Test report

Comparative test of advanced emergency braking systems

Products tested: Audi A7, BMW 5-series, Infiniti M, Mercedes CLS, Volvo V60, VW Passat

Test criteria: Collision warning, autonomous brake assist, autonomous brake strategy, false alarm
1 Summary of results

1.1 Key story

*Any of the advanced emergency braking systems (AEBS) tested are capable of significantly reducing the severity of rear-end collisions.* This is the bottom line of the complex comparative test of AEBS conducted by ADAC. Already today, these systems are a great safety plus. Since rear-end collisions qualify as a type of the most severe road accidents, in addition to ESC (electronic stability control), AEBS are among the most important active driver assistance systems.

The Volvo V60 is the winner of our test and the only car to achieve a very good rating. Reducing impact energy drastically before the collision, the Volvo's system mitigates the severity of the accident. City Safety prevents collisions altogether in urban traffic if vehicle speed is low.

The Volvo is followed by the Mercedes CLS and the Audi A7. When approaching a moving object, the systems in both vehicles automatically reduce speed significantly. Although the Mercedes also brakes if the object is stationary, it fails to prevent a collision. While the Audi does not brake automatically if the object is stationary, it wins our test in terms of alert cascade. Both manufacturers have announced to upgrade their AEBS so that they brake the car to avoid collisions with a stationary object.

While the VW Passat does not show any major weaknesses, it is outperformed by e.g. the Mercedes or Audi in terms of impact speed reduction. Up to speeds of 30kph, the Passat’s system automatically applies the brakes to successfully prevent the car from colliding with a stationary object.

Like the Infiniti M, which comes in last in our test, the BMW 5-series achieves a satisfactory rating. In both vehicles, speed reduction during the autonomous braking is only marginal. In addition, the Infiniti’s collision warning is ineffective. The Japanese car comes with an innovative accelerator pedal which pushes back against the driver’s foot if the distance to the car in front is inadequate. Lacking fine-tuning, however, this innovation may irritate drivers.

A useful additional functionality of AEBS is the autonomous brake assist which effectively applies the adequate amount of brake pressure if the driver steps onto the brake pedal too lightly to avoid a collision. The BMW and Infiniti are the only cars of the vehicles tested which comes without this functionality.

**Bottom line:** Even if most motorists regard themselves as good drivers who do not need such a system, AEBS is a useful technology not only for inexperienced motorists. Any driver has already experienced moments of distraction when e.g. operating the radio, calming down children or being exposed to other external influences. If their cars come with AEBS, drivers should always bear in mind that the systems can never replace an attentive driver. Motorists keeping a safe distance at all times and driving defensively considerably enhance road safety. The systems are, however, a safety asset in emergency situations, preventing serious accidents or mitigating their consequences.
1.2 Summarised table of results

<table>
<thead>
<tr>
<th>Manufacturer/type</th>
<th>ADAC verdict</th>
<th>Overall rating</th>
<th>B1: approaching a slow-moving object</th>
<th>B2: approaching an object decelerating constantly</th>
<th>B3: approaching an object which has come to a halt</th>
<th>B4: approaching a stationary object</th>
<th>Alert cascade</th>
<th>Plus points: autonomous brake assist</th>
<th>Plus points: distance warning</th>
<th>Minus points: fail operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volvo V60 D5 AWD Geartronic</td>
<td>++</td>
<td>1,5</td>
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<td>VW Passat Variant 2.0 TFSI DSG</td>
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1.3 Test objectives, product selection, test scope

With the development of passive safety features, vehicle safety has increased steadily over the past decades. The introduction of the safety belt and airbag was a milestone in passive vehicle safety. In addition to the systems which mitigate the consequences of an accident, active systems for the prevention of accidents and the mitigation of their consequences have become increasingly important.

With the launch of ABS, the first driver assistance system was successfully introduced some 30 years ago. The mandatory introduction of ESC from 2012 is another milestone in driver safety. While ESC is a highly effective technology to prevent cars from skidding or running off the road or to mitigate the consequences of an accident, it is more or less ineffective in accidents which occur in the same and opposite direction of traffic.

Rear-end collisions are the most frequent same and opposite-direction crashes. The causes are momentary inattention, inadequate speed or inadequate distance. While most rear-end collisions in urban traffic only result in vehicle damage or slight injuries, rear-end collisions outside built-up areas or motorways usually cause fatal or serious injuries.
To mitigate the consequences of rear-end collisions or ideally to prevent collisions altogether, some manufacturers equip their vehicles with advanced emergency braking systems (AEBS). Using radar sensors, cameras and/or laser, these systems recognise vehicles in front and alert the driver if a collision is imminent. If the driver does not react to the warning and the collision cannot be avoided (e.g. by swerving), the system automatically brakes the car to reduce impact speed (electronic crumple zone) or prevent the crash altogether. AEBS help to significantly lower the number of road deaths and seriously injured accident victims.

The ADAC AEBS test assessed the AEBS capability to reduce impact speed as well as when and how effectively the driver is alerted to an imminent collision in six current family and executive car models. Preventing a collision because of timely warning is always better than an autonomous emergency braking with unforeseeable consequences. Another important factor for enhanced driver safety is system reliability. Most drivers will not accept false alarms even if they are no injury risk. Unlike accidental emergency braking, which may be fatal. In view of this our test also assessed the probability of false alarms or unnecessary emergency braking.

Mercedes was the first manufacturer to fit its cars (S-Class) with AEBS (Pre-Safe) in 2005. Initially, Pre-Safe used to be a very expensive option for luxury cars.

While AEBS is still only optionally available, it has meanwhile been introduced into smaller vehicle classes such as executive and a few family cars.

1.4 Products of exceptionally high or low quality

The Volvo V60 wins our comparative test by a narrow margin. Its great forte is its high potential to prevent crashes into stationary obstacles. Up to speeds of 40kph, the V60’s AEBS completely prevents the car from crashing into a stationary object. Performance is good also at higher speeds. The system sets off the alarm early and automatically brakes the car to reduce impact speed if the driver fails to react to the warning.

