AEB TEST PROCEDURES

AUTONOMOUS EMERGENCY BRAKING

AEB Group
VEHICLE AND TECHNOLOGY DEVELOPMENTS REDUCE CRASHES

- Euro NCAP is working; 5 star cars are a lower risk in the real world
- 90% of crashes have some element of driver error
- Many due to distraction
- Advanced Driver Assistance Systems (ADAS) aim to support the driver if an error is made
- ADAS could help to reduce crashes

Real world risk study by Folksam, 2011
ADVANCED DRIVER ASSISTANCE SYSTEMS

ADAS

- ESC is an established life saver
- Other ADAS systems show potential

- ESC saves lives; an ESC equipped vehicle is 25% less likely to be involved in a serious or fatal crash in the UK
- Material damage claims show 15% reduction with ESC
AUTONOMOUS EMERGENCY BRAKING

AEB

Car-to-Car Rear (CCR)  Car-to-Pedestrian (CP)

- Forward looking sensors (RADAR, LIDAR, Camera)
- System detects an imminent collision
- Some systems issue driver warnings (acoustic, visual, haptic)
- Automatic application of the brakes if driver is unresponsive or distracted
PERSONAL INJURY AND DAMAGE SAVINGS

- Estimates based on ABI (Association of British Insurers) motor claims statistics
- Estimates project crashes forward to 2018
- Model of AEB fitment in the UK fleet is estimated based on ESC fitment rates
- Savings are estimated based on the IIHS study of XC60 effectiveness of City Safety
- Personal Injury (PI) and damage crashes combined
- Approximately 800,000 crashes could be saved in period 2012 to 2018
“To design and implement test procedures reflecting real world data that can encourage the development of autonomous braking technology that can help prevent or mitigate the effects of car-to-pedestrian and car-to-car crashes”

- Incorporate provisional results from real world accident data to define test conditions
- Define and specify test measurement equipment
- Define test metrics and rating process
- Publish initial results/ratings to inform consumers/stakeholders of technology capability
- Integrate into existing consumer test programs (RCAR)
- Offer to Euro NCAP P-NCAP for consideration for future test program
AEB SYSTEMS

CITY

- Low speed crashes below 50km/h
- Addresses most common traffic shunts
- Prevents whiplash injuries
- Crashes into stationary vehicles

- AEB systems operational at low speeds
  - Avoidance or mitigation
- Low speed systems currently available:
  - Ford Focus, many Volvos models
- Recent launches:
  - Mazda CX5, Fiat Panda, VW up!
- Also other AEB systems operate into low speed ranges
  - Mercedes Pre-Safe Brake

Ford: Active City Stop
AEB SYSTEMS

INTER-URBAN

- Crashes generally higher speeds >20km/h
- Dual carriageway and motorways
- Can help to mitigate the more severe damage and injuries

- AEB systems can provide warning and autobrake for avoidance and crash mitigation
- Systems available from Honda, Mercedes, Volvo for example
AEB SYSTMS

PEDESTRIAN

• Low-medium speed crashes <60km/h
• Addresses pedestrian collisions with high risk of severe and fatal injury

• AEB systems can provide warning and autobrake for avoidance and crash mitigation
• Examples from Volvo and Subaru

Volvo: Pedestrian Detection
## TYPICAL SPEED RANGES & SENSORS

<table>
<thead>
<tr>
<th>Collision Type</th>
<th>Speed (km/h)</th>
<th>Typical Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>City</td>
<td></td>
<td>LIDAR / RADAR</td>
</tr>
<tr>
<td>Inter-urban</td>
<td></td>
<td>RADAR / Camera</td>
</tr>
<tr>
<td>Pedestrian</td>
<td></td>
<td>Camera</td>
</tr>
</tbody>
</table>

### City
- 75% crashes under 20mph (1)
- Most insurer relevant

### Inter-urban
- 26% of crashes are front into rear (2)

### Pedestrian
- 6,000 pedestrian fatalities & serious injuries in UK (3)

1) Study by Volvo of US real world data: NASS and STO
2) Study by Thatcham of UK real world insurance claims
3) UK Department for Transport statistics
CRASH TYPES BEING ADDRESSED BY AEB

- **CITY**: Low speed shunts, low injury risk, high volume
- **INTER-URBAN**: Higher risk of injury, lower volume
- **PEDESTRIAN**: Much higher injury risk, but much smaller volume of crashes
REAL WORLD DATA

CITY SAFETY REDUCES CLAIMS IN THE REAL WORLD

- Study of US insurance claims by Insurance Institute for Highway Safety (IIHS)
- 260 Volvo XC60 claims
- Comparison against other similar 4x4s
- Comparison against other Volvos (to isolate any Volvo brand effect)

### Claim Frequency vs. other similar 4x4s

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>Severity</th>
<th>Overall Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Third party damage</td>
<td>-27% ↓</td>
<td>+$270 ↑</td>
<td>-$17 ↓</td>
</tr>
<tr>
<td>Third party injury</td>
<td>-51% ↓</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>First party damage</td>
<td>-22% ↓</td>
<td>-$517 ↓</td>
<td>-$98 ↓</td>
</tr>
</tbody>
</table>

- Published study in Status Report, Vol 46, No 6, July 2011
REAL WORLD DATA

SUMMARY OF REAL WORLD STUDIES: CITY SAFETY

TREND: AEB is reducing collisions in the real world

IIHS study: all claims

Insurance claims study from Switzerland; 31% reduction in 3rd party rear-end claims

Insurance claims study from Germany; 9% reduction in all claims

Tristar worldwide; 28% reduction at fault rear impacts
REAL WORLD DATA

REDUCTION IN 3RD PARTY ACCIDENT DAMAGE CLAIMS

Study examines the effect of optional fit systems

- Volvo (with AEB & FCW)
- Volvo (with FCW)
- Mercedes (with AEB & FCW)
- Mercedes (with FCW)
- Acura (with AEB & FCW)

Note that Volvo AEB system is also bundled with LDW.
LOUGHBOROUGH STUDY OF ALL UK CRASHES

Unique in-depth study commissioned by Thatcham investigating real world crashes and their causation factors to formulate realistic test scenarios that drive AEB functionalities suitable for Euro NCAP and Insurers

Aim for 4-6 clusters
≥75% of cases

Report available at: www.thatcham.org/AEB
INITIAL SPEEDS AT START OF COLLISION

- **EDR data – AXA Switzerland**
  - Initial speed prior to braking was below 50km/h for 78% of cases

- **Delta-V**
  - 93% of all accidents had a delta-v of less than 20km/h

- **OTS case reconstructions – UK**
  - Initial speed prior to braking was below 60km/h for majority of cases
REAL WORLD DATA

BRAKING LEVELS IMMEDIATELY BEFORE COLLISION

86% of drivers braked before the accident

- Majority of drivers did not brake hard enough

Mean braking in CCR crashes

86% of drivers braked before the accident

- Majority of drivers did not brake hard enough

OTS case reconstructions – UK

EDR data – AXA Switzerland
REAL WORLD DATA

UK ACCIDENT CLUSTERS: WIDE VARIETY OF ACCIDENT TYPES

Too many scenarios to be feasible for testing, so select scenarios based on real world frequency
## TEST SCENARIOS SELECTED TO REPRESENT GREATEST FREQUENCY OF REAL WORLD CRASHES

