Last Point to Brake/Last Point to Steer for Trucks

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Method

Goal

- Derive performance requirements from basic principles
- Break down definition of AEBS performance to a few parameters
- This method has been used in AEBS-M1-N1 (for R152)

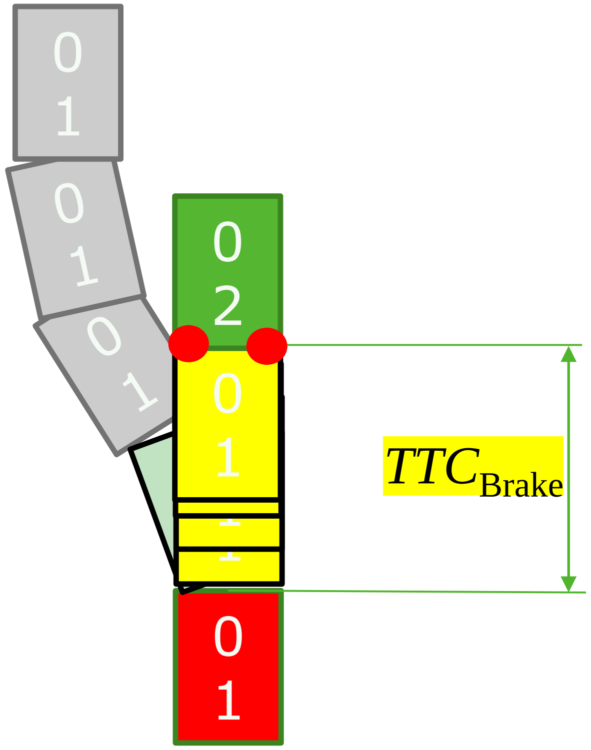
Some References (from Informal Working Group AEBS-M1N1)

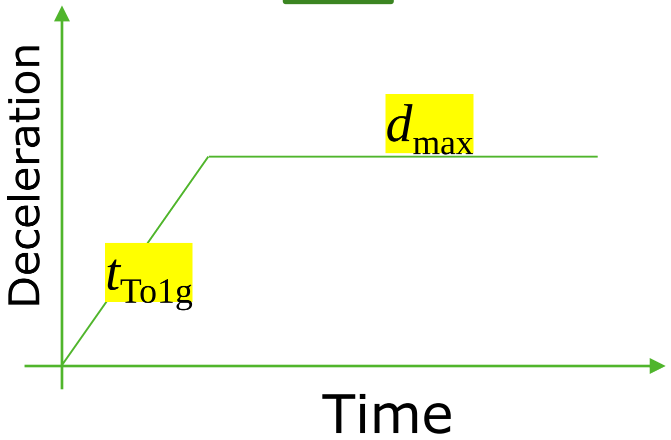
- GRVA-01-31: Speed reduction calculation sheet
  https://unece.org/DAM/trans/doc/2018/wp29grva/GRVA-01-31.zip
- AEBS-M1N1-03-04: LPB/LPS and pedestrian safety zone
  https://wiki.unece.org/download/attachments/54429506/AEBS-03-04%20%28D%29%20Comments%20to%20skelton.pdf
- AEBS-M1N1-04-05: LPB/LPS and pedestrian safety zone (cont‘d)
  https://wiki.unece.org/download/attachments/60360943/AEBS-04-05%20%28Germany%29%20D%20approach.pdf
- AEBS-M1N1-11-02: Bicycle brake performance
  https://wiki.unece.org/download/attachments/94046350/AEBS-11-02%20%28D%29%20Bicycle%20braking%20performance.pdf

Concept from AEBS-M1-N1 (1)

Car-Car Scenarios *(longitudinal conflict situations, vehicles moving in same direction)*

- Braking possible at the latest at „Last Point to Steer" LPS
  - TTC_{Brake}
  - Depends on vehicle width, possible a_y
- Identify possible speed reduction after LPS with brake system characteristics
  - Time to 1g - t_{To1g}
  - Maximum deceleration - d_{max}