Reducing a greater amount of speed and lowering injury severity drastically in our high-speed dynamic tests, the Mercedes CLS and the Audi A7 outperform the Volvo V60 in terms of response. However, the Mercedes and the Audi do not win the test since neither is able to completely prevent a collision and come to a stop in front of stationary objects like the Volvo. Both manufacturers have already announced the launch of an enhanced AEBS which stops the car in front of stationary obstacles in the course of the year.

For the VW Passat to be able to stop in front of stationary obstacles, speeds must be very low. Although the Passat reliably prevents collisions with stationary objects at low
speeds, performance in our test was not too impressive since (at high speeds) it sets off the alarm too late or not at all.

The AEBS in the BMW 5-series is not on a par with its competition. While the driver is warned very early, the initial alarm is too easy to ignore. If the driver fails to react to the warning, the BMW initiates partial braking, which does not reduce speed as effectively as the rival systems. If the obstacle is stationary, the BMW does not brake at all.

Far behind its competitors, the Infiniti comes in last. The reasons for the negative overall result are ineffective collision warning, inadequate speed reduction through autonomous emergency braking and the lack of an autonomous brake assist. A plus is the innovative accelerator pedal which pushes back against the driver’s foot if the distance to the car in front is inadequate. Since the system still lacks fine-tuning, it is not yet well-accepted among motorists.

While the overall results vary greatly, all of the AEBS tested are a safety plus. Even if they lower impact speed only minimally, any kph less can help save lives in an emergency.
# Overall result

<table>
<thead>
<tr>
<th>Manufacturer/type</th>
<th>ADAC verdict</th>
<th>Overall rating</th>
<th>B1: approaching a slow-moving object</th>
<th>B2: approaching an object decelerating constantly</th>
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<th>Alert cascade</th>
<th>Plus points: autonomous brake assist</th>
<th>Plus points: distance warning</th>
<th>Minus points: fail operation</th>
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<tbody>
<tr>
<td>Volvo V60 D5 AWD Geartronic</td>
<td>++</td>
<td>20%</td>
<td>1 2</td>
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<tr>
<td>Mercedes CLS 350 CGI</td>
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<td>20%</td>
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<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>2 2 2 1</td>
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<tr>
<td>Audi A7 3.0 TFSI</td>
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<td>2 2 2 1</td>
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<tr>
<td>VW Passat Variant 2.0 TFSI DSG</td>
<td>+</td>
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<td>1 2</td>
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<tr>
<td>BMW 530d Automatic</td>
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<tr>
<td>Infiniti M37S Premium</td>
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<td>1 2</td>
<td>20%</td>
<td>20%</td>
<td>20%</td>
<td>2 2 2 1</td>
<td>20%</td>
<td></td>
<td></td>
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</table>

* assessment only includes collision warning

## Rating scale:

| ++  | very good | 0.6 – 1.5 |
| +   | good      | 1.6 – 2.5  |
| O   | satisfactory | 2.6 – 3.5 |
| Θ   | acceptable | 3.6 – 4.5  |
| –   | poor       | 4.6 – 5.5  |
3 Product evaluation

<table>
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<tr>
<th>Volvo V60 D5 AWD Geartronic SUMMUM</th>
<th>ADAC verdict: very good</th>
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<td><strong>Base price test vehicle:</strong></td>
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<tr>
<td><strong>Total price AEBS:</strong></td>
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<td>ACC incl. Full Auto Brake:</td>
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<tr>
<td>City Safety:</td>
<td>standard</td>
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<td><strong>Available for:</strong></td>
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<tr>
<td>any engine version and grade (manual + automatic gearbox)</td>
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<tr>
<td><strong>Available models:</strong></td>
<td>S60, XC60, S70, V70, V80</td>
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</table>

**Bottom line:**

The Volvo V60 comes with an excellent City Safety system which completely prevents collisions with stationary vehicles up to speeds of 40kph. System performance at higher speeds and when the object ahead is moving is not yet on a par with that of outstanding rival systems which reduce speed more effectively.

The alert cascade is effective: a set of LEDs resembling the brake lights of a vehicle in front is projected onto the windscreen and a clearly audible acoustic signal alerts the driver. A haptic warning would make the alarm even more effective (e.g. little jerk or partial braking).

The autonomous brake assist is very effective. If a collision is imminent and the driver steps onto the brakes too lightly, the Volvo effectively optimises braking pressure to prevent the collision.

The visible yet unobtrusive warning projected onto the windscreen to alert the driver to inadequate safety distance (less eye-catching than the collision warning) is a useful extra since it reminds the driver to keep a safe distance even before a critical situation occurs.

- Prevention of collisions with stationary objects up to speeds of 40kph
- Effective collision warning
- Effective autonomous brake assist
- Inadequate-distance warning

- Sometimes too early collision warning (fail operation)
Comparative test of advanced emergency braking systems

**Mercedes CLS 350 BlueEfficiency**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Price</th>
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<tbody>
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<tr>
<td>Audio 50 APS:</td>
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</table>

**Available for:**
any engine version (automatic gearbox standard in any version)

**Available models:**
E-Class, S-Class

**Bottom line:**
The Mercedes Pre-Safe system was designed to mitigate the consequences of accidents where differential speed is high. In such accidents, system performance is excellent and speed reduction is enormous. While Pre-Safe also kicks in to reduce impact speed if the object is stationary, it is unable to completely prevent collisions. An advanced Pre-Safe system which completely prevents collisions with stationary objects up to a velocity from 30 kp/h will be available from mid 2011.

The alert cascade is good but could still be improved. The visual alert is too unobtrusive. The system should project a visual signal onto the windscreen. Early and slight partial braking gives the driver time to react. If he ignores the warning, the system decelerates more strongly before initiating autonomous full braking shortly before the crash.