<table>
<thead>
<tr>
<th>Combining accident data from other international sources</th>
<th>UK</th>
<th>UK</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 19 n=34,764 cluster analysis rear-end collisions</td>
<td>61%</td>
<td>42%</td>
<td>52%</td>
</tr>
<tr>
<td>OTS n=50 cluster analysis rear-end collisions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UDV n=285 (N=30,155) 3rd party vehicle claims 2002-2006 rear-end collisions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CITY &amp; INTER-URBAN</td>
<td>Car drives into lead vehicle stopped</td>
<td>61%</td>
<td>42%</td>
</tr>
<tr>
<td>INTER-URBAN</td>
<td>Car drives into slower lead vehicle</td>
<td>30%</td>
<td>10%</td>
</tr>
<tr>
<td>INTER-URBAN</td>
<td>Car drives into lead vehicle decelerating</td>
<td>14%</td>
<td>6%</td>
</tr>
</tbody>
</table>

In addition real world data scenarios are also selected using engineering judgements. CCR 2 is situation noted from track testing where some AEB systems appear to fail. This scenario is under investigation, not yet tested due to limitation of 3D appearance of target.
• **CCR Lead Vehicle Stopped**
  – Stationary target
  – Approach speeds 10 to 80km/h in 10km/h steps, 5km/h when impacting

• **CCR Slower Lead Vehicle**
  – 20km/h target
  – Approach speeds 50 to 80km/h in 10km/h steps, 5km/h when impacting

• **CCR Lead Vehicle Decelerating**
  – 50km/h target
  – Approach speed 50km/h
  – Headways of 12 and 40m, target decelerations of 2 and 6m/s²

• **CCR Junction**
  – Under development with appropriate target
REAL WORLD DATA

TEST SCENARIOS SELECTED TO REPRESENT GREATEST FREQUENCY OF REAL WORLD CRASHES

<table>
<thead>
<tr>
<th>City &amp; Inter-Urban</th>
<th>Car drives into lead vehicle stopped</th>
<th>UK</th>
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</tr>
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<tbody>
<tr>
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</tr>
<tr>
<td></td>
<td></td>
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<td>42%</td>
<td>52%</td>
</tr>
</tbody>
</table>

- A proportion of CCR stationary type collisions at junctions
- Road geometry dictates that vehicles not necessarily aligned
- Track tests indicate AEB system performance deteriorates in junction type manoeuvres
<table>
<thead>
<tr>
<th>PEDESTRIAN</th>
<th>Combining accident data from other international sources</th>
<th>UK</th>
<th>UK</th>
<th>Germany</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pedestrian walks from nearside</td>
<td></td>
<td>51%</td>
<td>30%</td>
<td>32%</td>
<td></td>
</tr>
<tr>
<td>Pedestrian walks out from behind obstruction</td>
<td></td>
<td>14%</td>
<td>15%</td>
<td>7%</td>
<td>27%</td>
</tr>
<tr>
<td>Pedestrian runs out from the far side</td>
<td></td>
<td>9%</td>
<td>6%</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>Pedestrian walks along in the dark</td>
<td></td>
<td>3%</td>
<td>14%</td>
<td>8%</td>
<td>9%</td>
</tr>
<tr>
<td>Pedestrian walks out into the path of turning car</td>
<td></td>
<td>6%</td>
<td>14%</td>
<td>18%</td>
<td>-</td>
</tr>
</tbody>
</table>

Darkness scenarios are not yet tested, but closest possible scenario is under investigation.
For example CP4 is tested as stationery pedestrian, but not in darkness.
**REAL WORLD DATA**

**TEST SCENARIOS SELECTED FOR GREATEST FREQUENCY OF REAL WORLD CRASHES**

<table>
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<tr>
<th>Combining accident data from other international sources</th>
<th>UK</th>
<th>UK</th>
<th>Germany</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATS 19 n=10,574 cluster analysis frontal collisions</td>
<td>OTS n=175 cluster analysis frontal collisions</td>
<td>UDV n=234 (N=18,571) 3rd party vehicle claims 2002-2006 frontal collisions</td>
<td>IIHS 1997-2006 FARS &amp; GES all car-pedestrians</td>
<td></td>
</tr>
<tr>
<td>Pedestrian walks along in the dark</td>
<td>3%</td>
<td>5%</td>
<td>8%</td>
<td>9%</td>
</tr>
</tbody>
</table>

- Darkness scenarios are not yet tested, but closest possible scenario is under investigation
- For example CP4 is tested as stationary pedestrian, but not in darkness
- Currently only assessing the warning capability of the systems, not assessing for autobraking

- Darkness represents low frequency from all crashes; but high fatalities:
WHAT TARGET?

COMPARISON OF DIFFERENT TEST TARGETS

RADAR and Camera Systems

Car  Assessor - Tyres  Assessor - Ground  Balloon Car

Touran  Rabbit & Assessor  Rabbit & Suzuki  ABsessor

Adult  Pedestrian target  Manikin

Rabbit (Landrover Discovery with radar shielding) is not acquired as a target by the system.
WHAT TARGET?

CITY: CAR TO STATIONARY CAR

- Target identification based on RADAR and Camera sensors

ROAD
- Approx 60 km/h
- Target identified at 63m *

TRACK
- 20 km/h
- Target identified at 76m

- Target was identified earlier at 180m (RADAR range is approx 190m), but the match with the camera was a low confidence level
WHAT TARGET?

TRACK: TARGET COMPARISON

REAL CAR
20 km/h
Target identified at 64m

CAR TARGET
20 km/h
Target identified at 66m
COMPARISON AT APPROACH SPEED ≈ 20KM/H

- System outputs confidence level of an object based on radar and visual attributes
- Scored on a scale of 0-5 with 5 being the higher confidence (green)
- Score of 0 indicates insufficient visual detail to confirm the object (red)
EURO NCAP CAR TARGET FINALISATION

- ADAC – Thatcham collaborative testing
  - Volvo V60 camera and radar data

- Ongoing testing by stakeholders to confirm target attributes
- Finalised version for October 2012
Anonymised VW Touran target cover:

- Visibility attributes as per HP2
- Appropriate geometry, representative of typical vehicles
- Silver colour challenging for vision based systems
- Represents substantial proportion vehicles
CAR TARGET

TARGETS AS TESTED
WHAT TARGET?

TARGETS UNDER DEVELOPMENT INTERNATIONALLY

- Future:
  - Consideration for 2016 – Euro NCAP - Robot Platform

DRI Guided Soft Target
**CITY Lead Vehicle Stopped < 50km/h; INTER-URBAN > 50km/h**

- Approaching a stopped vehicle at test speeds from 10 to 80km/h
- Speed increased in 10km/h increments if system avoids collision with car target
- Speed in 5km/h increments to identify collision point

**CITY Junction**

- 10km/h following a curved path behind the target car stationary at junction
- Target car at a range of angles 0, 15, 30, 45 degrees

**INTER-URBAN Slower Lead Vehicle**

- Approaching a moving target at 20km/h
- Speed starting at 50km/h and increased in 10km/h increments up to 80km/h if system avoids collision with car target
- Speed in 5km/h increments to identify collision point

**INTER-URBAN Lead Vehicle Decelerating**

- Approaching a decelerating target, both initially moving at 50km/h
- Target car: initial headway 12m, target deceleration at 2 and 6 m/s²
- Target car: initial headway 40m, target deceleration at 2 and 6 m/s²

Note that CCR2 is currently under development
Commence with the AEB test at the lowest test speed to assess the vehicle autonomous braking response.

