VOLKSWAGEN

AKTIENGESELLSCHAFT

rateEFFECT

Effectiveness Evaluation of Active Safety Systems

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Volkswagen Group Research

rateEFFECT: Effectiveness Evaluation of Active Safety Systems

1. Intention and Motivation
2. Evaluation Approach - Introduction to rateEFFECT
3. Evaluation of Crash Avoiding Systems
4. Database – GIDAS-preCrashMatrix
5. Opportunities of rateEFFECT for the US - Discussion

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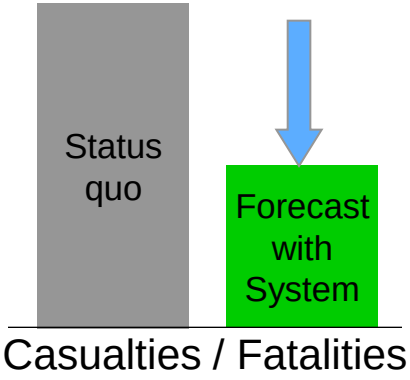
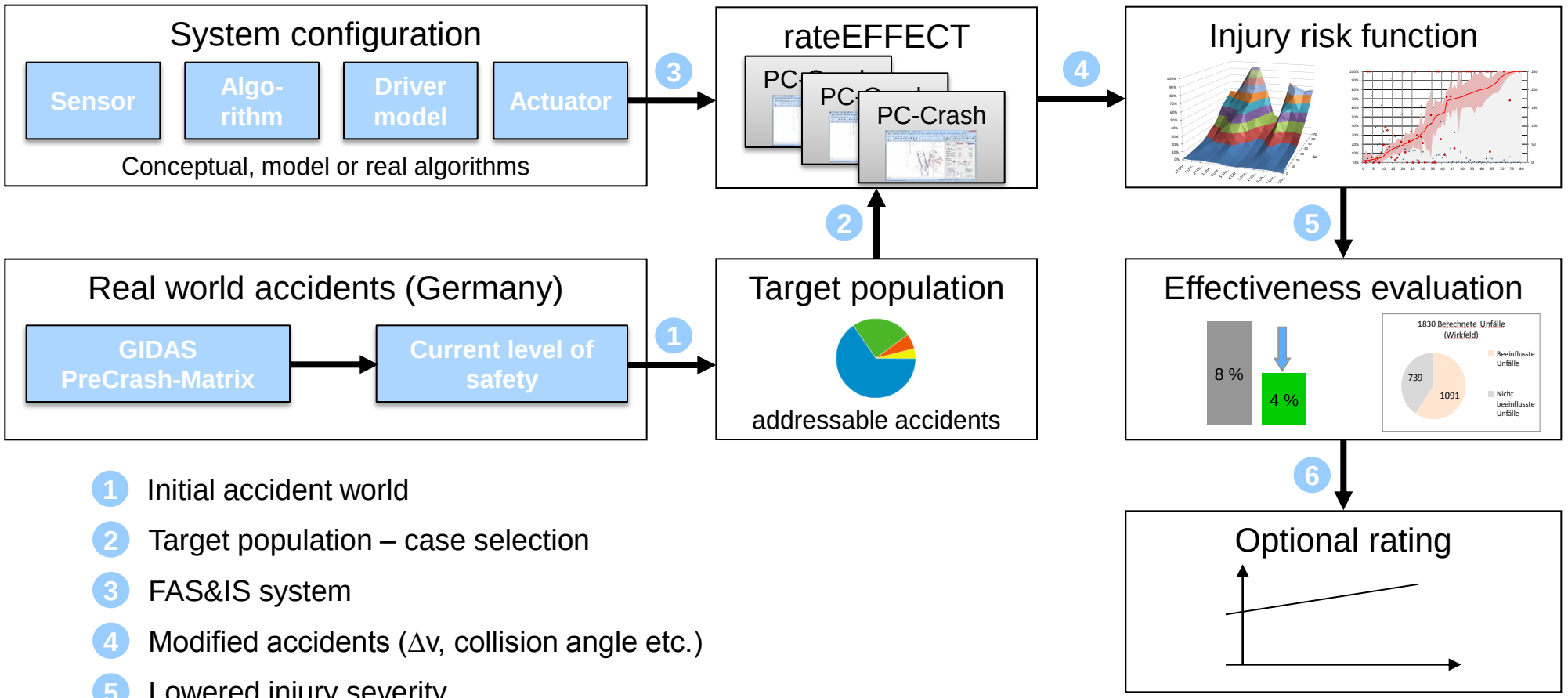
Intention and Motivation

A **Which active safety systems should be developed to maximize safety benefit in real traffic accidents?**

B **What is the effectiveness of a specific active safety system in the real world? How many casualties could be avoided by such a system?**

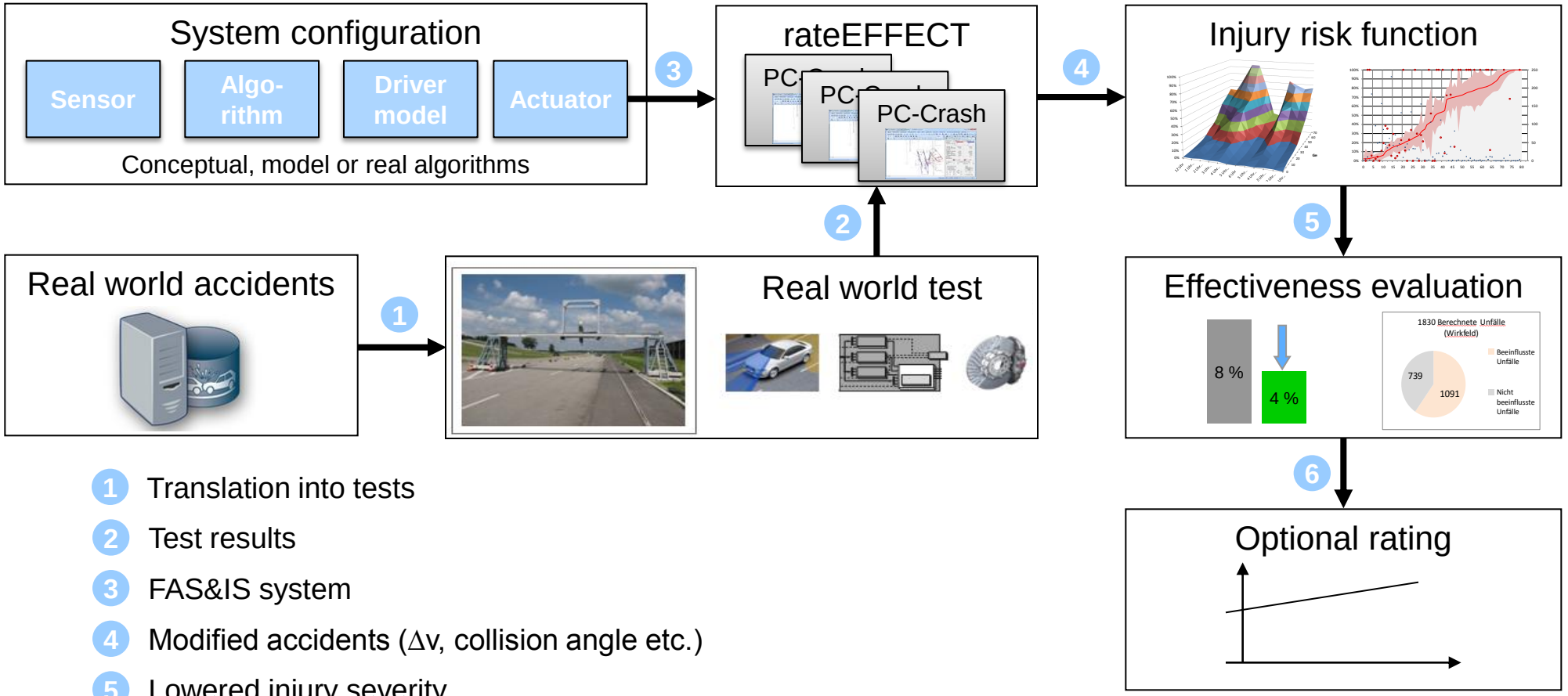


Rating Process



1. Initial accident world
2. Target population – case selection
3. FAS&IS system
4. Modified accidents (Δv, collision angle etc.)
5. Lowered injury severity
6. Translation into a rating

Integrating Real World Tests

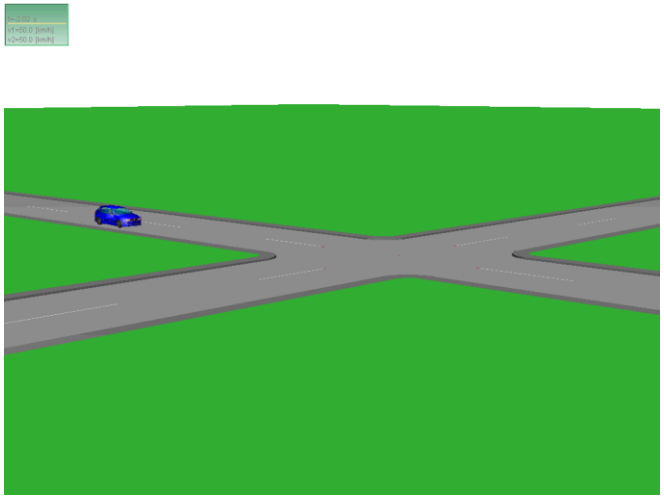


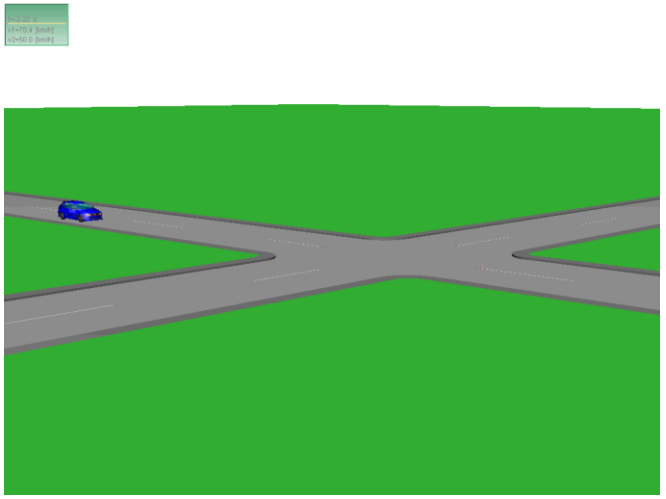
1. Translation into tests
2. Test results
3. FAS&IS system
4. Modified accidents (Δv, collision angle etc.)
5. Lowered injury severity
6. Translation into a rating

Effectiveness vs. Target Population – Need for Simulation

Questions the target population alone cannot answer:

- How does a specific system design influence its performance?
- Is driver reaction relevant for this scenario?
- What is the performance of a warning system compared to an AEB?





rateEFFECT Analysis with Different Levels of Detail

1 Target population

- Potentially addressable accidents
- Best-case-analysis

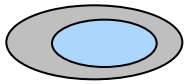
2 Simplified system

- rateEFFECT analysis of a simplified system
- Maximum of the achievable effect of a modelled System