The autonomous brake assist is very effective. If a collision is imminent and the driver steps onto the brakes too lightly, the Mercedes effectively optimises braking pressure to prevent the collision.

The unobtrusive inadequate-distance warning, a lamp in the instrument cluster that also warns the driver of an imminent collision, is a useful extra since it reminds the driver to keep a safe distance even before a critical situation occurs.

- ✓ Drastic speed reduction if the object is moving
- ✓ Initiates braking if the object is stationary
- ✓ Highly effective autonomous braking
- ✓ Effective autonomous brake assist
- ✓ Inadequate-distance warning

- ✓ Barely noticeable visual collision warning
- ✓ No fully autonomous collision prevention

ADAC Vehicle Testing
Audi A7 3.0 TFSI quattro  

**ADAC verdict:** good

**Base price test vehicle:** €48,900  
**Total price AEBS:** €4,120  
ACC incl. pre-sense: €1,460  
Side assist: €500  
Park assist plus: €780  
Head-up display (no must-have): €1,380  

**Available for:**  
any engine version (automatic gearbox standard in any version)

**Available models:**  
A6, A8

**Bottom line:**

If differential speed is high, performance of the Audi pre-sense is top with the autonomous braking causing a tremendous decrease in impact energy. Unfortunately, the system does not yet initiate autonomous braking if obstacles are stationary. This is the reason why the Audi did not win our test. According to the manufacturer, an enhanced system is under way.

The Audi system comes with the most effective warning consisting of a highly visible signal on the instrument cluster and optional head-up display and a buzzer. If the driver fails to react, the system makes the car jerk a little to alert the driver before initiating multi-stage partial braking. If the crash cannot be averted, the car automatically applies full braking power. Unfortunately, the first alert is set off somewhat late.

The autonomous brake assist is very effective. If a collision is imminent and the driver steps onto the brakes too lightly, the Audi effectively optimises braking pressure to prevent the collision.

- ✓ Considerable speed reduction if the object is moving  
- ✓ Highly effective warning and autonomous braking  
- ✓ Effective autonomous brake assist  
- ✓ No braking if the object is stationary  
- ✓ Rather late collision warning
**VW Passat Variant 2.0 TFSI DSG Highline**

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<tr>
<td><strong>ACC incl. Front Assist:</strong></td>
<td>€1,195</td>
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</tbody>
</table>

**Available for:**
any engine version and grade (excl. 90kW TSI and 77kW TDI) (manual + automatic gearbox)

**Available models:**
Passat, Passat CC

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**Bottom line:**
The VW Passat achieves a good overall rating although performance of the Front Assist is less than impressive. While the system fully prevents the car from colliding into stationary objects up to speeds of 30kph, it is of no use at higher speeds. If objects are moving, the Front Assist automatically initiates partial braking while increasing brake pressure steadily. Since the Passat has no autonomous full braking function, it reduces speed less effectively than its rivals.

The alert cascade is similar to that of the Audi A7. The first phase includes a highly visible visual warning (no head-up display) and a useful acoustic signal. If the driver ignores them, the Front Assist makes the car jerk before initiating partial braking.

The autonomous brake assist is very effective. If a collision is imminent and the driver steps onto the brakes too lightly, the VW effectively optimises braking pressure to prevent the collision.

- ✓ Collision prevention up to speeds of 30kph
- ✓ Effective warning and autonomous braking
- ✓ Effective autonomous brake assist
- ! No stationary object warning/braking beyond 30kph
- ! Marginal speed reduction at high differential speeds
BMW 530d Automatic

**Base price test vehicle:** €40,350

**Total price AEBS:** €5,140

ACC incl. Adaptive Brake Assistant: €1,550

Automatic transmission: €2,200

Head-up display (no must-have): €1,390

**Available for:**
any engine version and grade (only in combination with automatic transmission)

**Available models:** 5-series Touring, 5-series GT, 7-series

**ADAC verdict:** **satisfactory**

**Bottom line:**

BMW lags behind its competitors. While the 530d is able to initiate autonomous braking, it applies too little braking pressure to significantly reduce impact speed. In addition, autonomous braking is limited to approx. 1.5sec unless the driver steps onto the brake pedal within this period. Speed reduction is relatively minimal. Maximum reduction is 13kph. If the object is stationary, the BMW does not automatically apply full braking pressure.

Collision warning is half-hearted. Our impression is that BMW really wishes to warn drivers but is afraid of causing damage to its sporty image by patronising them. While the system produces an advance warning, a visual signal in the instrument cluster and on the optional head-up-display, very early, the warning tone comes on only when autonomous partial braking is initiated.

The BMW does not come with an autonomous brake assist. If a collision is imminent, the car slightly aligns the brake shoes and improves braking response by priming the brakes. If, however, the driver applies inadequate brake pressure, it does not automatically adjust brake force to prevent the crash.

✔️ Early collision warning

❗️ Rather ineffective collision warning

❗️ Rather small speed reduction through autonomous braking

❗️ Limited autonomous partial braking

❗️ No braking if the object is stationary

❗️ No autonomous brake assist
### Infiniti M37S Premium

<table>
<thead>
<tr>
<th>ADAC verdict: satisfactory</th>
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</thead>
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<tr>
<td><strong>Base price test vehicle:</strong></td>
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<tr>
<td><strong>Total price AEBS:</strong></td>
</tr>
<tr>
<td>ACC incl. Intelligent Brake Assist:</td>
</tr>
</tbody>
</table>

**Available for:**
any engine versions of Premium models (automatic transmission standard in any model)

**Available models:**
EX, FX (both without DCA)

### Bottom line:
The Infiniti M37S brings up the rear in our test. Its IBA (Intelligent Brake Assist) is not yet as effective as rival systems. Partial braking where maximum brake force is 50% is initiated very late. The Infiniti brakes if objects are moving or stationary, but IBA fails to achieve a significant reduction in impact speed. The systems of most other cars tested are definitely more effective.

