Submitted by the expert from Germany

Federal Ministry
of Transport and
Digital Infrastructure

Informal document **GRVA-01-30**
1st GRVA, 25-28 September 2018
Agenda item 7

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

Structure - Overview

Current Structure:

5 – Specifications
- General requirements

6 – Testing
- Warning timing
- Restriction of speed Reduction in warning phase
- Definition of test speed (ego Vehicle)
- Tolerances

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:

5 – Specifications
- General requirements
- Warning timing for whole speed range
- Speed reduction

6 – Testing
- Tolerances
- Parametric test description
- Test speeds
- Pass/fail per reference to chapter 5

Target

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

Federal Ministry
of Transport and
Digital Infrastructure

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 <u>state of the art</u>; included for clarification.

Warning

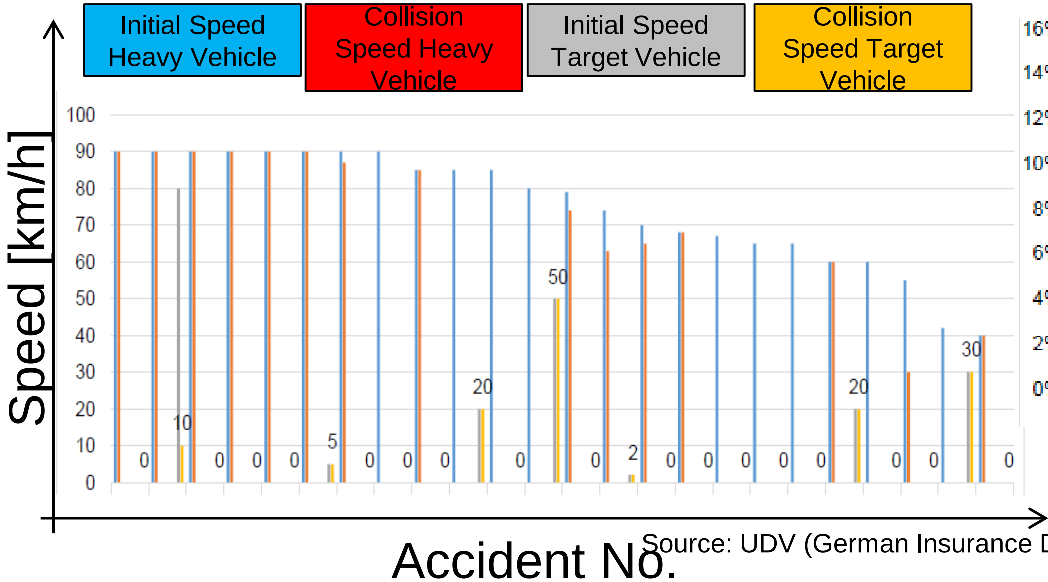
- Current warning requirements: too frequent warnings in certain situations
  - Low speeds: Manual brake application in regular situations late
  - Warning required 1.4 seconds before emergency brake phase → long before manual brake application!
- Current warning requirements prevent effective braking 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

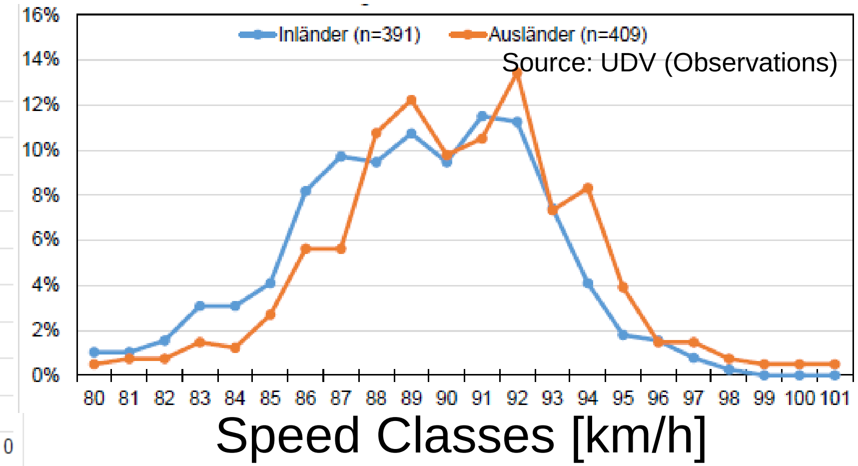
- Documents ECE/TRANS/WP.29/GRRF/2017/24 and GRRF-86-32 included in the text
- Changes to warning timing (effectively removing mandatory warnings for city speeds)
  → less unjustified warnings in cities! See GRRF-85-21, third bullet point
- While GRRF-86-32 introduced provisions for detecting sensor 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 N_3 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