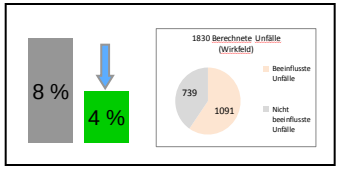
n Real system

- rateEFFECT analysis of a real approximated system
- Approximated effect of a real systems

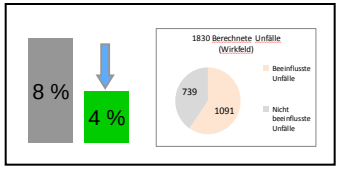
Target population



Effectiveness evaluation



Effectiveness evaluation



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3 Evaluation of Crash Avoiding Systems

4 Database – GIDAS-preCrashMatrix

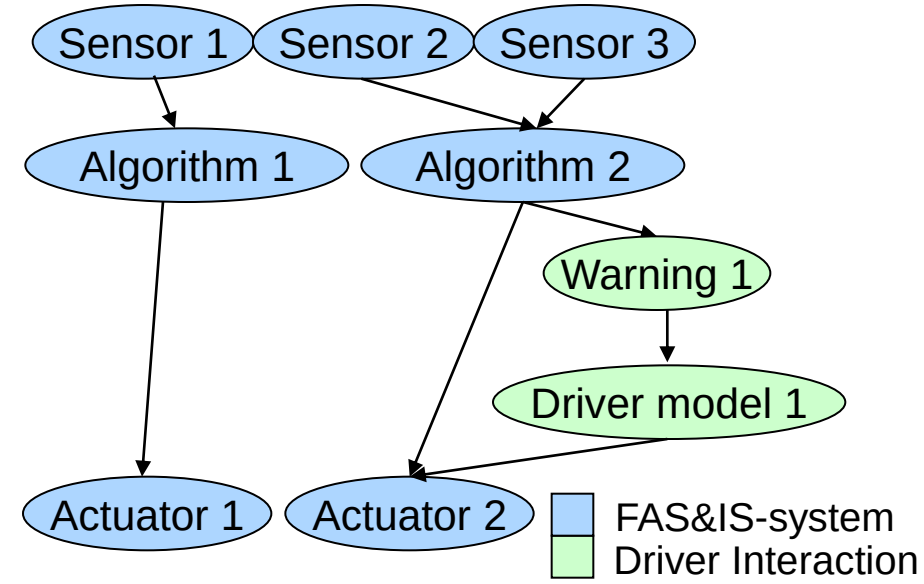
5 Opportunities of rateEFFECT for the US - Discussion

The Effectiveness Analysis is based on the In-the-Loop-Method

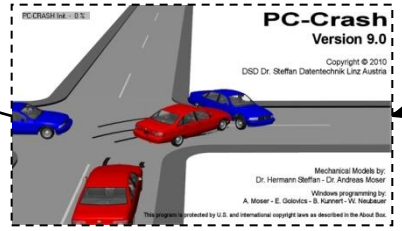
System Description

- Corresponds to the behavior of real vehicle components
- Classical simulator approach: Interaction in every integration step
- Based on PC-Crash (vehicle dynamics and scenery)
- Modelling of arbitrary systems possible (including continuous feedback control systems)
- Integration of arbitrary algorithms and complex driver models
- Adaption of the database to current safety level

System Modelling

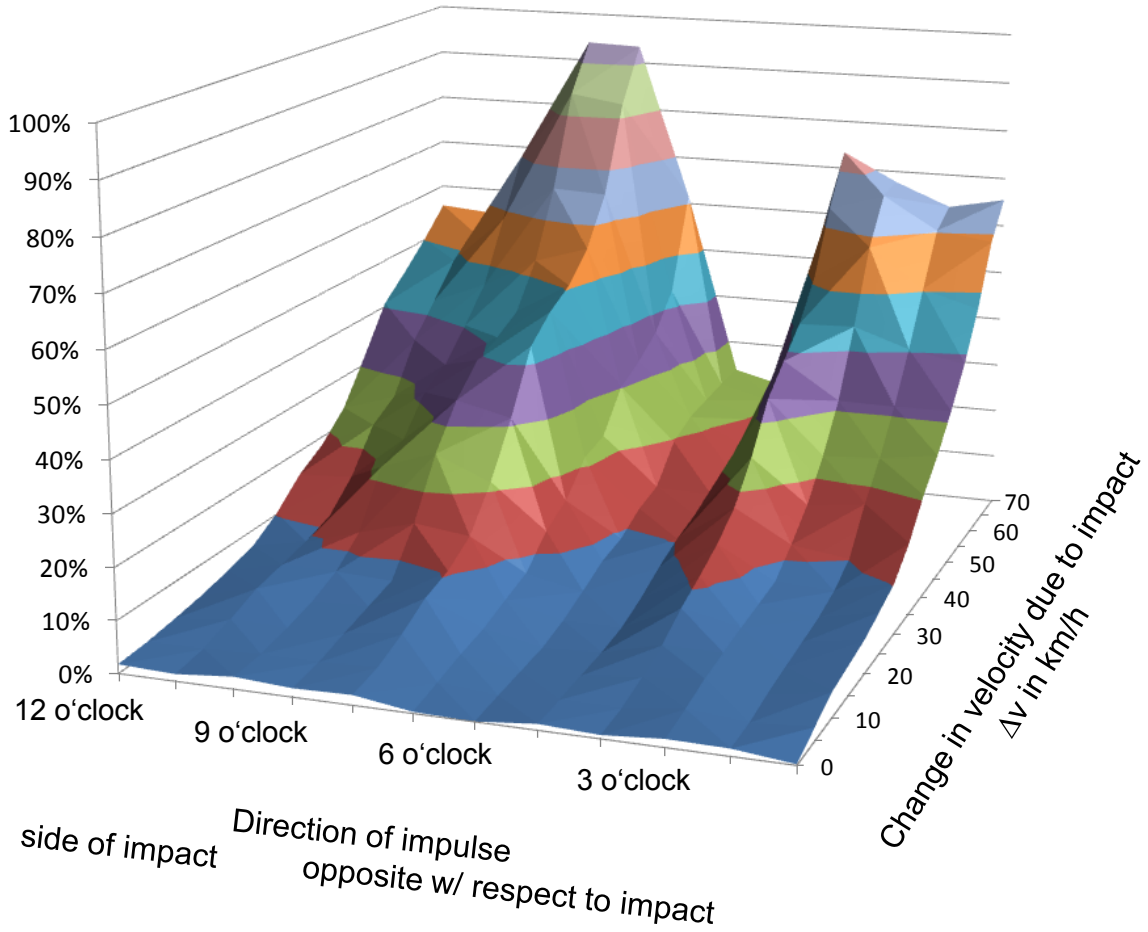


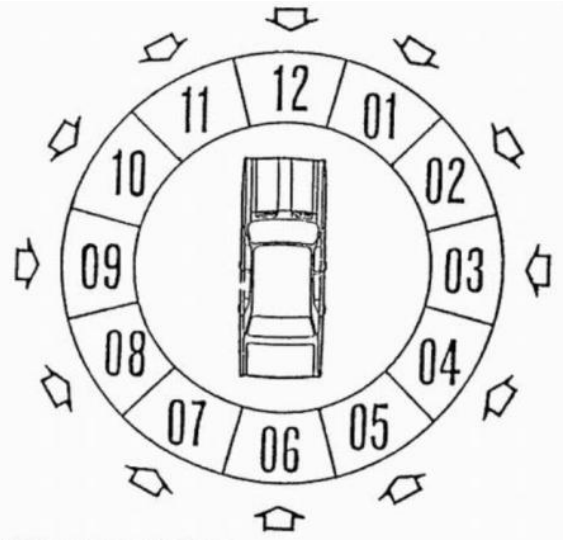
PC-Crash



Analysis is based on Injury Risk Functions

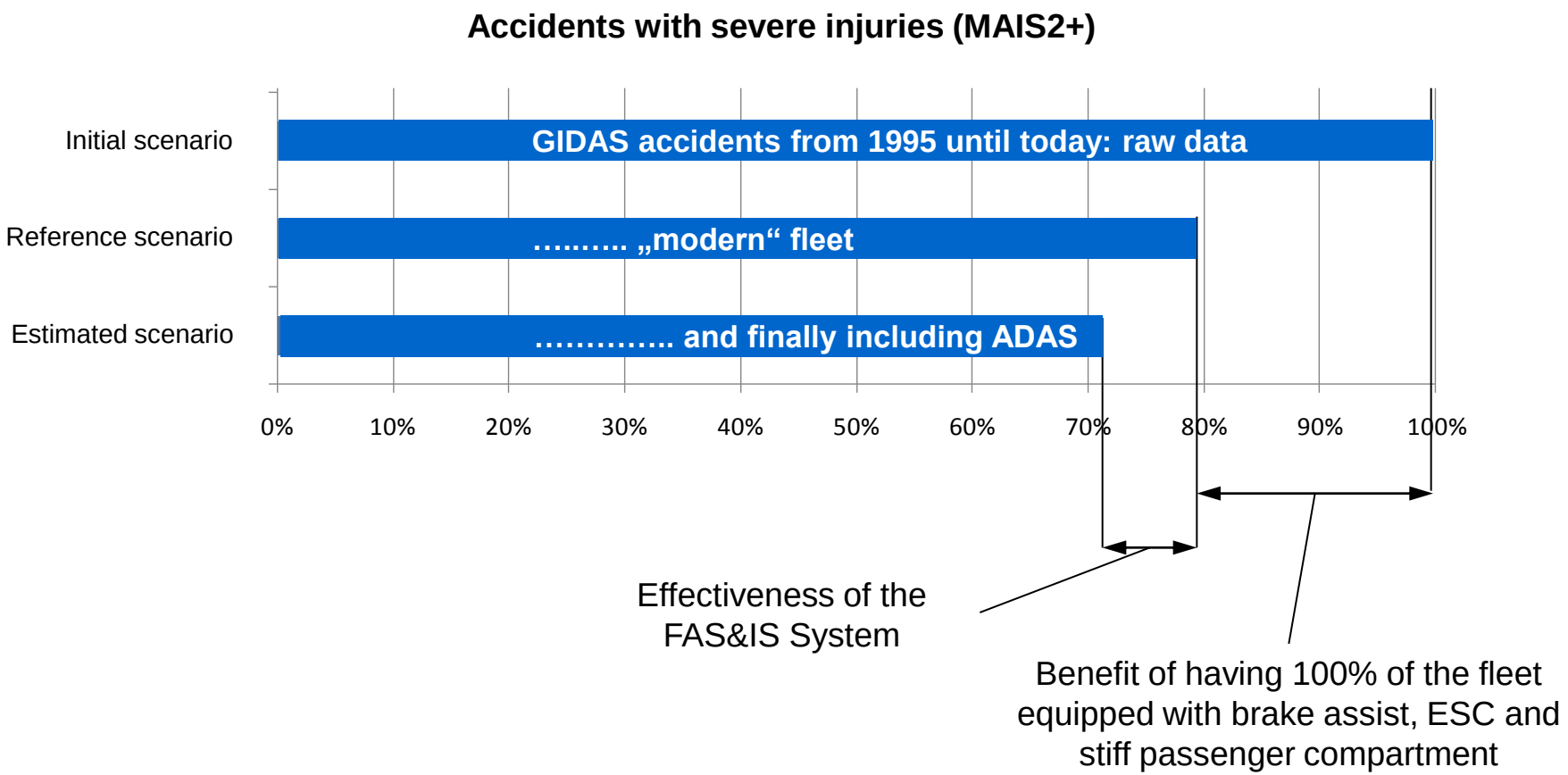
Example (severe injuries, MAIS 2+) for occupants of passenger cars*





