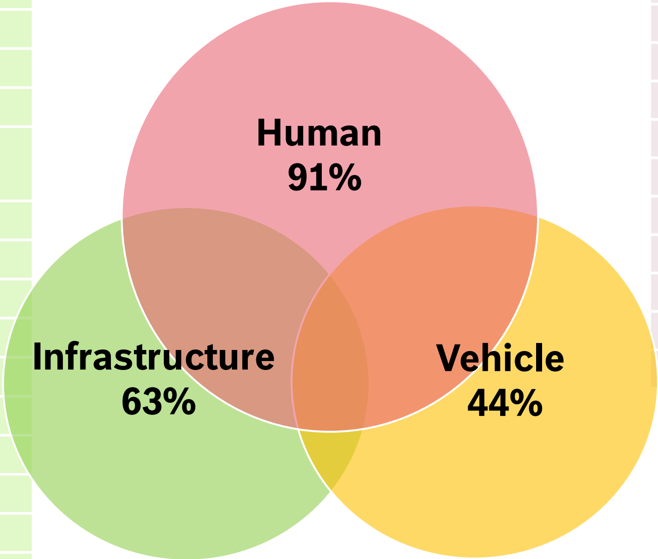
Pedestrian accidents contributing factor

Infrastructure 63%

- No paved shoulders
- No pedestrian Crossing (Zebra Crossing)
- Poor pedestrian infrastructure
- Lack of pedestrian walking facilities
- Inadequate warning about accident/parked vehicle
- Object impact - road side - trees/plantation
- No lightings on road.
- No path for pedestrian.
- EMS availability
- Poor street lighting
- Vision obstruction due to slow moving bus
- Intersection
- Gap in between jersey barrier
- Gap in fence at the curb
- No lane for pedestrian and bicycles



Human : 91%

- Pedes Dangerous behavior on roadway
- Driver - Over Speeding
- Peds- Violation of Right of Way
- Pedestrian walking on the roadway
- Parked-vehicle on road(Partial)
- Pedestrian in attention
- Driver - Alcohol
- Driver -Sleep/Fatigue/Drowsiness
- Careless crossing of Road (Pedestrian)
- illegal pedestrian entry
- Pedestrian influenced Alcohol

Vehicle 44%

- Cargo not secured
- Passenger Compartment Intrusion
- Illegal alteration/fitment - Bull bars
- Vision obstruction due to vehicle interiors
- Poor braking efficiency
- Protruding/ over-sized cargo
- Vehicle not in good condition
- Very old vehicle
- poor vehicle maintenance
- Defective-Tires

RASSI*

Accidents involving Pedestrians

n=168

Occurrence Index

- High (>30%)
- Medium (>10%-30%)
- Low (<10%)

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

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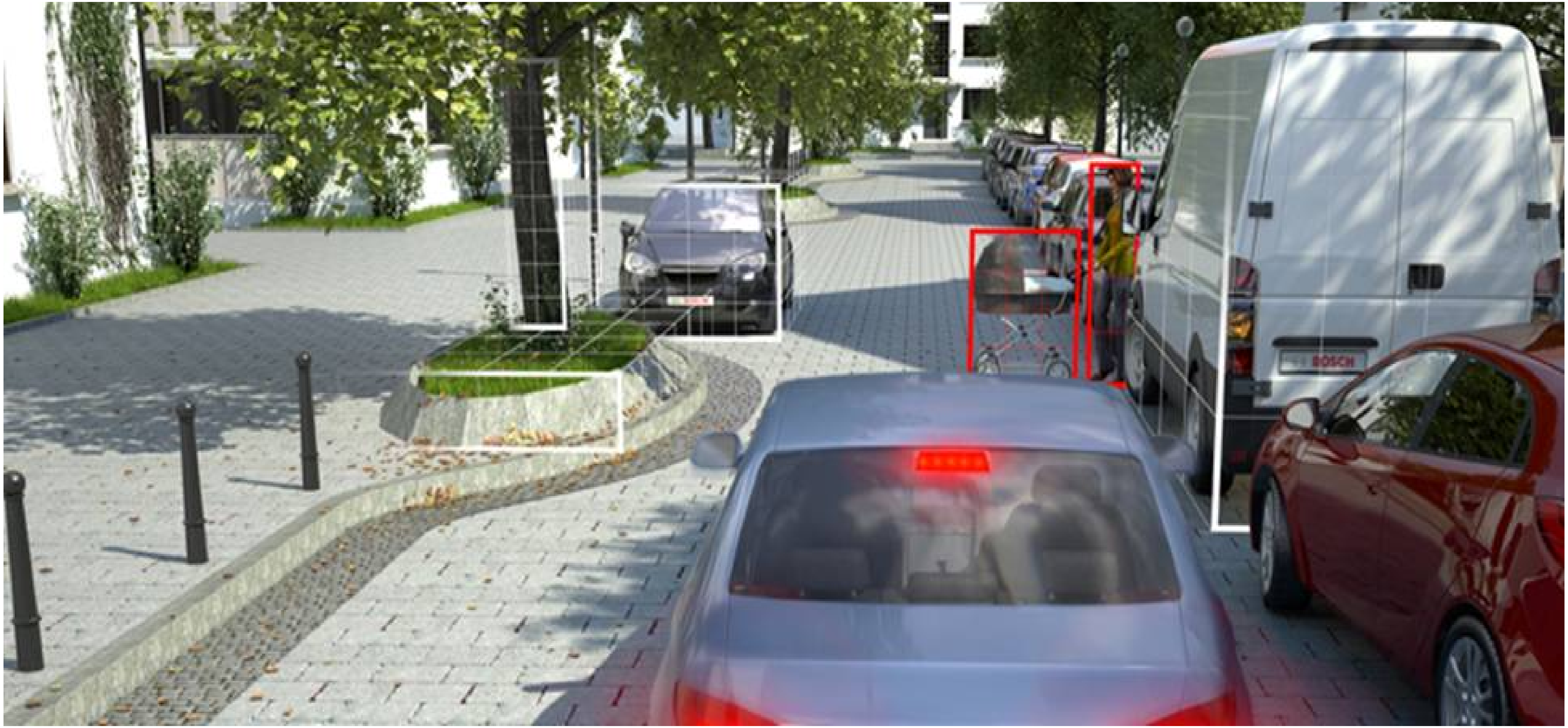
AEB-VRU Benefit Estimation



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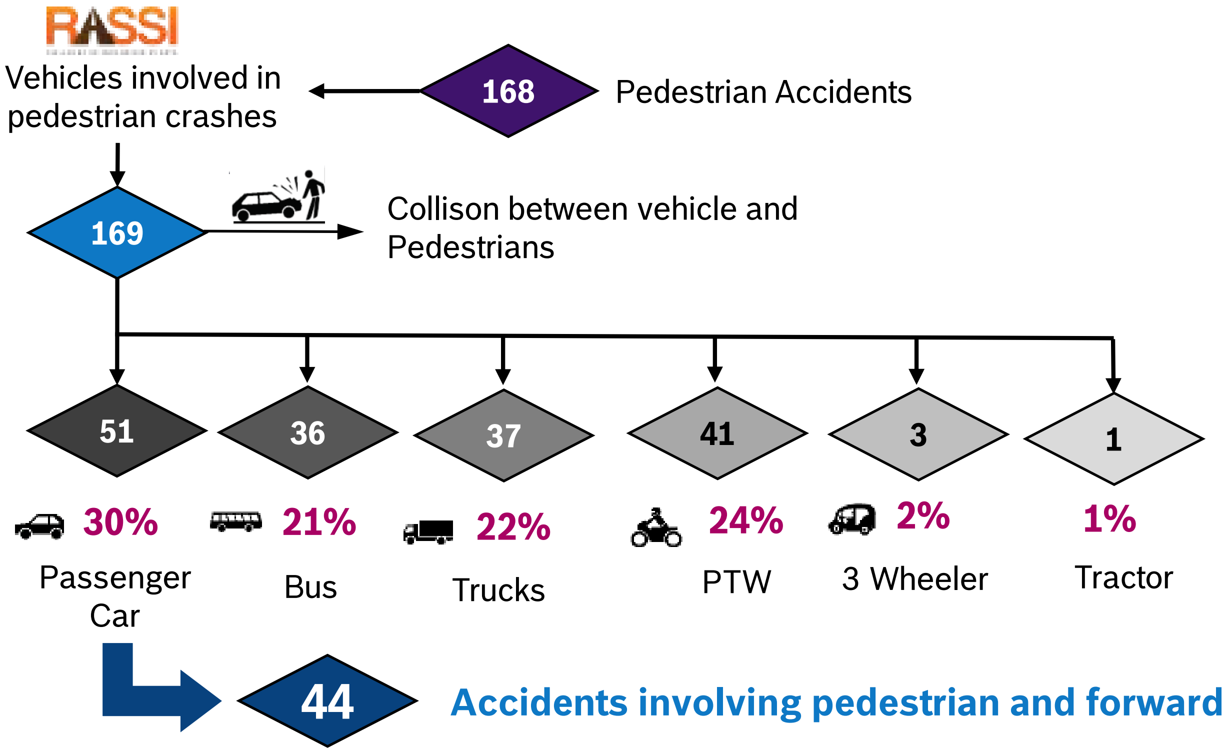
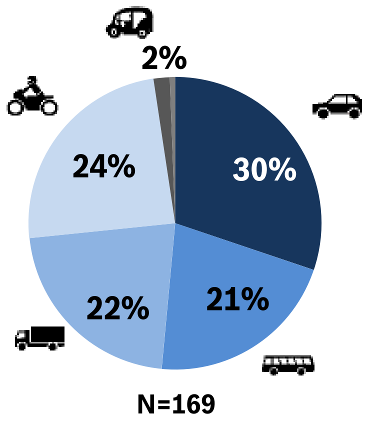
Vehicles involved in pedestrian crashes





Analysis is at vehicle level –multiple pedestrian involvement in single vehicle possible

*Source : Road Accident in India 2015, Transport Research Wing, Ministry of Road Transport and Highway Department, GOI, RASSI data 2010-2016 (Road Accident Sampling System India)

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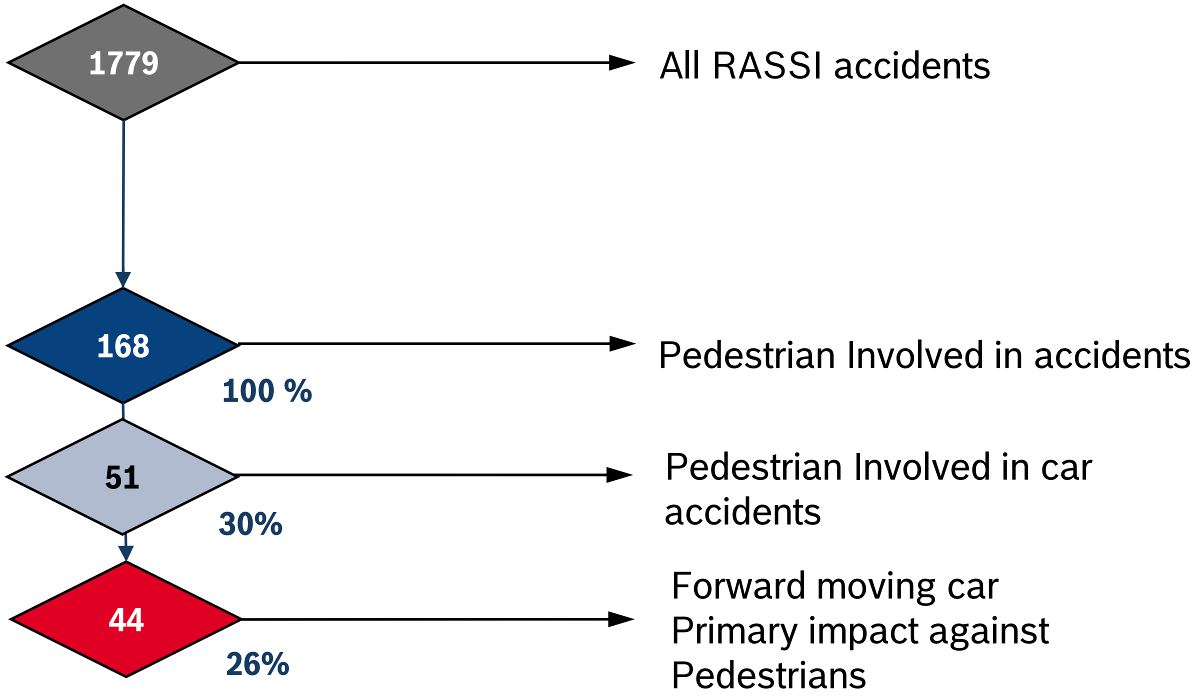
Relevant Car – Pedestrian accidents

