Accident Research 2.0:
New methods for representative evaluation of integral safety in traffic

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Vehicle safety has achieved a high level in recent years. Human, vehicle and environmental factors are essential factors that influence safety to varying degrees within the pre-crash, crash and post-crash phases. Generally, only the parameters of the vehicle are relevant for analyzing potential benefits of passive safety measures. Traffic accidents are predominantly caused by human factors, but the driver also plays an important role in accident avoidance. Active Safety reduces not only the frequency of accidents, but also mitigates crash and injury severity. In contrast to Passive Safety, Active safety involves human, vehicle and environmental factors.

In view of the limited influencing factors, existing databases and simulation approaches are adequate in principle for an estimate of passive safety effectiveness, although there is still some potential for refinements. In contrast, for an estimate of effectiveness of novel active safety measures, we need entirely new methodologies and far more advanced simulation tools, requiring significant improvements in our knowledge base regarding human responses. In particular, evaluation methods that rely on a "pre-crash database" are not capable of taking the influence of active safety on human factors into account.

Passive safety measures have a strong positive impact on reducing injury severity that can be comparatively rated by standardized crash tests; current crash tests are designed to represent 95% of all real-world accidents. Analogously to passive safety ratings, consumer ratings for advanced driver assistance systems (ADAS) are being introduced. However, design of rating procedures for ADAS and active safety is much more complex than design of rating tests for passive safety. A central problem is to specify requirements on methodologies to obtain reliable, representative and valid active safety ratings. A valid rating should reflect the reduction of injury probabilities in practice. Since the pre-crash phase is involved, active safety rating requires a traffic-based approach and should include for example a specification of which traffic scenario(s) are to be considered, a weighting scheme reflecting the importance of each scenario, and most importantly a procedure for evaluating reliably how the active safety measure would influence the accident probability in each such scenario.

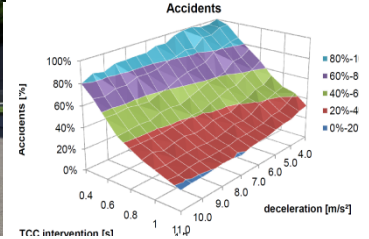
Key statistics for active safety systems are percentages of "true positives" (e.g., interventions that are justified), "false negatives" (e.g., missed opportunities for an intervention) and "false positives" (e.g., superfluous interventions). System design at the sensor level usually aims to maximize true positives and minimize false positives. (Minimization of false positives in ADAS is an important optimization and testing criterion because of the risk of critical conflicts or loss of control.) At the actuator level, systems aim to achieve best possible accident avoidance or reduction of injury.

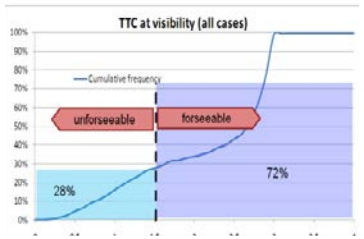
There are clearly design trade-offs between these aims; for example, earlier interventions may achieve greater injury reduction but also increase false positives. System design thus requires an estimate of these key statistics and how the tradeoffs vary with the operating point. These tradeoffs cannot be estimated by an "accident-based" approach. False-positive estimation obviously requires consideration of the vast majority of situations in which the system is active, but an accident would not have occurred. While comprehensive, controlled laboratory or field tests including the required variations are not feasible, virtual experiments using traffic-based simulation can provide the needed statistics and also quantify the expected benefits of "true positives" in reducing accidents and fatalities.

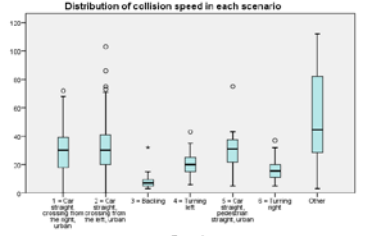
BMW has developed a procedure for rating ADAS benefits that integrates two distinct tools. The tool "S.A.F.E.R.", is designed to analyze the pre-crash phase. The aim of S.A.F.E.R. is to simulate all relevant processes in sufficient detail to obtain reproducible estimates of key indicators (effectiveness, false positives, etc.). The relevant processes include not only traffic and vehicle dynamics, but also environmental and most importantly human factors. Representative distributions of factors and parameters are obtained by taking the stochastic variation of all relevant parameters into account in the simulations.

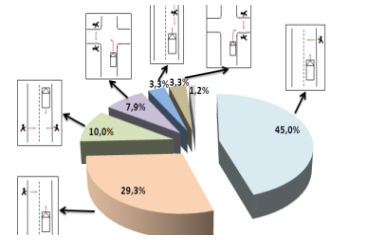
The second tool, known as "ICOS", has been designed to provide a high-resolution, high-fidelity description of crash phase dynamics. If one converts the outputs of stochastic simulation into inputs for crash dynamics, the result is a comprehensive description of exactly how a safety system can reduce injuries. Applications currently focus on high-fidelity simulation of individual crashes in order to enhance our understanding and optimization of connected safety systems. An integrated simulation process thus allows an exact prediction of the effectiveness in individual cases in terms of injury severity.

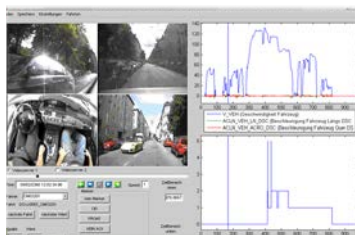
The development and rating of integral safety need to reflect the true efficiency in the field. The integrated approach described here could provide a valid and reproducible basis for rating connected systems of active and passive safety. In particular, "virtual experiments" using a traffic-based approach and incorporating models of all relevant processes constitute an essential element of the approach.

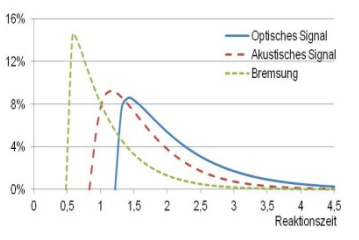



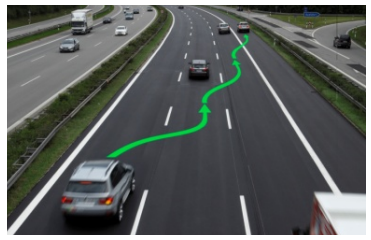
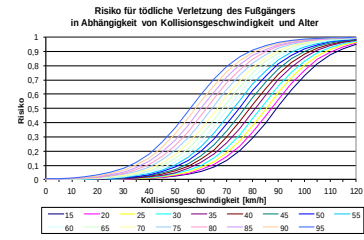



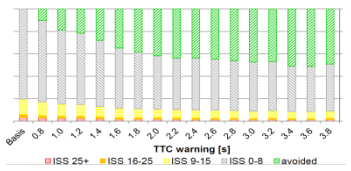



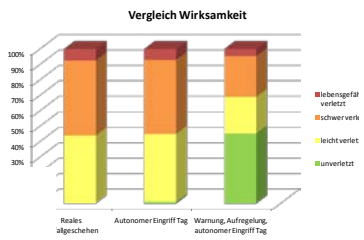



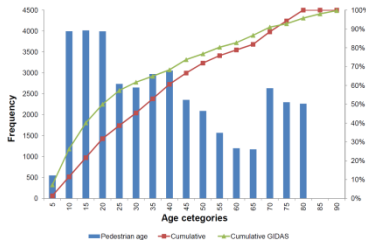







Klaus Kompass, 7. September 2012

ACCIDENT RESEARCH 2.0.

NEW METHODS FOR REPRESENTATIVE EVALUATION OF INTEGRAL SAFETY IN TRAFFIC.