- e.g. Mercedes Collision Prevention Assist
  - FCW only, no AEB
  - Mercedes B-Class
- e.g. Ford Active City Stop
  - AEB only, no FCW
  - Ford B-Max
- e.g. Volvo CADSIII+
  - FCW & AEB
  - Volvo V40
TEST FLOW

EXAMPLE TEST FLOW – CITY

Lead Vehicle Stopped:
Approaching a stopped vehicle at test speeds from 10 to 50km/h

1. Start at 10km/h
2. If collision avoided, proceed in 10km/h increments
3. If impact occurs, decrease speed by 5km/h to identify collision point
4. Continue testing in 5km/h increments to identify mitigation
5. Perform tests up to 50km/h, or until the vehicle no longer mitigates

Cover range of test speeds
- Assess range of vehicle performance
- Collisions occur over a range of speeds in the real world
  - Testing represents real world
- Safety of test drivers
  - Start at low speed and build up is safer than first test at higher speeds
- Repeated runs are not a big time burden
  - Most time is spent on set up for different scenarios
EXAMPLE TEST FLOW – INTER-URBAN

**Lead Vehicle Stopped:**
Approaching a stopped vehicle at test speeds from 50 to 80km/h

1. Start at 50km/h
2. If collision avoided, proceed in 10km/h increments
3. If impact occurs, repeat test with braking input in response to collision warning (if present)
4. Continue testing in 5 or 10mk/h increments depending on AEB avoidance or mitigation
5. Perform tests up to 80km/h, or until the vehicle neither mitigates by AEB nor provides a collision warning

**Cover range of test speeds**
- Assess range of vehicle performance
- Collisions occur over a range of speeds in the real world
  - Testing represents real world
- Safety of test drivers
  - Start at low speed and build up is safer than first test at higher speeds
- Repeated runs are not a big time burden
  - Most time is spent on set up for different scenarios
FCW BRAKING RESPONSE (WARNING-IN-THE-LOOP)

- Qualifying warning: loud and clear audible + 1 other (haptic, visual)

- 86% of drivers braked pre-crash

- Partial braking only, greater deceleration achievable

- Dynamic Brake Support (DBS) required to realise potential benefit
FCW BRAKING RESPONSE (WARNING-IN-THE-LOOP)

• Perform robot brake response characterisation test in non critical situation
  – 80km/h, ~20mm/s ramp input to >6m/s², determine pedal position & force for [4.0]m/s²

• FCW robot braking response triggered by audible warning recognition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Modality</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Pr &gt; F</th>
</tr>
</thead>
<tbody>
<tr>
<td>23</td>
<td>All</td>
<td>8</td>
<td>1.263</td>
<td>0.320</td>
<td>0.750</td>
<td>1.825</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Beep</td>
<td>8</td>
<td>1.598</td>
<td>0.351</td>
<td>1.260</td>
<td>2.140</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>BeepHUD</td>
<td>7</td>
<td>1.437</td>
<td>0.384</td>
<td>0.905</td>
<td>2.070</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Belt</td>
<td>7</td>
<td>1.436</td>
<td>0.489</td>
<td>0.895</td>
<td>2.070</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>BeltBeep</td>
<td>8</td>
<td>1.087</td>
<td>0.362</td>
<td>0.700</td>
<td>1.645</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>BeltHUD</td>
<td>6</td>
<td>1.129</td>
<td>0.428</td>
<td>0.775</td>
<td>1.795</td>
<td>0.0002</td>
</tr>
<tr>
<td>6</td>
<td>HUD</td>
<td>5</td>
<td>2.002</td>
<td>0.129</td>
<td>1.840</td>
<td>2.195</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td>7</td>
<td>1.802</td>
<td>0.207</td>
<td>1.475</td>
<td>2.000</td>
<td></td>
</tr>
</tbody>
</table>

- Typical braking reaction time of 1.2s after FCW start


- Apply pedal force equivalent to [4.0]m/s² deceleration by ramping up under position control over [0.25]s and then maintain force – clearly see DBS effect
Thatcham is currently using the following equipment:

<table>
<thead>
<tr>
<th>Test Car</th>
<th>Target Car</th>
<th>Target Pedestrian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Accelerator robot (ABD)</td>
<td>• Braking robot (ABD)</td>
<td>• Motorised rig</td>
</tr>
<tr>
<td>• Steering robot (ABD)</td>
<td>• Steering robot (ABD)</td>
<td></td>
</tr>
<tr>
<td>• GPS signal and base station (OXTS)</td>
<td>• GPS signal (OXTS)</td>
<td></td>
</tr>
<tr>
<td>Measurement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Motion pack (OXTS)</td>
<td>• Motion pack (OXTS)</td>
<td></td>
</tr>
<tr>
<td>• Including RT-Range system to measure relative data between the test and target cars (OXTS)</td>
<td>• Electronic switch to record contact time with target car</td>
<td></td>
</tr>
<tr>
<td>Target</td>
<td>• Car target</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pedestrian target</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Obscuration vehicles (Landrover Freelander and Volkswagen Golf in matt black to give clear identification)</td>
<td></td>
</tr>
</tbody>
</table>
• Receive vehicle, pre-test safety checks, fuel, weights and measures
• [Driving amongst other traffic on road for system initialisation/calibration]
• Fit instrumentation:
  – Vehicle control equipment (ABD steer, accelerator and brake robots)
  – DGPS inertial measurement system (OxTS RTs and Range system)
  – Impact sensor
  – Warning identification system
  – Cameras etc.
• Test weight and measures etc.
CCR TESTING – ON TRACK TEST PREPARATION

- **Brake conditioning** (as per ESC testing)
  - 10 stops from 56km/h at 5m/s² and 3 stops from 72km/h with full ABS
  - 72km/h for 5 minutes to cool
- **Tyre conditioning** (as per ESC testing)
  - ø30m circle at speed for lat. acc. of 5-6m/s², 3 laps clockwise and 3 anticlock
  - 56km/h 1Hz sinusoidal steering with peak lat. acc. of 5-6m/s², 4 passes with 10 cycles each, final cycle of final pass at double steering wheel amplitude
- **Robot tuning**
  - Path following
  - Speed control
  - Braking
- **Brake pedal force characterisation** for braking response
  - 80km/h, ~20mm/s ramp input to >6m/s²
CCR TESTING – TOLERANCES

• Target consistency limits (CCR lead vehicle stopped and CCR lead vehicle decelerating)
  – Speed +1.0km/h
  – Yaw rate ±1.0°/s
  – Lateral position ±0.10m
  – Deceleration ±[0.5]m /s²

• Test vehicle approach consistency limits
  – Nominal test speed +1.0km/h (consider allowance for brake jerk warnings)
  – Steering wheel velocity ±10 °/s
  – Accelerator pedal position ±5%
  – Lateral position ±0.10m
  – Yaw rate ±1.0°/s
  – Headway +1.0m

• Test vehicle FCW reaction
  – Brake pedal force corridor ±[10]N
AEB test procedures under development to allow system performance relevant to insurers to be evaluated

Five different test vehicles have been selected that represent the different technical solutions currently available.