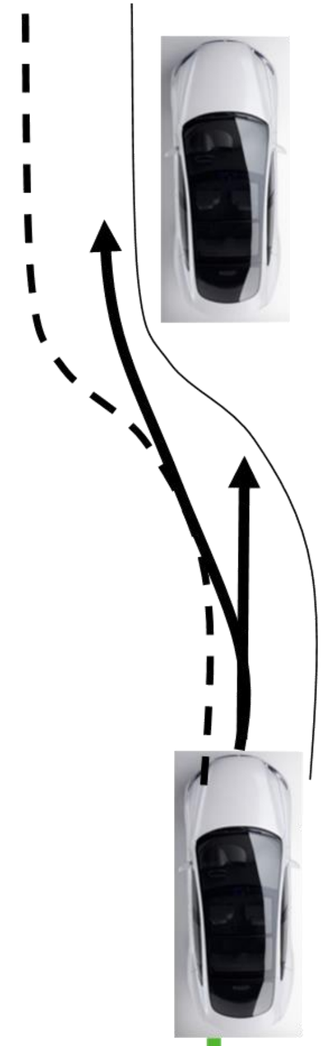
From AEBS-02-11

Federal Ministry
of Transport and
Digital Infrastructure

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

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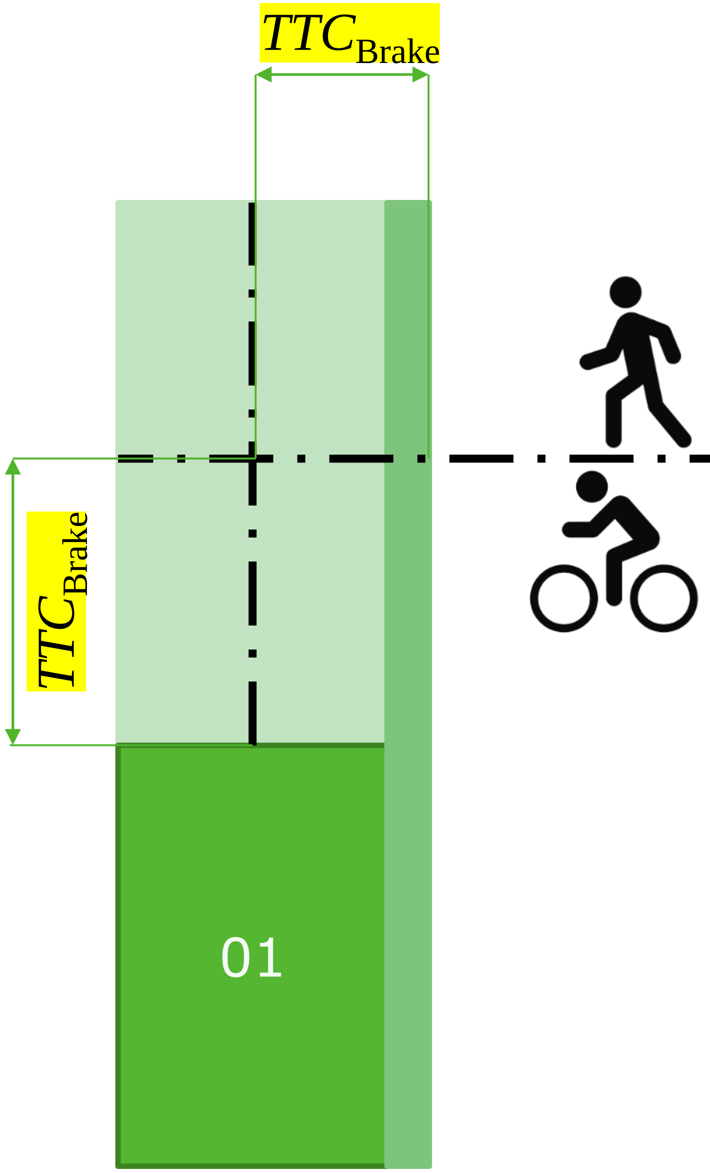
Concept from AEBS-M1-N1 (2)

Car-VRU Scenarios

(lateral conflict situations, vehicle + VRU moving orthogonal)

- LPS not meaningful
- Brake at the latest when VRU is in vehicle path (evt. including safety zone/stopping dist)
  - TTC_{Brake}
  - Depends on vehicle width, decel of VRU, impact location
- Identify possible speed reduction after LPS with brake system characteristics
  - Time to 1g - t_{To1g}
  - Maximum deceleration - d_{max}

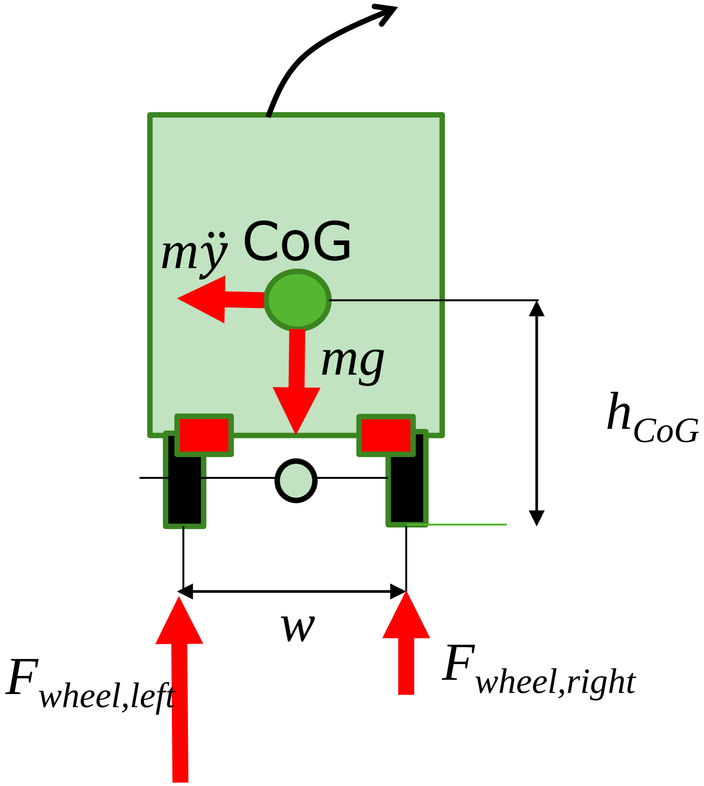


Overall concepts and assumptions

- Do not define exact brake behavior!
- Define performance requirements (speed reduction) instead in order to leave the exact algorithm to the VMs