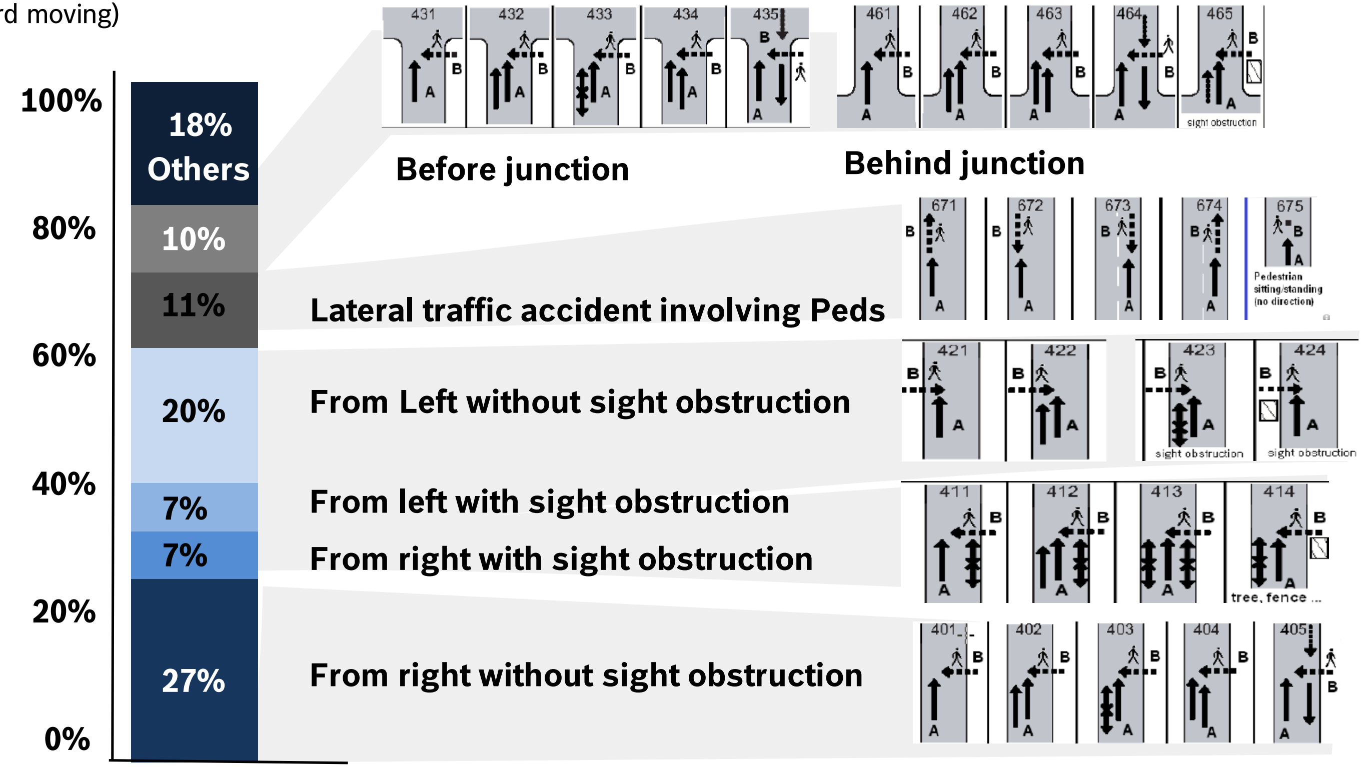


- Field of effect for car-AEB pedestrian is 26% of all pedestrian accidents, in other words every 4th pedestrian accidents in RASSI is relevant for car-AEB pedestrian

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

Overview of car-pedestrian accident types

Accidents involving Car–Pedestrians
n=44 (Forward moving)



- Crossing pedestrian covers more than 70% of all car-pedestrian crashes (including obstruction), 10% of pedestrian crashes occur in road junctions

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

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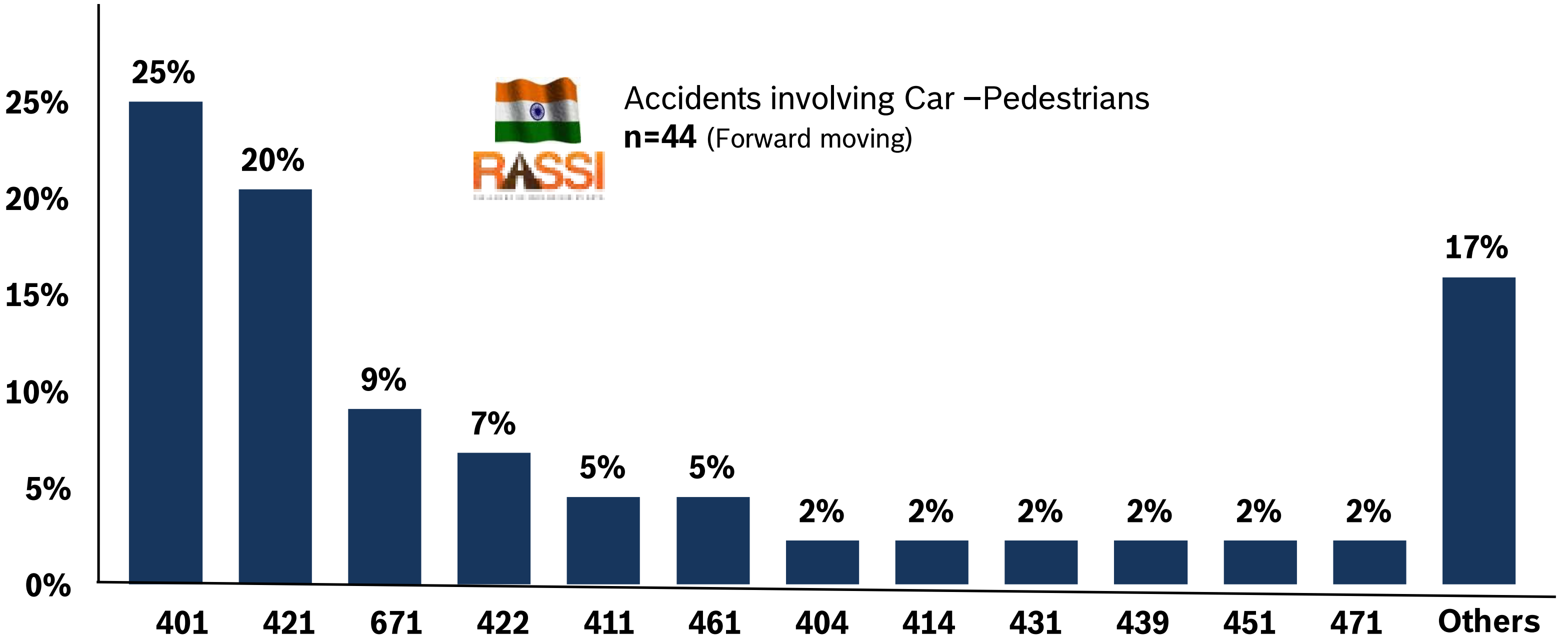
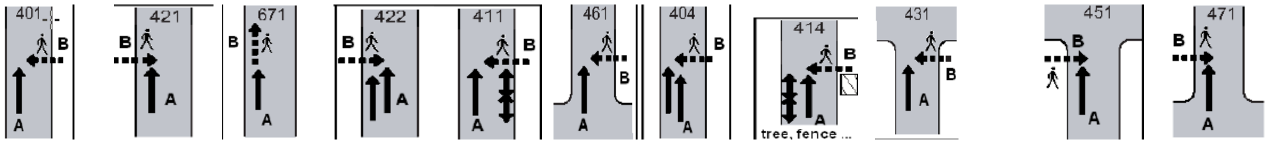
Accident types of car-pedestrian crashes





▶ Major primary car-pedestrian collisions with forward moving car are crossing pedestrian scenarios

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

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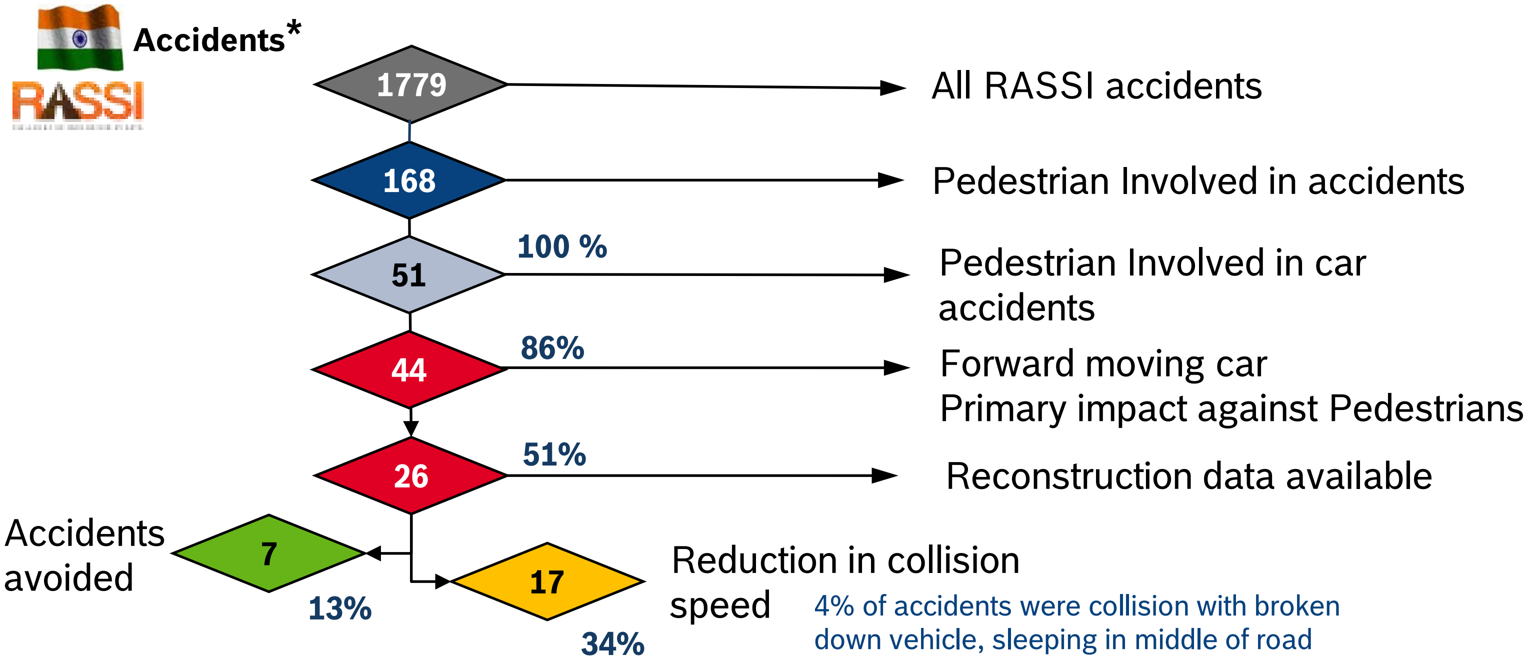
AEB-VRU – Pedestrian – Benefit estimation



