From
CR/AEV1

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Renningen
06 December 2019
Report Number
19/030

R&D Report: **Final Report**

Security Class: Internal   Export control relevant: No

Title: Bosch Accident Research (VM-064): Annual report 2018

Abstract

1. Issues (situation, motivation and tasks)

Bosch Accident Research (VM-064) as part of AEV is a scouting activity with focus on road traffic accidents. Major idea of this activity is to support the benefit oriented system development for driver assistance, active and passive safety along with the vision of injury (accident) free driving. It also covers the impact of automated vehicles towards road traffic. Here for real-world crash data along with road traffic observation and simulated data is assessed. Key studies covers different functions/systems for all BBM units and utilized for:

- strategic decisions
- give benefit or sensor requirements for all vehicle systems
- risk analyses
- communication and political consulting
- future forecast and prediction

2. Results

The present annual report contains an overview of studies carried out in the framework of accident research in the year 2018. For example, as first of its kind an analysis involving trams is included along with some analysis on intersections accidents supporting the front Cross Traffic Alert function. Internationally the benefit of Electronic Stability Control for India and Indonesia is included. For China, sensor requirements derived for car AEB VRU crashes with focus on 2W opponents. Finally, the public funded project OSCCAR, aiming to determine the impact of automated driving is introduced here.

3. Conclusions and Consequences

The activity covers a broad variety of topics, thus conclusions are with respect to each topic covered in the report. Kindly refer to the single short abstracts included in the report. Further details are available through Bosch Accident Research, therefore kindly contact the author.

Corporate Research

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Document approval			
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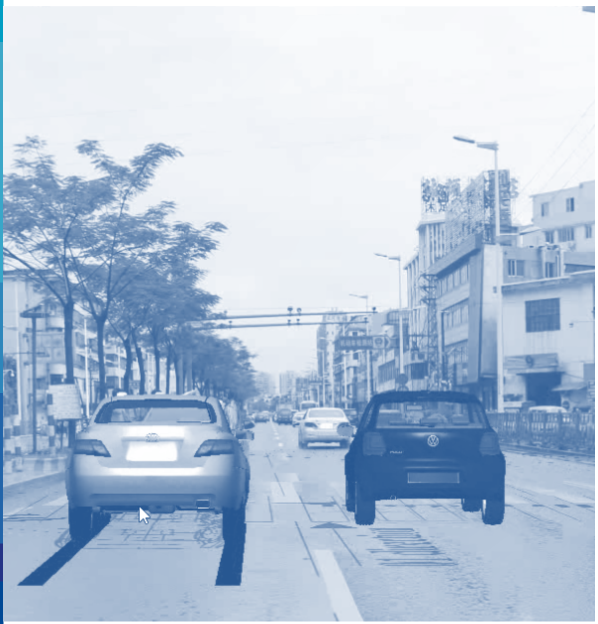
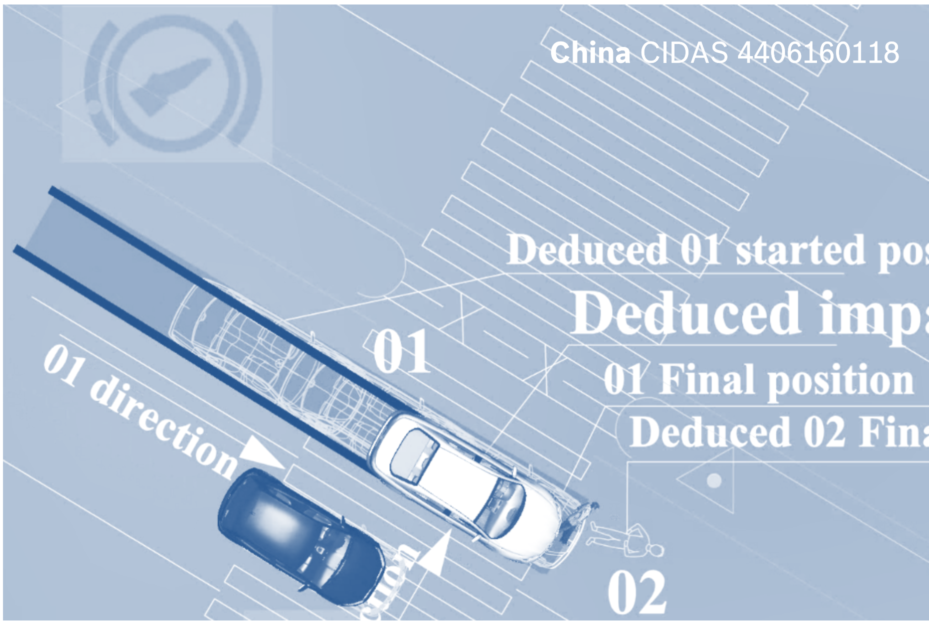
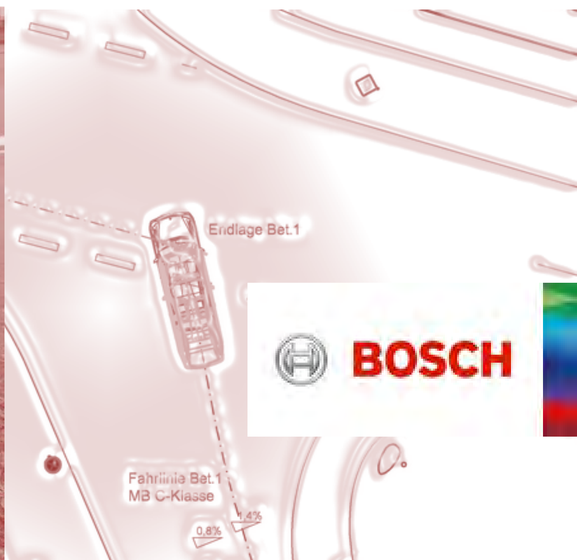
Report 2018

BOSCH Accident Research

VM-064







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CR/AEV1; RBEI/NE1-VS	Bosch Accident Research (Lich T., Schlender T., Sulzberger L., Mönnich J., Schmidt D., Girikumar K.)	+49(711)811-34831	30-Jul-19

Topic **Bosch Accident Research Report 2018 (VM-064)**

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**KAUSAL = Auswirkung automatisiertes Fahren auf Rückhaltesystem-Gestaltung*

Chapter 02

Germany: Accidents involving trams

Accident Research
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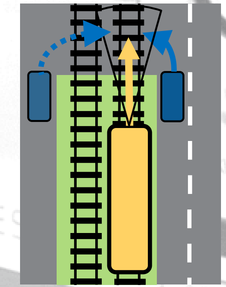
Summary

Aim of study:
(1) Overview about accidents involving trams
(2) Estimating influence of an automatic tram emergency braking system (tram AEB) on selected crossing scenarios

Method:
- Descriptive analysis of accidents from GIDAS and DESTATIS
- Simulating 50 crossing conflicts between tram and other vehicle from GIDAS

Results:
- Tram is involved in less than 1% of all accidents with casualties in D
- About ¼ of all accidents with casualties involving trams correspond to the relevant conflict situation
- Early and fast detection of opponent and its turning intention needed to avoid these crash situations by automatic tram emergency brake system
- Assuming “best case” with no dead times and emergency brake usage: ~80 accidents expected to be avoided by tram AEB in D per year

Considered conflict situation



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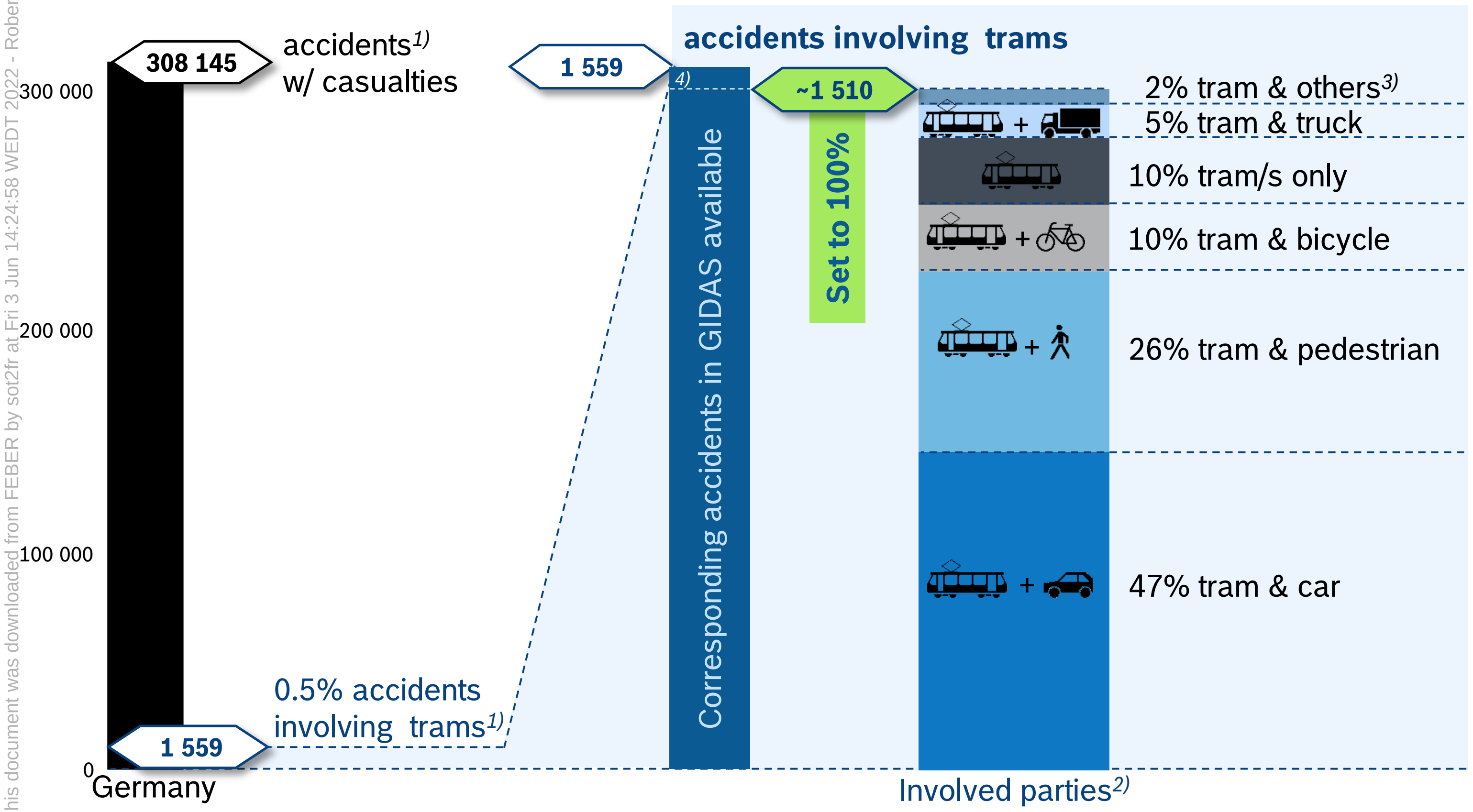
Accidents w/ casualties involving trams

Content

Accidents w/ casualties involving trams

Overview Germany & involved parties



- Trams are rarely involved in accidents on German roads.
- High share of tram accidents w/ casualties against cars.

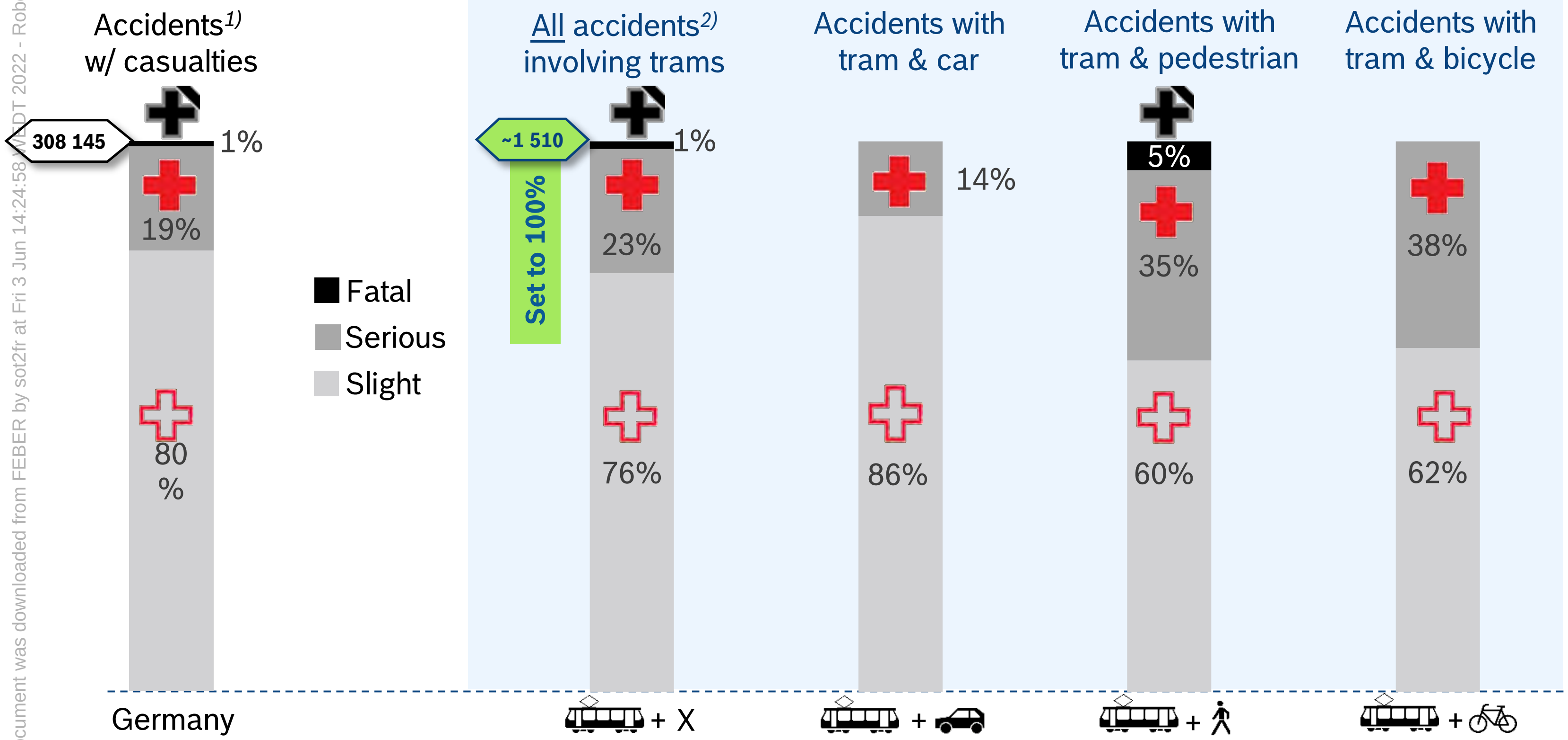
1) *Source: DESTATIS Yearbook 2016, "Fachserie 8 Reihe 7" and extra inquiry to DESTATIS*
2) *Source: 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany. GIDAS is only representative for a part of all accidents involving trams in Germany, at least 3% are expected to be missing.*
3) *"others" contains accidents involving more than two participants, e.g. "tram + car + pedestrian"*
4) *~50 accidents cannot be represented with GIDAS because these kind of accidents are not reported in GIDAS*

Accidents w/ casualties involving trams

Severity of Accidents

Chapter 02

2016



▶ Increased severity in accidents involving trams, especially for accidents involving tram and vulnerable road users

1) Source: DESTATIS Yearbook 2016, "Fachserie 8 Reihe 7"
2) Source: 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany

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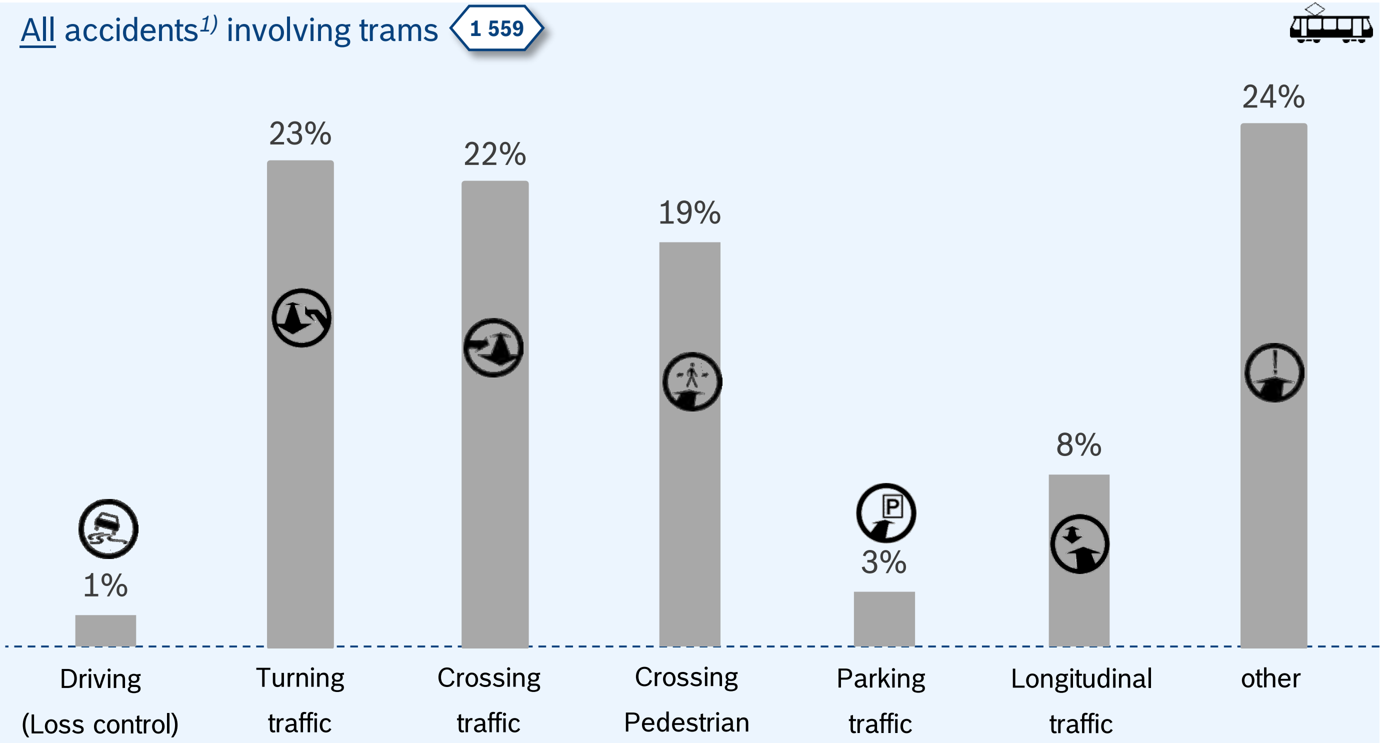
Accidents w/ casualties involving trams

Conflict situation resulting in accident (type of accident)



- Most common conflict situation is "other" which contains "U-turn"
- Followed by "turning traffic" and "crossing traffic"

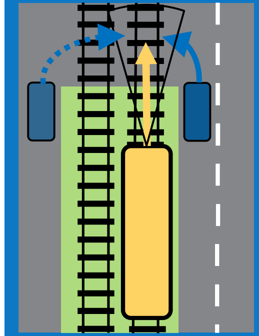
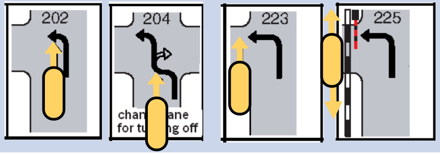
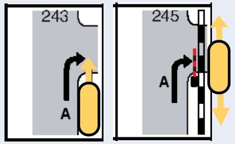
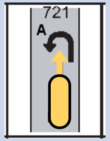
1) *Source: DESTATIS Yearbook 2016, "Fachserie 8 Reihe 7" and extra inquiry to DESTATIS*

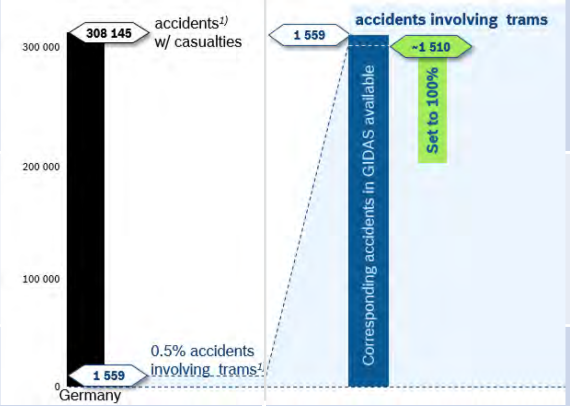
Accidents w/ casualties involving trams

Chapter 02

2016

Crossing Scenarios: Share of relevant tram accident situations

Accident scenario		Corresponding number of crashes w/injuries in Germany[1),2)]	Share in accidents involving trams only[1)]
	Turning in from the right 	~230 *(0.08%)*	15%
	Turning in from the left 	~30 *(0.01%)*	2%
	U-turn 	~150 *(0.05%)*	10%



- More than ¼ of all accidents involving trams have a relevant initial situation
- Emergency braking occurs in ~20% of these relevant initial crash situations, which do not end in a collision but in injured persons caused by braking manoeuver of the tram[1)3)]

1) Source: 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany
2) Source: DESTATIS Yearbook 2016, "Fachserie 8 Reihe 7" and extra inquiry to DESTATIS
3) This means that there is no collision btw. tram and other vehicle. Injuries are caused by the braking maneuver during which tram participants are falling down.

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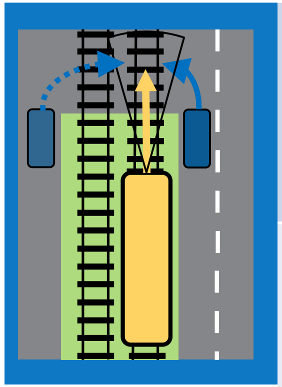
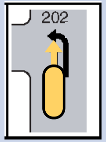
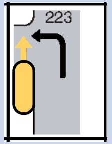
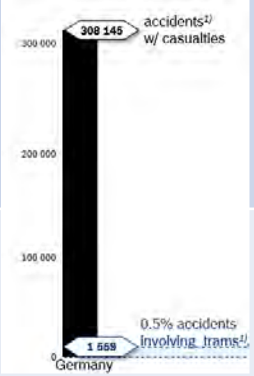
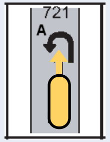
Accidents w/ casualties involving trams
Simulations for relevant accident situations

- Focusing on scenario “turning in from the right” and “U-turn”
- Oncoming vehicles must be excluded
- Lane change not yet simulated
- Accidents with collision between tram and another vehicle (cases w/ falling tram occup. excluded)
- Known vehicles’ decelerations and speeds

Accident scenario		Absolute number of simulated accidents	Corresponding number in all accidents with injuries[1),2)]
	Turning in from the right  	31	 [~90 – ~130*]
	U-turn 	21	[~70 - ~110*]

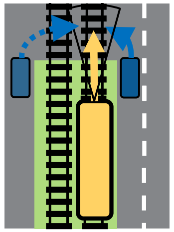
*assuming accidents with unknown values are be distributed as accidents with known values

1) Source: 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany
2) Source: DESTATIS Yearbook 2016, “Fachserie 8 Reihe 7” and extra inquiry to DESTATIS

Accidents w/ casualties involving trams

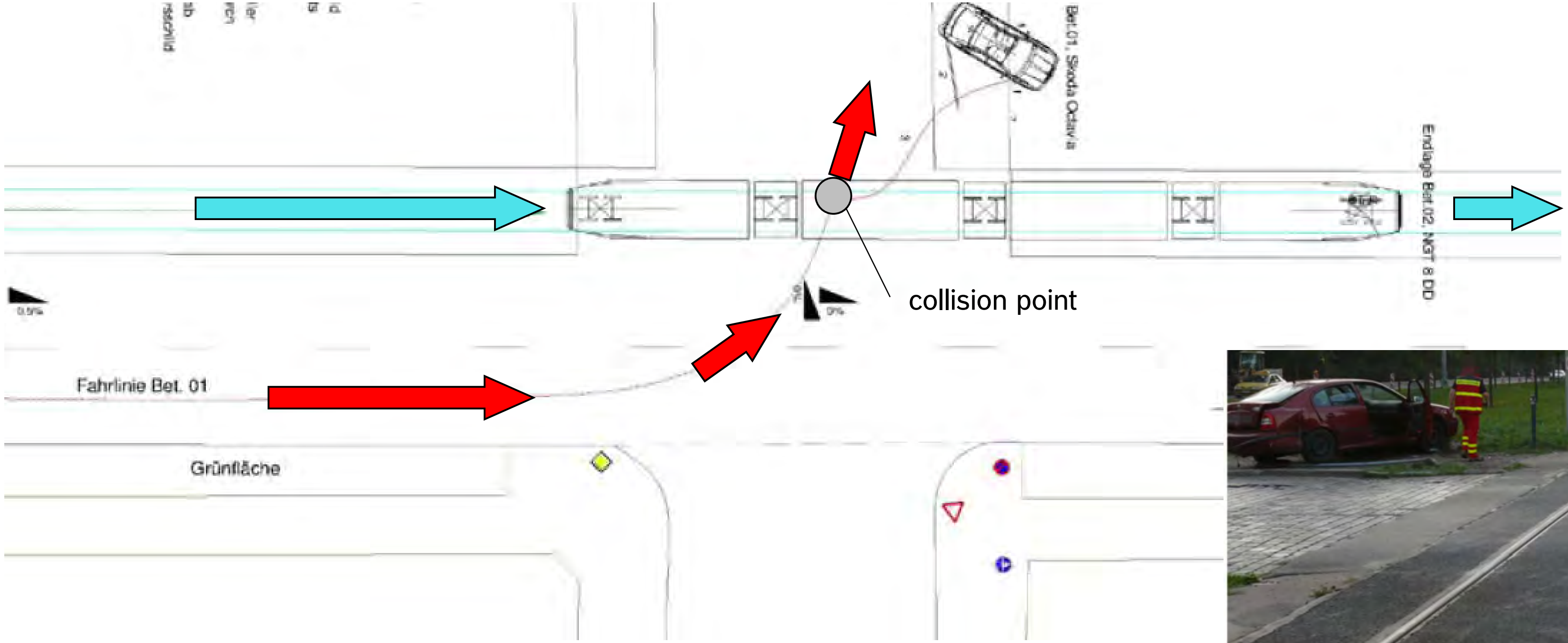
Example[1)] for simulated accident w/ relevant course (1/3)

Chapter 02



2016

Conflict situation:
Participant 01 (car), travels „Stübelalle“ towards city centre. At the „Müller-Berset“ intersection the car intended to turn left. Participant 02 (tram) also travelled in parallel on a seperated track in the middle of the road. During the left turn maneuver from 01 while crossing the tracks, the car collides with ist front against the parallel moving tram…



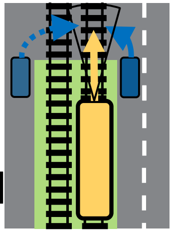
1) GIDAS case no.: 1090570

Accidents w/ casualties involving trams

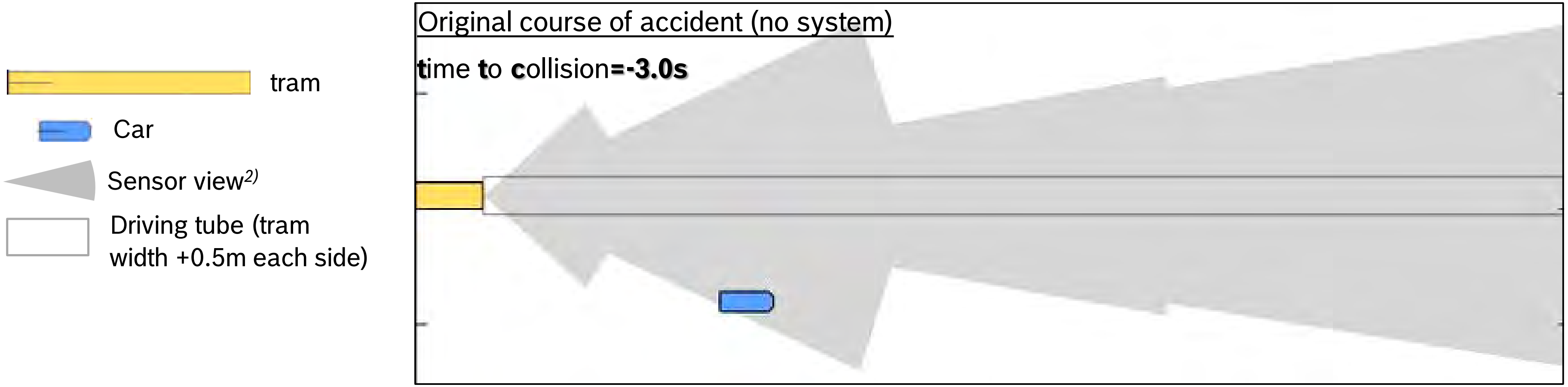
Example[1)] for simulated accident w/ relevant course (2/3)

Chapter 02

2016



Accidents are reconstructed by using initial vehicle speeds (tram: 53 kph, car: 31kph), additionally sensor device installed in front of the tram w/ pre-defined sensor parameters is assumed



- Opponent (car) already within the sensor view[2)] from the beginning of simulation, thus additional sensors at tram’s side not or less required
- It is more likely that the car is already tracked by the sensor, thus the challenge will be to clearly detect that the car starts a turning maneuver

1) GIDAS case no.: 1090570, simulation with time steps of 10ms
2) It is assumed that sensor detects the complete vehicle edge but limitation because fixed obstacles (e.g. trees, buildings) are not considered in simulation

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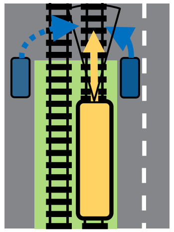
Accidents w/ casualties involving trams

Example[1)] for simulated accident w/ relevant course (3/3)

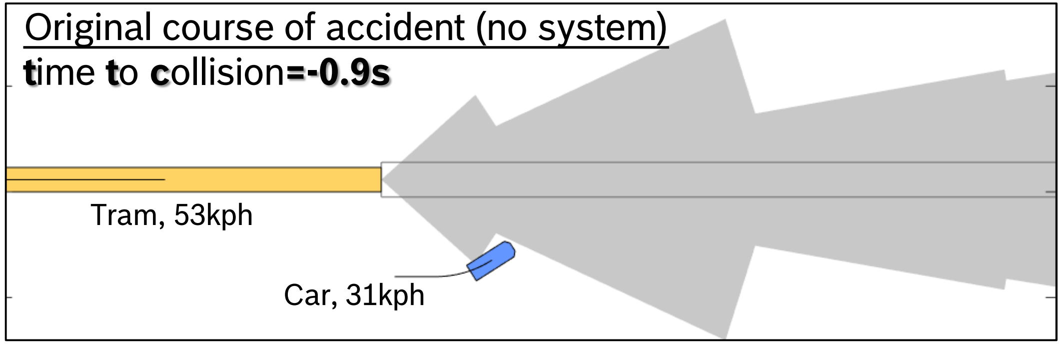
Chapter 02

2016



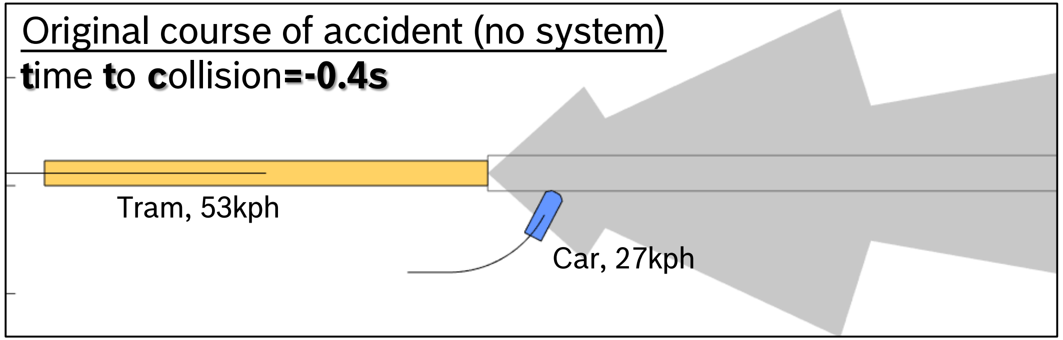
Best case[3)]

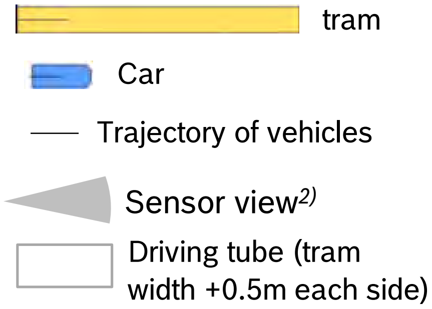
vehicles visualized at time in which opponent starts turning and is in sensor view



Conservative case

vehicles visualized at time in which opponent is for the 1st time in driving tube



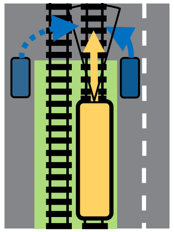


- In "*best case*", braking could be initiated as opponent begins to turn and is in trams' sensor view, "accessing driving tube" is criterion for "*conservative case*"
- In the current example "*best case*" is 0.5s earlier than the "*conservative case*"

1) GIDAS case no.: 1090570, simulation with time steps of 10ms
3) expected to be only available in theory (upper border)
2) It is assumed that sensor detects the complete vehicle edge but limitation because fixed obstacles (e.g. trees, buildings) are not considered in simulation

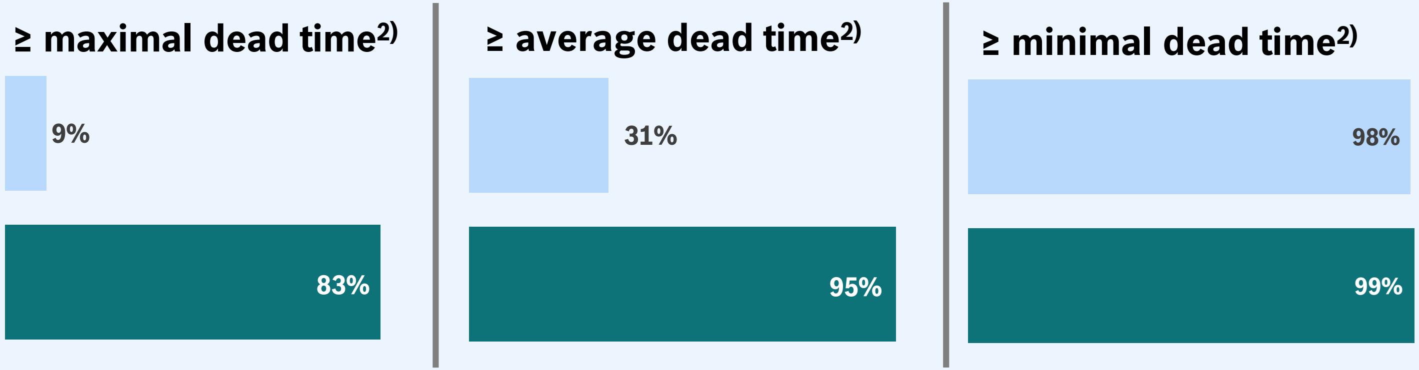
Accidents w/ casualties involving trams

Analyzing time before collision for all simulated crashes

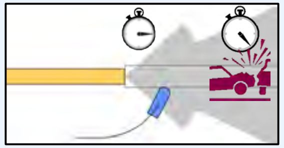


2016

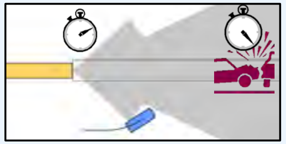
Share of accidents with time from recognition to collision:



Conservative case:
Start of recognition at time of opponent in tram's driving tube



Best case:
Start of recognition at time of opponent starting to turn and in tram's sensor view, expected to be only available in theory (upper border)



▶ Assuming maximal dead time *(1000ms sensor + 150ms brake)* time is left for braking:
- in **~80%** of crashes in best case scenario
- in less than **10%** of crashes in conservative scenario

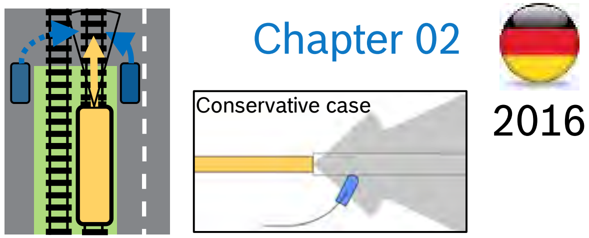
▶ For average dead time *(500ms sensor + 150ms brake)* time is left for braking:
- in **almost all** crashes in best case scenario
- in less than ⅓ of crashes in conservative case

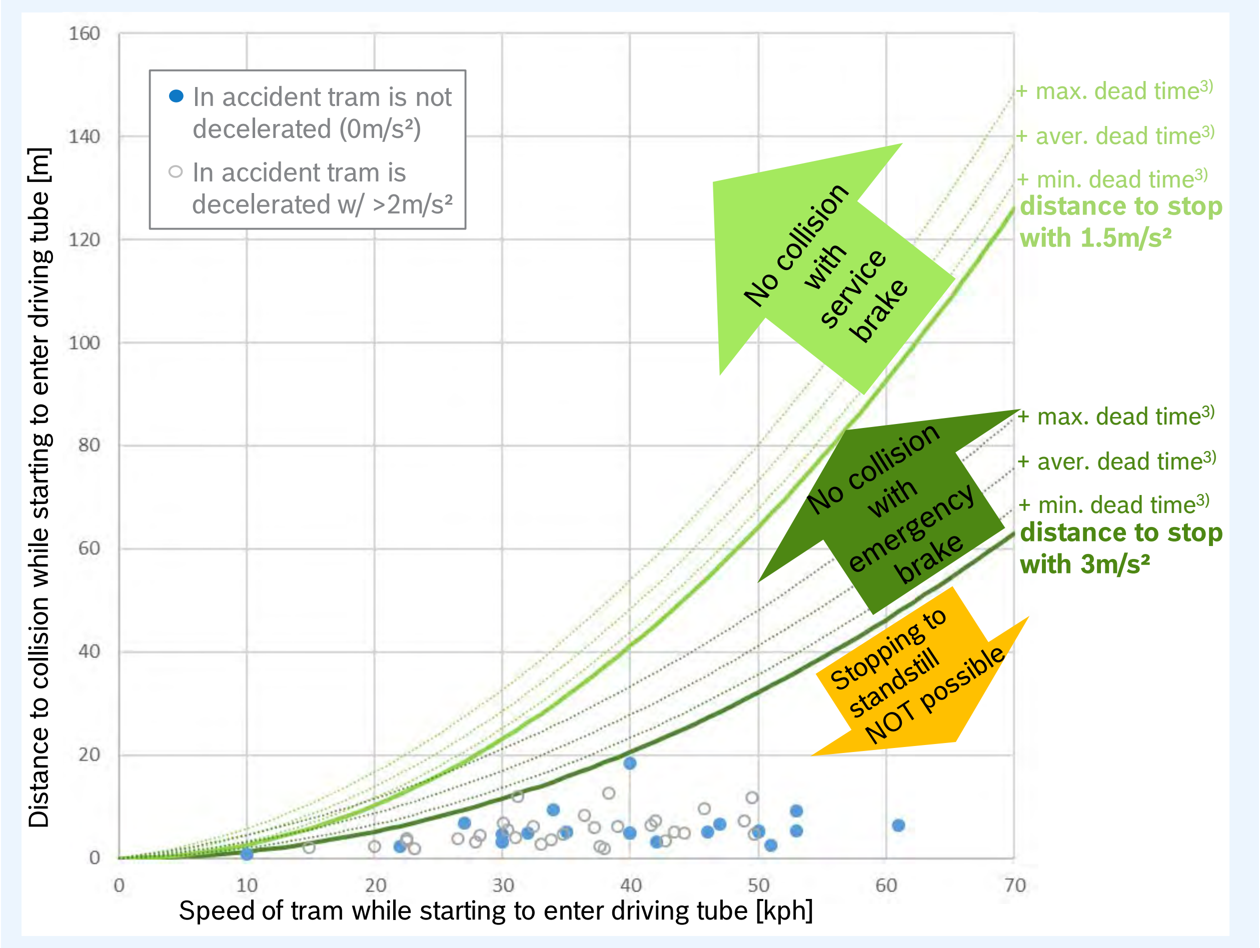
▶ From "conservative" to "best case" scenario clear gain in time!

1) Source: 52 accidents from GIDAS, representing ~160-~240 accidents involving trams, fixed obstacles (e.g. trees, buildings) are not considered
2)) It is assumed that sensor detects the complete vehicle edge, assumed sensor dead times: minimal 100ms, average 500ms, maximal 1000ms + brake pressure time of 150ms each

Accidents w/ casualties involving trams

Distance analysis[1)]: **conservative case**[2)]





- <u>No</u> simulated accident in which the distance is big enough to stop tram before collision neither with service brake nor with emergency brake!
- In the selected scenario early detection of opponent and of opponent's turning intention is essential for accident avoidance!

1) Source: 52 accidents from GIDAS, representing ~160-~240 accidents involving trams, fixed obstacles (e.g. trees, buildings) are not considered
2) Start of recognition at time of opponent entering tram's driving tube
3) It is assumed that sensor detects the complete vehicle edge, assumed sensor dead times: minimal 100ms, average 500ms, maximal 1000ms + brake pressure time of 150ms each
4) Collision avoidance possible because of changed collision point by reduced speed.