The FCW (Forward Collision Warning) still needs improving. While the alert is set off at the right time, it is much too unobtrusive to be reliably noticed by the driver.

The Infiniti’s special feature is its active accelerator (DCA, Distance Control Assist) which can be activated in addition to FCW and IBA. If the distance to the car in front is inadequate, the accelerator pedal strongly pushes back against the driver’s foot so that the driver steps off the gas. When he lifts the foot off the pedal, the car automatically slows down by a maximum of 2.5m/s² (similar to ACC) until following distance is safe. This system is an innovative complement to FCW and IBA. Since it lacks fine-tuning, sporty drivers (Infiniti’s target group) are, however, likely to reject this excessively patronising innovation.

The Infiniti does not come with an autonomous brake assist. If a collision is imminent, the car slightly aligns the brake shoes and improves braking response by priming the brakes. If, however, the driver applies inadequate brake pressure, it does not automatically adjust brake force to prevent the crash.

- ✔ Innovative yet poorly conceived active accelerator
- ⚠ Inadequate collision warning
- ⚠ Small speed reduction through autonomous braking
- ⚠ No autonomous brake assist
4 Detailed results

4.1 Approaching a slow-moving object

<table>
<thead>
<tr>
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<tr>
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<td>1.2 – 0.5</td>
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<td>1.9 – 1.4</td>
<td>1.3 – 0.7</td>
<td>0.6 – 0.1</td>
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</table>

If the object is moving slowly, AEBS are effective. Both the Volvo V60 and the VW Passat automatically apply the appropriate brake pressure to decelerate from 50kph to avoid colliding with a vehicle going at 20kph. The Audi A7 and the Mercedes CLS are able to lower impact speed strongly and minimise the occupants’ injury risk (impact speed Audi: 13kph; Mercedes: 7kph). They are, however, unable to prevent vehicle damage. In the BMW 5-series and the Infiniti, impact speed is considerably higher. If impact speed is approx. 20kph, occupants may sustain slight injuries. Except for the Audi A7, all of the vehicles tested alert the driver to collisions on time.

In our test where a vehicle doing 100kph approaches a car going at 60kph, the wheat is separated from the chaff. The Audi A7 is the only car to perform excellently, reducing speed by 32kph. With a speed reduction ranging between 19kph and 22kph, perform-
ance of the Mercedes, VW and Volvo is just about good. The BMW and the Infiniti bring up the rear also in this test. At an impact speed of approx. 30kph, the occupants may be injured. At least, all systems set off the collision warning early enough, giving the driver sufficient time to react.

### 4.2 Approaching an object decelerating constantly

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<td>60</td>
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<td>5.1 – 2.6</td>
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<td>2.0 – 1.4</td>
<td>1.3 – 0.1</td>
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<table>
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<td>Volvo V60 D5 AWD Geartronic</td>
<td>2.2</td>
<td>3.9</td>
<td>1.0</td>
<td>17.0</td>
<td>3.5</td>
</tr>
<tr>
<td>VW Passat Variant 2.0 TFSI DSG</td>
<td>2.4</td>
<td>3.1</td>
<td>1.0</td>
<td>15.0</td>
<td>3.7</td>
</tr>
</tbody>
</table>

In this test scenario, the warning time is ideal in all vehicles tested while autonomous braking and thus impact speed reduction vary greatly.

If the vehicle in front brakes suddenly, the Audi A7 reduces speed by an exemplary 36kph. Lowering speed by 28kph, the Mercedes CLS performs well. Braking is less effective in the Volvo V60 and the VW Passat (speed reduction of 17kph and 15kph respectively). The BMW and the Infiniti bring up the rear also in this test. A speed reduction of a meagre 11kph in the Infiniti will mitigate the consequences of an accident only marginally. Nevertheless, in an accident, every kph less may massively lower the severity of the injuries the occupants sustain (including those of the vehicle in front).
4.3 Approaching an object which has come to a halt

In this scenario, the vehicle in front suddenly brakes to a standstill at quite a distance. This is a common accident cause at the tail end of a traffic jam. An early warning may prevent serious accidents. As in the other tests, the Audi warns the diver somewhat late yet still on time. In terms of impact speed reduction, it is a great performer, reducing speed from 50kph to a less dangerous 21kph. Autonomous braking is equally good in the Mercedes which lowers impact speed by 25kph.

The Volvo and VW reduce speed by no less than 17kph and 15kph respectively. Speed reduction is approx. 13kph in both the BMW and the Infiniti. Since impact speed is still far beyond 30kph, occupants may be injured in a crash.
### 4.4 Approaching a stationary object

<table>
<thead>
<tr>
<th></th>
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<td>250</td>
<td>0</td>
<td>3.3 – 1.7</td>
<td>1.6 – 1.1</td>
<td>1.0 – 0.4</td>
<td>0.3 – 0.1</td>
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<td>1.8 – 1.3</td>
<td>1.2 – 0.6</td>
<td>0.5 – 0.1</td>
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<td>B4_3</td>
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<td>1.9 – 1.4</td>
<td>1.3 – 0.7</td>
<td>0.6 – 0.1</td>
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<td>2.4 – 1.9</td>
<td>1.8 – 1.2</td>
<td>1.1 – 0.1</td>
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<tr>
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<th>Overall rating</th>
<th>Warning time TTC [sec]</th>
<th>Warning rating</th>
<th>Deceleration [kph]</th>
<th>Deceleration rating</th>
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<td>1.0</td>
<td>0.0</td>
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<tr>
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<td>5.5</td>
<td>0.0</td>
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<tr>
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<td>8.0</td>
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</tr>
<tr>
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<td>1.0</td>
<td>20.0</td>
<td>0.6</td>
</tr>
<tr>
<td>VW Passat Variant 2.0 TFSI DSG</td>
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<td>0.8</td>
<td>4.0</td>
<td>20.0</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Making a car brake autonomously before colliding into a stationary vehicle while preventing accidental operation is one of the greatest challenges AEBS development poses for manufacturers.