Source: UDV (German Insurance Data)



Source: UDV (Observations)

Federal Ministry of Transport and Digital Infrastructure

Performance Requirements (Speeds in km/h)

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

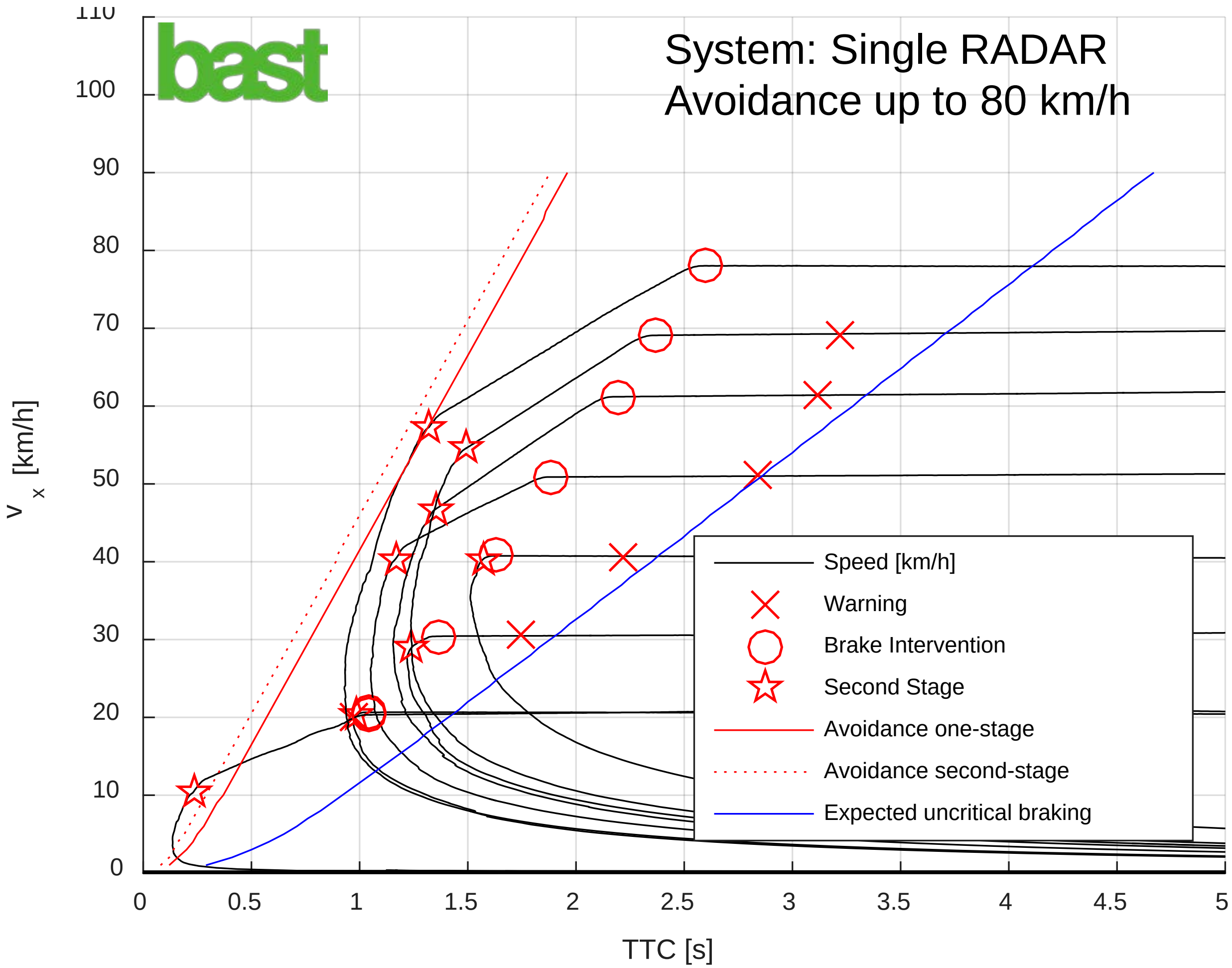
	Stationary Vehicles	Constant Moving Vehicles	Proposal
N2*, M2* (current R131)	v_{red} = 10	v_{red} = 12	$v_{rel,avoid}$ = 70 $v_{rel,red,mitig.}$ = f(v_{rel})
N3**, M3** (current R131)	v_{red} = 20	v_{red} = 68	$v_{rel,avoid}$ = 70 $v_{rel,red,mitig.}$ = f(v_{rel})
Test Speeds	80	v_{Ego} 80, v_{Target}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