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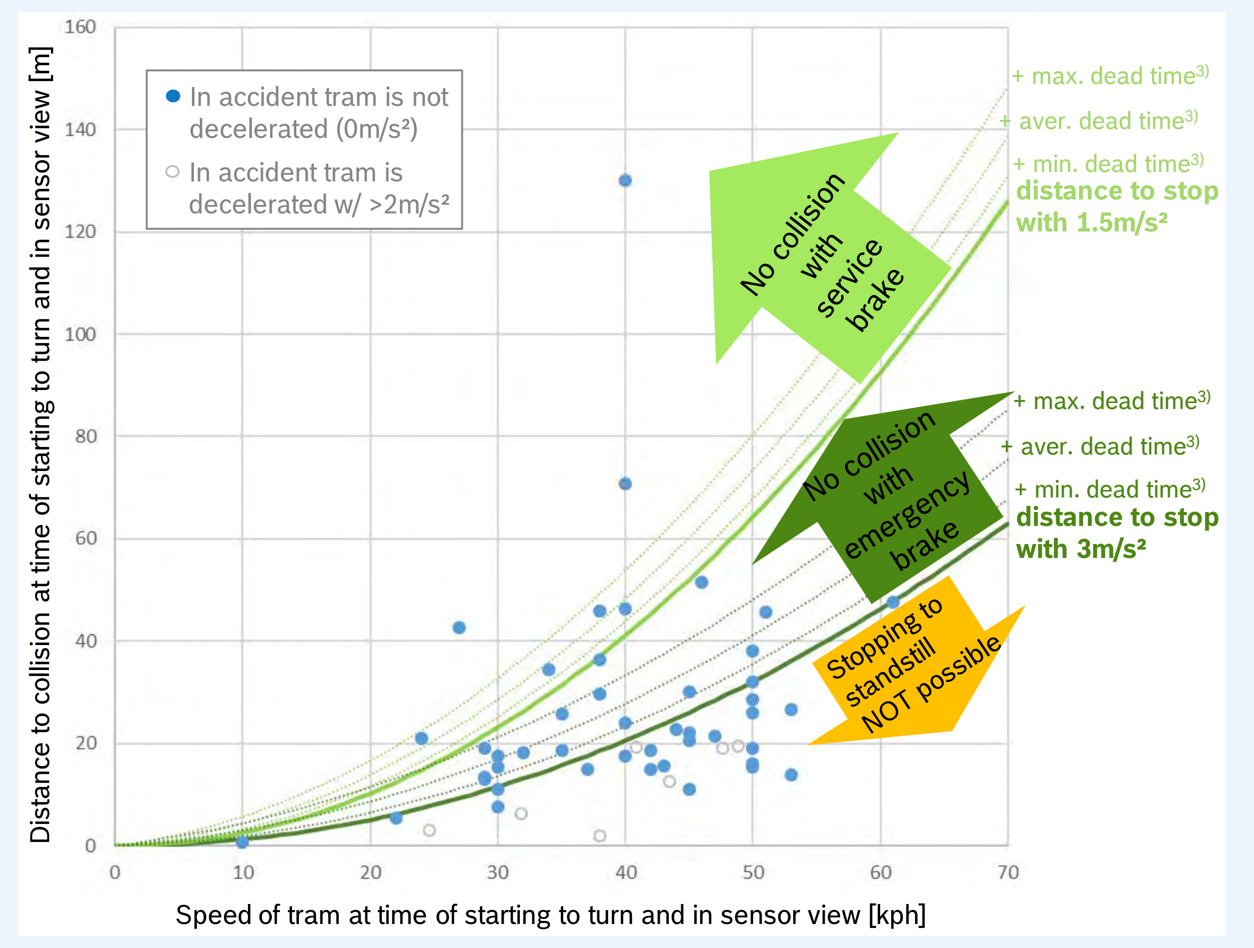
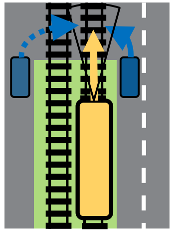
Accidents w/ casualties involving trams

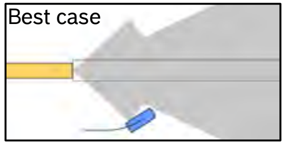
Distance analysis[1)]: **best case**[2)]





Chapter 02

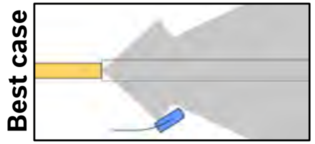
2016



- In at least 7 simulated accidents (≙ ~20 accidents in D) collision is avoided with **service brake**
- In at least 21 simulated accidents (≙ ~80 accidents in D) collision is avoided with **emergency brake**
- Collision mitigation[4)] in accidents below green line expected by reduced impact speed (for results see following slide)

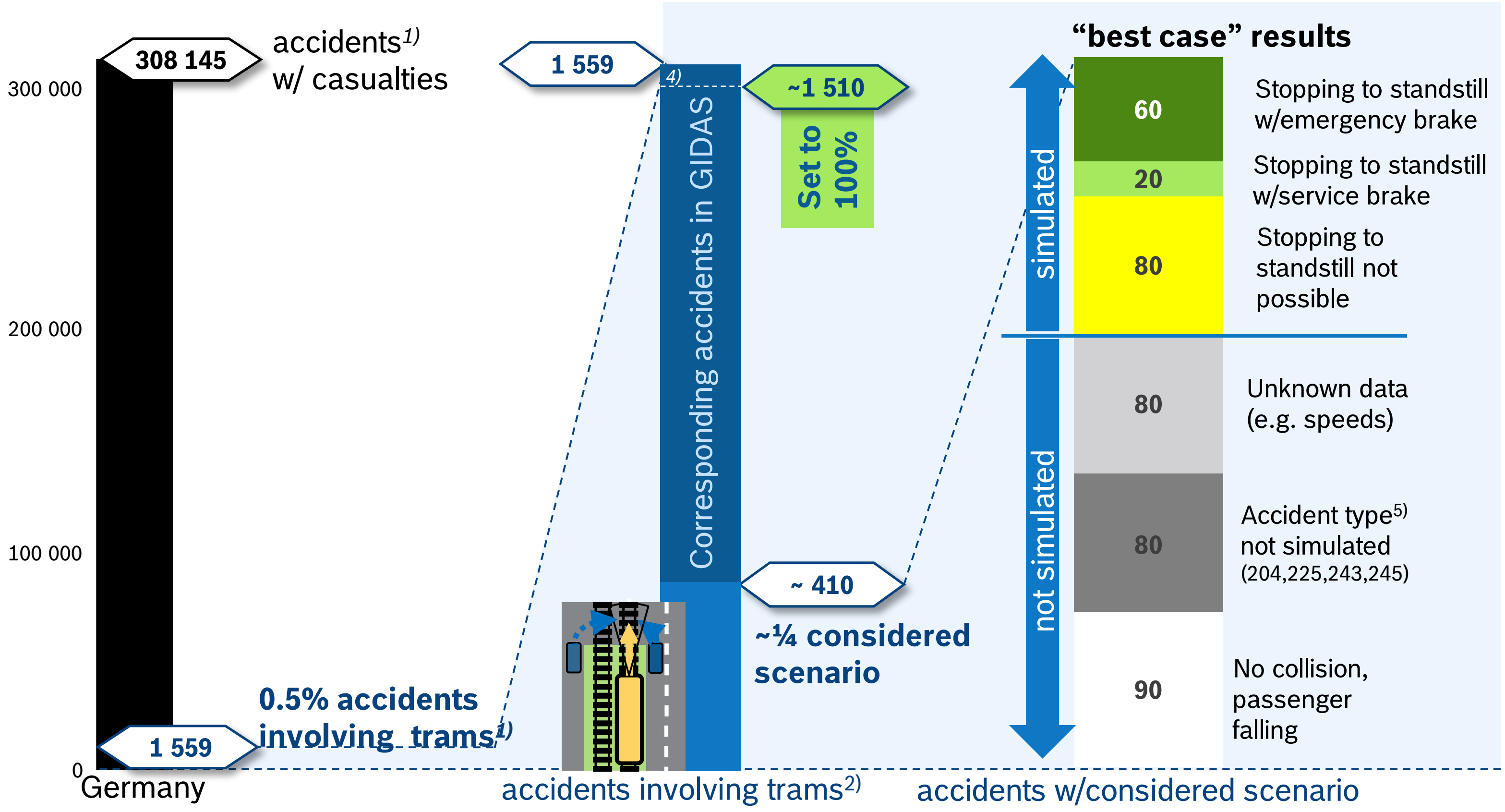
1) Source: 52 accidents from GIDAS, representing ~160-~240 accidents involving trams, fixed obstacles (e.g. trees, buildings) are not considered
2) Start of recognition at time of opponent entering tram's driving tube
3) It is assumed that sensor detects the complete vehicle edge, assumed sensor dead times: minimal 100ms, average 500ms, maximal 1000ms + brake pressure time of 150ms each
4) Collision avoidance possible because of changed collision point by reduced speed.

Accidents w/ casualties involving trams
Summary



Chapter 02
Start of recognition at time of opponent starting to turn and in tram's sensor view (upper border only in theory available)

2016



▶ **"Best case" scenario:**
Assuming no dead times, tram is stopped to standstill 3 times more often with emergency brake compared to service brake only in simulated accidents

1) DESTATIS Yearbook 2016, "Fachserie 8 Reihe 7" and extra inquiry to DESTATIS
2) 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany
3) 52 simulated accidents from GIDAS, representing ~160-~240 accidents involving trams, fixed obstacles (e.g. trees, buildings) are not considered; it is assumed that the complete vehicle edge is detected by the sensor
4) Service brake: 1.5m/s², emergency brake: 3 m/s² (no dead times)
5) These types do not contain directly information about approaching direction of vehicles to each other

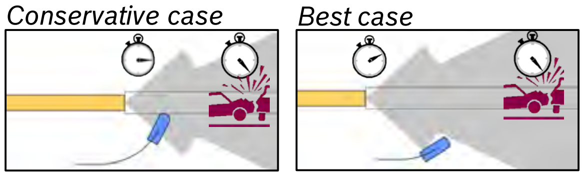
Accidents w/ casualties involving trams

Measures to increase accident avoidance potential

1) Early and fast detection of opponent‘s turning intention[1)]

Compare gain of time from “conservative” to “best case” on slide 12

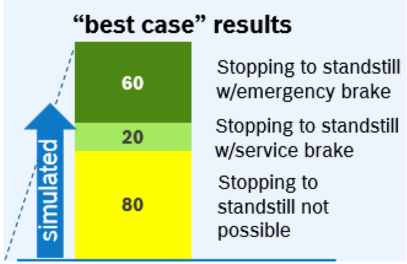
- **Improve prediction of opponent’s turning intention** *e.g. by C2tram*



2) Increase brake deceleration

Using emergency brake increases the number of accidents with tram stopped to standstill 3 times compared with service brake (considering “best case” scenario)

- **Persuade opponent to stop** *e.g. by bright projection stripe on tracks*

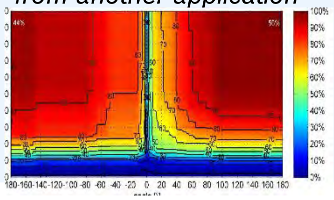


3) Optimize sensor

In ¾ of simulated accidents opponent is in sensor[3)] view at time of starting to turn

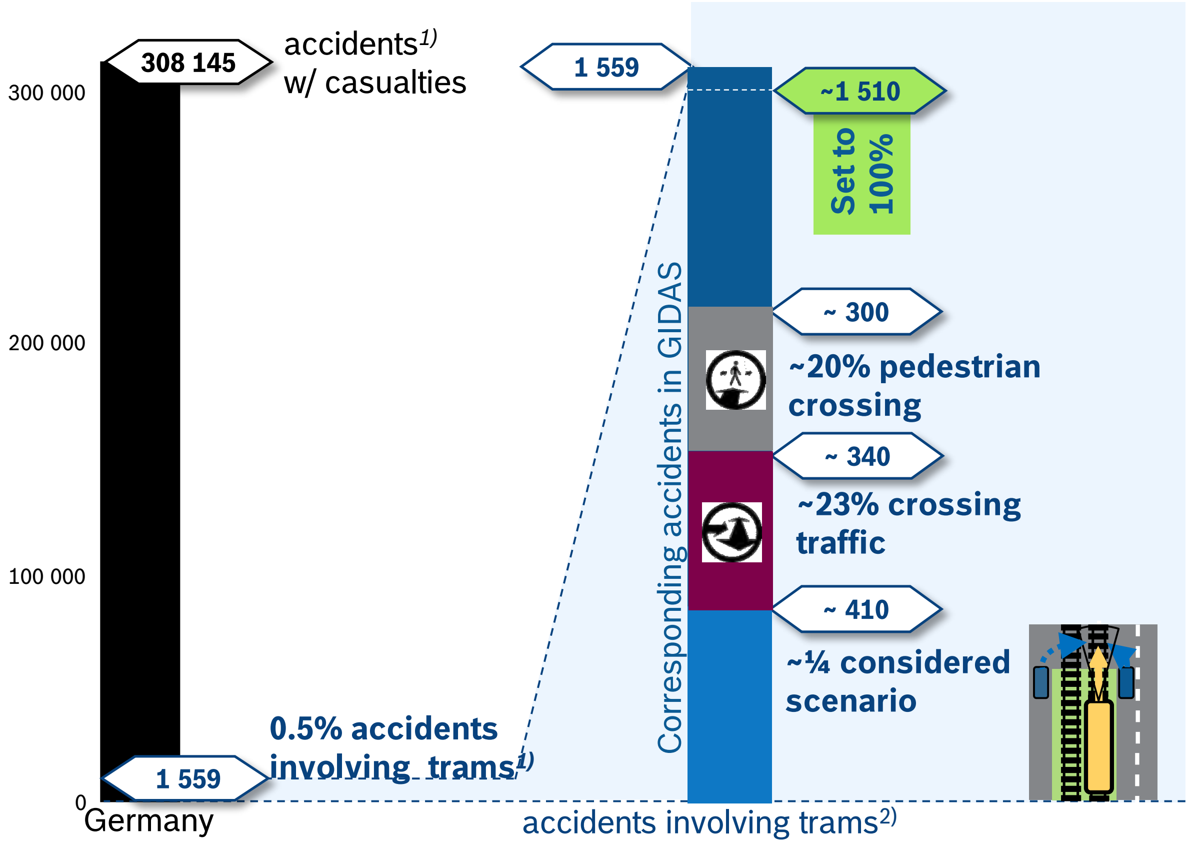
- **check other sensor concepts** (video, LIDAR, …) concerning applicability (e.g. weather conditions)
- **overview about needed sensor angles and ranges** dependent on time of detecting opponent’s turning intention e.g. by sensor requirements analysis

Exemplary visualization taken from another application



1) 52 simulated accidents from GIDAS, representing ~160-~240 accidents involving trams, fixed obstacles (e.g. trees, buildings) are not considered
2) Conservative case: Start of recognition at time of opponent in tram’s driving tube, best case: Start of recognition at time of opponent starting to turn and in tram’s sensor view (upper border only in theory available)
3) Attention: it is assumed that the complete vehicle edge is detected by the sensor, sensor range and angle as provided

Accidents w/ casualties involving trams
Outlook



- Additional potential for tram safety systems expected in pedestrian accidents and crossing accidents.
- Analyzing these situations provide an indication whether the current system specification is suitable and if not which adaptation might increase benefit!

1) DESTATIS Yearbook 2016, "Fachserie 8 Reihe 7" and extra inquiry to DESTATIS

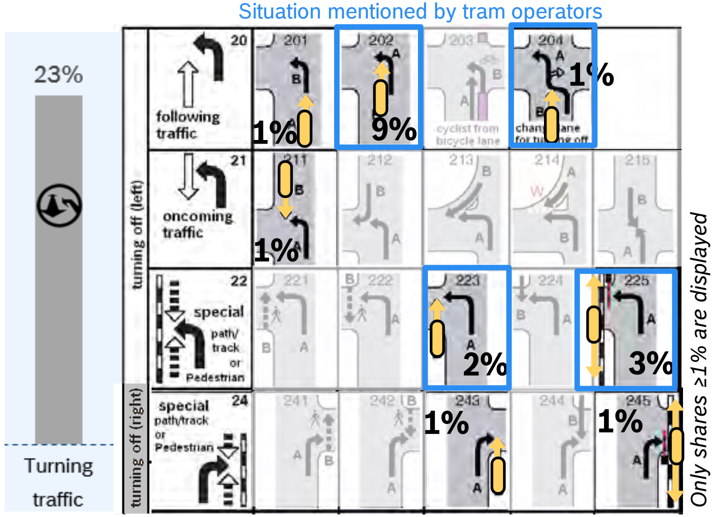
2) 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany

Accidents w/ casualties involving trams

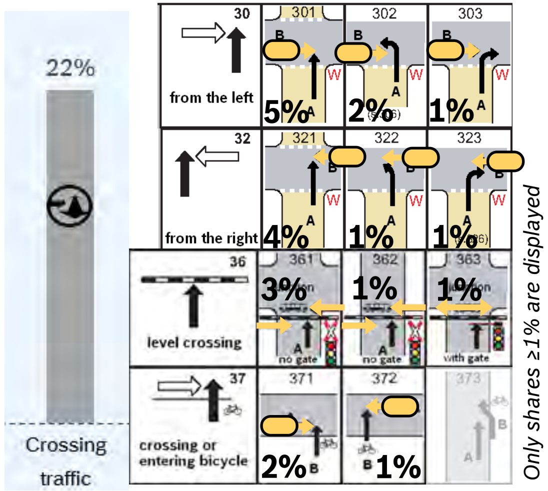
2016

Appendix I: Conflict situations in detail (3 digit type of accident)

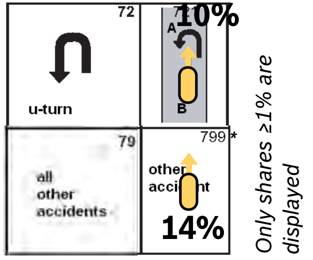
Turning traffic



Crossing traffic



Others



** Accidents of type 799 are manifold. Often these accidents are without other traffic participants, e.g. tram passenger is falling and injured because of unauthorized usage of emergency brake or falling passenger while getting in tram. Some cases maybe wrongly assigned to this type because accident causing situation is not interpreted correctly because there was no collision (only injured passenger because of falling down)*

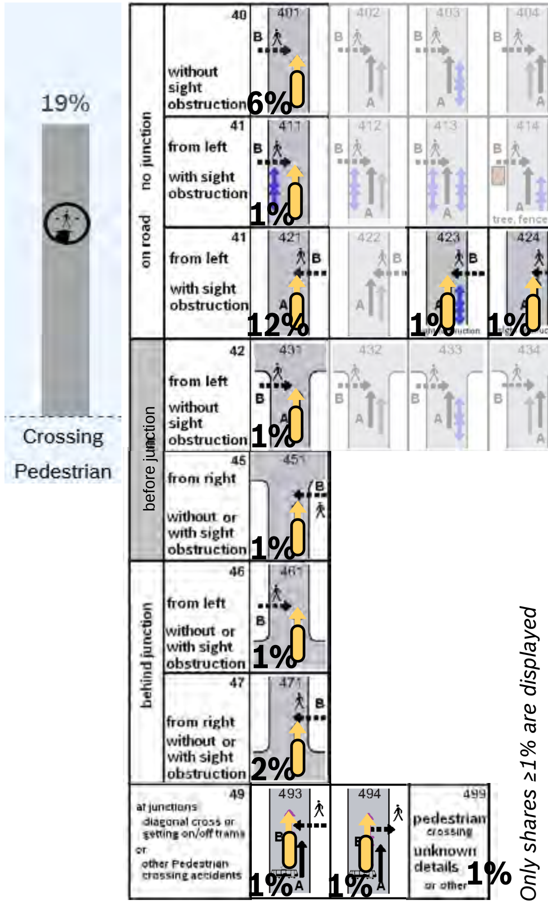
- Mainly trams collide with another vehicle turning in from the right-hand side
- Trams collide a bit more frequently with a vehicle approaching from the right-hand side (301-303/371) than from the left-hand side (321-323/372)
- U-turn situations are very common

1) *Source: 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany*

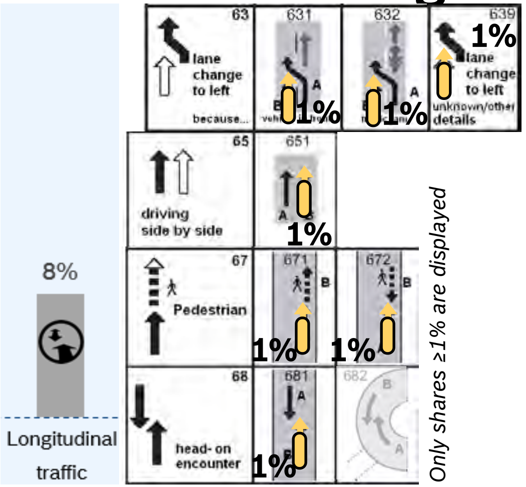
Accidents w/ casualties involving trams

Appendix I: Conflict situations in detail (3 digit type of accident)

Pedestrian accidents



Accidents in longitudinal traffic



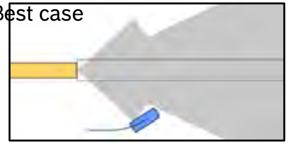
In accidents involving trams:

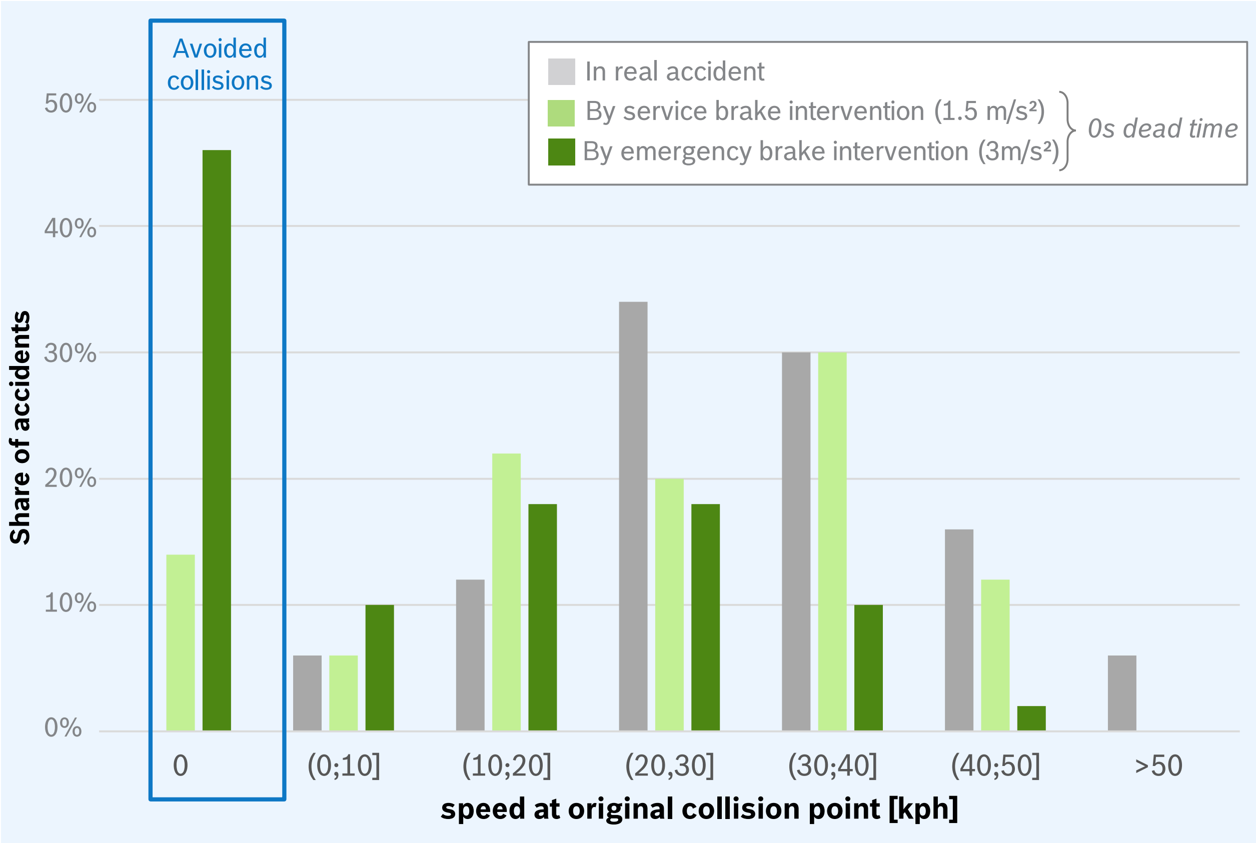
- a pedestrian crosses tracks from the left-hand side in 10%, from the right-hand side in 17%
- a pedestrian is injured while getting on/off tram in 2% (493/494)
- a vehicle changes into tram's lane from the right hand side in ~3% (631-639)
- a pedestrian walks on tracks in/against tram's direction in ~2% (671/672)

1) Source: 588 accidents involving trams from GIDAS analysis weighted and mapped to Germany

Accidents w/ casualties involving trams

Appendix II: Collision mitigation by reduced speed[1)]: **best case**[2)]





Collision could be avoided

- with service brake in more than 10% of simulated accidents (≙ ~20 accidents in D)
- with emergency brake in more than 40% of simulated accidents (≙ ~70 accidents in D)

In ~30% of simulated accidents speed[3)] at collision point of real accident can be reduced to 20kph and below with service/ emergency brake.

1) Source: 52 accidents from GIDAS, representing ~160-~240 accidents involving trams, fixed obstacles (e.g. trees, buildings) are not considered
2) Start of recognition at time of opponent starting to turn and in tram's sensor view (upper border only in theory available), it is assumed that sensor detects the complete vehicle edge,
3) Attention: it is not checked whether there is still an impact at original collision point. It is possible that the vehicles do not touch each other by speed reduction.

Chapter 03

BENEFIT ESTIMATION OF AN ANTILOCK BRAKING SYSTEM FOR PEDELECS

BASED ON REAL WOLD ACCIDENTS

JÖRG MÖNNICH

Accident Research
CR/AEV1

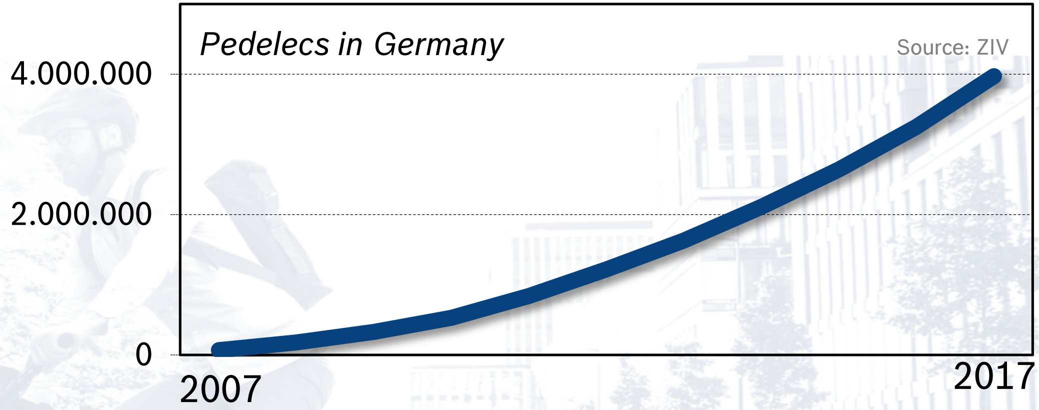
Publication

Results published on ICSC Paper and Presentation

BOSCH

Benefit estimation of ABS for Pedelecs

Aim of the study



High popularity of pedelecs

ABS for Pedelecs

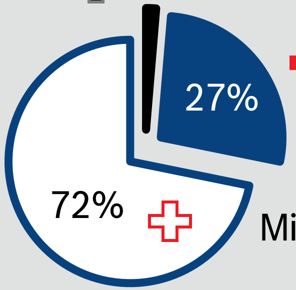
A possibility to increase road safety?

Accident Data → Simulation → Benefit estimation

Benefit estimation of ABS for Pedelecs

Accident situation involving pedelecs for Germany (2017)

- **Casualties:** Pedelec riders **5 115** Trend
- **Age 65+** years: **46%**



Often no braking reaction!

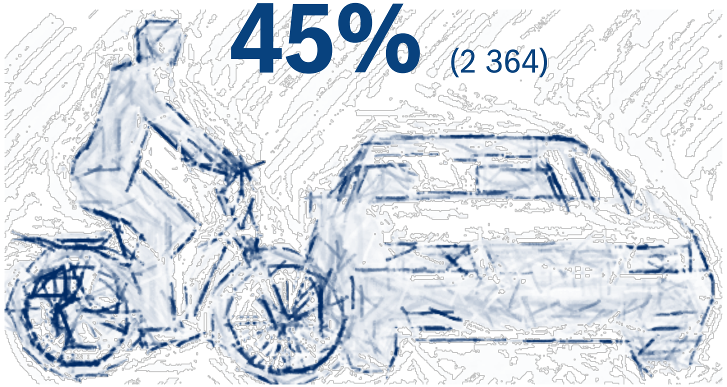
No visibility?

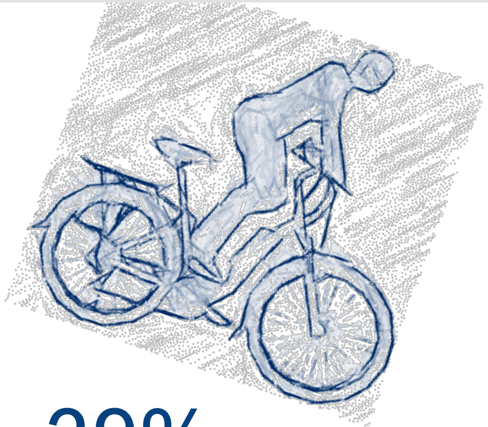
Fear to fall?

Overreaction → Fall over

- **Pedelec – Car** conflicts:

45% (2 364)





29% (1 537)
Single accidents

Benefit?

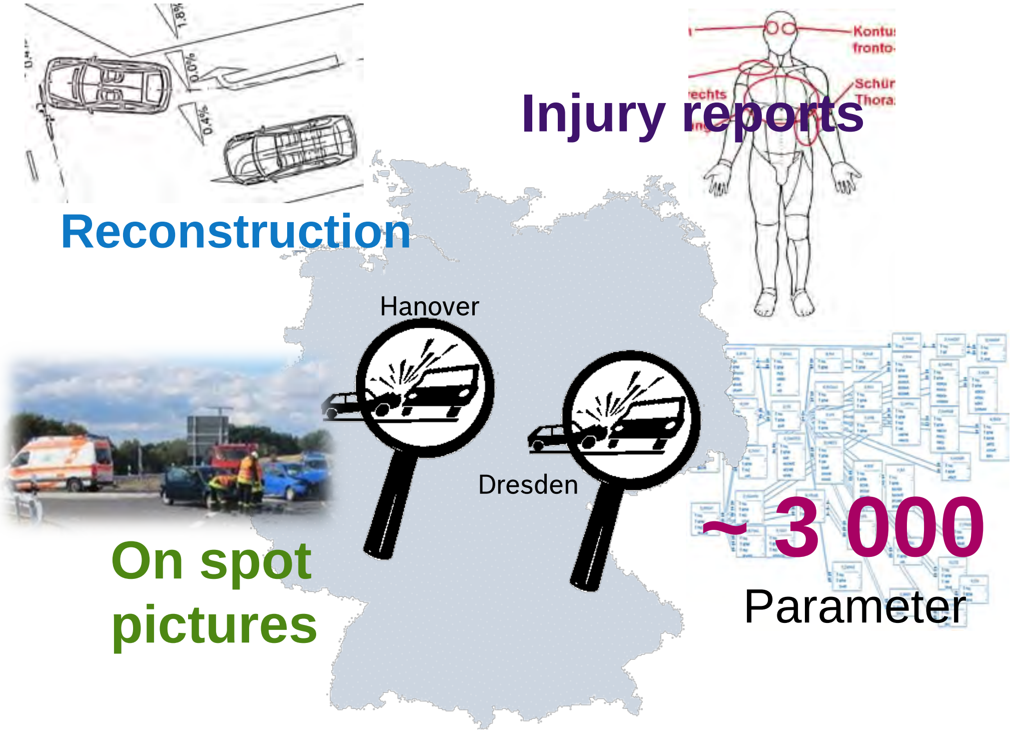
ABS avoid fall over, and allow optimal braking

Bosch Accident Research (CR/AEV1-Mönnich) | Jan/31/2019
AEV-064 annual report 2018

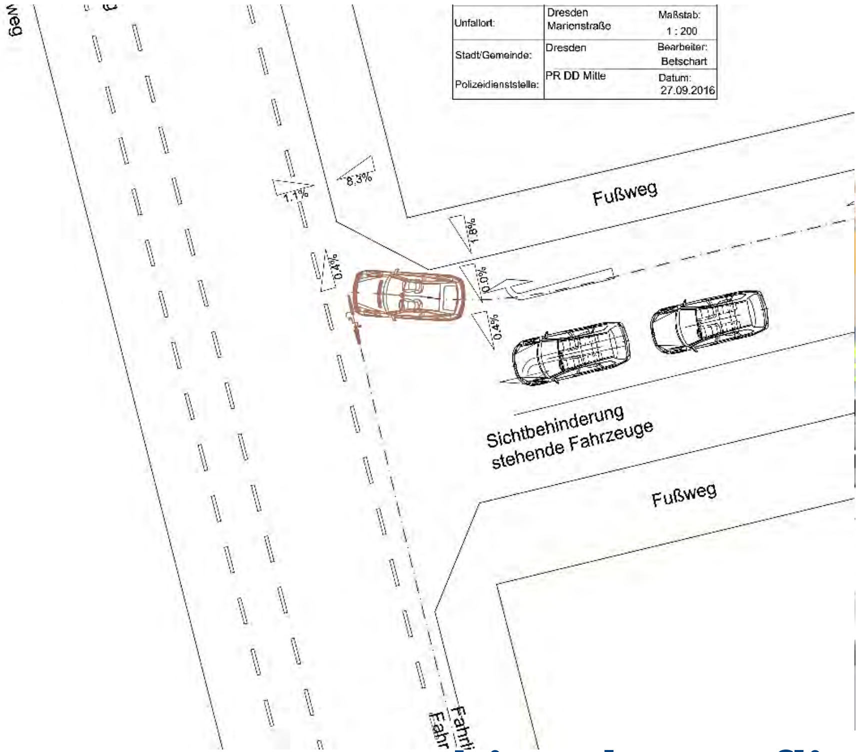
BOSCH

Benefit estimation of ABS for Pedelecs
Data sources and methodology

GIDAS
GERMAN IN-DEPTH ACCIDENT STUDY



~ 10 000
Accidents involving bicycles

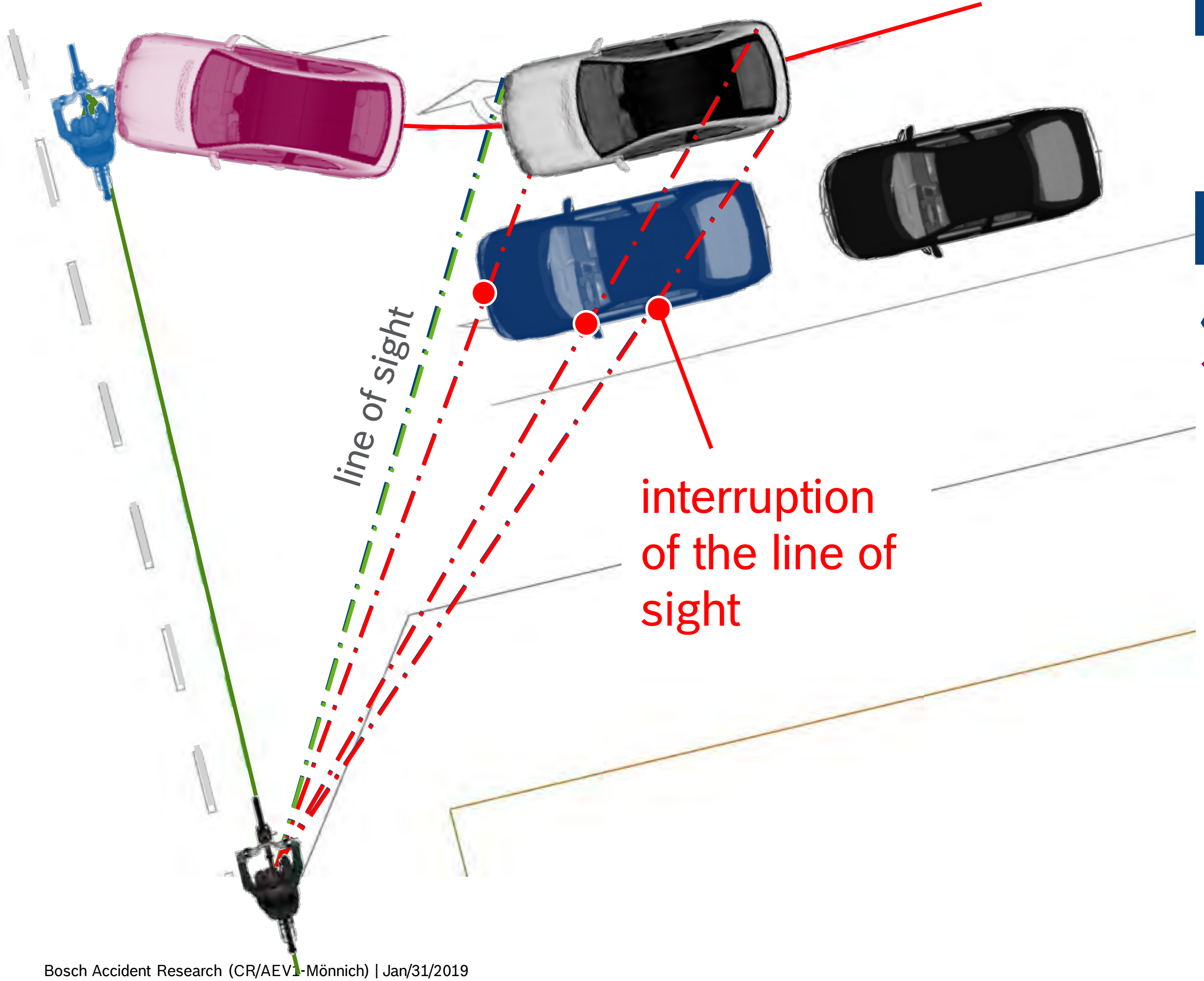


Study focusses on car - bicycle conflicts
2 366 different case simulations

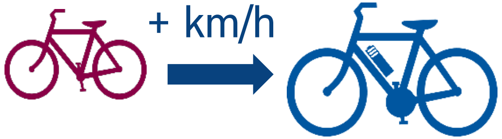
BOSCH

Benefit estimation of ABS for Pedelecs

Case simulation

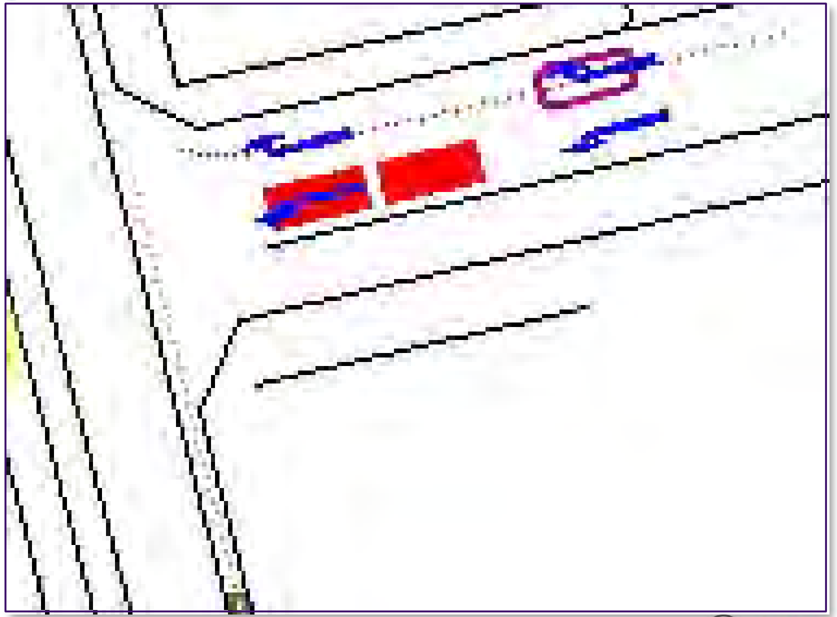


Starting from collision situation



Check: Opponent visibility

More than 2 blocked: No reaction!



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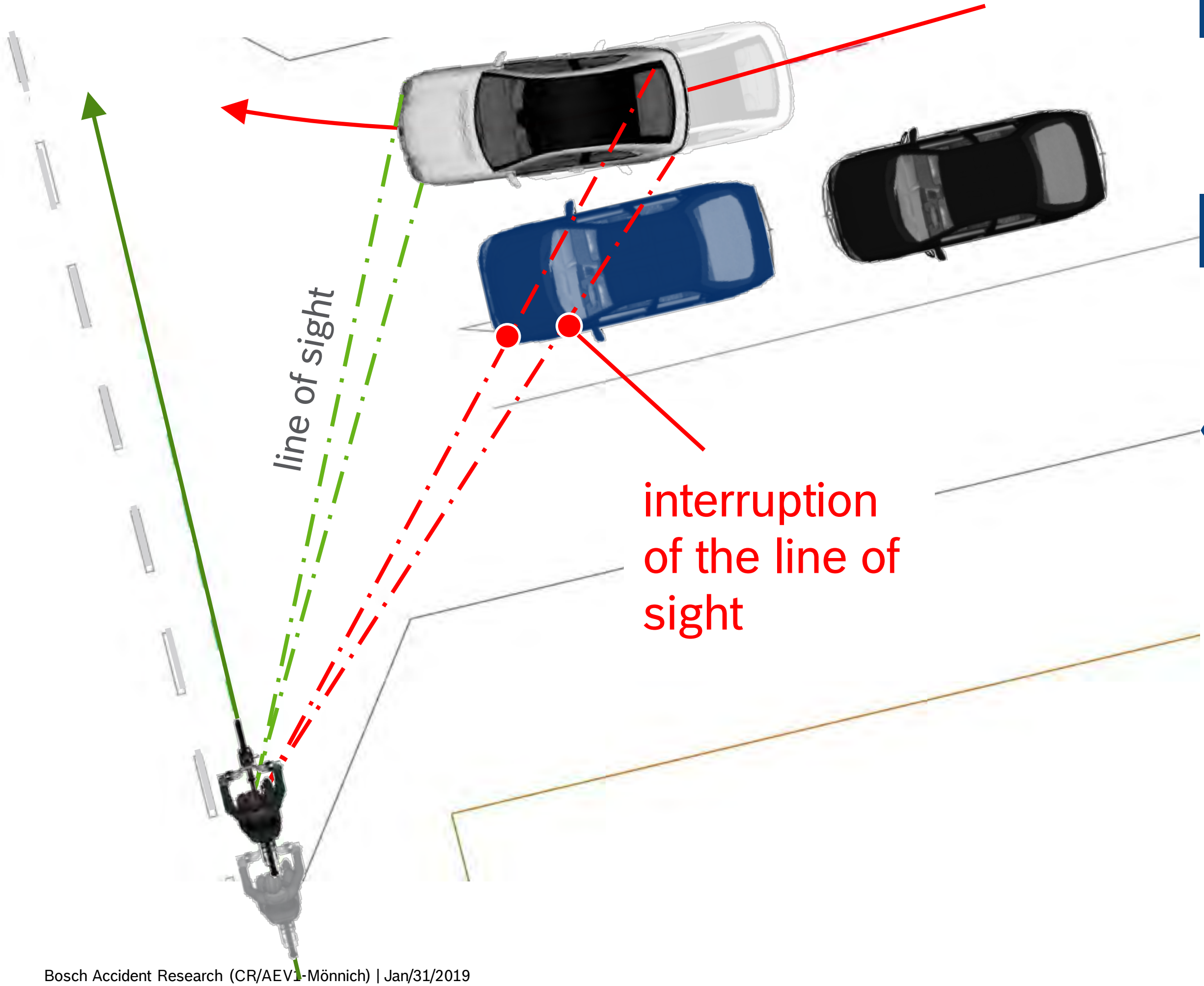
Benefit estimation of ABS for Pedelecs
Point of Reaction

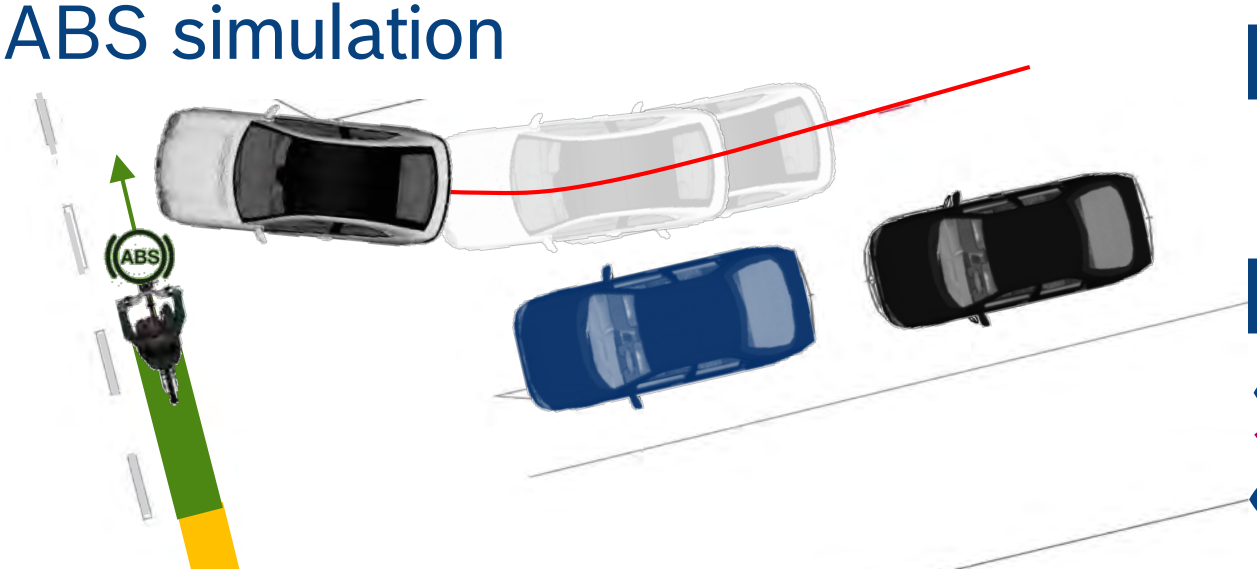


Starting from collision situation

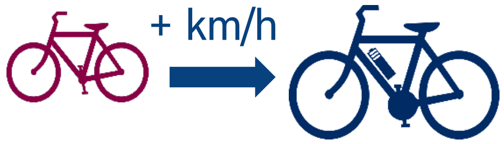
Check: Opponent visibility

Benefit estimation of ABS for Pedelecs

ABS simulation



Starting from collision situation



Pedelec

Check: Opponent visibility

More than 2 blocked: No reaction!