Volvo and VW seem to have made the greatest progress. Both the Volvo V60’s City Safety and the VW Passat’s City Emergency Braking initiate full braking to bring the car to a stop before colliding with another vehicle. The Infiniti at least reduces impact speed by nearly 50%. The other vehicles tested (Audi, BMW, Mercedes) do not brake autonomously in this test.

A collision warning is set off on time in the Volvo, the BMW and the Infiniti. The VW Passat does not provide an early warning since it would make autonomous braking redundant. It alerts the driver only before initiating the autonomous braking. The Audi A7 and the Mercedes CLS do not set off a collision warning either.
The results of the test conducted at 30kph are similar to that conducted at 20kph. The Volvo and the VW fully prevent the collision. The Infiniti reduces speed by approx. 10kph. At 30kph and beyond, the Mercedes CLS initiates autonomous braking and reduces impact speed by a good 15kph. Neither the Audi A7 nor the BMW 5-series initiate autonomous braking.

At 30kph, all vehicles tested alert the driver to an imminent collision. The warning is set off too late both in the Audi and the VW.

In the test conducted at 40kph, the Volvo V60 is the only car to fully prevent colliding with the stationary vehicle. Thanks to autonomous braking, the Mercedes reduces impact speed by 50% to 20kph. Reduction in the Infiniti is 13kph. The Audi A7, BMW 5-series and the VW Passat do not brake automatically (at speeds beyond 30kph).

As at 30kph, the Audi warns the driver too late. The VW Passat does not set off an alarm at all. In the other cars tested, the collision warning is activated on time.

The assessment at 70kph only included the collision warning because of the high impact speed. The Mercedes, Infiniti and Volvo alert drivers early enough to enable them to initiate braking. The warning in the BMW and Audi is set off somewhat late. The VW Passat does not warn at all.
4.5 Alert cascade

The assessment of the alert cascade includes the activation time(s) and whether or not the alarm is noticeable and effective. The figures below show the alert cascades of the vehicles tested in test B1_2 (test vehicle approaching a slow-moving (60kph) vehicle at 100kph).

**Audi A7**

From 100kph to 60kph

With its effective alert cascade, the Audi A7 delivers an impressive performance. Initially, the alarm consists of an acoustic and visual warning on the instrument cluster and (optional) head-up display. If the driver fails to react, the car makes a little jerk to alert the driver. The dual-stage partial braking reduces speed relatively early, giving the driver time to react. Right before the crash, the car initiates autonomous full braking.

**BMW 5er**

100 km/h auf 60 km/h

The alert cascade of the BMW 5-series is not as effective as that of e.g. the Audi A7. The BMW sets off an early and an immediate warning. The early warning is activated relatively early: a red vehicle symbol on the instrument cluster and, if available, the optional head-up display. The warning is effective enough only if the car is equipped with the head-up display. The symbol on the instrument cluster is too difficult to notice for an inattentive driver. The immediate warning includes an acoustic signal and partial braking for a maximum of 1.5 seconds. After this period the driver must brake the car himself.
Although the Mercedes CLS does not come with a complex visual warning (small red triangle on the instrument cluster), the acoustic warning is effective enough. If the driver ignores the warning, the car initiates partial braking to give the driver more time to react. The final stage includes full braking.

The visual and acoustic warnings of the Infiniti M37S are inadequate. The visual warning merely includes a small vehicle symbol which is no eye-catcher in terms of colour and therefore difficult to notice. The acoustic signal is very quiet and drowned out by the radio if the volume has been turned up slightly. Initiated immediately before the crash, partial braking occurs too late to be a haptic warning for the driver.
The Volvo's visual warning is excellent. If a collision is imminent, the car projects bright LEDs onto the windscreen which the driver notices from the corners of his eyes (e.g. when taking his eyes off the road). The visual warning is complemented by a clearly audible warning tone. Unfortunately, there is neither a haptic warning (e.g. brake jerk) nor partial braking afterward to give the driver time to react. Immediately before the crash, the Volvo primes the brakes and applies full braking pressure.

The VW Passat's alert cascade is similar to that of the Audi A7. The initial warning includes an acoustic and a visual signal on the instrument cluster. Since no head-up display is available for the Passat, the visual warning is not as effective as that of the Audi. If the driver fails to react, the car makes a little jerk to alert the driver. The dual-stage partial braking reduces speed relatively early, giving the driver time to react. The VW Passat does not apply full braking pressure.
4.6 Autonomous brake assist

<table>
<thead>
<tr>
<th>B5: autonomous brake assist</th>
<th>Bonus points: 100_20</th>
<th>Collision prevented by autonomous brake assist?</th>
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<tr>
<td>Audi A7 3.0 TFSI</td>
<td>-0.3</td>
<td>yes</td>
</tr>
<tr>
<td>BMW 530d Automatic</td>
<td>-0.1</td>
<td>no</td>
</tr>
<tr>
<td>Mercedes CLS 350 CGI</td>
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<td>yes</td>
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<tr>
<td>Infiniti M37S Premium</td>
<td>-0.1</td>
<td>no</td>
</tr>
<tr>
<td>Volvo V60 D5 AWD Geartronic</td>
<td>-0.3</td>
<td>yes</td>
</tr>
<tr>
<td>VW Passat Variant 2.0 TFSI DSG</td>
<td>-0.3</td>
<td>yes</td>
</tr>
</tbody>
</table>

Apart from the Infiniti, all of the vehicles tested are fitted with an autonomous brake assist. In our test, a vehicle was following a significantly slower vehicle (20kph) at 100kph. Approx. one second after the collision warning, the driver stepped onto the brakes at approx. 3m/s² and kept his foot pressed against the pedal. Applying this amount of brake force, the driver would not have been able to avoid a collision. In all vehicles with an autonomous brake assist, the AEBS applied the amount of force required to stop the car before hitting the other vehicle. This worked very well in all cars.