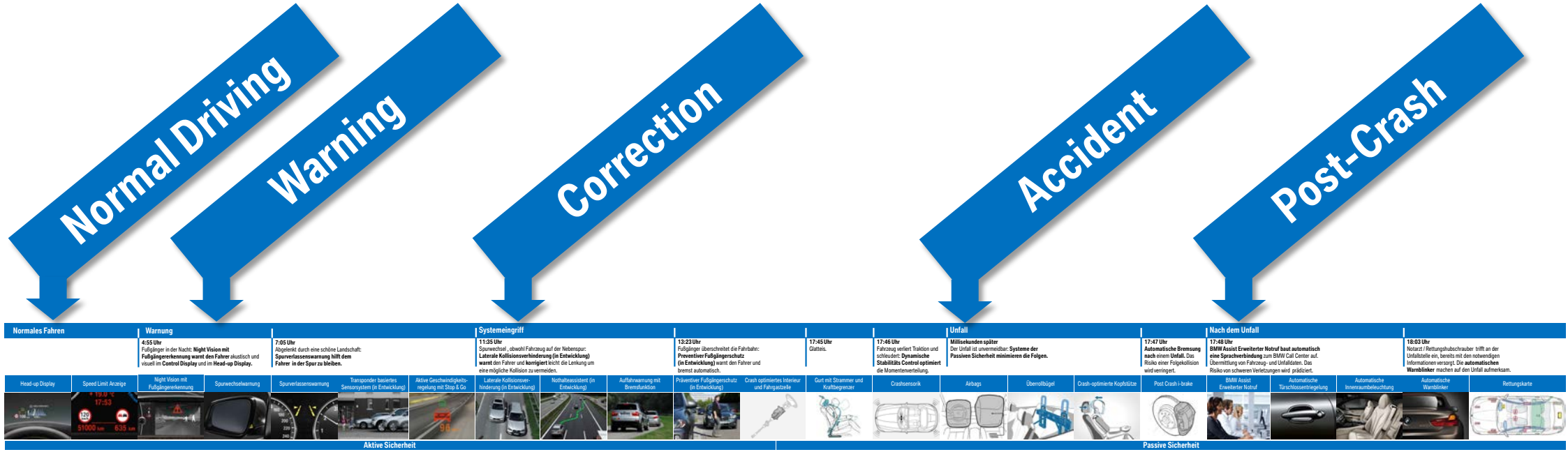
BMW GROUP

ACCIDENT RESEARCH 2.0.
AGENDA.

- Safety systems.
- Accident causation.
- Accident and traffic simulations.
- New requirements for databases.
- Traffic vs. accident simulation.
- S.A.F.E.R. – Traffic simulation tool.
- ICOS – Simulation tool for individual cases.
- Conclusion.

ACCIDENT RESEARCH 2.0.
INTEGRAL SAFETY.

- Safety systems.
- Accident causation.
- New requirements on databases.
- Potential of safety systems.
- Traffic vs. accident simulation.
- S.A.F.E.R.
- ICOS.
- Conclusion.



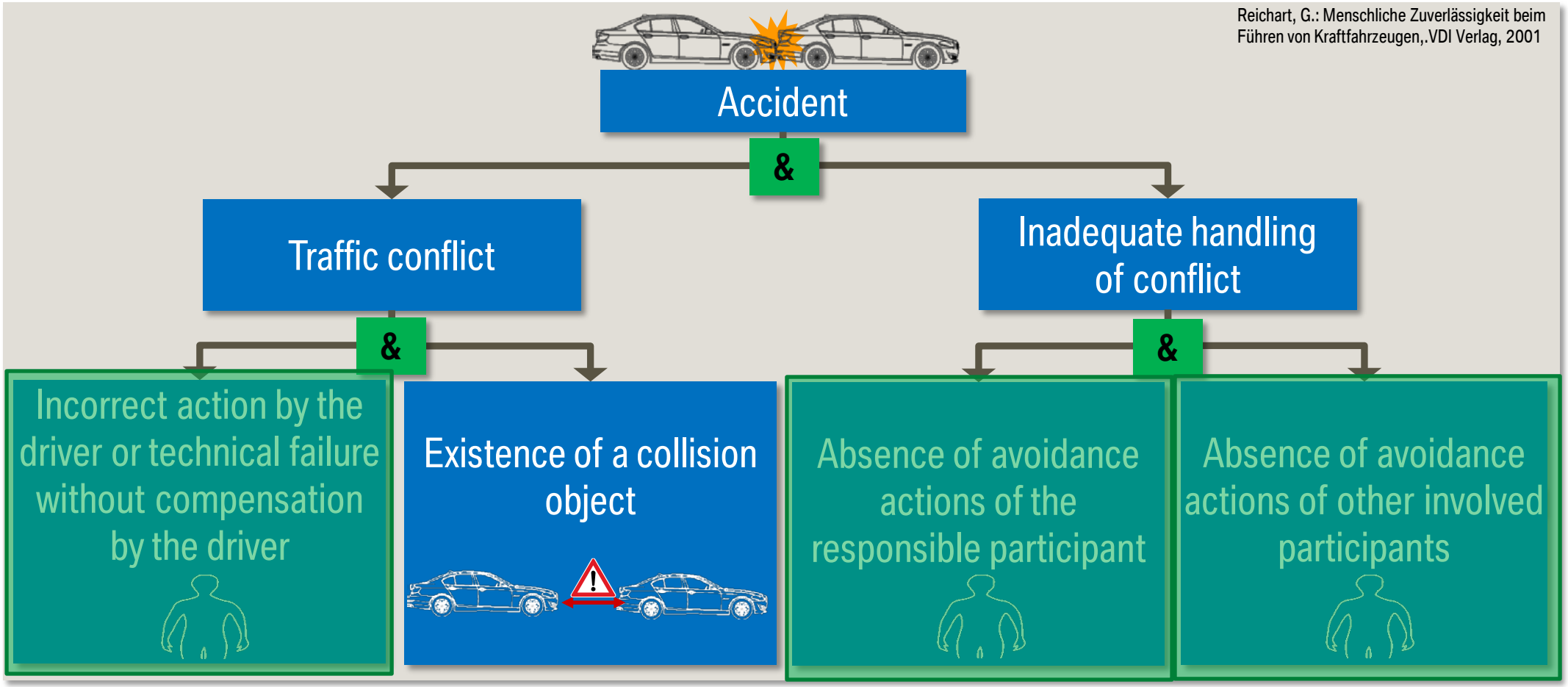
ACCIDENT RESEARCH 2.0.
HADDON MATRIX: THE FACTORS HUMAN, VEHICLE, AND ENVIRONMENT.

	Pre-crash	Crash	Post-crash
	Crash Prevention	**Injury prevention during the crash**	**Life sustaining**
Human	–Information –Attitudes – Impairment –Police enforcement	–Use of restraints –Impairment	–First-aid skill –Access to medics
Vehicles and Equipment	–Roadworthiness –Lighting –Braking –Handling	–Occupant restraints –Other safety devices –Crash protective design	–Ease of access –Fire risk –Automatic crash notification
Environment	–Road design and road layout –Pedestrian infrastructure –Speed management	–Crash protective roadside objects	–Rescue resources –Congestion

Traffic accidents are predominantly caused by the driver; only 0.7% can be attributed to technical problems*

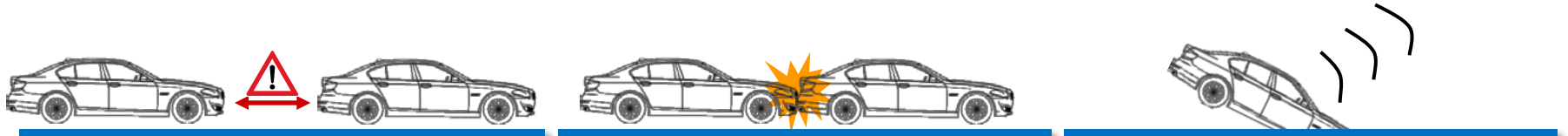
* DESTATIS: Verkehr, Fachserie 8 Reihe 7. Statistisches Bundesamt, Wiesbaden 2011

ACCIDENT RESEARCH 2.0.
GENERIC FAULT TREE OF ACCIDENT OCCURRENCE IN TRAFFIC.



