Modifications to UN R131
AEBS for Heavy Vehicles

Explanation of ECE/TRANS/WP.29/GRVA/2018/4
at the 1st GRVA
Structure of Presentation

- Structure of R131
- Target
- Overriding
- Warning Requirements
- Deactivation
- Performance Requirements & Test Conduction
Proposed Structural Changes

- **Current** structure defines performance requirements ONLY for one speed
- Performance requirements for other speeds unclear
- **Proposed** structure introduces requirements for whole speed range
- All performance requirements are included in section 5 (Specifications)
- **Proposed structure increases clarity of requirements**
### Current Structure:

<table>
<thead>
<tr>
<th>5 – Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• General requirements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6 – Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Warning timing</td>
</tr>
<tr>
<td>• Restriction of speed</td>
</tr>
<tr>
<td>Reduction in warning phase</td>
</tr>
<tr>
<td>• Definition of test speed (ego Vehicle)</td>
</tr>
<tr>
<td>• Tolerances</td>
</tr>
</tbody>
</table>

### Annex 3

- Definition of target speed
- Definition of warning timing (for test speed 80 km/h)
- Definition of speed reduction (for test speed 80 km/h)

### Proposed Structure:

<table>
<thead>
<tr>
<th>5 – Specifications</th>
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<tbody>
<tr>
<td>• General requirements</td>
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<td>• Warning timing for whole speed range</td>
</tr>
<tr>
<td>• Speed reduction</td>
</tr>
</tbody>
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<tr>
<th>6 – Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tolerances</td>
</tr>
<tr>
<td>• Parametric test description</td>
</tr>
<tr>
<td>• Test speeds</td>
</tr>
<tr>
<td>• Pass/fail per reference to chapter 5</td>
</tr>
</tbody>
</table>

27. September 2018
Target

- Current R131 allows any M1 AA saloon car
- Proposal: Use compact car, such as the target defined in ISO 19206-3.
Overriding

• R131 mentions direction indicator as example for overriding.
• Example for direction indicator as positive action could suggest that a direction indicator signal might be sufficient for abortion of AEBS intervention.
• Conclusion: Delete example reference
• Natural driver movements caused by braking could lead to system override.
• “5.3.4. The vehicle manufacturer shall demonstrate to the satisfaction of the technical service that natural driver movements generated purely by brake activations shall not lead to an interruption of the emergency braking phase.”
• This is assumed to be state of the art; included for clarification.
Warning

- Current warning requirements: too frequent warnings in certain situations
  - Low speeds: Manual brake application in regular situations late
  - Warning required 1.4 seconds before emergency brake phase → long before manual brake application!
- Current warning requirements prevent effective braking e.g. for decelerating lead vehicles
  - Minimum warning time of 1.4 seconds (0.8 s for lighter vehicles) before full braking can be applied
  - Speed reduction in warning phase is limited
- **Conclusion:** Speed reduction/deceleration constraints for warning phase need to be removed for efficient braking!
Deactivation

• Documents ECE/TRANS/WP.29/GRRF/2017/24 and GRRF-86-32 included in the text
• Changes to warning timing (effectively removing mandatory warnings for city speeds)
  → less unjustified warnings in cities! See GRRF-85-21, third bullet point
• While GRRF-86-32 introduced provisions for detecting sensor blocking, it is anticipated that it will be more beneficial to address this problem by exempting the relevant vehicles by national legislation from the requirement to use UN Regulation No. 131.
• Certain N₃ vehicles are available without switch!
Accidentology

- Collision speed of heavy vehicles with stationary targets often high
- Typical speeds on German highways: >> 80 km/h
- Requirements for speed reduction on moving and stationary vehicles should be harmonized
- Speed reduction should be required/tested for full speed range