Field of view 2 lines visible!

Benefit Estimation

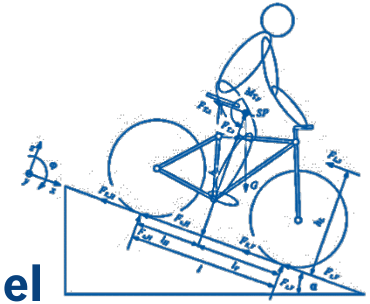
Avoidance or assessment of new collision scenario

Avoidance maneuver: Braking

Reaction time

Road conditions

Generic **ABS Model**



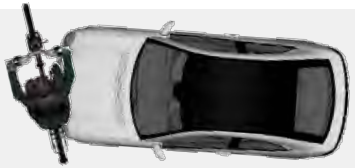
Benefit estimation of ABS for Pedelecs

Chapter 03

Assessment of new collision scenario

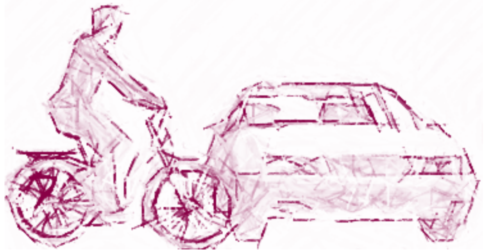
7 km/h

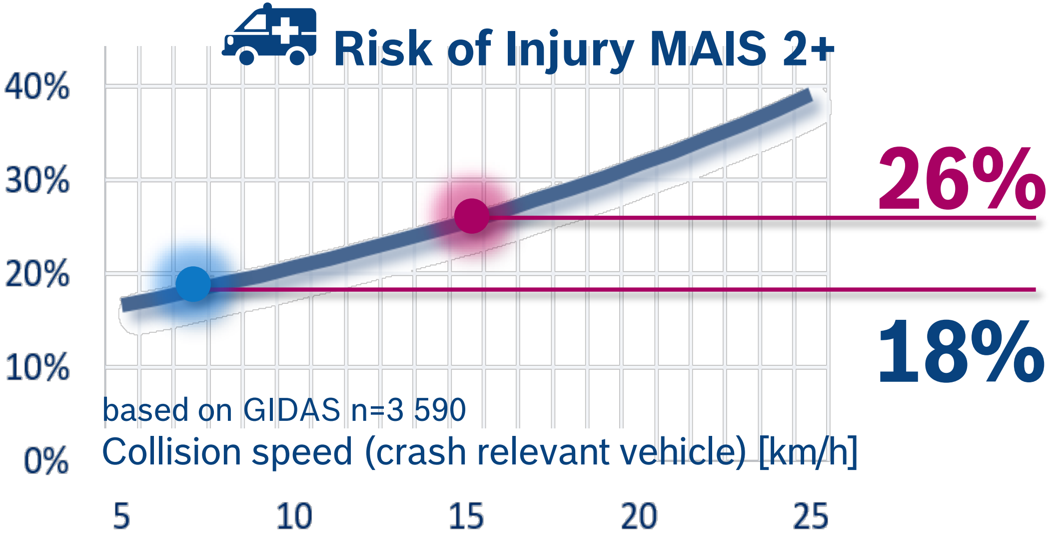
... braking with
ABS support



15 km/h
Original

Benefit estimation





Benefit

Impact speed

Collision type

Age of cyclists

Bosch Accident Research (CR/AEV1-Mönnich) | Jan/31/2019
AEV-064 annual report 2018

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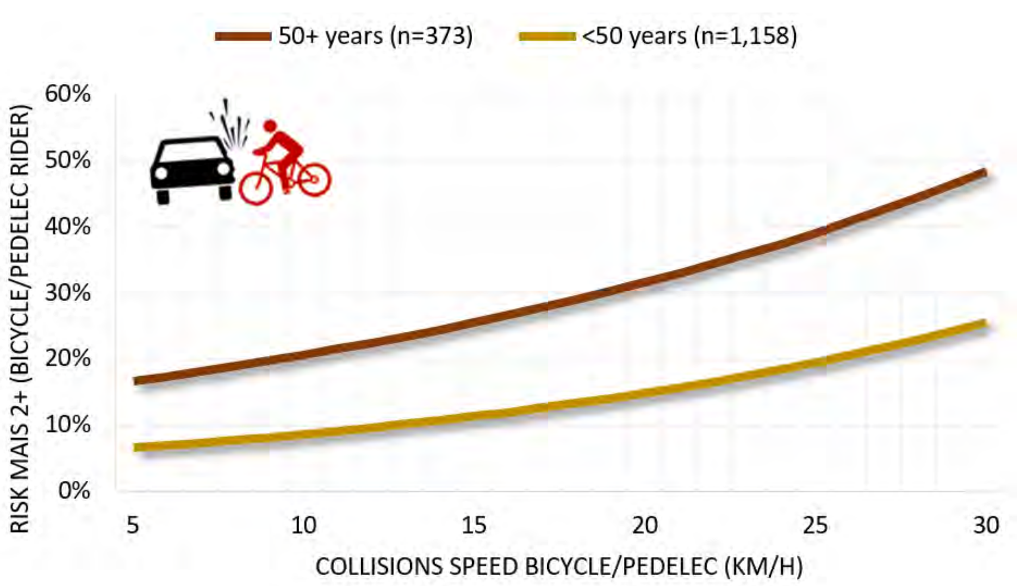
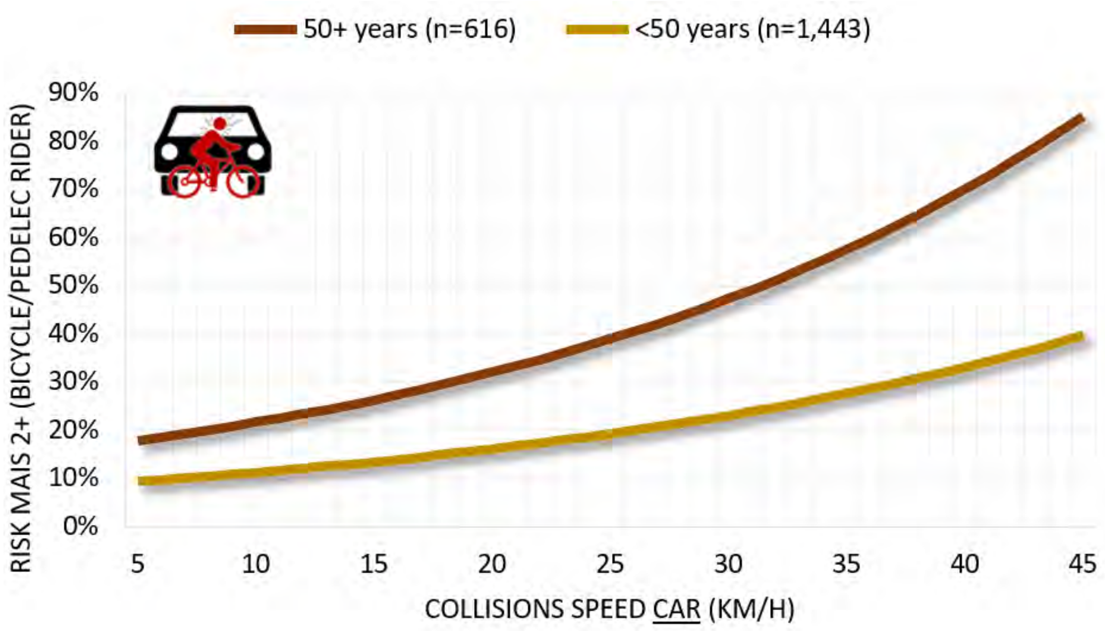
Benefit estimation of ABS for Pedelecs

Injury Risk function



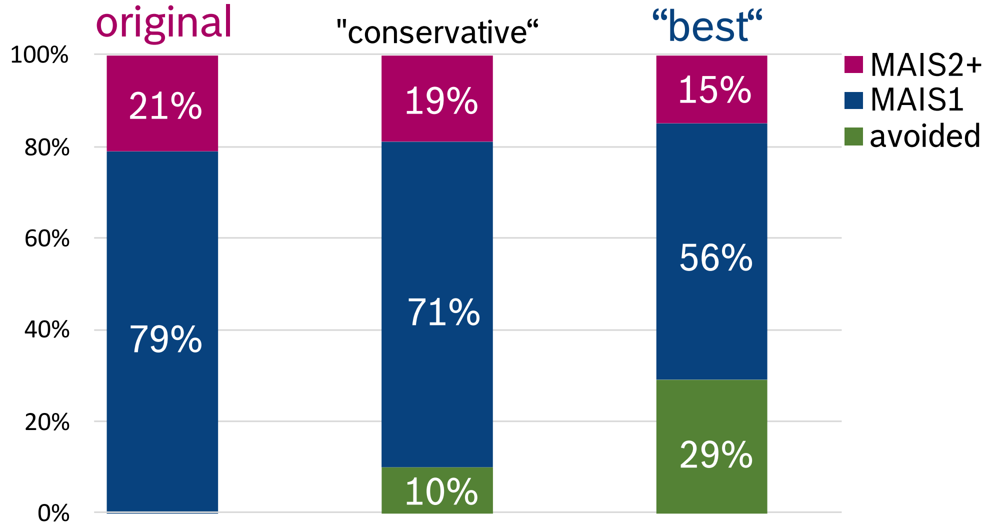


Benefit estimation of ABS for Pedelecs

Main results and relevance for Germany

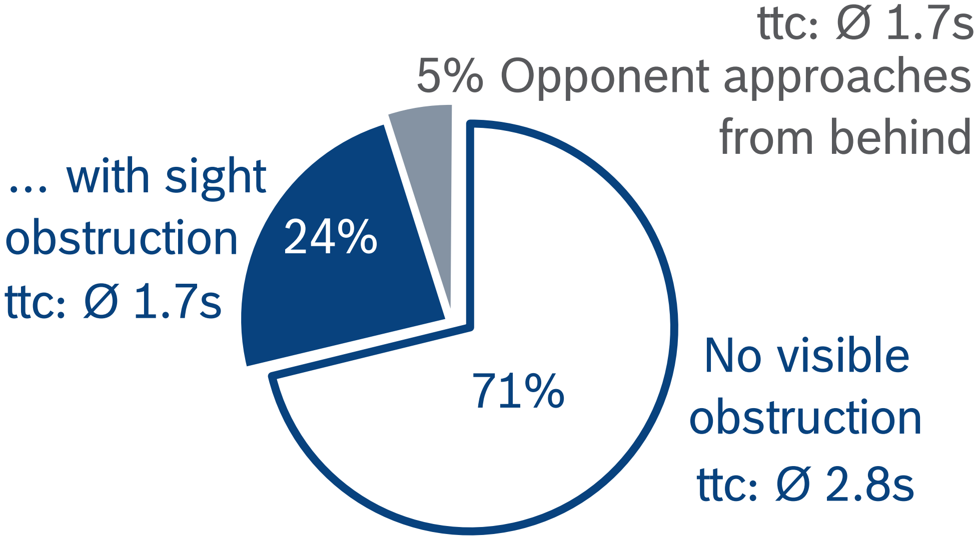
- ABS potential for Germany in all accident scenarios

GIDAS GERMAN IN-DEPTH ACCIDENT STUDY



Potential 2017: ≈ 1500 avoided accidents
(All Pedelecs with ABS*)

- Visibility & Time to react in pedelec car conflicts



Braking in majority of cases possible

* Brake reaction assumed

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AEV-064 annual report 2018

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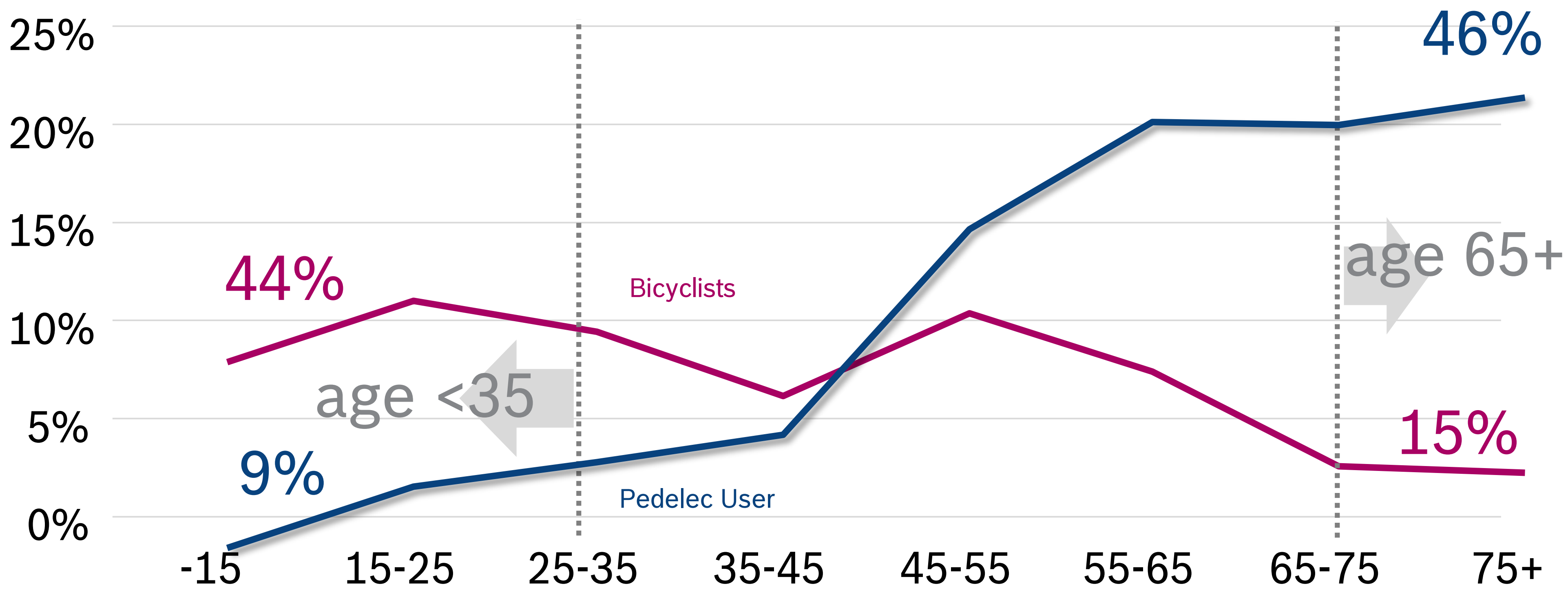
Benefit estimation of ABS for Pedelecs

Age of casualties



Benefit estimation of ABS for Pedelecs

Conclusion

Number of casualties

Germany 2017: **5 115**

4 million pedelecs
high popularity

Injury severity

46% age 65+
Influence of age

Conflicts with cars

71%
Opponent is visible

Braking

possible
Ø 2.8s time

Avoidance potential in **up to 29%*** of all accidents with pedelec in Germany if cyclists brakes

Pedelec ABS allows safe emergency braking!

(*all Pedelecs with ABS)

Chapter 04

Germany: Field of effect estimation of LDW/LKS for heavy trucks

Accident Research
CR/AEV1

BOSCH

Accident Research - CV LDW/LKS
Overview Analysis

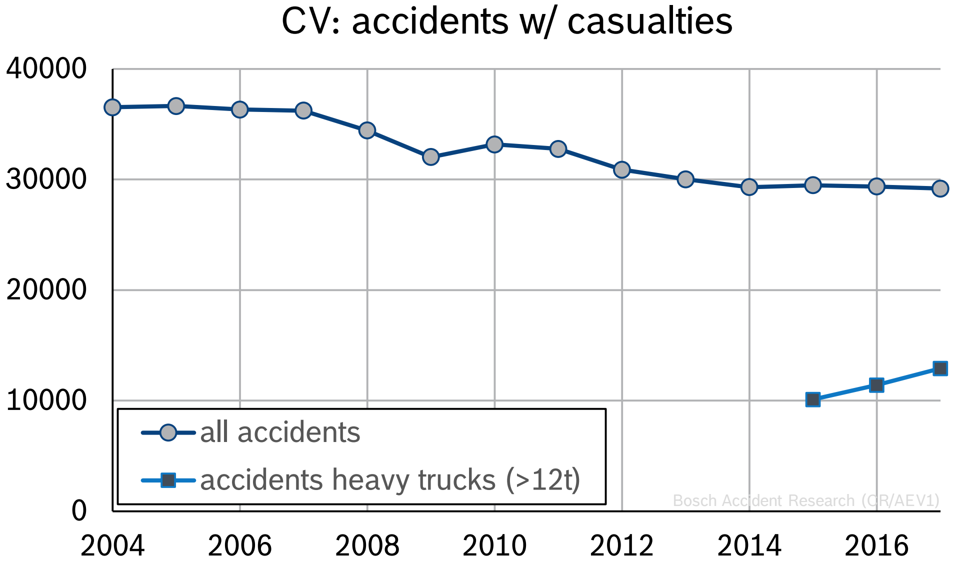
	 N1	 N2	N3 (Results all to N3 related accidents) 
ESC	Field of effect: **6%** Benefit: n/a	Field of effect: **3%** Benefit: n/a	Field of effect: **4%** Benefit: **2% - 3%**
LDW/LKS	Field of effect: **9%** Benefit: n/a	Field of effect: **13%** Benefit: n/a	Field of effect: **7%** Benefit: n/a
AEBS	Field of effect: **19%** Benefit: n/a	Field of effect: **23%** Benefit: n/a	Field of effect: **22%** upper limit benefit EU conform system **<9%** Benefit of Bosch system: **~17%**

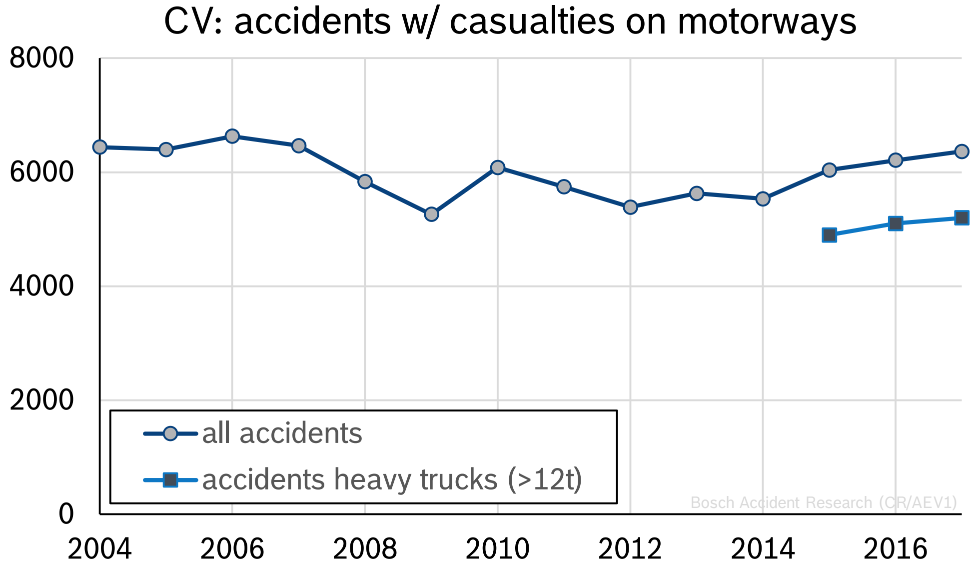
Accident Research - CV LDW/LKS

Overview: accident numbers commercial vehicles

Chapter 04

DESTATIS Statistisches Bundesamt





- slowly decreasing numbers of accidents w/ casualties for commercial vehicles
- increasing numbers for heavy trucks (>12t): +25%
- accidents numbers increase on motorways for all types of commercial vehicles

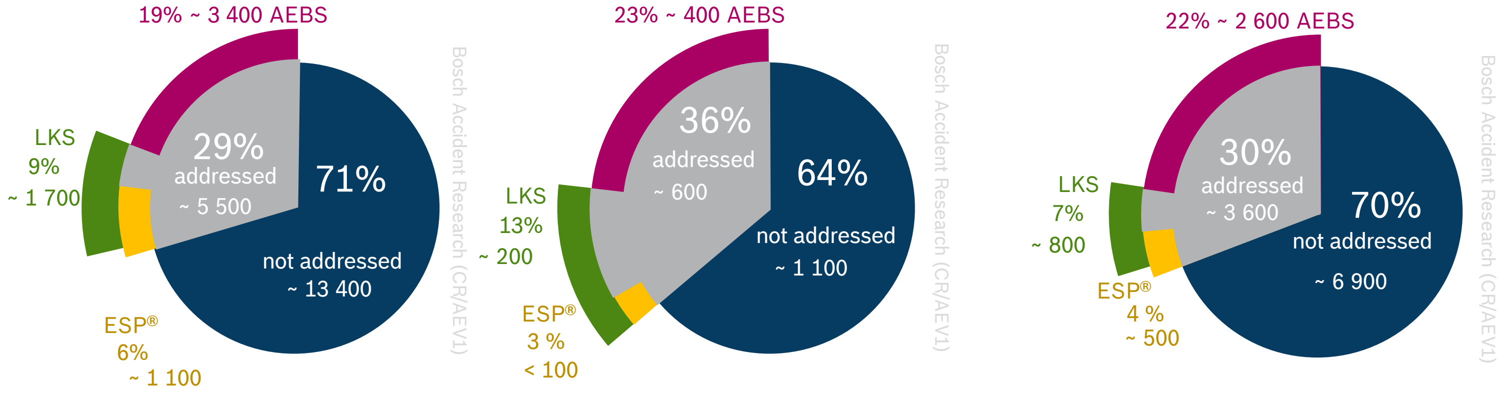
Accident Research - CV LDW/LKS

Field of Effect - AEBS, LKS, ESP® (CV)

Chapter 04

2017

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



18 900 Accidents w/ trucks ≤7,5t | **1 700 Accidents w/ trucks 7,5t to 12t** | **12 900 Accidents w/ trucks >12t**

AEBS: Truck as main causer of a rear-end crash
LDW/LKS: Truck leaves lane unintentionally 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 set on N3 (>12t)

Source: GIDAS database (2001-2017) weighted and representative for Germany; N2 analysis includes also special vehicle sizes i.e. construction vehicles etc.

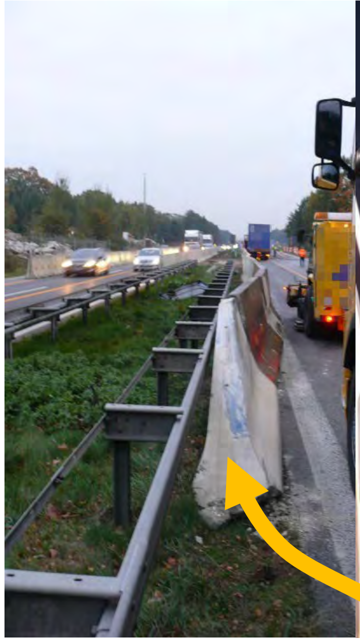
CV LDW / LKS FIELD OF EFFECT FOR HEAVY TRUCKS (N3)

Accident Research - CV LDW/LKS

Example case

▶ GIDAS-Fall 1090817

A semi-trailer truck travels on the BAB 13 (E 55) from Berlin in the direction of Dresden. About 1000 m after the exit “Schönborn” the driver leaves the road to the left BEFORE a construction site. Truck collides with a concrete safety barrier. Driver is seriously injured and the vehicle is heavily damaged (tank is ripped open).



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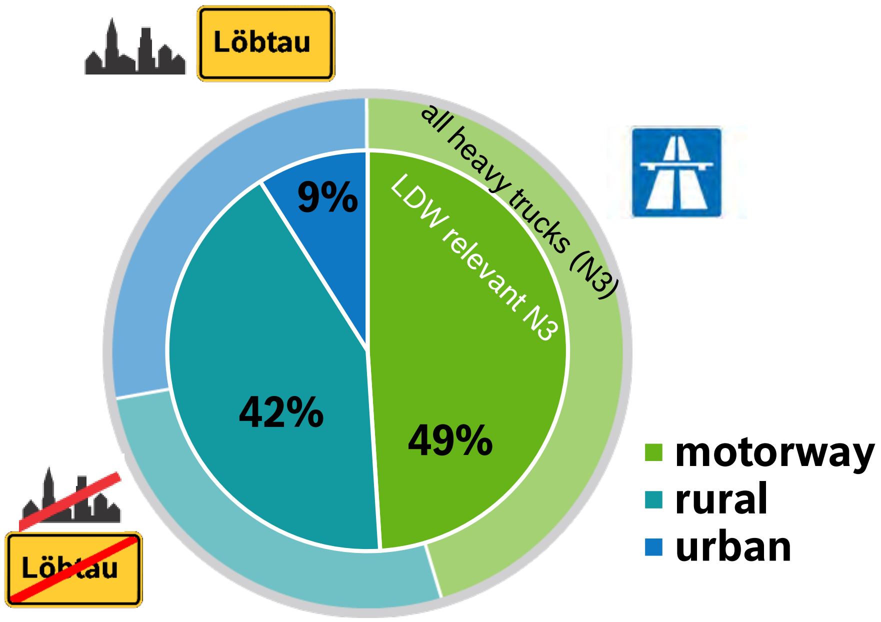
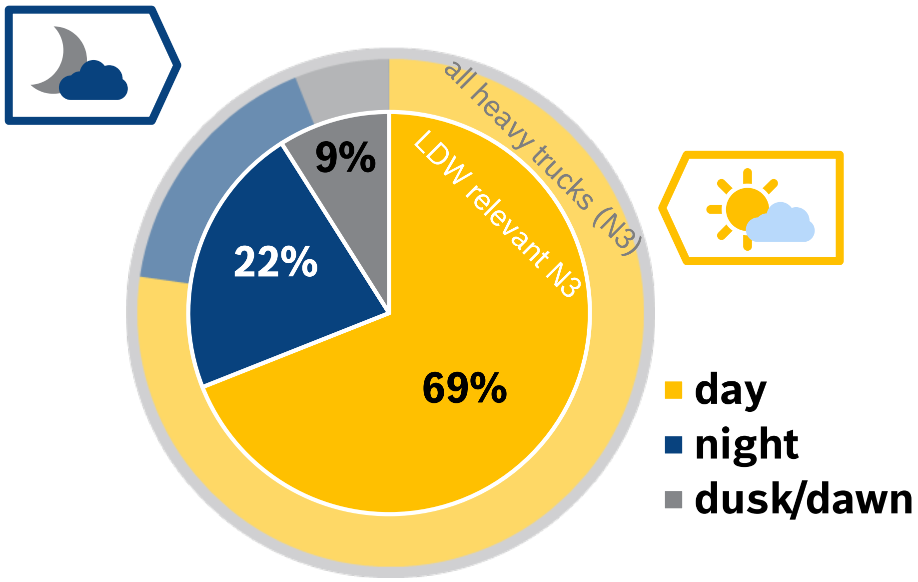
Accident Research - CV LDW/LKS

Chapter 04

2017

Location and light conditions for LDW/LKS relevant collisions



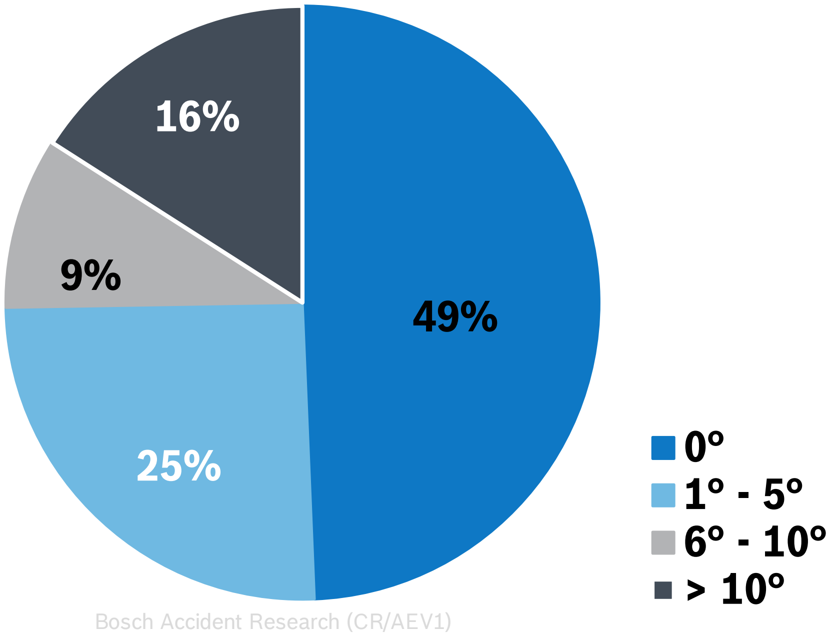


- half of all LDW/LKS relevant N3-vehicle collisions w/ casualties on motorways
- 2 out of 3 collisions in daylight conditions

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=79 N3 caused collisions w/ casualties in Germany

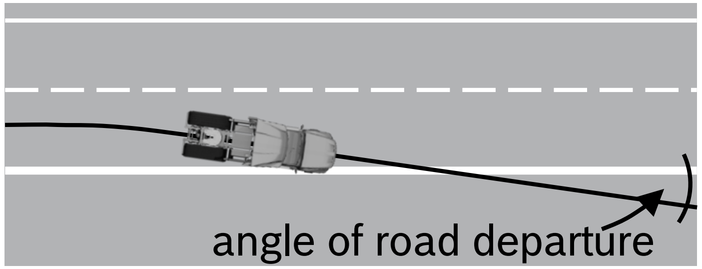
Accident Research - CV LDW/LKS

Angle of road departure



definition GIDAS code book:

angle of road departure (ABWINK): The angle between the edge of the roadside and the velocity vector



▶ Three out of four collisions w/ road departure angles ≤5°

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=79 N3 caused collisions w/ casualties in Germany

Accident Research - CV LDW/LKS

Angle of road departure - details

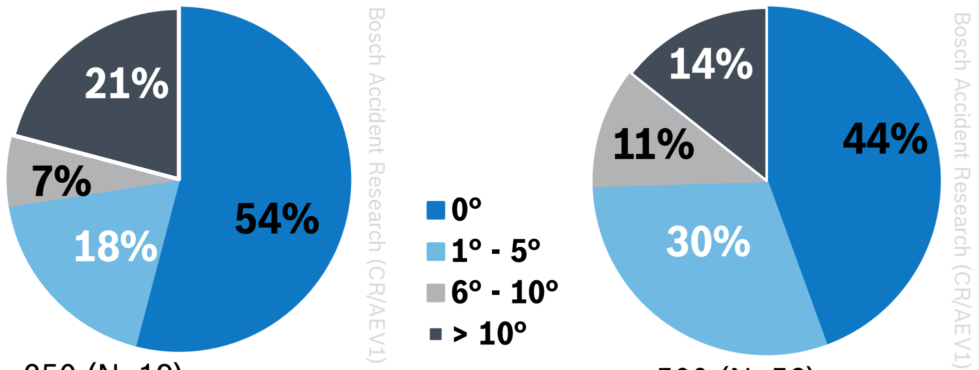
Chapter 04

2017

GIDAS

Initial velocity ≤ 60 km/h

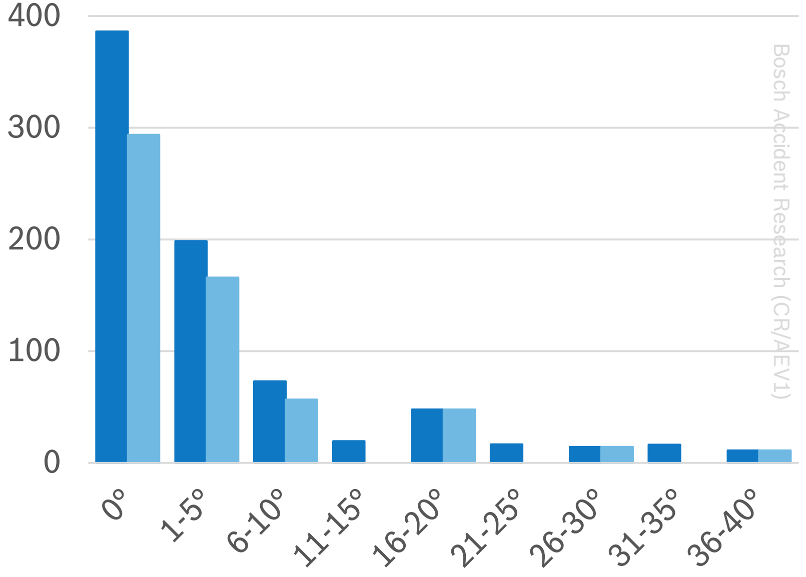
Initial velocity > 60 km/h



~250 (N=19)

~500 (N=56)

▶ NB: large volatility! only few cases!



▶ NO significant difference in road departure angles for different initial velocities

▶ systematic issues measuring 0° road departure angles possible:
difficult reconstruction of start of road departure

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=79 N3 caused collisions w/ casualties in Germany

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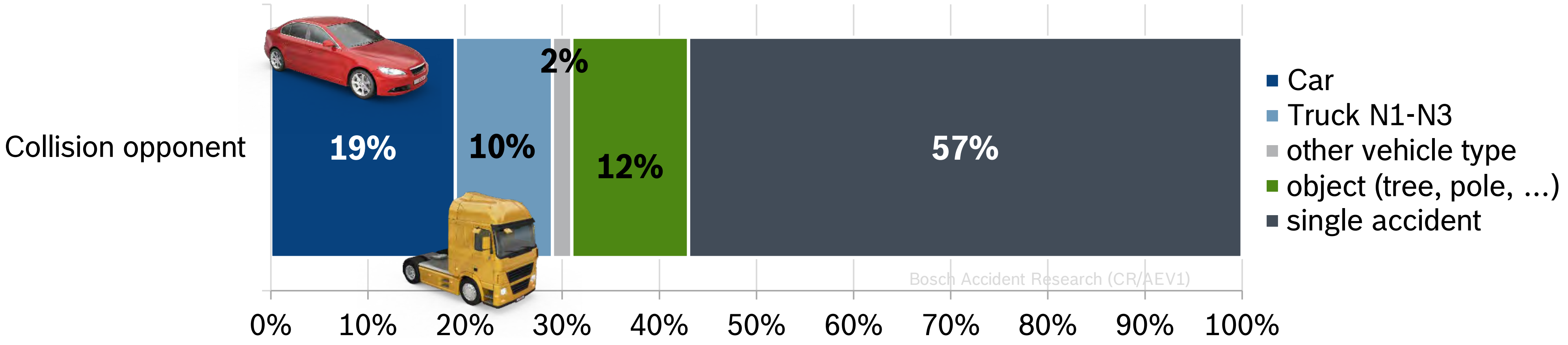
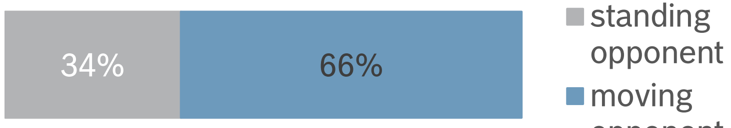
Accident Research - CV LDW/LKS

Opponent for LDW/LKS relevant N3-vehicle



- half of all accidents w/o any collisions (single accident)
- 1 out of 3 accidents against other vehicles thereof 2 out of 3 against moving vehicles
- almost no cases reported in construction sites

if 1st collision against other vehicle:



~200 (N=15)

- NB: large volatility! only few cases!

Source: Bosch Accident Research (CR/AEV1); GIDAS (2001-2017), n=79 N3 caused collisions w/ casualties in Germany

Chapter 05

Germany: FCTA – Frontal Cross Traffic Alert

Accident Research
CR/AEV1

Accident Research - FCTA

Chapter 05

Aim of study:

- Distribution of injury severity over impact area for accidents w/ passenger cars w/ personal injury of occupant w/ first collision is a side collision due to frontal impact of a vehicle w/ at least 4 wheels

Method:

- Determination of relevant accidents out of DESTATIS and GIDAS
- Mapping of relevant accidents of GIDAS to Germany
- Evaluation of relevant accidents with respect to possible FCTA functionalities

Results:

- In 2017 ~16 400 cars suffer an accidents w/ casualties w/ side collision as first collision due to frontal impact of a vehicle w/ at least 4 wheels
- ~5% of relevant cars suffer a subsequent collision w/ higher severity than 1st collision
- If impact area is adjustable by system intervention, it should be outside of lateral cabin area and for avoidance of subsequent collisions not in the rear area
- Analysis show clear dependency of MAIS from dv

Accident Research - FCTA

Accident Selection – Germany 2017

Accidents		Involved parties
302 656	Accidents w/ casualties	583 208
236 835	... w/ passenger car involved	372 144
143 000	... w/ personal injury of passenger car occupant	184 000
55 200	... Accident Type 2 or 3 or 7	73 500
16 400	... w/ side collision as first collision due to frontal impact of a vehicle w/ at least 4 wheels	**16 400**
relevant accidents		relevant cars

DESTATIS Statistisches Bundesamt

GIDAS GERMAN IN-DEPTH ACCIDENT STUDY

Figures projected from GIDAS

▶ Passenger cars w/ relevant collisions for FCTA: about **16 400** in 2017 in Germany

Sources: GIDAS 01/2018, weighted cases since 2005; DESTATIS FS8R7 2017

Accident Research - FCTA

FCTA relevant accidents: near-side vs. far side

Involved parties

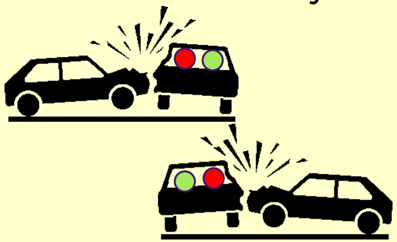
GIDAS
GERMAN IN-DEPTH ACCIDENT STUDY

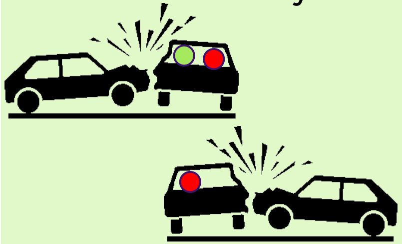
Germany		GIDAS	
16 400	← Projection	1 098	
15 700		1 044	1st collision as severest collision
		992	All occupants belted

498 52%	288 30%	135 14%	36 4%	35 0%*
Near side only	Far side only	Near and Far side	No front occupant injured	Unknown MAIS of occupant at front seat

Injured person at front seat...

- person injured
- person not injured





▶ In ~66% (n=633) of relevant cases injured occupant on near side, in 44% (n=423) on far side.

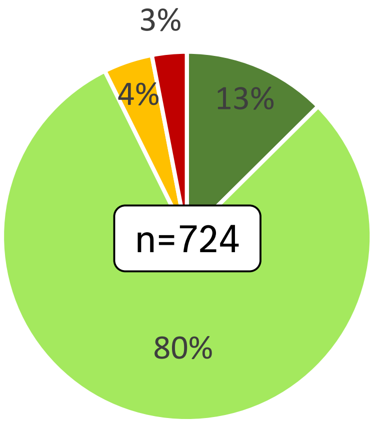
*) Cases w/ unknown MAIS excluded from calculation of percentages → This approach assumes that the distribution in the unknown cases is the same as in the known cases.