<table>
<thead>
<tr>
<th>Vehicle Model</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ford Focus with Active City Stop</td>
<td>LIDAR</td>
</tr>
<tr>
<td>Honda CR-V with Collision Mitigation Braking System</td>
<td>RADAR</td>
</tr>
<tr>
<td>Mercedes CLS Class with Pre-Safe Brake</td>
<td>RADAR fusion</td>
</tr>
<tr>
<td>Subaru Outback with Eye Sight</td>
<td>Stereo camera</td>
</tr>
<tr>
<td>Volvo V60 with Collision Warning with Full Auto-Brake and Pedestrian Detection</td>
<td>Camera &amp; RADAR fusion</td>
</tr>
</tbody>
</table>
**EXAMPLE TEST SCENARIO – FORD FOCUS**

**CITY & INTER-URBAN: LEAD VEHICLE STOPPED 10 TO 80 KM/H**

**LVS**: Approaching a stopped vehicle at test speeds from 10 to 80km/h
- Speed increased in 10km/h increments if system avoids collision with car target
- If impact occurs, run test at 5km/h lower
- Speed increased in 5km/h increments to establish collision point
EXAMPLE TEST SCENARIO – FORD FOCUS

CITY & INTER-URBAN: LEAD VEHICLE STOPPED 10 TO 80 KM/H

**LVS:** Approaching a stopped vehicle at test speeds from 10 to 80km/h
- Speed increased in 10km/h increments if system avoids collision with car target
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- Speed increased in 5km/h increments to establish collision point

**MITIGATION:**
Impact speed 12km/h
LVS: Approaching a stopped vehicle at test speeds from 10 to 80km/h
• Speed increased in 10km/h increments if system avoids collision with car target
• If impact occurs, run test at 5km/h lower
• Speed increased in 5km/h increments to establish collision point
INTER-URBAN: SLOWER LEAD VEHICLE

**SLV**: Approaching a target moving at 20km/h
- Speed starting at 50km/h and increased in 10km/h increments if system avoids collision with car target
- If impact occurs, run test at 5km/h lower
- Speed increased in 5km/h increments to establish collision point

Subaru Outback CCR3 70k | run 1

AVOIDANCE
INTER-URBAN: SLOWER LEAD VEHICLE

**SLV**: Approaching a target moving at 20km/h
- Speed starting at 50km/h and increased in 10km/h increments if system avoids collision with car target
- If impact occurs, run test at 5km/h lower
- Speed increased in 5km/h increments to establish collision point

MITIGATION:
Impact speed 48km/h
**EXAMPLE TEST SCENARIO – VOLVO V60**

**INTER-URBAN:**
**LEAD VEHICLE DECELERATING**

**LVD**: Approaching a decelerating target, both initially moving at 50km/h
- Headway has 2 conditions: 12m or 40m
- Braking has 2 conditions: 2m/s² (normal) or 6m/s² (emergency)
- Total 4 combinations

<table>
<thead>
<tr>
<th>Braking m/s²</th>
<th>Headway m</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>X</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
</tr>
</tbody>
</table>

*Mitigation:*

Impact speed 25km/h

40m headway with 2m/s² braking
INTER-URBAN: LEAD VEHICLE DECELERATING

**LVD**: Approaching a decelerating target, both initially moving at 50km/h
- Headway has 2 conditions: 12m or 40m
- Braking has 2 conditions: 2m/s² (normal) or 6m/s² (emergency)
- Total 4 combinations

MITIGATION:
Impact speed 24km/h

40m headway with 6m/s² braking

![Volvo V60 CCR4 40m 6ms^-2 | run 2](image)
INTER-URBAN: LEAD VEHICLE DECELERATING

**LVD**: Approaching a decelerating target, both initially moving at 50km/h
- Headway has 2 conditions: 12m or 40m
- Braking has 2 conditions: 2m/s$^2$ (normal) or 6m/s$^2$ (emergency)
- Total 4 combinations

<table>
<thead>
<tr>
<th>Headway m</th>
<th>Braking m/s$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>X</td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

**AVOIDANCE**

12m headway with 2m/s$^2$ braking
INTER-URBAN: LEAD VEHICLE DECELERATING

**LVD:** Approaching a decelerating target, both initially moving at 50km/h
- Headway has 2 conditions: 12m or 40m
- Braking has 2 conditions: 2m/s$^2$ (normal) or 6m/s$^2$ (emergency)
- Total 4 combinations

<table>
<thead>
<tr>
<th>Headway m</th>
<th>Braking m/s$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
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<td>40</td>
<td>2</td>
</tr>
<tr>
<td>40</td>
<td>6</td>
</tr>
</tbody>
</table>

**MITIGATION:**
Impact speed 20km/h

12m headway with 6m/s$^2$ braking
PEDESTRIAN TESTING

PEDESTRIAN TARGET

- **Impactable pedestrian dummy**
  - Full playout of AEB system performance to impact
  - Strong media representation of performance
  - Requires resetting after impact test
  - Potential target degradation with repeated impacts

- **Rescued pedestrian dummy**
  - Gantry system signature
    - Easily recognised by sensor systems
  - Effect on performance when rescued
  - Estimate speed reduction?
    - Maintain deceleration?
    - Release deceleration? Would the car have stopped?
    - Increase deceleration immediately pre-impact?
  - Simple resetting between tests
  - Confusing consumer media message
Pedestrian target attributes as per HP2 specification
• 50th percentile male and 6 year old child dummy
• Visual, radar, lidar etc. attributes equivalent to pedestrian
• Walking stance of MSt in accordance with SAE J2782
• Impactable at speeds up to 60km/h

Pedestrian target motivation
• Platform mounted
• Guided path following and speed profile
• Speed capability up to 15km/h
• Impactable up to 60km/h with minimal vehicle damage
• Reconstructable for repeat testing
**CAR & PEDESTRIAN TEST TARGETS**

**COMPARISON AT APPROACH SPEED ≈ 20KM/H**

- System outputs confidence level of an object based on radar and visual attributes
- Scored on a scale of 0-5 with 5 being the higher confidence (green)
- Score of 0 indicates insufficient visual detail to confirm the object (red)

Note: Adult and walking man target were obscured by other vehicles; manikin was unobscured

<table>
<thead>
<tr>
<th>Target</th>
<th>Distance from target m</th>
<th>Avoidance distance m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult walking</td>
<td>20.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Walking Man Target</td>
<td>8</td>
<td>1.5</td>
</tr>
<tr>
<td>Manikin (unobscured)</td>
<td>36.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

Driver braking for safety
TARGET

PEDESTRIAN – PROTOTYPE TESTING

Subaru Outback 50km/h  Subaru Outback 60km/h
PEDESTRIAN TARGET

PROTOTYPE TESTING

Test speed 30km/h pedestrian avoidance

Avoidance

Test speed 40km/h mitigation

Mitigation
• Guided platform with programmable speed and path following ability
• Dummy separation from platform at impact
• Knee joints engineered to set dummy stance, but fracture upon impact to minimise damage
• Fast re-build time and good reproducibility
PEDESTRIAN TESTING

DSD UFO Pedestrian Platform

- Pedestrian Platform
- Holds impactable light weight pedestrian dummy
- Dummy secured by magnets
- 5-15 Km/h performance
- High Acceleration typical of real pedestrians
- 90mm High Profile
- 840mm x 1115mm
- Drive-Over ruggedised design
- Minimum radar and visual signatures
CP AEB TEST PROCEDURES

CP1: Unobscured pedestrian walks out from nearside
- Test speeds from 10 to 60km/h
- Speed increased in 10km/h increments if system avoids collision
- Speed in 5km/h increments to identify collision point

CP2: Obscured pedestrian walks out from nearside
- Test speeds from 10 to 60km/h
- Speed increased in 10km/h increments if system avoids collision
- Speed in 5km/h increments to identify collision point

CP3: Unobscured pedestrian runs out in front of car from far side
- Test speeds from 40 to 60km/h
- Speed increased in 10km/h increments if system avoids collision
- Speed in 5km/h increments to identify collision point

CP4: Pedestrian walking along the road at night
- Test speeds 50km/h and 70km/h

CP5: Car turns at junction and pedestrian walks out
- Test speeds 15km/h and 25km/h

Note that CP4 is currently not being tested in darkness, but a stationary target is being used to give initial investigation of the test scenario.
CP5 is currently under investigation.
EXAMPLE TEST SCENARIO – VOLVO V60: CP1