- One in tenth pedestrian accidents is avoided by car AEB-Pedestrian, in every third pedestrian accident the collision speed is reduced thereby minimizing the severity of the accident

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

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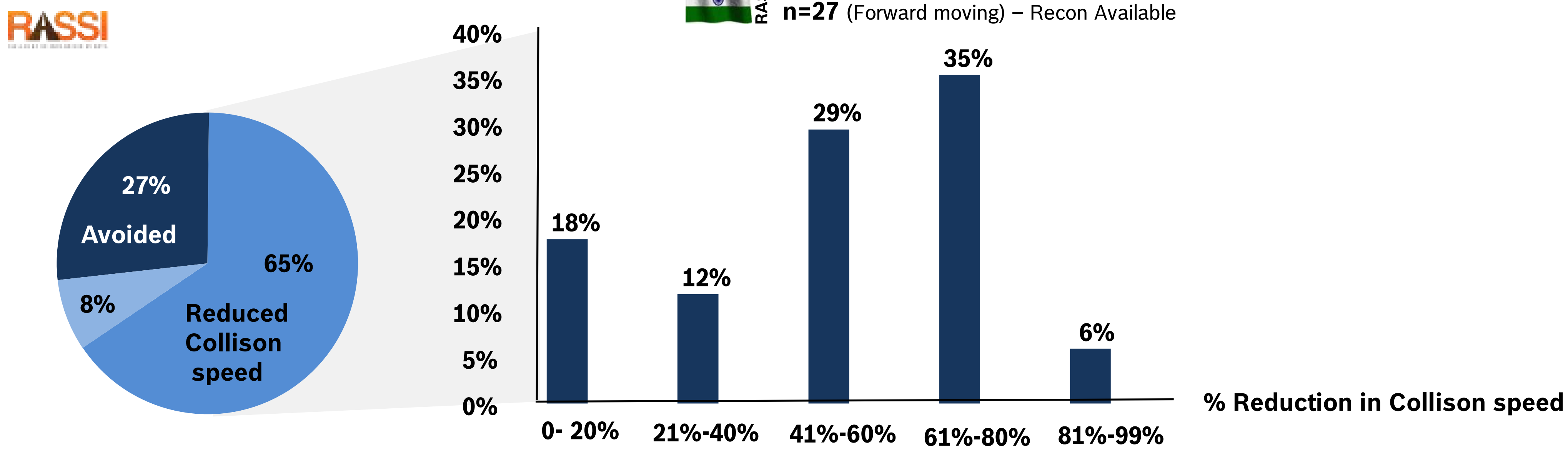
AEB-VRU – Pedestrian – Benefit estimation

RASSI* Accidents involving Car –Pedestrians
n=27 (Forward moving) – Recon Available



- In every second pedestrian accident which is not avoided by car AEB-Pedestrian, nearly 40% to 80% of collision speed is reduced thereby minimizing severity of the accident

*Source: RASSI database (2010-2016), RASSI - Road Accident Sampling System India

Annual Report - ReGe India
Results 1/2

- 13 900 pedestrians died annually in India, potential of pedestrian protection systems and VRU safety technology
- Study based on in-depth accident database* with 1179 cases
- The accidents were analyzed from in depth accident data covering 5 different location involving mainly rural, urban & semi urban
- Every 2nd pedestrian accident occurred in daytime, one in third pedestrian accident occurred during night without illumination
- Every 2nd pedestrian accident occurred while walking and crossing the road straight, nearly 12% of pedestrian accident occurred while standing on road
- Maximum fatality in pedestrian seen while thrown out & vehicle run over pedestrians

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Results 2/2

- Preliminary estimation states the VRU test scenarios of EURO NCAP relevance for India (Left hand drive) covers 72% of all forward collision car accidents – this covers 41% Farside, 24% near side w/o obstruction, & 7% near side with obstruction
- Car – Pedestrian accidents are evaluated based on the reconstruction data
- Crossing pedestrian covers more than 70% of all car-pedestrian crashes (including obstruction), 10% of the pedestrian crash occurs in road junctions
- One in tenth pedestrian accidents is avoided , in every third pedestrian accident the collision speed is reduced there by minimizing the severity of the accident with 100% installation of AEB-VRU
- Field of effect for car-AEB pedestrian is ~26%, in other words every 4th pedestrian crash in this study is relevant for car-AEB pedestrian
- In every second pedestrian accident which is not avoided by the system, nearly 40% to 80% of collision speed is reduced there by minimizing severity of the accident

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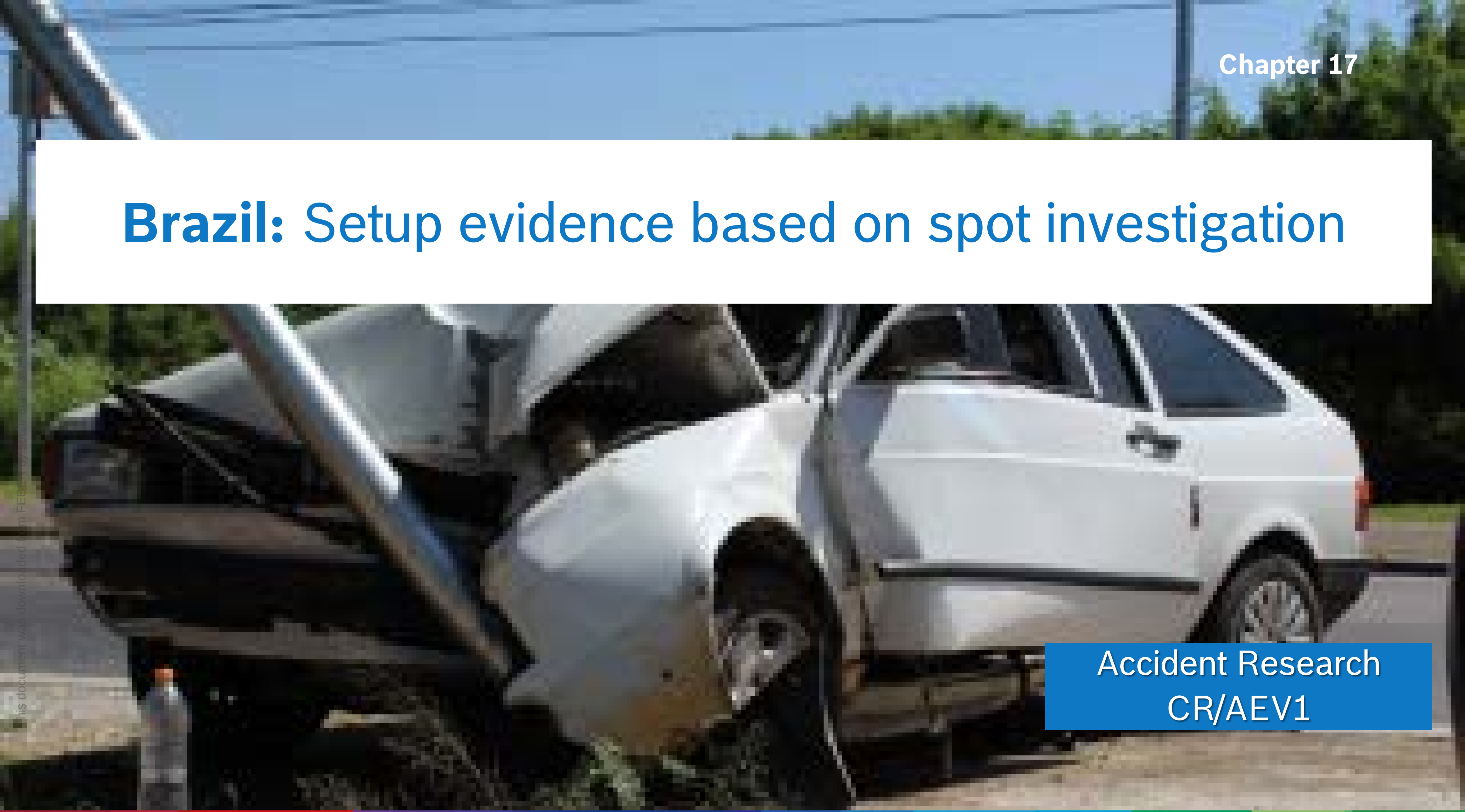
Summary

- 13 900 pedestrians died annually in India, potential of pedestrian protection systems and VRU safety technology
- India is currently using pedestrian protection system regulations for cars (AIS 100): AIS-100 Protection of Pedestrian and other Vulnerable Road Users in the event of a Collision with a car
- No Active safety pedestrian detection / avoidance system available yet in India
- Preliminary study reveals that field of effect for car AEB-Pedestrian is ~26%, in other words every 4th pedestrian crash in this study is relevant for car AEB-Pedestrian
- One in 10th pedestrian crashes could be avoided by car AEB-Pedestrian, in every third pedestrian accident which is not avoided - the collision speed is reduced up to 40- 80% there by minimizing the severity of the accident (assuming 100% installation rate)
- Sample size and reconstruction data sample size is small to project to whole of India – validation and extrapolation possible on availability of the required sample size

Chapter 17

Brazil: Setup evidence based on spot investigation



Accident Research
CR/AEV1

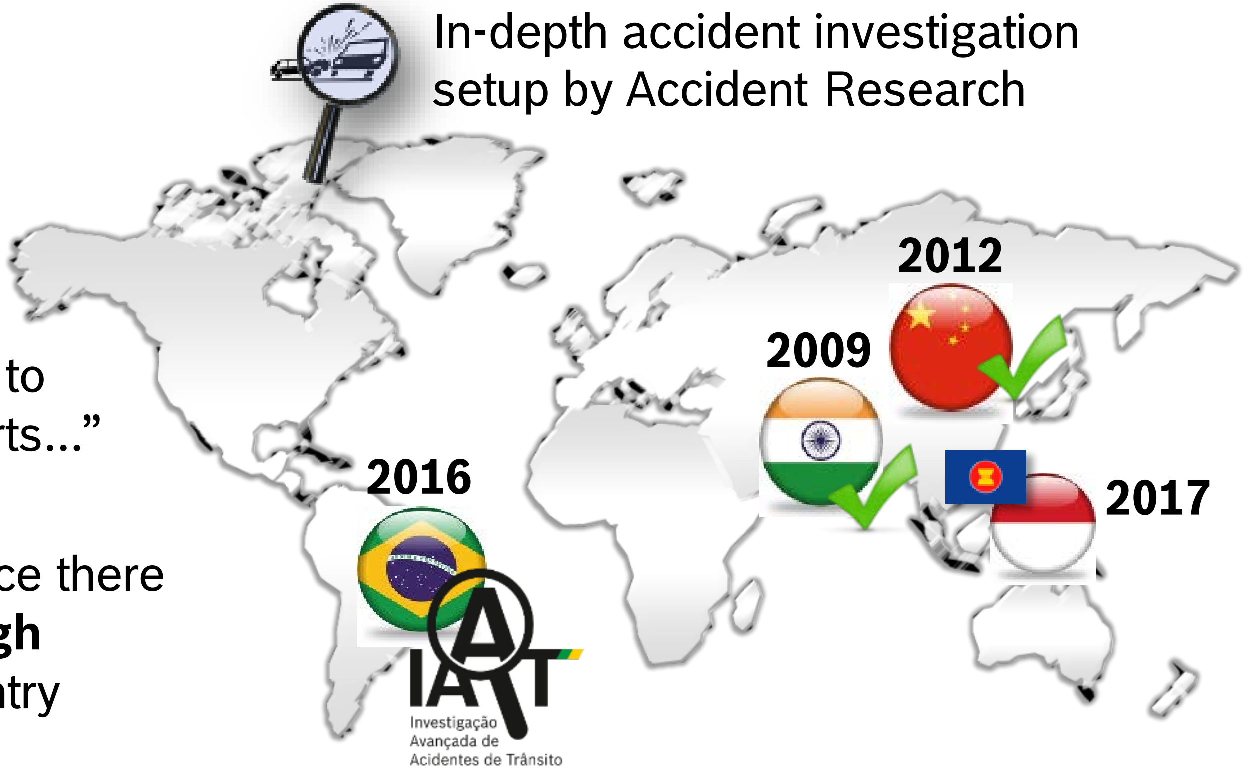
Annual Report – ReGe Brazil

Asia-Pacific well established further expansion towards LA

Political consulting requires **effectiveness** of CC products based on **national data**