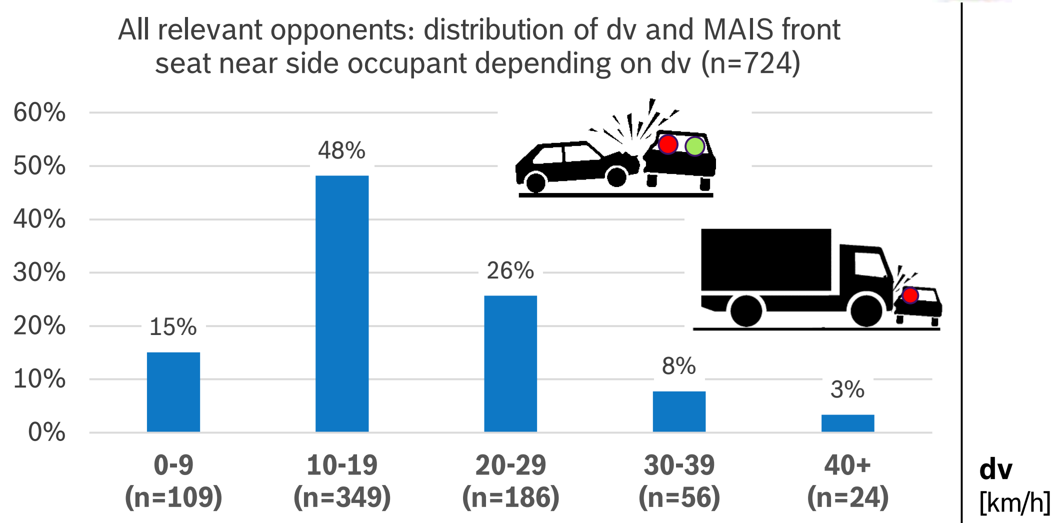
Source: GIDAS 01/2018, cases since 2005

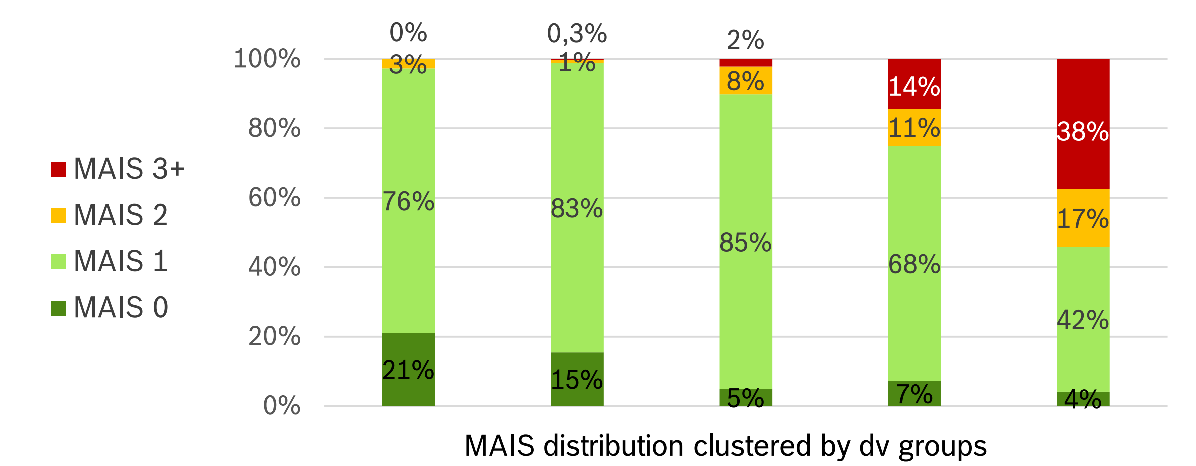
Accident Research - FCTA
MAIS vs. dv – near side occupant

- Difference in amount of cases in comparison to previous slide due to MAIS=0 (n=91) of near side occupant in case of injury for far side occupant only
- To get a clear picture: separation of passenger cars and trucks on next slide

MAIS distribution of frontal near side occupant for all relevant side crashes







- In ~3% of affected cars near side occupant suffers MAIS 3+ injury, ~13% uninjured

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AEV-064 annual report 2018

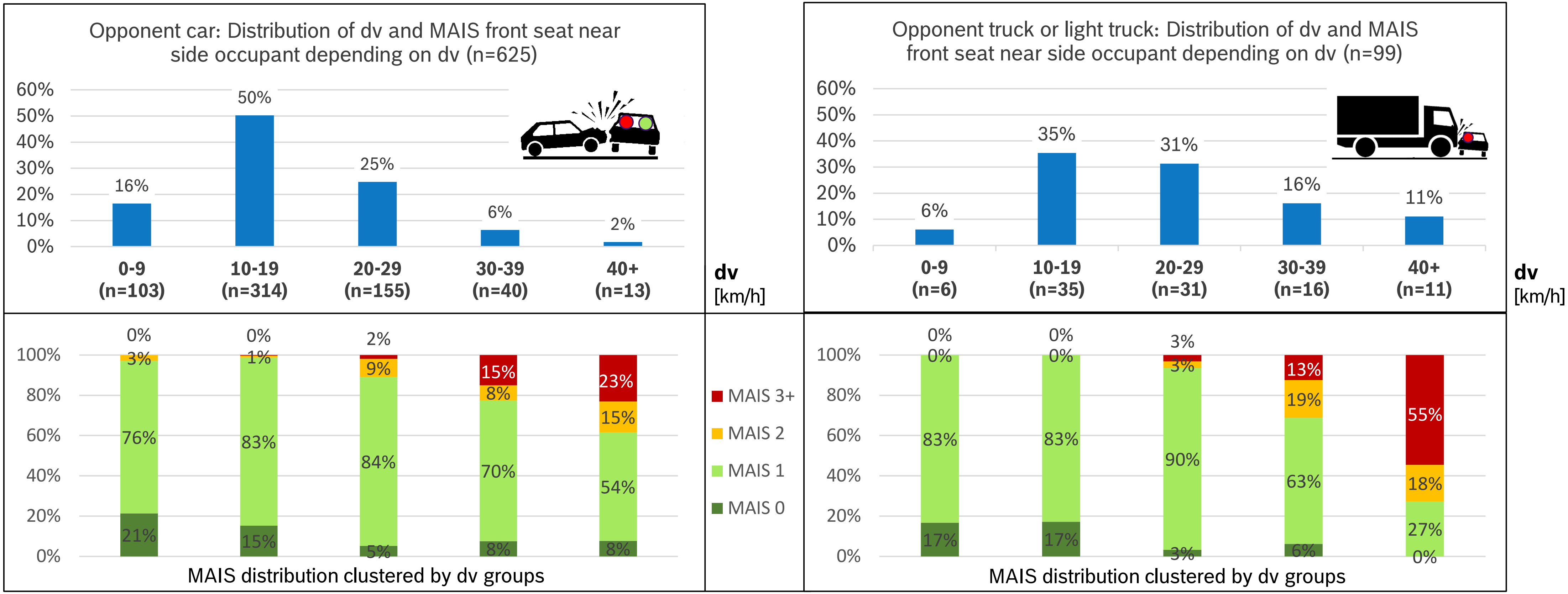
Source: GIDAS 01/2018, cases since 2005

Accident Research - FCTA

498 52% | 288 30% | 135 14%

Chapter 05

MAIS vs. dv – front seat near side occupant



▶ Clear dependency of MAIS from dv

Trucks @dv=40+ : higher severity due to three cases w/ dv=60-69km/h)

Definitions: car corresponds to GIDAS FZGKLASS 1-13; truck and light truck to FZGKLASS 14-33 (bus included)

Source: GIDAS 01/2018, cases since 2005

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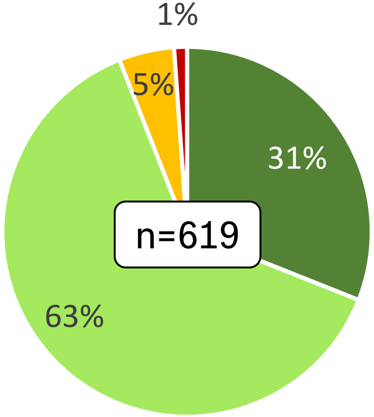
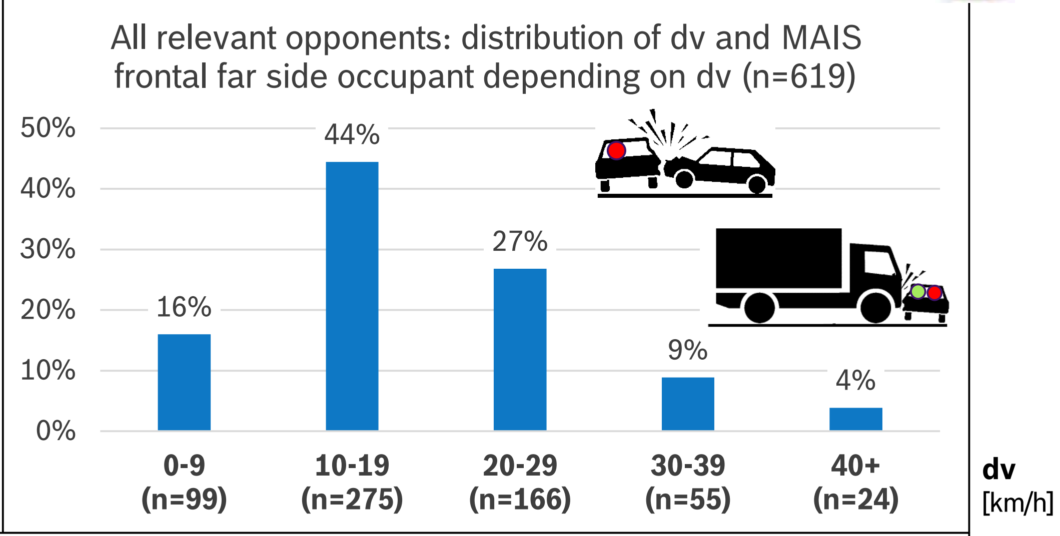
Accident Research - FCTA

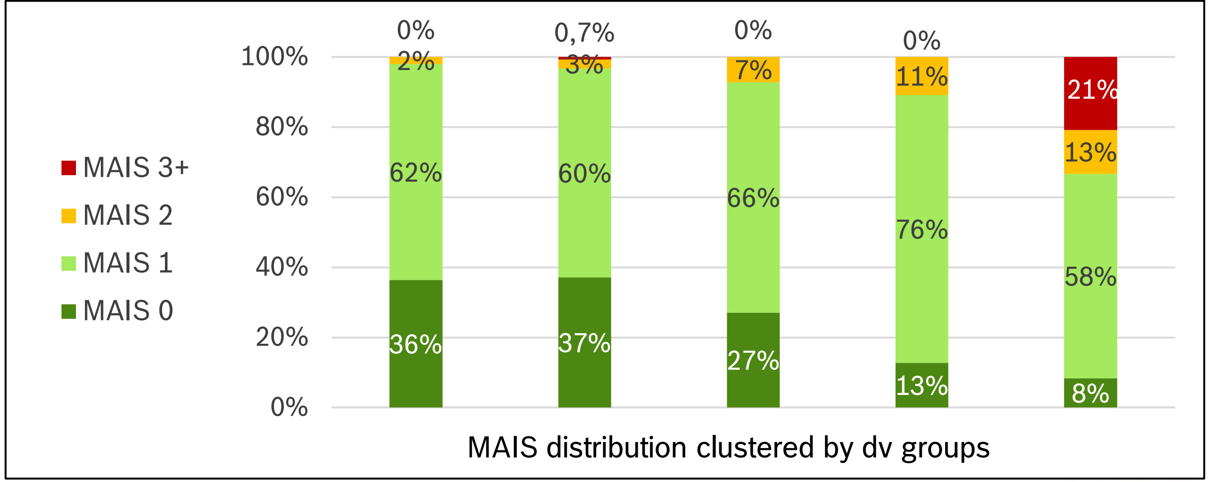
MAIS vs. dv – far side occupant

- Difference in amount of cases in comparison to a previous slide due to MAIS=0 (n=192) of far side occupant in case of injury for near side only
- To get a clear picture: separation of passenger cars and trucks on next slide

MAIS distribution of frontal far side occupant for all relevant side crashes







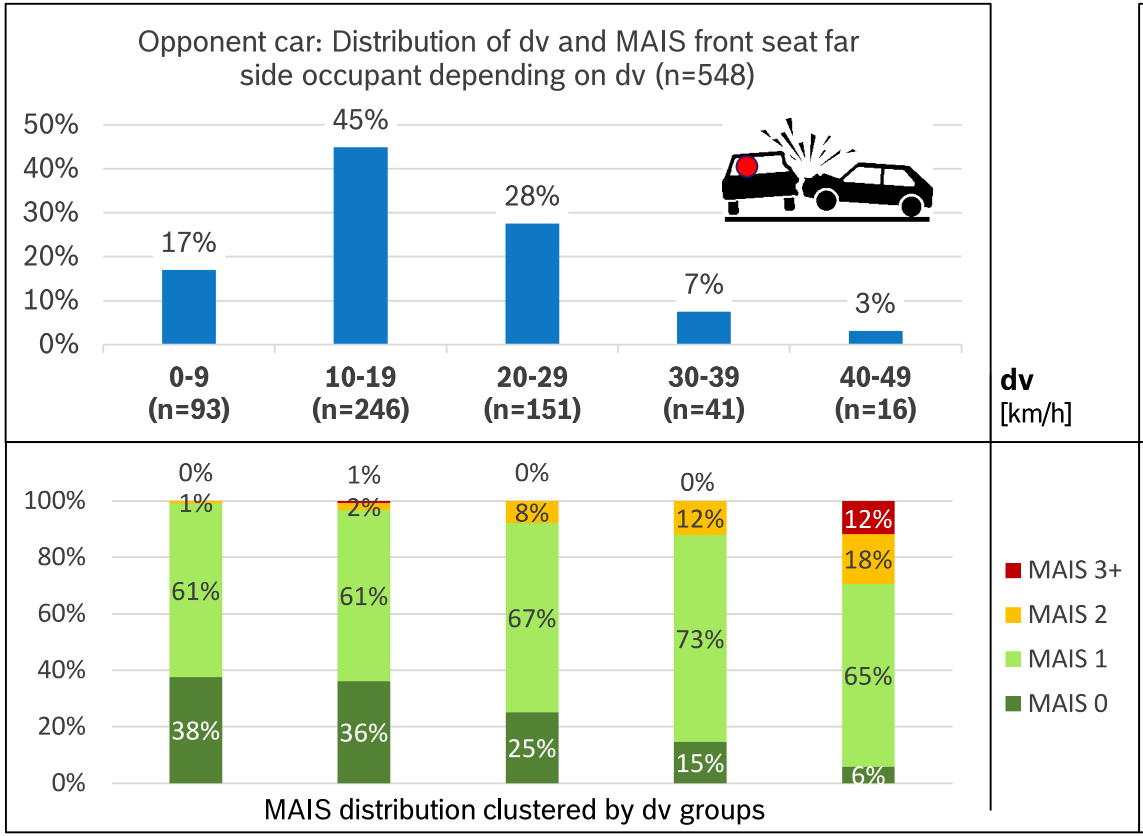
- In >30% of affected cars far side occupant suffers no injury; ~1% MAIS 3+ injury

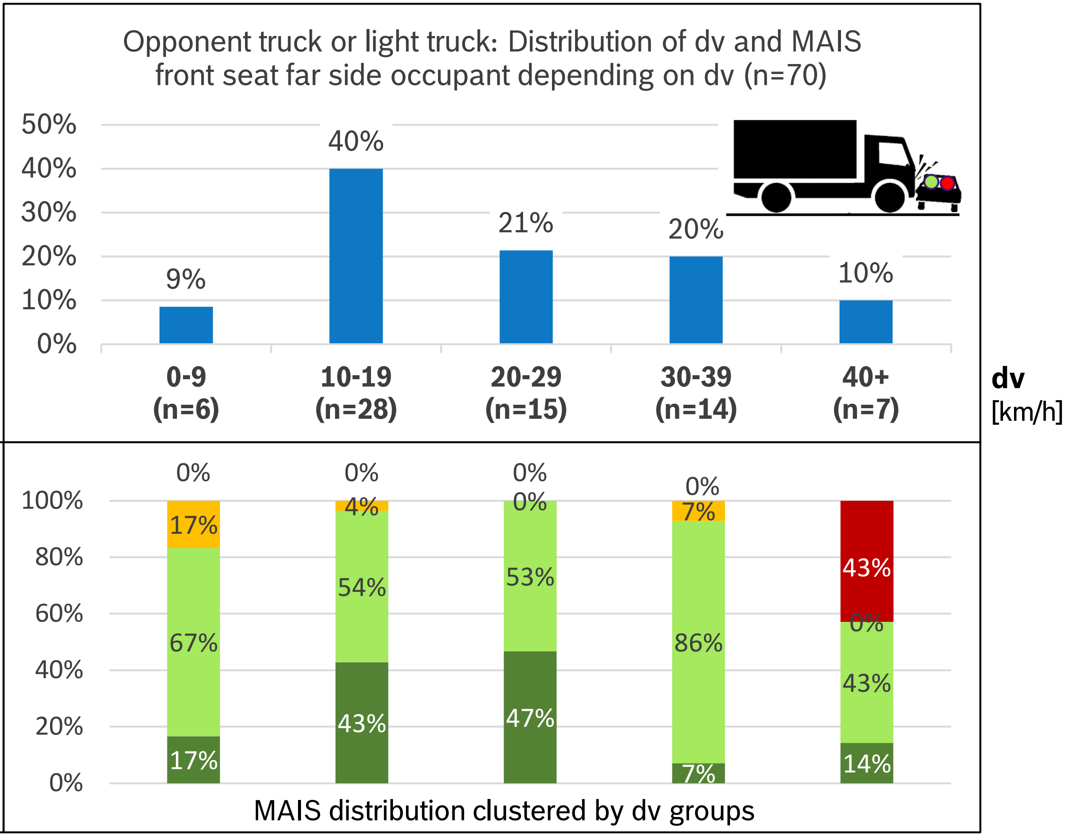
Source: GIDAS 01/2018, cases since 2005

Accident Research - FCTA

498	288	135
52%	30%	14%

MAIS vs. dv – front seat far side occupant





▶ Clear dependency of MAIS from dv

<u>Trucks @dv=40+ :</u> higher severity due to two cases w/ dv=50-79km/h

Definitions: car corresponds to GIDAS FZGKLASS 1-13; truck and light truck to FZGKLASS 14-33 (bus included)

Source: GIDAS 01/2018, cases since 2005

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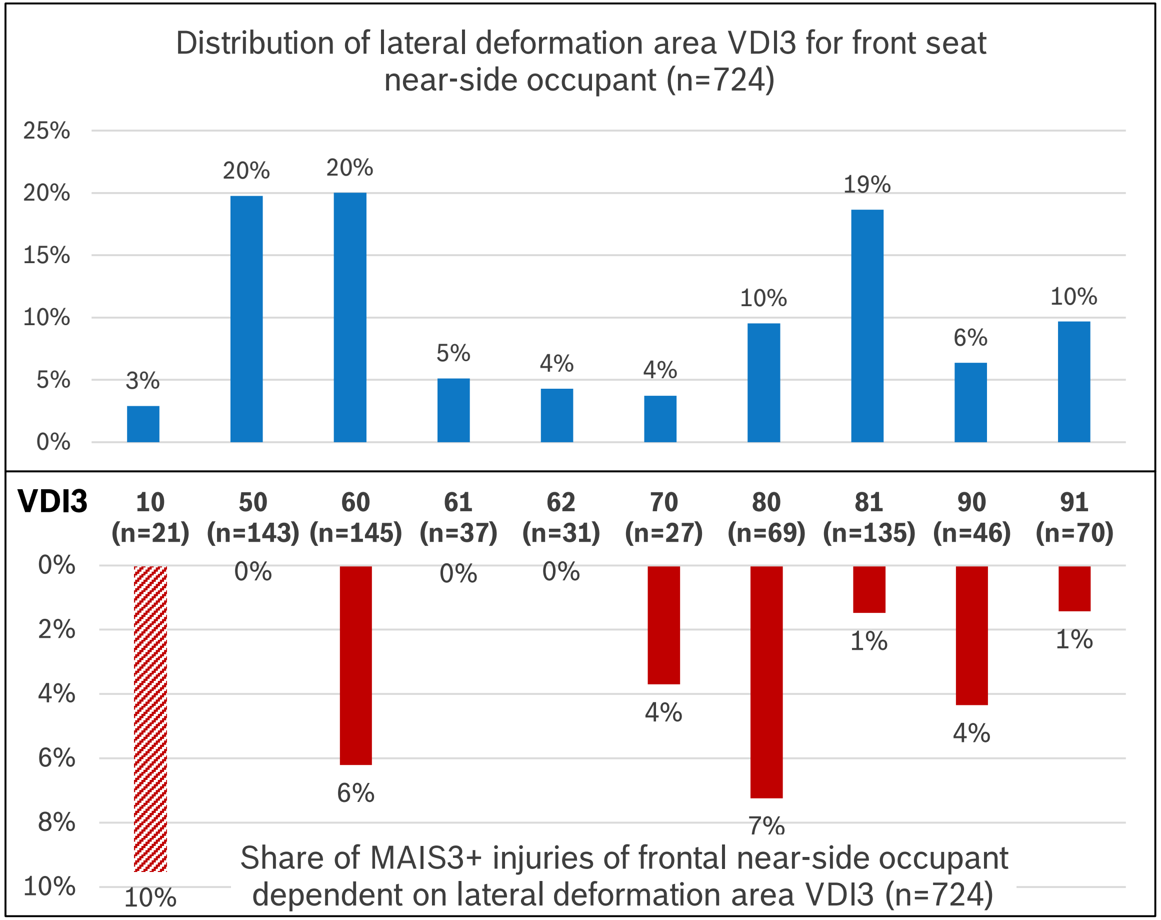
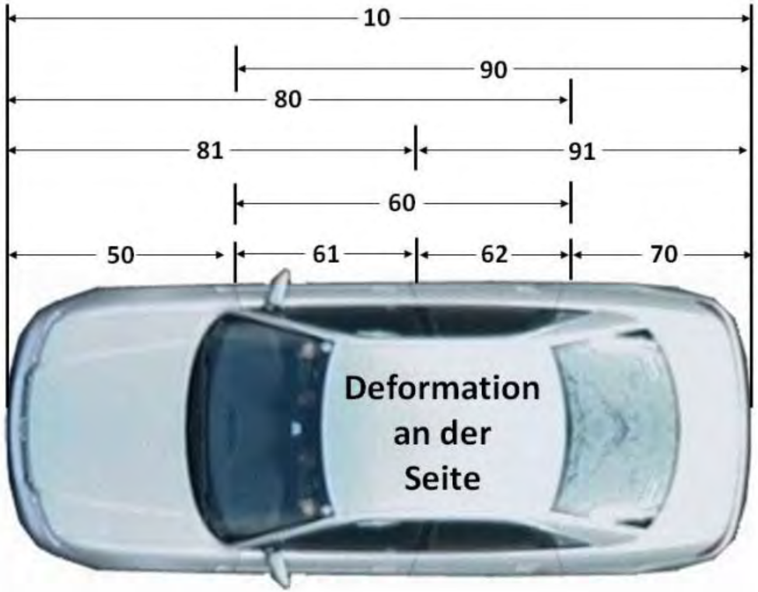
VDI3 near side: Lateral deformation vs. MAIS



Definition of **VDI3** (for details see annex):

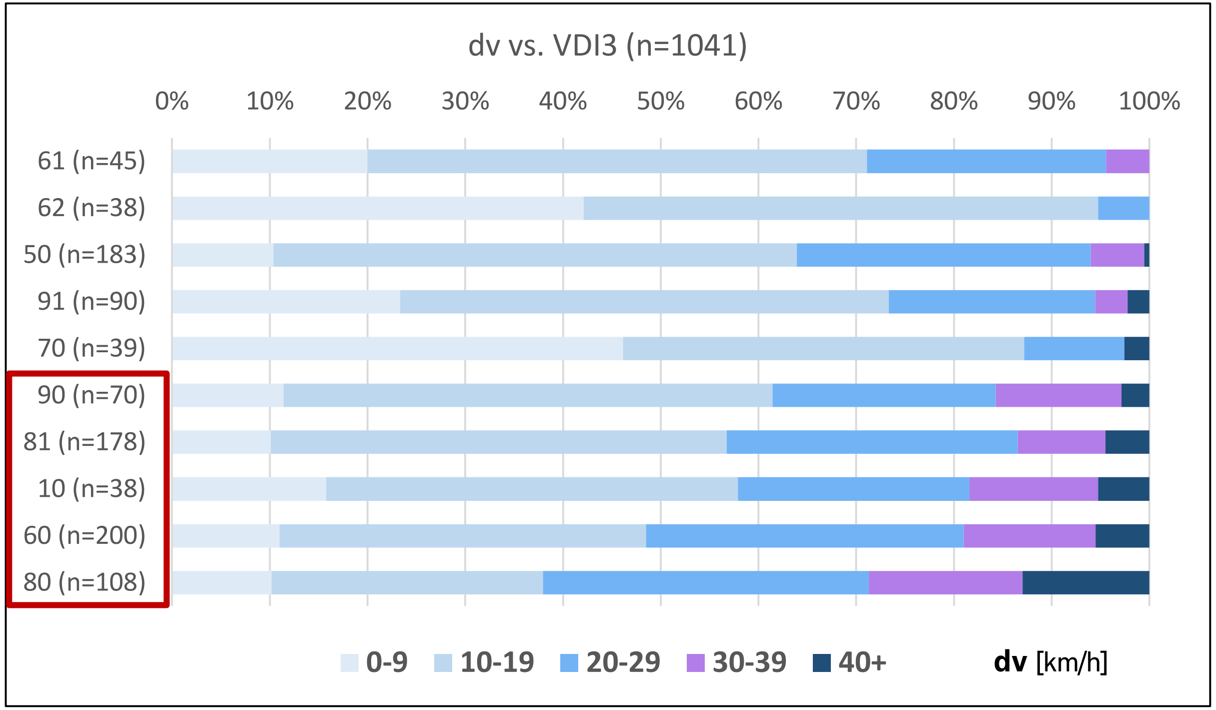


- Carefully interpretation of results due to small numbers in a few groups (e.g. VDI3=10)!
- Potentially “safest” lateral collision area: VDI3=50

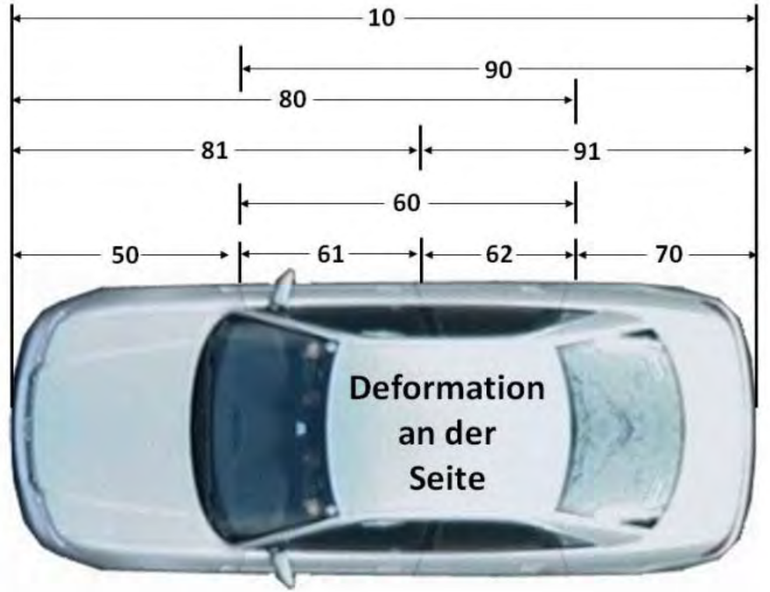
Source: GIDAS 01/2018, cases since 2005

Accident Research - FCTA

Distribution VDI3 dependent on dv



Definition of **VDI3** (for details see annex):



Source: GIDAS 01/2018, cases since 2005

▶ In general, higher dv induce wider deformation areas

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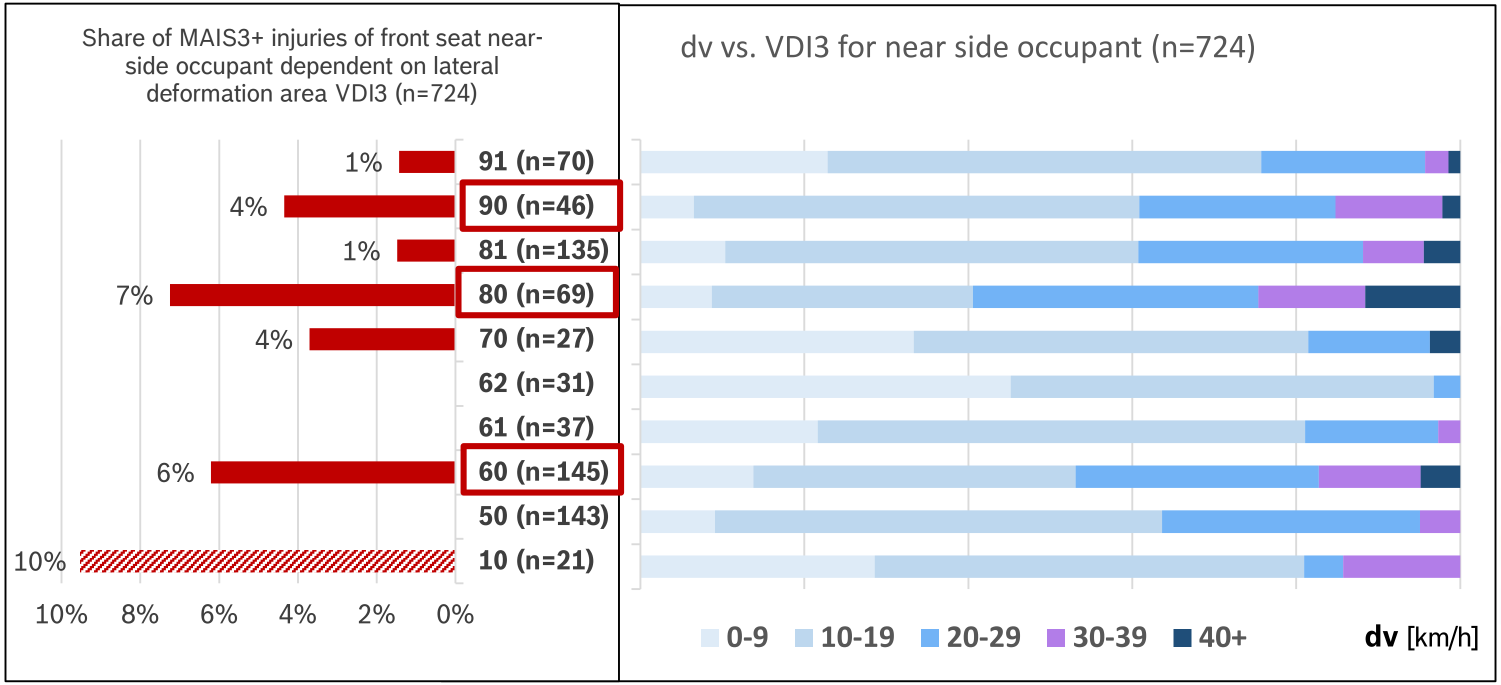
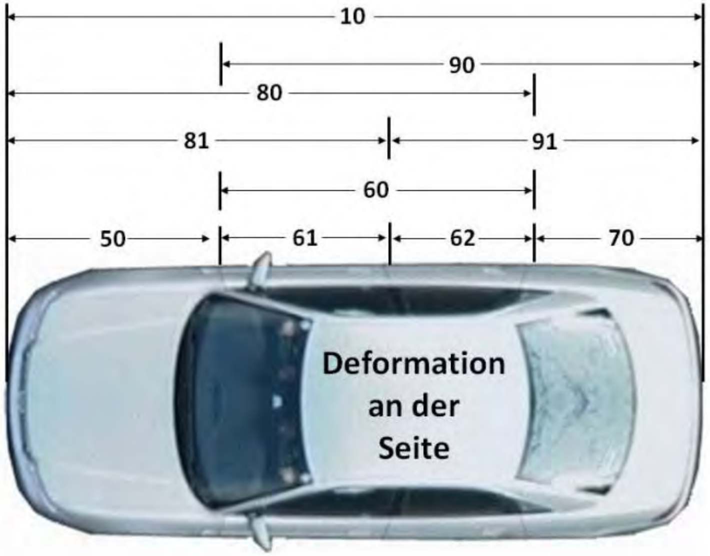
VDI3 over dv for front near side occupant relevant cases



shaded areas: not suitable for evaluation due to small number of cases

Definition of **VDI3**:



Source: GIDAS 01/2018, cases since 2005

- Critically: if cabin is involved in a collision w/ dv ≥ 30km/h (e.g. VDI3=60/80/90) → see red frames in diagram
- Cases w/ VDI3=81 have partially similar characteristic like VDI3=50 (collisions with minor damage of cabin)

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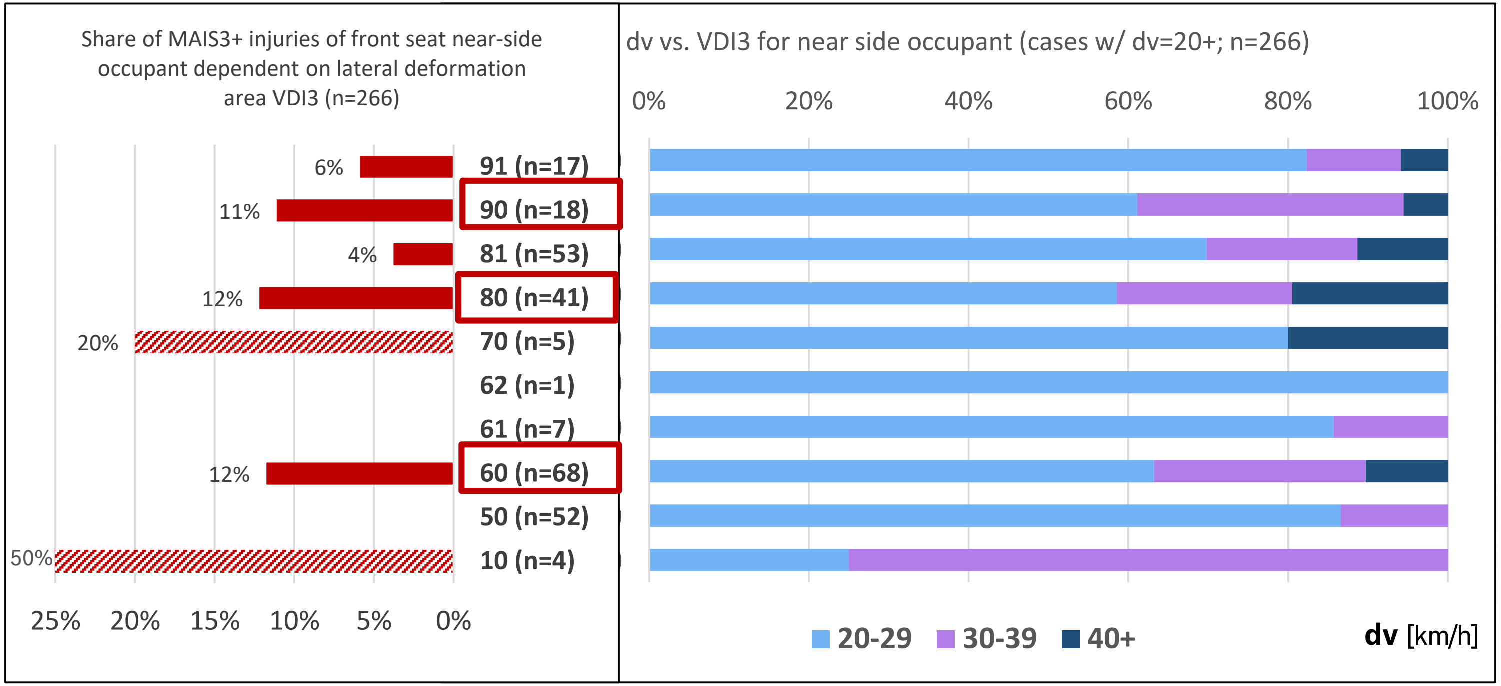
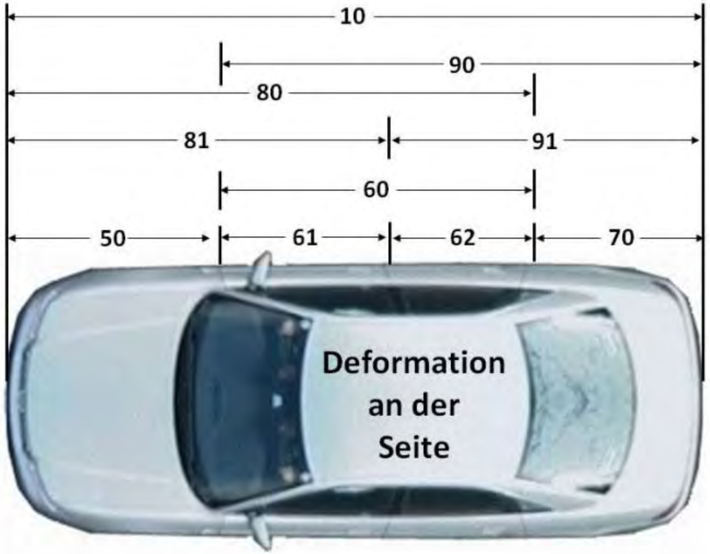
VDI3 over dv for front near side occupant relevant cases (dv20+)



shaded areas: not suitable for evaluation due to small number of cases

Definition of **VDI3**:



Source: GIDAS 01/2018, cases since 2005

- Critically: if cabin is involved in a collision w/ dv ≥ 30km/h (e.g. VDI3=60/80/90) → see red frames in diagram
- Cases w/ VDI3=81 results in lower share of MAIS3+ in spite of high dv

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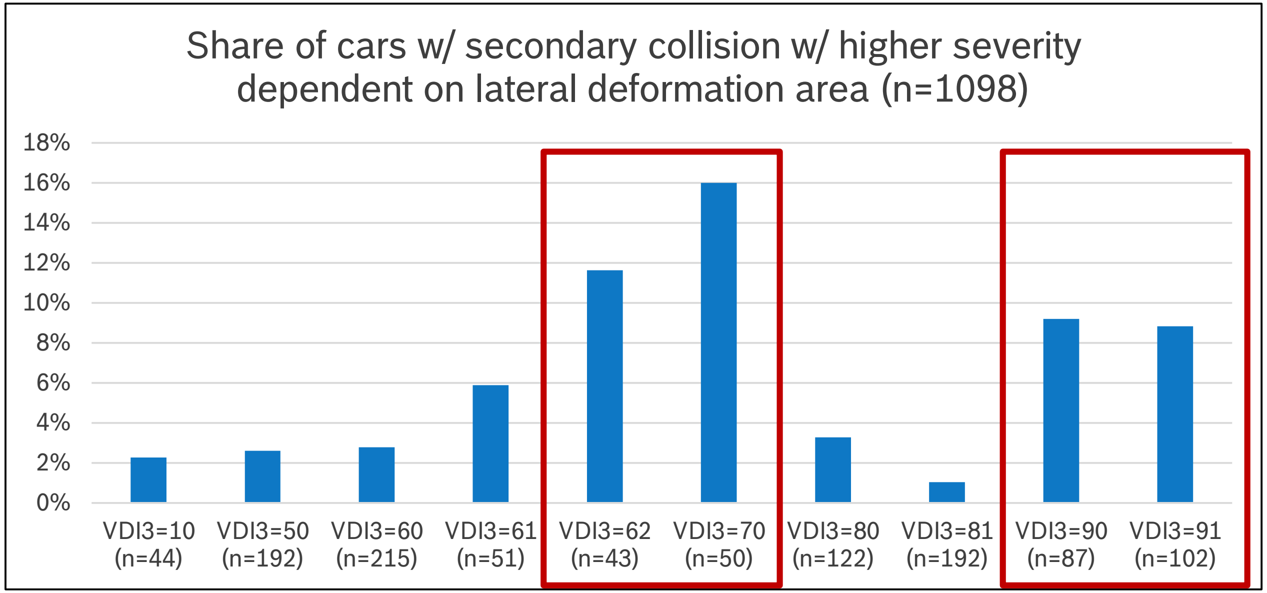
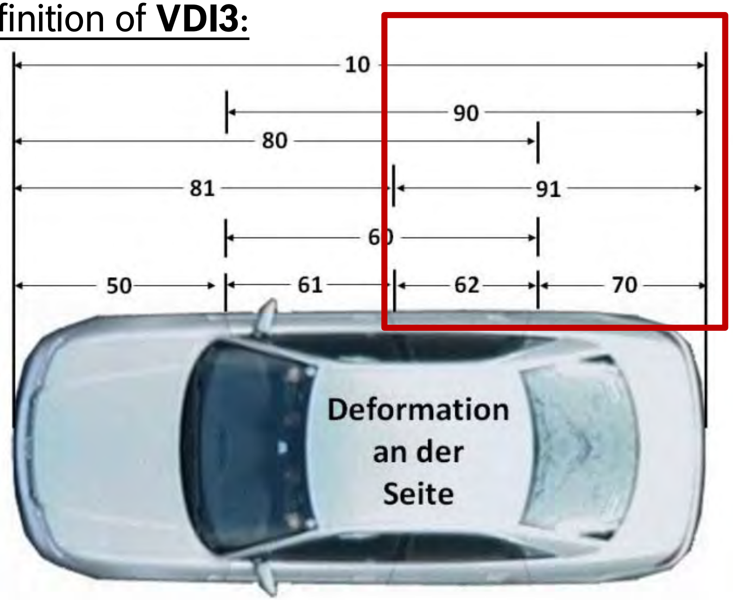
1 098

Cars w/ subsequent collisions w/ higher severity than 1st collision



Definition of **VDI3**:



- ~5% (n=54) of relevant cars suffer a subsequent collision w/ higher severity than 1st collision
- Distribution of secondary collisions plausible from driving dynamics perspective: rear axle is the track-guiding axle, instability in the rear area of the car leads much more easily to skidding than in the front area
- Risk of skidding: uncontrolled trajectory of vehicle which can lead to further collisions with objects or other road users including pedestrians on sidewalk

Source: GIDAS 01/2018, cases since 2005

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Accident Research - FCTA

Recommendations out of Accident Research

- If impact area is **adjustable**, it should be outside of lateral cabin area (VDI3 != 60 / 61 / 62)
- If lateral collision is unavoidable: "safest" lateral collision area is front fender
- If predicted lateral impact area is rear part of car → possible avoidance by acceleration boost (vehicle in front of ego has to be considered!)

  → for electric drive / hybrid: highest possible overload of electrical motor;

  → for combustion engine: "kick-down" (full throttle, insert suitable gear for most possible acceleration in advance)

- **Braking intervention reasonable if (virtual) collision point can be moved…**

  a) in front of car (no collision → **accident avoidance**) or

  b) at least to front fender (VDI3=50) → area with the lowest expected injury severity

- **Acceleration intervention reasonable if collision can be avoided thereby**

  → virtual collision point will be moved behind ego car

Source: GIDAS 01/2018, cases since 2005

TechCenter i-protect
Overview KAUSAL

Accident Research
CR/AEV1

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KAUSAL

a virtual tool chain to estimate the impact of automated driving on occupant restraint systems

Daniel Schmidt

with

H. Freienstein, G. A. D'Addetta, T. Lich, A. Georgi (Robert Bosch GmbH)
J. Dobberstein, P. Lewerenz, A. Öztürk, C. Geisler (Daimler AG)
K. Blenz, M. Mai (TU Dresden)
F. Ressi, W. Sinz (TU Graz)

ESAR conference, April 20, 2018

KAUSAL - a virtual tool chain

Motivation

- Many companies are working on Highly Automated Driving (HAD; SAE level 4)
- HAD enables new interior designs and seating positions
- Accidents will still occur in future due to
  - mixed non-AD / AD traffic
  - unpredictable behavior of VRUs

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- **Need for integrated occupant restraint systems**

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Introduction

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Target:

optimize and improve vehicle safety

Areas of activity

- Accident reconstruction
- Preventive occupant protection

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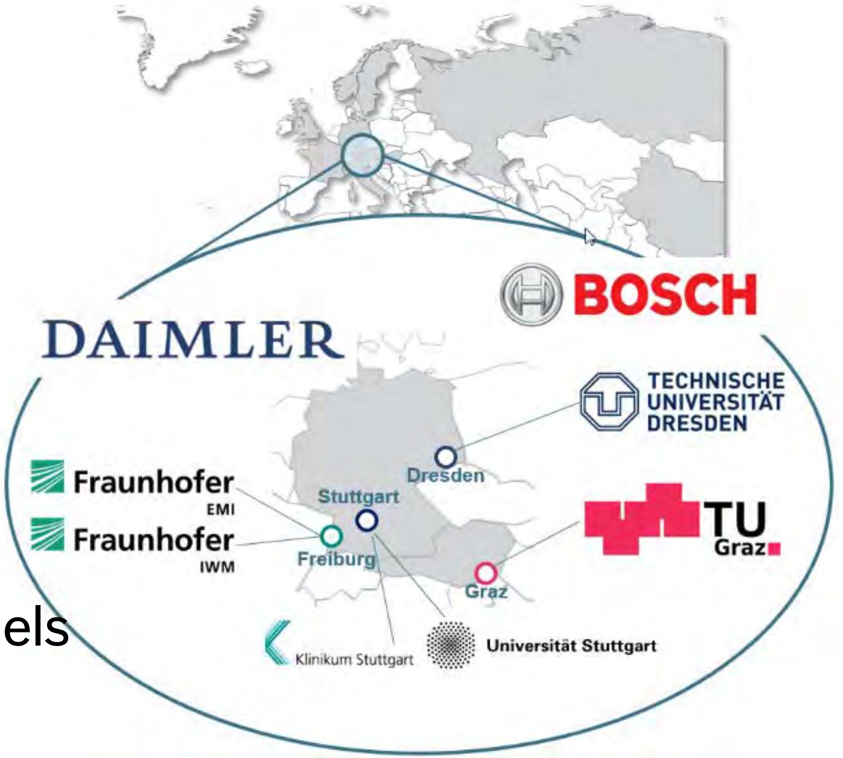
- Alternative occupant restraint systems and human models
- Future testing technologies in vehicle safety
- Innovative materials



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iProtect: Project KAUSAL

Tech Center i-protect

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„Auswirkung automatisiertes Fahren auf Rückhaltesystem-Gestaltung“

TU Graz BOSCH DAIMLER TECHNISCHE UNIVERSITÄT DRESDEN

Research question:

What will be

(1) relevant non-preventable accident scenarios
(2) on highways
(3) with high probability for large severity

with respect to Highly Automated Driving?

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Tool chain overview

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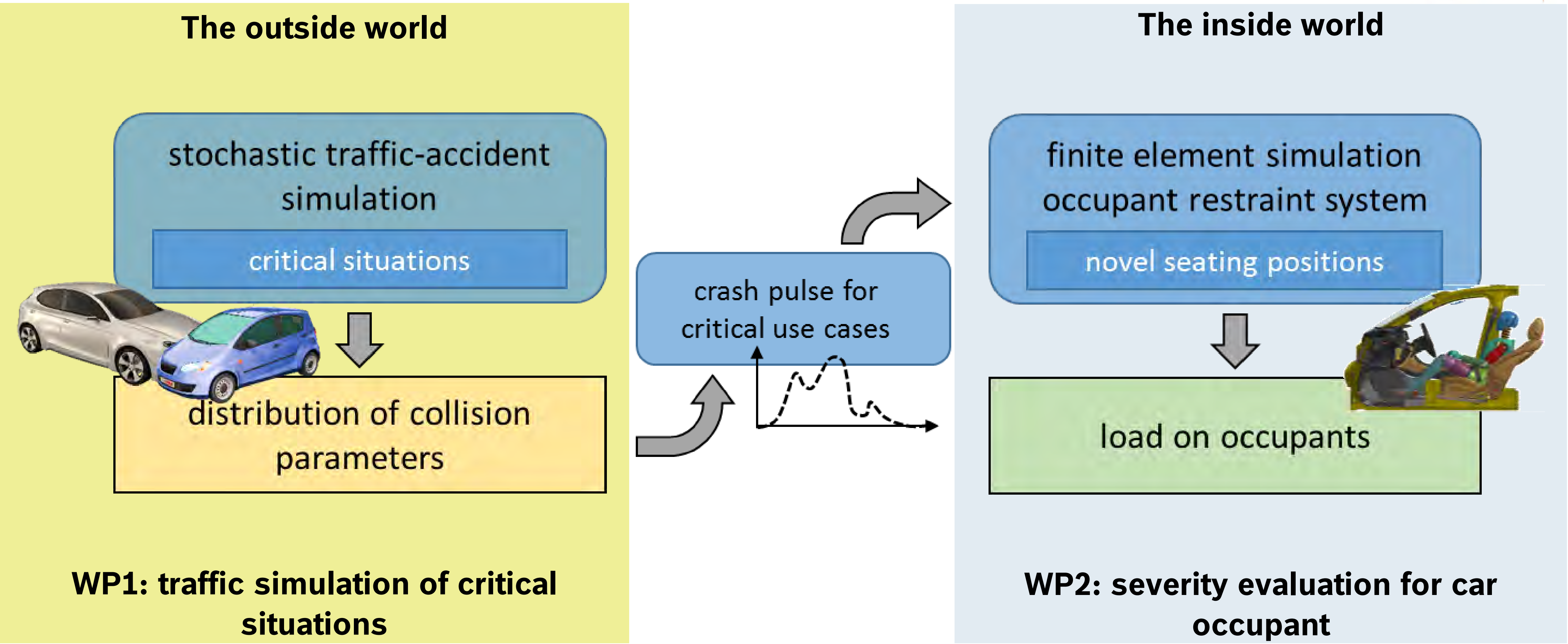

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WP1: Stochastic traffic simulations of critical situations

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▶ Simulation framework

openPASS

enable simulations of traffic situations to predict real-world effectiveness of ADAS and AD functions

Source: TU Dresden /AMFD

▶ Identified scenarios

traffic jam: opponent collides w/ end of traffic jam

traffic jam: opponent initially hidden

lane change: lane change from behind obstruction

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Example: emergency lane change of preceding car

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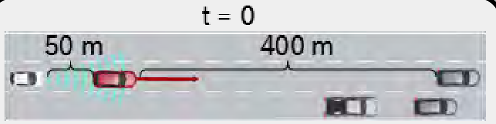
Assumptions:



HAD (white car)
- $\triangle t$ = 1.8s to prec. car
- v_{max} = 130kph
- Delay system ≤ 0.5s
- AEBS w/ TTC_{max} = 2.5s
- ...