- Derive performance requirements from physical model of the system
    - Ego vehicle should brake at the latest when avoidance per steering is not possible anymore (→ **TTC for the start of braking**)
    - At start of braking, increase brake decel linear until it reaches the maximum deceleration (→ **Time to 1 g**)
    - Maintain maximum deceleration until standstill (→ **d_max**)

General Properties – Tipping when turning



Right wheel load is

$$F_{wheel,right} = \frac{1}{2} m \cdot g - m \cdot \ddot{y} \cdot \frac{h_{CoG}}{w}$$

Tipping when right wheel load is 0:

$$\ddot{y} = \frac{w}{2 \cdot h_{CoG}} g$$

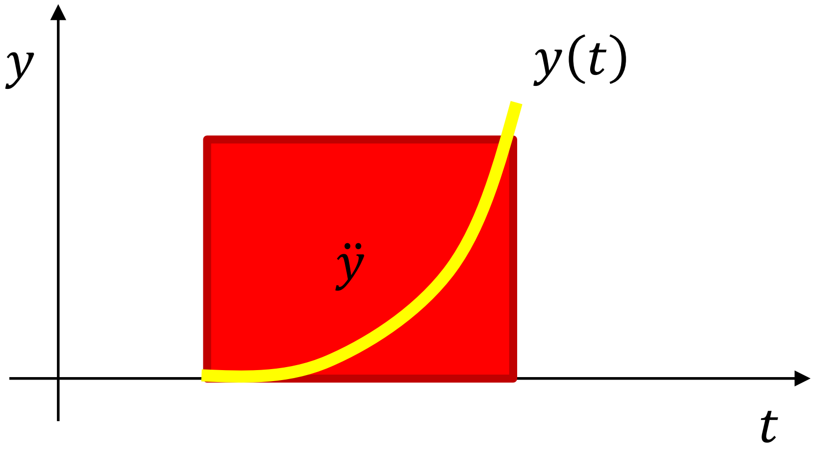
Example:

$$\ddot{y} = \frac{2\ \mathrm{m}}{2 \cdot 3\mathrm{m}} \mathrm{g} = 0.33\mathrm{g}$$

Lateral Movement and Last Point to Steer

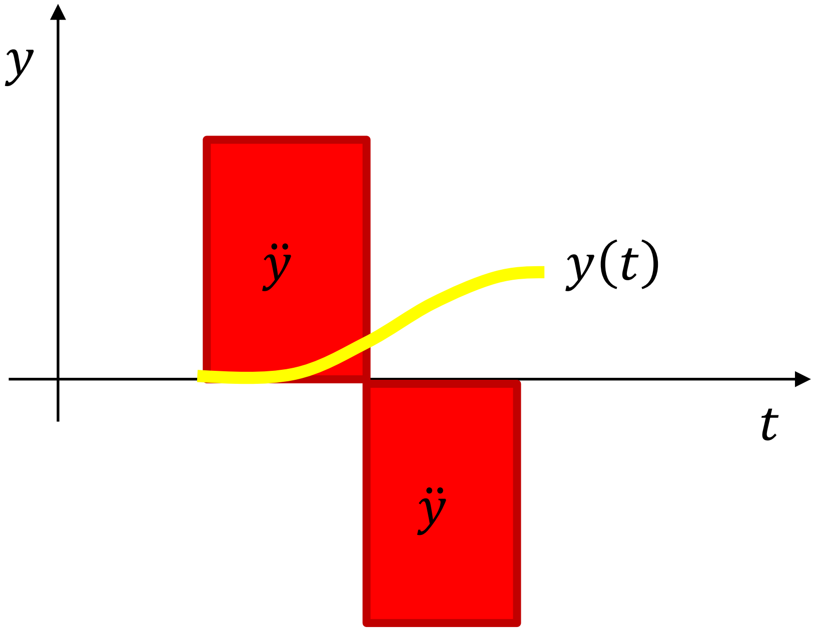
$$y(t) = \iint \ddot{y}\,\mathrm{d}t^2 = \left[\frac{1}{2}\ddot{y}t^2\right]_{t=0}^{t=t_{end}}$$