CP1 UNOBSCURED NEARSIDE PEDESTRIAN 10 TO 60 KM/H

CP1: Unobscured pedestrian walks out from nearside
  • Test speeds 10km/h to 60km/h

Volvo V60 CP1 10k | run 3

AVOIDANCE
EXAMPLE TEST SCENARIO – VOLVO V60: CP1

CP1 UNOBSCURED NEARSIDE PEDESTRIAN
10 TO 60 KM/H

CP1: Unobscured pedestrian walks out from nearside
- Test speeds 10km/h to 60km/h

Volvo V60 CP1 30k | run 4

AVOIDANCE

km/h 10 15 20 25 30 35 40 45 50 55 60
CP1 UNOBSCURED NEARSIDE PEDESTRIAN 10 TO 60 KM/H

**CP1**: Unobscured pedestrian walks out from nearside
- Test speeds 10km/h to 60km/h

**MITIGATION**: Impact speed 24km/h
CP2: Obscured pedestrian walks out from nearside
- Test speeds 10km/h to 60km/h
EXAMPLE TEST SCENARIO – VOLVO V60: CP2

CP2 OBSCURED NEAR SIDE PEDESTRIAN
10 TO 60 KM/H

CP2: Obscured pedestrian walks out from nearside
- Test speeds 10km/h to 60km/h

Volvo V60 CP2 30k | run 3

AVOIDANCE
EXAMPLE TEST SCENARIO – VOLVO V60: CP2

CP2 OBSCURED NEARSDIE PEDESTRIAN
10 TO 60 KM/H

**CP2**: Obscured pedestrian walks out from nearside
- Test speeds 10km/h to 60km/h

**Volvo V60 CP2 35k | run 1**

**MITIGATION**: Impact speed 28km/h
<table>
<thead>
<tr>
<th>Car-to-Car Rear (CCR)</th>
<th>Car-to-Pedestrian CP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CITY</strong></td>
<td>CP1 Unobscured nearside walking pedestrian</td>
</tr>
<tr>
<td>Lead Vehicle Stopped &lt;50km/h</td>
<td></td>
</tr>
<tr>
<td><strong>INTER-URBAN</strong></td>
<td>CP2 Obscured walking nearside pedestrian</td>
</tr>
<tr>
<td>Lead Vehicle Stopped 50-80km/h</td>
<td></td>
</tr>
<tr>
<td><strong>INTER-URBAN</strong></td>
<td>CP3 Unobscured running farside pedestrian</td>
</tr>
<tr>
<td>Slower Lead Vehicle Target 20km/h Test 50-80km/h</td>
<td></td>
</tr>
<tr>
<td><strong>INTER-URBAN</strong></td>
<td></td>
</tr>
</tbody>
</table>
AEB GROUP – RATINGS PROPOSAL

COMPILATION OF SCORES

AEB
Avoidance

AEB
Mitigation

FCW
Avoidance

FCW
Mitigation

Score
WEIGHTING OF AEB AND FCW

Insurance study shows the real world difference in claims between an AEB system and a FCW system;

AEB 50%; FCW 50%

AEB + FCW = 14%

FCW = 7%

Therefore AEB = 7%
### CITY AND INTER-URBAN TEST SPEEDS (km/h)

<table>
<thead>
<tr>
<th>CITY</th>
<th>INTER-URBAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>-</td>
</tr>
<tr>
<td>15</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td>-</td>
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<td>70</td>
</tr>
<tr>
<td>-</td>
<td>75</td>
</tr>
<tr>
<td>-</td>
<td>80</td>
</tr>
</tbody>
</table>

- Reward for AEB only
- Reward for AEB and FCW

- Test speeds represent AEB, ASSESS, ADAC and vFSS scenarios
- CITY test represents typical whiplash injuries ($\Delta v$ 5 to 15km/h, short and long term)
- INTER-URBAN represents higher severity but lower frequency collisions (KSI)
- Overlap at 50km/h, potential double reward encourages system development
CITY – STATIONARY LOW SPEED

- Stationary target
- Test speeds 10 to 50km/h in 5km/h steps
- Reward for AEB only
- Test speeds 10, 15 and 20km/h
  - Full AEB avoidance required to earn reward in City test, mitigation only at any speed disqualifies system from earning reward in City test at all speeds
- Test speeds 25 to 50km/h
  - Assuming qualification by performance at lower speeds; full points awarded for avoidance, mitigation awarded proportionally to speed reduction
CITY – STATIONARY LOW SPEED (WHIPLASH)

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Points available</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
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<tr>
<td>30</td>
<td>2</td>
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<tr>
<td>35</td>
<td>2</td>
</tr>
<tr>
<td>40</td>
<td>1</td>
</tr>
<tr>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
</tr>
</tbody>
</table>

Weighting reflects product of injury severity and collision frequency

UK whiplash injuries

ASSESS proposal

Folksam EDR

Weighting reflects product of injury severity and collision frequency

BMW

I: only damage to car
II: slight risk to passenger
III: high risk to passenger

Whiplash injuries without system

Delta-V (km/h)
CITY – STATIONARY LOW SPEED

- Test speeds 10, 15 and 20km/h
  - Avoidance required at 10, 15 and 20km/h
    AEB collision avoidance = full points awarded
    \[ = 1^{(10)} + 2^{(15)} + 2^{(20)} \]
    \[ = 5 \]
  - Qualify for additional reward at test speeds 25 to 50km/h in CITY test

AEB collision mitigation = 0 points awarded
- Mitigation only in 10, 15 or 20km/h test disqualifies system from earning reward in CITY test

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Points available</th>
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</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
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<td>25</td>
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</tr>
<tr>
<td>45</td>
<td>1</td>
</tr>
<tr>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
</tr>
</tbody>
</table>
### CITY – STATIONARY LOW SPEED – EXAMPLE

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>AEB impact speed (km/h)</th>
<th>Points available</th>
<th>Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>2</td>
<td>2.000</td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>2</td>
<td>2.000</td>
</tr>
</tbody>
</table>

An impact speed of 0km/h indicates collision avoided

**CCR low speed stationary (City) - Example**

![Graph showing crash severity and number of crashes and injured](image)

- **Not scored**
- **AEB mitigation**
- **AEB avoidance**
• Test speeds 25 to 50km/h

AEB collision avoidance = Full point(s) awarded

AEB collision mitigation = Points awarded proportionally to speed reduction achieved
AEB GROUP – RATINGS PROPOSAL

CITY – STATIONARY LOW SPEED

- AEB collision mitigation calculation
  \[
  \text{AEB mitigation} = \text{points available} \times \frac{(\text{test speed} - \text{speed at impact})}{\text{test speed}}
  \]

- e.g. 30km/h test, if
  - \text{AEB collision avoided} = 2 \text{ points}
  - \text{AEB collision at 15km/h} = 2 \times \frac{(30 - 15)}{30} = 1 \text{ point}
  - \text{AEB collision at 10km/h} = 2 \times \frac{(30 - 10)}{30} = 1.33 \text{ points}

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Points available</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
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<tr>
<td>15</td>
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</tr>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14</strong></td>
</tr>
</tbody>
</table>

AEB Mitigation
### CITY – STATIONARY LOW SPEED – EXAMPLE

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>AEB impact speed (km/h)</th>
<th>Points available</th>
<th>Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>15</td>
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</tr>
<tr>
<td>50</td>
<td>50</td>
<td>1</td>
<td>0.000</td>
</tr>
</tbody>
</table>