<table>
<thead>
<tr>
<th>Speed Classes [km/h]</th>
<th>Source: UDV (Observations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed [km/h]</td>
<td>Accident No.</td>
</tr>
<tr>
<td>0-10</td>
<td>0</td>
</tr>
<tr>
<td>10-20</td>
<td>5</td>
</tr>
<tr>
<td>20-30</td>
<td>20</td>
</tr>
<tr>
<td>30-40</td>
<td>30</td>
</tr>
<tr>
<td>40-50</td>
<td>50</td>
</tr>
<tr>
<td>50-60</td>
<td>20</td>
</tr>
<tr>
<td>60-70</td>
<td>0</td>
</tr>
<tr>
<td>70-80</td>
<td>0</td>
</tr>
<tr>
<td>80-90</td>
<td>0</td>
</tr>
<tr>
<td>90-100</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: UDV (German Insurance Data)
Performance Requirements (Speeds in km/h)

- 70 km/h relative speed reduction already required for moving vehicles
- Now: require this also for stationary vehicles

<table>
<thead>
<tr>
<th></th>
<th>Stationary Vehicles</th>
<th>Constant Moving Vehicles</th>
<th>Proposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>N2*, M2* (current R131)</td>
<td>$v_{\text{red}} = 10$</td>
<td>$v_{\text{red}} = 12$</td>
<td>$v_{\text{rel,avoid}} = 70$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$v_{\text{rel,red,mitig.}} = f(v_{\text{rel}})$</td>
</tr>
<tr>
<td>N3**, M3** (current R131)</td>
<td>$v_{\text{red}} = 20$</td>
<td>$v_{\text{red}} = 68$</td>
<td>$v_{\text{rel,avoid}} = 70$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$v_{\text{rel,red,mitig.}} = f(v_{\text{rel}})$</td>
</tr>
<tr>
<td>Test Speeds</td>
<td>80</td>
<td>$v_{\text{Ego}} = 80$, $v_{\text{Target}}$ 12 (N3), 68 (N2*)</td>
<td>To be selected from whole operating speed range</td>
</tr>
</tbody>
</table>

* N2 < 8t, M2, N3 with hydraulic brakes
** N2 > 8t, M3, N3 with pneumatic brakes
Performance Requirements – Consequences

- Brake strategy (TTC, Last Point to Steer etc) same as for moving vehicles ($N_3$)
- In that sense, the proposal does not ask for new system designs!
- Classification of stationary targets as "in vehicle path - relevant for braking" might require more advanced sensor technology
  - Fusion with lane detection could be required
  - High resolution RADAR could be required
- Systems on the market show: this technology has become readily available in recent times
State of the Art

System: Single RADAR
Avoidance up to 80 km/h

Other Data:
- ADAC (2017)
- 3 trucks from independent companies
- Trucks fully loaded
- Speed reduction: \( \geq 70 \text{ km/h} \) on stationary target
- 3 of 5 truck corporations with > 50% market share in Western Europe
Proposed Speed Reduction Requirements

Valid for parameters:

- Maximum Deceleration [m/s²] = 7
- Time-To-1g [s] = 1
- TTC_{brake} [s] = 1,8

(Derivation of curves: see annex to this presentation)
Identification of Parameters for Mitigation Req’s possible from measurements

\[ v_{\text{impact,rel}} = \sqrt{v_{0,\text{rel}}^2 - 2 \left( t_{tC,\text{Brake}} - \frac{1}{2} t_{\text{Increase}} \right) \cdot v_{0,\text{rel}} \cdot a_{\text{max}}} \]

Hypothetical brake measurements

<table>
<thead>
<tr>
<th>Speed [km/h]</th>
<th>Deceleration [m/s²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>e.g. 7 m/s²</td>
</tr>
<tr>
<td>7</td>
<td>e.g. 7 m/s²</td>
</tr>
<tr>
<td>4</td>
<td>e.g. 4 m/s²</td>
</tr>
</tbody>
</table>

\[ t_{tC,\text{Brake}} = t_{tC,4} \cdot \frac{v_{0,\text{rel}}}{v_{4,\text{rel}}} \]

\[ t_{\text{Increase}} = \frac{a_{\text{max}} \cdot (t_{a,\text{max}} - t_{4})}{a_{\text{max}} - 4 \text{ m/s}^2} \]

Maximum Deceleration [m/s²] | 7
Time-To-1g [s] | 1
TTC\(_{\text{Brake}}\) [s] | 1.8
Implementation: Performance Requirements

