Edge Case Testing of Advanced Emergency Braking Systems for the Protection of Vulnerable Road Users.

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Introduction & Objectives

The Vision Zero of road safety, i.e. no fatalities or serious injuries in road traffic, is a declared goal of road safety in the EU as well as in Austria and Switzerland. New vehicle technologies such as advanced driver assistance systems (ADAS) are of great importance in this context. Especially those that actively support drivers in critical traffic situations - not only to protect themselves, but also to protect vulnerable road users (VRU) outside the vehicle (cf. Ewert 2014: 5, Deublein 2020: 13). The advanced emergency braking system (AEBS) is probably the driver assistance system with the highest safety potential (cf. Hummel et al. 2011: 56, Bubb & Bengler 2015: 567). According to EU Regulation 2019/2144, the AEBS will be mandatory for new vehicle types or newly registered vehicles from 2022/2024.

The aim of the present research project was to examine the reliability of AEB systems available on the market today and their protective effect for VRU in real traffic and environmental situations based on the current state of vehicle technology, existing test procedures and findings from current accidents in Austria and Switzerland.

Specifically, the following questions were investigated:

1. how well do AEB systems perform in different weather conditions (e.g. rain, fog) and lighting conditions (clear, twilight and darkness)?
2. how well do AEB systems detect new types of UVT such as scooters, e-scooters, bicycles, or e-bikes?
3. how well do AEB systems with newer sensor generation (i.e. with newer approval date) perform compared to AEB systems with older sensor generation (i.e. with older approval date)?

The starting point for the selection of the test scenarios was the standardised tests according to Euro-NCAP (European New Car Assessment Programme) for the AEBS with pedestrian and cyclist detection. Four basic scenarios were selected because of their relevance for urban accidents with vulnerable road users in Austria and Switzerland. The aim was not to test exactly in accordance with NCAP, but to use their individual test scenarios as an initial setting for the test series, to then sound out the limits of the functionality of the systems with continuous changes to the test parameters towards an increasing complexity.

Test Design

AEB systems of different vehicle types and generations (i.e. different vehicle models with different AEBS sensor types) were investigated. The aim was to test how well the AEB systems work outside the basic scenarios/test scenarios specified by Euro NCAP (e.g. with regard to the weather or light conditions tested so far). The tests were conducted in the outdoor and indoor facilities of the CARISSMA (Center of Automotive Research on Integrated Safety Systems and Measurement Area) test centre at the Ingolstadt University of Technology in Germany.

Three vehicles from three different manufacturers in the mid-range were rented. They were chosen to best represent the further development of vehicle technology and sensor technology in recent years. The years of market introduction span a period between 2014 and 2019, which is decisive because the test protocols of the standardised test scenarios, e.g. according to Euro NCAP, have also changed within this period and the installed AEBS must therefore be able to fulfil different requirements. This means that although all three vehicles have an AEBS installed, the underlying functionality and the system limits can be significantly different between the vehicles. The selected vehicles cover three generations of the AEB system and thus represent very well the current generation mix in the vehicle fleet in Austria and Switzerland. In total, more than 230 tests were conducted. The figures below show examples of the outdoor and indoor test track on the left and right side, respectively.

Figure 1: Outdoor testing with e-scooter target.

Figure 2: Indoor testing, pedestrian during foggy conditions

The AEB systems were tested under different weather and lighting conditions, both indoor and outdoor. This results in scenarios with optimal, suboptimal, and poor conditions (best-case, middle-case, and worst-case scenarios). In the best-case scenarios, the most favourable, optimistic situations possible were assumed (good visibility during the day and clear weather). In the worst-case scenarios, the systems were tested under particularly unfavourable weather and lighting conditions (darkness and rain). Systems in the middle-case scenarios were tested at dusk in combination with rain or fog, or at darkness with drizzle. Different targets were used to represent the group of vulnerable road users: pedestrians (adult and child), bicycle/e-bike, scooter/e-scooter. In addition, the velocities of the vehicles as well as the targets were increased in some of the test scenarios to increase the complexity of the test scenario.

To calculate the performance of an AEB system, points were distributed per test execution. For example, an AEB system received the full number of points if the AEB system detected the object correctly and performed a braking manoeuvre without touching the object. For the system performance, the mean value of the first three valid test executions was calculated. A test was considered valid if the collision points between the vehicle and the target corresponded to the NCAP protocol of the underlying base scenario.

Results and Lessons learned

On a higher level, the test results show a decrease in system functionality with increasing complexity of the test setting. Even with small deviations from the standardised test scenarios according to Euro NCAP, some AEB systems were either no longer able to detect the dummy or no longer able to stop in time. As expected, the AEB systems of all vehicle types work best during daytime and clear weather. The tests showed that the systems do not work reliably in adverse weather and light conditions (rain and darkness). Overall, the systems detected pedestrians crossing the road from an obscured position during the day and in clear weather well, and always initiated emergency braking. Cyclists, both when crossing the road from a concealed position and when riding on the road in the same direction as the vehicle behind them, were also mostly detected and a collision could usually be avoided. For each vehicle model, many different vehicle configurations are available, which are solved differently by the manufacturers. There is a tendency that older models, which were homologated according to an old testing standard, perform worse than newer models, because the installed sensors/vehicle architecture can hardly be updated to a current testing standard despite regular software updates. Finally, differences between the indoor and outdoor test environments were also found. All tested systems functioned worse indoors in artificial light than outdoors in natural light conditions.

In summary, the test results confirm that traffic safety can be significantly improved by the advanced emergency brake assistant. However, the systems are not sufficiently mature for all situations and their functionality and performance can drop sharply in the event of minor deviations from the basic scenario.

Discussion and Outlook

For practical purposes, the results mean that a star rating system such as the one used by Euro NCAP is a good orientation tool, especially for the end user/consumer. However, this should not be overrated, as the established test scenarios do not cover all real road traffic situations. Basically, the differences in the performance of different vehicle generations (vehicle type A: market launch 2014, vehicle type B: market launch 2017 and vehicle type 3: market launch 2019) illustrate the necessity of conducting regular functionality tests. Although the complete representation of real road traffic is not or at least only very difficult to realise due to its complexity and diversity, it is nevertheless recommendable to include tests in rain and darkness in the NCAP protocols in the future. This is not only because - at least the AEB systems tested in the present research project - do not yet function satisfactorily under such conditions, but also because drivers and VRUs perceive their surroundings less well under these conditions.