An impact speed of 10km/h in the 30km/h test earns 1.333 points, as indicated chart.
AEB GROUP – RATINGS PROPOSAL

CITY – STATIONARY LOW SPEED – EXAMPLE

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>AEB impact speed (km/h)</th>
<th>Points available</th>
<th>Points scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
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</tr>
<tr>
<td>Total</td>
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<td>8.000</td>
<td></td>
</tr>
</tbody>
</table>

Result 57%

AEB avoidance at 10 to 20km/h, half AEB mitigation at 25 to 35km/h and no effect at 40 to 50km/h achieves an overall result of 57%
Stationary target
Test speeds ranging from 50 to 80km/h
Reward for AEB and FCW
Mitigation rewarded proportionally to speed reduction
Maximum points awarded for AEB maximum mitigation capacity
Full FCW avoidance required

What is ‘maximum mitigation capacity’?
AEB EXPECTATIONS – LOWER SPEEDS

- Collision avoidance by braking
- At lower speeds – braking avoidance point later than steering point

Variation in braking, acceleration, and steering:

Point of last steer to avoid impact

Point of last brake to avoid impact

Variation in Struck car movement
AEB EXPECTATIONS – HIGHER SPEEDS

- As speed builds – steering avoidance point later than braking point
- Latest time point for braking may be earlier than last time for steering response
- Therefore cannot necessarily expect full AEB avoidance at all speeds
AEB GROUP – RATINGS PROPOSAL

AEB MAXIMUM MITIGATION CAPACITY

- Real world driver studies report that drivers attempt limit collision avoidance steering manoeuvres at 1.0 to 0.8s TTC. TU Darmstadt, OEM and Tier 1 supplier trials etc.
- Base AEB maximum mitigation capacity on this principle, speed reduction achievable from this TTC position.
- Calculate speed reduction based on ideal vehicle braking response – simple and clear calculation
  - 10m/s² deceleration step input
  - Braking applied at 0.7s TTC
  - Shorter TTC than reported in studies acknowledges lag time for deceleration build up in vehicle, but ideal deceleration step input provides demanding performance criteria for future systems.
AEB GROUP – RATINGS PROPOSAL

AEB MAXIMUM MITIGATION CAPACITY

- Speed reduction = $\sqrt{\text{speed}^2 + 2 \cdot \text{deceleration} \cdot \text{speed} \cdot \text{TTC}}$
  Rounded to nearest whole km/h

- If speed reduction greater > test speed = AEB avoidance, otherwise AEB maximum mitigation capacity

![Graph showing AEB system performance](chart)
AEB GROUP – RATINGS PROPOSAL

FCW PERFORMANCE REQUIREMENTS

• Full FCW avoidance required for maximum points
• Mitigation points rewarded proportionally to speed reduction
AEB PERFORMANCE REQUIREMENTS

CITY: Stationary Low

INTER-URBAN: Braking

INTER-URBAN: Stationary High

INTER-URBAN: Moving

Test specification:
- 12m headway, 2m/s2 braking
- 12m headway, 6m/s2 braking
- 40m headway, 2m/s2 braking
- 40m headway, 6m/s2 braking

Relative speed (km/h):

AEB system performance (km/h):
FCW PERFORMANCE REQUIREMENTS

**CITY: Stationary Low**

**INTER-URBAN: Braking**

Only AEB rewarded in City test

**INTER-URBAN: Stationary High**

**INTER-URBAN: Moving**
INTER-URBAN – STATIONARY HIGH SPEED

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Points available</th>
</tr>
</thead>
<tbody>
<tr>
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<td>3</td>
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<tr>
<td>55</td>
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<tr>
<td>60</td>
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<td>80</td>
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</tr>
<tr>
<td>Total</td>
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</tbody>
</table>
## AEB GROUP – RATINGS PROPOSAL

### INTER-URBAN – STATIONARY HIGH SPEED – EXAMPLE

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Impact speed for full AEB mitigation (km/h)</th>
<th>AEB speed reduction required (km/h)</th>
<th>AEB impact speed (km/h)</th>
<th>Points available</th>
<th>AEB points</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>3</td>
<td>3.000</td>
</tr>
<tr>
<td>55</td>
<td>16</td>
<td>39</td>
<td>35.5</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>60</td>
<td>24</td>
<td>36</td>
<td>42</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>65</td>
<td>31</td>
<td>34</td>
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<tr>
<td>70</td>
<td>37</td>
<td>33</td>
<td>53.5</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>75</td>
<td>43</td>
<td>32</td>
<td>59</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>80</td>
<td>49</td>
<td>31</td>
<td>64.5</td>
<td>1</td>
<td>0.500</td>
</tr>
</tbody>
</table>

Total: 10, AEB points: 6.500

Result: 65%

AEB avoidance at 50km/h and half AEB mitigation at all other speeds

---

**AEB Avoidance & Mitigation**
## FCW Avoidance & Mitigation

### CCR stationary high speed - Example

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Impact speed for full FCW mitigation (km/h)</th>
<th>FCW speed reduction required (km/h)</th>
<th>FCW impact speed (km/h)</th>
<th>Points available</th>
<th>FCW Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>3</td>
<td>3.000</td>
</tr>
<tr>
<td>55</td>
<td>0</td>
<td>55</td>
<td>27.5</td>
<td>2</td>
<td>1.000</td>
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<tr>
<td>60</td>
<td>0</td>
<td>60</td>
<td>30</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>65</td>
<td>0</td>
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<td>0.500</td>
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<td>70</td>
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<tr>
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<tr>
<td>80</td>
<td>0</td>
<td>80</td>
<td>40</td>
<td>1</td>
<td>0.500</td>
</tr>
</tbody>
</table>

Total: 10 points | Result: 65%

FCW avoidance at 50km/h and half FCW mitigation at all other speeds
AEB GROUP – RATINGS PROPOSAL

INTER-URBAN – STATIONARY HIGH SPEED - EXAMPLE

AEB and FCW results sum together

\[
\frac{6.500}{10} + \frac{6.500}{10} = \frac{13.000}{20} = 65\% 
\]
• Moving target 20km/h
• Test speeds ranging from 50 to 80km/h
• Reward for AEB and FCW
• Mitigation rewarded proportionally to speed reduction
• Maximum points awarded for AEB maximum mitigation capacity
• Full FCW avoidance required
### INTER-URBAN – MOVING

<table>
<thead>
<tr>
<th>Test speed (km/h)</th>
<th>Points available</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>1</td>
</tr>
<tr>
<td>55</td>
<td>1</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
</tr>
<tr>
<td>65</td>
<td>2</td>
</tr>
<tr>
<td>70</td>
<td>2</td>
</tr>
<tr>
<td>75</td>
<td>2</td>
</tr>
<tr>
<td>80</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

![GIDAS data chart](image)

The GIDAS data chart shows the distribution of test speeds and available points across different test scenarios. The chart indicates that the highest number of points is available at test speeds of 60 km/h and above.
AEB GROUP – RATINGS PROPOSAL