"…The **lack of accident data** represents a serious limitation to the development of such reports…"

Conclusions **not possible**, since there is no data available with **enough quality** and **details** in the country



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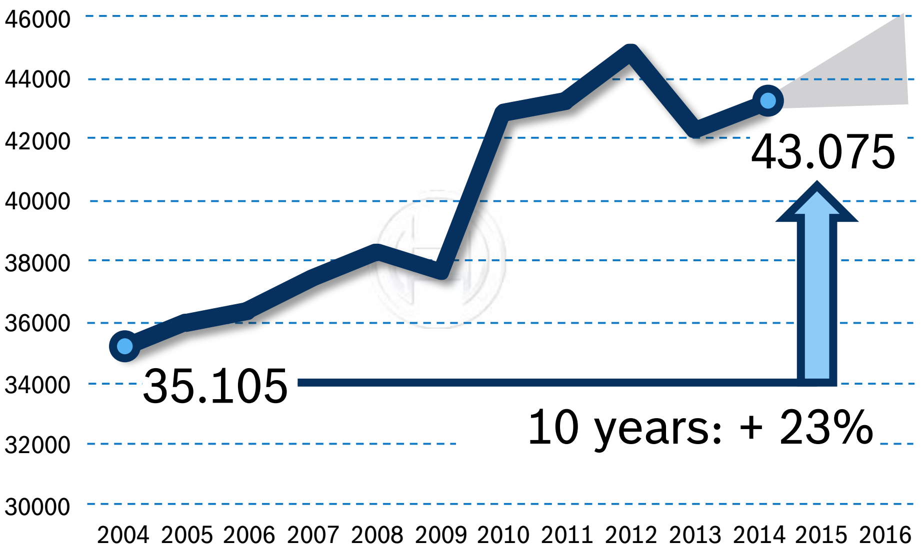
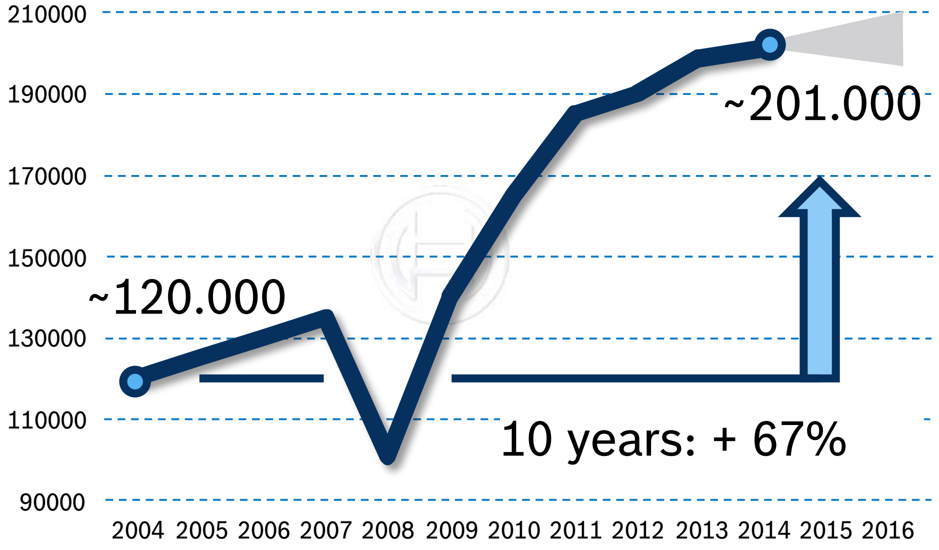
Motivation for further investigation

▶ Traffic accident fatalities – Brazil



▶ Injured road users – Brazil



Within one decade an increasing trend of fatal and injured road users seen in Brazil

Source: Ministry of Health – Brazil - DATASUS database Update 02/2016 Brazilian association for the prevention of traffic accidents

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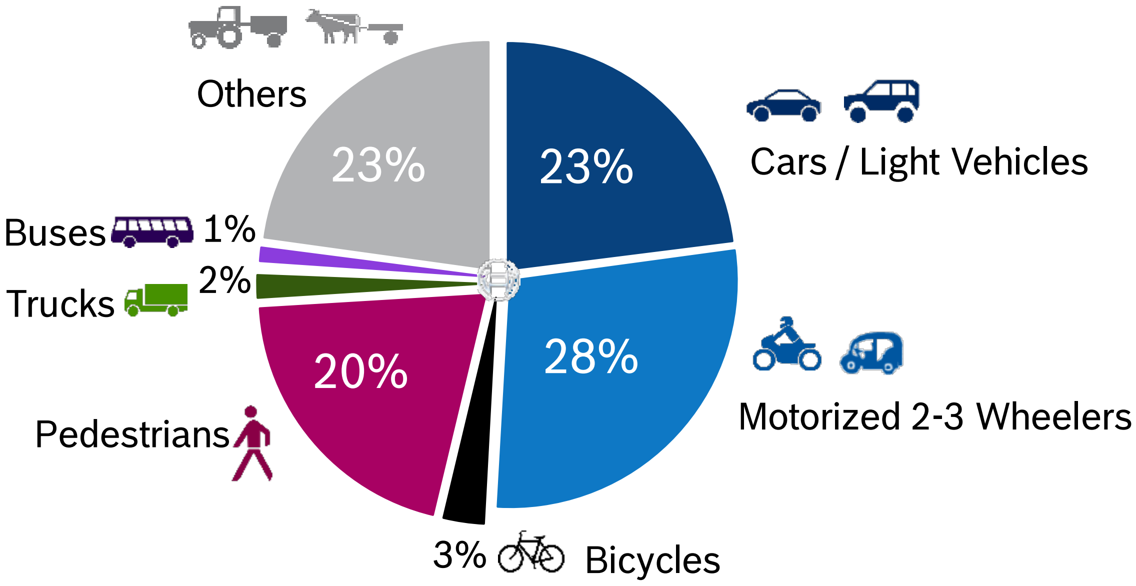
Motivation for further investigation

- ~50% of fatalities are VRU
- High share of “other” road users

Other accident situation compared with other countries especially in:

- Behaviour of transport
- Climate conditions
- Vehicle fleet
- Infrastructure



- Deriving measures to improve traffic safety in future by identifying accident root causes
  → Initiative of a pilot study on behalf of SAE Brazil started at the end of March 2016

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Local partner enable quick access to accident site

- **City of Campinas**
  - 1.024 million inhabitants
  - highway, multi lanes, residential roads

- **Investigation area**
  - ~3.5 km radius, urban area
  - Focus: Crashes w/ casualties

- **Data collection by EMDEC**
  - Traffic management
  - Existing operation vehicles
  - Accident notification available
  - Access to registered vehicle data

IAT
Investigação
Avançada de
Acidentes de Trânsito

EMDEC

Empresa Municipal do Desenvolvimento de Campinas

Target: collect **50 cases** up to December 2016

Result: 90 cases involving **179** vehicles/participants

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Chapter 17

Creation of a technical cooperation between SAE & EMDEC

EMDEC
- Accident communication
- Traffic agents
- Data acquisition

SAE BRASIL
- Coordination of Project and Sponsors

BOSCH
- Training by Bosch Accident Research (Germany) Equipments + Software

Applus+ IDIADA
- Reconstructions

Mackenzie
- Engineering students

TAKATA
- Scholarship

+ coordination with forensic and emergency care services in the region

Internal | Bosch Accident Research (CR/AEV1-Lh,Mö) | Jan/31/2018
AEV-064 annual report 2016/17

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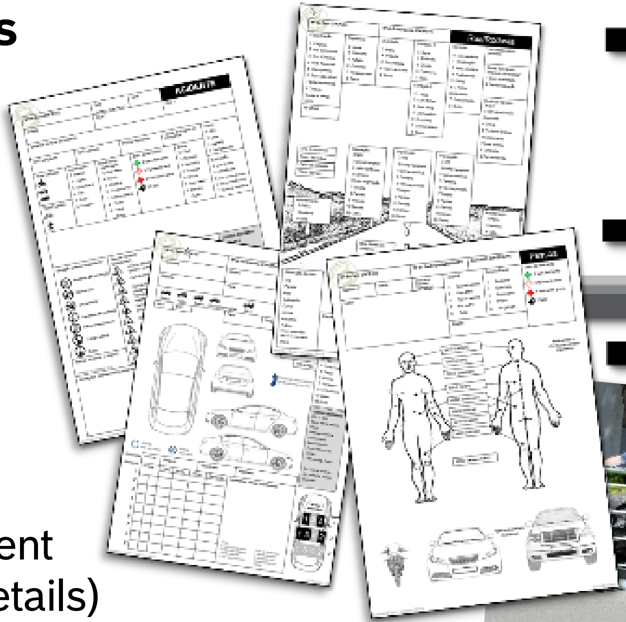
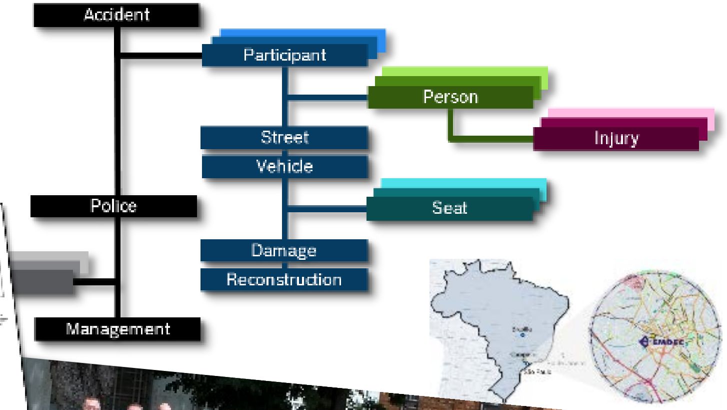
Initial training along with database setup

- **400 variables w/ ~3,000 specifications**
- **International comparable**
  - iGLAD scheme
  - GDV accident type classification
  - Crash specification
- **Content:**
  - Traffic control, location details
  - Weather, street conditions
  - Vehicle details, damage
  - Person information, injury, cause of accident
  - Reconstruction (event and vehicle wise details)





- Database setup supports international harmonization of accident databases
- Investigation on a scientific way hence technical expertise included