$$t_{end} = \sqrt{\frac{2y_0}{\ddot{y}}}$$



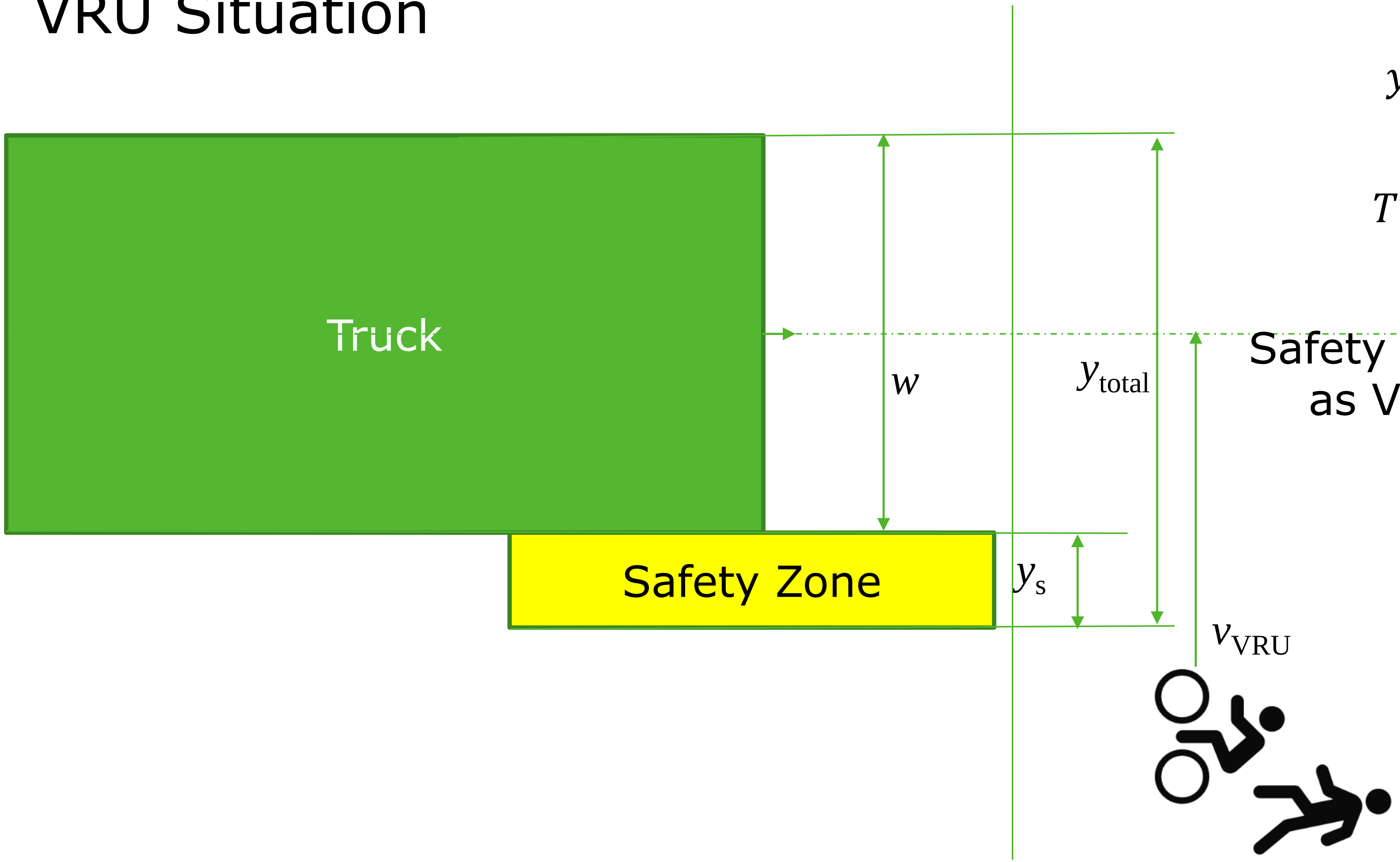
Using Symetry:

$$t_{end} = 2\sqrt{\frac{y_0}{\ddot{y}}}$$



More appropriate for heavy vehicles due to poor lateral dynamics.