INTER-URBAN – MOVING – EXAMPLE

AEB Avoidance & Mitigation

<table>
<thead>
<tr>
<th>Target speed (km/h)</th>
<th>Test speed (km/h)</th>
<th>Impact speed for full AEB avoidance (km/h)</th>
<th>AEB speed reduction required (km/h)</th>
<th>Relative speed for full AEB avoidance (km/h)</th>
<th>AEB Avoid / Impact</th>
<th>AEB impact speed (km/h)</th>
<th>Points available</th>
<th>AEB points</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>50</td>
<td>20</td>
<td>30</td>
<td>0</td>
<td>Avoid</td>
<td>20</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>55</td>
<td>20</td>
<td>35</td>
<td>0</td>
<td>Avoid</td>
<td>20</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
<td>20</td>
<td>40</td>
<td>0</td>
<td>Impact</td>
<td>40</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>20</td>
<td>65</td>
<td>20</td>
<td>45</td>
<td>0</td>
<td>Impact</td>
<td>42.5</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
<td>20</td>
<td>50</td>
<td>0</td>
<td>Impact</td>
<td>45</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>75</td>
<td>36</td>
<td>59</td>
<td>16</td>
<td>Impact</td>
<td>55.5</td>
<td>2</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>80</td>
<td>44</td>
<td>36</td>
<td>24</td>
<td>Impact</td>
<td>62</td>
<td>2</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Total 11 6.500

Result 59%

AEB avoidance at 50 and 55km/h, and half AEB mitigation at all other speeds

AEB Avoid / Impact
FCW Avoidance & Mitigation

### FCW Avoidance at 50 to 65km/h, and FCW Mitigation at all other speeds

<table>
<thead>
<tr>
<th>Target speed (km/h)</th>
<th>Test speed (km/h)</th>
<th>Impact speed for full FCW avoidance (km/h)</th>
<th>FCW speed reduction required (km/h)</th>
<th>Relative speed for full FCW avoidance (km/h)</th>
<th>FCW Avoid / Impact</th>
<th>FCW impact speed (km/h)</th>
<th>Points available</th>
<th>FCW points</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>50</td>
<td>20</td>
<td>30</td>
<td>0</td>
<td>Avoid</td>
<td>20</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>55</td>
<td>20</td>
<td>35</td>
<td>0</td>
<td>Avoid</td>
<td>20</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
<td>20</td>
<td>40</td>
<td>0</td>
<td>Avoid</td>
<td>20</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>65</td>
<td>20</td>
<td>45</td>
<td>0</td>
<td>Avoid</td>
<td>20</td>
<td>2</td>
<td>2.000</td>
</tr>
<tr>
<td>20</td>
<td>70</td>
<td>20</td>
<td>50</td>
<td>0</td>
<td>Impact</td>
<td>40</td>
<td>2</td>
<td>1.200</td>
</tr>
<tr>
<td>20</td>
<td>75</td>
<td>20</td>
<td>55</td>
<td>0</td>
<td>Impact</td>
<td>42</td>
<td>2</td>
<td>1.200</td>
</tr>
<tr>
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<td>80</td>
<td>20</td>
<td>60</td>
<td>0</td>
<td>Impact</td>
<td>44</td>
<td>2</td>
<td>1.200</td>
</tr>
</tbody>
</table>

Total 11 8.600

Result 78%
AEB GROUP – RATINGS PROPOSAL

INTER-URBAN – MOVING – EXAMPLE

AEB and FCW results sum together

\[
\begin{align*}
6.500 & \quad 11 \\
8.600 & \quad 11 \\
\hline
15.100 & \quad 22 \\
\end{align*}
\]

=69%
Test target and test vehicle initially driving at 50km/h
12m and 40m headways, target deceleration 2 and 6m/s²
Reward for AEB and FCW
Mitigation rewarded proportionally to speed reduction
### INTER-URBAN – BRAKING

<table>
<thead>
<tr>
<th>Test Scenario</th>
<th>Points Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>12m 6m/s²</td>
<td>1</td>
</tr>
<tr>
<td>12m 2m/s²</td>
<td>1</td>
</tr>
<tr>
<td>40m 6m/s²</td>
<td>1</td>
</tr>
<tr>
<td>40m 2m/s²</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>

**GIDAS data**

[Graph showing braking distance & deceleration rate]
AEB GROUP – RATINGS PROPOSAL

INTER-URBAN – BRAKING

• Test speeds 50km/h for both vehicles
  – Avoidance required to gain full AEB collision avoidance point

AEB collision mitigation points are awarded proportionally to the relative speed reduction achieved.

AEB mitigation = points available * \(\frac{\text{test speed} - \text{test vehicle speed at impact}}{\text{test speed} - \text{target speed at impact}}\)
## AEB GROUP – RATINGS PROPOSAL

### INTER-URBAN – BRAKING – EXAMPLE

<table>
<thead>
<tr>
<th>Test Scenario</th>
<th>Target speed (km/h)</th>
<th>Test speed (km/h)</th>
<th>Impact speed for full AEB avoidance (km/h)</th>
<th>AEB speed reduction required (km/h)</th>
<th>AEB impact speed (km/h)</th>
<th>Points available</th>
<th>AEB points</th>
</tr>
</thead>
<tbody>
<tr>
<td>12m 6m/s²</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>12m 2m/s²</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>20</td>
<td>1</td>
<td>0.600</td>
</tr>
<tr>
<td>40m 6m/s²</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>25</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>40m 2m/s²</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>24</td>
<td>1</td>
<td>0.520</td>
</tr>
</tbody>
</table>

**Total** 4 2.620

**Result 66%**

AEB avoidance in 12m 6m/s² scenario, AEB mitigation in others
AEB GROUP – RATINGS PROPOSAL

INTER-URBAN – BRAKING – EXAMPLE

<table>
<thead>
<tr>
<th>Test Scenario</th>
<th>Target speed (km/h)</th>
<th>Test speed (km/h)</th>
<th>Impact speed for full FCW avoidance (km/h)</th>
<th>FCW speed reduction required (km/h)</th>
<th>FCW impact speed (km/h)</th>
<th>Points available</th>
<th>FCW points</th>
</tr>
</thead>
<tbody>
<tr>
<td>12m 6ms-2</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>1</td>
<td>1.000</td>
</tr>
<tr>
<td>12m 2ms-2</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>10</td>
<td>1</td>
<td>0.800</td>
</tr>
<tr>
<td>40m 6ms-2</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>20</td>
<td>1</td>
<td>0.600</td>
</tr>
<tr>
<td>40m 2ms-2</td>
<td>50</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>17.5</td>
<td>1</td>
<td>0.650</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>4</strong></td>
<td><strong>2.050</strong></td>
</tr>
</tbody>
</table>

Result: 51%

FCW avoidance in 12m 6m/s² scenario, FCW mitigation in others

AEB Avoidance & Mitigation
AEB and FCW results sum together

\[
\begin{align*}
2.620 & \quad \text{(4 points)} \\
2.050 & \quad \text{(4 points)} \\
\hline
4.670 \quad \text{=58%}
\end{align*}
\]
Mean overall Inter-Urban result = 64%
(Scenarios unweighted)
<table>
<thead>
<tr>
<th>AEB PROCEDURES: PROPOSED ALLOCATION OF POINTS</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Adult Occupant Protection</th>
<th>Child Occupant Protection</th>
<th>Pedestrian Protection</th>
<th>Safety Assist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front, side, pole Whiplash</td>
<td>Front, side</td>
<td>Lower &amp; upper leg</td>
<td>ESC, SLD, SBR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Adult &amp; child head</td>
<td></td>
</tr>
</tbody>
</table>

**CITY**
- Lead Vehicle Stopped

**PEDESTRIAN**
- Unobscured nearside walking
- Obscured nearside walking
- Unobscured farside running

**INTER-URBAN**
- Lead Vehicle Stopped
- Slower Lead Vehicle
- Lead Vehicle Decelerating

**EURO NCAP: AEB RATINGS**
- CITY PEDESTRIAN INTER-URBAN
  - Lead Vehicle Stopped
  - Slower Lead Vehicle
  - Lead Vehicle Decelerating
**EURO NCAP & AEB**