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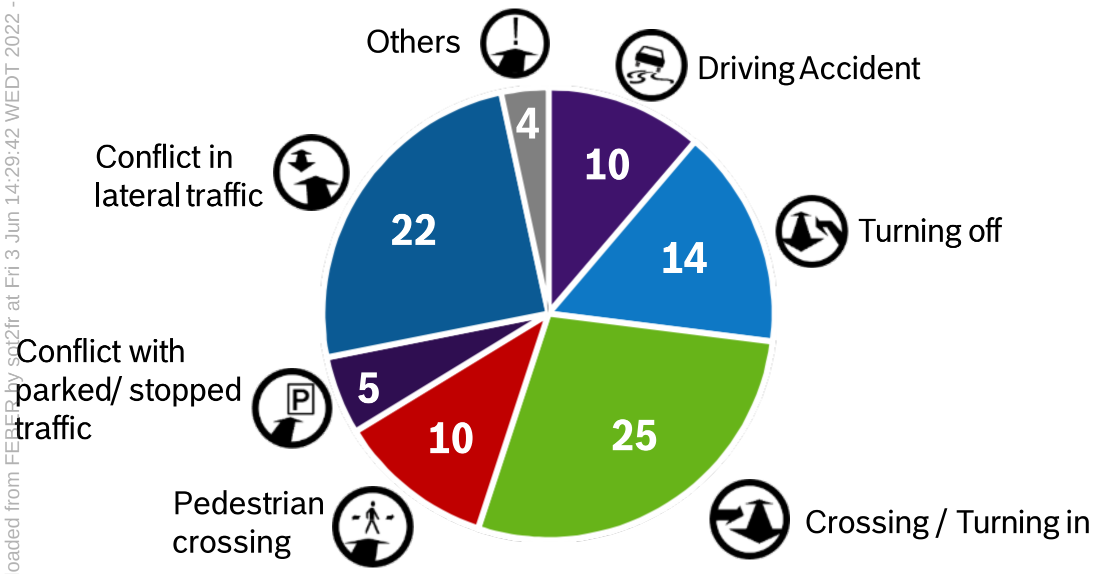
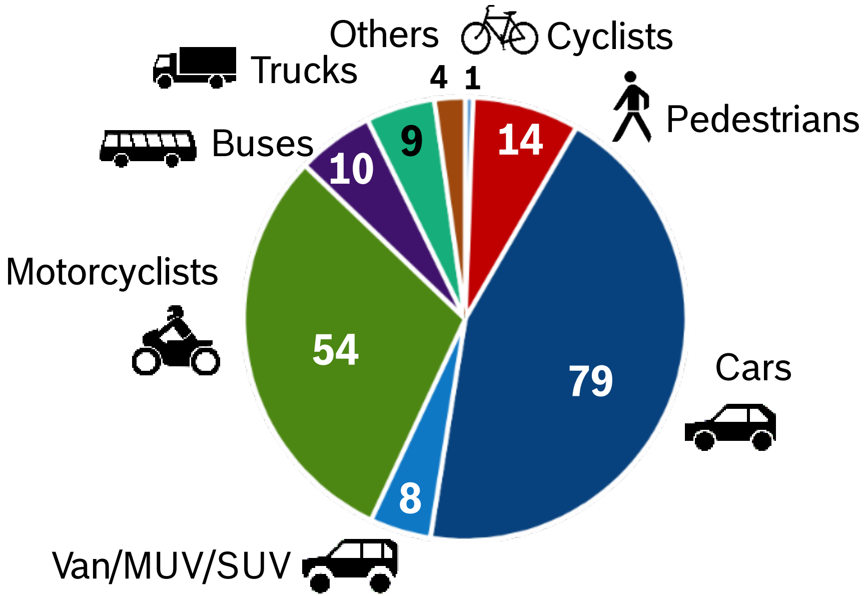
Results out local accident data

Type of accident (conflict situation)



Type of road user involved



- Database represents typical urban crash scenarios i.e. crossing
- Remarkable: More crashes involving motorcyclists

Source: IAAT database, E12/2016, 90 crashes involving 179 participants

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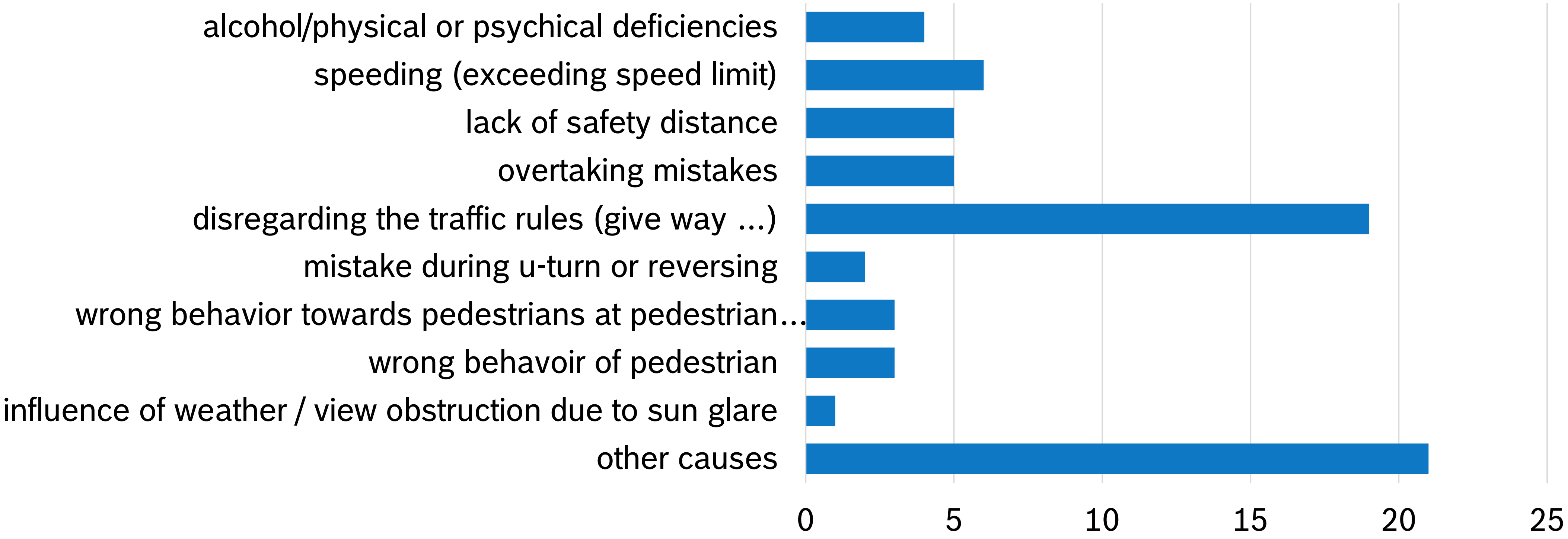
Root causes of crashes out of local investigated data



- High share of these accidents caused by disregarding the traffic rules like e.g. give way, followed by speeding and mistakes while overtaking

Source: IAAT database, E12/2016, 90 crashes involving 179 participants

Example of skidding car accident
ESC could prevent cars from skidding

Chapter 17

- Due to speeding driver loss control and left the carriageway to the right followed by a left front collision against a wall, rotated clockwise and hits a pole from the back to the final position – both occupants sustained severe injuries

Source: Bosch Accident Research CR/AEV1, TASB database, Campinas urban accidents only – case study #55201610021

IAT Investigação Avançada de Acidentes de Trânsito

Example of rear-end car accident
AEB would prevent these crashes

- Due to inattention the car driver did not recognize the stationary truck in front of its carriageway. Even with brake intervention the car hit the truck full frontal – airbags deployed and occupants sustained slight injuries.

Source: Bosch Accident Research CR/AEV1, TASB database, Campinas urban accidents only – case study #55201610006

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Chapter 17

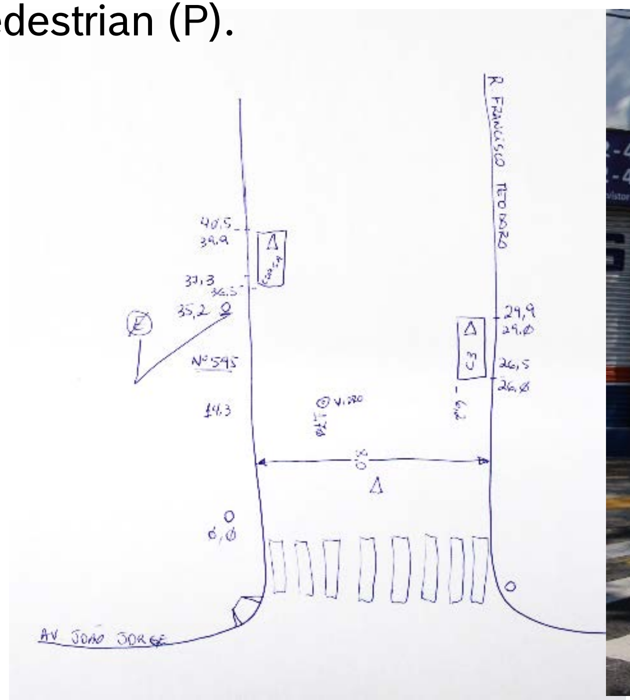
ABS prevents from wheel locking and avoids crash

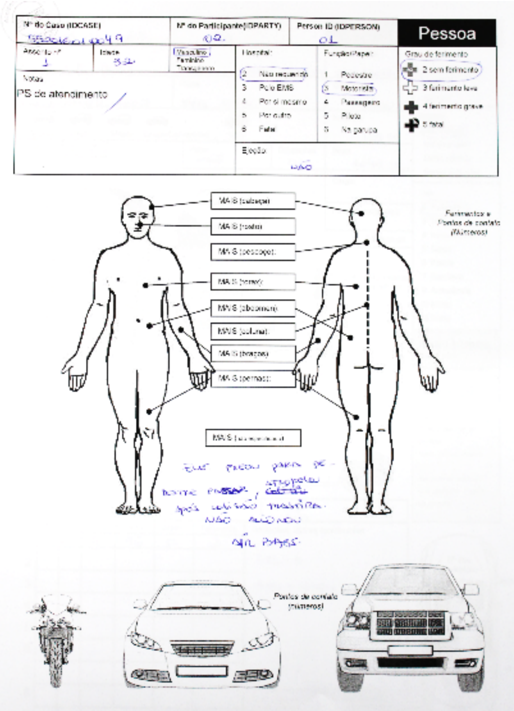
- In front of the motorcycle the car started to decelerate while the motorcycle rider was speeding up to pass the crossing. Due to low friction brake intervention of motorcycle was not successful thus motorcycle hit car at rear end.

Source: Bosch Accident Research CR/AEV1, TASB database, Campinas urban accidents only – case study #55201610065

Annual Report – ReGe Brazil
Campinas / SP case 552016010049

Description: While the pedestrian B was crossing the road, vehicle (B) imitated a braking maneuver in order to avoid a collision. Either due to close distance or distraction the vehicle (A) Behind vehicle (B) vehicle (A) initiated a late braking maneuver and hit vehicle (B) in the back. As a consequence vehicle (B) was accelerate against the pedestrian (P).





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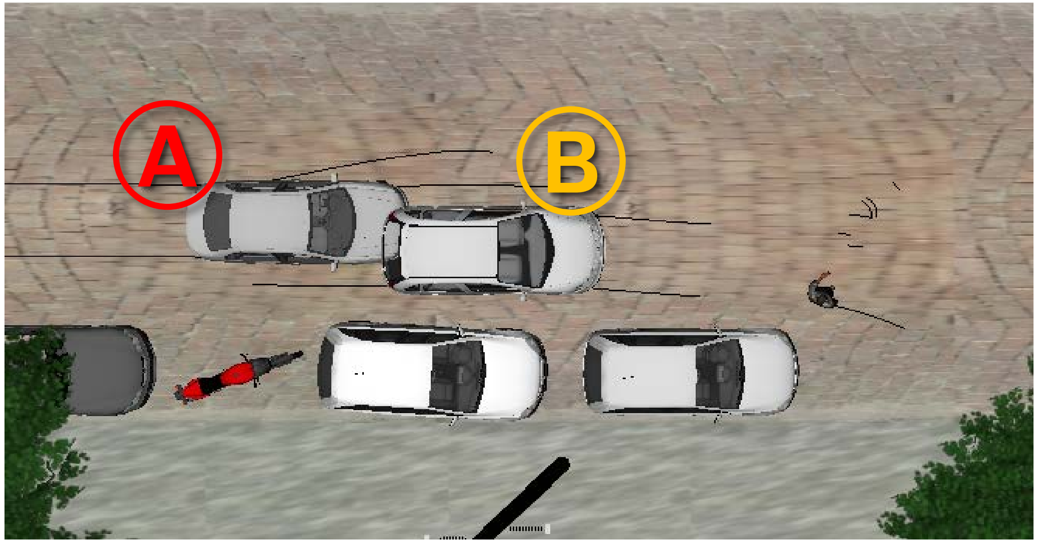
Campinas / SP case 552016010049