While the Infiniti and BMW are unable to adapt brake pressure, they are equipped with a system which recognises imminent collisions and automatically aligns the brake shoes and improves braking response by priming the brakes.

4.7 Distance warning

The distance warning gently alerts the driver to an inadequate following distance. The Mercedes CLS and the Volvo V60 are equipped with this additional feature which helps prevent dangerous situations caused by inappropriate distance.

Although the Audi, BMW and VW warn drivers if following distance is inadequate, by the time the warning is set off the distance has become so small that even an inexperienced driver will be aware of the situation. The distance warning is no advantage in real-life traffic.

The Infiniti’s special feature is its active accelerator (DCA, Distance Control Assist) which can be activated separately. If the distance to the car in front is inadequate, the accelerator pedal strongly pushes back against the driver’s foot so that the driver steps off the gas. When he lifts the foot off the pedal, the car automatically slows down by a maximum of 2.5m/s² (similar to ACC) until following distance is safe. This system is an innovative complement to FCW and IBA and qualifies as an active distance warning. Since it lacks fine-tuning, sporty drivers (Infiniti’s target group) are, however, likely to reject this excessively patronising innovation.
4.8 Fail operation

False or too early collision warnings do not only irritate drivers but cause the acceptance of the systems to drop and, in a worst-case scenario, the driver to deactivate (boycott) them. Accidental autonomous full braking must be prevented by all means since it may cause dangerous situations and increase the accident risk rather than prevent crashes.

Accidental autonomous braking was observed in none of the vehicles tested.

Some collision warnings were set off too early in the BMW. While the vehicle symbol which flashes up to warn the driver poses no safety risk, it irritates the driver.

False alarms also occur in the Volvo. Although this was observed only in one fail operation test (implausible braking), it resulted in a slight downgrade.

4.8.1 Fail operation test A1 – cornering

- Ego vehicle: 60kph ± 3kph
- CO vehicle: 30kph ± 3kph
- Curve radius (lane of Ego vehicle): 100m ± 10%
- Lane width: 3.5m

False alarms were observed in none of the vehicles tested.

4.8.2 Fail operation test A2 – overtaking of moving traffic

- Ego vehicle: 130kph ± 3kph
- Target vehicle: 90kph ± 3kph
- 50m ± 10% behind the target vehicle, the Ego vehicle changes the lane within 1.0sec. Before changing the lane, the driver must activate the indicator light.

Overtaking a moving vehicle was no problem for any of the vehicles tested. All of them met our requirements.

In the Infiniti, the active accelerator (DCA) was switched on and strongly pushed back against the driver’s foot until the lane change manoeuvre was completed. The Infiniti failed to recognise when the driver e.g. turns on the indicator to indicate an overtaking manoeuvre.

4.8.3 Fail operation test A3 – implausible braking

- Ego vehicle: 50kph ± 3kph
- Target vehicle: 50kph ± 3kph
- Initial distance between vehicles: 30m ± 10%
- CO brakes from 50kph to 30 kph in approx. 2sec (this translates into approx. -3m/s²) before making a 90-degree turn. The driver of the CO must turn on the indicator.
False alarms were usually set off during implausible braking manoeuvres. Although the vehicle in front had already left the lane, both the BMW and the Volvo warned the driver of an imminent collision until catching up with the vehicle in front.

4.8.4 Fail operation test A4 – approaching a stationary object

- Ego vehicle: 50kph ± 3kph
- Target vehicle: 0kph
- 30m ± 10% behind the target vehicle, the Ego vehicle changes the lane within 1.0sec. Before changing the lane, the driver must activate the indicator light.

False alarms were observed in none of the vehicles tested.
5 ADAC accident research into rear-end collisions

The crashes the ADAC accident researchers analyse and to which ADAC air rescue sends its helicopters to provide assistance involve serious consequences. 95% of these crashes cause serious or fatal injuries.

Since the prevention of serious injuries or the mitigation of their consequences is essential, the trends the researchers identify are important indicators for further studies into active and passive safety aspects.

A study using several accident research surveys showed that ADAC accident research data is highly representative of crashes causing serious injuries.

To identify the significance of rear-end collisions, we analysed ADAC car accident data based on their causes. The data referred to all accidents involving at least one passenger car.

According to ADAC data, inadequate distance is the second most frequent cause of accidents. This means that the more serious car accidents (7%) are caused by tailgating. A study focusing on the causes of accidents involving vans and HGV showed an even greater significance of rear-end collisions. 10% of all accidents involving vans are caused by tailgating. With regard to HGV, inadequate distance is the main accident cause. 29% of HGV accidents analysed by ADAC researches were caused by inadequate distance.

Using a case-by-case analysis, we looked into some typical accidents. Their main causes include:

- Misjudging one’s own speed or ignoring obstacles (e.g. traffic jam tail end) completely when view is adequate
- Inadequate following distance – inadequate response time
- Driver distraction/inattention

► This may result in very high impact speeds.
Rear-end collisions involving serious injuries usually occur on motorways and outside built-up areas. Since rear-end collisions occurring in urban traffic mostly cause slight injuries, they account for a small percentage in the ADAC accident research data.

The injury pattern in rear-end collisions depends on the vehicle in which the occupants travel. Occupants of the impacting car mostly sustain chest, head and pelvis/leg injuries.

Occupants of the impacted car (rear) usually suffer spinal, chest and head injuries.

Summary:

According to ADAC accident researchers, rear-end collisions:
• occur frequently and are very often caused by inadequate distance;
• are frequently caused by experienced male drivers;
• partly show very high (impact) speeds and differential speeds in excess of 30kph;
• often involve underriding;
• mainly occur on motorways and outside built-up areas.
6 AEBS and its impact on accident severity

As early as 2006, ADAC road and crash-tested the first-generation Pre-Safe system by Mercedes. The tests also assessed the mitigation of accident consequences through impact speed reduction.