VRU Situation



$$y_{total} = y_s + \frac{w}{2}$$

$$TTC_{Brake} = \frac{y_s}{v_{VRU}} + \frac{w}{2 \cdot v_{VRU}}$$

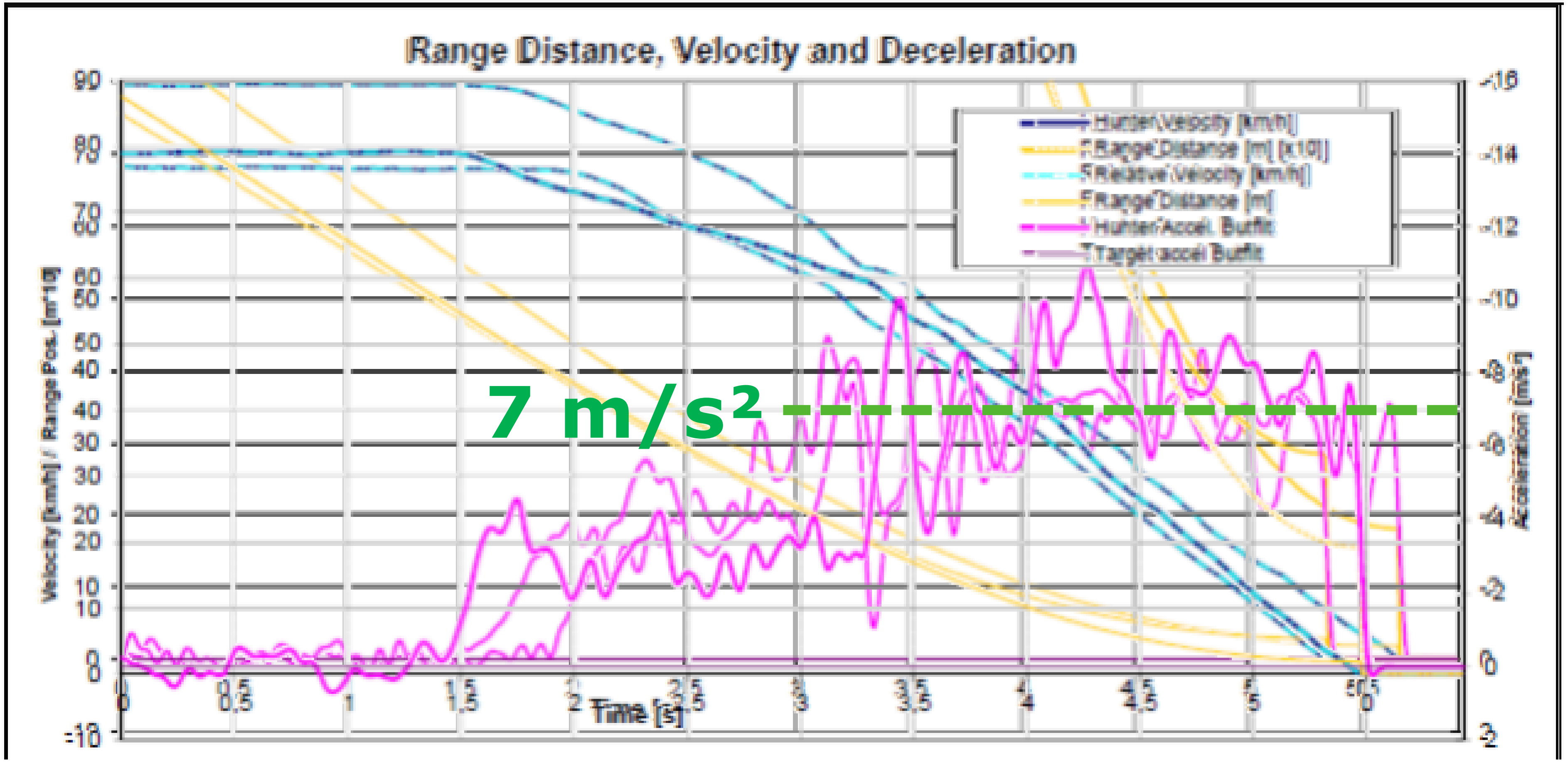
Safety Zone can be interpreted as VRU stopping distance:

$$y_s = \frac{v_{VRU}^2}{2 \cdot a_{VRU}}$$

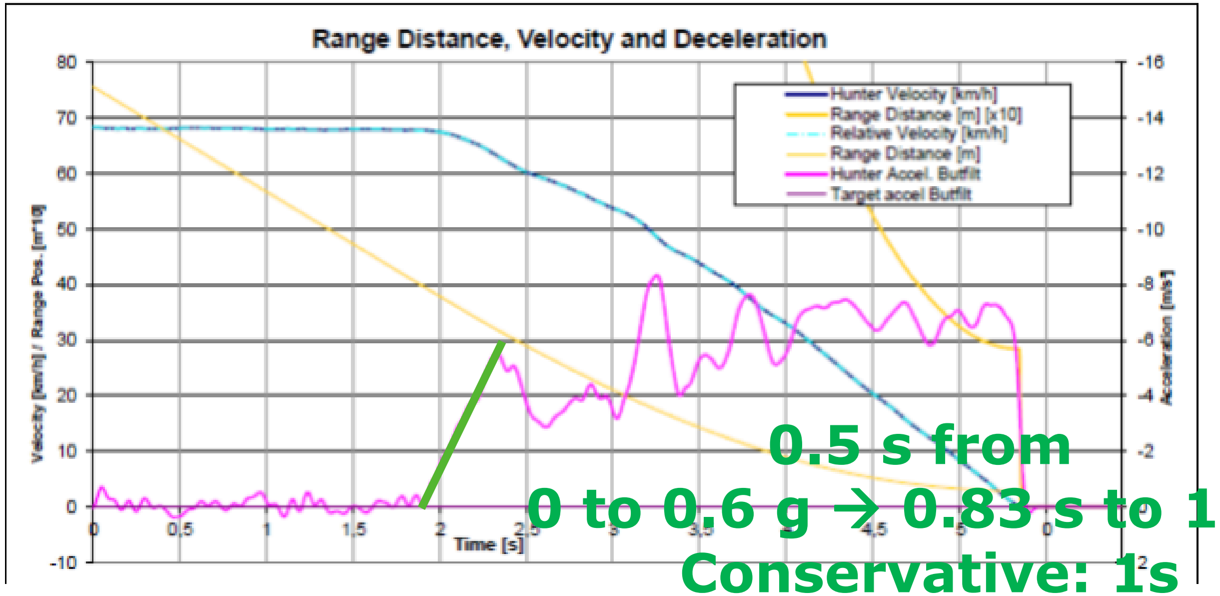
$$TTC_{Brake} = \frac{v_{VRU}}{2 \cdot a_{VRU}} + \frac{w}{2 \cdot v_{VRU}}$$

Calculations

Deceleration of fully loaded N3-tractor-semitrailer combinations, 3 major brands (data: ADAC)