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

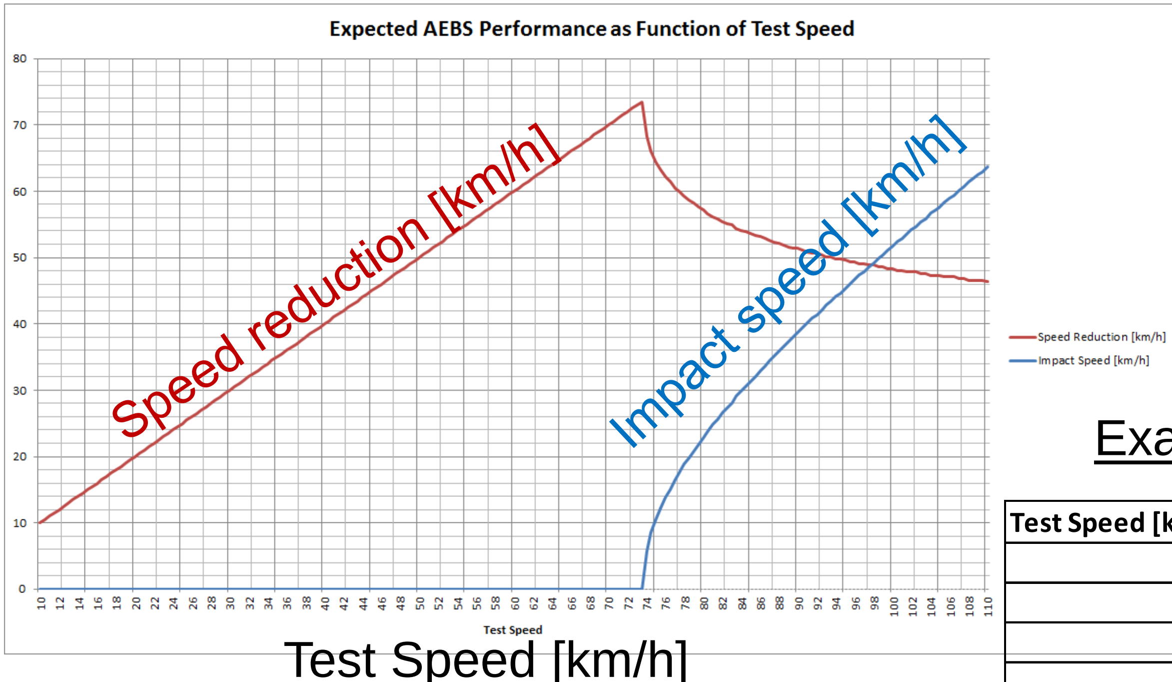


<u>Other Data:</u>

- **ADAC (2017)**
- 3 trucks from <u>independent</u> companies
- Trucks fully loaded
- Speed reduction: ≥ 70 km/h on stationary target
- 3 of 5 truck corporations with > 50% market share in Western Europe

Federal Ministry
of Transport and
Digital Infrastructure

Proposed Speed Reduction Requirements



Valid for parameters:

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

Example: Required Performance

Test Speed [km/h]	Speed Reduction [km/h]	Impact Speed [km/h]
10	10,00	0,00
20	20,00	0,00
30	30,00	0,00
40	40,00	0,00
50	50,00	0,00
60	60,00	0,00
70	70,00	0,00
80	57,16	22,84
90	51,36	38,64
100	48,34	51,66
110	46,32	63,68

(Derivation of curves: see annex to this presentation)

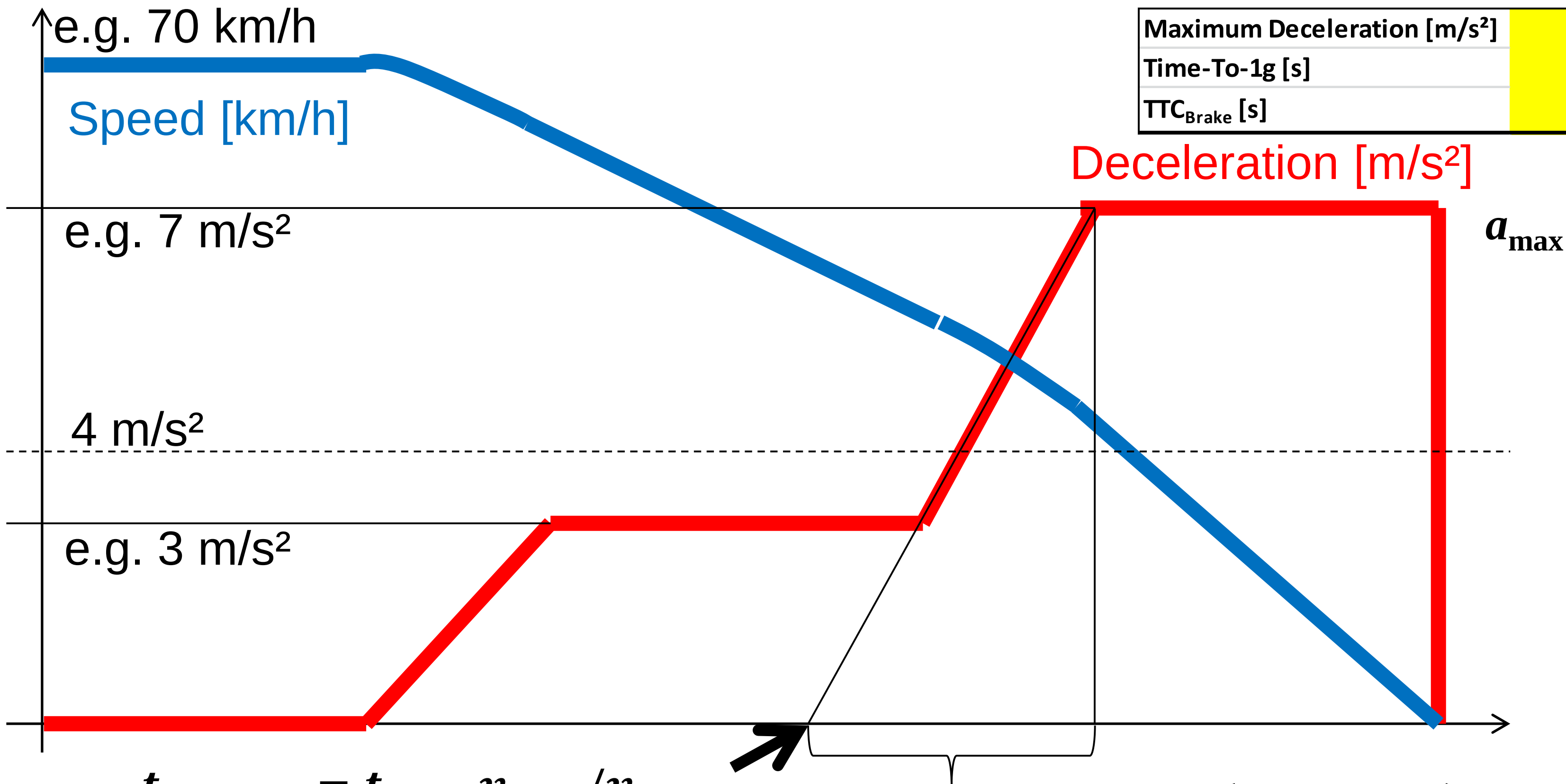
Federal Ministry of Transport and Digital Infrastructure