The driver causes some accidents, but also plays an essential part in accident avoidance!

ACCIDENT RESEARCH 2.0.
HADDON MATRIX: THE FACTORS HUMAN, VEHICLE, AND ENVIRONMENT.



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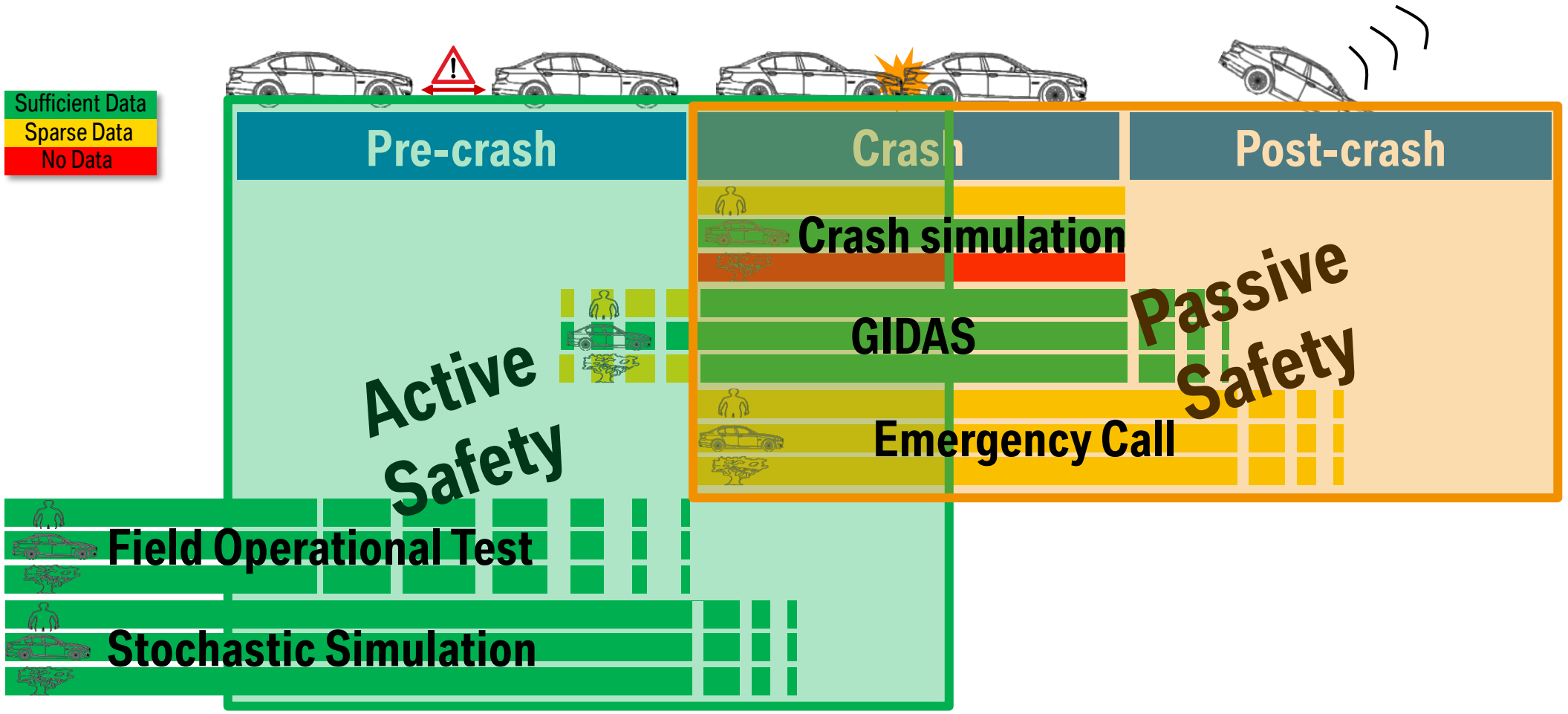
Active Safety

Passive Safety

Active Safety: The human factor, the vehicle and the environment are relevant in vehicle development.

Passive Safety: Only the parameters of the vehicle are relevant in vehicle development.

ACCIDENT RESEARCH 2.0.
DIFFERENT DATABASES AND THEIR SPECIAL FOCUS.



We need new databases, methodologies and simulation tools for evaluation of Active Safety.

There are sufficient databases and simulation tools for Passive Safety analysis.

ACCIDENT RESEARCH 2.0.
NEW REQUIREMENTS FOR EVALUATION OF ACTIVE SAFETY ANALYSIS.

Passive Safety

Euro NCAP
Overall rating
★★★★★

Euro NCAP Advanced
For enhanced automatic crash notification (eACN)

INSURANCE INSTITUTE FOR HIGHWAY SAFETY — TOP SAFETY PICK 2010

Frontal offset test results	Good
Side impact test results	Good
Roof strength test results	Good

US NCAP
Overall rating
★★★★★

– Only car and crash parameters are relevant.

– Evaluation by **standardized tests.**

– 95% of all real world accidents are addressed.

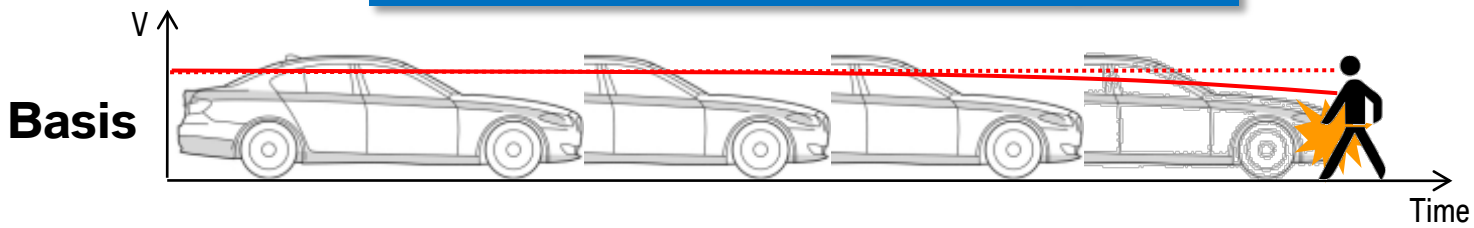
Active Safety

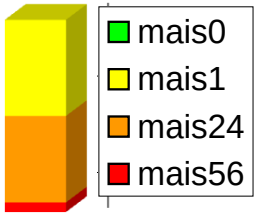
– Which **traffic based scenario(s)** can be used for representative evaluation of ADAS?

– Which **data** can be used **for representative evaluation** of Active Safety?

ACCIDENT RESEARCH 2.0.
ACTIVE SAFETY AVOIDS ACCIDENTS OR MITIGATES THE CONSEQUENCES.