*source: GIDAS 06/2010

Adaption of the Database to the Current Safety Level

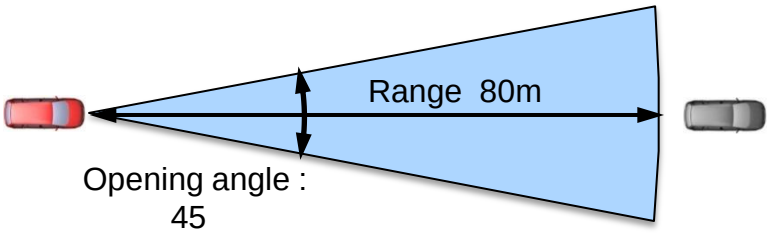


fictitious

rateEFFECT Analysis of a Fictitious Emergency Brake System

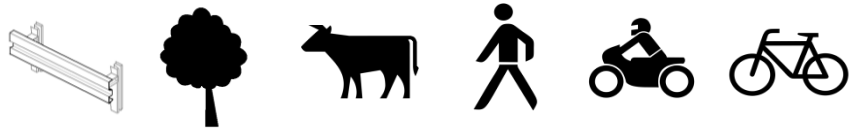
System description:

- PreCrash system with distance sensors to avoid or mitigate frontal impacts
- Velocity range:
  0 – 200 km/h
- Sensor properties:



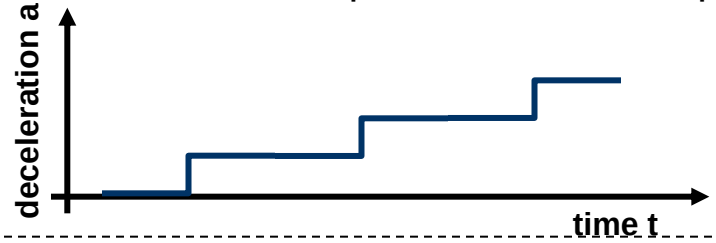
Detectable:

Not detectable:



System action:

- Three step braking up to full emergency brake in case an impact is about to happen



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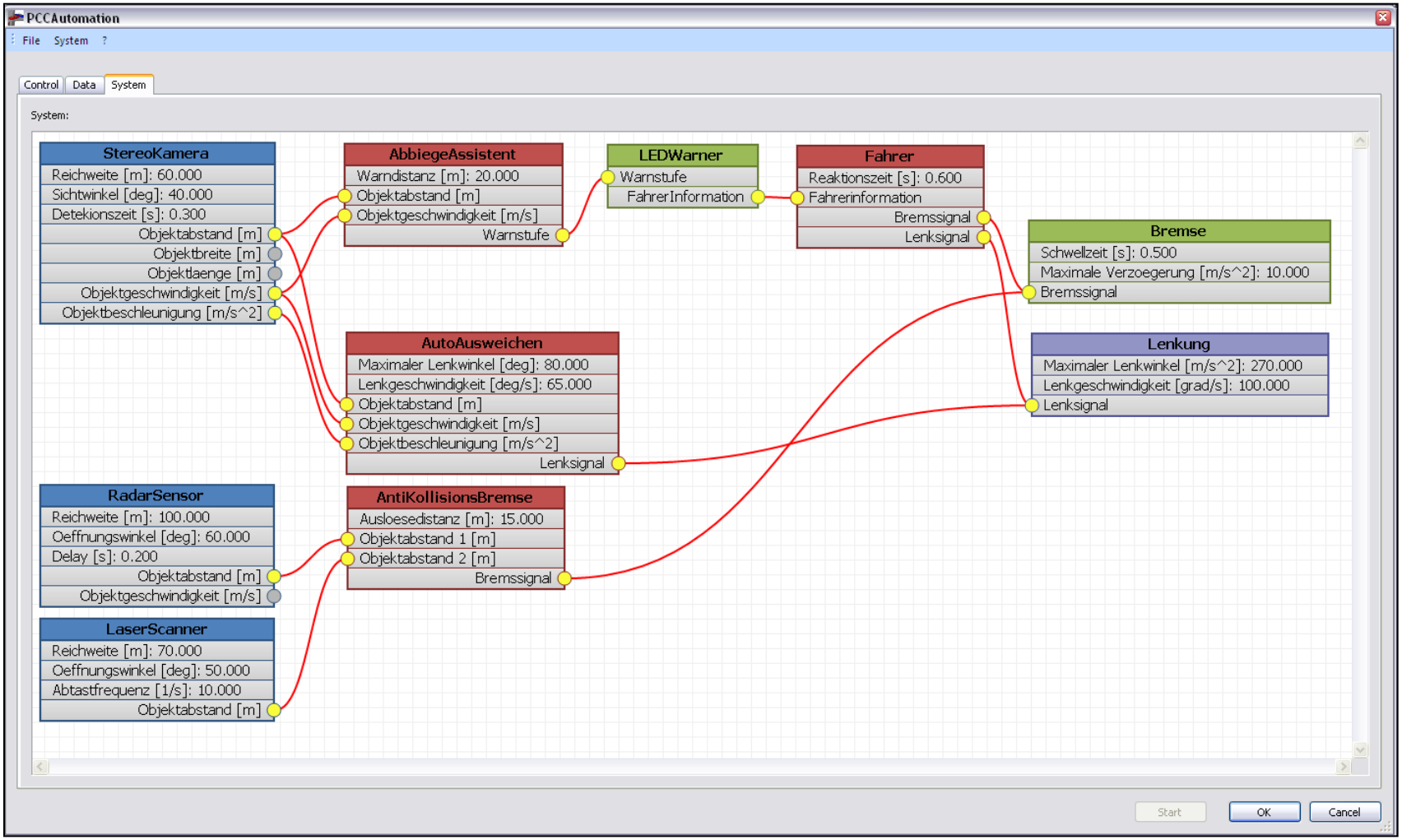
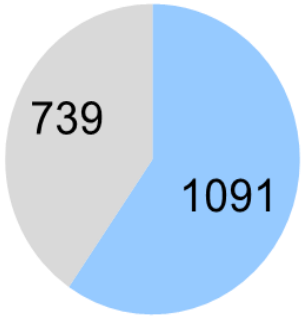


Example

Effectiveness Evaluation via Reduction of Injury Risk (MAIS2+)

Number of accidents simulated (target population)

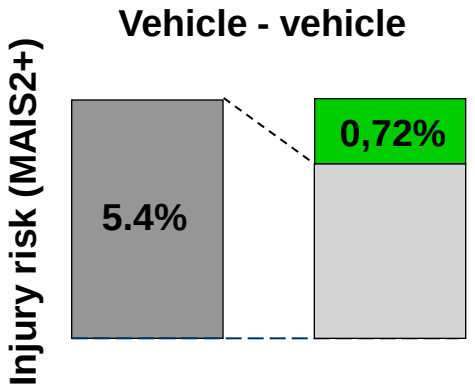


Accidents altered by system

Accidents not altered by system

Performance figures

- Ø dV original accident data (1830): 15,64 m/s
- Ø dV altered accidents (1091): 13,82 m/s
- Ø dV reduction altered accidents (1091): 7,07 m/s

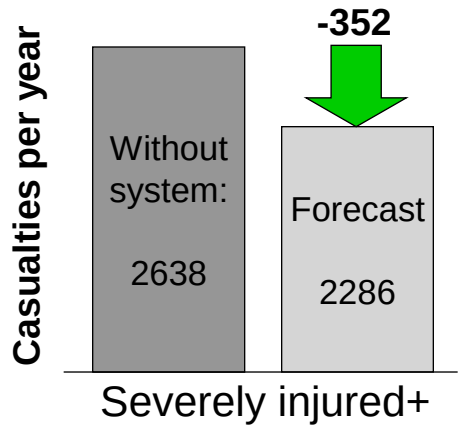


Target population

Adjusted to meet current safety level

System effectiveness

Difference between reference and estimated scenario



Without System

Adjusted to meet current safety level

System

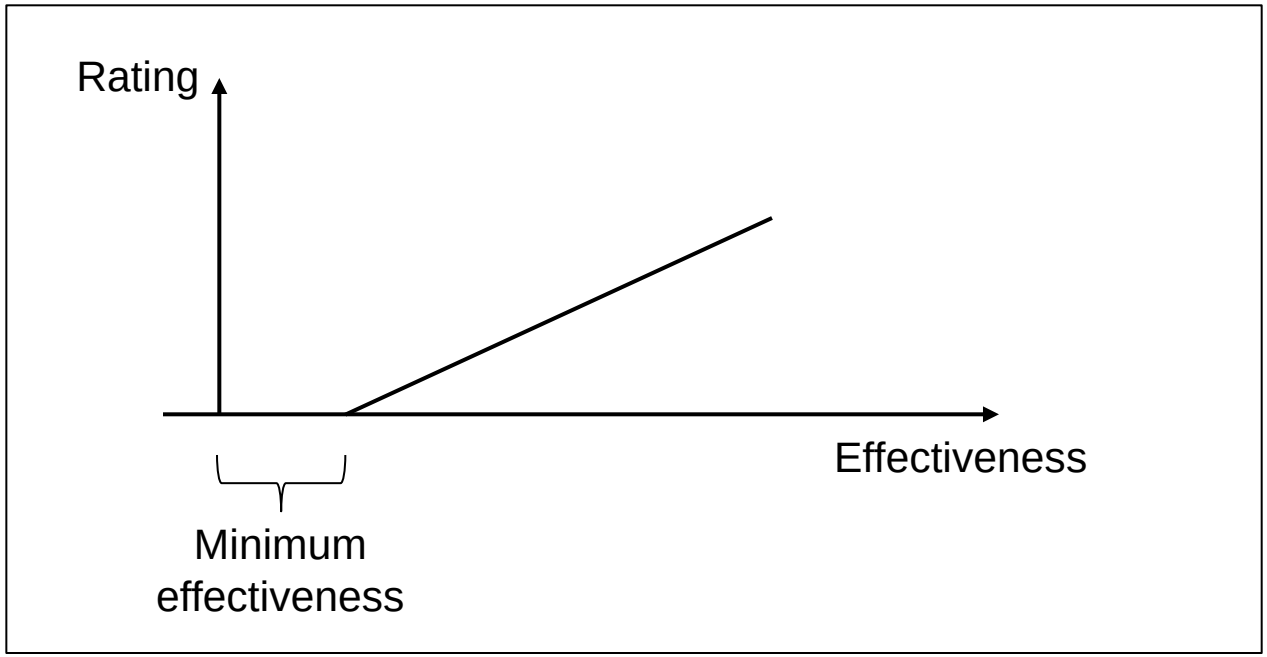
Difference between reference and estimated scenario

