EVALUATION OF VEHICLE SAFETY SYSTEMS: STATUS QUO AND FUTURE APPROACH

AsPeCSS Final Event, July 1st, Bergisch Gladbach
DEVELOPMENT OF SAFETY SYSTEMS.
THE VEHICLE’S MOST IMPORTANT SAFETY FEATURE.

Extract from the owner’s manual of the BMW 5 series from 1972:

“The double dual-circuit brake system with brake booster and brake proportioning valve offers a brake performance above legal requirements even if one circuit failed.”

Features 1972:
- Disc Brake on front axle
- Disc Brake on rear axle
- Double Dual-Circuit Brake System
- Brake Booster
- Brake Proportioning Valve

Active Cruise Control:
Automatic deceleration of the vehicle

Features 2013:
- Anti-Lock Brake System (ABS)
- Electronic Brake Force Distribution (EBD)
- Hydraulic Brake Assist (HBA)
- Drive-off Assistant
- Dynamic Stability Control (DSC)
- Dynamic Traction Control (DTC)
- Hill Descent Control (HDC)
- Active Cruise Control (ACC) with Stop&Go Function
- Post Crash Braking System
- Forward Collision Warning with Braking Function
-...

Year
- 1972
- 1978
- 1987
- 1994
- 1998
- 2013
THE ROLE OF „VEHICLE SAFETY“. ACTIVE SAFETY HAS HIGH POTENTIAL.

Developing concepts for increased vehicle safety considering:

- passive safety
- active safety
- functional safety
- operational safety
INTRODUCING ACTIVE SAFETY SYSTEMS.
HIGH POTENTIAL FOR COLLISION MITIGATION AND AVOIDANCE.

- **Driver support**
  - Object detection: Camera

- **Driver warnings**:
  - Optical pre warning
  - Optical and acoustical warning
  - Active brake assist

**Normal driving** — **Warning** — **Correction** — **Collision mitigation** — **Crash** — **Post-crash**

**Driver in the loop**
Support driver’s abilities to avoid accidents.

**Collision unavoidable**
Driver is no longer able to avoid the collision.

**Fail-Safe Operation**
Safety backup: basic protection via passive safety.

**Automatic Emergency Braking (AEB)**

**Enhanced Automatic Crash Notification**: “BMW Intelligent e-Call”
DESIGN OF ACTIVE SAFETY SYSTEMS.
AEB PEDESTRIAN DEVELOPMENT CHALLENGE.

Decision of an automatic brake intervention should only be made if an accident is unavoidable.

The duration of the brake intervention and thus the velocity reduction is limited.

Use case (from Accident Analysis)

Scenario description:
- Crossing pedestrian
- Vehicle going straight

Avoiding unjustified system responses

Scenario description:
- Pedestrian walking fast on the sidewalk towards the street.
- Pedestrian stops abruptly at the curb.

Full AEB Intervention might not be accepted by the driver and could be critical for the vehicles behind.
AEB PEDESTRIAN IMPROVEMENTS.
A CRITICAL VIEW ON HIGH DECELERATION GRADIENTS.

A „fast“ braking system can realize a higher speed reduction.

Example:

Activation time until full deceleration:

<table>
<thead>
<tr>
<th>Normal activation time:</th>
<th>ΔV = 11,9 km/h</th>
<th>ΔE_{Kin} = -50 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>600 ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expected activation time for upcoming high end braking systems:</th>
<th>ΔV = 24,6 km/h</th>
<th>ΔE_{Kin} = -85 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 ms</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Starting speed 40 km/h
- TTC at activation is 600 ms

System concept dictate the limits for deceleration gradients and magnitude!

Accurate fulfillment of these limits is a crucial factor for meeting the small range between effectiveness and functional safety requirements.

Following driver does not expect braking

- situation must be controllable for the vehicle behind.
- the outcome is: limits for deceleration gradient and magnitude
- higher reliability of situation awareness allows higher limits
EVALUATION OF UNJUSTIFIED SYSTEM RESPONSES: ASPECTS TASK 2.3.

Definition of TTC Zones for acceptable system reactions

<table>
<thead>
<tr>
<th>TTC_{\text{intervention}} &lt; TTC_{\text{green}}</th>
<th>TTC_{\text{green}} &lt; TTC_{\text{intervention}} &lt; TTC_{\text{yellow}}</th>
<th>TTC_{\text{intervention}} &gt; TTC_{\text{yellow}}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian is not able to come to a complete stop before entering the driving corridor</td>
<td>Pedestrian is able to stop between the beginning of the driving corridor and an additional safety distance to the driving corridor</td>
<td>Safety System is prematurely triggered and the unsure intervention is still unsubstantiated and typically not tolerated by the user</td>
</tr>
</tbody>
</table>

Evaluation of unjustified system responses as part of the system assessment

- First step has been done in AsPeCSS
- Future task: Implementation of these tests into assessment protocols to get an overall view of the systems
1. Accident analysis: Identify critical crash scenarios and injury patterns using accident data

2. Standard test design: Development and standardization of laboratory test procedures


4. Verification of results: System performance testing in specific crash scenarios

Current assessment approach addresses majority of relevant accident configurations
CURRENT ASSESSMENT OF ACTIVE SAFETY SYSTEMS.
EXAMPLE: AEB PEDESTRIAN FOR EURO NCAP.