Time to 1 g



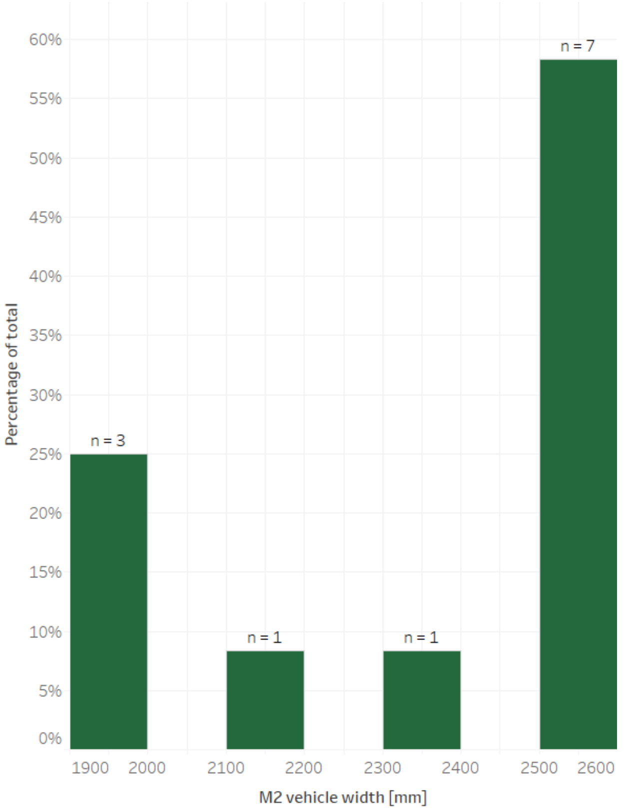
0.5 s from

0 to 0.6 g → 0.83 s to 1.0 g

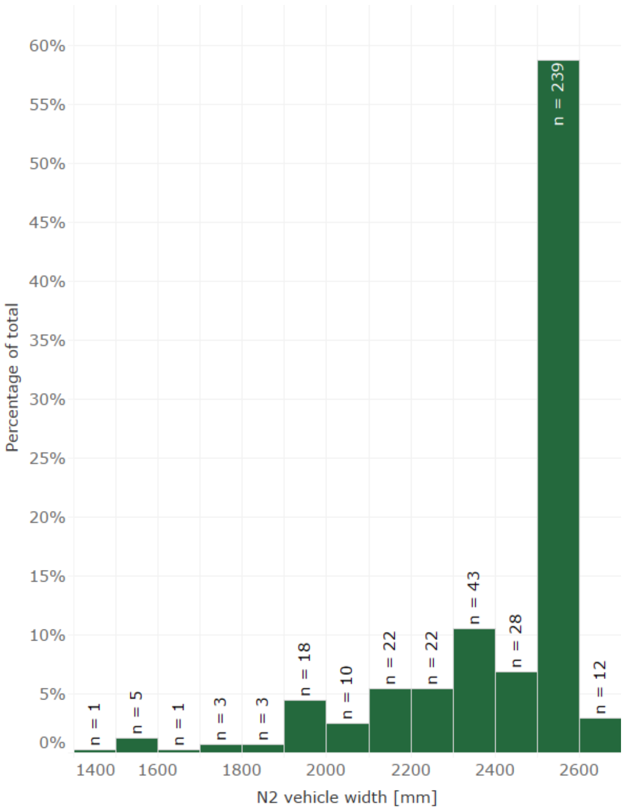
Conservative: 1s

Vehicle width