Translation into an Optional Rating

Draft

Translation into a Rating depending on the derived effectiveness in the field

- Possible scheme: Offset + linear correlation



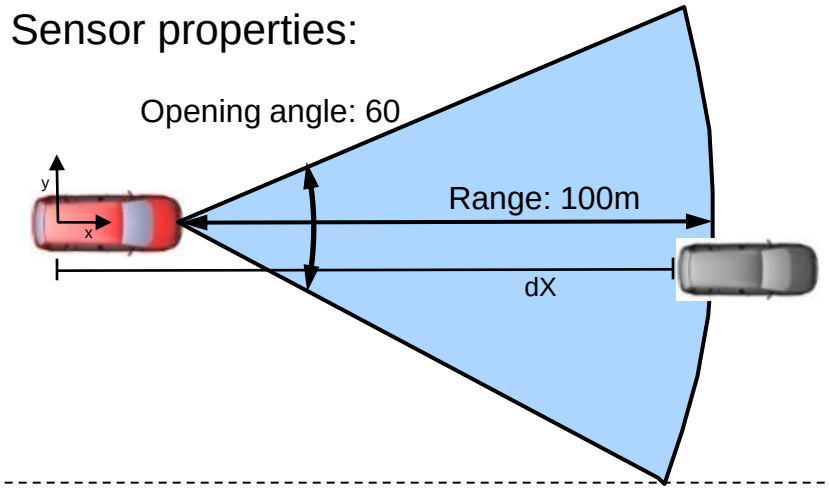
rateEFFECT: Effectiveness Evaluation of Active Safety Systems

fictitious

rateEFFECT Analysis of a Fictitious Emergency Brake System

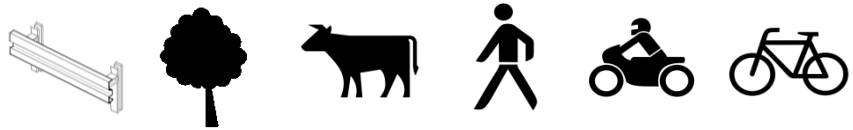
System description:

- PreCrash system with distance sensor to avoid or mitigate frontal impacts
- Velocity range: 0 – 200 km/h
- Detects stationary vehicles at v < 30 km/h
- Sensor properties:



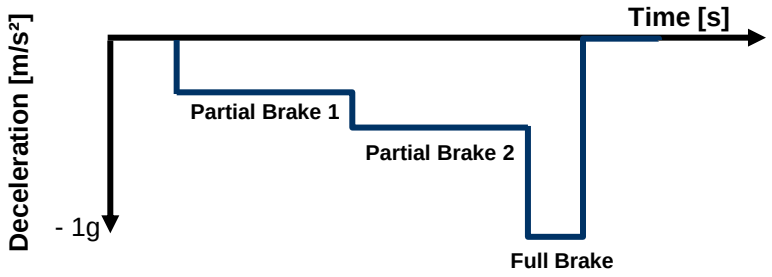
Detectable:

Not detectable:



System action:

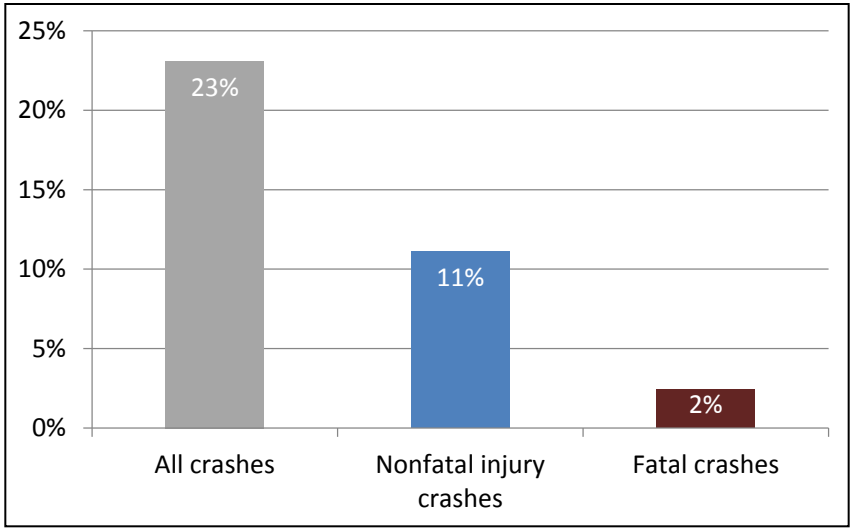
- Three step braking up to full emergency brake in case an impact is about to happen
  BAS to full brake in case driver is braking



Five Steps for the Target Population

1. Target population study (U.S.)
2. Accident level
3. Target population on person level
4. Comparison with target population in Germany
5. Target population in Germany (used for effectiveness calculation)

Target Population Forward Collision Warning

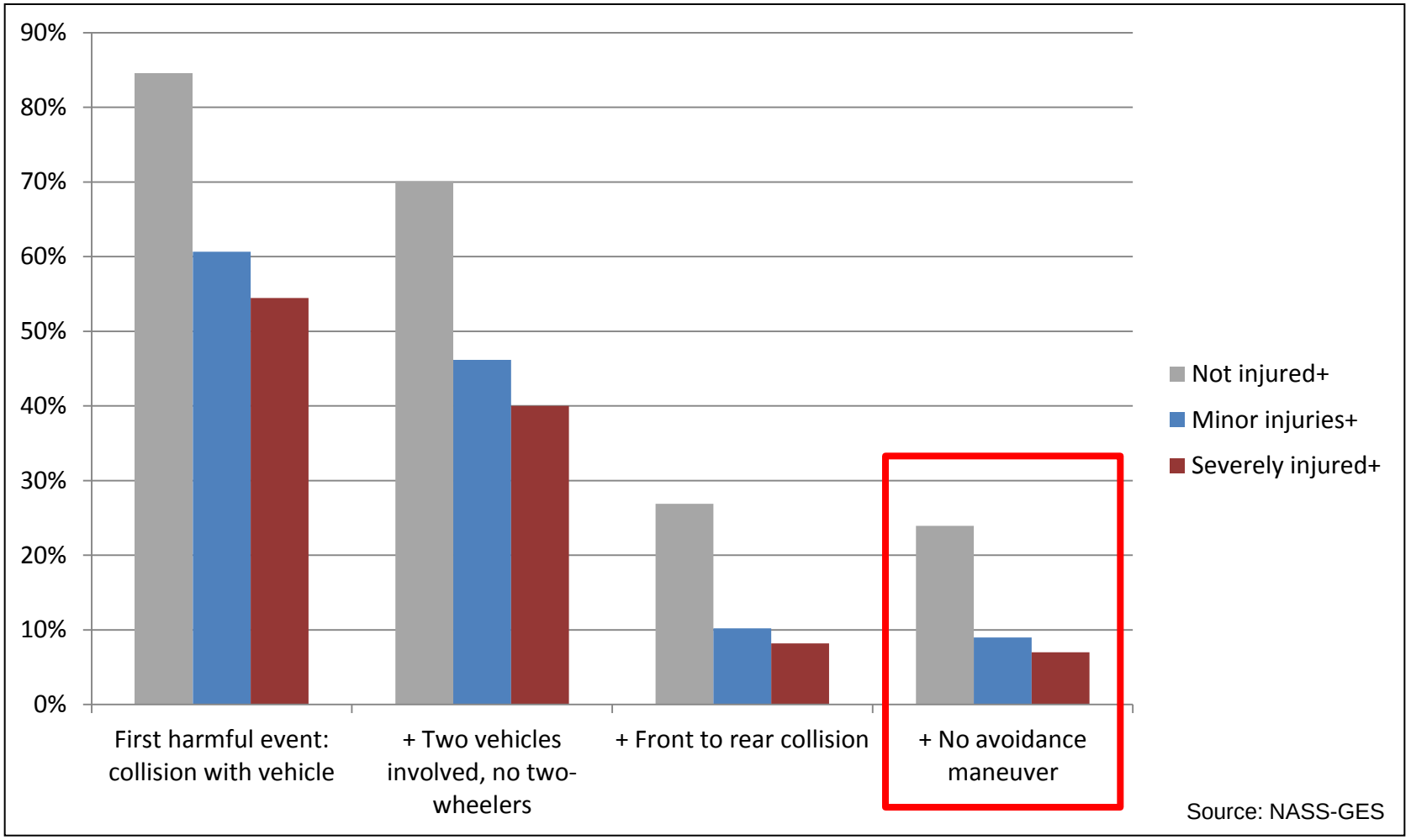


Source: Farmer 2008, Crash Avoidance Potential of Five Vehicle Technologies

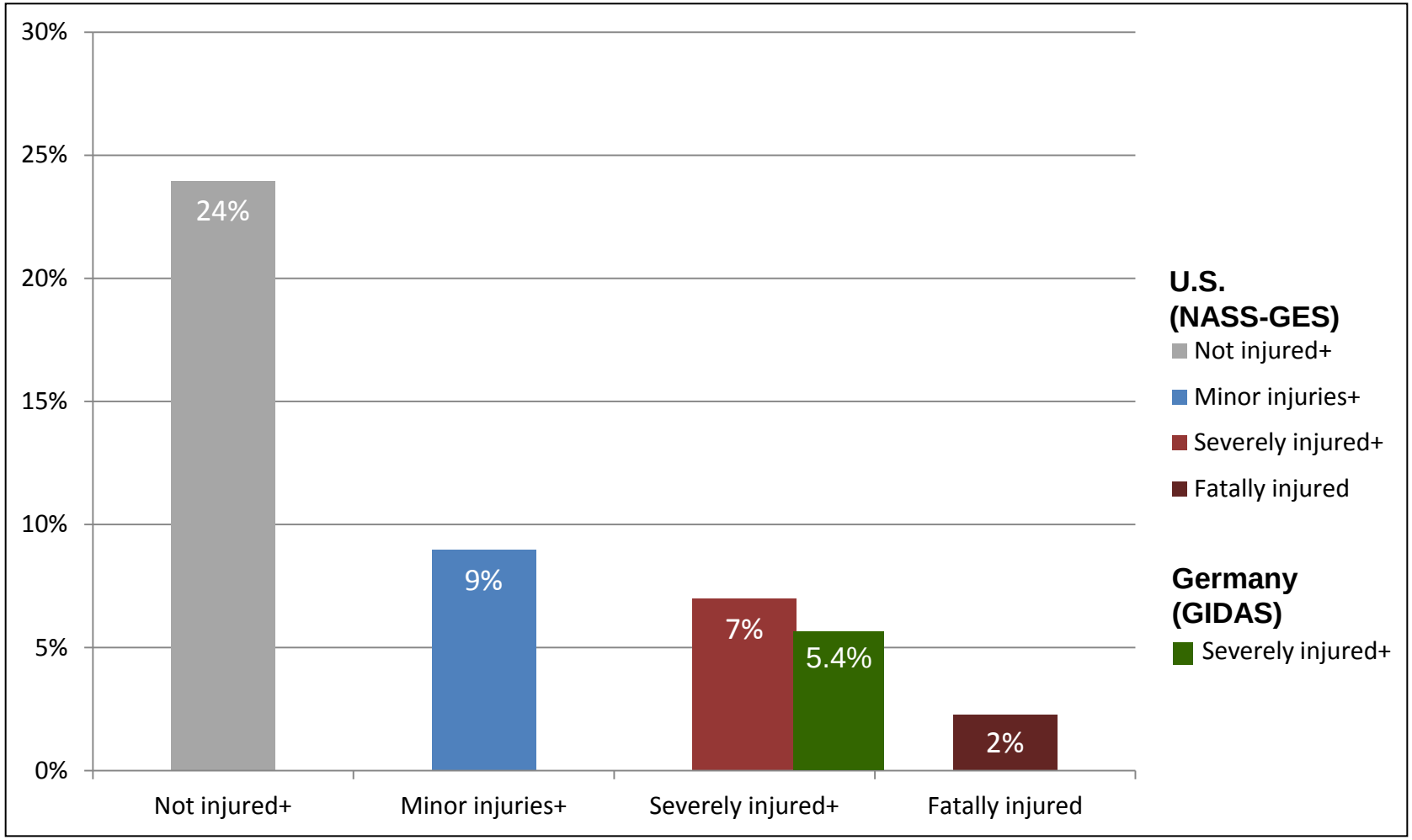
Table 3B. Annual front-rear crashes relevant to forward collision warning systems