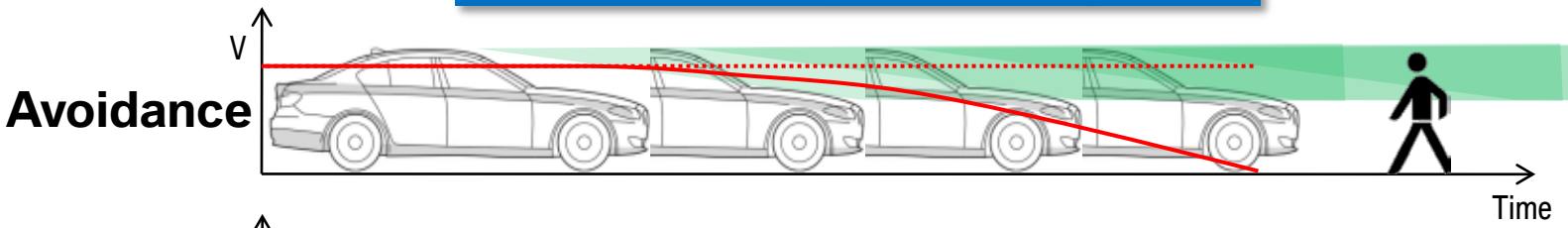
Scenario **without** preventive system

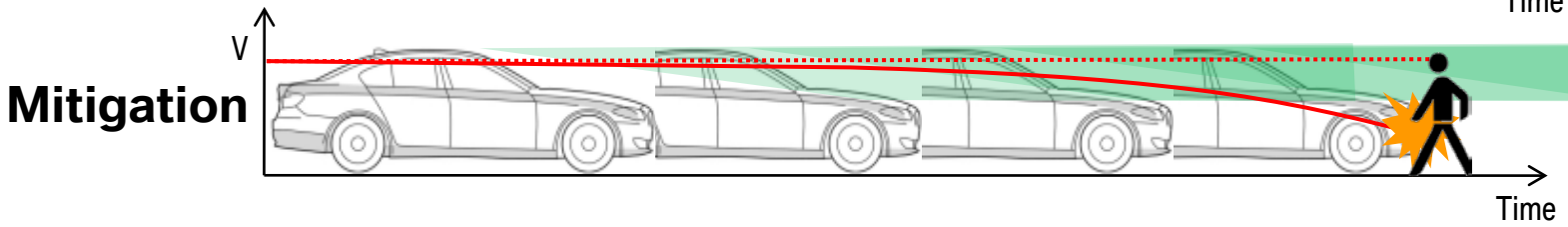


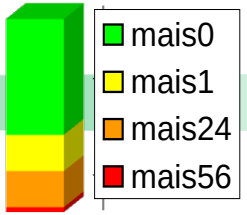


Probability distribution of injury severity (MAIS scale)

Use case **with** preventive system





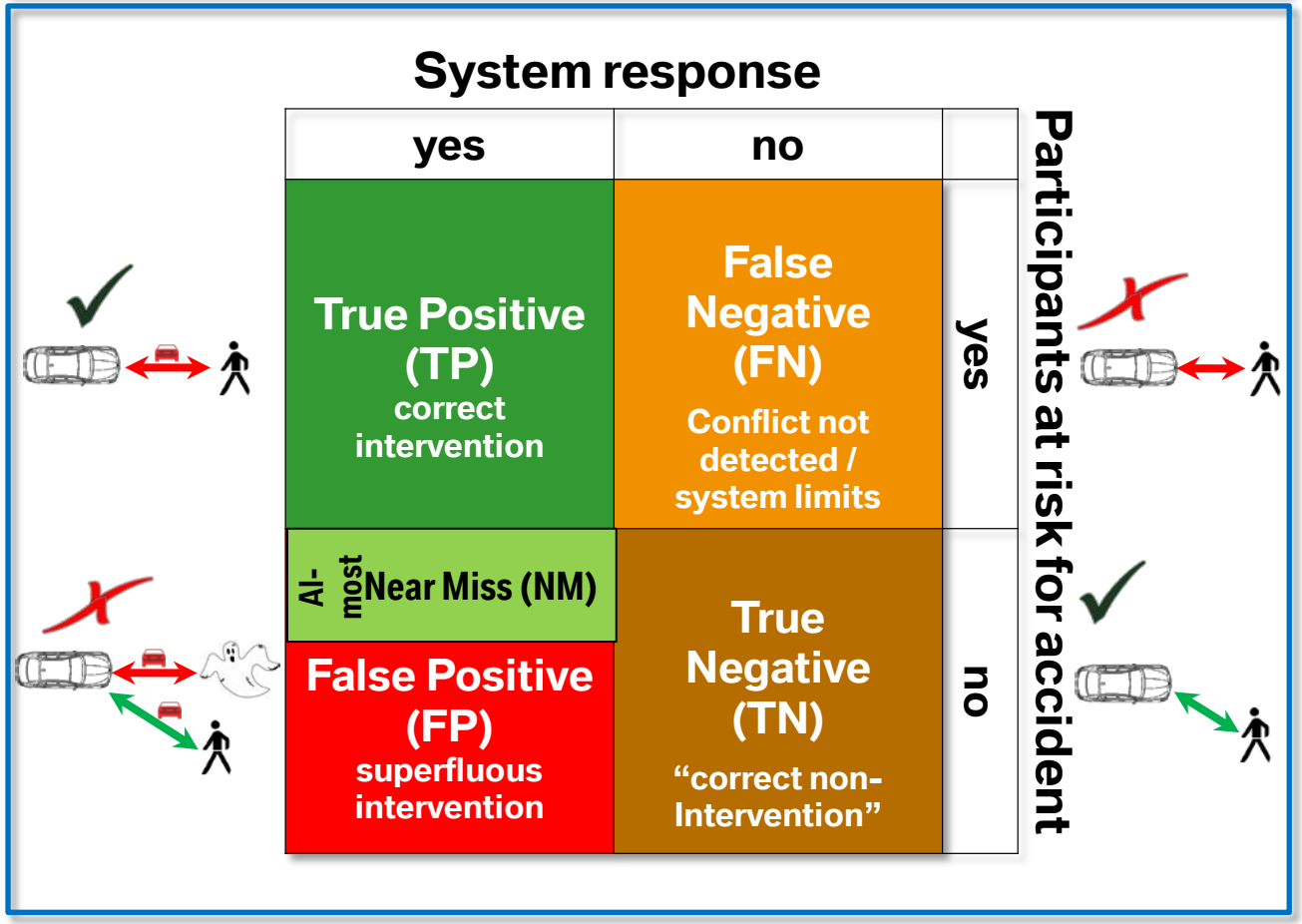


Delay the conflict!

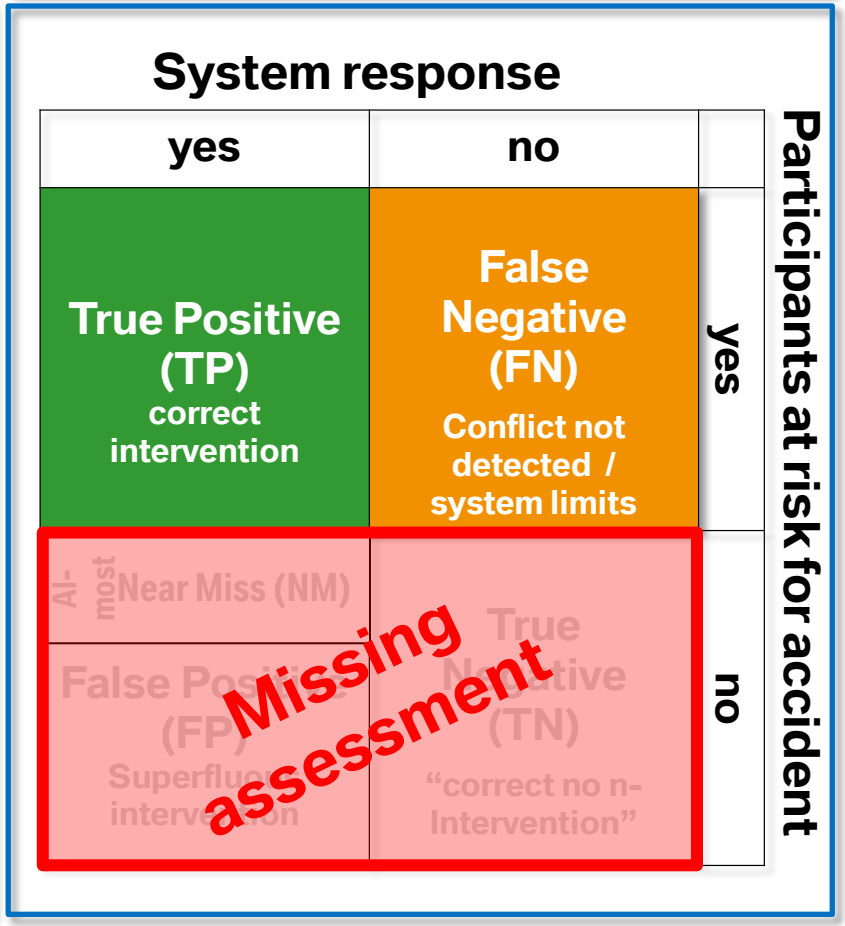
1. Vehicle brakes to a stop
2. Pedestrian escapes

ACCIDENT RESEARCH 2.0.
DIFFERENCES OF TRAFFIC AND ACCIDENT BASED APPROACH.