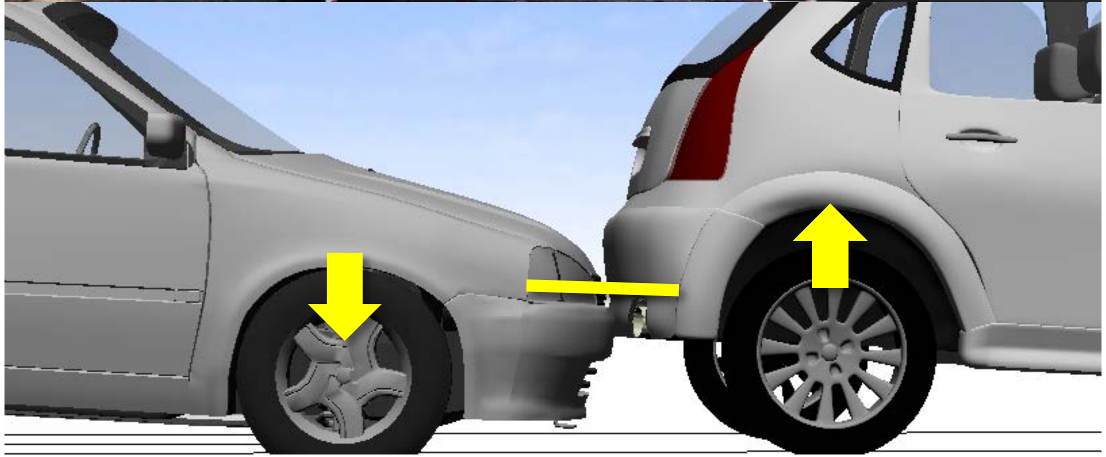


- Pedestrian was crossing the road
- Braking maneuver of vehicle "B"
- Late braking maneuver of vehicle "A"
- Rear-End collision between "A" and "B"
- Vehicle "B" hits the pedestrian

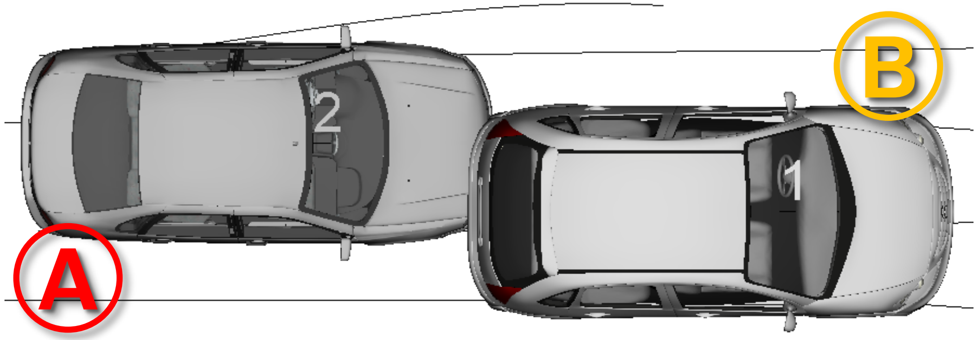
Annual Report – ReGe Brazil

Campinas / SP case 552016010049 (Collision Details)

Chapter 17



Braking maneuver



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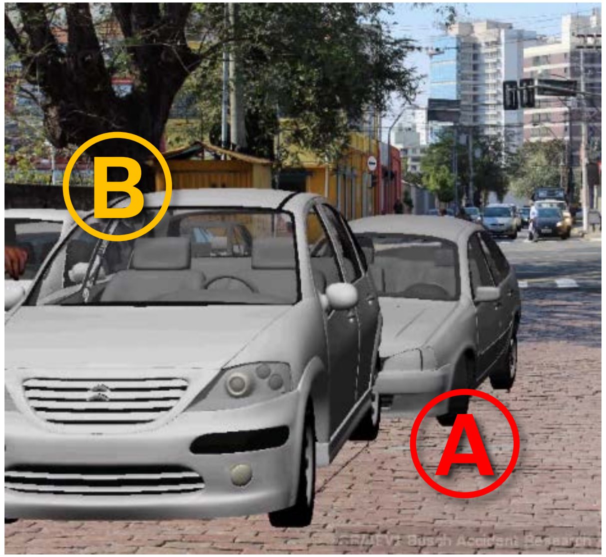
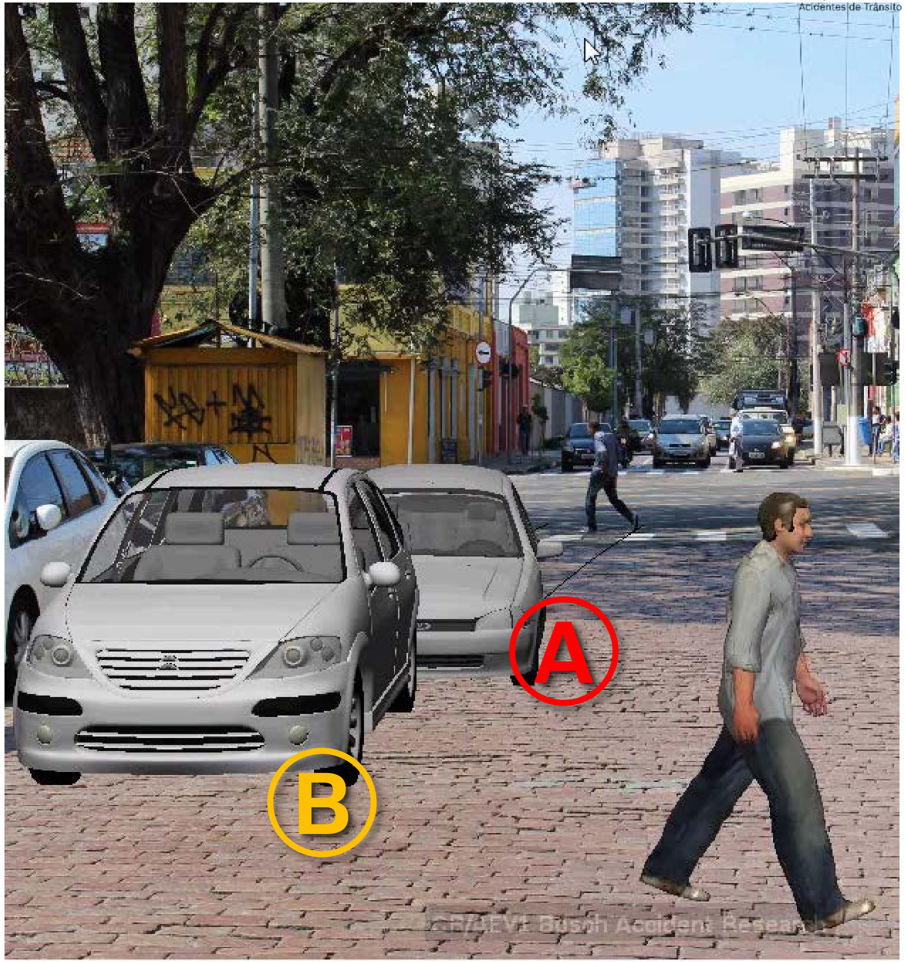
Campinas / SP case 552016010049 (accident simulation)



Annual Report – ReGe Brazil

Simulation with Emergency Braking Assist



Annual Report – ReGe Brazil

Local access requires long term investigation

2012 Bosch initiative to find appropriate partners for data collection (CC/MBL-LA, CR)

2014 **SAE Brazil** hosting pilot project → **City of Campinas** (urban only)

2016 **Kick-off:** Pilot study along w/ training by Bosch Accident Research & IDIADA

2017 **Status:** Finalize contract renewal → long-term solution & consortium setup

Next: Extend to highways & diversify schedules of data collection

Annual Report – ReGe Brazil

First results used for political consulting of car AEB in Brazil

Legislation effective:

2014 Car ABS, Dual Front Airbag

2019 2WP-ABS (>125cc only)*

2020 ESP®

* Still in discussion due to high resistance from ABRACICLO

2030 New Automotive Policy: Systems on political agenda

- **AEB**, LDW for PC/HCV (waiting for PC regulation in Europe)
- BOA for PC: Alerts or visibility system
- Side impact for PC: Requirements with Deformable Barrier and Pole

Political agenda will be supported w/ benefit studies based on regional real-world crashes along with national data

AEB: Advanced Emergency Braking; LDW: Lane Departure Warning; BOA: Back-over avoidance; PC: Passenger car HCV: Heavy Commercial Vehicle

Chapter 18

I_HeERO 112

Harmonised eCall European Deployment

Public funded project:
I_HeERO – eCall powered two-wheeled vehicles

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Annual Report – EU project: I_HeERO
P2W project overview

▶ **<u>EU project: I_HeERO</u>** *(No: 2014-EU-TA-0582-S)*
- Duration: M2015 – E2017
- Total funding: 15 Mio.€
- Bosch 2WP leads activity 3: Topic "*eCall powered two-wheeled vehicles*"
- Members: P2W manufacturer (BMW, KTM, ...), suppliers (Bosch,...), universities and research institutes

▶ **<u>Key objectives:</u>**
- Define the requirements and architecture of an eCall device for P2W
- Define a reliable triggering mechanism for P2W
- Identify determining factors for accident and injury severity
- Define minimally complex system architecture to improve industry and market uptake

▶ **<u>Activities supported by Bosch Accident Research (VM-064):</u>**
1. Estimate benefit potential by eCall system for P2W for European Union
2. Determine eCall necessity by classification methods
3. Estimation of rider injury severity in accidents

Annual Report – EU project: I_HeERO
1. P2W eCall benefit potential

Aim: Estimate the potential benefit by introducing an *eCall* system for P2W in the European Union

Method: Review of existing eCall benefit studies within the EU.

Estimate P2W accident numbers for European countries and European Union.

Assess accident characteristics by rating schema and estimate eCall benefit potential. Therefore various data sources used e.g. GIDAS database

Result: Within EU28 4,564 P2W riders are killed annually and out of that 1,400 fatalities (30%) could benefit from an eCall system if each motorcycle was equipped with such a system. In other words in nearly every 3rd fatal motorcycle crash in the EU an eCall system could have been beneficial.

Annual Report – EU project: I_HeERO

1. eCall benefit: Available studies

Literature survey*:

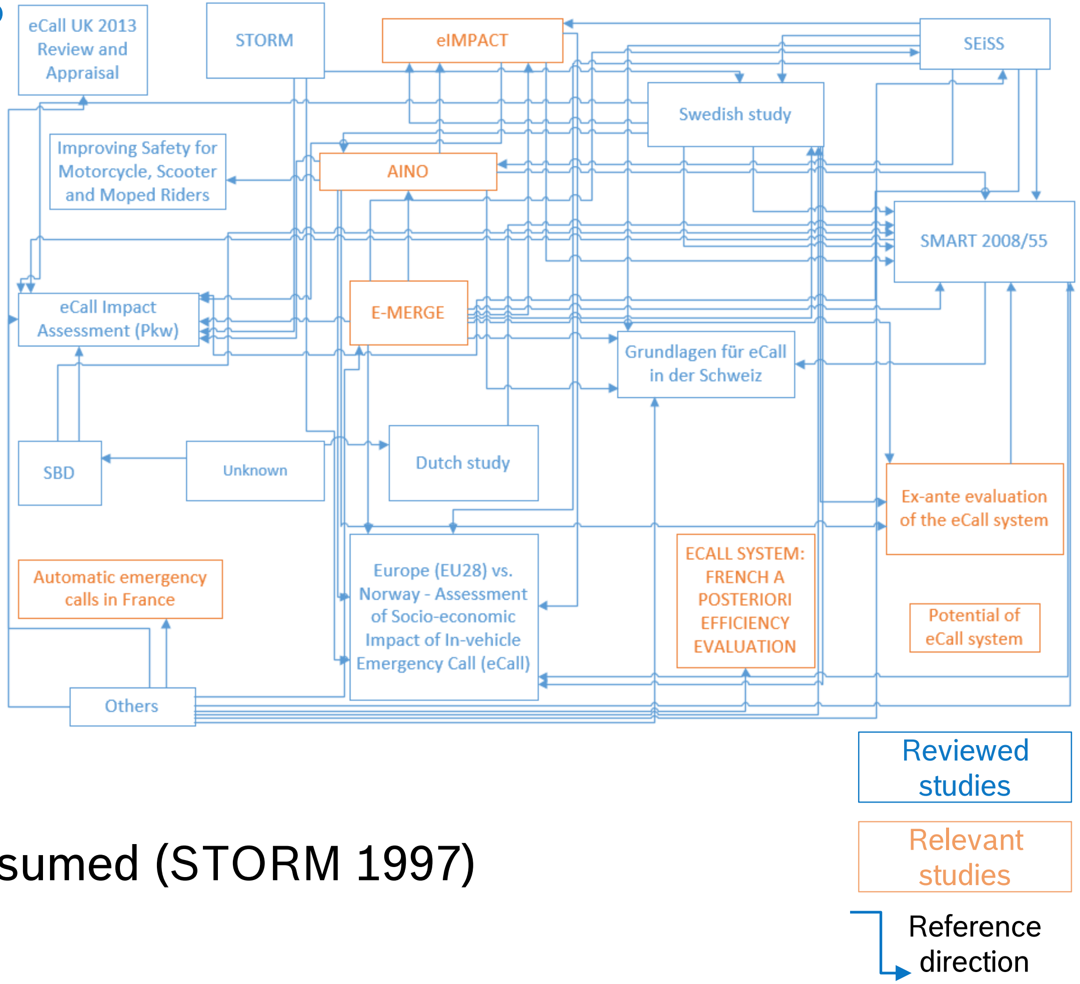
- Overall 20 *eCall* benefit studies analyzed
- 6 out of 20 identified as being primary

Expected eCall impact:

- Between 3 % to 8% reduction of fatalities
- Up to 10% reduction of serious injuries

Limitations:

- Mainly relevant for passenger cars
- 50% reduction of arrival time by rescue teams assumed (STORM 1997)
  → Assumption to be confirmed in further studies



* Details available in the official report or at Bosch Accident Research (CR/AEV)

Annual Report – EU project: I_HeERO

1. eCall benefit: Methodology

Basic idea:

- Determination of benefit potential based on German data
  → Mapping to 7 EU countries based on similar statistics
  → Extrapolating to EU based on fatality numbers

Assumption:

- German P2W accident situation is representative for Europe within selected subgroups (weighting methodologies considered)

Method advantage:

- Low information depth needed
- Country specific accident situation considered

Accident parameter	Benefit rating scheme
Location	Urban= +1, Rural= +3
Involved parties	>1 Party= +1, 1 Party= +3
Light condition	Daylight= +1, Darkness= +3
Severity	Light injuries= -3, Serious injuries= +3 Fatalities= +4

Benefit potential level	Expected benefit
Low (0-6)	No/ only slight severity reduction expected
Medium (7-9)	Severity reduction expected
High (10-13)	High severity reduction expected

Annual Report – EU project: I_HeERO

1. eCall benefit: Result

Country	Year	Road user	Fatal injured road users	Seriously injured road users	Slightly injured road users
EU 28[1]	2014	P2W	4,564	~45,000	~238,000

Rating scheme applied

Country	Year	Benefit potential	Resulting average[2] potential range within PTW users injury category		
			Fatalities	Seriously injured	Slightly injured
EU 28[1] All P2W	2014	Low	0	14,000 – 18,000	~238,000
		Medium	3,200 – 3,600	17,000 – 18,000	0
		High	1,000 – 1,400	9,000 – 13,100	0

- **Note:** Benefit potential ≠ reduced fatalities/severe injuries
- **Result:** A high eCall benefit expected for 1,400 P2W fatalities within the EU annually
- **Recommendations:** Determine influence of improved rescue time on rider injury reduction

1) Missing European numbers were extrapolated based on the fatalities and the distributions from seven European countries. EU28: 28 member states of the European Union

2) Potential mapped by different methods

Annual Report – EU project: I_HeERO

Chapter 18

2. Classification of eCall necessity

Aim: Determine eCall necessity using statistical methods

Method: Accidents from databases categorized in eCall relevant and non relevant cases. Databases were split into training and testing sets and two classification methods "logistic regression" and "random forest" were applied.

Result: Random forest increases eCall trigger robustness from 48% to 91% compared to a classically developed classification algorithm

2. Classification of eCall necessity: Challenge & Idea

Injury Severity	Injury severity level	Launch eCall
	Fatally injured (IS4)	✓
	Seriously injured (>24h) (IS3)	
	Slightly injured (<24h) (IS2)	
	Slightly injured (IS1)	✗
	Not injured (IS0)	

IS4=fatally injured within 30 days

IS3=seriously injured w/ hospitalization (>24h)

IS2=slightly injured w/ hospitalization (<24h)

IS1=slightly injured without hospitalization

IS0=not injured

Current situation:

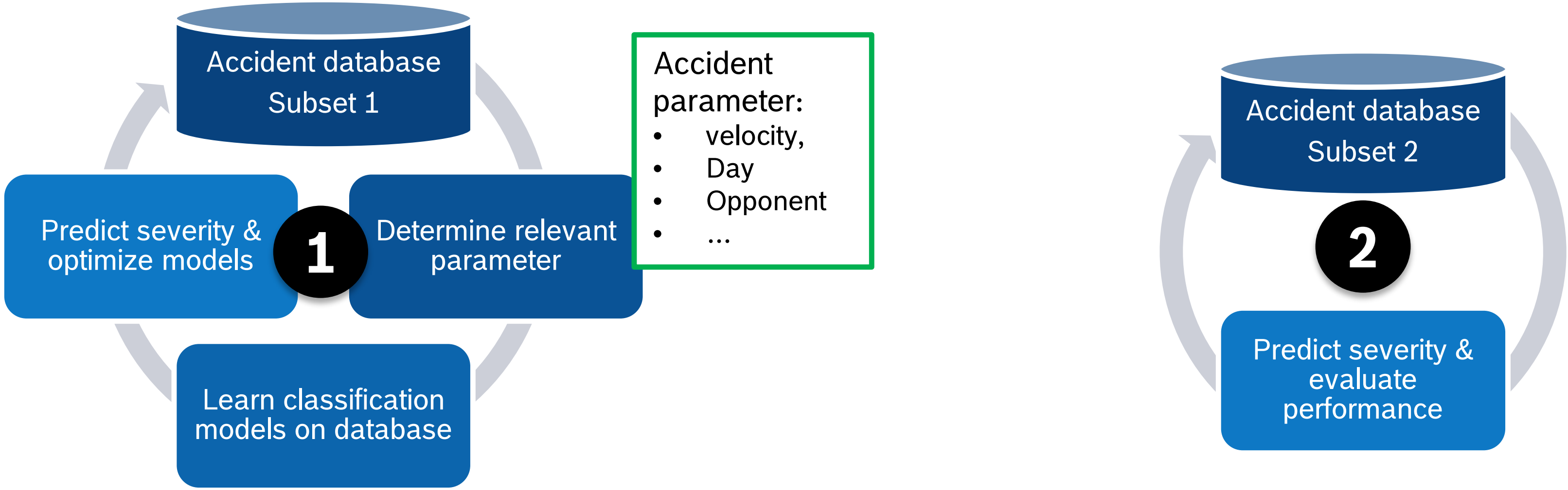
- Within the I_HeERO project a classically developed classification algorithm based on collision speed, final bike position, assumptions of rider and other party interaction was developed.

Aim:

- Development of a classification model which determines the necessity of eCall launch
- Optimize the relation: High eCall benefit ⇔ Low false call rate

Internal | Bosch Accident Research (CR/AEV1-Sk) | Jan/31/2018
AEV-064 annual report 2016/17

2. Classification of eCall necessity: Methodology



Database:

▶ GIDAS: 2,635, GES/FARS: 31,385 motorcycle accidents

Methods:

▶ Classification models learned on accident databases
- Logistic regression model, 8 accident parameter used
- Random forest, 13 accident parameter used

1) GIDAS: German in-depth accident study
2) FARS/GES: Fatality Analysis Reporting System/ General Estimate System

Annual Report – EU project: I_HeERO
2. Classification of eCall necessity: Result

Result:

- Random forest increases eCall trigger robustness from 48% to 91%

Classification Method	Accuracy eCall relevant	Accuracy not eCall relevant	Total Accuracy[1]
A3.4 used approach[2]	92%	48%	83%
Logistic regression	80%	80%	80%
Random forest	89%	91%	90%

Challenges:

- Algorithm integration and data availability of used information (e.g. sex or helmet usage) for an in-vehicle application
- Method transferability to other countries (e.g. Germany → Spain)

1) Accuracy: Number of correct classifications to all classifications within test group.
2) Rider cancels the call if unnecessary, other party makes the call if not triggered automatically.

Annual Report – EU project: I_HeERO

3. Severity estimation

Aim: Develop models estimating rider injury severity in accidents

Method: Simulation of various accident constellation with PC-Crash using multi body models. Assessing physical loads with injury risk functions and creating generalized injury prediction models.

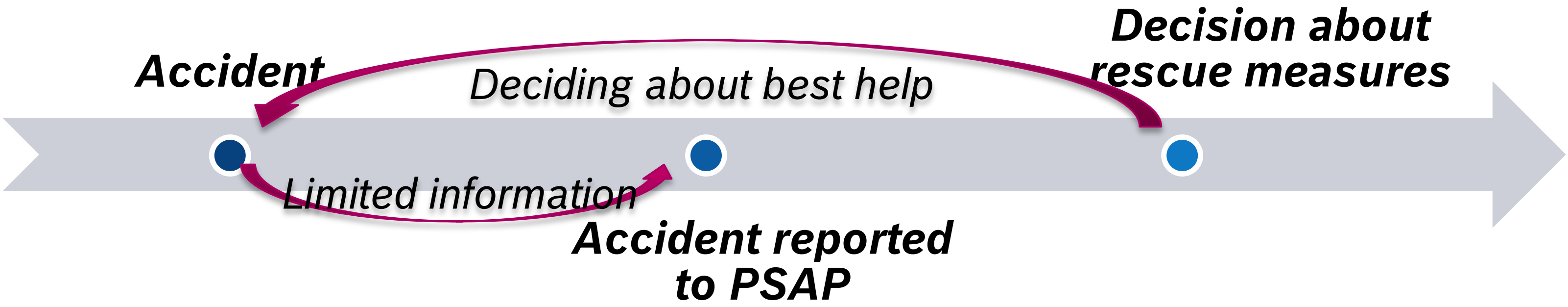
Result: Three P2W-vehicle accident scenarios and one single accident scenario assessed and severity models built up

Annual Report – EU project: I_HeERO

3. Severity estimation: Situation & Idea

Current situation:

- Severity information only transferred verbally to PSAPs[1] or not at all → High uncertainty of suitable rescue measures



Potential:

- Increase efficiency of rescue chain and minimize needed resources → reduce injury severity
- Reduction of unneeded eCalls