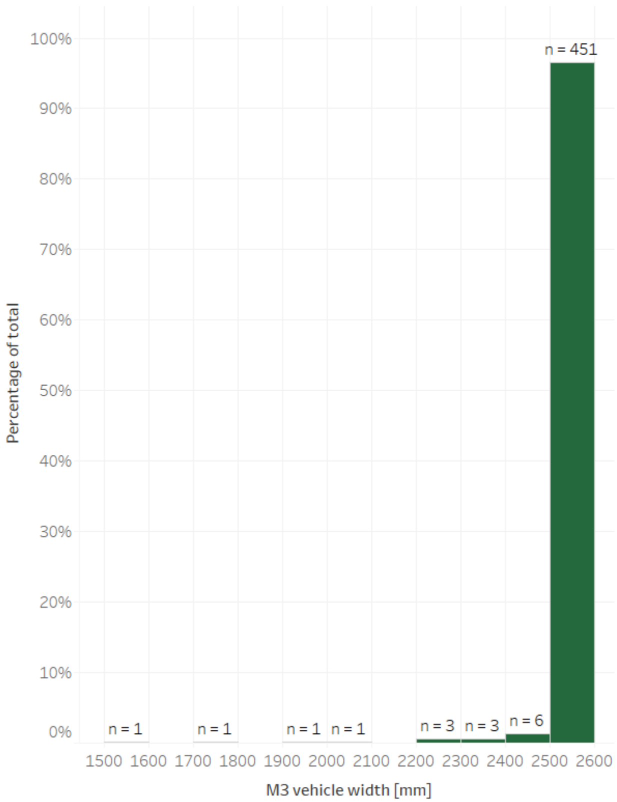
M2



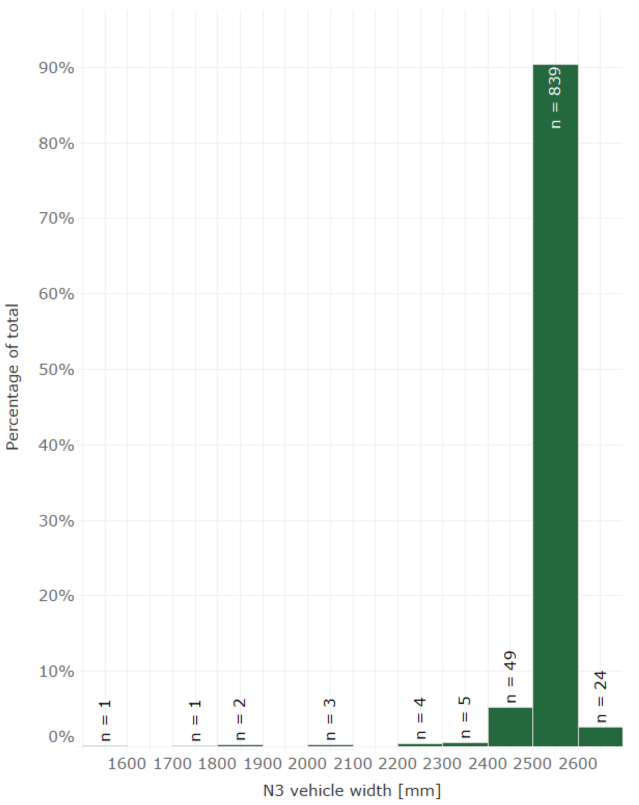
N2



M3



N3

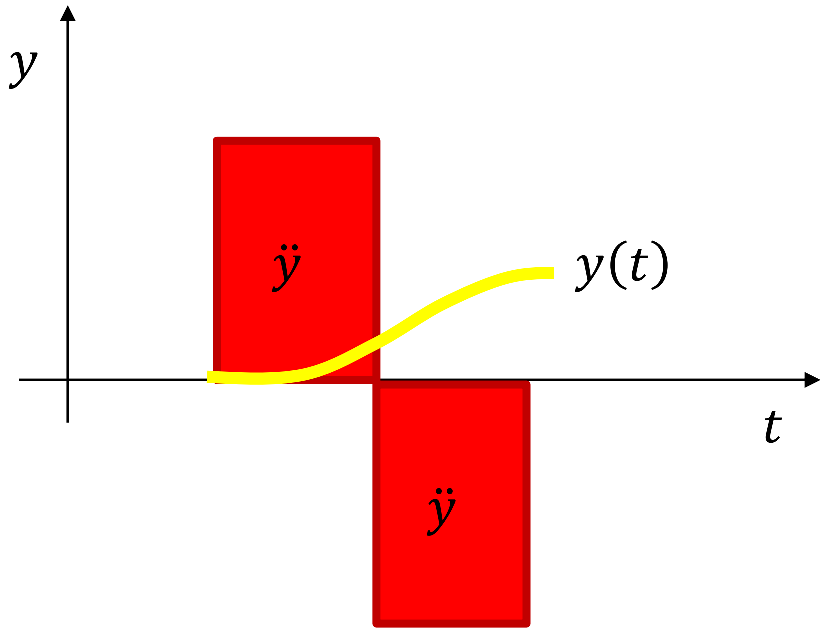


➲ Vehicle width used for calculation:

- M2/N2: 2000 mm (due to small share in the accident situation)
- M3/N3: 2550 mm

Lateral Movement and Last Point to Steer

$$t_{end} = 2\sqrt{\frac{y_0}{\ddot{y}}}$$



Width M3/N3 limited to 2.55 m

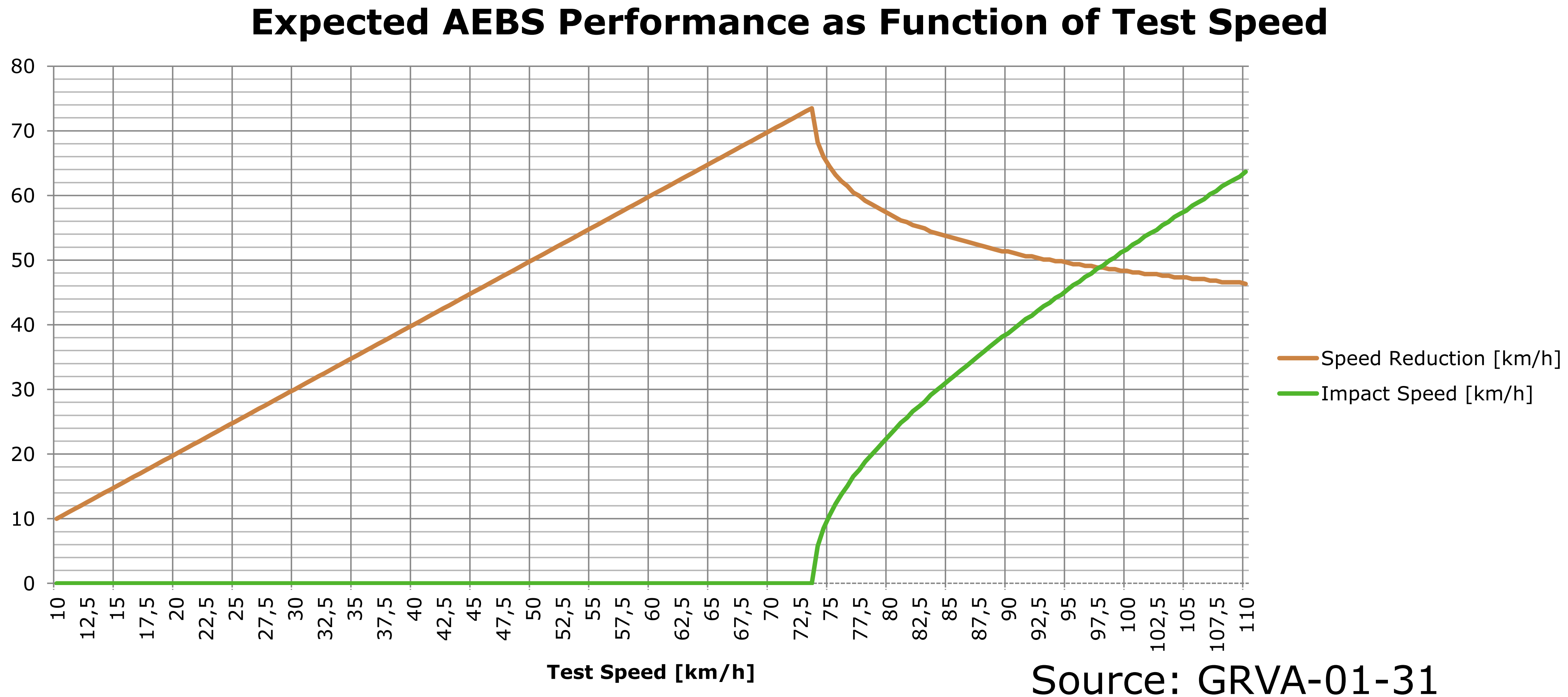
$$t_{end} = 2\sqrt{\frac{2.55\text{m}}{3\text{m/s}^2}} = 1.84\text{s}$$

Width M2/N2 from 2 to 2.55 m

$$t_{end} = 2\sqrt{\frac{2\text{m}}{3\text{m/s}^2}} = 1.63\text{s}$$

Expected AEB Performance (using GRVA-01-31)

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



Source: GRVA-01-31

Results (brake when VRU in path)

$$TTC_{Brake} = \frac{w}{2 \cdot v_{VRU}}$$

Parameter	Value	Source
v_{VRU}	5 km/h = 1,39 m/s (Ped) 15 km/h = 4,17 m/s	UN-R152
w	2 m (N2/M2) 2.55 m (N3/M3)	N2/M2: Typical width N3/M3: EU Dimensions limit

	Pedestrian	Bicycle
N2/M2	0.72 s (20 km/h*)	0.24 s (1.5 km/h*)
N3/M3	0.91 s (29 km/h*)	0.3 s (2 km/h*)

* Avoidance speed, calculated using GRVA-01-31 with 7 m/s² peak deceleration, 1 s Time-to-1-g.

Results (with safety zone)

$$TTC_{Brake} = \frac{v_{VRU}}{2 \cdot a_{VRU}} + \frac{w}{2 \cdot v_{VRU}}$$

Parameter	Value	Source
v_{VRU}	5 km/h = 1,39 m/s (Ped) 15 km/h = 4,17 m/s	UN-R152
a_{VRU}	1,5 … 3 m/s² (Ped) 4…5 m/s² (Bicycle)	Ped: Tiemann, N., Branz, W., Schramm, D.: *„Predictive Pedestrian Protection – Situation Analysis with a Pedestrian Motion Model*". In: Proceedings of the 10th International Symposium on Advanced Vehicle Control. Loughborough, UK, 2010. Bicycle: AEBS-11-02 (AEBS-M1-N1=
w	2 m (N2/M2) 2.55 m (N3/M3)	N2/M2: Typical width N3/M3: EU Dimensions limit

	Pedestrian	Bicycle
N2/M2	1.03 s (35 km/h*)	0.76 s (22 km/h*)
N3/M3	1.09 s (38 km/h*)	0.82 s (25 km/h*)

* Avoidance speed, calculated using GRVA-01-31 with 7 m/s² peak deceleration, 1 s Time-to-1-g.

Conclusions and Position

Possible Avoidance Speeds (up to…)

(Mitigation to be discussed later)

Theoretical considerations; only few systems availabe.

Vehicle Category	Vehicle-Vehicle (DE Position)	Vehicle-Pedestrian (Step 1)*	Vehicle-Bicycle (Step 1)	Vehicle-Pedestrian (Step 2)*	Vehicle-Bicycle (Step 2)*
N2	65 km/h	20 km/h	-	35 km/h	22 km/h
M2	65 km/h	20 km/h	-	35 km/h	22 km/h
N3	75 km/h**	29 km/h	-	38 km/h	25 km/h
M3	75 km/h**	29 km/h	-	38 km/h	25 km/h

*It should be noted that these speed reductions are possible ONLY when the mandatory warning phase of 1.4s is removed.

**Measurement data from production vehicles confirms these values.