Using the test sled of the ADAC crash test facility, we conducted the crash tests below. We equipped the sled with a reinforced Mercedes S-Class body and fitted the cabin with all components relevant for the crash test result, i.e. operational original seats, dashboard, steering wheel, safety belts and all electric and pyrotechnic passive safety components. Airbags, belt pretensioners and the Pre-Safe components were activated through the crash control at the pre-determined time.

The basis for our tests was a sled test with deceleration and occupant loads corresponding to the values of a frontal crash against a rigid barrier with 100% overlap and an impact speed of 50kph.

6.1 Basic crash test (test A) at 50kph

This crash test represents the loads on the occupants in a frontal crash against a rigid barrier at 50kph with 100% overlap. All Pre-Safe components remained deactivated.

The analysis of our dummy measurements showed a low injury risk and an average chest and lower leg injury risk for the two front-seat occupants and the rear-seat passenger (only right dummy was instrumented) (see left character in figure overleaf).

6.2 Test B at 37.5kph with activated Pre-Safe brakes

The second test was conducted with the identical dummy placement but with all Pre-Safe components fully activated. Test deceleration was adapted to achieve the reduced impact speed of 37.5kph which was identified in a previous assessment of the Pre-Safe brakes.

The results of our test show the effect of the speed reduction achieved by the Pre-Safe brakes.
The occupant loads in test B are lower than in test A. If we use the same weighting for the various areas of the body, average load on the driver and the right front passenger decreases by 27% and 30% respectively. Average reduction for the right rear-seat passenger is 45%.
7 ADAC demands

- The systems must be made available in small vehicle classes and developed steadily to become more affordable.

- False alarms must be avoided. Accidental emergency braking manoeuvres are intolerable. To ensure that a large number of driver types benefits from AEBS, driver observation models and plausibility checks are required (alarm dilemma: sporty vs. inexperienced drivers …).

- Warnings must be effective yet unobtrusive. Permanently flashing lights or obtrusive warning tones are only accepted in emergency situations.

- Specific haptic warnings (e.g. brake jerk and subsequent partial braking) give the driver time to react and tell him what to do (depress the brake pedal). With its active accelerator that warns the driver exactly when expected (“danger ahead, step off the gas”), Infiniti follows a very promising approach.

- AEBS must be switched on whenever the driver starts the engine. Permanent deactivation should not be possible.

8 Tips for consumers

Although many motorists regard themselves as good drivers who do not need such a system, AEBS was not designed to exclusively assist bad drivers. Any driver has already experienced moments of distraction when operating the radio, calming down children or being exposed to other external influences etc. This is exactly when AEBS kicks in to prevent serious accidents and injuries or mitigate their consequences.

Nevertheless, drivers should always bear in mind that the systems can never replace an attentive driver. Motorists keeping a safe distance at all times and driving defensively enhance road safety considerably.

The systems are, however, a safety asset in emergency situations, preventing serious accidents or mitigating their consequences.
9 Active assistance systems in the car of the future

Today's driver assistance systems are designed to intervene in very specific situations. While AEBS assists the driver in same and opposite-direction traffic (rear-end collisions), ESC stabilises the car and prevents skidding. The lane departure warning system monitors the vehicle's position between too lane markings. Future systems will interact and thus enable the introduction of new safety functions.

According to ADAC accident researchers, crashes at intersections (caused by non-compliance with the right-of-way rule) are among the accident types where people are injured most frequently. This shows great potential for future inter-vehicular systems to further reduce the number of road injuries or deaths using all-around monitoring technology or vehicle-to-vehicle or vehicle-to-infrastructure communication.

Which active safety systems aboard the car of the future will help further reduce the number of serious accidents? The answers of the manufacturers are as follows:

“Future BMW models will focus on the protection of drivers, vehicles and the surroundings. New active safety systems will be integrated systems for the prevention of frontal, side and rear-end impacts which will also include the urban environment. In combination with the future driver assistance systems, interconnected all-around sensors and navigation data will ensure a much higher safety level.”

Gerhard Fischer, Head of Integrated and Active Safety, BMW Group

“Audi has been active in the field of accident research for more than 10 years. We use our results for the development of effective passive and active safety systems. In the future, our focus will be on improved all-around monitoring features. The priority will be the interconnection of various sensors. The interconnection between other vehicles or traffic infrastructure, i.e. vehicle-to-vehicle and vehicle-to-x communication, will help further develop active safety systems. Our aim still is to effectively alert drivers so that they initiate early braking or steer the car in the right direction to prevent an accident. Different assistance systems will help them master difficult situations.”

Peter Duba, Head of Driver Assistance Systems, Audi AG
“To ensure easier parking in poor visibility and complement the Infiniti Dynamic Safety Shield, we are developing systems that are able to detect moving objects. While Moving Object Detection (MOD) which is based on our camera system Around View Monitor produces a warning tone to alert the driver to pedestrians etc. in the immediate surroundings, the radar sensors of the Back-up Collision Intervention (BCI) technology detect vehicles approaching from the side when backing out of a parking lot. BCI will automatically brake the car to prevent a collision.”

Alexander Sellei, Kommunikationsmanager, INFINITI Deutschland

“Stronger propagation of the known and successful active safety features, notably AEBS, is a short-term tool to enhance road safety. Mercedes-Benz will therefore factory-fit its new-generation A and B-Class with the radar-based Collision Prevention Assist including distance warning and adaptive brake assist. Mercedes-Benz’s mid-term challenge is the control of more complex traffic situations such as intersections and pedestrians. In the long term, we are working to implement our vision of accident-free motoring through perfect assistance and safety features.”

Thomas Breitling (Prof Dr-Ing), Director of Active Safety/Vehicle Dynamics/Energy Management, Development Mercedes-Benz Cars

The car’s detection and autobraking system performed as expected in the tests. Traffic accidents of these kinds are common and our technologies will make a difference also in real life. Volvo has a vision of no one should be killed or severely injured in a new Volvo by year 2020. Therefore we are developing even more advanced and exciting safety features that can help the driver to avoid accidents e.g. in intersections and also by developing autonomous driving technologies.