- **Paragraph 5.2.2.2.** asks for an avoidance up to [70] km/h on dry, [40] km/h on wet roads.
- This avoidance speed is the maximum achievable speed reduction. For mitigation, the speed reduction is lower:
  - **Paragraph 5.2.2.3.** defines a speed reduction according to the equation for mitigation (test speed > avoidance speed).
  - The input parameters for the equation in **paragraph 5.2.2.3.** can be taken from actual measurement in **paragraph 5.2.2.2.**
  - Effectively this means the brake strategy should not be changed above the avoidance speed!

- **Paragraph 5.2.2.4.** requires that the maximum deceleration is used for decelerating lead vehicle situations (no other requirements set!)
Proposed Changes for Test Conduction

<table>
<thead>
<tr>
<th></th>
<th>Current (Stationary)</th>
<th>Current (Moving)</th>
<th>Proposal (Stationary)</th>
<th>Proposal (Moving)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functional part of test shall start...</td>
<td>50 m distance</td>
<td>120 m distance</td>
<td>6 s TTC (133m@80km/h)</td>
<td>6 s TTC (113m@80-20)</td>
</tr>
<tr>
<td>Test Speed</td>
<td>80 ± 2 km/h</td>
<td></td>
<td>X* ± 2 km/h</td>
<td>X* ± 2 km/h</td>
</tr>
<tr>
<td>Test Speed Target</td>
<td>-</td>
<td>67 km/h**, 12 km/h***</td>
<td>-</td>
<td>12 km/h or any other speed within requirements</td>
</tr>
<tr>
<td>Tolerance for Speed Reduction</td>
<td>-</td>
<td></td>
<td>5 km/h (up to [70] km/h vrel)</td>
<td>10 km/h (above [70] km/h vrel)</td>
</tr>
</tbody>
</table>

*Test Speed: (20 for stationary), 40, 60, 80, 100, $v_{\text{Avoidance}}, v_{\text{max}}$,

where: $v_{\text{Avoidance}} = v_{\text{relative, avoidance}} + v_{\text{Target}}$

** $N_2 < 8t$, $M_2$, $N_3$ with hydraulic brakes
*** $N_2 > 8t$, $M_3$, $N_3$ with pneumatic brakes
Summary

• New structure
• **Scope NOT changed** – still highway systems!
• Clarification of requirements for speeds other than 80 km/h
• Target size limited to compact class vehicle
• Overriding clarified
• Warning – increased flexibility of warning (e.g. allow full braking in warning phase)
• Deactivation – no changes to last proposals.
  • Deactivation less required in complex situations
• Performance:
  • Accidentology shows stationary targets are highly relevant.
  • Proposal aims to **align** requirements for moving and stationary vehicles (NO new requirements introduced!)
  • State of the art systems (for N₃, M₃) are able to **meet** the proposed performance requirements
  • Assumption: Different performance req’s for lighter vehicles not needed anymore.
Thank you for your attention!
Annex (1) – Derivation of Mitigation Speed Reduction (paragraph 5.2.2.3.)

Easy case: What is the TTC needed to come to a full stop for a certain relative velocity?

Stopping distance:
\[ v = a \cdot t \]
\[ s = \frac{1}{2} \cdot a \cdot t^2 \]

Combine them for the stopping distance:
\[ s = \frac{1}{2} \cdot a \cdot \frac{v^2}{a^2} \]
\[ \Rightarrow s = \frac{v^2}{2 \cdot a} \]

The initial TTC combined with the initial velocity define the initial distance:

\[ \text{TTC} = \frac{\Delta x}{\Delta v} = \frac{s}{v} \]
\[ \Rightarrow s = \text{TTC} \cdot v \]

Insert that into the stopping distance equation:

\[ \text{TTC} \cdot v = \frac{v^2}{2 \cdot a} \]
\[ \text{TTC} = \frac{v}{2 \cdot a} \]

Complex case: what if the TTC is not enough to come to a full stop?