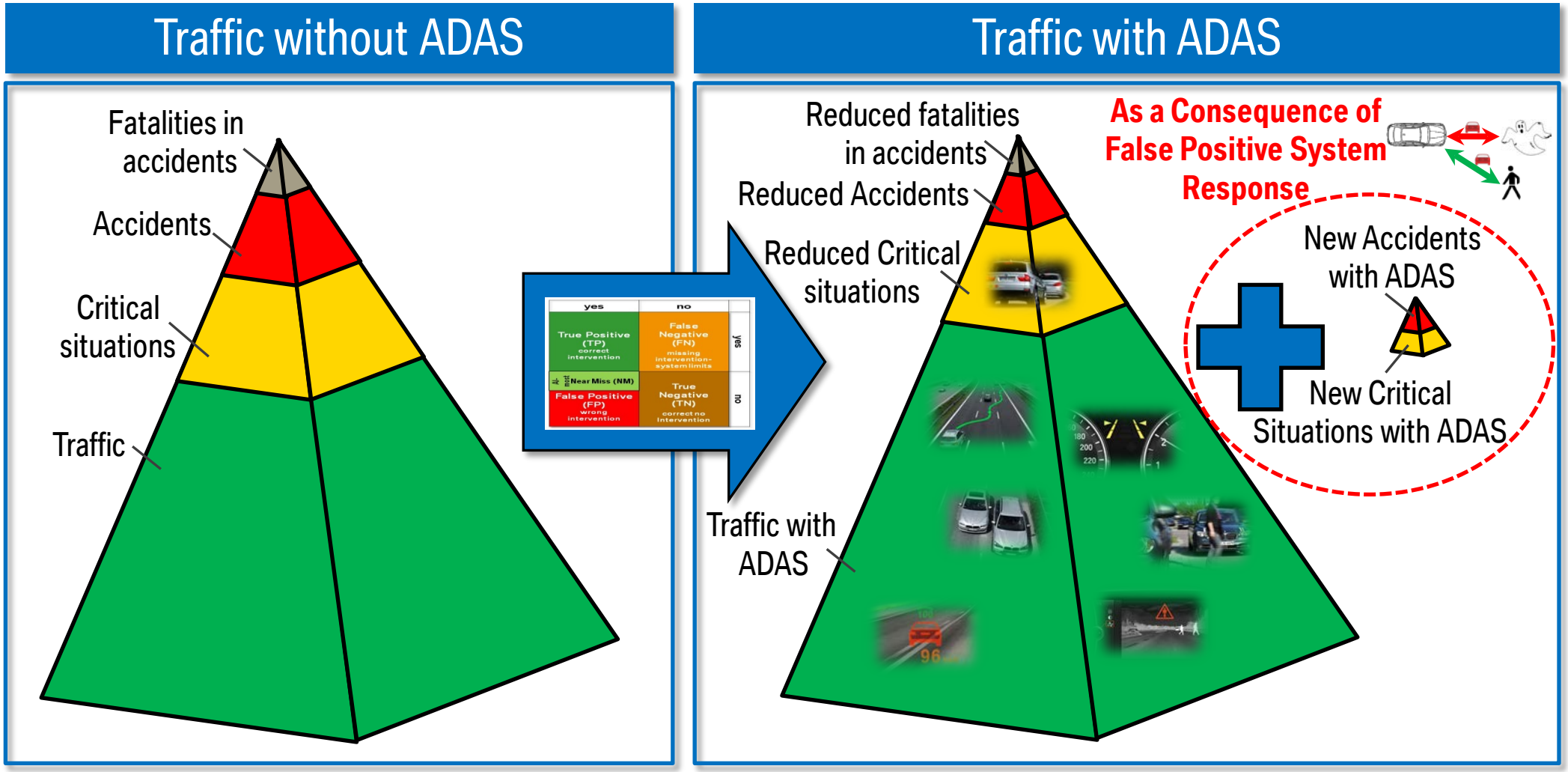
Traffic based approach



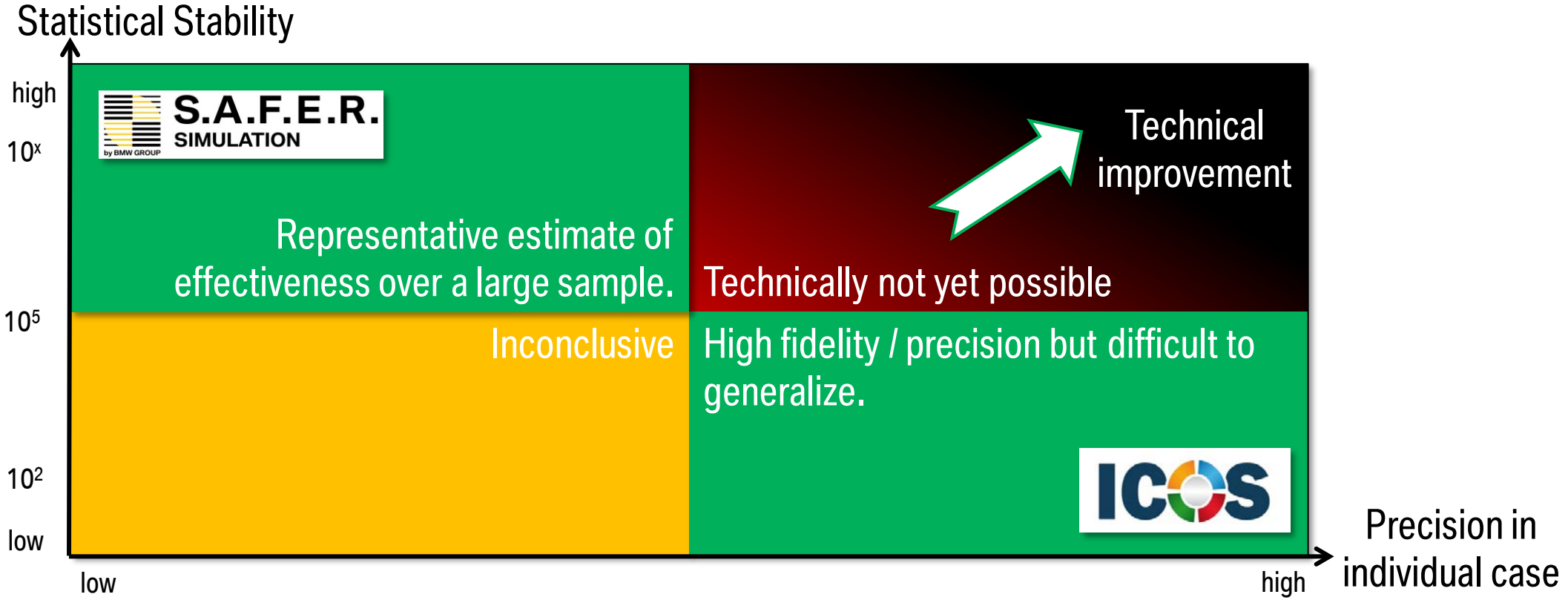
Accident based approach



ACCIDENT RESEARCH 2.0.
EVALUATION OF ACTIVE SAFETY IN TRAFFIC.