**ANNIVERSARY AND AEB EVENT**

13th June 2012: fitment survey and demos

---

<table>
<thead>
<tr>
<th>Model</th>
<th>System Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercedes-Benz A-Class (2012 - )</td>
<td>Collision Prevention Assist</td>
</tr>
<tr>
<td>Mercedes-Benz B-Class</td>
<td>Collision Prevention Assist</td>
</tr>
<tr>
<td>Mercedes-Benz CLS-Class</td>
<td>Collision Prevention Assist</td>
</tr>
<tr>
<td>Mercedes-Benz GL-Class (Q3 2012 - )</td>
<td>Collision Prevention Assist</td>
</tr>
<tr>
<td>Mercedes-Benz M-Class</td>
<td>Collision Prevention Assist</td>
</tr>
<tr>
<td>Volvo S80</td>
<td>City Safety</td>
</tr>
<tr>
<td>Volvo V40</td>
<td>City Safety</td>
</tr>
<tr>
<td>Volvo V60</td>
<td>City Safety</td>
</tr>
<tr>
<td>Volvo V70</td>
<td>City Safety</td>
</tr>
<tr>
<td>Volvo XC60</td>
<td>City Safety</td>
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<tr>
<td>Volvo XC90</td>
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<tr>
<td>Mazda 6</td>
<td>SmartCity Braking System</td>
</tr>
<tr>
<td>Lexus GS</td>
<td>Advanced Pre-Crash System</td>
</tr>
<tr>
<td>Audi A4 (2012 - )</td>
<td>Pre Sense Front</td>
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<tr>
<td>Audi A5</td>
<td>Pre Sense Front Plus</td>
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<td>Audi A7</td>
<td>Pre Sense Front Plus</td>
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<tr>
<td>Audi Q7</td>
<td>Braiding Guard</td>
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<tr>
<td>Jaguar XE</td>
<td>Advanced Emergency Braking Assist</td>
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<tr>
<td>Jaguar XF</td>
<td>Intelligent Emergency Braking</td>
</tr>
<tr>
<td>Mercedes-Benz A-Class (2012 - )</td>
<td>DISTRONIC PLUS</td>
</tr>
<tr>
<td>Mercedes-Benz B-Class</td>
<td>DISTRONIC PLUS</td>
</tr>
<tr>
<td>Mercedes-Benz CLS-Class</td>
<td>DISTRONIC PLUS (inc. Pre-SAFE Brake)</td>
</tr>
<tr>
<td>Mercedes-Benz GL-Class (2012 - )</td>
<td>DISTRONIC PLUS</td>
</tr>
<tr>
<td>Mercedes-Benz GL-Class (mid 2012 - )</td>
<td>DISTRONIC PLUS (inc. Pre-SAFE Brake)</td>
</tr>
<tr>
<td>Mercedes-Benz GLA-Class (2012 - )</td>
<td>DISTRONIC PLUS (inc. Pre-SAFE Brake)</td>
</tr>
<tr>
<td>Mercedes-Benz S-Class</td>
<td>DISTRONIC PLUS (inc. Pre-SAFE Brake)</td>
</tr>
<tr>
<td>Mercedes-Benz CLS-Class</td>
<td>DISTRONIC PLUS (inc. Pre-SAFE Brake)</td>
</tr>
<tr>
<td>Mercedes-Benz S-Class</td>
<td>DISTRONIC PLUS (inc. Pre-SAFE Brake)</td>
</tr>
<tr>
<td>Range Rover Sport</td>
<td>Advanced Emergency Braking Assist</td>
</tr>
<tr>
<td>Range Rover Sport</td>
<td>Advanced Emergency Braking Assist</td>
</tr>
<tr>
<td>Seat Alhambra</td>
<td>Brake Assistant Town</td>
</tr>
<tr>
<td>Skoda Octavia</td>
<td>City Safety Drive</td>
</tr>
<tr>
<td>Volvo S80</td>
<td>Collision Warning with Full Autobrake &amp; Pedestrian Detection</td>
</tr>
<tr>
<td>Volvo V40</td>
<td>Collision Warning with Full Autobrake &amp; Pedestrian Detection</td>
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<td>Volvo V60</td>
<td>Collision Warning with Full Autobrake &amp; Pedestrian Detection</td>
</tr>
<tr>
<td>Volvo V70</td>
<td>Collision Warning with Full Autobrake &amp; Pedestrian Detection</td>
</tr>
<tr>
<td>Volvo XC60</td>
<td>Collision Warning with Full Autobrake &amp; Pedestrian Detection</td>
</tr>
<tr>
<td>Volvo XC70</td>
<td>Collision Warning with Full Autobrake &amp; Pedestrian Detection</td>
</tr>
<tr>
<td>Audi Q5</td>
<td>Pre Sense Front</td>
</tr>
<tr>
<td>Audi A4</td>
<td>Pre Sense Front</td>
</tr>
<tr>
<td>Audi Q7</td>
<td>Pre Sense Front Plus</td>
</tr>
<tr>
<td>Audi Q8</td>
<td>Pre Sense Front Plus</td>
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<td>BMW 7 Series</td>
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<td>BMW 8 Series</td>
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<td>DISTRONIC PLUS</td>
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<tr>
<td>Ford Kuga</td>
<td>Active City Stop</td>
</tr>
<tr>
<td>Ford Kuga (2011 - )</td>
<td>Active City Stop</td>
</tr>
<tr>
<td>Ford Mondeo</td>
<td>Pre-Crash System</td>
</tr>
<tr>
<td>Ford Mondeo</td>
<td>Pre-Crash System</td>
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<tr>
<td>Ford Mondeo</td>
<td>Pre-Crash System</td>
</tr>
<tr>
<td>Ford Mondeo</td>
<td>Pre-Crash System</td>
</tr>
<tr>
<td>Honda Civic (2012 - )</td>
<td>Collision Mitigation Braking System</td>
</tr>
<tr>
<td>Honda Civic (2012 - )</td>
<td>Collision Mitigation Braking System</td>
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<td>Honda Civic (2012 - )</td>
<td>Collision Mitigation Braking System</td>
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<tr>
<td>Honda Civic (2012 - )</td>
<td>Collision Mitigation Braking System</td>
</tr>
<tr>
<td>Honda Civic (2012 - )</td>
<td>Collision Mitigation Braking System</td>
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<tr>
<td>Honda Civic (2012 - )</td>
<td>Collision Mitigation Braking System</td>
</tr>
<tr>
<td>Toyota Aygo</td>
<td>Pre-Crash System</td>
</tr>
</tbody>
</table>

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Euro NCAP has decided to include AEB assessments as part of the overall star rating from 2014.
**PROPOSED RATING SCHEME**

**PROPOSAL FOR INSURANCE GROUP RATING**

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**Car-to-Car Rear (CCR)**

**CITY**
Lead Vehicle Stopped
<50km/h (from CCR1)

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- UK insurance group rating intends to recognise AEB during 2012

- RCAR P-Safe group is developing test procedures to support insurance group rating

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Research Council for Automobile Repairs
CONCLUSION

- New **ADAS** systems coming on to vehicles offer potential reduction in crashes and injuries
- Real world data shows current generation **AEB systems are reducing crashes**
- **AEB** tests under development relevant to real world crash scenarios; designed to measure system performance
- Initial test results show performance range of current generation systems
- Test procedures have been proposed to **Euro NCAP** as the basis of new test procedures to be introduced by 2014 to address car to car rear; 2016 for addressing pedestrian injuries
- UK insurance **group rating** intends to recognise AEB during 2012; using the CITY test (low speed car to car); relevant to whiplash injuries

www.thatcham.org/AEB