Erik Coelingh, Senior Safety Expert, Volvo Cars

“Volkswagen’s priority will be to develop known active safety systems or make them attractive for the price-sensitive downmarket. Only if these systems strongly penetrate the passenger car market, we will substantially improve road safety. The car of the future should ensure that all users enjoy a high level of active safety. Crash prevention is particularly important with regard to supermini cars since they have comparatively small crumple zones. Our Up! will show how serious we are about this issue. With this car, Volkswagen will set a new benchmark. We will surprise you. We are also continuing our intensive efforts to develop the automatic emergency brake assist to ensure reliable detection in traffic situations that are difficult to monitor (e.g. intersections).”

Stefan Gies (Prof Dr-Ing), Head of Passenger Car Chassis Development, Volkswagen AG
10 Test methodology

10.1 Products tested

Mercedes was the first manufacturer to fit its cars (S-Class) with AEBS (Pre-Safe) in 2005. Initially, Pre-Safe used to be a very expensive option for luxury cars.

While AEBS is still mostly only optionally available, it has meanwhile been introduced into smaller vehicle classes such as executive and a few family cars.

The test vehicles are as follows:

- Audi A7 3.0 TFSI
- BMW 530d Automatic
- Infiniti M37S Premium
- Mercedes CLS 350 CGI
- VW Passat Variant 2.0 TFSI DSG Highline
- Volvo V60 D5 AWD Geartronic SUMMUM
10.2 AEBS and how it works

AEBS uses the three components below:

Sensor system
The sensor system consists of at least one sensor monitoring the area in front of the vehicle. Maximum sensor range is 200m to ensure early detection of objects at high speeds and to account for the system’s response time. The sensor’s main task is to detect objects moving in front of the vehicle. Sensors for the detection of objects are usually radar sensors. Laser sensors (LIDAR) are a less expensive but rarely used alternative. To ensure the better classification of objects, radar sensors may be used in combination with cameras.

Control system
The control system consists of a control unit which is usually installed in the sensor housing. The control unit’s task is to analyse the sensor data. It calculates the object’s position in relation to the vehicle and the relative speed between the vehicle in which the sensor is installed and the object in front. Based on the object’s measured path of movement, the unit also calculates the relative acceleration between the vehicle and the object.

To enable the parallel use of several sensors such as two radar sensors, one video sensor and the in-vehicle sensors (steering angle sensor, acceleration sensor etc.), the sensors are connected to another control unit via the CAN bus. The control unit makes a plausibility check by comparing the input data to prevent accidental emergency braking. Because of the integration of the steering angle sensor, the vehicle’s desired path of movement can be estimated. This helps AEBS identify the objects which the vehicle is likely to collide with. Analysing the data transmitted from the acceleration sensor and the indicator, AEBS knows whether or not the driver has seen the object and responds to it by stepping on the brakes or swerving.

Human-machine-interface
A human-machine-interface (HMI) integrates all actuators that exchange information with the driver, including acoustic signals (via speakers), warning lights or LEDs and haptic signals such as a brake jerk or accelerator force feedback pedal.
10.3 Test criteria

We rated and compared different AEBS using an ADAC-developed catalogue of test criteria.

The catalogue includes three chapters:

- fail operation
- benefit
- alert cascade

To test fail operation, we selected scenarios of day-to-day traffic which AEBS may not always identify as harmless.

We conducted the fail operation tests below:

- Fail operation test A1 – cornering (static)
- Fail operation test A2 – overtaking of moving traffic
- Fail operation test A3 – implausible braking
- Fail operation test A4 – avoiding a stationary object
The tests for the assessment of the benefit reflect typical traffic and accident scenarios. We assessed whether or not

- the warning is set off early enough to give the average driver sufficient time to brake the car and prevent a collision.
- the system helps the driver prevent a collision if he applies insufficient brake pressure.
- the system autonomously reduces impact speed to mitigate the consequences of a crash if the driver ignores the warning and a collision is imminent.

The following tests were conducted with varying driving and differential speeds:
- Benefit test B1 – approaching a slow-moving object

![Diagram of Benefit test B1](image)

- Benefit test B2 – approaching an object decelerating constantly

![Diagram of Benefit test B2](image)

- Benefit test B3 – approaching an object which has come to a halt

![Diagram of Benefit test B3](image)

- Benefit test B4 – approaching a stationary object

![Diagram of Benefit test B4](image)

- Benefit test B5 – autonomous brake assist

![Diagram of Benefit test B5](image)

The assessment of the alert cascade includes the warning strategy and effectiveness. An ideal alert cascade consists of a highly visible visual warning (e.g. projected onto the windscreen), a loud acoustic warning and a clearly noticeable haptic warning (e.g. brake jerk or partial braking).
10.4 ADAC target and measurement instrumentation

The ADAC target which was specifically designed for the AEBS test is a static and dynamic mock vehicle for assessing and comparing the performance of the test vehicles’ AEBS while preventing any vehicle damage.

ADAC has developed a mock vehicle that meets all requirements of the different systems and that all systems identified as a real vehicle. Since the vehicles are equipped with radar and laser sensors as well as video cameras, we had to ensure reliable detection with all technologies. For this purpose, we simulated the radar reflection properties of a real vehicle and made the target’s silhouette resemble that of a real vehicle so that the camera systems would recognise our target as a vehicle.

The ADAC target can either be used as a stationary object or slide back and forth on a sophisticated rail system. The mock vehicle is pulled by a tractor vehicle. In a collision, it slides forward on the rails while reducing impact forces significantly.

To record the time of the warning and impact speed, we connected a specific radar sensor to a GPS-supported data recorder. Additional cameras, microphones and acceleration sensors autonomously measured all relevant signals from the vehicle. To measure the exact impact speed, we installed a trigger in the vehicle front.