Accident cases from accident databases
(e.g. ca. 650 cases in GIDAS*)

Accident Scenarios
6 cases

Test scenarios
3 cases

Assessment:
Speed reduction

AEB Pedestrian testing

- Development of potential solution concepts
- Development of tests based on existing technical solution concepts

* German In-Depth Accident Study
LABORATORY TESTING.
TEST RESULT VS. REAL WORLD SYSTEM PERFORMANCE.

<table>
<thead>
<tr>
<th>System</th>
<th>Laboratory testing</th>
<th>Lab. results</th>
<th>Real-world system performance</th>
<th>Real results</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>![Image A]</td>
<td>![Green Up]</td>
<td>![Green Up]</td>
<td>![Green Up]</td>
</tr>
</tbody>
</table>

- **Safety performance**
- **Negative effects**
- **Acceptance**
CURRENT ASSESSMENT METHODOLOGY. COMPARING PASSIVE AND ACTIVE SAFETY.

- The Passive Safety “laboratory only” approach is not suitable for active safety assessments:
  - Active safety systems can be optimized for specific scenarios. Numerous remaining scenarios not addressed and assessed.
  - Laboratory tests follow precise/well-defined protocols: highly reproducible, comparable, etc.
  - Laboratory tests by nature incorporate a very limited sample of real traffic conditions and contributing factors.
  - An excessive test effort is needed for active safety systems to address all relevant real-world traffic accident scenarios and negative side effects (e.g. false positive testing).

A “laboratory only” testing approach is unable to adequately assess the performance of active safety systems in real-world traffic.
FUTURE APPROACH TO EVALUATION OF ACTIVE SAFETY.

Accident Data Base
- Causation
- Type of Accidents
- ...
Small database, severe accidents

Traffic Data Base
- FOT, NDS, Driving Recs
- Typical, "uncritical Situations
- ...
Larger scale data base, less accidents

Scenarios (e.g. Pedestrian Accidents)
- Type of Road
- Visibility
- Driving Direction
- Ped. Moving Direction
- Daytime, Brightness
- ...

Output
- Focal Points, Scenarios most important
- Parameters, describing the before identified focal points
- Factors that discriminate uncritical from critical situations

Contributing Factors
- Driver reaction
- Pedestrian reaction
- Vehicle performance
- ...

Model of Collision Avoidance System
- Describing parameters of innovations
- Provided by OEM, supplier or others
- Model quality standard req.

Modeling
- Stochastic
- Monte Carlo, ...
Creation of thousands of artificial, yet representative situations

Simulation / Evaluation
- Evaluation of system benefit
- Calculation of number and severity of unwanted side effects
- Prospective effectiveness analysis

Detailed description of safety-relevant scenarios for the effectiveness analysis

Considering additional basic conditions, e.g. driver’s performance

Simulation Model of the ADAS System (OEM) and overall simulation model

Effectiveness Analysis for the ADAS System
EVALUATION PROCESS FOR ACTIVE SAFETY. DETAILS.

- Accident data
- Traffic Data
- Human Factors Data
- Parameter Variation
- Computer model CAS
- Analysis, Metrics
- Results of Scenario
- Case Selection
- Spot Testing
- Compare Results
- Results Evaluation
- Rating
HARMONIZATION OF EFFECTIVENESS EVALUATION.

OBJECTIVES.

- Representative assessment of active safety requires harmonized methods.

- For simulation: methods, processes, and models for prospective assessment have to be harmonized.

- Harmonization enables comparable and comprehensible assessments.

- World-wide harmonization / standardization as primary objective.

- Open harmonization initiative founded by BMW was very well received; early support by other OEMs and Autoliv.
HARMONIZATION OF EFFECTIVENESS EVALUATION.
THE ROAD SO FAR.

2011
2012

20.11.2012: 1st meeting
- Methodology
- Expectations
- Experiences

06.05.2013: 3rd meeting
- Method paper (prelim. ISO-Draft)
- Definition of working groups

27.11.2013: 5th meeting
- Results from WGs
- Next steps

2013

23.02.2013: 2nd meeting
- Long-term objectives
- Workshop on work-packages

03./04.09.2013: 4th meeting
- Workshop in working groups
- Formulation of actions

2014 ff
HARMONIZATION OF EFFECTIVENESS EVALUATION.
CURRENT PARTICIPANTS.
CONCLUSION

• A “laboratory only” approach is not suitable for harnessing the potential of active safety systems in real traffic conditions.

• Active safety systems: a good result in a laboratory test doesn’t necessarily equate to an effective system in real traffic conditions.

• Suggested new approach for evaluation of active safety:
  i. Evaluation via simulation to ensure real world scenarios are adequately addressed
  ii. Verification of simulation results via random hardware tests

• Evaluation approaches to active safety need international harmonization and standardization.