ACCIDENT RESEARCH 2.0.
TRAFFIC AND ACCIDENT APPROACH NEED DIFFERENT SIMULATIONS.



- S.A.F.E.R. (**S**afety **A**nalysis **F**ramework for **E**valuation and **R**esearch): Goal is statistically stable estimation of effectiveness representative of a real-world sample; focus on the pre-crash phase.
- ICOS (**I**ndependent **Co**-**S**imulation): Goal: high-fidelity single-case sim; focus on pre- and crash phase.

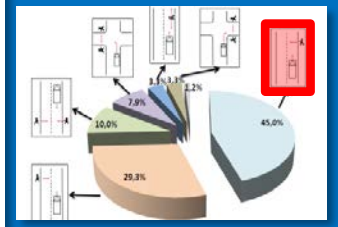
ACCIDENT RESEARCH 2.0.
TRAFFIC BASED SIMULATION: SCENARIO DEFINITION.

Accident database

–Causation of accident
–Type of accident
–Art of accident
–…

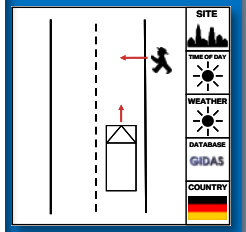
Pedestrian scenarios

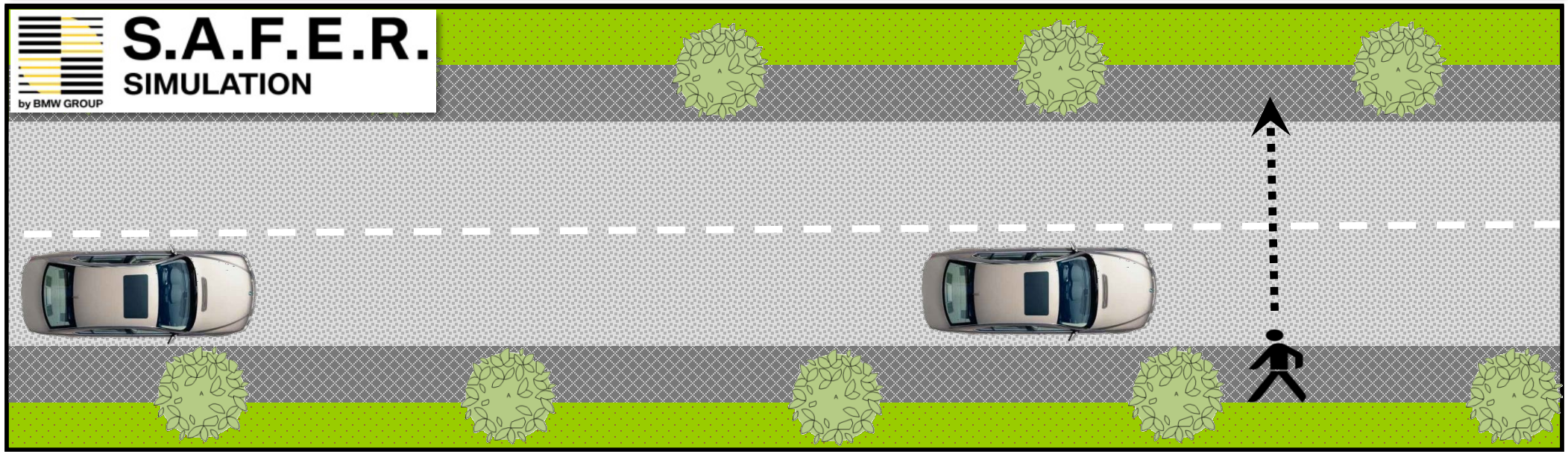
–Crossing conflict
–Road layout
–Visibility obstruction
–Driving direction
–Pedestrian direction
–…



Specification of traffic scenarios

–Time of day
–Lighting conditions
–Type of street
–Speed / density
–Road geometry
–…





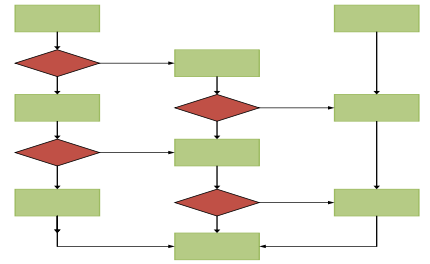
ACCIDENT RESEARCH 2.0.
TRAFFIC BASED SIMULATION: MODELING THE TRAFFIC SCENARIO.

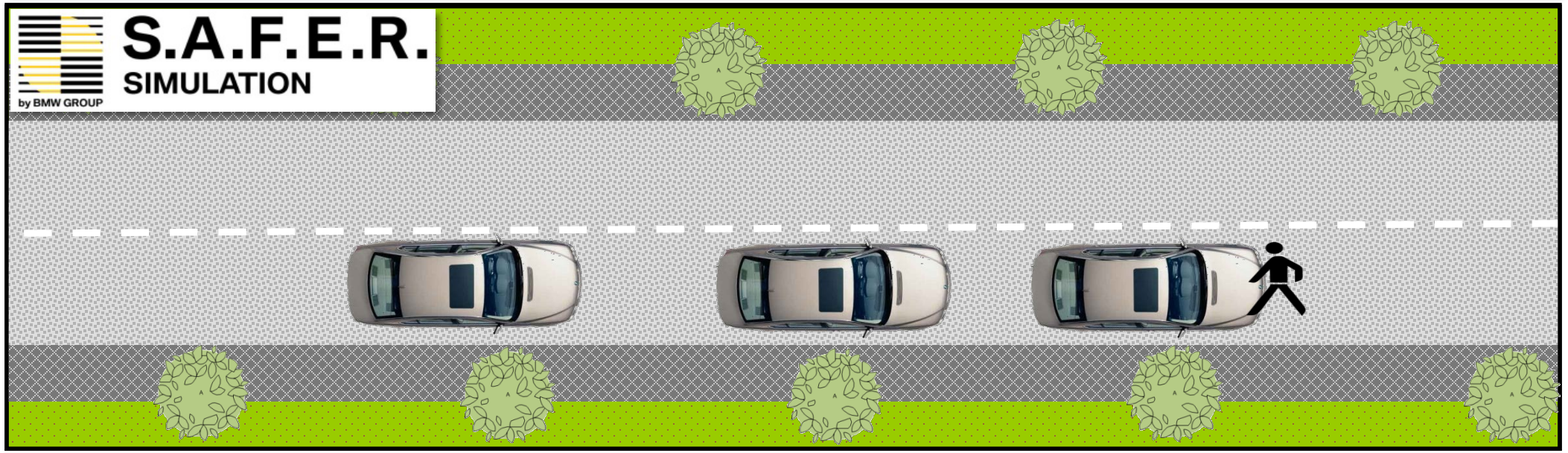
Appropriate data sources

–Accident data
–Traffic data
–Field operational test
–Subject experiments
–Vehicle characteristics
–System characteristics

Modeling (exposure, processes)

–Driver
–Vehicle
–Participant
–Traffic
–Assistance system
–Interactions

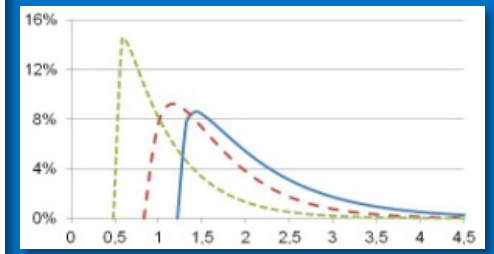




ACCIDENT RESEARCH 2.0.
TRAFFIC BASED SIMULATION: SIMULATION AND EVALUATION.