Crash type	All crashes	Nonfatal injury crashes (A or B)	Fatal crashes
Front-to-rear, off roadway	6,000	<1,000	118
Front-to-rear, more than two vehicles	271,000	37,000	537
Front-to-rear, vehicle/road defect	4,000	<1,000	4
Front-to-rear, avoidance maneuver	8,000	1,000	108
Front-to-rear, struck by non-passenger vehicle	44,000	5,000	182
(Total nonrelevant)	(333,000)	(43,000)	(949)
Front-to-rear, other, with braking (relevant?)	**206,000**	**16,000**	**76**
Front-to-rear, other, without braking (relevant)	**1,176,000**	**67,000**	**746**
(Total relevant)	**(1,382,000)**	**(83,000)**	**(822)**
	1,714,000	126,000	1,772

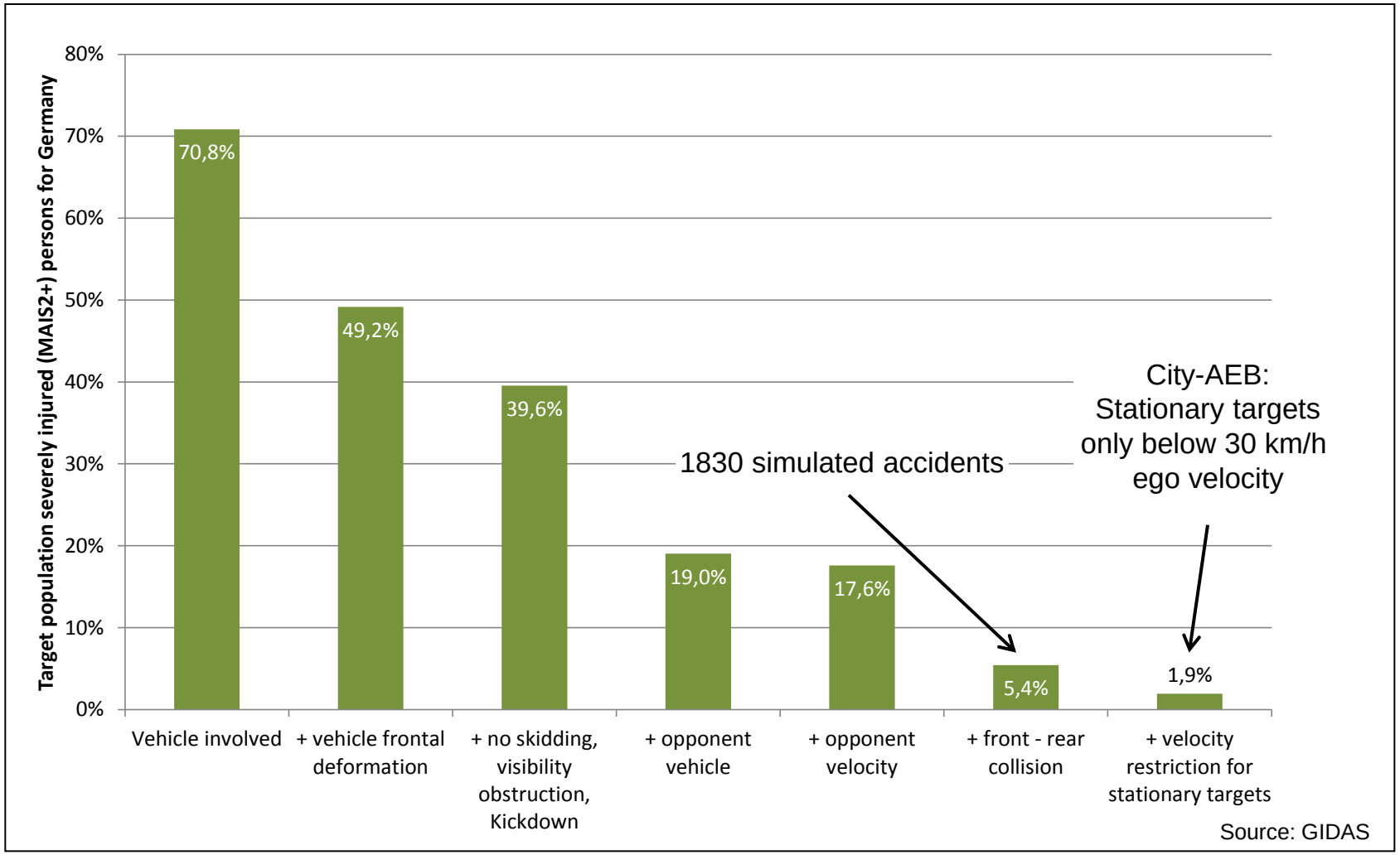
Target Population (Persons) Front to Rear / Car to Car in U.S.



Target Population (Persons) Front to Rear / Car to Car



Target Population Front to Rear / Car to Car Germany



fictitious

Four Different Variations of the Safety System

1 Basic Configuration: Brake Assist (BAS)

- BAS: If driver is braking above 6 m/s² in the original accident, this is increased to maximum braking

2 "…" + Autonomous Brake

- Three braking levels based on criticality
- Driver braking in original accident: increased to maximum braking
- System can detect stationary vehicles up to ego velocity of 30 km/h (city AEB)

3 "…" + Warning + Driver's Reaction

- Three braking levels based on criticality
- Autonomous braking triggers warning function, driver reacts with 1s reaction time
- Driver reaction is always braking. This is increased to maximum braking by the system

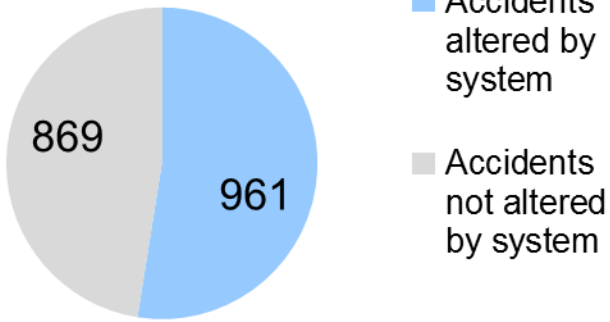
4 "…" + always detect stationary vehicles

- System can detect stationary vehicles regardless of ego vehicle velocity

fictitious

Effectiveness Evaluation via Reduction of Injury Risk (MAIS2+)

1830 accidents simulated
(target population)



Performance figures

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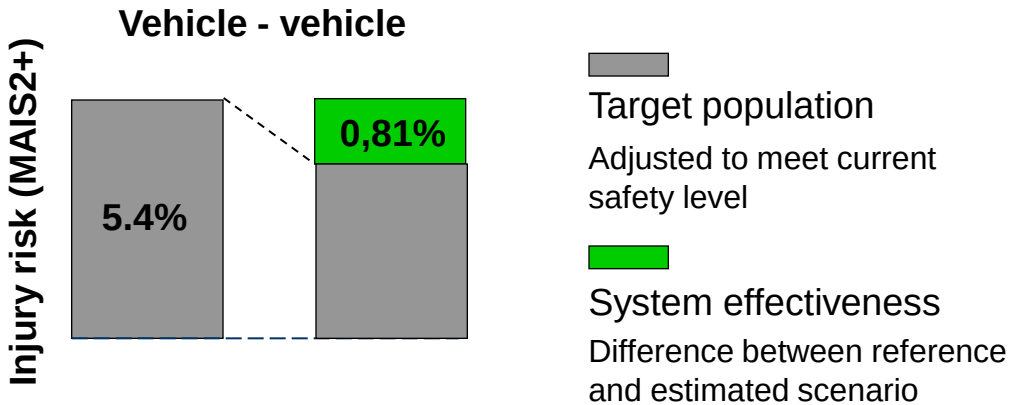
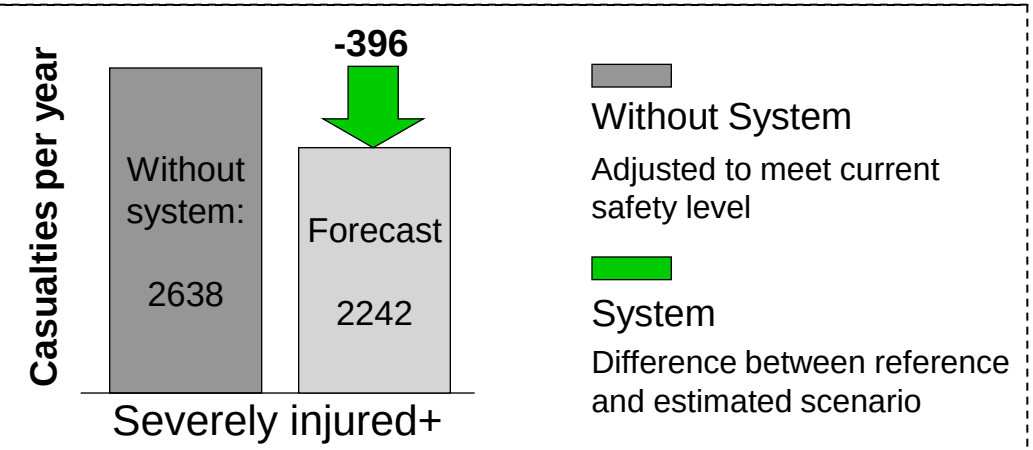