Preceding car (red car)
- initiate lane change manoeuver @ distance to obstacle >50m
- max. lateral acc 2m/s²
- ...

...

Accident scenario

traffic jam: opponent initially hidden

Data basis:	10 000 simulations
(for this set-up)	3 617 collisions

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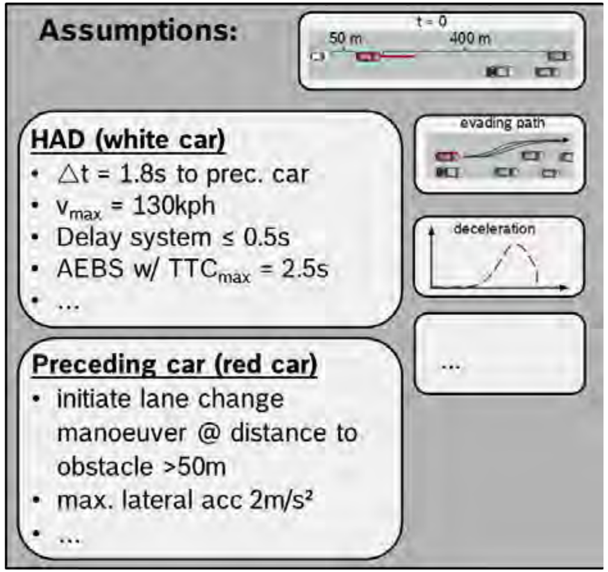
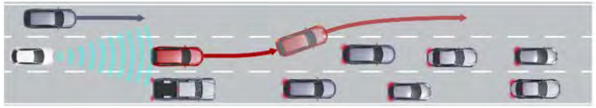
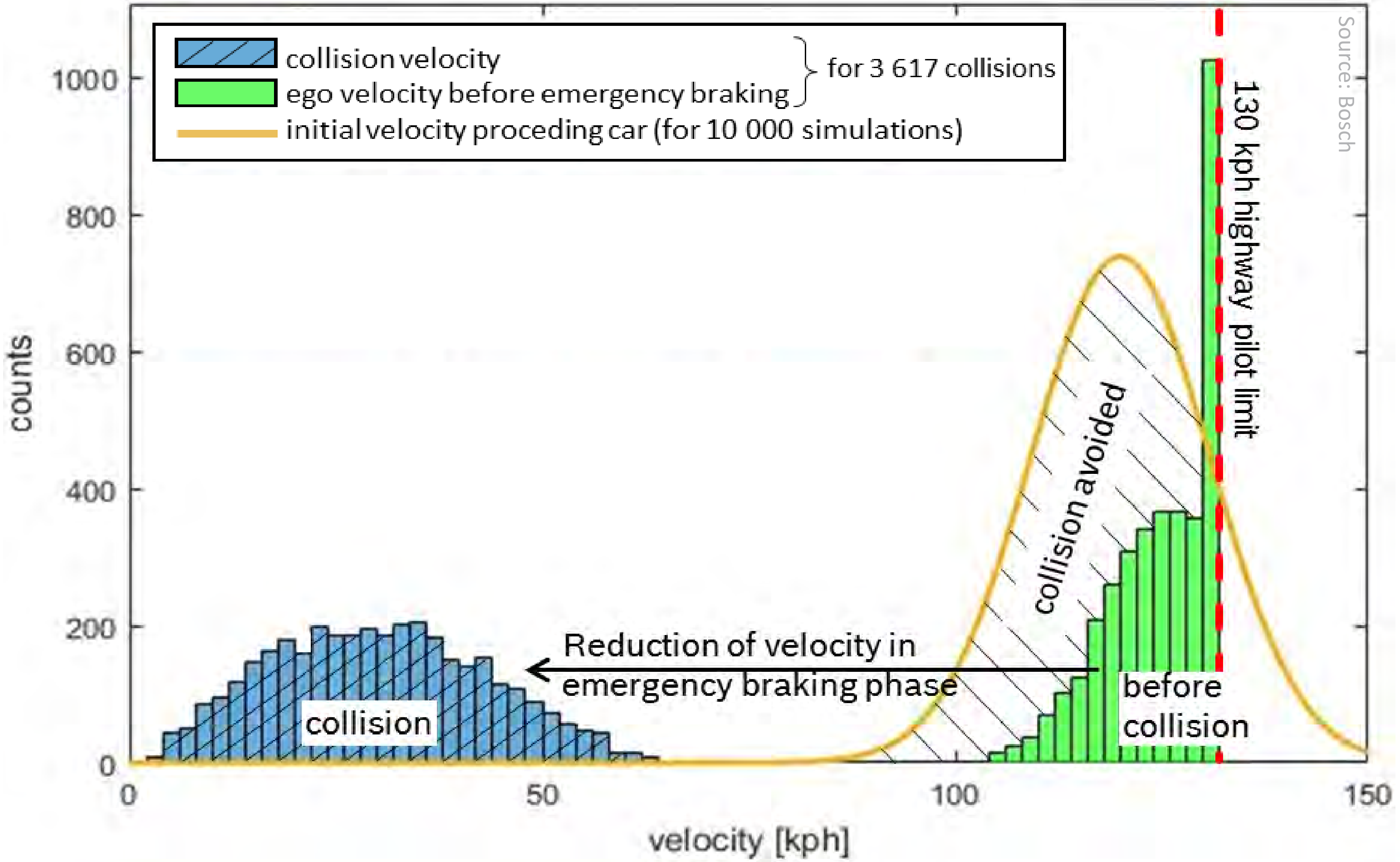
Example: results





Data basis: 10 000 simulations

(for this set-up) 3 617 collisions



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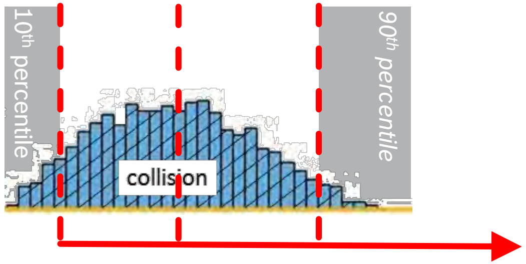
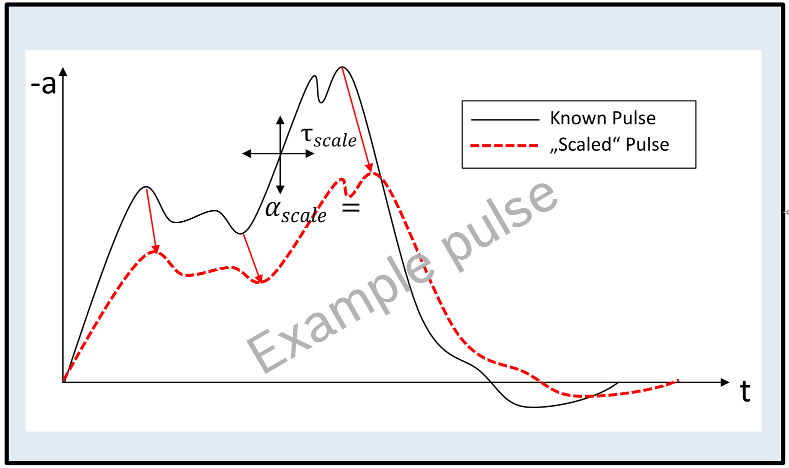
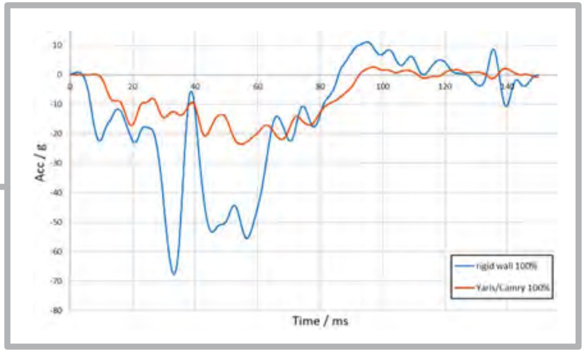
Crash pulse generation

Multidimensional scaling of crash pulses to velocity of interest
- full frontal vs. moderate frontal overlap

Relevant crash parameters
- collision velocities
- offset & collision angle
- …



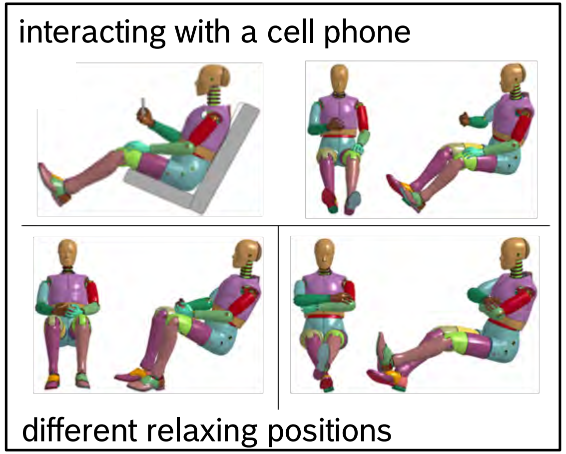


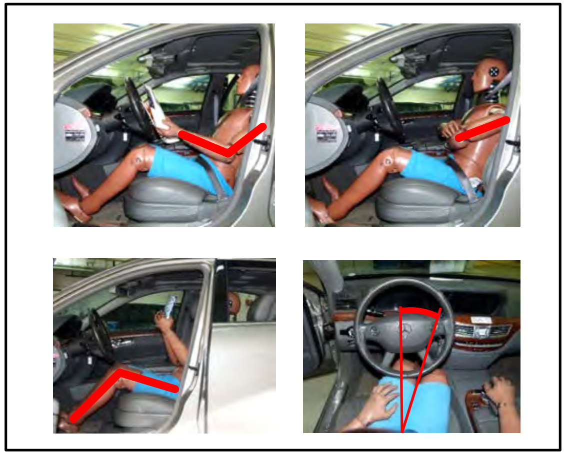


▶ **Crash pulse used for occupant crash simulation**

KAUSAL - a virtual tool chain
WP2: Novel seating positions in automated vehicles

Severity evaluation for car occupant:
- Variations of seating positions of drivers in automated vehicles (SAE level 4)
  - seat longitudinal adjustment
  - back angle
  - arm & leg positions
  - ...
- State-of-the-art restraint systems
- Detailed FEM simulation of Hybrid III Dummy





Source: TU-Graz I VSI

Aim:
▶ Loads on occupant wrt novel seating positions
▶ Possible adjustments to further improve current restraint system

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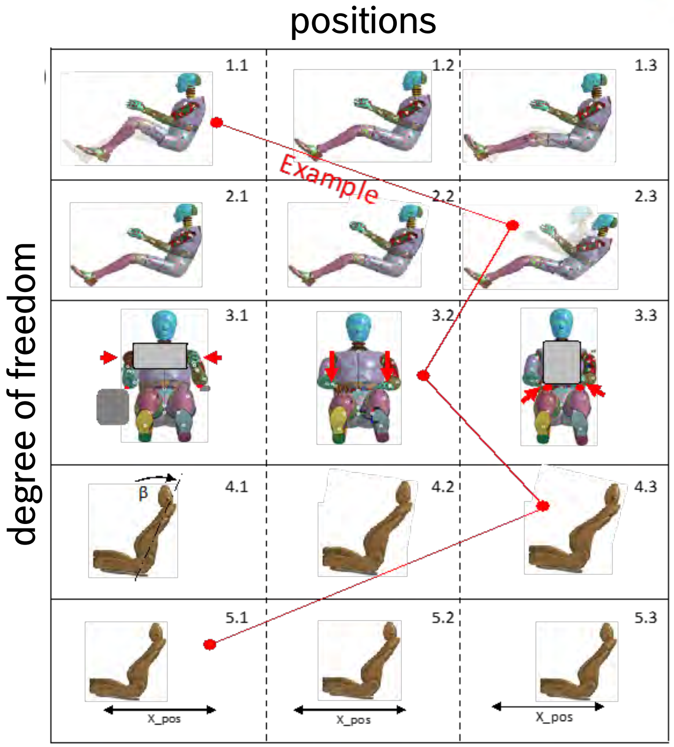
WP2: Challenges

huge overall computational costs

- large computational costs for each FEM simulation
- different sizes of Hybrid III Dummy
- many combinations of new seating positions
- various crash pulses from accident scenarios



possibilities

➔ $3^5 = 243$

Note:
Positions were created for visualization only – some are infeasable w/ hardware dummies.

Source: TU-Graz I VSI

Minimize number of combinations by

▶ expert knowledge of frequent and critical situations

▶ further prioritization of accident scenario simulations (WP1)

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Conclusions and next steps

Tech Center i-protect: KAUSAL

(1) Stochastic simulation of potentially non-preventable scenarios for HAD

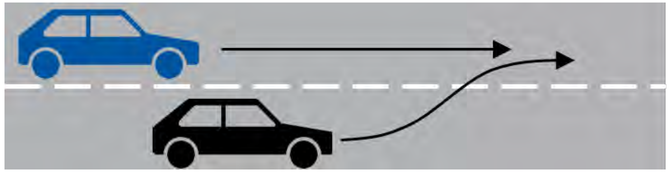
(2) Crash pulse generation

(3) Detailed FEM simulations (Hybrid III) in new seating arrangements for HAD (from SAE level 4) w/ current occupant restraint systems

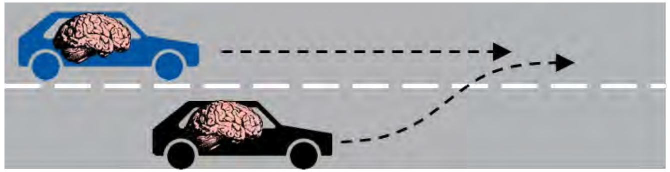
Next steps → 2018

- enable drivers with intelligent behaviour for car following and lane change functions
- intelligent cars (and trucks) form realistic motorway traffic

KAUSAL 2017



KAUSAL 2018



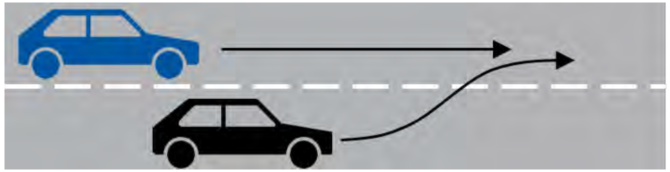
Bosch Accident Research – KAUSAL 2018

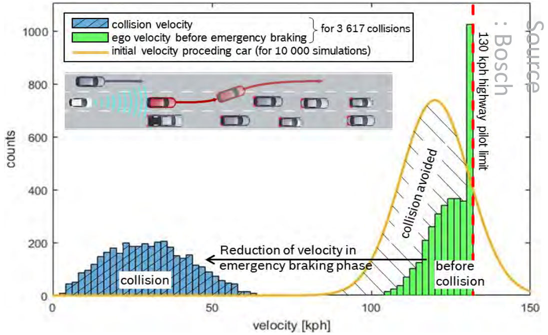
Targets of KAUSAL in 2018

Tech Center i-protect

openPASS

KAUSAL 2017





Results (example): 10 000 simulations
3 617 collisions

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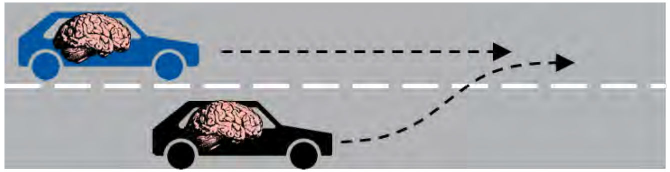
Aim 2018:

Replace agents through “intelligent” agents, thus self initiated longitudinal- and lateral manoeuvring enabled

KAUSAL 2018



➔simulation of free traffic on motorway possibly

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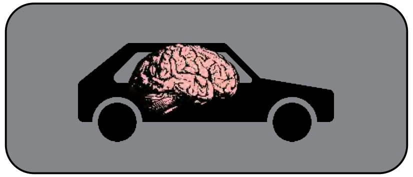
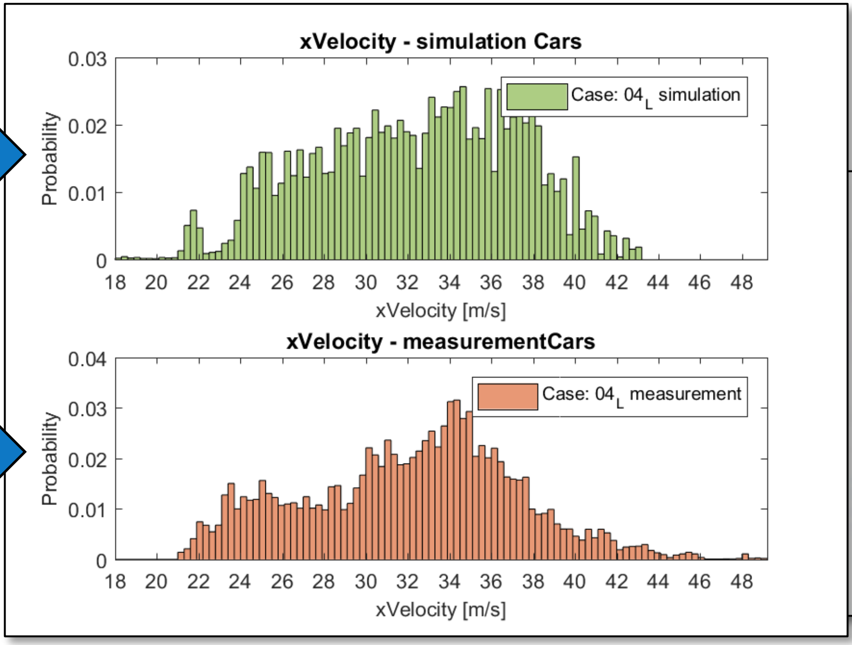
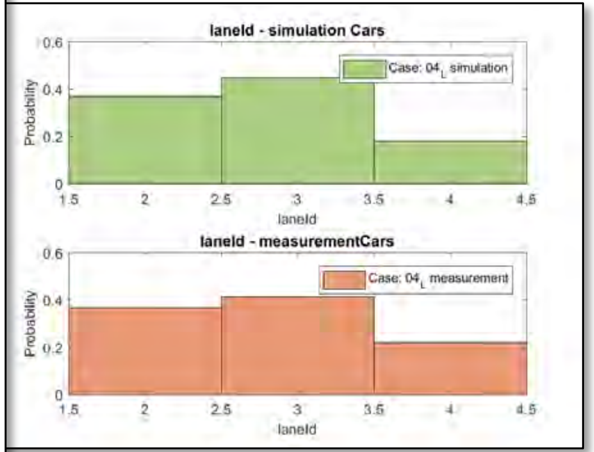
Bosch Accident Research – KAUSAL 2018
Plausibility of an intelligent traffic simulation

- **Interim results:** “*Intelligent motorway traffic simulation” realized*
- **Open topics:** Will the road traffic simulation plausible?
- **Approach:** Comparison simulation versus real-world traffic observation data

Source: https://www.highd-dataset.com/





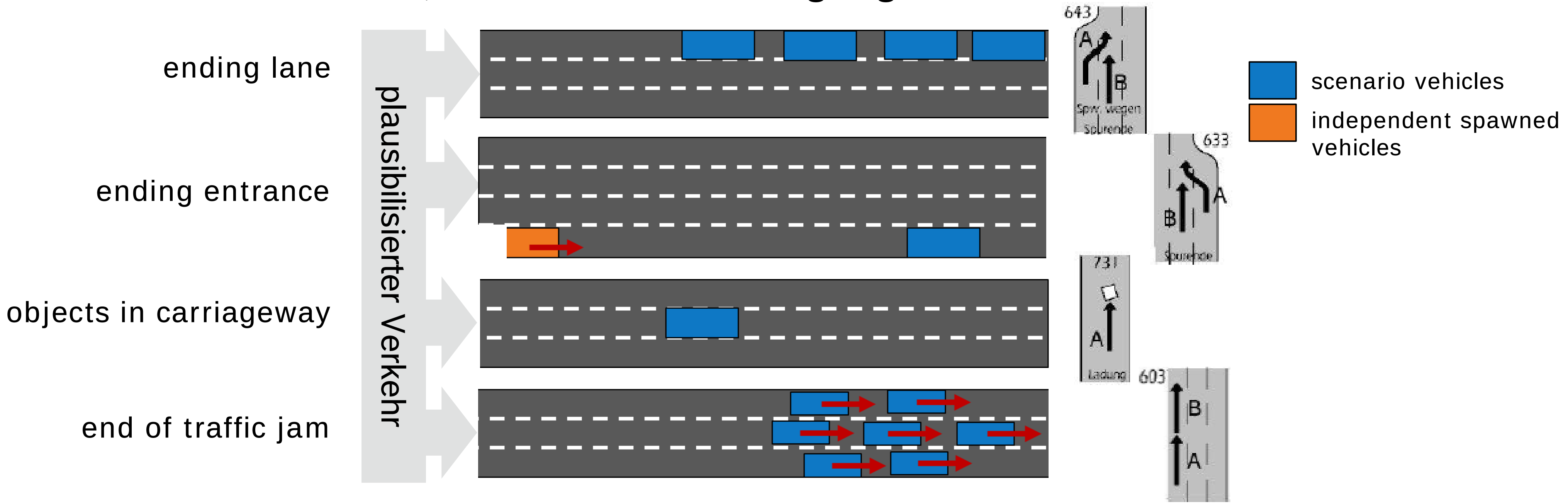


▶ Parametrization for motorway (car/truck) according to various values verified

Bosch Accident Research – KAUSAL 2018

KAUSAL 2018: Simulation of accidents

- **Challenges:** agents well know their environment, hence no crashes occur
- **Approach:** accidents initiated by “scenarios” – similar like in AdaptIVe
- **Status:** simulations available, final evaluation still ongoing



▶ According to roadmap final results being available in March 2019

India: Loss of control car accidents – benefit estimation of Electronic Stability Control

Accident Research
CR/AEV1

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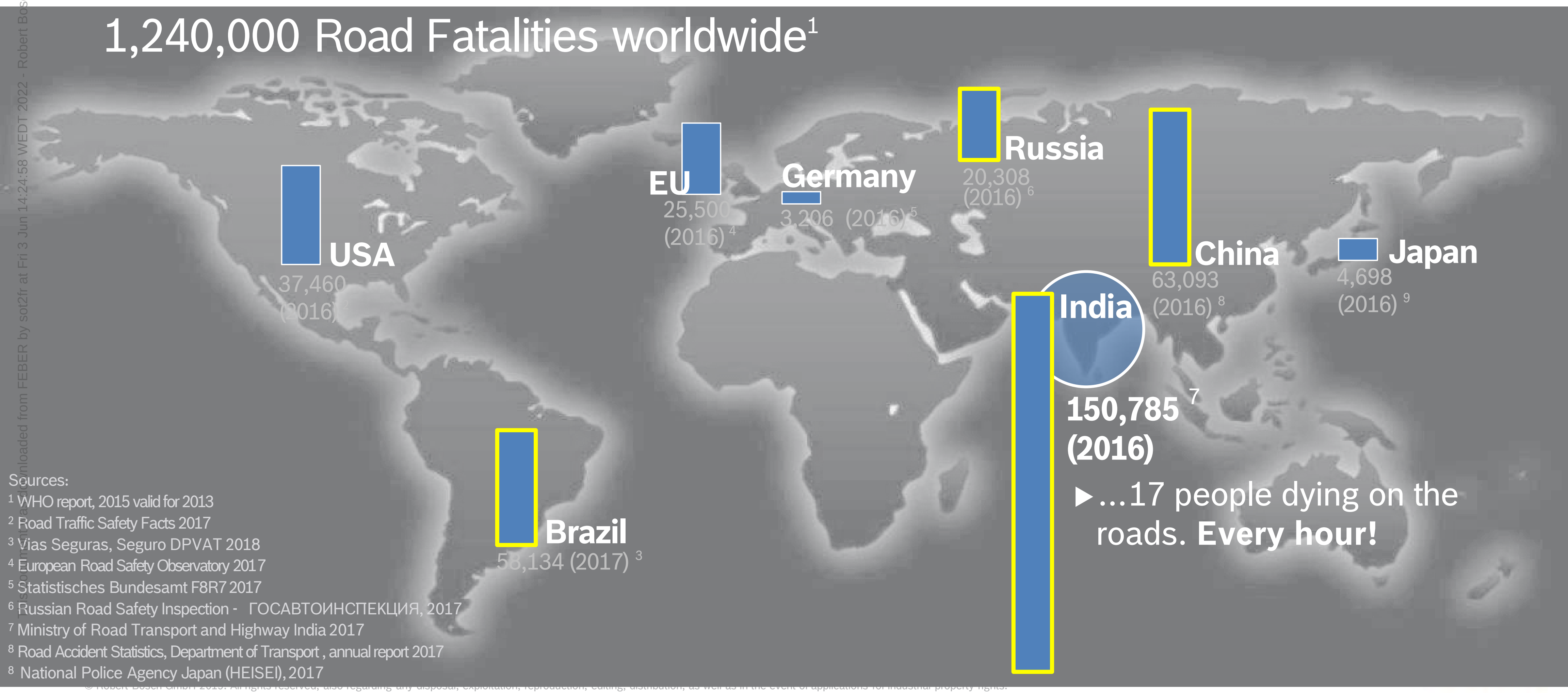
Loss of control car accidents – benefit of ESC

Publication SAE 2019-26-0009

Results published in a SAE Paper and Presentation at Symposium on International Automotive Technology 2019 in Pune India

Loss of control car accidents – benefit of ESC

What drives us?



Sources:

1 WHO report, 2015 valid for 2013
2 Road Traffic Safety Facts 2017
3 Vias Seguras, Seguro DPVAT 2018
4 European Road Safety Observatory 2017
5 Statistisches Bundesamt F8R7 2017
6 Russian Road Safety Inspection - ГОСАВТОИНСПЕКЦИЯ, 2017
7 Ministry of Road Transport and Highway India 2017
8 Road Accident Statistics, Department of Transport , annual report 2017
8 National Police Agency Japan (HEISEI), 2017

Loss of control car accidents – benefit of ESC

Data source – Road Accident Sampling System for India

- covers **police**- or **hospital** reported crashes
- detailed documentation

Loss of control car accidents – benefit of ESC

Data representativeness

- police reported crashes well documented in annual statistics (MoRTH)
- 1,286,000 crashes with injuries or heavy damage for India in 2017 determined by including hospital reported crash data

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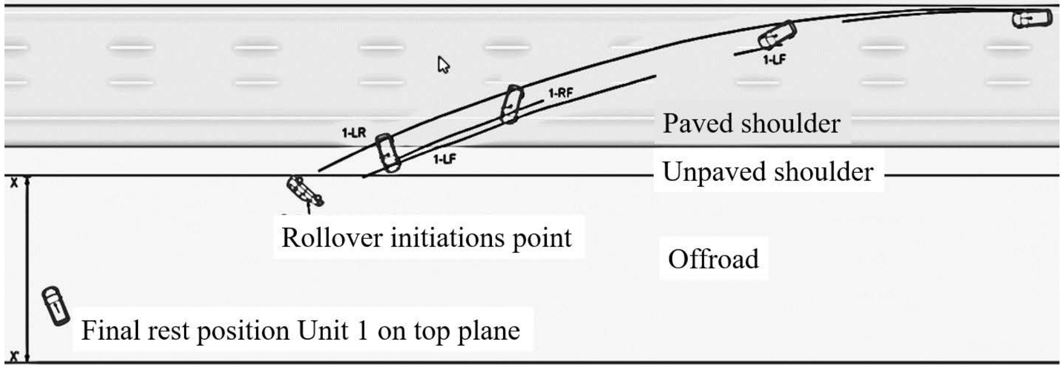
Loss of control car accidents – benefit of ESC

What is a “ ” car accident?

- Before a first impact occurs the …

  car has a precedent skidding maneuver **or**

  driver loss the control to handle his car



Pictures: Bosch Accident Research

RASSI case 91-2017-010-0059

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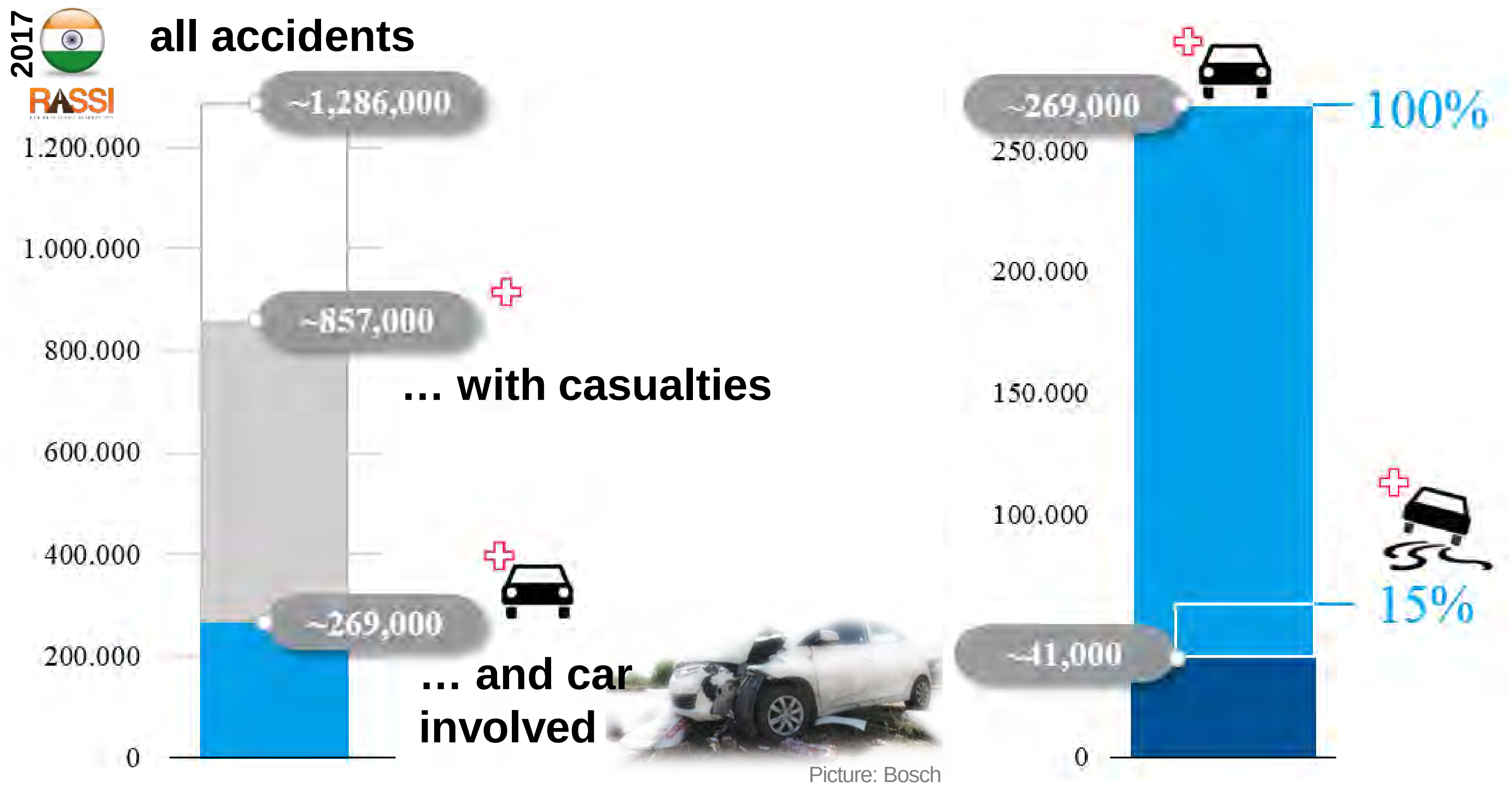
Loss of control car accidents – benefit of ESC

How often are "loss of control" car crashes?



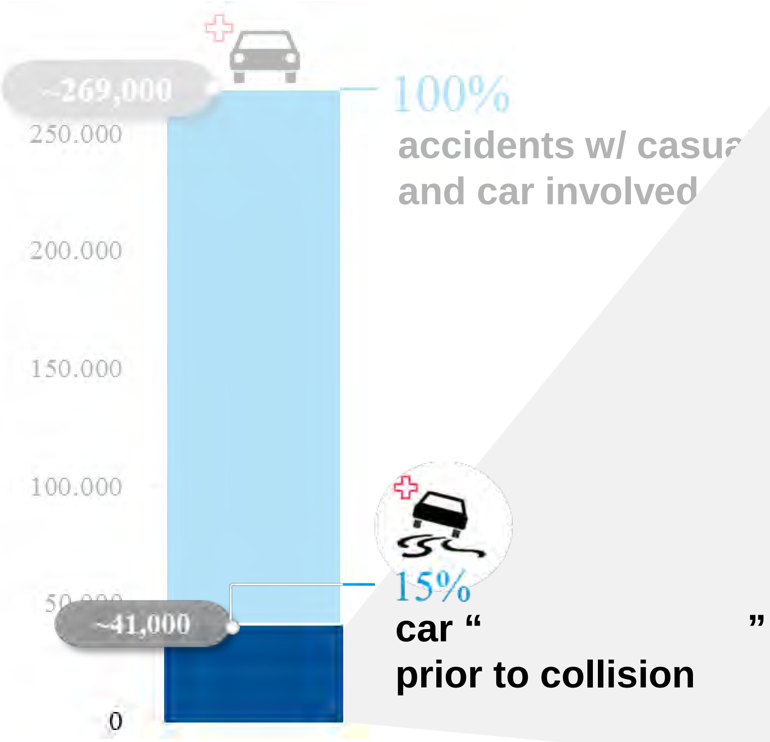
Picture: Bosch

▶ **41,000 car crashes** with casualties occur due to " " in India p.a.

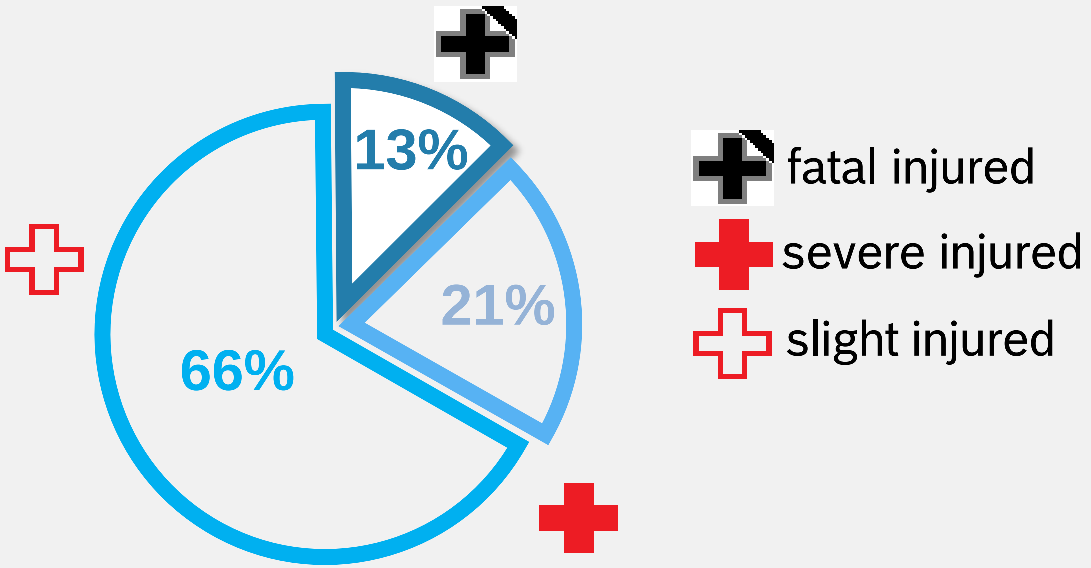
Source: RASSI (2009-2017) data weighted and representative for India; analysis based n=3,046 crashes w/ injured

Loss of control car accidents – benefit of ESC

How severe are car crashes due to “loss of control”?



85,000 injured car occupants in India due to “loss of control”



▶ “ ” characterized by a high injury severity (~11’000 fatalities p.a.)

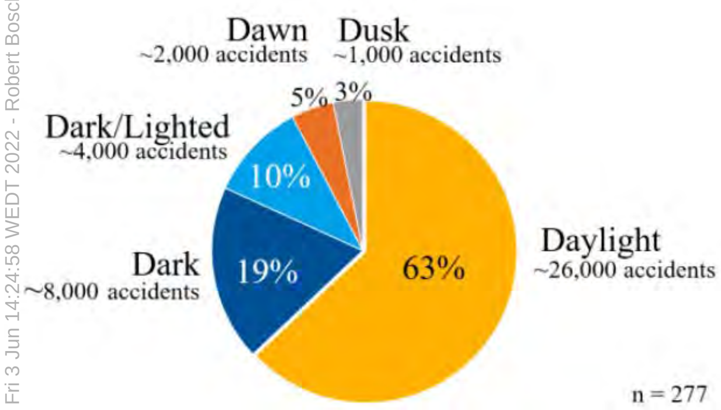
Source: RASSI (2008-2017) data weighted and representative for India; analysis based n=3,046 crashes w/ injured

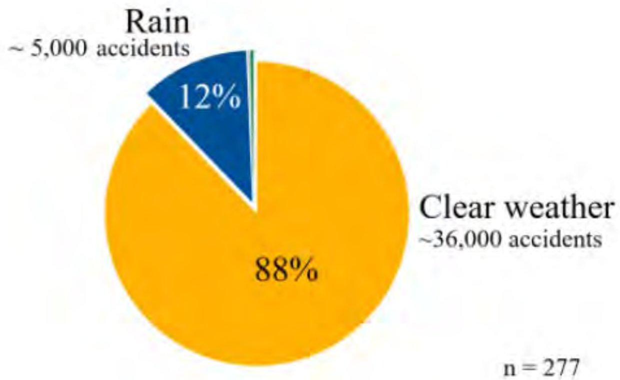
Loss of control car accidents – benefit of ESC

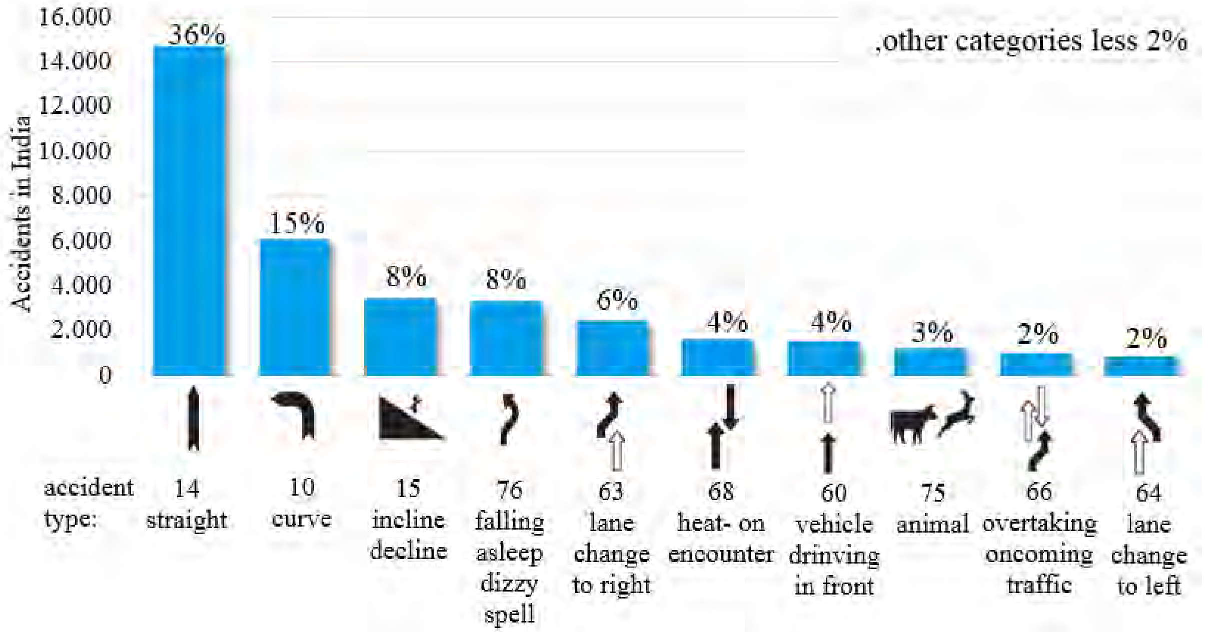
Chapter 07

2017 RASSI

Characteristics of “loss of control” car crashes







- 2 out 3 of these crashes occur at daytime and in dry street conditions
- every 2nd “ ” car crash is single vehicle accident

Source: RASSI (2009-2017) data weighted and representative for India; analysis based n=3,046 crashes w/ injured

Loss of control car accidents – benefit of ESC

What are root causes of “loss of control” car crashes?