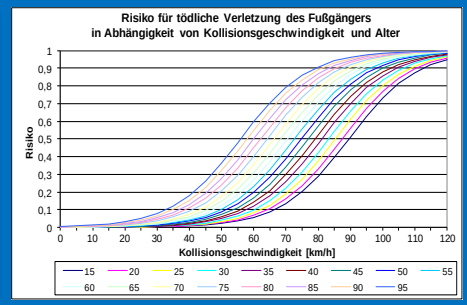
Simulation with stochastic processes

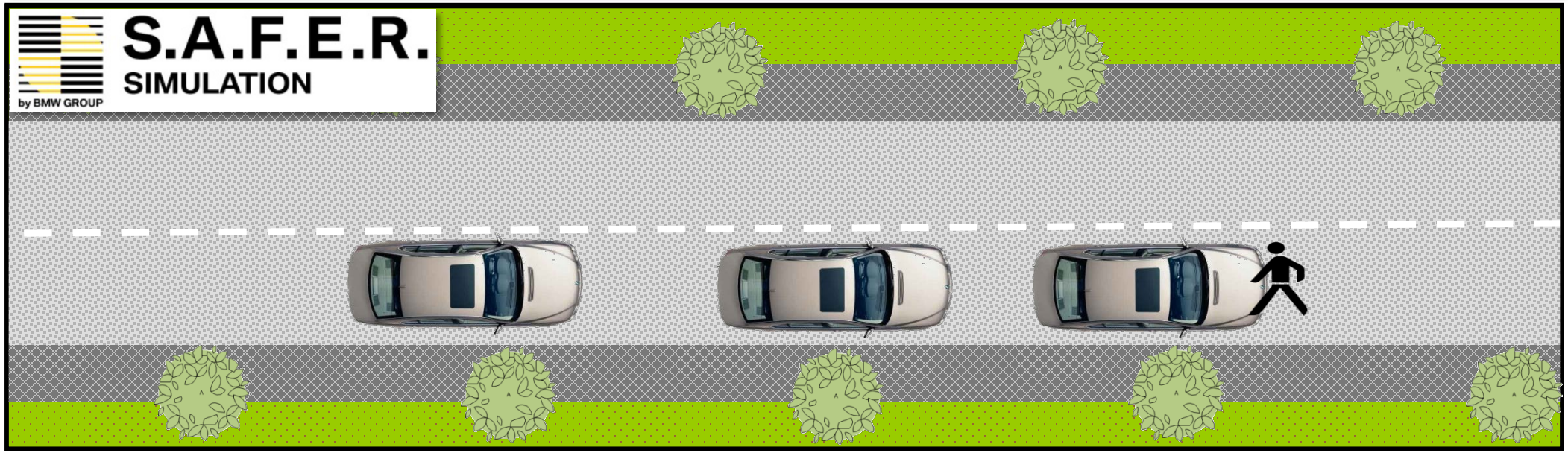
–Critical situations / Accidents
–With / without system
–Realistic parameter distributions



Evaluation using a crash metric

–Avoided accidents
–Crash characteristics
–Injury severity probabilities
–Economic evaluation





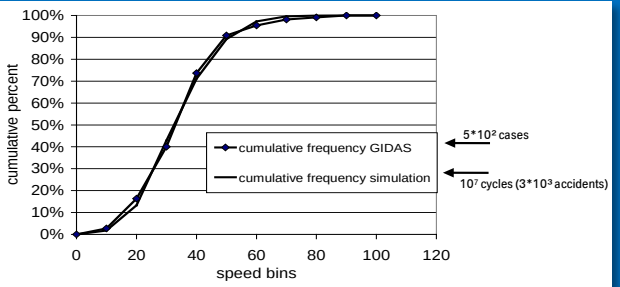
ACCIDENT RESEARCH 2.0.
TRAFFIC BASED SIMULATION: VALIDATION THE SCENARIO.

- Safety systems.
- Accident causation.
- New requirements on databases.
- Potential of safety systems.
- Traffic vs. accident simulation.
- S.A.F.E.R.
- ICOS.
- Conclusion.

Simulation distributions

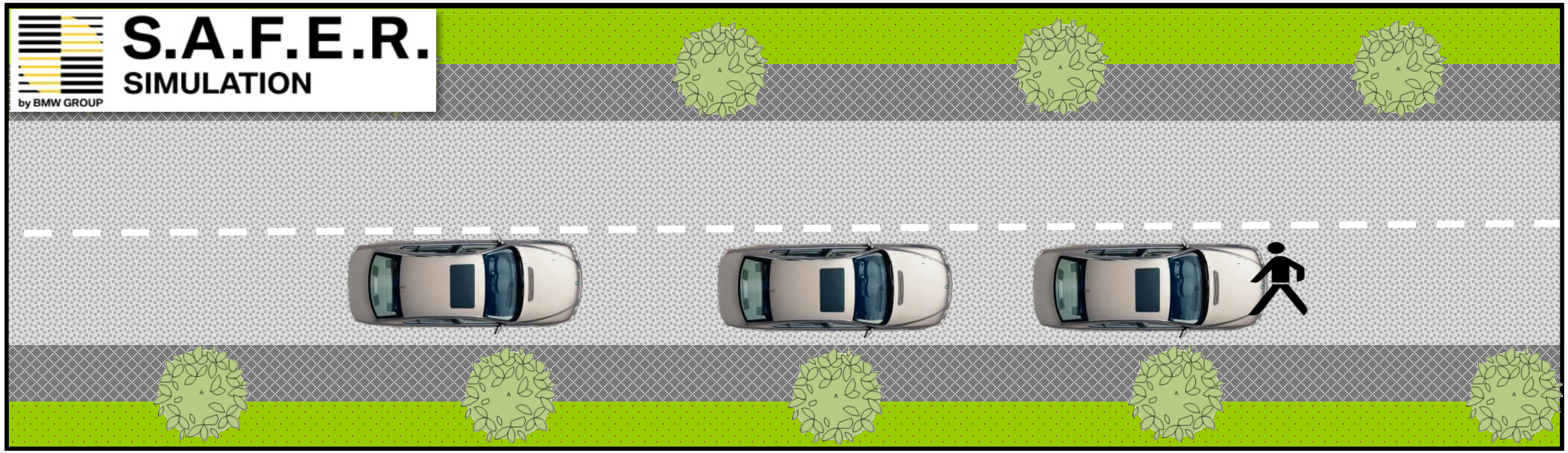
–Collision speed
–Deceleration
–Point of impact
–Injury
–Fatalities
–…

Validation



Distributions in accidents

–Collision speed
–Deceleration
–Point of impact
–Injury
–Fatalities
–…



ACCIDENT RESEARCH 2.0.
INDEPENDENT CO-SIMULATION: CONNECTED SIMULATION DOMAINS.