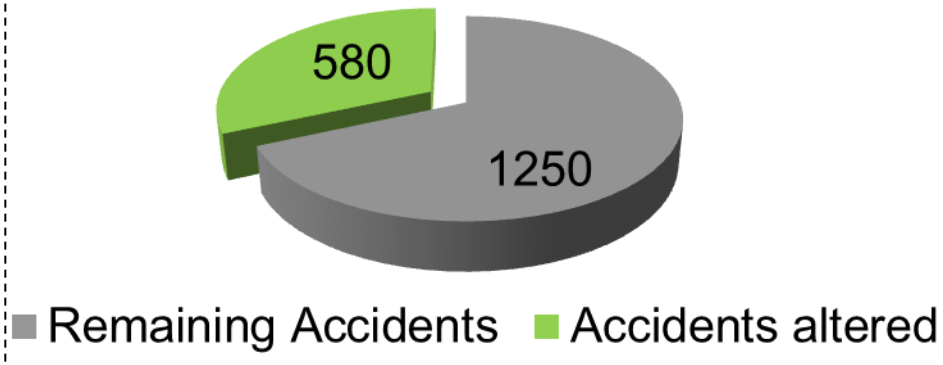


Configuration 3: Brake Assist + Autonomous Brake + Warning + Driver‘s Reaction

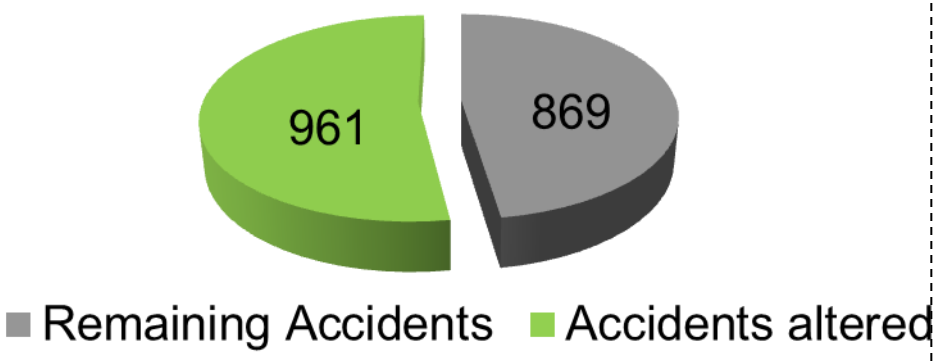
fictitious

Summary of the Evaluation: Altered Accidents

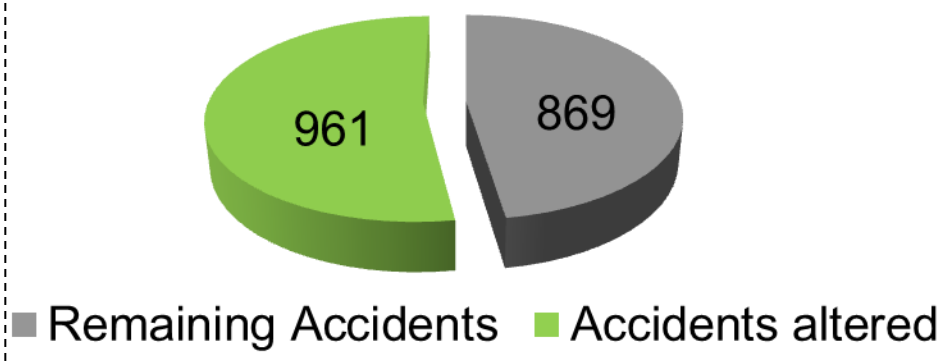
1 Basic Configuration: Emergency Brake System



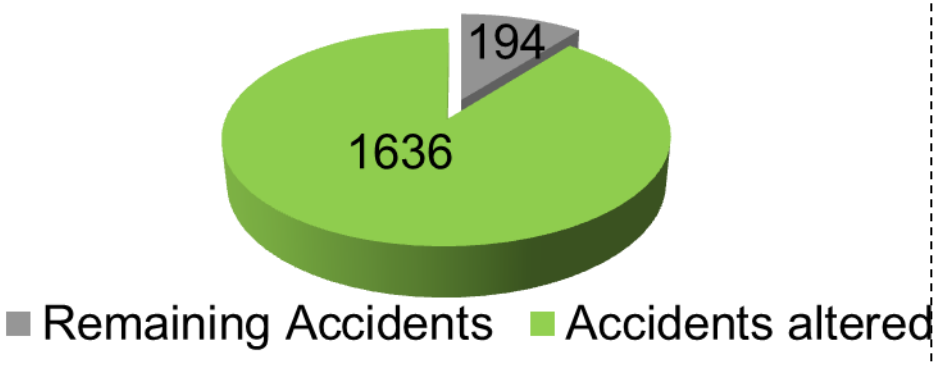
2 BAS + Autonomous Brake



3 "…" + Warning + Driver's Reaction



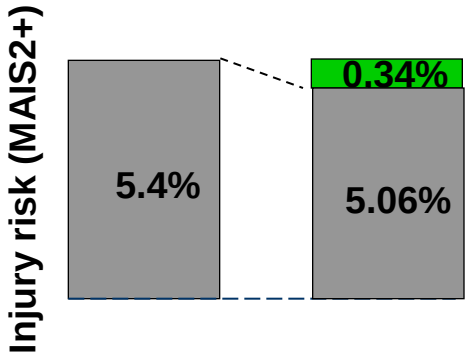
4 "…" + always detect stationary vehicles



fictitious

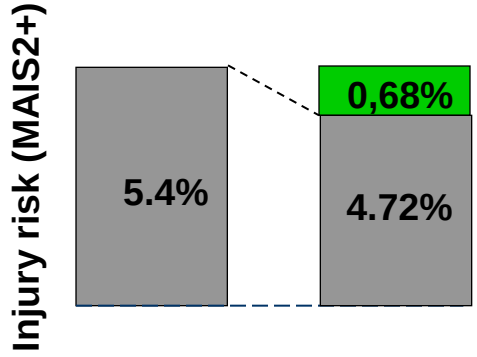
Summary of the Evaluation: System Effectiveness

1 Basic Configuration: Emergency Brake System



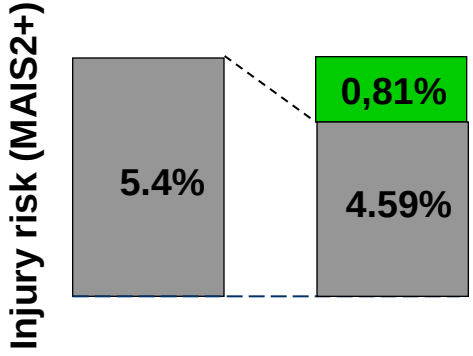
≙ 6.3 % of Target Population

2 BAS + Autonomous Brake



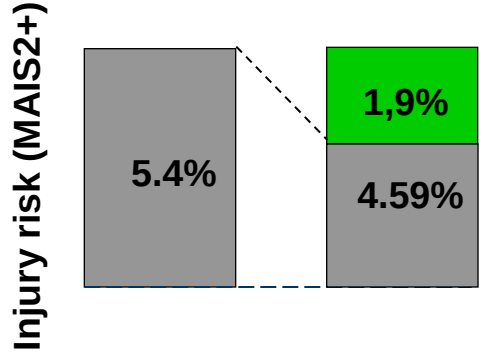
≙ 12.6 % of Target Population

3 "…" + Warning + Driver's Reaction



≙ 15 % of Target Population

4 "…" + always detect stationary vehicles

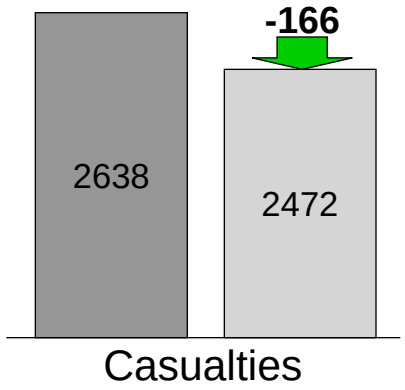


≙ 35.2 % of Target Population

fictitious

Summary of the Evaluation: Injuries and Fatalities

1 Brake Assist (BAS)



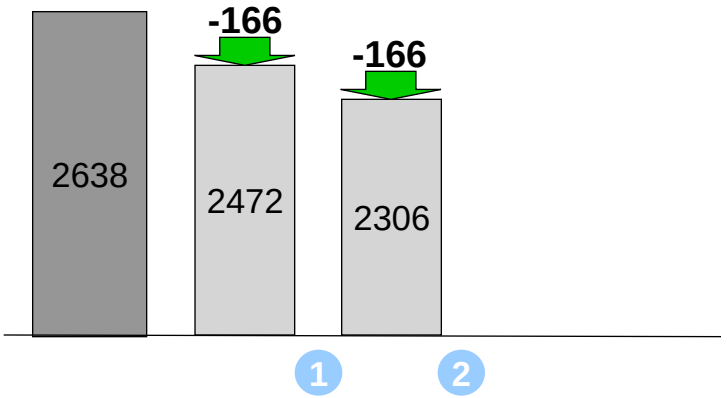
Without System

Adjusted to meet current safety level

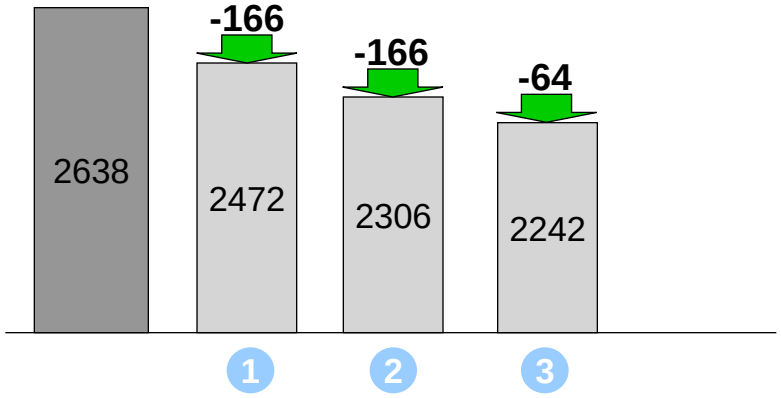
System effectiveness

Difference between reference and estimated scenario

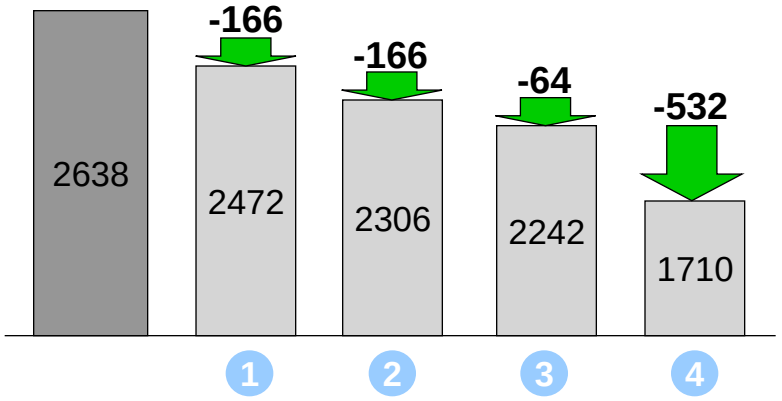
2 BAS + Autonomous Brake



3 "…" + Warning + Driver's Reaction



4 "…" + always detect stationary vehicles



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Requirements for the Database - Germany

In-depth data for each accident

- Vehicle & road parameters
- Detailed pre crash phase
- Environment & psychology
- Numerical accident data from reconstruction