Pre-Crash Phase

Human Error
95% of loss of control

- Over speeding
- Driver inattention
- Drowsiness

Infrastructure related
41% of loss of control

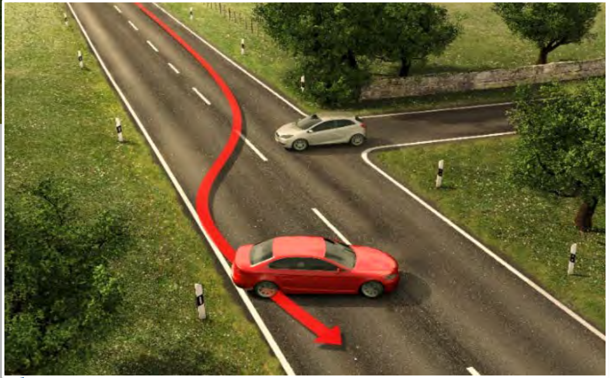
- Poor road marking
- Sharp curvature
- Slippery road surface

Crash Phase

Infrastructure related
19% of loss of control

- Object impact – manmade structures e.g. concrete
- Object impact – trees e.g. side intrusion

“Under-steering” situation due to over speeding



“Over-steering” situation in high dynamic manoeuvres

Source: RASSI (2009-2017) data weighted and representative for India; analysis based n=3,046 crashes w/ injured

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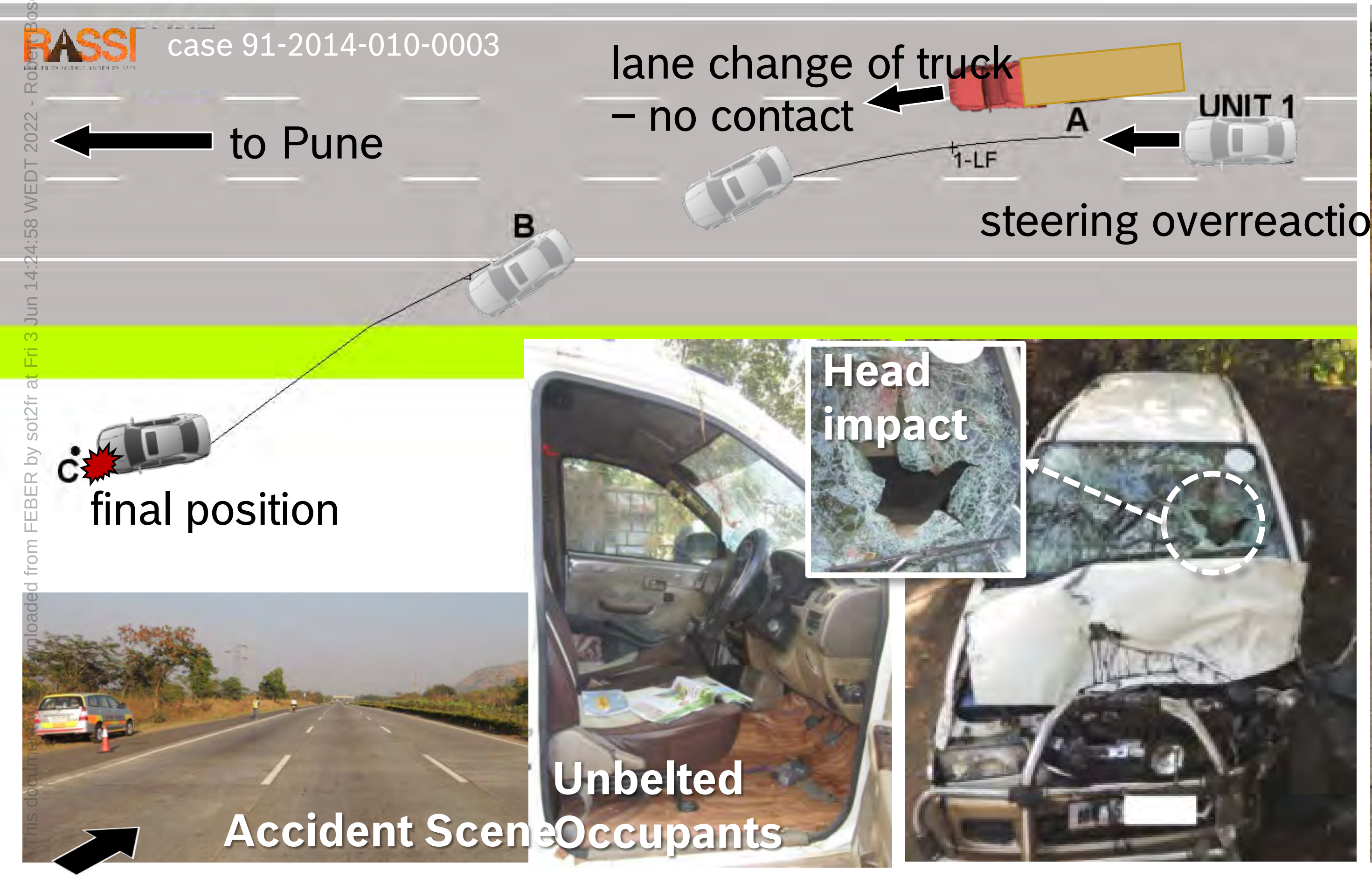
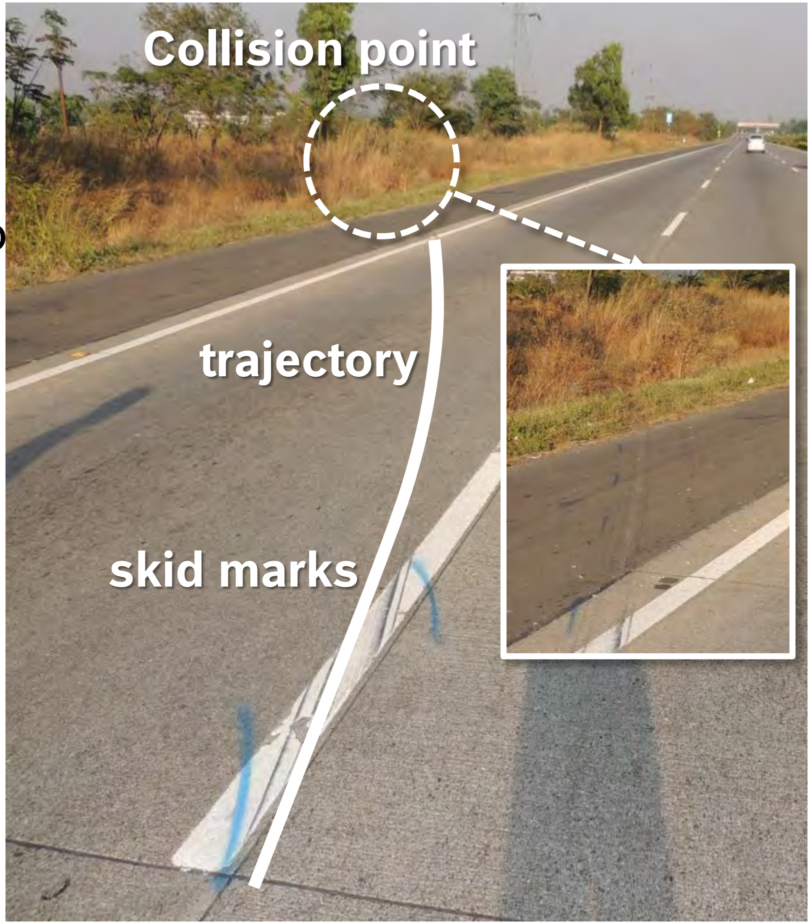
Loss of control car accidents – benefit of ESC
Skidding due to overreaction!





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2019-26-0009

Loss of control car accidents – benefit of ESC

Accident reconstruction

case 91-2014-010-0003

Accident w/o ESP®

Accident w ESP®

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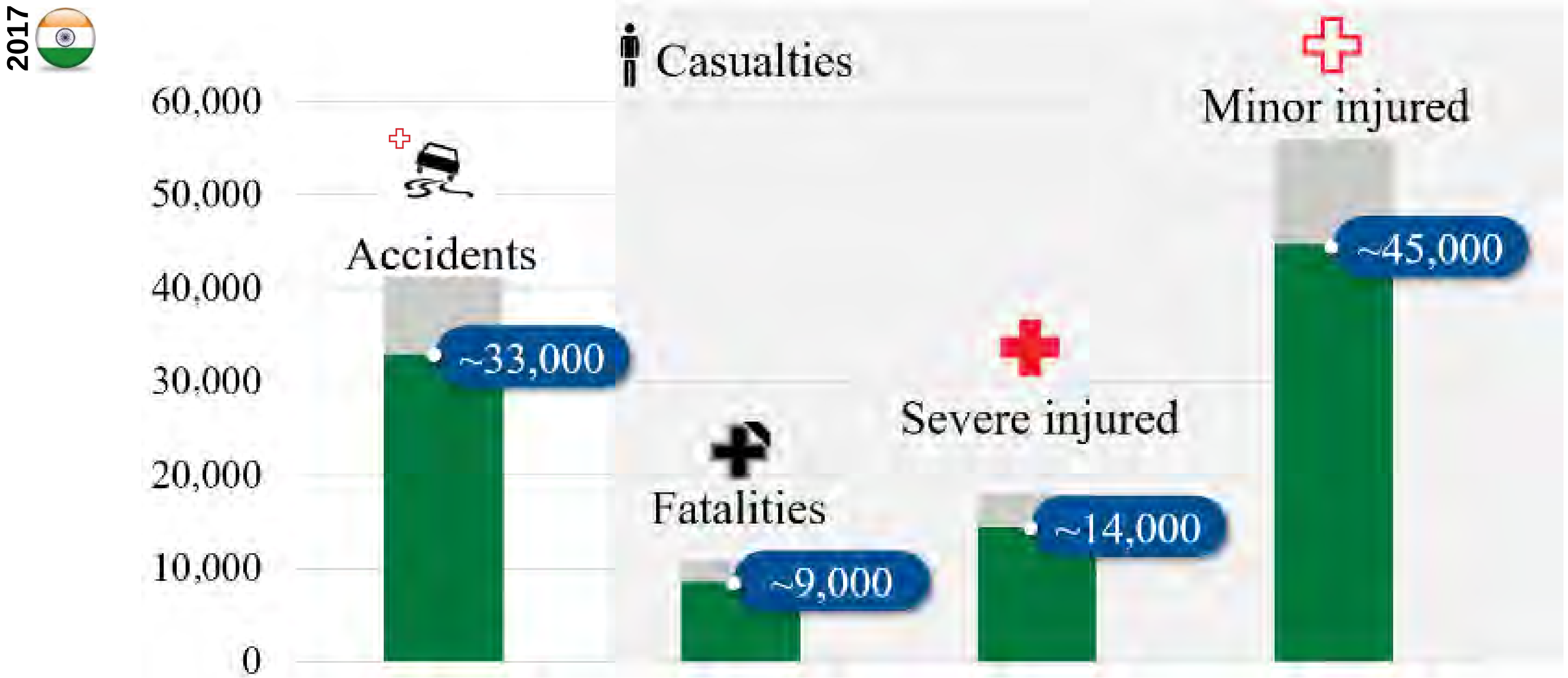
Loss of control car accidents – benefit of ESC

Impact to India: Life saving potential of ESC!



- About **33,000 car crashes** could be avoided and at least **9,000 lives** could be saved annually in India if each car would be equipped with an ESC system!

Source: RASSI (2009-2017) data weighted and representative for India; analysis based n=3,046 crashes w/ injured

Loss of control car accidents – benefit of ESC

Summary & discussion

- **Accident situation:**
  "Loss of control" car accidents common in India (41,000 accidents with casualties p.a.) thereof a majority are single vehicle accidents

- **Root causes:**
  Inappropriate speed, drug abuse, visibility conditions but less impact through weather conditions

- **Potentials:**
  Up to 33,000 accidents with a total number of 9,000 road fatalities and 14,000 severe injured road users could be avoided if each car would be equipped with ESC

- **Furthermore…**
  - increase education & safety awareness especially the use of a seatbelt!
  - improve infrastructure
  - rescue: faster and harmonized post crash response

Chapter 08

China: Sensor requirements for car AEB 2W detection and simulated benefit for accident avoidance potential

Accident Research
CR/AEV1

CIDAS #4406140032

BOSCH

Summary:

Aim of study:

- Determination of sensor characteristics wrt to local Chinese accident situation to detect 2W
- CC-DA sensor settings applied on accident situation and used for benefit assessment
- Determine field of effect and benefit for car AEB 2W in China

Method:

- CIDAS accident database analysis along with national statistics out from 2015
- CIDAS data re-simulated and reconstructed to an PCM-based dataformat. Simulation using "crash-package" (AEV1 internal tooling) to determine benefit and accident avoidance potential based on current CC-DA sensor settings.

Results:

- 339 900 out 1 252 200 crashes w/ casualties are collisions between a car and another 2W vehicle (bicycle, eMoped, eMotorcycle, motorized 2W) in China
- Field of effect for a car AEB 2W is determined to 46%, these are ~146 450 crashes with casualties
- Analysis shows: 1 out of 3 car AEB-2W relevant crashes are at challenging light or weather conditions and ~70% of the crashes occur at EGO speed below 40km/h
- Benefit estimation of current fusion system is determined to ~15%. In other words if each vehicle would be equipped w/ a car AEB 2W system 15% of all crashes w/ casualties could be avoided. This corresponds to ~180 000 up to 200 000 accidents w/ casualties in China

CIDAS #4406140032

Detailed analysis report as PDF is available

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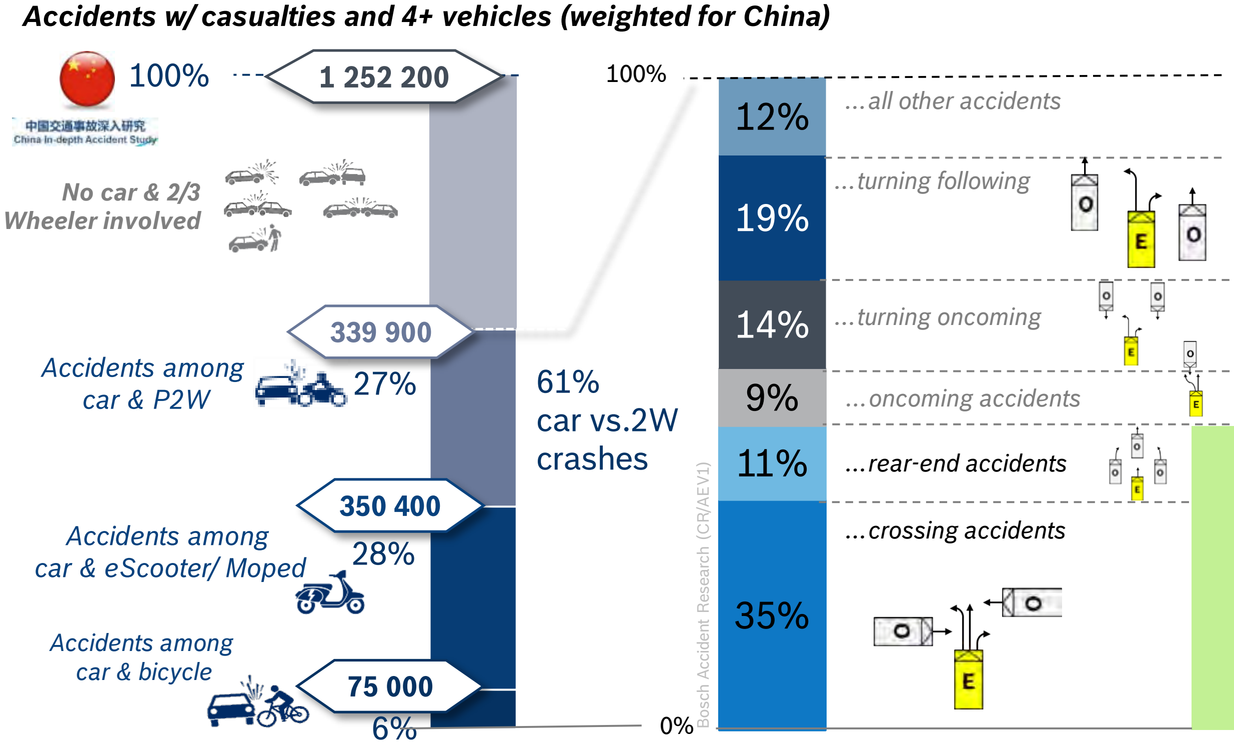
Accident Research: Car AEB-2W study for China

Chapter 08 2015

CIDAS analysis on car against two wheeler accidents



Field of effect:

46% car AEB-2W relevant

→ represents 28% of all accidents w/ casualties

Bosch Accident Research (CR/AEV1)

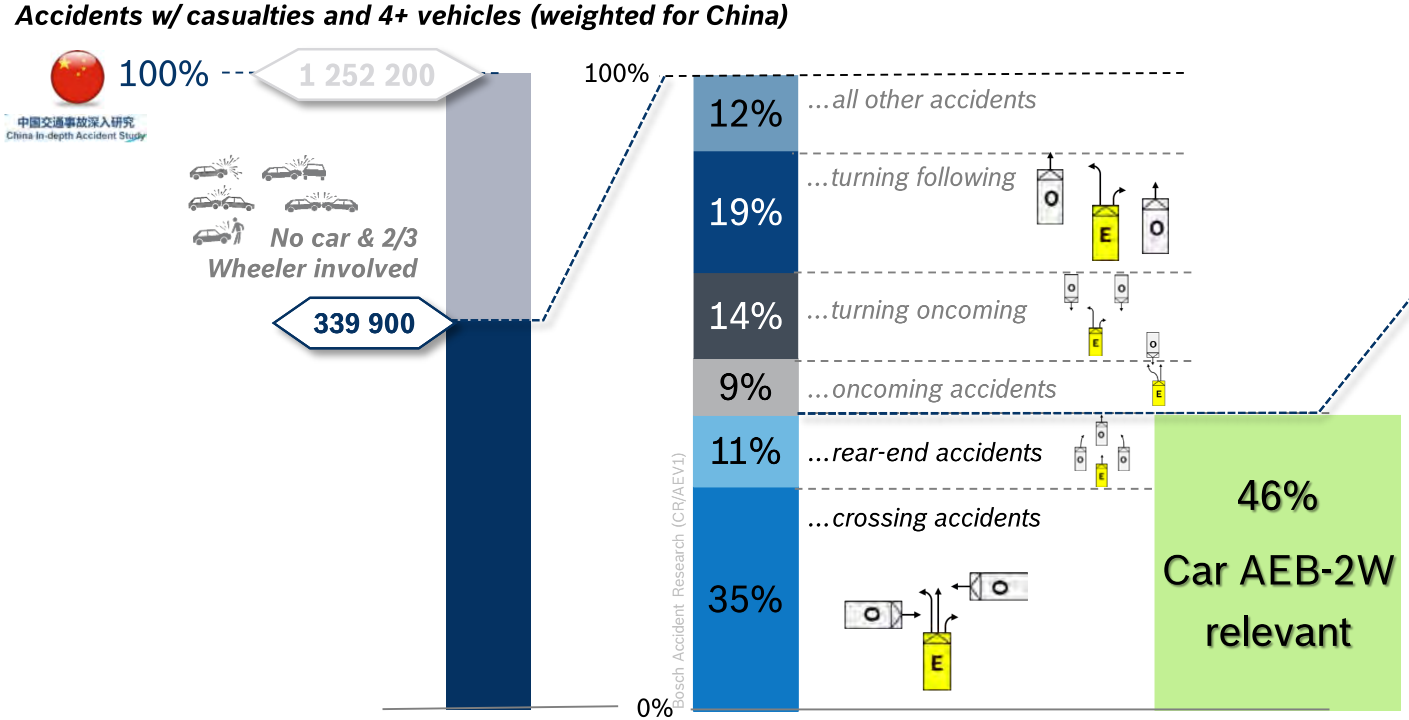
- Major conflict between car and 2W at crossings in dry and daylight conditions
- **Field of effect:** 28% of <u>all</u> accidents w/ casualties relevant for car AEB-2W

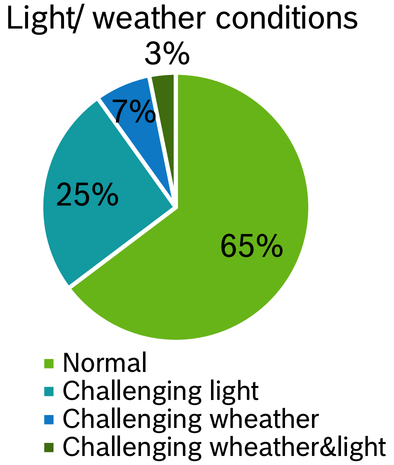
Source: Bosch Accident Research; CIDAS database (2014-2017) analysis based on 2.699 accidents weighted to China; only crashes w/ casualties & 4(+) wheeled vehicle analyzed

Bosch Accident Research (CR/AEV1-Lich, Skiera) | 31/Jan/2019
AEV-064 annual report 2018

Accident Research: Car AEB-2W study for China

CIDAS analysis on car against two wheeler accidents





- 35% @challenging weather/light conditions
- 91% below 60 km/h car velocity
- 62% detection possibility @TTC=2s for frontal sensor: ±40°, 50m

Bosch Accident Research (CR/AEV1)

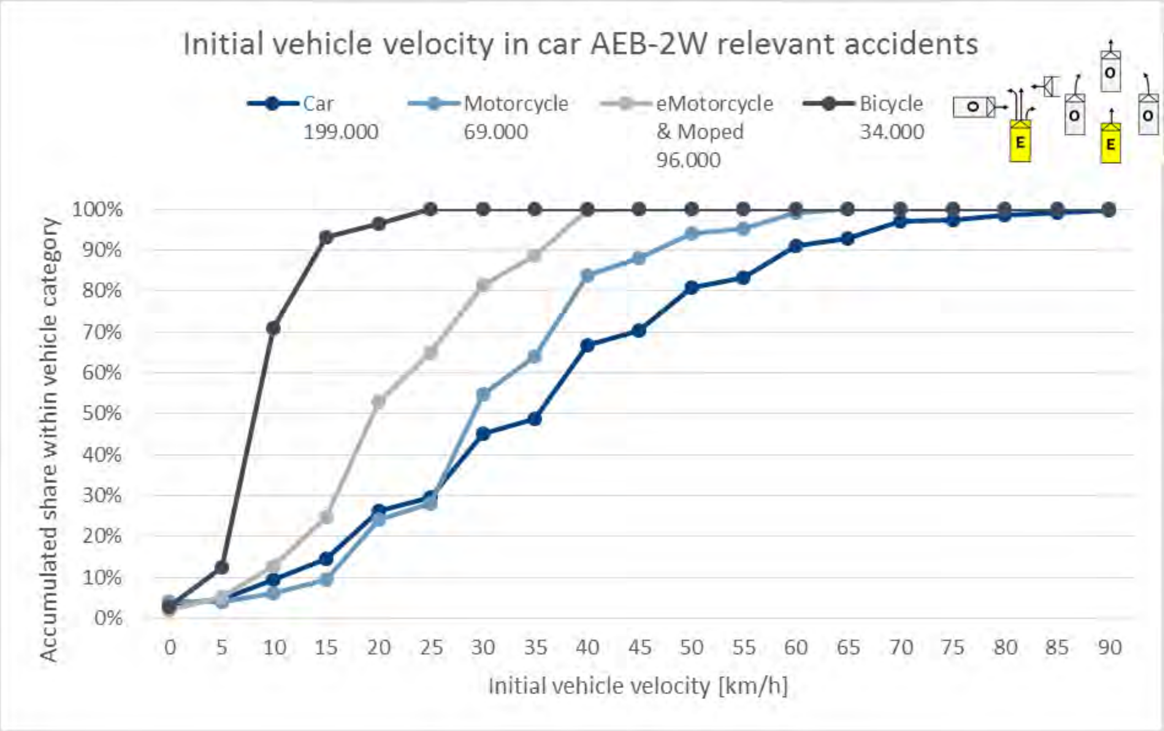
- Every 3rd relevant crash for car AEB-2W have challenging light conditions
- Further analysis reveals majority of relevant crashes (91%) below 60 km/h as crash velocity
- Focus in the following analysis set on sensor characteristics

Source: Bosch Accident Research; CIDAS database (2014-2017) analysis based on 2.699 accidents weighted to China; only crashes w/ casualties & 4(+) wheeled vehicle analyzed

Bosch Accident Research (CR/AEV1-Lich, Skiera) | 31/Jan/2019
AEV-064 annual report 2018

Accident Research: Car AEB-2W study for China

Speed distributions in car AEB-2W accidents

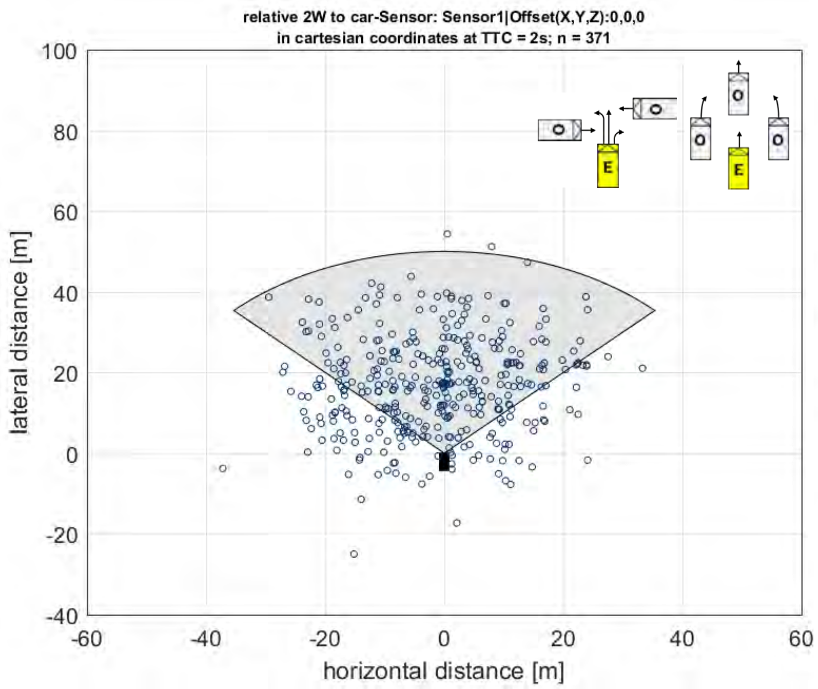


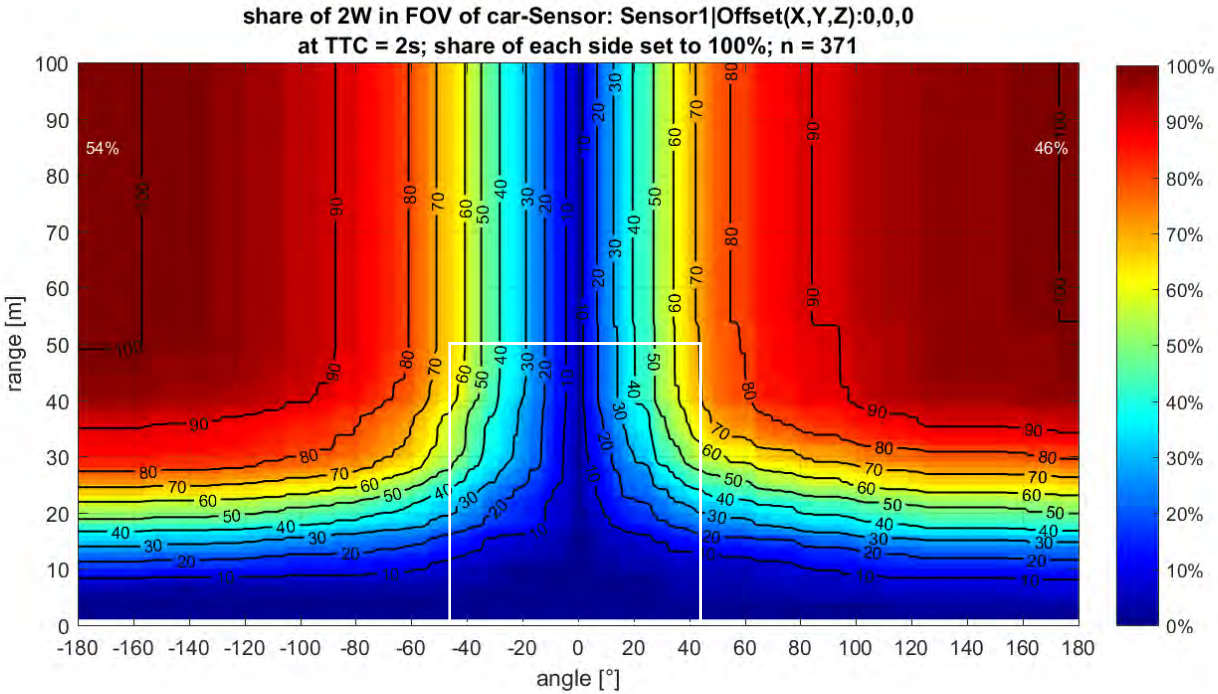
- Bicycle speed comparable to other countries with a speed <25 km/h thus slowest vehicle type of 2W vehicles
- eMotorcycles & eMopeds speeds limited to 60 km/h, thus max. speed of the vehicles to be considered

- According to current accident data, a car AEB-2W system in China should operate between 5km/h and 80 km/h of its EGO velocity!
- A specific system for electrified 2W requires a speed up to 60km/h

Accident Research: Car AEB-2W study for China

Sensor requirements for car AEB-2W relevant accidents





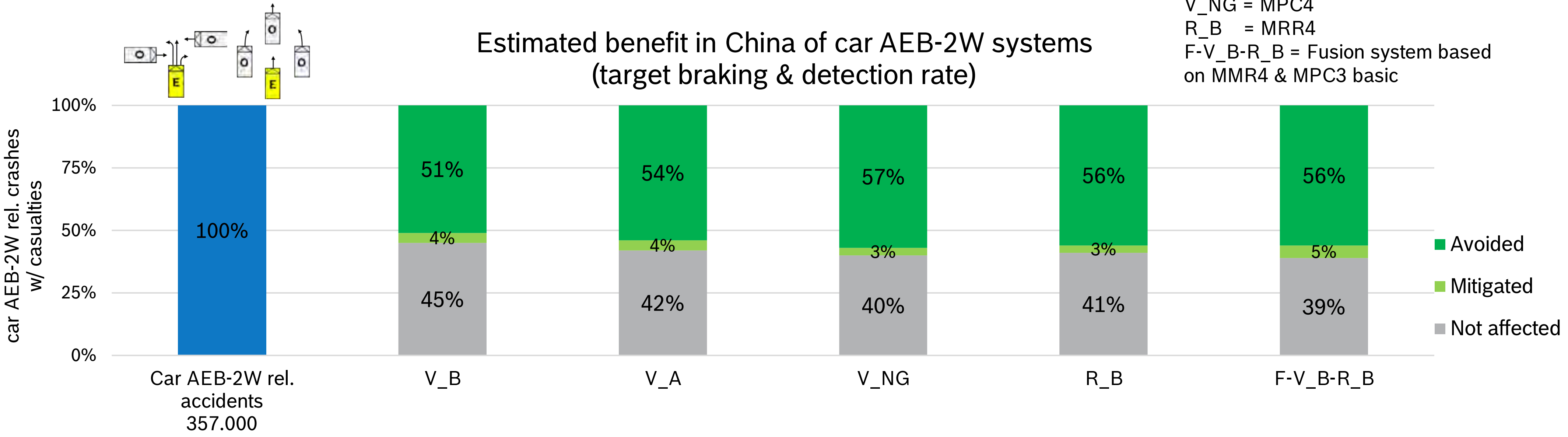
Results wrt to TTC = 2s:

- 2W crashes rather equally distributed between right and left
- With FoV of ±45° and range= 50m about ~70% of all car 2W collisions could be detected

Accident Research: Car AEB-2W study for China

Benefit for car-AEB-2W in China

V_B = MPC3 basic
V_A = MPC3+
V_NG = MPC4
R_B = MRR4
F-V_B-R_B = Fusion system based on MMR4 & MPC3 basic

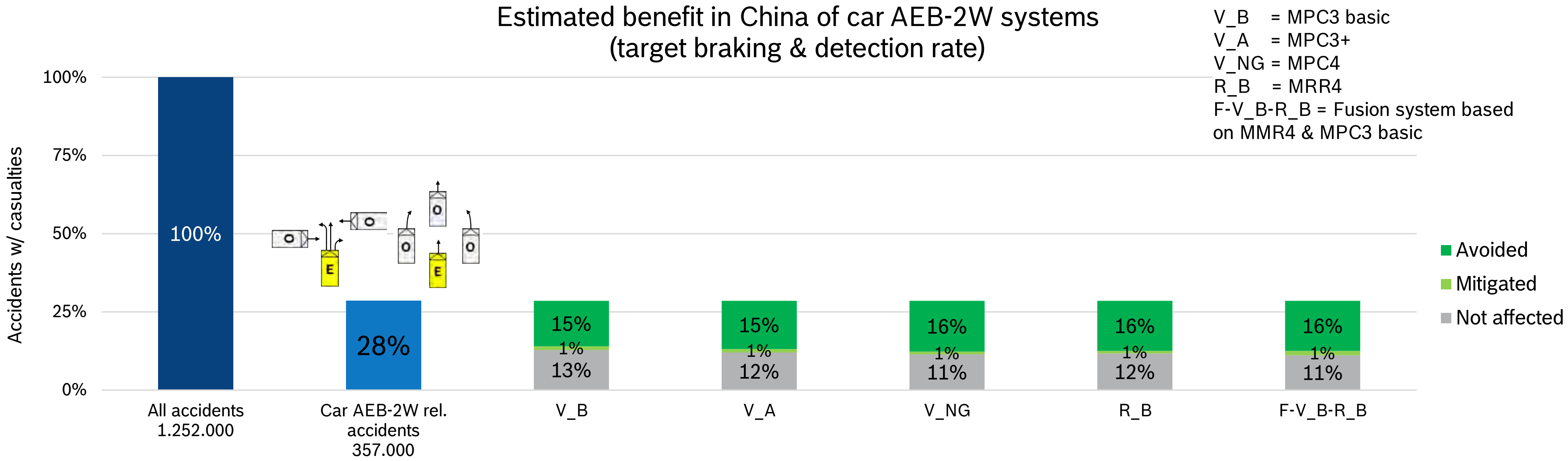


- Avoidance potential determined to 51% (MPC3 basic) up to 57% (MPC3) for relevant car 2W crashes w/ casualties in China
- Increased detection performance would enable additional + ~7% avoidance potential to current system
- Main limitation for the overall performance is a limited sensor FoV → system w/ corner radars or larger field of view for high real world performance needed

Source: Bosch Accident Research; CIDAS database (2014-2017) simulation based on 260 accidents weighted to China; only crashes w/ casualties & 4(+) wheeled vehicle analyzed

Accident Research: Car AEB-2W study for China

Benefit for car-AEB-2W in China



- A car AEB 2W system could address ~28% of all crashes w/ casualties in China
- Assuming each car would be equipped w/ a car AEB 2W system it is estimated that ~16% of all crashes could be avoided in China
- Limitations currently given due to detection performance and sensor characteristics (FoV)
  →Corner radars or larger FoV beneficial to address real world requirements in China

Source: Bosch Accident Research; CIDAS database (2014-2017) simulation based on 260 accidents weighted to China; only crashes w/ casualties & 4(+) wheeled vehicle analyzed

Accident Research: Car AEB-2W study for China

Conclusion & Recommendation out of Accident Research

- 2 out of 3 accidents w/ casualties (~61%) are conflicts between car and a 2W (bicycle, eMoped, eMotorcycle, motorized 2W)
- Nearly every 2nd (46%) of car 2W conflicts are relevant for a car AEB 2W system (**Field of effect**)
- Further analysis reveals:
  - 1 out of 3 car AEB-2W relevant crashes are at challenging light or weather conditions
  - An EGO vehicle speed of 40km/h covers majority of crashes. To cover all accidents a system should operate between 5km/h and 80 km/h of its EGO velocity.
- Benefit estimation of current fusion system is determined to ~15%. In other words if each vehicle would be equipped w/ a car AEB 2W system 15% of all crashes w/ casualties could be avoided. This corresponds to ~180 000 up to 200 000 accidents w/ casualties in China

Proposals:

- Separate radar from fusion system below 25m to use its complete sensor FoV
- Focus on FoV by either increasing the sensor FoV or combining multiple sensors
- Improve detection rates for next sensor generation

Accident Research: Car AEB-2W study for China

Limitations

- CIDAS database (2014-2017) simulation based on 260 accidents weighted to China; only crashes w/ casualties & 4(+) wheeled vehicle analyzed → **Further analysis required ones more data available**
- The used systems in the simulation are only simplified models and do not match the actual system.
  → **Real world performance of system could be higher or lower**
- The simulation considers any sensor detection errors or limitations only in a statistical manner.
  → **Real world performance of system could be higher or lower**
- The simulation does not consider any view obstructions as these are not available in the used data.
  → **Real world performance of system could be lower**
- The simulation does not consider the real condition of the tires or the braking system and always assumes a vehicle in best conditions.
  → **Real world performance of system could be higher or lower**
- The simulation uses simplified reconstructed accident data, which do not necessarily reflect the real happened accident in terms of speed, moving trajectory and driver behavior.
  → **Real world performance of system could be higher or lower**

Chapter 09

Indonesia: Benefit estimation of ESC in Indonesia by applying efficiency on local accident data

Accident Research
CR/AEV1

BOSCH

Summary:

Aim of study:

- Determine field of effect for ESC in Indonesia using IRSMS data
- Transfer avoidance potential / efficiency from Germany/China towards Indonesia to estimate potential benefit of ESC in ID

Method:

- Study was done together with the University of Indonesia.
- Determined efficiency out of Germany and China (80% of skidding accidents being avoided) applied on pre-selected accident scenarios evaluated out of the IRSMS data provided by the University of Indonesia.

Results:

- In Indonesia 103 838 accidents w/ casualties occurred in 2016, thereof are ~22 300 in which a passenger car was involved.
- Field of effect for ESC on cars was determined to about 11% (2 400 crashes), moreover the transferred benefit of 80% avoidance potential leads to an estimated benefit of 9% (2 000 crashes) in Indonesia.
- It is recommended to have a follow up analysis in case on-spot accident data will be available, due to the fact that a high under-reporting of skidding accidents is given in Indonesia according to University of Indonesia

CONTENT

- Electronic Stability Control in a nutshell
- Which accidents will be influenced by ESC?
- What is the effectiveness of ESC?
- What is the impact of ESC in Indonesia?

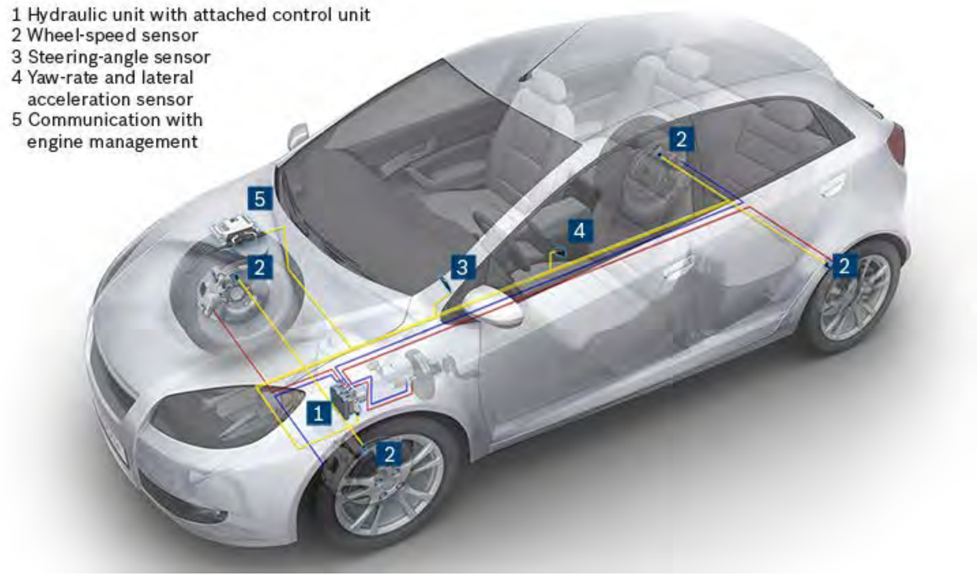
Electronic Stability Control in a nutshell

ESC components & benefits

Road safety relies on ESC market availability

- Increases driving stability actively in all driving situations
- Vehicle stabilization by individual wheel braking and engine management control

Components of Bosch ESC



Customer benefits

- Reduced risk of skidding
- Manoeuvrability maintained even in extreme situations
- Significant decrease of severe and fatal accidents due to skidding

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Relevance of ESC in the accident situation

Which accidents will be influenced by ESC?

- Over- and understeering situations with loss of control or with precedent skidding are in the scope of ESC
- Loss of control crashes are mainly single vehicle accidents or crashes in which avoidance or overreaction takes place

ESC relevant accidents – Example (Germany GIDAS #30030911)

Accidents w/ loss of control – oversteering situation

- Due to micro sleep the driver of the car hit the left guardrail, speed at this time was ~136 km/h. Near the event of contact to the guardrail the driver overreacted and started a avoidance maneuver (hard right steering).
- The vehicle started to oversteer and hits the right guardrails followed by a multiple rotation of the vehicle. In a second event the car was hit from another vehicle approaching from behind.

trajectory of the Citroen C3

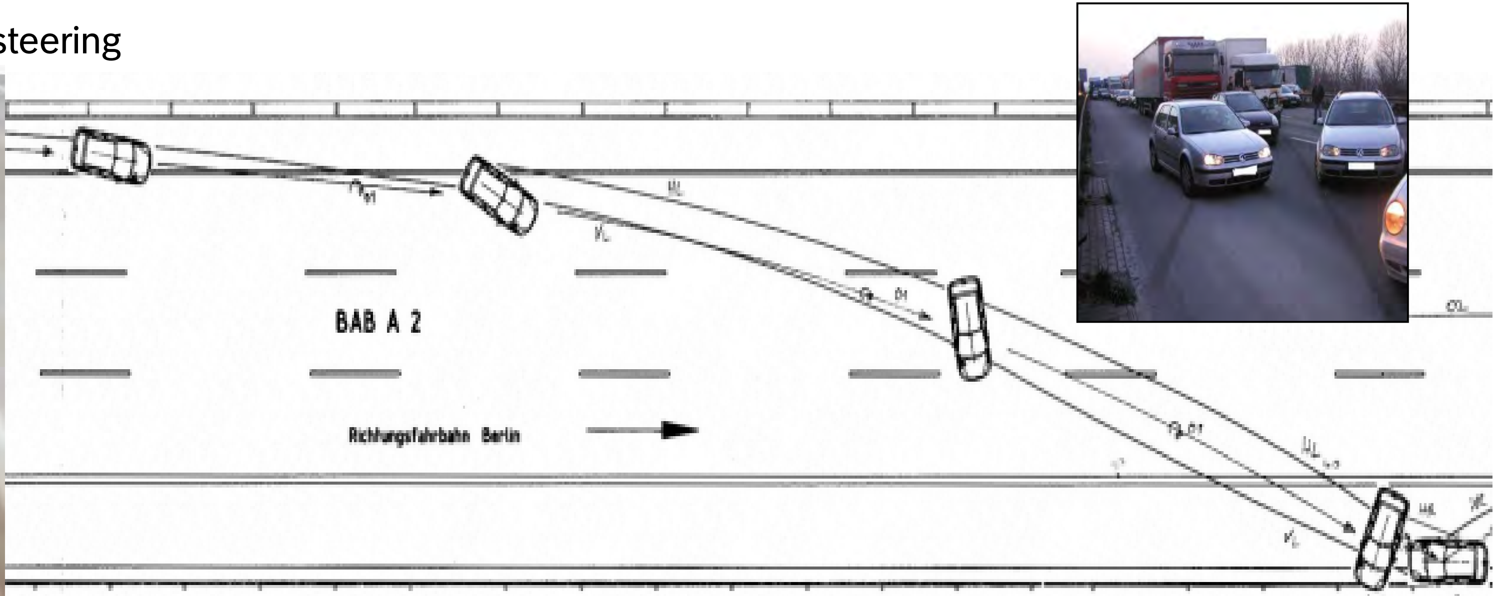
final position of the vehicle and its damages

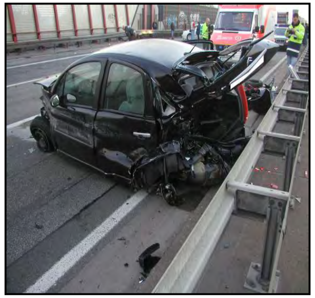
ESC relevant accidents – Example (Germany GIDAS #30030911)

Chapter 09

Accidents w/ loss of control – oversteering situation

▶ Reconstruction of the collision with oversteering





- ▶ These type of accidents are in the scope of Electronic Stability Control (ESC)
- ▶ This accident w/ precedent skidding could have been avoided by ESC,
- ▶ However, the micro-sleep of driver caused the initial oversteering maneuver

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ESC relevant accidents – Example (Germany GIDAS #1050858)

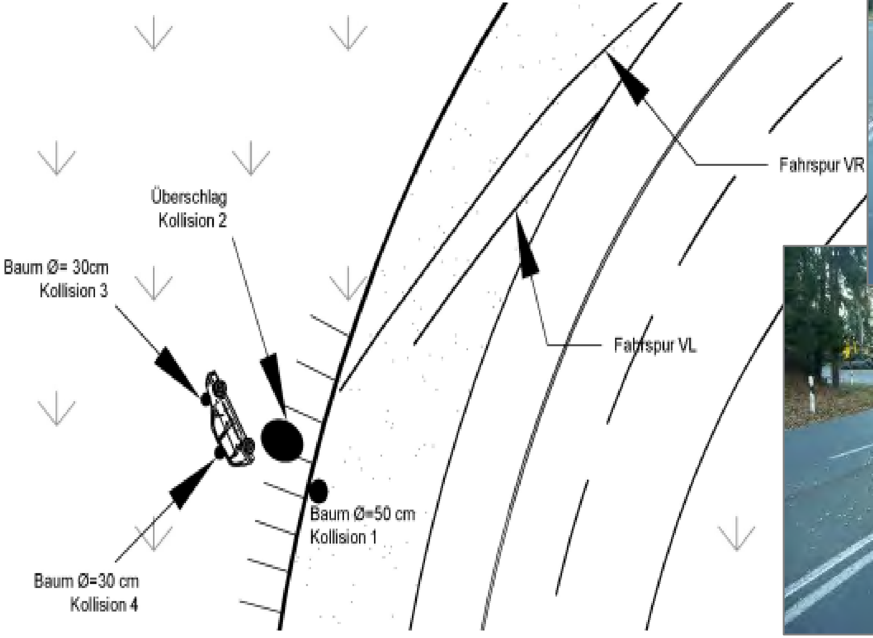
Accidents w/ loss of control – understeering situation

- Due to speeding (~75 km/h) and inattention the driver was not able to follow the left curve, thus an understeering situation occurred which results in a road departure to the right.
- In the 1st event the car hits the tree, followed by a rollover event with a collisions against another trees.