Identification of Parameters for Mitigation Req's possible from measurements

Hypothetical brake measurements

$$v_{\mathrm{impact,rel}} = \sqrt{v_{0,\mathrm{rel}}^2 - 2\left(t_{\mathrm{tc,Brake}} - \frac{1}{2} t_{\mathrm{Increase}}\right) \cdot v_{0,\mathrm{rel}} \cdot a_{\max}}$$

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



$$t_{tC,Brake} = t_{tC,4} \cdot v_{0,rel} / v_{4,rel}$$

$$t_{\mathrm{Increase}} = \frac{a_{\max} \cdot \left(t_{\mathrm{a,max}} - t_4\right)}{a_{\max} - 4\ \mathrm{m/s^2}}$$

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!)

Federal Ministry of Transport and Digital Infrastructure

Proposed Changes for Test Conduction

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

*Test Speed: (20 for stationary), 40, 60, 80, 100, $v_{\text{Avoidance}}$, v_{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 N_3, M_3) are able to meet the proposed performance requirements
  - Assumption: Different performance req's for lighter vehicles not needed anymoe.

Thank you for your attention!

Federal Ministry of Transport
and Digital Infrastructure

Robert-Schuman-Platz 1
D-53175 Bonn

Federal Ministry of Transport and Digital Infrastructure

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:

$$s = \frac{1}{2} \cdot a \cdot \frac{v^2}{a^2}$$

$$\Leftrightarrow s = \frac{v^2}{2 \cdot a}$$

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

$$TTC = \frac{\Delta x}{\Delta v} = \frac{s}{v}$$

$$\Leftrightarrow s = TTC \cdot v$$

Insert that into the stopping distance equation:

$$TTC \cdot v = \frac{v^2}{2 \cdot a}$$

$$TTC = \frac{v}{2 \cdot a}$$

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:

$$\dot{x}(t) = \int \ddot{x} \mathrm{d}t$$

$$\dot{x}(t) = -\mu \cdot g \cdot \int \mathrm{d}t$$

$$\dot{x}(t) = -\mu \cdot g \cdot t + C_0$$

Initial conditions for first equation:

$$\dot{x}(t=0) = v_0 \rightarrow C_0 = v_0$$

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

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

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

$$x(t) = v_0 \cdot \int \mathrm{d}t - \mu \cdot g \cdot \int t \mathrm{d}t$$

$$x(t) = v_0 \cdot t - \frac{1}{2} \mu \cdot g \cdot t^2 + C_1$$

Initial condition for location

$$x(t=0) = x_0 = -TTC \cdot v_0$$

$$C_1 = TTC \cdot v_0$$

Annex (2)

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

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

$$0 = v_0 \cdot t - \frac{1}{2}\mu \cdot g \cdot t^2 - TTC \cdot v_0 \quad \Big| : \left(-\frac{1}{2} \cdot \mu \cdot g\right)$$

$$\Leftrightarrow t^2 + \frac{-2v_0}{\mu \cdot g} \cdot t + \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g} = 0$$

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

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

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

$$\Leftrightarrow t_{1,2} = \frac{v_0}{\mu \cdot g} \pm \sqrt{\frac{v_0^{\,2}}{\mu^2 \cdot g^2} - \frac{2 \cdot TTC \cdot v_0}{\mu \cdot g}}$$

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:

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

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

$$\Leftrightarrow t = \frac{v_0}{\mu \cdot g} - \frac{1}{\mu \cdot g}\sqrt{{v_0}^2 - 2 \cdot TTC \cdot v_0 \cdot \mu \cdot g}$$

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

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 µg with the deceleration level d (positive for braking), then the final result for the residual speed at impact is:

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