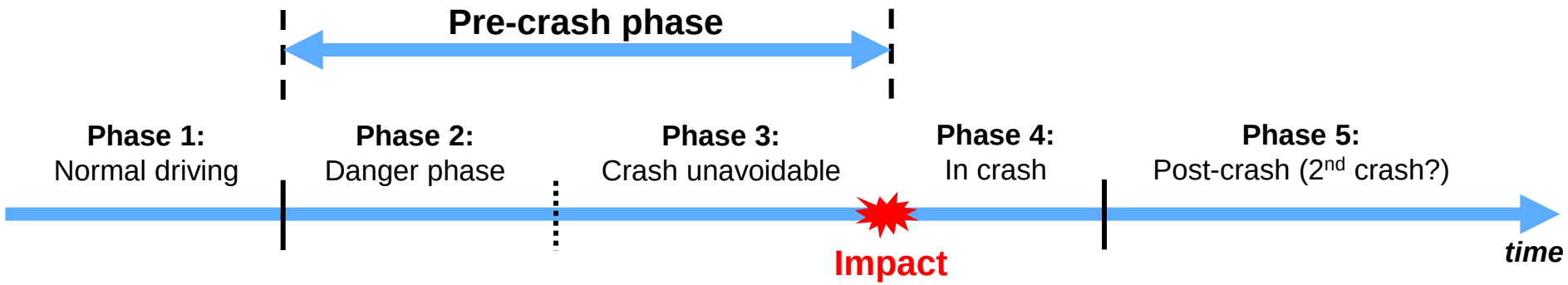
Statistically representative and significant sample

- Minimum number of cases: ~2000

Phases of a Road Accident

A Crash can be Divided into Five Phases

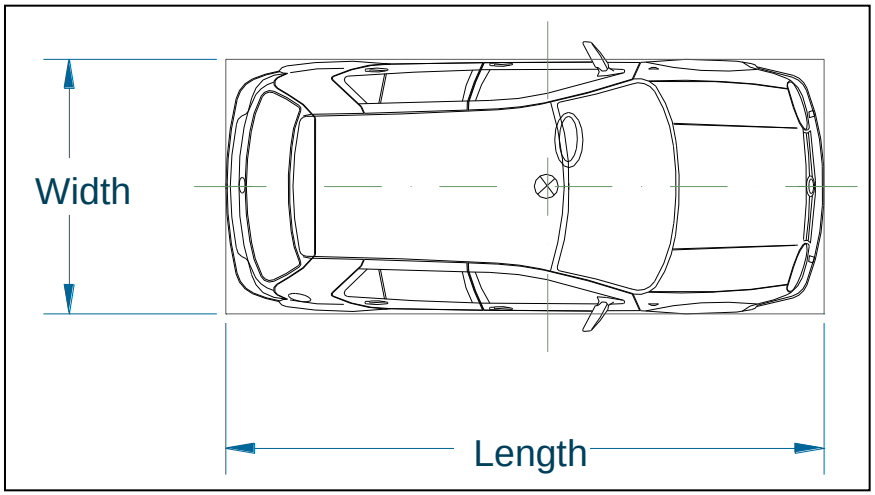
- „Traditional“ safety research focuses on the in-crash phase and its effects on the vehicle as well as occupants
- Active safety research focuses on the pre-crash phase
- The pre-crash phase can be divided into sequences



Requirements for the Simulation – Vehicle & Road Parameters

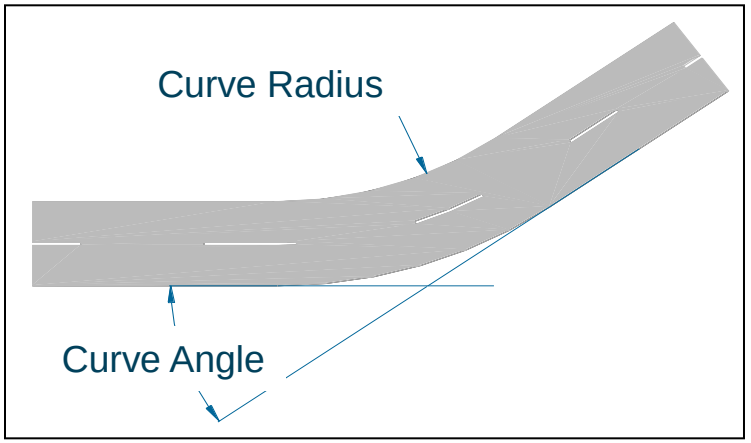
Vehicle Parameters:

- Length
- Width
- Wheelbase
- Track width
- Maximum steering angle
- …



Road Parameters:

- Curve radius
- Slope
- Surface (asphalt, paved, …) – friction coefficient
- Weather conditions (wet, icy, …)
- …



Requirements for the Simulation – Environment & Psychology

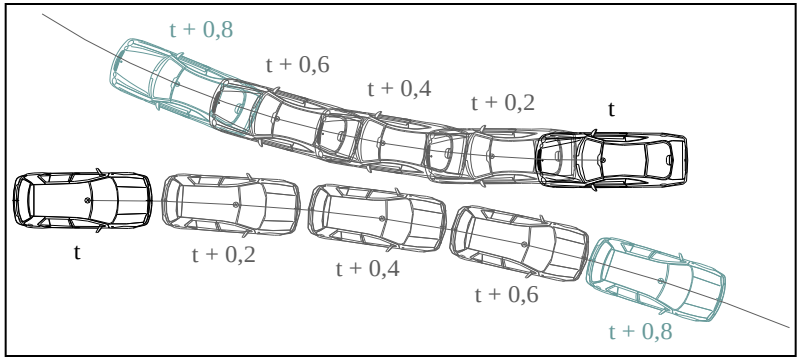
Environment parameters like

- Light conditions, fog etc.
- Traffic lights, road signs
- Visibility obstructions
- Vicinity (tall buildings?)
- Traffic situation, flow, density (hard to obtain)

→The actual field of view

Drivers reaction

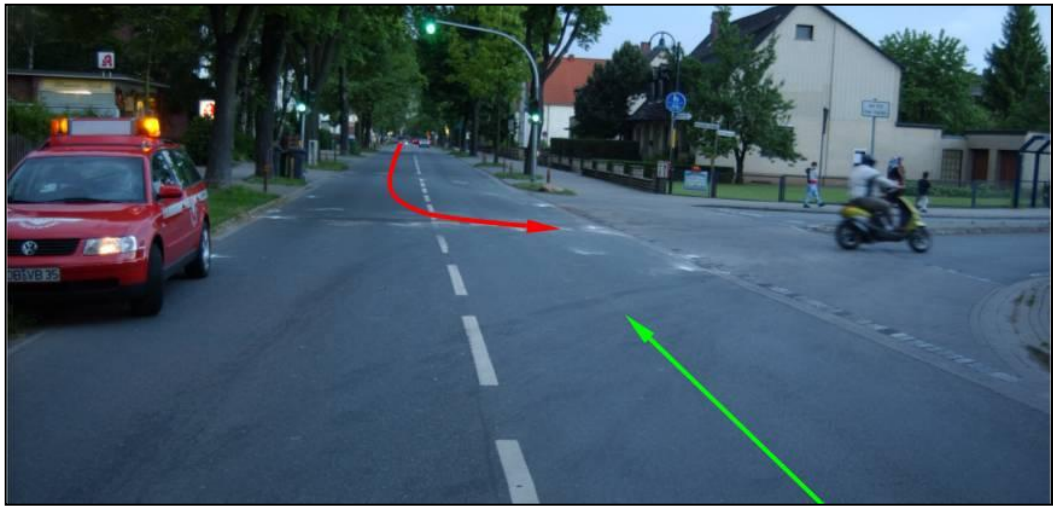
- How did the driver react in a certain accident?
- What is an average reaction time?
- Age, physical conditions, …

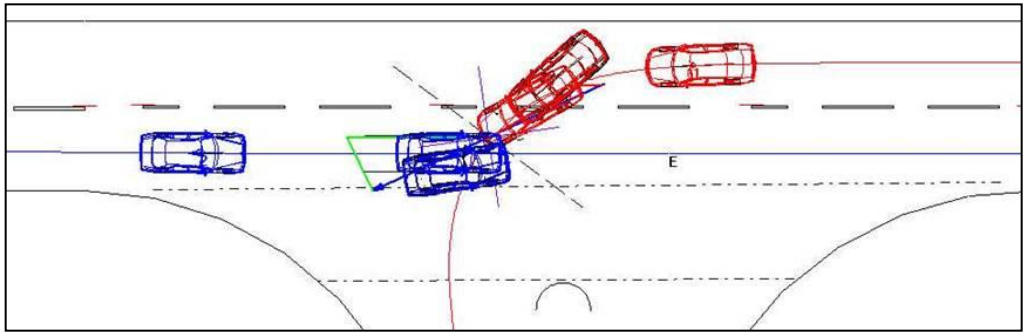


Requirements for the Simulation – Numerical Accident Data

Numerical information about pre-crash phase through reliable accident reconstruction

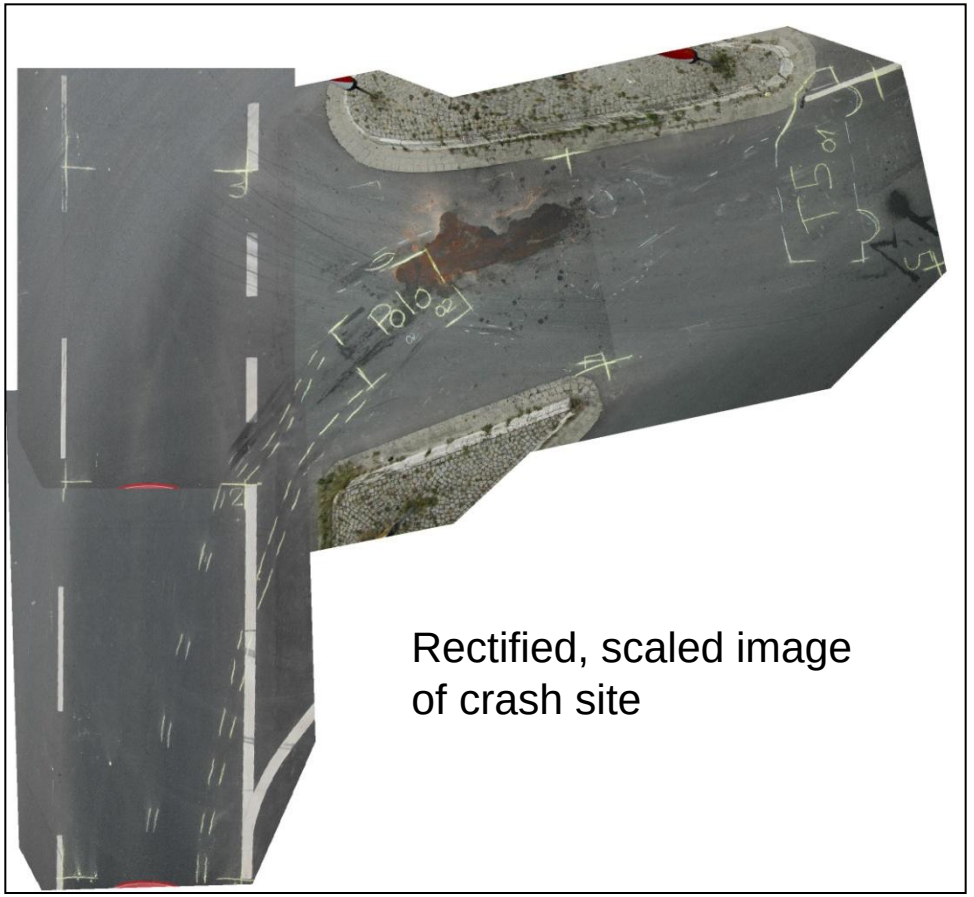
- Initial velocity v0
- Velocity after sequence
- b(t) – braking as a function of time
  Minimum: Mean braking deceleration / distance travelled
- Information about steering
- Interaction of active safety system?
- Skidding parameters
- Roadway departure with angle
- …