Derivation of residual speed as a function of initial TTC, for the case that the vehicle cannot come to a full stop:

\[ \dot{x}(t) = \int \dot{x} \, dt \]
\[ \dot{x}(t) = -\mu \cdot g \cdot \int dt \]
\[ \dot{x}(t) = -\mu \cdot g \cdot t + C_0 \]

Initial conditions for first equation:
\[ x(t = 0) = v_0 \Rightarrow C_0 = v_0 \]
\[ \dot{x}(t) = v_0 - \mu \cdot g \cdot t \]

Since TTC is a measure of distance, not time, we need to introduce an initial condition of location. Therefore, another integral is needed:

\[ \dot{x}(t) = v_0 - \mu \cdot g \cdot t \]
\[ x(t) = v_0 \int dt - \mu \cdot g \cdot \int t \, dt \]
\[ x(t) = v_0 \cdot t - \frac{1}{2} \mu \cdot g \cdot t^2 + C_1 \]

Initial condition for location:
\[ x(t = 0) = x_0 = -\text{TTC} \cdot v_0 \]
\[ C_1 = \text{TTC} \cdot v_0 \]
Annex (2)

\[ x(t) = v_0 t - \frac{1}{2} \mu \cdot g \cdot t^2 - \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g} \]

Now, what is the duration of the accident? What is \( t \) for \( x = 0? \)

\[ 0 = v_0 t - \frac{1}{2} \mu \cdot g \cdot t^2 - \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g} \]
\[ \Rightarrow t^2 + \frac{2v_0}{\mu \cdot g} t + \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g} = 0 \]

This is the regular form of a quadratic equation.

\[ p = \frac{-2v_0}{\mu \cdot g} \]
\[ q = \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g} \]

There are two possible values for \( t \). The solutions are given by

\[ t_{1,2} = -\frac{p}{2} \pm \sqrt{\left(\frac{p}{2}\right)^2 - q} \]

\[ t_{1,2} = \frac{-2v_0}{\mu \cdot g} \pm \sqrt{\left(\frac{-2v_0}{\mu \cdot g}\right)^2 - \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g}} \]

\[ \Rightarrow t_{1,2} = \frac{v_0}{\mu \cdot g} \pm \frac{v_0^2}{\mu^2 \cdot g^2} - \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g} \]

Now which one is the correct solution? The first term \( \frac{v_0}{\mu \cdot g} \) is the time needed to come to a complete stop. Thus, the time we calculate here cannot be bigger. The correct solution for \( t \) in this case is
Annex (3)

\[ t = \frac{v_0}{\mu \cdot g} - \sqrt{\frac{v_0^2}{\mu^2 \cdot g^2} - \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g}} \]

Some simplifications:

\[ t = \frac{v_0}{\mu \cdot g} - \sqrt{\frac{1}{\mu^2 \cdot g^2} \left( v_0^2 - 2 \cdot TTC \cdot v_0 \cdot \mu \cdot g \right)} \]

\[ \iff t = \frac{v_0}{\mu \cdot g} - \frac{1}{\mu \cdot g} \sqrt{v_0^2 - 2 \cdot TTC \cdot v_0 \cdot \mu \cdot g} \]

\[ t \cdot \mu \cdot g = v_0 - \sqrt{v_0^2 - 2 \cdot TTC \cdot v_0 \cdot \mu \cdot g} \]

This is the time duration from initial braking to collision. Now this goes back to the velocity equation, the first one:

\[ \dot{x}(t) = v_0 - \mu \cdot g \cdot t \]

\[ \dot{x} = v_0 - v_0 + \sqrt{v_0^2 - 2 \cdot TTC \cdot v_0 \cdot \mu \cdot g} \]

\[ v_{\text{Impact}} = \sqrt{v_0^2 - 2 \cdot TTC \cdot v_0 \cdot \mu \cdot g} \]

Let’s substitute \( \mu g \) with the deceleration level \( d \) (positive for braking), then the final result for the residual speed at impact is:

\[ v_{\text{Impact}} = \sqrt{v_0^2 - 2 \cdot TTC \cdot v_0 \cdot d} \]