ESC relevant accidents – Example (Germany GIDAS #30030911)

Accidents w/ loss of control – oversteering situation

- Reconstruction of the collision with understeering



- These type of accidents are in the scope of Electronic Stability Control (ESC)
- This accident w/ understeering conditions could have been avoided by ESC
- However, mainly speeding cause such understeering situations

ESC relevant accidents – Example (India #9120110020001)

Loss of car control due to collisions avoidance maneuver

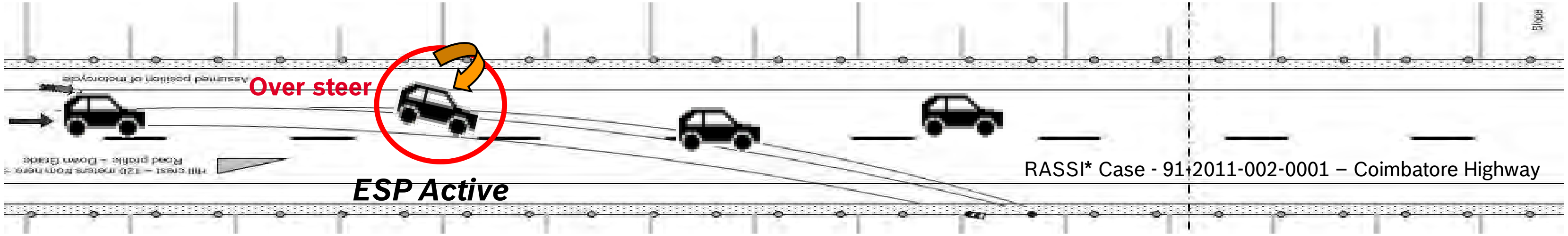
- Vehicle 1 avoids collision against a motorcycle by steering right thus he lost control and left the carriageway to the right, hit two concrete poles and roll down a ditch

*Source: Bosch Accident Research CR/AEV1, RASSI (2010-2015), case 9120110020001 – Coimbatore Highway

ESC relevant accidents – Example (India #9120110020001)

ESC helped to prevent such type of accidents

- Reconstruction



*Source: Bosch Accident Research CR/AEV1, RASSI (2010-2015), case 9120110020001 – Coimbatore Highway

Effectiveness evaluation of ESC

What is the effectiveness of ESC?

- Effectiveness is determined by using retrospective evaluation of relevant crashes equipped with and without ESC!
- Results from Germany and China shows ESC prevents 80% of car crashes with loss of control or precedent skidding
- Effectiveness of ESC is independent of the country but depends on the regional accident situation

Bosch Accident Research

How to determine effectiveness safety technologies?

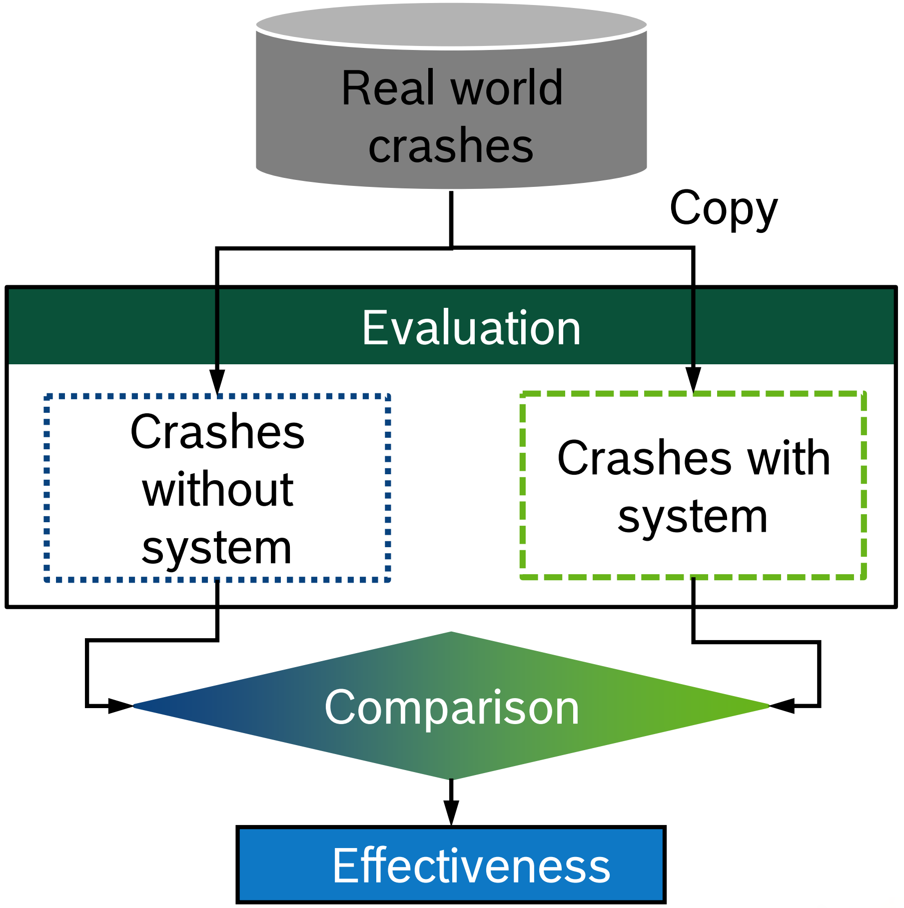
Retrospective Evaluation

- Comparison between vehicles with and without a safety technology i.e. applied on ESC effectiveness evaluation

car accidents w/injuries	*Skidding*	*No skidding*	Sum
ESC	18	486	**504**
no ESC	751	4 164	**4 914**
Sum	**769**	**4 650**	**5 419**

$$\omega_{ESC} = \left(\frac{S_{ESCyes}}{S_{ESCno}}\right) / \left(\frac{S_{yes}}{S_{no}}\right) = 0.20$$

(CI 95%: 0.13 – 0.31)



Evaluation of effectiveness of ESC

Retrospective effectiveness evaluation of ESC[1] (2011)

car…	skidding	no skidding	**Total**
with ESC	131	2 955	**3 086**
without ESC	2 125	8 182	**10 307**
Total	**2 256**	**11 137**	**13 393**

RR_{ESC} relative risk of ESC
S_{ESC_yes} skidding cars w/ ESC
S_{ESC_no} no skidding cars w/ ESC
S_{yes} skidding cars w/o ESC
S_{no} no skidding cars w/o ESC
SUM_{ESC} cars w/ ESC
SUM_{ESCno} cars w/o ESC
E_{ESC} Effectiveness of ESC

$$RR_{ESC} = \left(\frac{S_{ESC\_YES}}{SUM_{ESC}}\right) / \left(\frac{S_{YES}}{SUM_{ESCNO}}\right) = 0.2$$

$$E_{ESC} = 1 - RR_{ESC} = 80\%$$

Reasons for skidding of ESC equipped cars:

- Speeding in curves, evading maneuvers or while lane change (physical limitations on snow or ice)
- Manual deactivation of ESC by driver
- Aquaplaning or tire blowout

▶ ESC avoids ~80% of all car accidents with precedent skidding

[1] Source: Bosch Accident Research study, 2011 using GIDAS 2001-2011, weighted by location, severity and accident type; representative for Germany

Evaluation of effectiveness of ESC

Retrospective effectiveness of ESC on Chinese highways

- Accidents w/ casualties caused by passenger car on highways only
- Odds ratio being used due to limited number of crashes

car…	skidding	no skidding	Total
with ESC	66	45	**111**
without ESC	460	67	**527**
Total	**526**	**112**	**638**

$$\omega_{ESC} = \left(\frac{S_{ESC\_YES}}{S_{ESC\_NO}}\right) / \left(\frac{S_{YES}}{S_{NO}}\right) = 0.21$$

(CI 95%: 0.14 – 0.33)

$$E_{ESC} = 1 - \omega_{ESP} = 80\%$$

ω_{ESC} odds ratio of ESC

S_{ESC_yes}	skidding cars w/ ESC
S_{ESC_no}	no skidding cars w/ ESC
S_{yes}	skidding cars w/o ESC
S_{no}	no skidding cars w/o ESC
E_{ESC}	Effectiveness of ESC

- Confirmation of ESC effectiveness out from Chinese highway accident data
- In other words, ESC avoids 80% of all car crashes with precedent skidding independent of the country its applied

[1] Source: China yearbook 2011 and CATARC (2009 – 2011) police reported accidents data weighted by road type

Benefit estimation of ESC in Indonesia

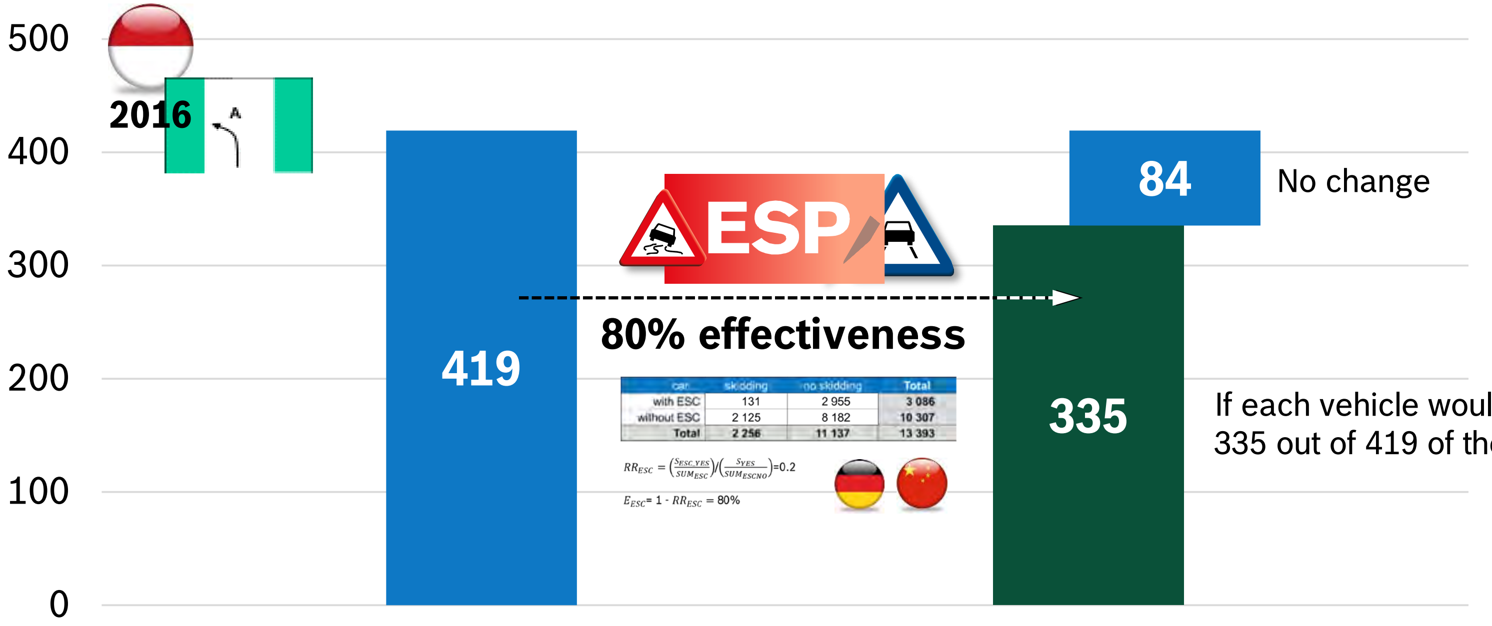
What is the impact of ESC in Indonesia?

- Effectiveness of ESC (80%) is applied on Indonesia's accident situation involving cars using IRSMS data
- If each would be equipped with ESC it is estimated that nearly every 10th car crash w/ casualties and precedent skidding could be avoided in Indonesia

How was the impact for Indonesia calculated?

Effectiveness of ESC applied on type of accident

- ESC works in each country equal, thus efficiency will be constant. Therefore effectiveness of 80% can be applied to relevant accident scenarios.
- Relevant accident scenarios are loss of control crashes or accidents with precedent skidding.

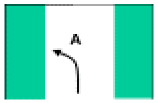


car	skidding	no skidding	Total
with ESC	131	2 955	3 086
without ESC	2 125	8 182	10 307
Total	2 256	11 137	13 393

$RR_{ESC} = \left(\frac{S_{ESC\_YES}}{SUM_{ESC}}\right) / \left(\frac{S_{YES}}{SUM_{ESCNO}}\right) = 0.2$

$E_{ESC} = 1 - RR_{ESC} = 80\%$

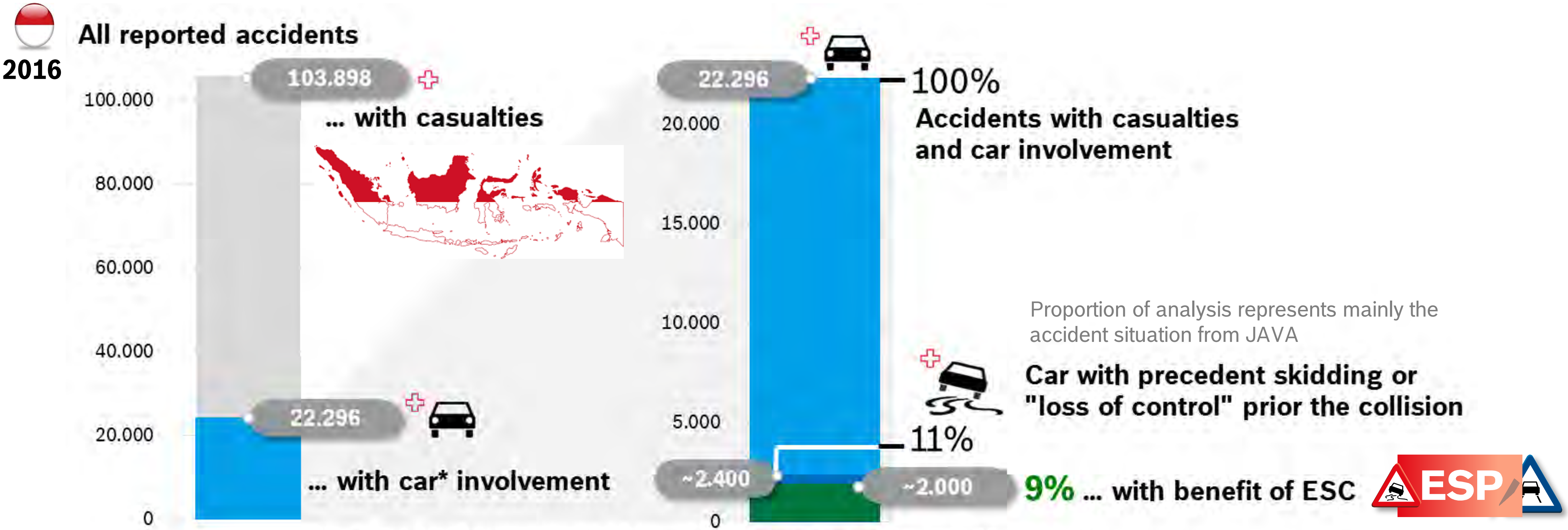
IRSMS accident type:
Single vehicle accident – departure to the left side



If each vehicle would have been equipped w/ ESC 335 out of 419 of these crashes could be avoided

Result: Benefit estimation of ESC in Indonesia

Nearly every 10th car crash w/ precedent skidding could be avoided by ESC



*car: Sedan, Jeep, Passenger van, Mini Bus

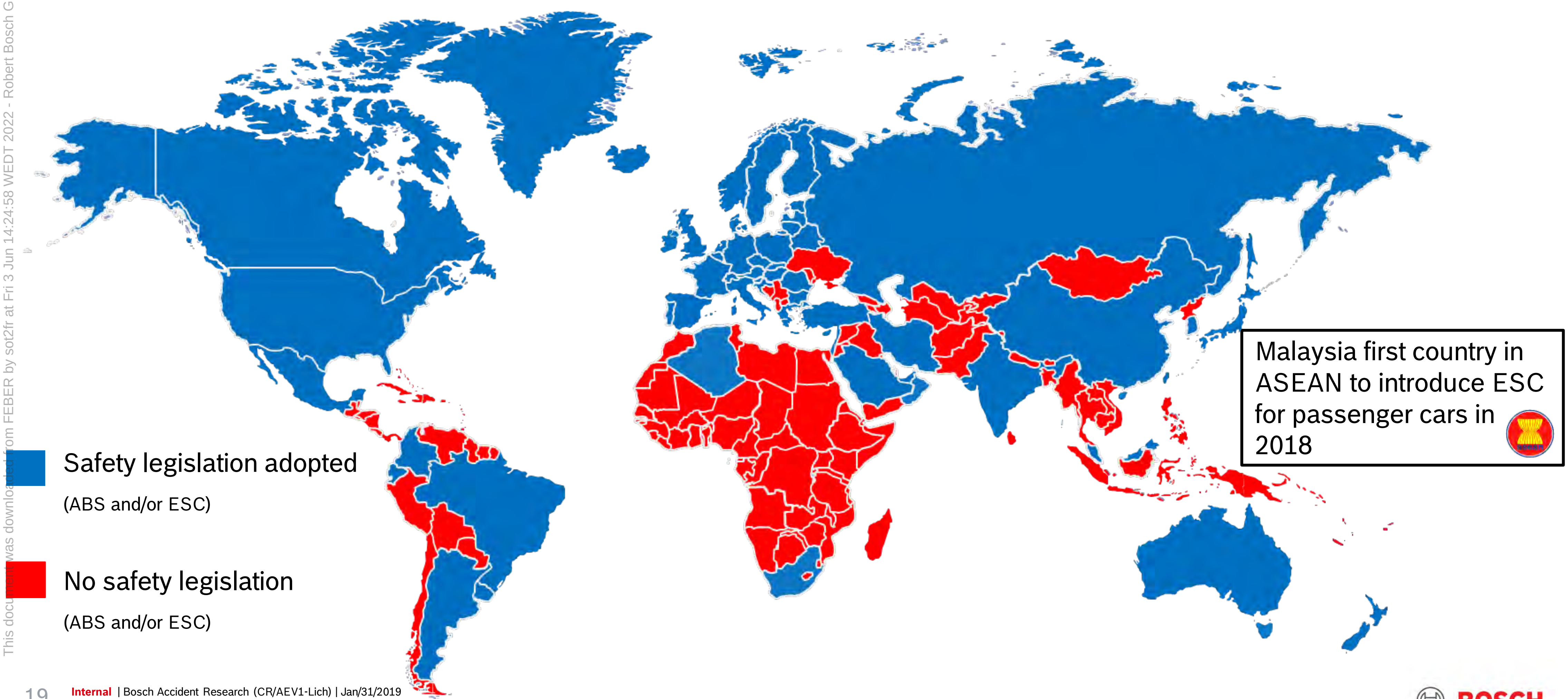
Proportion of analysis represents mainly the accident situation from JAVA

Source: Study by University of Indonesia, 2018 along with Bosch Accident Research (CR/AEV)

▶ Due to high number of underreported single vehicle car accidents in rural area the benefit of ESC is expected to be twice as high in Indonesia, however number of underreported cases[1] unknown.

[1] according to WHO report 2015, underreporting occurs in 45% wrt to number of traffic fatalities in Indonesia

Vehicle Safety Legislation across the World



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India – Passive Safety: How can vehicle safety contribute to road safety in India?

14th International Symposium on Sophisticated Car Occupant Safety Systems in Mannheim, Germany, November 26-28, 2018

Accident Research
CR/AEV1

Internal | Bosch Accident Research (CR/AEV1-Lich) | Jan/31/2019
AEV-064 annual report 2018

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Summary:

Aim of study:

- Determine research fields and potentials of crashes involving passenger cars in India with focus on Passive Safety System
- Apply weighting methodology established for India on selected cases
- Results published at “Airbag 2018 Symposium”

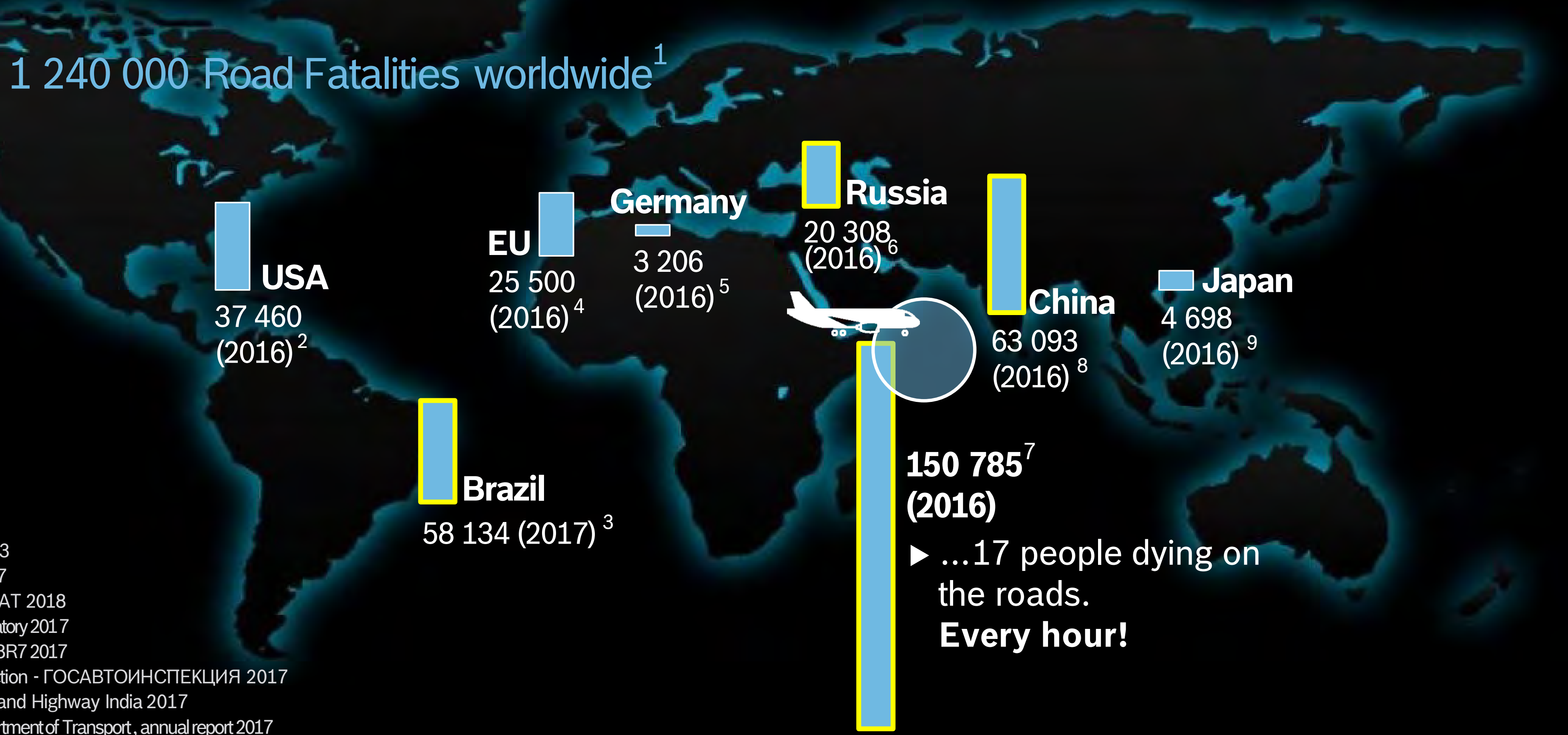
Method:

- Annual statistical report (MORTH), and RASSI database (2011-2018)
- First of its kind, weighting process applied in a two-step approach for India (methodology published in 2019 on ESC publication)

Results:

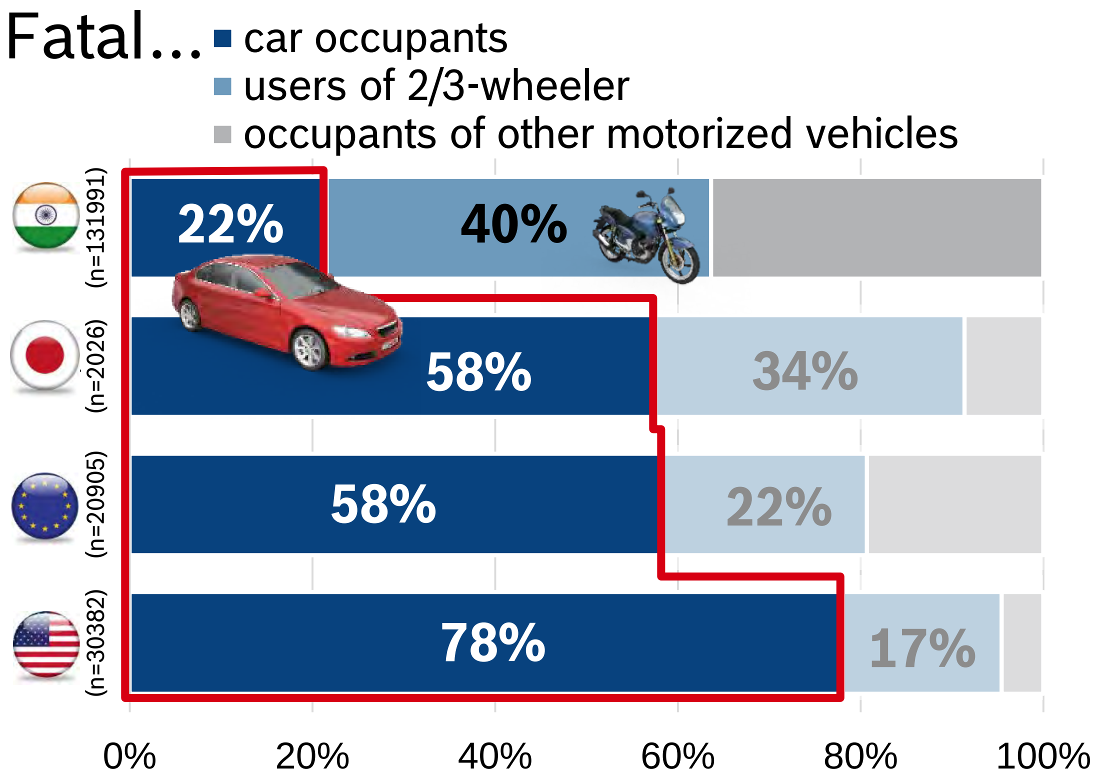
- Overall ~1.3 million crashes w/ injuries occurred in India in 2017 thereof are 118 700 (8%) crashes involving a passenger car with at least one car occupant injured!
- Seat belt usage rate on driver side (40%) and passenger side (10%) respectively
- Major accident situations are leaving carriageway, oncoming crashes and rear-end collisions
- 2/3 of the collisions are frontal impacts, with low overlap as one of the major impact scenarios

What drives us?



Sources:
[1] WHO report, 2015 valid for 2013
[2] Road Traffic Safety Facts 2017
[3] Vias Seguras, Seguro DPVAT 2018
[4] European Road Safety Observatory 2017
[5] Statistisches Bundesamt F8R7 2017
[6] Russian Road Safety Inspection - ГОСАВТОИНСПЕКЦИЯ 2017
[7] Ministry of Road Transport and Highway India 2017
[8] Road Accident Statistics, Department of Transport, annual report 2017
[8] National Police Agency Japan (HEISEI) 2017

India is not easily comparable amongst other countries



- **29 000 car occupants** killed annually
- users of **motorized 2-3 wheeler** are the majority

Note: pedestrians, cyclists or other non-motorized traffic excluded

Source: US Traffic Safety Facts 2016 DOT HS 812554, , 2018; India MORTH report 2016; EU Statistical Pocket book 2017
EU Transport ISBN 978-92-79-62312-7; JP HEISEI report 平成28年における交通事故の発生状況, 2016

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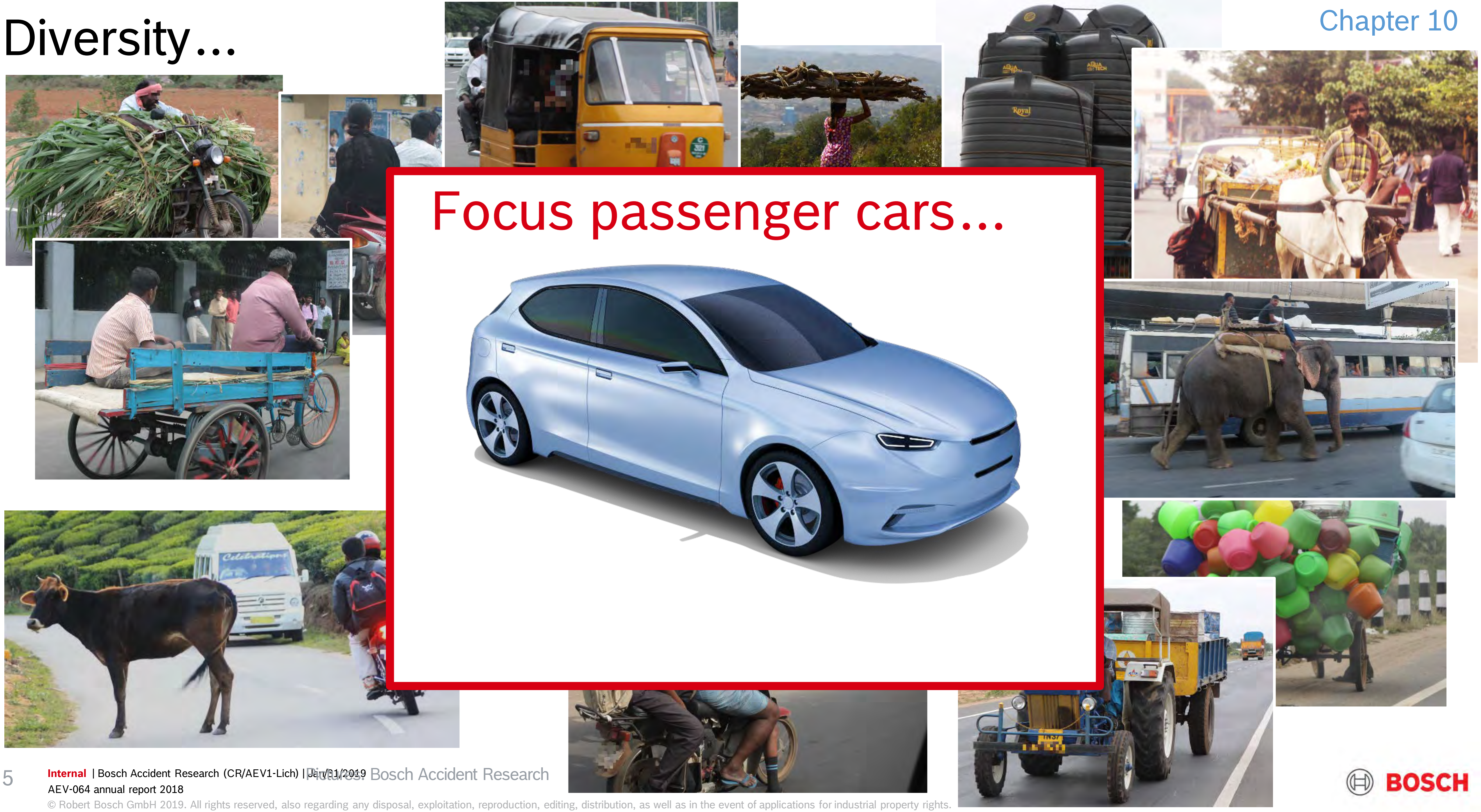
Diversity…



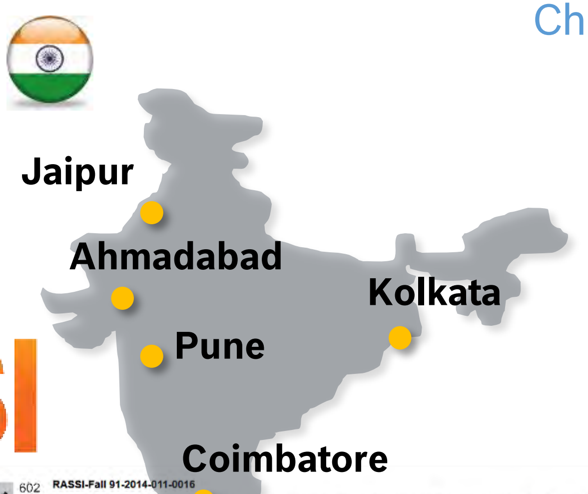
Focus passenger cars…

Pictures: Bosch Accident Research

Data source
Road Accident Sampling System India[1]

- **Police-** or **hospital** reported crashes
- Detailed documentation (avg. ≈700 information/crash)
- Digital case file (≈160 pictures/crash)
- **Injury** information coded
- Sketch & reconstruction of **every** crash
- **3 046** crashes w/ injuries[2]

RASSI



[1] RASSI – www.rassi.org.in   [2] all severities included

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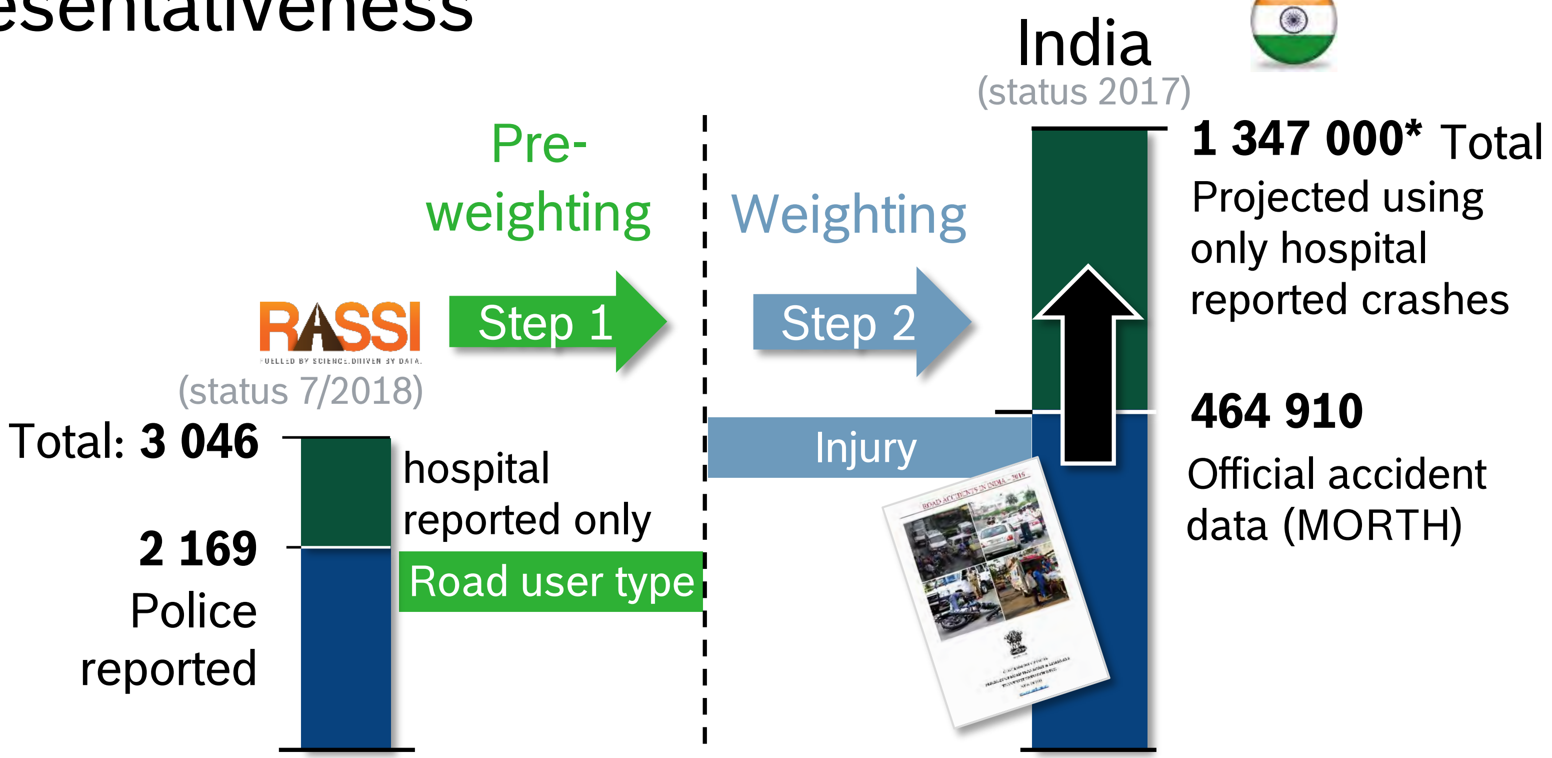
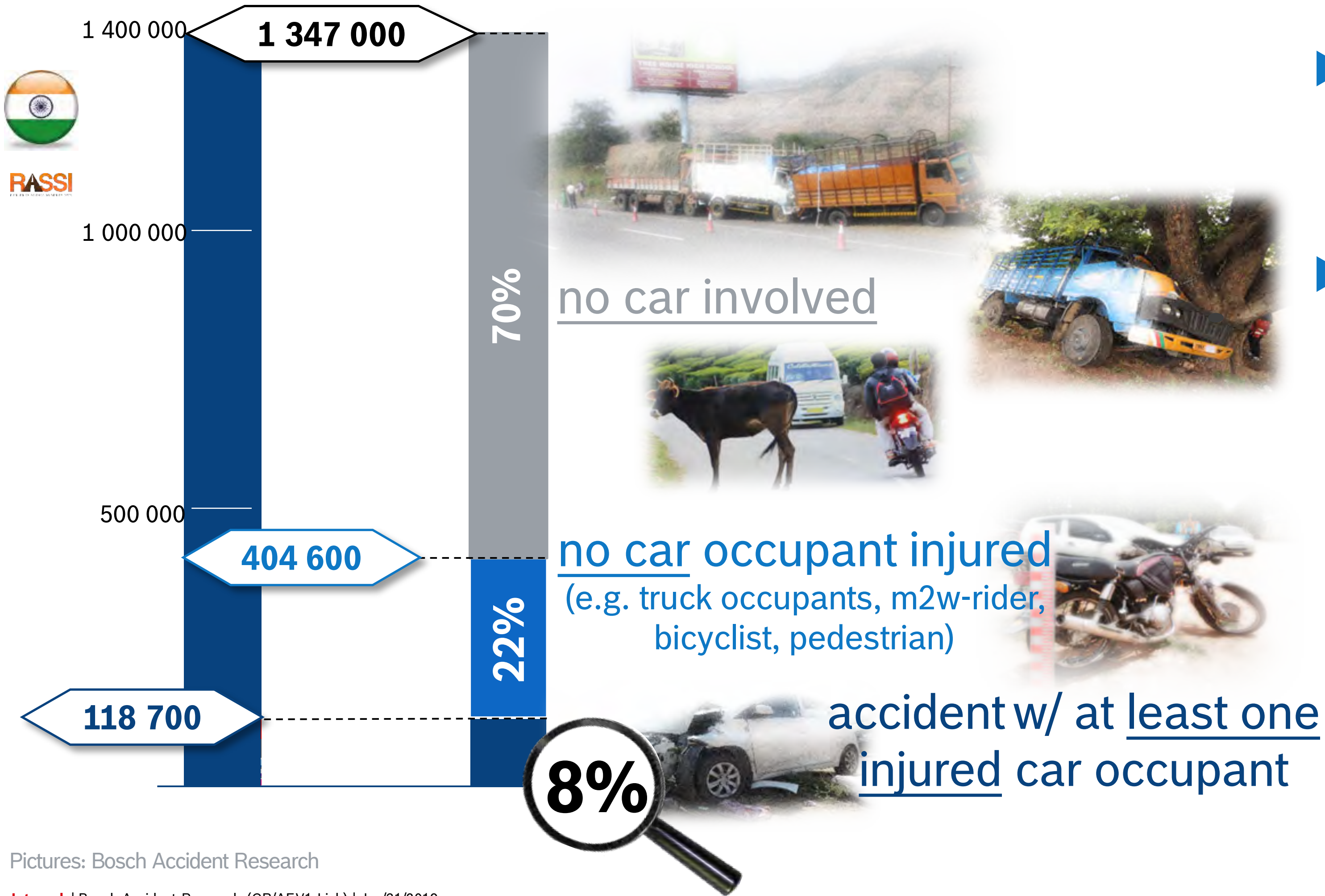
Data representativeness



- Police reported crashes in annual statistics (MORTH)
- 1 347 000 crashes with injuries for India in 2017 determined by including hospital reported crash data

* Sources: “Underreporting accident on Indian roads”, ESAR 2018 Hanover, “Loss of control car accidents in India – benefit of ESC”, SIAT 2019 Pune

Accident situation involving passenger cars



- Focus set on accidents w/ at least one injured car occupant
- Overall about 118 700 (8%) crashes w/ casualties in India

Pictures: Bosch Accident Research

RASSI (2009-2017) data weighted and representative for India; Analysis based n=3 046 crashes w/ injured

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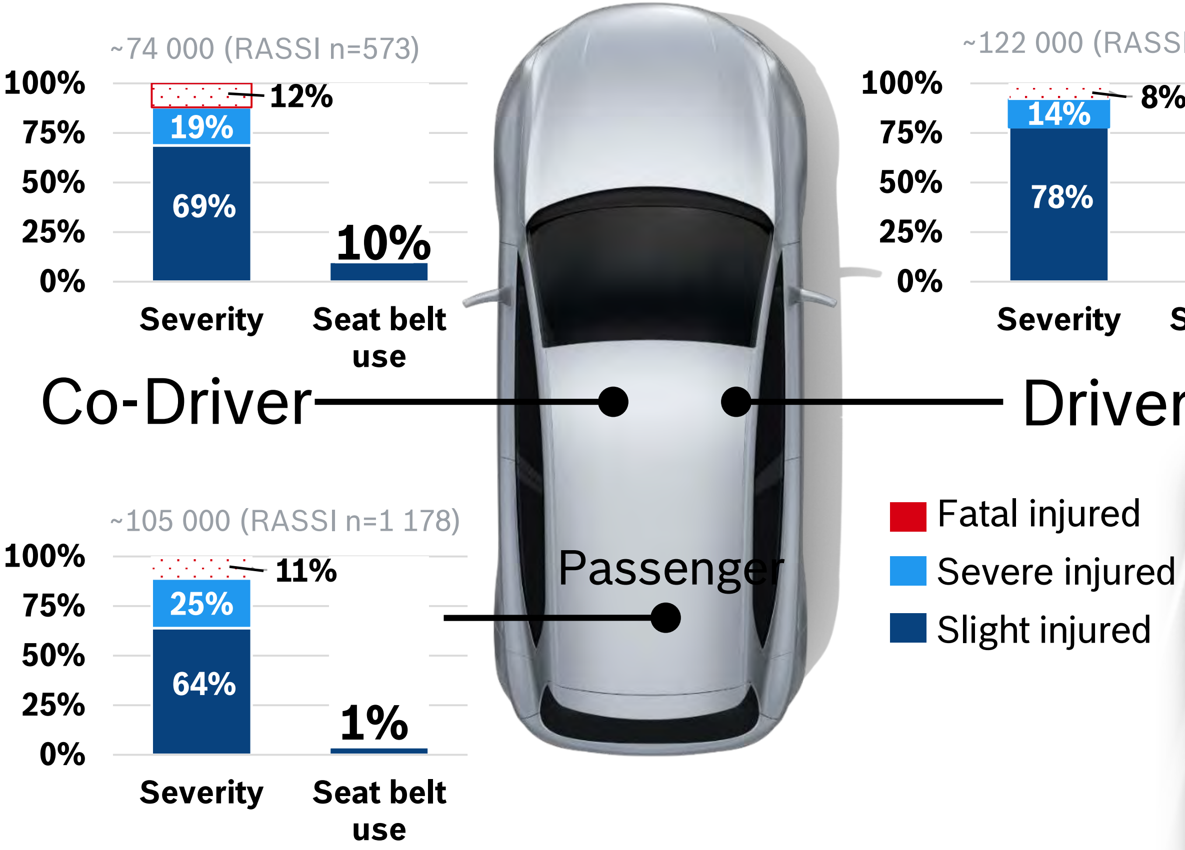
Status: Car safety

