AEB Car-Car and Pedestrian: Achievable Speed Reductions for Legislation 2020+

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Proposed Requirements for AEBS IWG

**Proposal**: Revision of UNR131 (Advanced Emergency Braking System) to establish new requirements of AEBS for M1/N1

**Scope**
To extend to M1, N1

*Based on test procedures of JNCAP/Euro NCAP

**02 series**  Moving obstacle/Stationary obstacle for M1/N1
Timeline: 2020 for new types of vehicles
          2022 for new vehicles

Test procedure*:

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<td>60 km/h</td>
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**03 series**  Pedestrian detection for M1/N1
Timeline: 2024 for new types of vehicles
          2026 for new vehicles

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Basics – Achievable Speed Reductions

AEB should act only if accident is imminent

- „Last Point to Steer“
- „Last Point to Brake“

AEB Systems cannot select which one is relevant
- Driver intention unknown
- Road geometry unknown
Last Point to Brake: Brake Timing for Avoidance

Brake distance depends on relative speed

\[ s_{rel} = \frac{v_{rel}^2}{2a} \]

Time-To-Collision

\[ t_{TC} = \frac{s_{rel}}{v_{rel}} \]

TTC when braking needs to start for avoidance

Relative Speed is relevant:
50 km/h for stationary == 70 km/h for 20 km/h moving target
Last Point to Brake: Avoidance by Braking

Autobrake: 10 m/s², achieved in 0.4 s

Driver braking: 3m/s², achieved in 1 s

Brake Timings for 47 cars from 4 NCAP labs (AEB City)
Brake Timings for 30, 40, 50 km/h

Cumulative Distribution for 47 official NCAP AEB City tests

- $v_{\text{Test}} = 50 \text{ km/h (Median:} 1.23 \text{s)}$
- $v_{\text{Test}} = 40 \text{ km/h (Median:} 1.09 \text{s)}$
- $v_{\text{Test}} = 30 \text{ km/h (Median:} 0.97 \text{s)}$
A Bit More Theory: Shark’s Fin-Curves

Speed reduction for a given braking time:

\[ \nu_{\text{Impact}} = \sqrt{v_0^2 - 2 \cdot TTC \cdot v_0 \cdot d} \]
Last Point to Steer: Avoidance by steering (Theory, worst case)

\[ y_{VU} = \int \ddot{y} dt^2 \]

Lateral displacement in m

Lateral acceleration in m/s²

\[ |\ddot{y}_{VuT}| = g \]

100% Overlap

Ca. 0.1 s

Ca. 0.7 s

Time in s
Last Point to Steer - Simulations

Necessary Steering Input Possible for Human Drivers?

t = 0.8s
Driving Tests (1) - Human

Task: perform a single lane change as quick as possible, if possible keep the overshoot small
Lane change width: 2m

Mercedes GLC 2017 with DGPS measurement system for speed, position and rotation
No measurement of steering angle

4 Individuals, 10 test runs each
Calculation of lane change time: increase of yaw rate $\rightarrow$ lateral shift $\geq 2$ m
Evaluation: Yaw rate $>1^\circ$ $\rightarrow$ y $> 2$m (best case)
### Results (1) - Human

**Fastest avoidance: t**  
\[ y_{2m} = 0.68 \text{s} \]

**Fastest avoidance with overshoot ≤ 3 m: t**  
\[ y_{2m} = 0.77 \text{s} \]

**Comment:**  
Yaw rate > 1° →  
\[ y > 2 \text{m}: 0.77 \text{ s} \]
Task: Robot programmed for lane change maneuver 0.9/1.0/1.1 s
Lane change width: 2m
Robot peak torque: 15 Nm
(ABD SR15+CBAR Robot System)

Evaluation:
Steering Rate > 10°/s \rightarrow y > 2m (new)
Results (2) - Robot

Lateral movement as function of desired lane change time

Steering Input

Yaw rate response (>0,11s)

Lateral shift (0,79s Robot) (0,68/0,77s Human)

Total time for steering avoidance: >0,79s / >0,88s
Discussion on Last Point to Steer

Subject Performance
- 4 drivers, all with Test Track License „ATP B“, 4x10 runs
- Values correspond to best try!
- Majority of drivers on the road likely performs worse

Vehicle Characteristics
- Mercedes GLC, total 1000 km
  (=new dampers/springs, new but appropriate tires)
- BASSt can perform tests with other, proposed cars as well, if desired

Other data
- ADAC data → similar, yet higher values

Transferability
- Measured values are considered transferable
0,88s: \( v_{\text{red}} = 49 \text{ km/h} \)
0,89s: \( v_{\text{red}} = 50 \text{ km/h} \)

Achievable Avoidance Speed - Conclusion

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\begin{align*}
\text{TTC} &= \text{time before impact for continuous movement} \text{ in s} \\
\text{Relative speed in km/h} &
\end{align*}
Conclusion – Brake Timing

Cumulative Distribution for 47 official NCAP AEB City tests

85% of the known vehicles brake earlier!

- Test $V = 50$ km/h (Median: 1.23s)
- Test $V = 40$ km/h (Median: 1.09s)
- Test $V = 30$ km/h (Median: 0.97s)
Summary

Avoidance by steering possible up to 0.88 s before the impact (driving tests)

Braking at 0.88 s results in avoidance up to 49 km/h (relative speed), 50 km/h would be achieved with 0.89 s

A relative speed reduction of 50 km/h is achievable

Higher speed reductions possible with earlier brake intervention

ALL tested vehicles start to brake much earlier than 0.8 s!

The Japanese proposal could even be adjusted to 50 km/h (relative) for moving cases as well

• Currently: moving target 40 km/h reduction, stationary target + pedestrian 50 km/h reduction