Example Crash Examined by Volkswagen Accident Research
(Investigation based on GIDAS methodology)

On-scene investigation
and measurements



Rectified, scaled image
of crash site

Three Different Databases are Available

Internal database

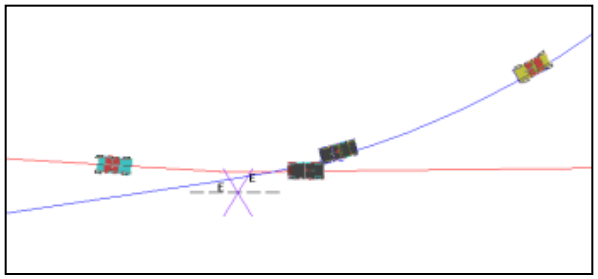
- Volkswagen-generated database with more than 70 variables
- Around 4200 data sets available
- Limited environment detail

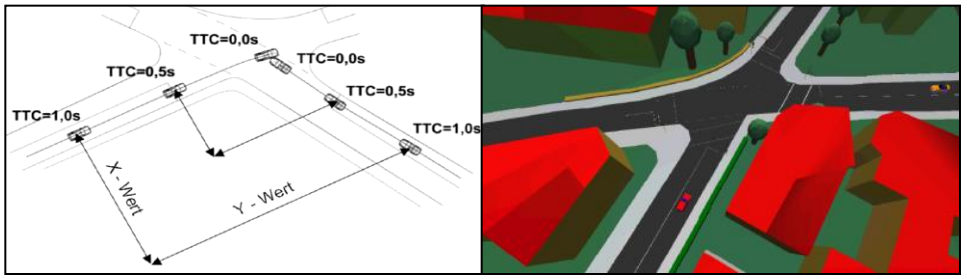
preCrash matrices VUFO

- Standardized among GIDAS participants
- 2750 cases
- Generated by VUFO GmbH
- Currently 2D, 3D under discussion

Single cases

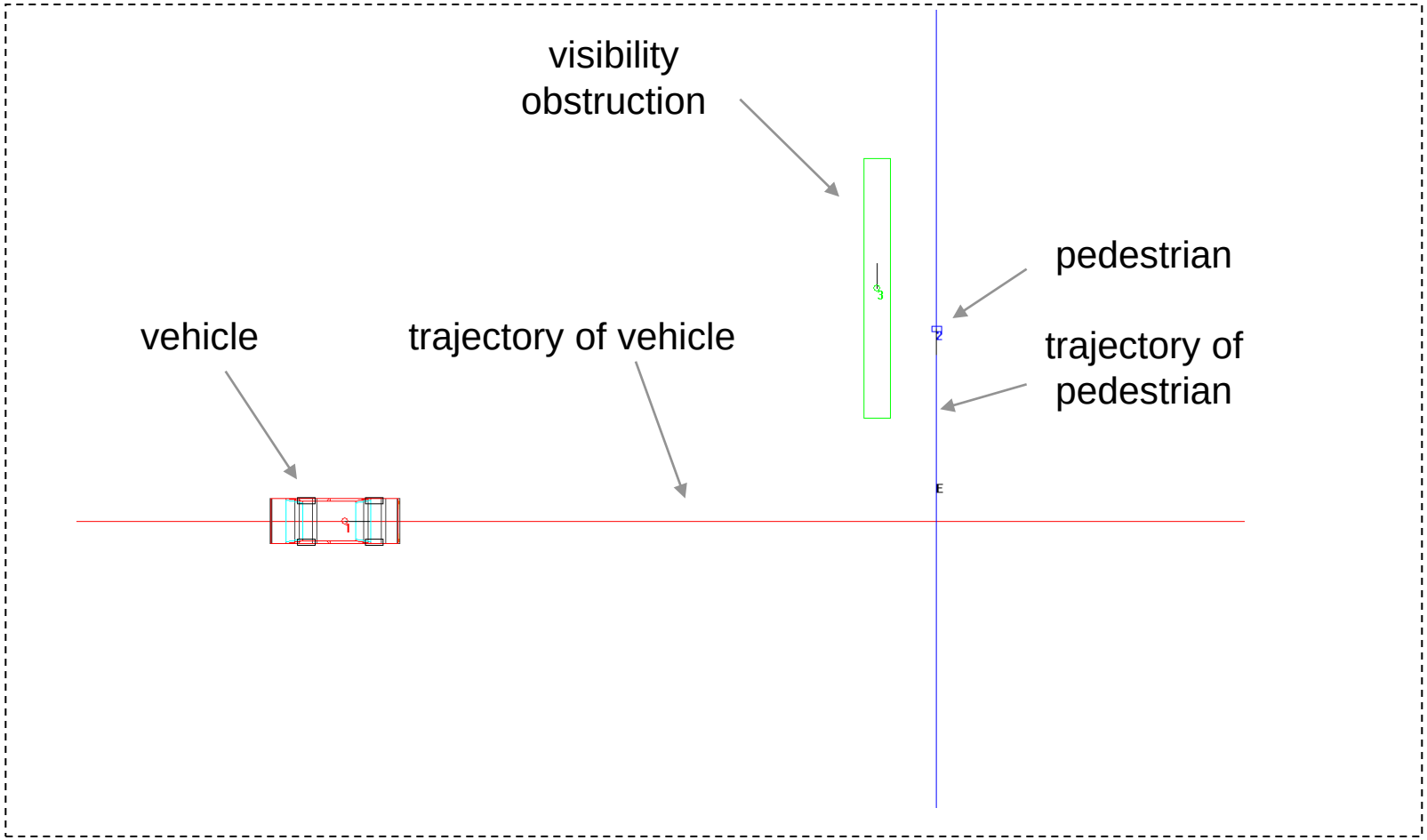
- Arbitrary accident cases
- Model scenes representative for accident types
- Single cases of interest



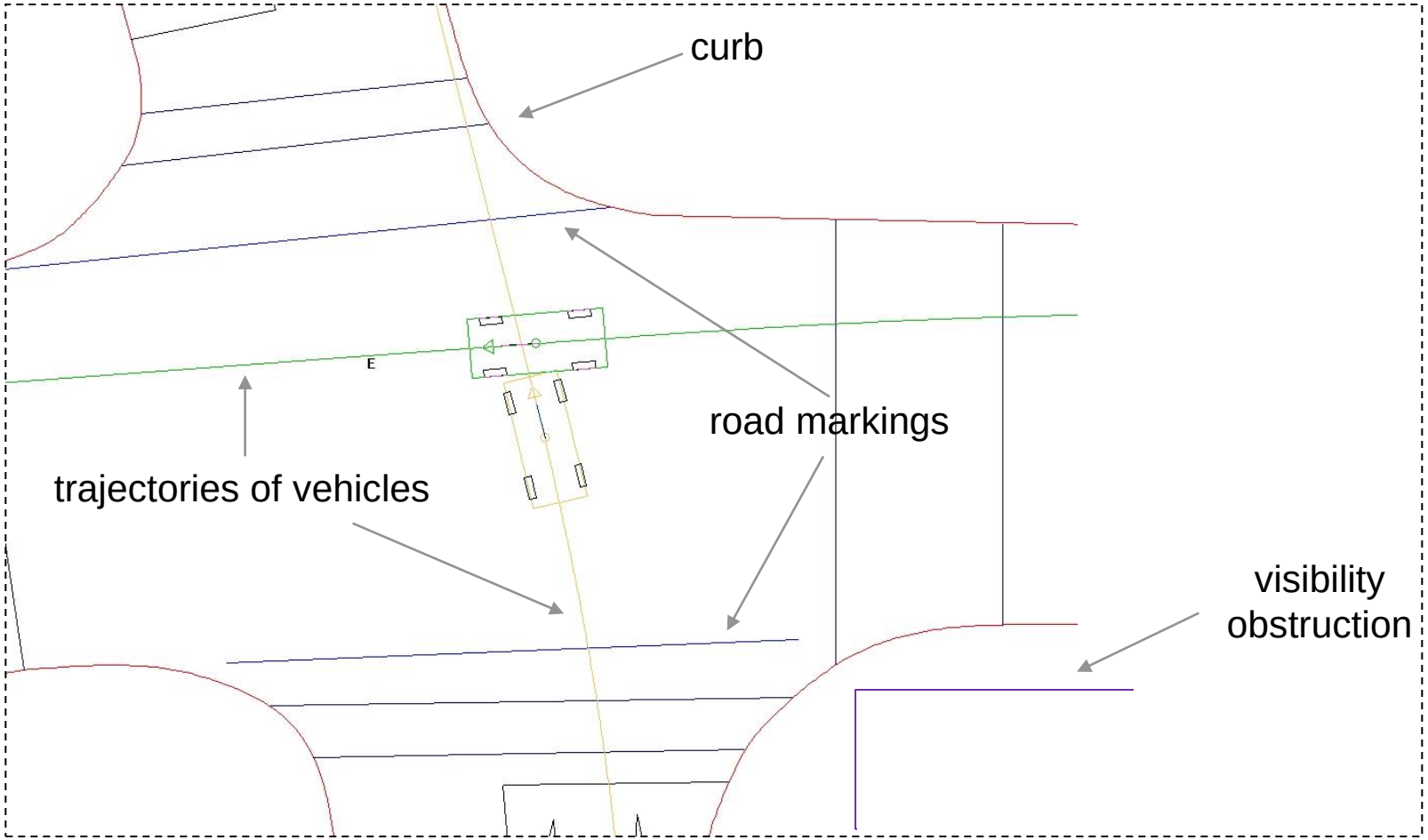


Source: VUFO GmbH

Minimum Dataset: Minimal Environmental Data



Current GIDAS Data Set: Most Relevant Environment Objects



Possibilities and limitations

Possibilities	Current Limitations
+ Effectiveness with respect to severely and fatally injured persons	- Some accident types (e.g. single-vehicle crashes due to driving errors) not included
+ Minor injuries evaluation possible as well, but definition is a little vague	- No traffic flow (e.g. lane change accidents)
+ Database covering a wide range of traffic participants and accident types	- No property damage – not included in GIDAS database
+ Representative for the accident types covered	- Germany only (Czech Republic and China(?) in preparation)
+ Datasets available: Vehicle – vehicle Vehicle – pedestrian Vehicle – two-wheeler	

rateEFFECT: Effectiveness Evaluation of Active Safety Systems

1. Intention and Motivation
2. Evaluation Approach - Introduction to rateEFFECT
3. Evaluation of Crash Avoiding Systems
4. Database – GIDAS-preCrashMatrix
5. Opportunities of rateEFFECT for the US - Discussion

Conclusions

- A lot of information is required to simulate existing accidents in order to estimate ADAS effects
- This particularly includes numerical values for the pre-crash and in-crash phase
- GIDAS provides a required minimum number of these parameters for a statistically significant sample
- How to apply this method to the U.S. market and compare results with existing methods?