- Safety systems.
- Accident causation.
- New requirements on databases.
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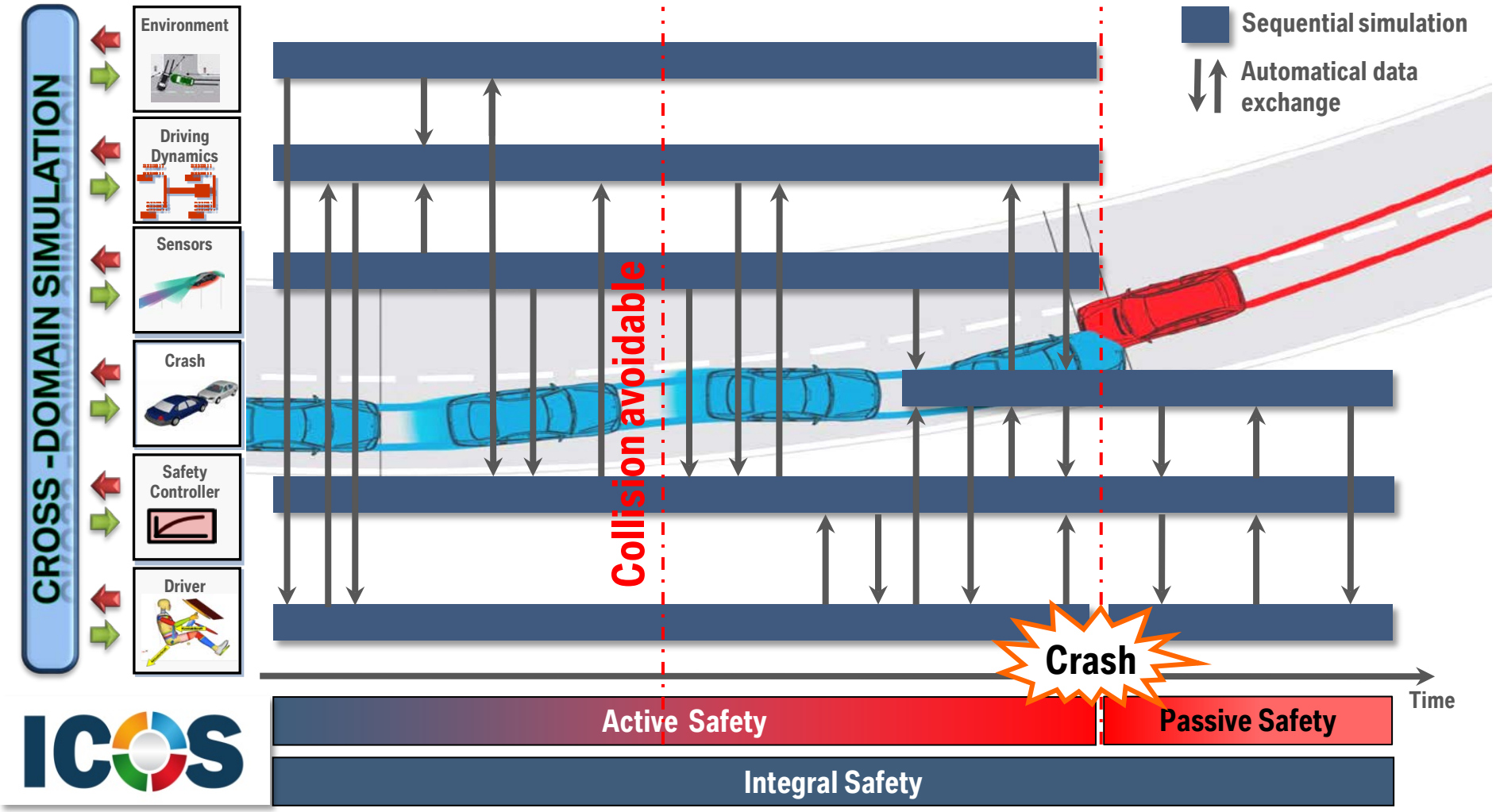
- Traffic vs. accident simulation.
- S.A.F.E.R.
- ICOS.
- Conclusion.



ACCIDENT RESEARCH 2.0.
STRUCTURE OF THE INDEPENDENT CO-SIMULATION.

- Safety systems.
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- New requirements on databases.
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- Traffic vs. accident simulation.
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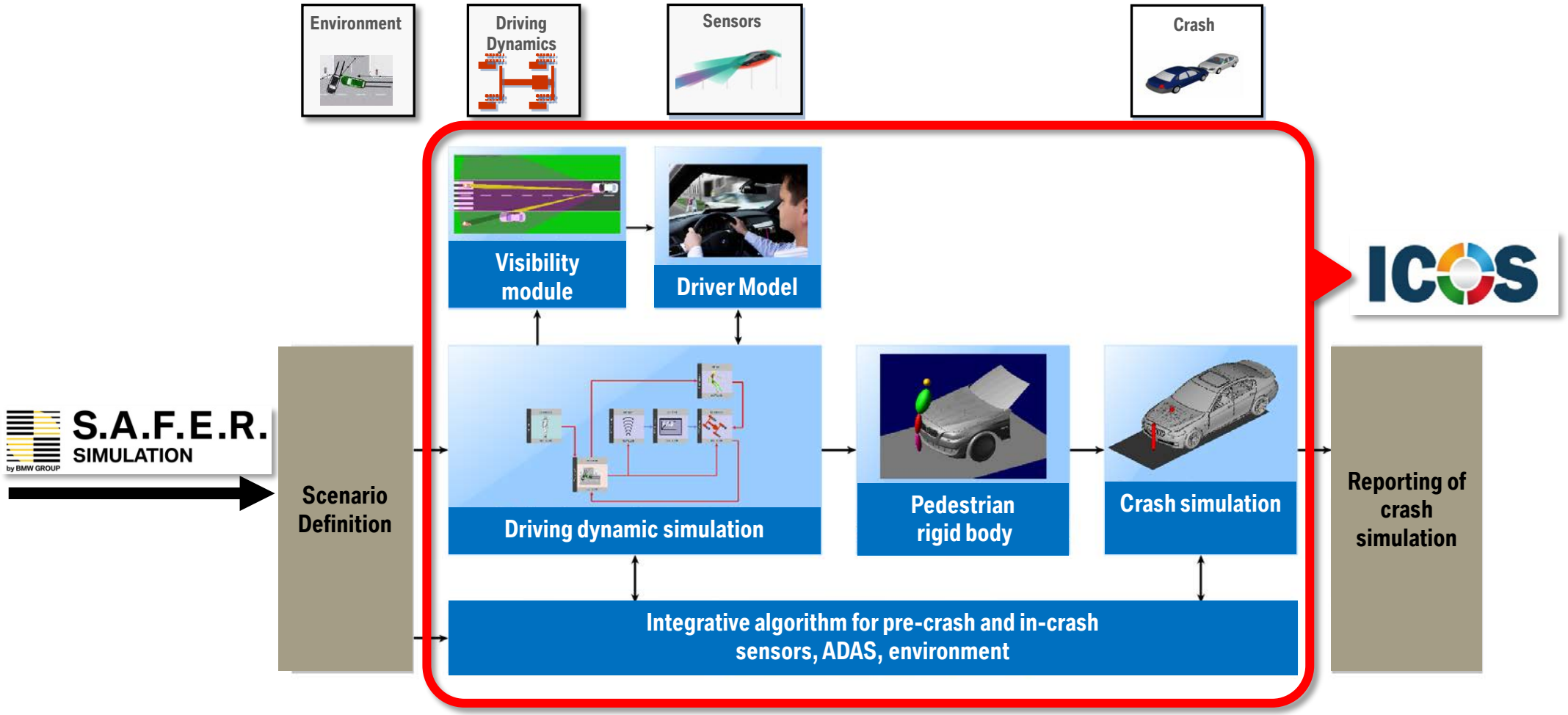

ACCIDENT RESEARCH 2.0.
CONCLUSION.

– The development and optimization of integral safety should be oriented to **the real world efficiency.**

– New generation of virtual methods needed to enable **prediction of the efficiency of new generation safety.**

– **Stochastic simulations** appear feasible of reproducing traffic scenarios (incl. accidents).

– **Comprehensive** evaluation of ADAS potential requires estimates of both effectiveness and false-positives .

– Effectiveness of ADAS can be estimated by simulating a large spectrum of **traffic scenarios.**

– Requirements on a traffic **simulation tool** (e.g., S.A.F.E.R.) should be **standardized.**