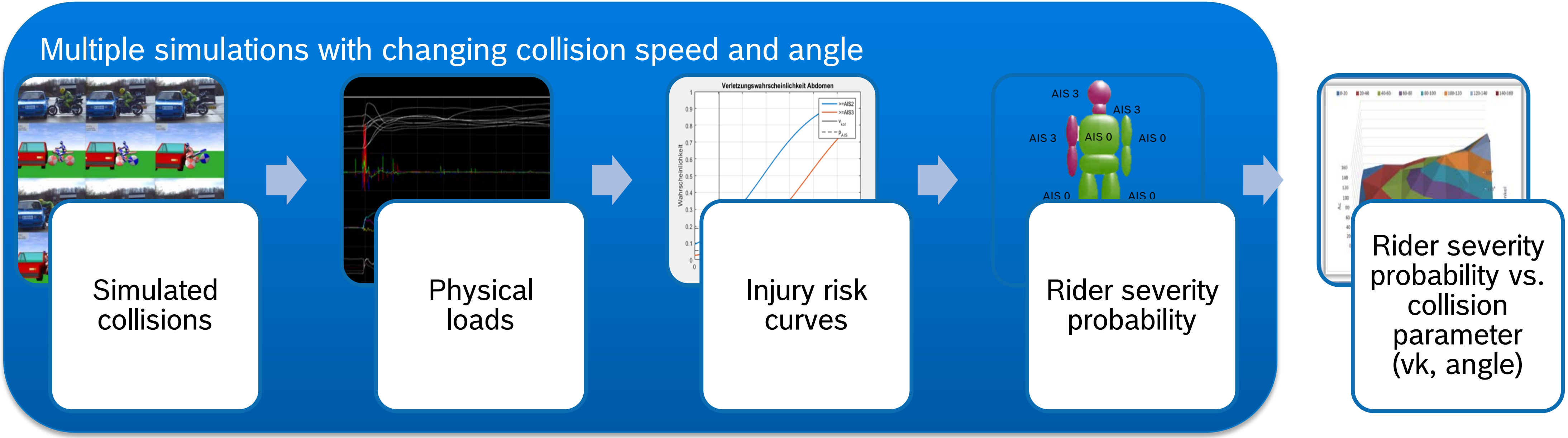
Mission:

- Provide accurate severity information to PSAP

1) Public Safety Answering Point

Annual Report – EU project: I_HeERO

3. Severity estimation: Methodology



Aim:

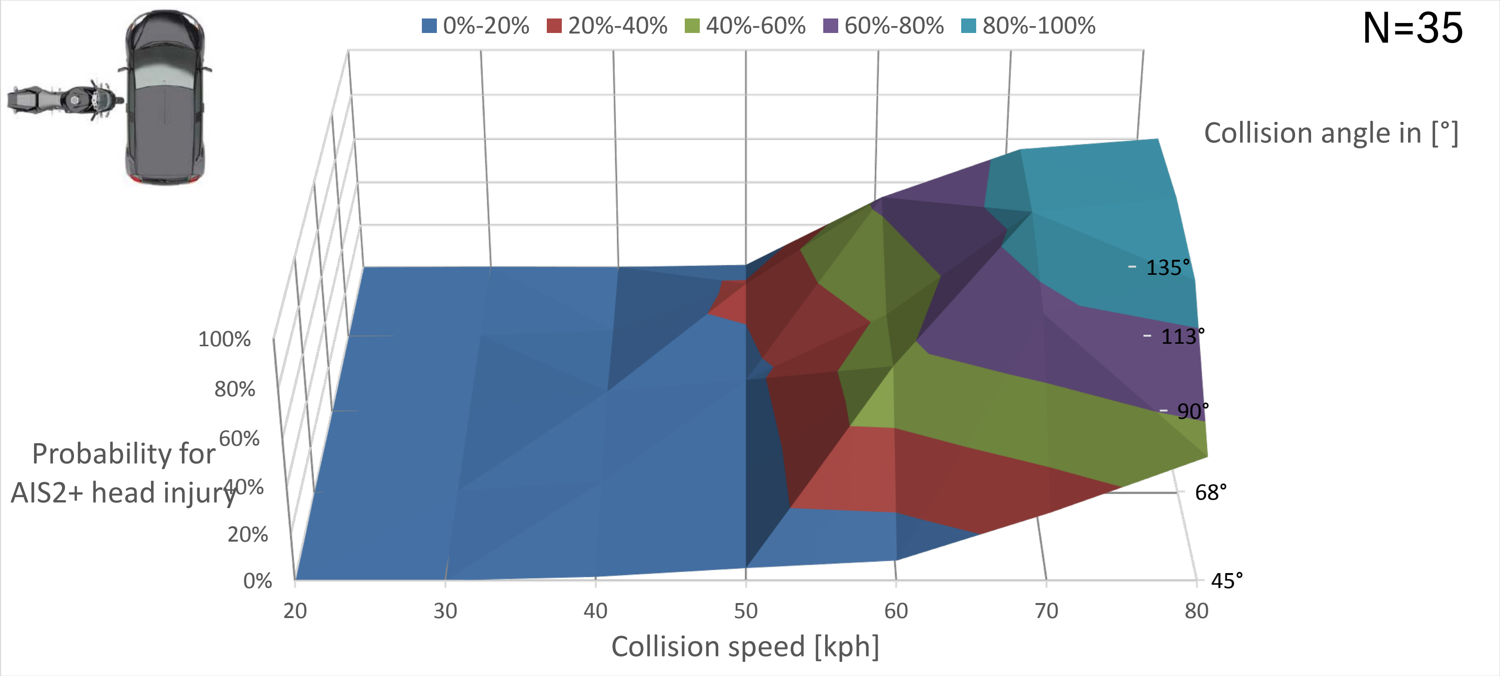
- Identification of correlations between injury severity and collision parameters
- Assessment of a potential IVS* based severity estimation

Result:

- Injury probability depending on “*collision type*”, “*-speed*” and “*-angle*”

*IVS – In Vehicle System

3. Severity estimation: Result



Interpretation:

- AIS2+ head injury probability increases from 50kph to 70kph by 80%
- AIS2+ head injury probability decreases from 90° to 45° by 40% at 80kph

[1] AIS: Abbreviated Injury Scale, ranges from 0 to 6, where 6 is most severe injury category

3. Severity estimation: Summary

Conclusion:

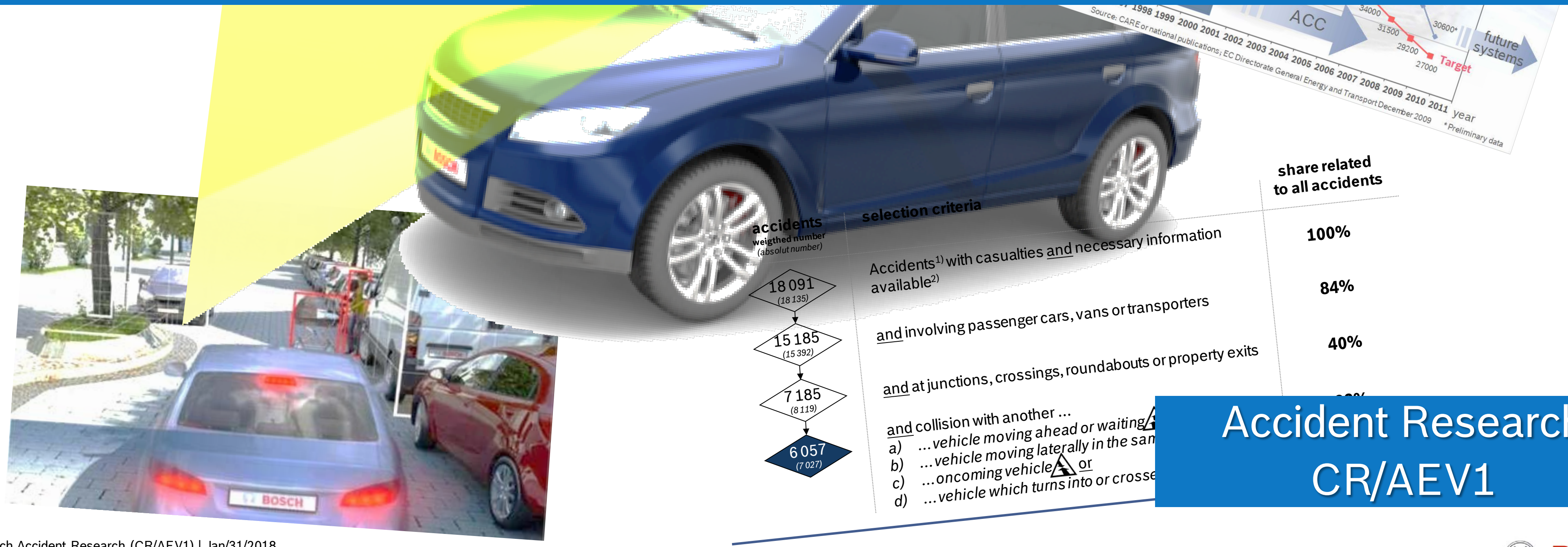
- Three P2W-vehicle accident scenarios assessed and severity models built up
- One single accident scenario in detail assessed
- P2W-vehicle accidents:
  - Opponent and collision point information necessary to evaluate related injury severity for IVS*
  - No correlation between opponent vehicle mass and injury severity seen
- Single accidents:
  - Slight correlation between in-vehicle information and injury severity given
  - Better results by using sensors on the rider expected

Outlook:

- Benefit of severity information for rescue chain to be assessed by PSAP experts
- Further analysis on the effect of age, motorcycle type on severity estimation needed

*IVS – In Vehicle System

Overview of short term studies
- Examples -



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Overview of short term studies – 2016

Studies are not planned inquiries hence funding across all stakeholders

Date	Selected short term inquires (Total = 41)
01/2016	Autonomous Mode Disengagements
01/2016	Estimation of impact of the BAIC-YX C20 CS-Topic (QMM CC-PS)
01/2016	Tire Related Safety (CC-AS)
01/2016	AEB regarding stationary vehicles (CC-DA)
02/2016	Analysis of parking accidents w/ property damage only
03/2016	Car accidents with technical defect on “wheel/tire” (CC-AS)
06/2016	Pedestrian accidents @low speed (CC-DA/PJ-HAP)
07/2016	M156 EDR Multi Crash Events USA (CC-PS)
11/2016	Support “PROGNOS” – External communication (C/CCE)
11/2016	Accidents involving wild animals (CC-DA)
12/2016	Is there a correlation of fatal accidents and emissions? (C/OFE1-T)

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Overview of short term studies – 2017

Studies are not planned inquiries hence funding across all stakeholders

Date	**Selected short term inquires** (Total = 38)
01/2017	CVO Platooning (CC/ENA)
01/2017	Evaluation regarding severity for HAP (CC-DA)
01/2017	Impact of a HAP backup mode without ESC (CC-AS)
02/2017	Prognosis of accident figures (C/CCM3)
03/2017	J-NCAP Pedestrian Far-Side-at-night (CC/MBL-JP)
03/2017	Field of effect of Bike-to-vehicle-communication (B2V) for motorcycles (C/CCM3)
05/2017	Truck accidents due to swaying trailer in US and AU (RBAU/SOE)
08/2017	Argentina Road Safety Status (CC/MBL-LA)
08/2017	Relevance of not moving passenger cars w/ occupied passenger seat which has suffered a front damage (CC-PS)
12/2017	Accidents w/ trams (BEG)

Publications 2016/2017

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Publications 2016/2017

ESAR`16	**Expert Symposium on Accident Research, Hanover, Germany** “In-depth crash investigation setup in Campinas, Sao Paulo, Brazil”
ECOC’16	**EU Commerce of Chamber, Taipeh, Taiwan** “Accident Research on MC ABS to improve motorcycle safety”, Oral presentation only
SAE’16	**SAE Brazil, Sao Paulo, Brazil** “Setup of in-depth investigation in Campinas”, Oral presentation only
SAE’17	**SAE Japan, Tokyo, Japan** “Advanced Occupant Safety for Current and Future Vehicle Concepts”
SAE’17	**SAE India, Pune, India** “Analysis on non-police reported accidents on Indian Highways”, Paper No.: 2017-26-0005
FASTZero	**Future Active Safety Technology, Nara, Japan** “Impacts on a test setup for the evaluation of Advanced Emergency Braking for cyclists in Japan using Event-Drive
Safe Roads	**Safe Roads India Summit 2017, New Dehli, India** “Pedestrian Accident in India”, Oral presentation only
IRTAD	**International Road Traffic Accident Database 2017, Marrakech, Marocco** “Setup of evidence based on spot investigation in Campinas, Sao Paulo, Brazil”, Poster presentation