RASSI



▶ **Measure:** Enforce the use of the seat belt

RASSI database (2009-2017) data weighted and representative for India; Analysis based on 2 492 injured occupants

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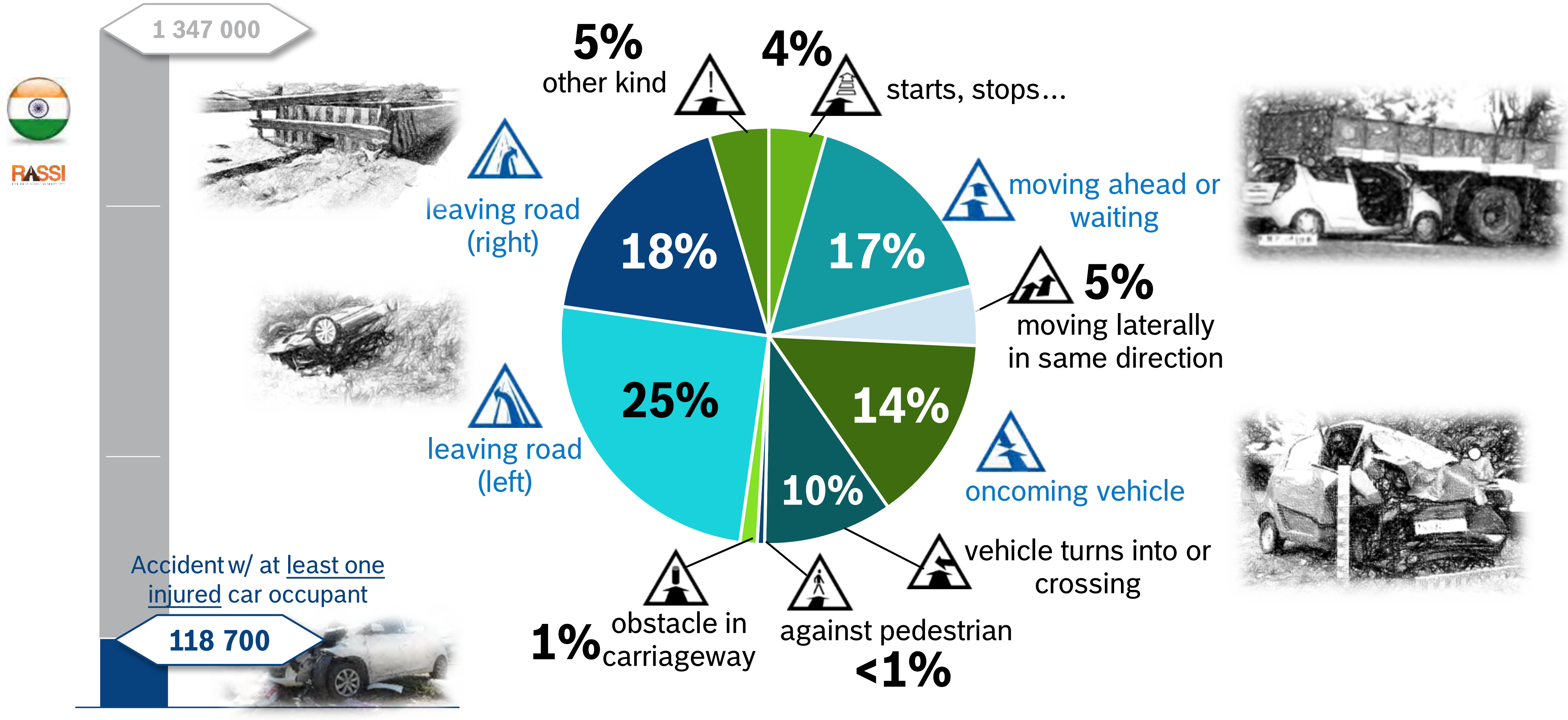
Accidents by kind of crash – TOP 3 scenarios highlighted

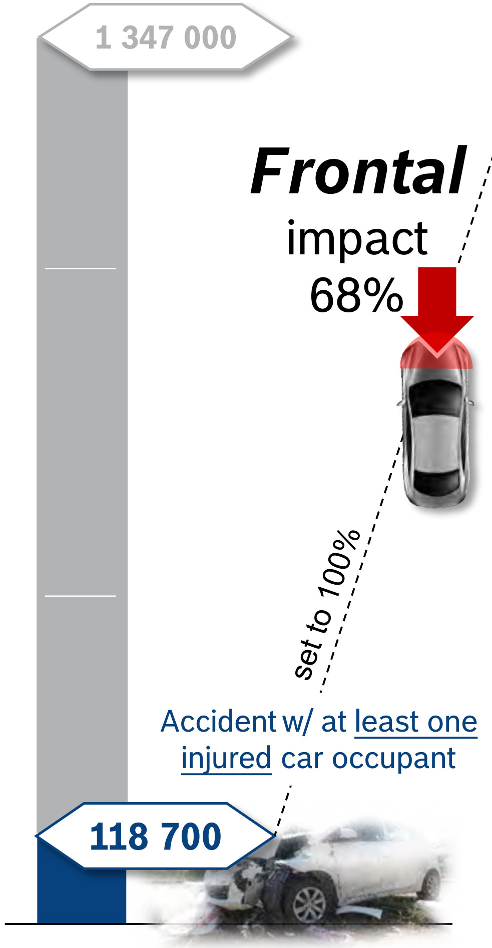


Pictures: Bosch Accident Research

RASSI (2009-2017) data weighted and representative for India; Analysis based on 3 046 crashes w/ injured

Crash configurations & opponents

RASSI



28%	**against object** (concrete, pole,...)
19%	**trucks, bus, ...**
10%	**passenger car**
11%	**VRU** (2W,...), **non motorized traffic**
21%	side- & rear-end impacts
11%	rollover

Pictures: Bosch Accident Research

RASSI (2009-2017) data weighted and representative for India; Analysis based on 850 cars with at least one car occupant injured

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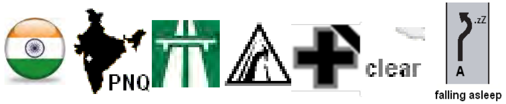
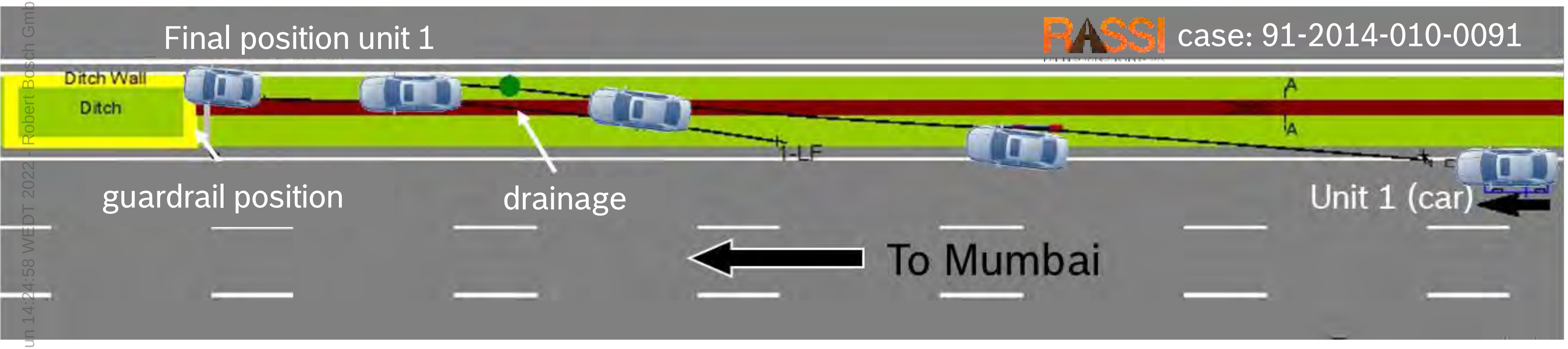
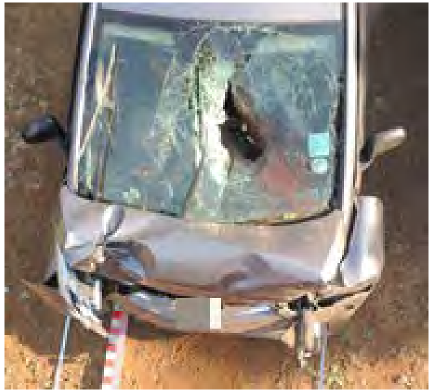
Collision against object







▶ Road departures often occur due to missing road separation and **road infrastructure** could support

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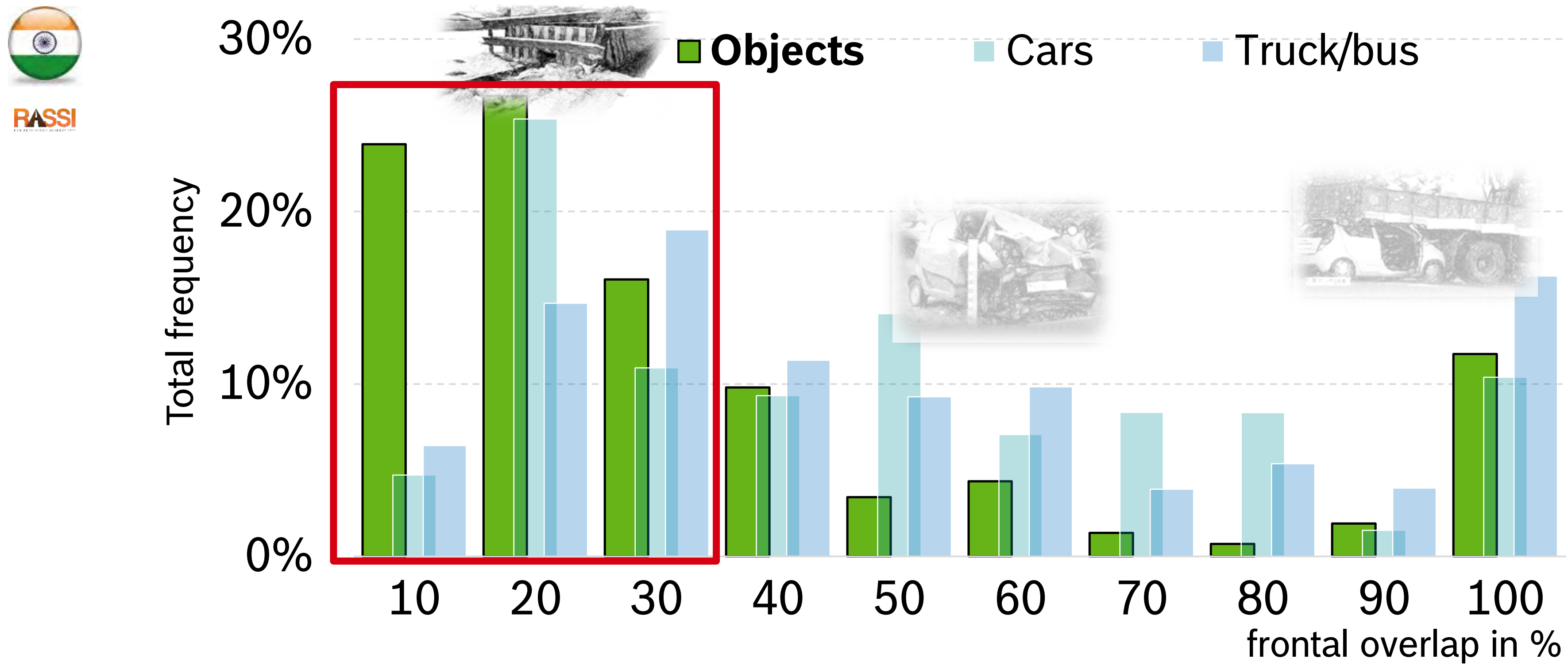
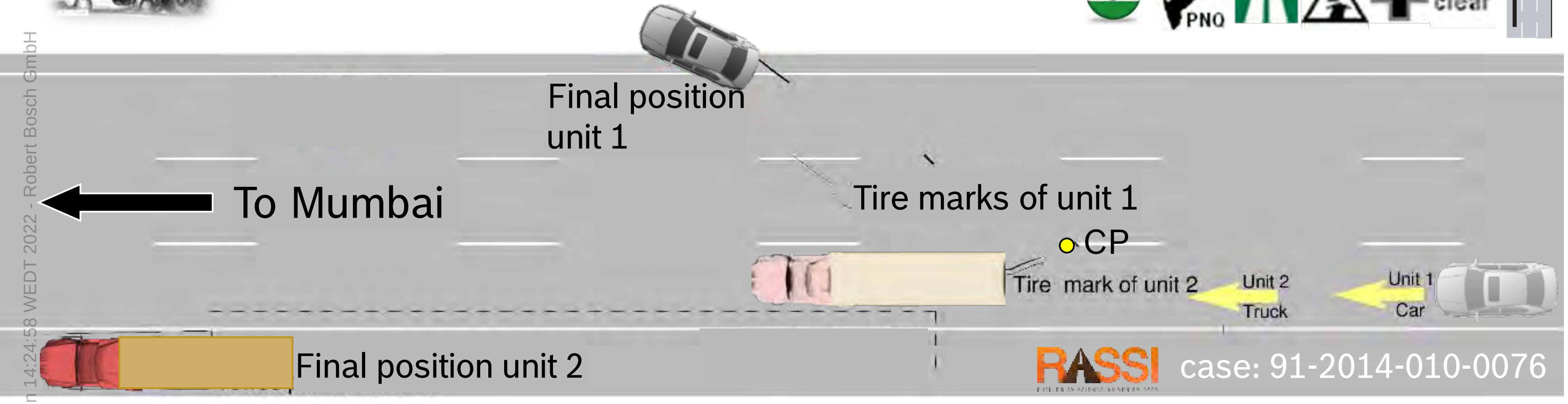
Point of impact: Overlap for car frontal crashes w/ at least one occupant injured



- Every 2nd object collision (52%) below <30% overlap
- Impact scenario challenging for central airbag ECU

RASSI (2009-2017) data weighted and representative for India;
Analysis based n=853 cars with at least one car occupant injured

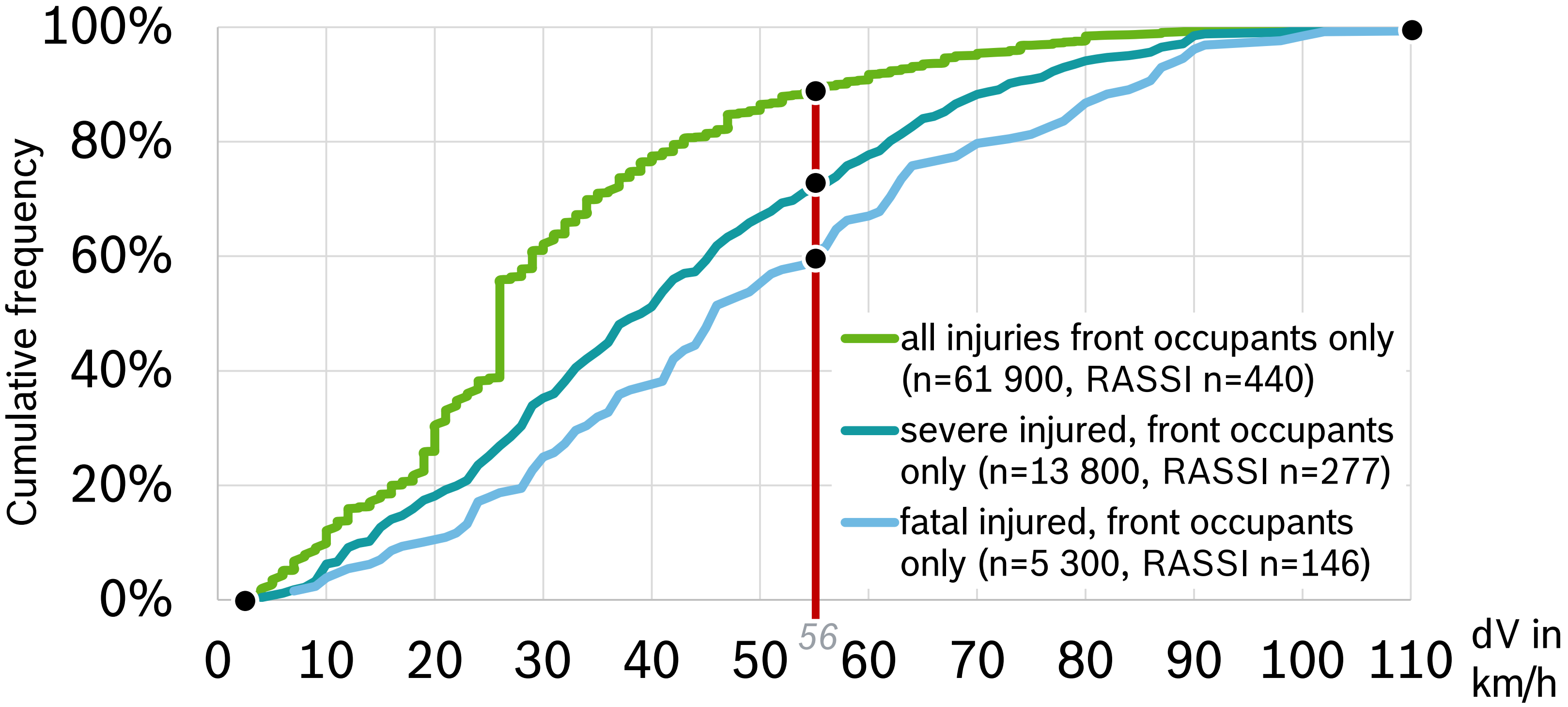
Truck rear-end collision



- Truck: Effective underride protection
- Car: Limits of passive safety reached → **Active Safety!**

Speed: Velocity change (dV) for car frontal crashes w/ at least one car occupant injured

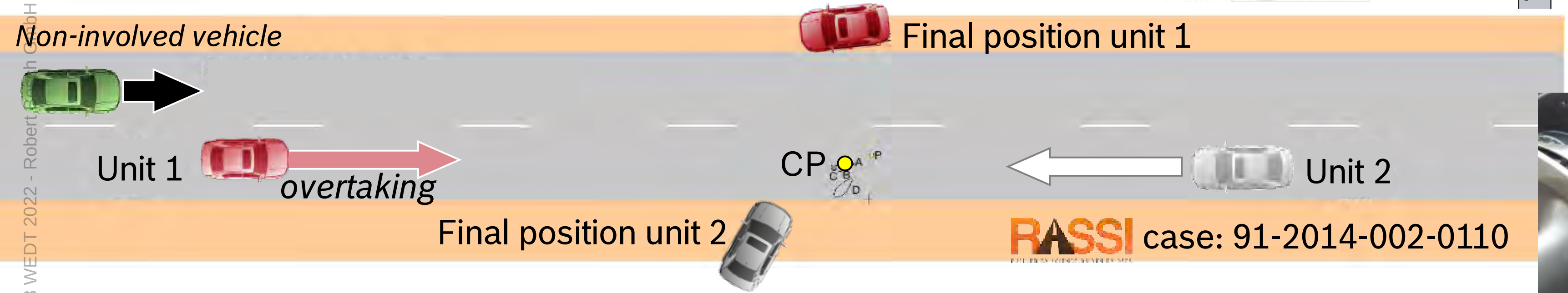
RASSI



- 75% of severe injured occupants occur at dV< 56 km/h, which is similar like in other countries

RASSI (2009-2017) data weighted and representative for India;
Analysis based n=853 cars with at least one car occupant injured

Car2Car collision



▶ Advanced **structure layout** for crashes along with **passive safety** could contribute

How can vehicle safety contribute to road safety in India?

- **Accident situation:**
  Main crash scenarios similar to other countries but amount differs
- **Crash compatibility:**
  Advanced vehicle structure layout and hardware protection
- **Passive safety:**
  Requirements cannot be reduced, advanced sensing
- **Active safety:** Skidding cars common in road departure accidents, standard technologies e.g. Electronic Stability Control could help
- **Furthermore ...**
  - increase education & awareness especially the use of a seatbelt!
  - improved infrastructure
  - rescue: faster post crash response

→ *Further information see publication on Airbag Symposium 2018*

Public funded project:
OSCCAR
Future occupant safety for crashes in cars

Accident Research
CR/AEV1

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Annual Report – EU project: OSCCAR

Chapter 11

Overview

EU project:

- 21 partners from eight countries
- ~720PM effort / ~7.5M€ budget
- run time: 01 June 2018 – 31 May 2021

Key Objectives:

- Understand future, new accident scenarios
- Demonstrate solutions for advanced occupant protection systems
- Harmonize and enhance virtual tools that are required by Tiers 1 suppliers and OEM’s

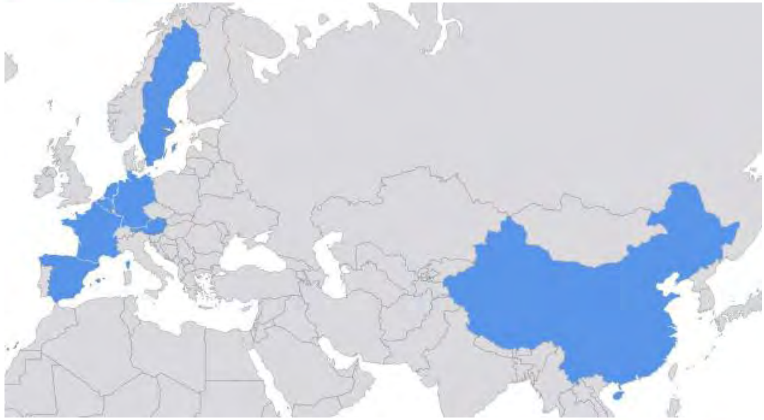
Activities with Bosch Accident Research participation in WP1:

- Methodology framework for integrated assessment
- Accident data analysis – remaining accidents and crash configurations of automated vehicles in mixed traffic

Annual Report – EU project: OSCCAR

Key figures

- Coordinator: Virtual Vehicle (VIF)
- 21 Partners from 8 countries AT,BE,CN,DE,ES,FR,NL,SE
    - o 6 Tier suppliers
    - o 4 OEMs
    - o 4 Research organizations
    - o 7 Universities
- Co-project “OSCCAR China” under H2020 Co-Funding Mechanism in initiation with Chinese MOST
- Twinning foreseen with US-DOT / NHTSA project (tbd.)
- 9 associated research and stakeholder partners from Europe, Canada, Japan, South Korea, USA
- Resources
    - o ~720 PM Effort
    - o ~7.5M€ Budget
- Project run time: from June 1st 2018 to Mai 31st 2021
- Expected OSCCAR Impact time: 2020 to 2040?



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Main objectives

Chapter 11

FUTURE OCCUPANT SAFETY FOR CRASHES IN CARS

- Understanding **future accident scenarios involving passenger cars**
- Demonstration of **new advanced occupant protection** principles and concepts addressing future desired sitting positions made possible by HAVs
- Contribution to the development of **diverse**, **omnidirectional**, **biofidelic** and **robust HBMs** for the prediction of occupant response in the pre- and in-crash phase for the development of advanced occupant protection systems for new sitting positions as made possible by HAVs
- Establishment of an **integrated, virtual assessment framework** for complex scenarios as needed for the development of advanced protection systems for all occupants
- Contribution to the **standardization of virtual testing procedures** and promotion of HBMs acceptance in order to pave the way for virtual testing based homologation
- Development of an **exploitation strategy** towards large scale **implementation of virtual testing methods** for advanced occupant safety solutions created during this project.

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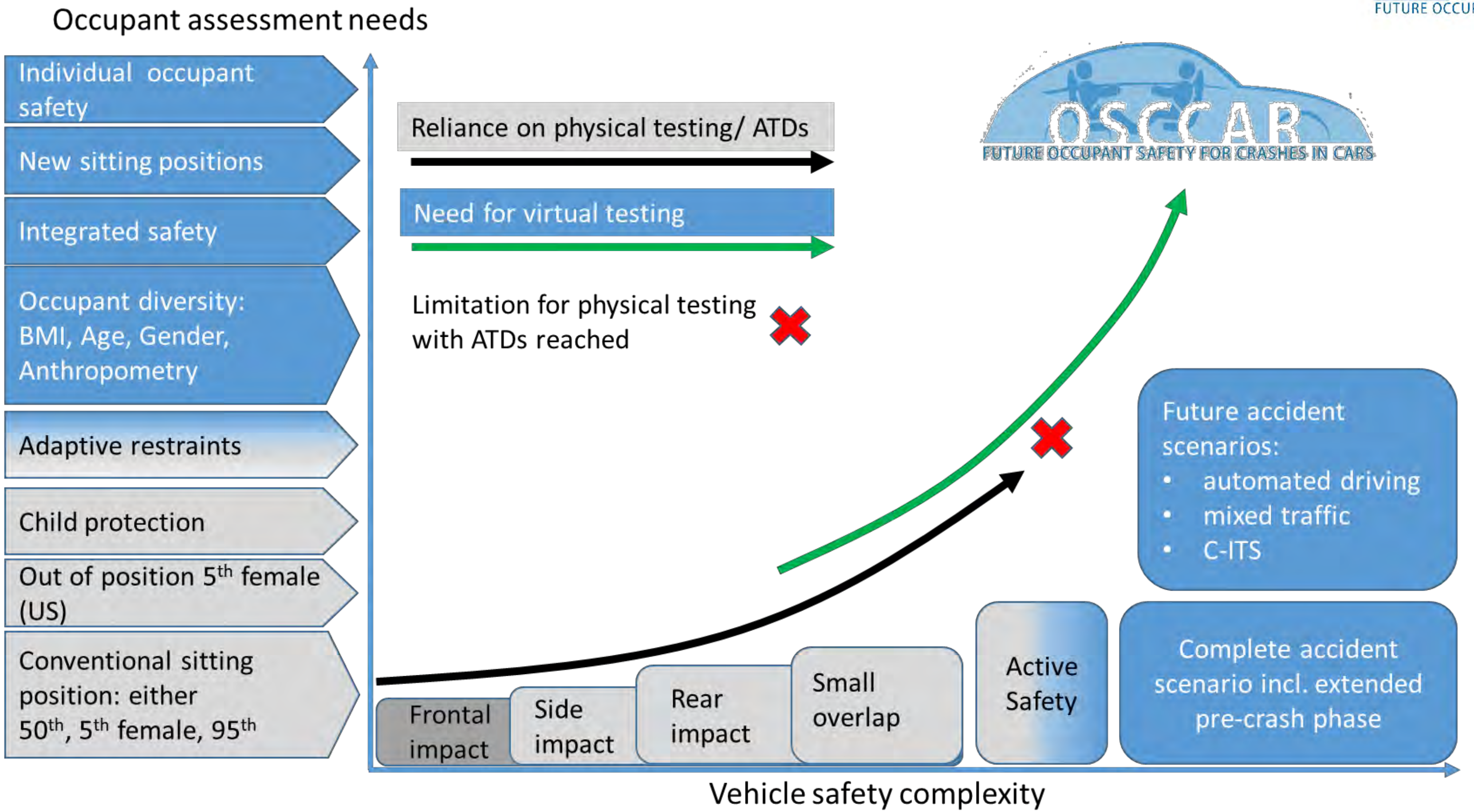
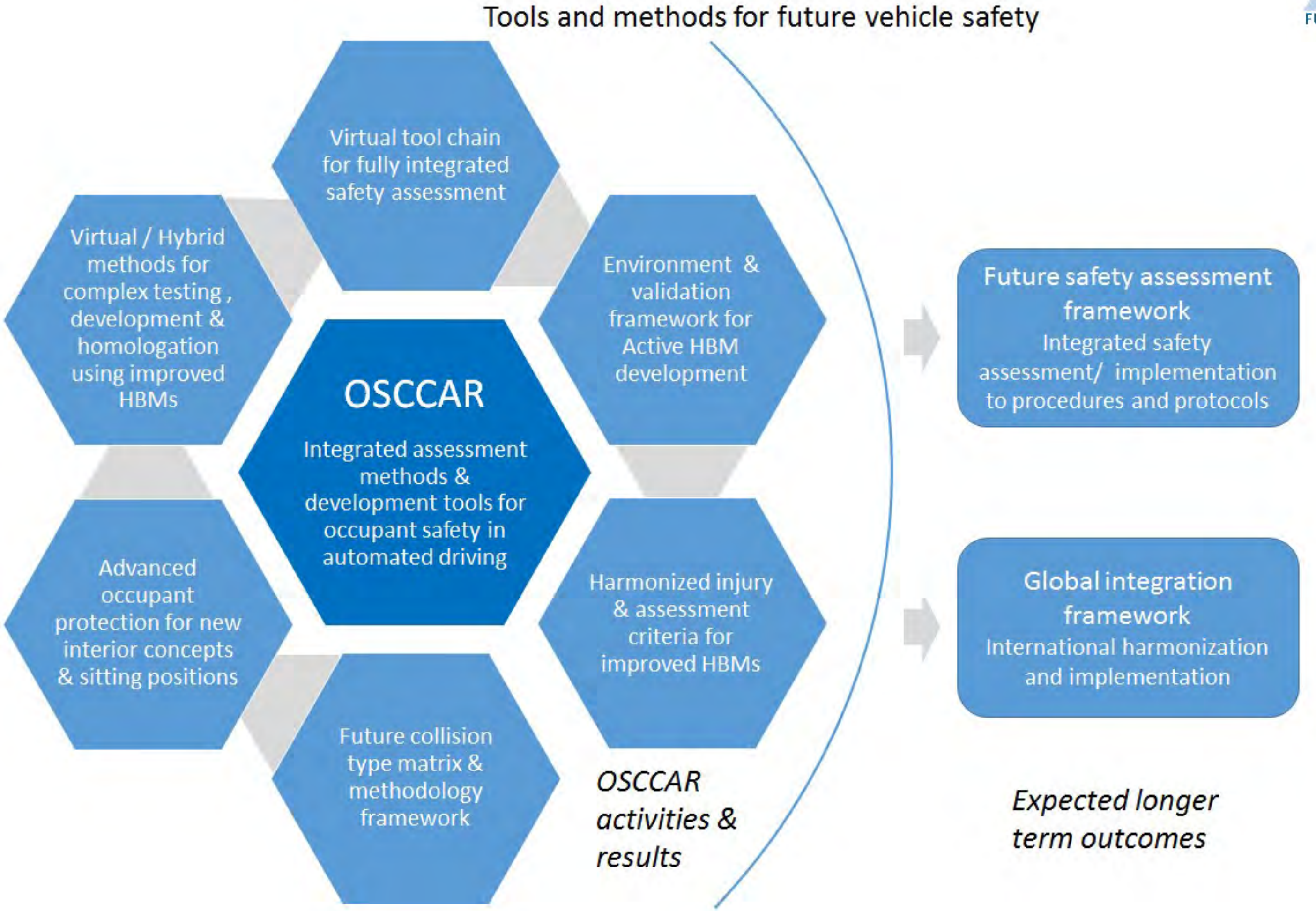
Accident scenario complexity



Annual Report – EU project: OSCCAR

Concept and project delineation



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Areas of impact (I)

OSCCAR
FUTURE OCCUPANT SAFETY FOR CRASHES IN CARS

- contribute to the reduction of
  - the number of **road fatalities**,
  - the **severity of injuries**,
  - the **number of injured persons**
- provide a public **future accident & conflict scenario database**
  - in particular for use OEMs, Tier suppliers and road operators/ infrastructure providers; even legislation authorities
- Develop **future occupant protection principles**
- Establish a basis for **standardization of virtual assessment** of advanced protection systems for **conventional vehicles <u>and</u> HAVs**

Annual Report – EU project: OSCCAR

Areas of impact (II)

OSCCAR
FUTURE OCCUPANT SAFETY FOR CRASHES IN CARS

- facilitate the evaluation and therefore the implementation of **new and innovative safety solutions** and related **enabling tools** that could boost the R&D of services and industries not only inside the automotive domain but also in other fields of application such as two-wheelers, VRU and even sports
- pave the way for **virtual homologation** of **future sitting positions** for HAVs
- define an accepted **procedure for harmonized and more biofidelic HBMs** allowing for an improved occupant safety for conventional vehicles and HAVs
- enable a **broad coverage of heterogeneous occupant population** (gender, age, height, weight, anthropometry,) for conventional vehicles and HAVs
- show the **applicability/usefulness of the developed framework for future safety systems** by several selected demonstrators
- **secure the required full scale manufacturing of critical products developed** in the project in Europe by key players from European industry
- **boost harmonisation and standardization on global level** (Europe, US, Canada, South Korea, India, China) and therefore speed up the implementation of the projected integrated assessment framework

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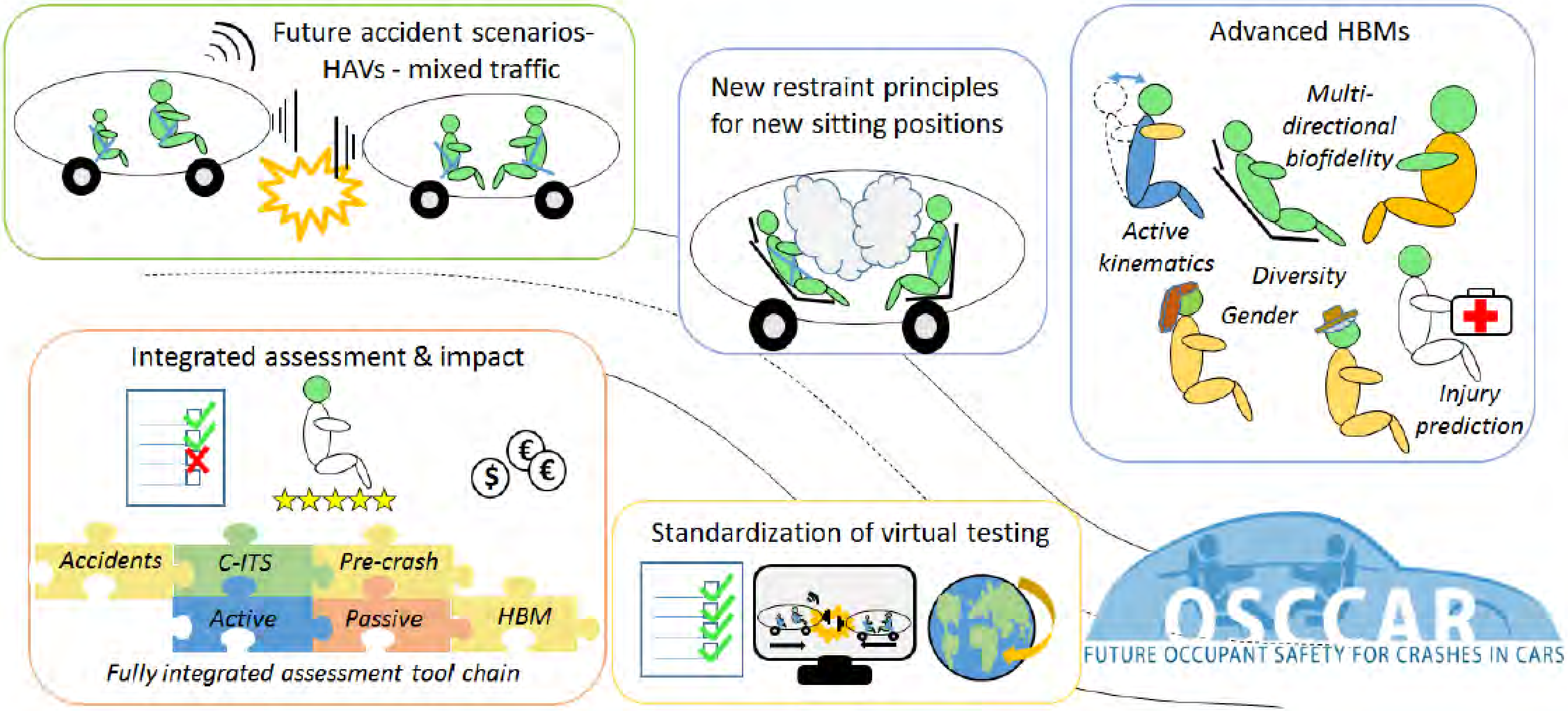
Areas of impact (III)

In short, and graphically:



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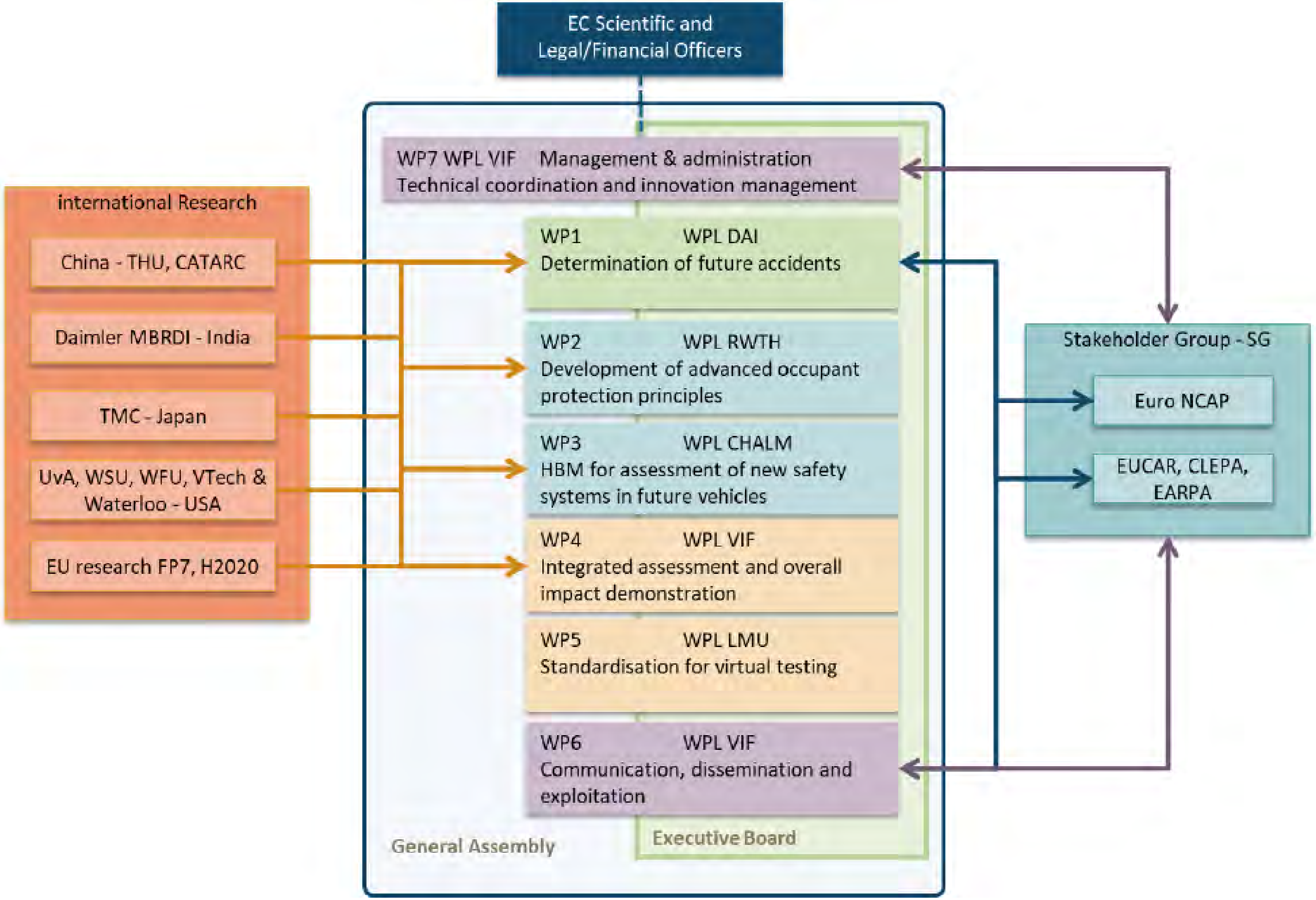
Governance Structure



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Workpackage Structure

FUTURE OCCUPANT SAFETY FOR CRASHES IN CARS

WP1 - Determination of future accidents (DAI)
- T1.1 Methodology framework for integrated assessment
- T1.2 Traffic simulation and accident scenarios definition
- T1.3 Parameter for EU & China traffic model based on real world data analysis and use cases

WP2 - Development of advanced occupant protection (RWTH)
- T2.1 Definition of test cases
- T2.2 Conception of passenger protection principles
- T2.3 Development of advanced passenger protection systems for HAVs
- T2.4 Demonstration and validation

WP3 - Human Body Models for assessment of new safety systems in future vehicles (CHALM)
- T3.1 Improved HBMs for injury risk predictions
- T3.1 Improved HBMs for pre-crash simulations
- T3.1 Injury prediction in new sitting positions and new crash scenarios

WP4 - Robust and efficient crash simulation tools for integrated assessment (VIF)
- T4.1 Development of a simulation quality check tool
- T4.2 Development of tool-independent injury assessment
- T4.3 Demonstration (Implementation effects & impact demonstration)

WP5 - Standardisation of virtual testing (LMU)
- T5.1 Environment Validation Procedures for Virtual Testing
- T5.2 HBM Procedures and Requirements
- T5.3 Harmonisation of Injury Risk Assessment

WP6 - Exploitation and dissemination (VIF)

WP7 - Project coordination and administration (VIF)

WP8 - Ethics requirements

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Deliverable D 1.1

Results out of workpackage 1 you will find on FEBER

https://rb-wam.bosch.com/workon01/workflow01/browse/FEBER-92712#

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Overview of short term studies
- Examples only -

Accident Research
CR/AEV1

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Overview of short term studies – 2018

These studies are not planned inquiries - hence funding across all stakeholders. List not complete

Date	Dep.	Selected short term inquires (2018 total: 38)
02/2018	CC-AD/PJ-CS	Probability of accidents due to vehicle breakdowns and health issues of driver at motorways → Estimated potentials due to HWP Safe Stop
02/2018	CC/ENA	Accidents due to brake defects
02/2018	CC-AD/EYU	Selection of accident descriptions for ATHENA
03/2018	C/QMT-FQB	Battery disconnection or damage due to accidents
03/2018	CC-DA/EAV	Driving time between start of trip and frontal impact
03/2018	CVO/PRM	Ultrasonic near range observation
03/2018	CC-PS/ESY	Front crashes with slight front offset/angle crash as 1st collision (pre-event)
05/2018	2WP/MBC	Support of teaser for DSM / EICMA
05/2018	CS	Vehicle Safety System Scoring
05/2018	CC-DA/EAR	Car AEB rear-end radar only

Overview of short term studies – 2018

These studies are not planned inquiries - hence funding across all stakeholders. List not complete

Date	Dep.	Selected short term inquires (2018 total: 38)
06/2018	CC-PS/ESY	Front crashes with any airbag-algorithm relevant pre-event → dv of main event within relevant range for potential disposal firing
06/2018	CC/QMC1	Providing available ESC effectiveness studies
07/2018	CC-AS/ECP	Brake intervention at accidents w/ preceding skidding
07/2018	CC-PS/QMM	China: Frontal accidents of cars – Upfrontsensor
08/2018	CC-DA	Truck accidents in China
10/2018	CC/MBL1-NA	Impact of iBooster on Accident Situation Estimation
10/2018	CC/MBC	Field of effect: AEB-2W & AEB-Animal
10/2018	CR/AEV	AEB-L relevant accidents for P2W in curves (for 2WP workshop)

Chapter 13

Publications 2018

Accident Research
CR/AEV1

Internal | Bosch Accident Research | Jan/31/2019
AEV-064 annual report 2018

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Publications 2018

ESAR`18	**Expert Symposium on Accident Research, Hanover, Germany** “KAUSAL – a virtual tool chain to estimate the impact of automated driving on occupant restraint systems”
ESAR`18	**Expert Symposium on Accident Research, Hanover, Germany** “Benefit estimation of eBike ABS based on simulation of bicycle accidents”
iCSC’2018	**International Cycling Safety Conference, Barcelona, Spain** “Benefit estimation of an Antilock-Braking System (ABS) for Pedelecs based on simulation of real world accidents”
MotoSafe	**1st Motorcycle Safety Forum (MIROS), Kuala Lumpur, Malaysia** “Effectiveness of Motorcycle ABS and its possible impact to road traffic safety in Malaysia”, Oral presentation only
Airbag’18	**14th International Symposium and accompanying Exhibition on Sophisticated Car Safety Systems, Mannheim, Germany** “How vehicle safety contribute to increase road traffic safety in India?”