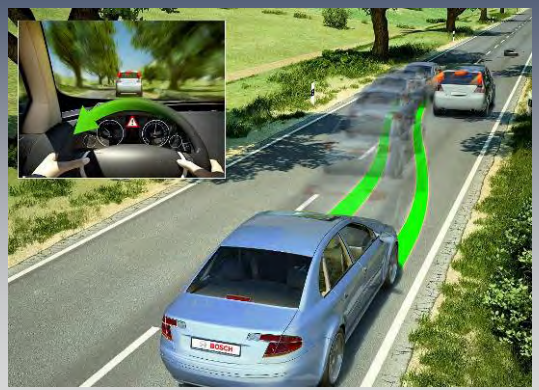
VMS
Vehicle Motion and Safety



Accident Avoidance by Evasive Manoeuvres

Challenges and steps towards technical solutions

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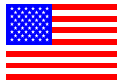
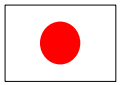
Motivation

➔ **Relevance of rear end crashes <u>with injuries</u> in 2006:**

	Number of rear end crashes	Share in all accidents
	500,000	28%
	284,000	32%
	266,000	16%
	49,200	15%

Real world accident example

Source: Youtube.com

➔ **Rear end crashes with injuries are very relevant**

➔ **Between 80% and 90% of all rear end crashes are caused by cars**

Sources: NHTSA/NCSA, IATSS, DESTATIS Year 2006, UNECE accident report, own calculation, EU27

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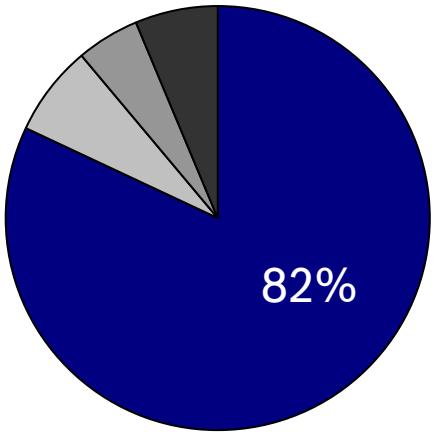
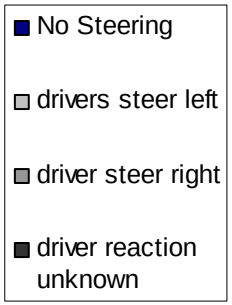
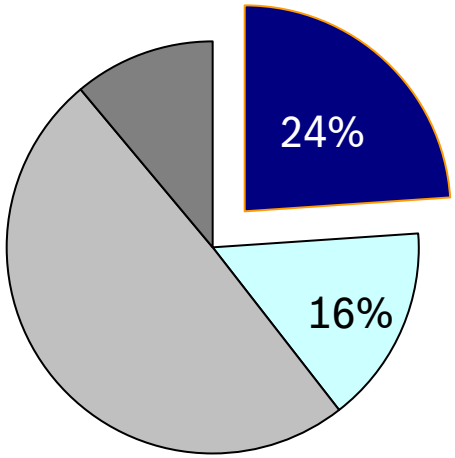
Options of accident avoidance by evasion

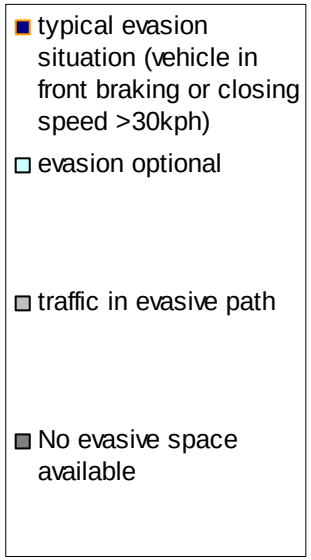
Driver reaction in rear end crashes with injuries.





Availability of adequate conditions for collision avoidance by evasion in rear end crashes.





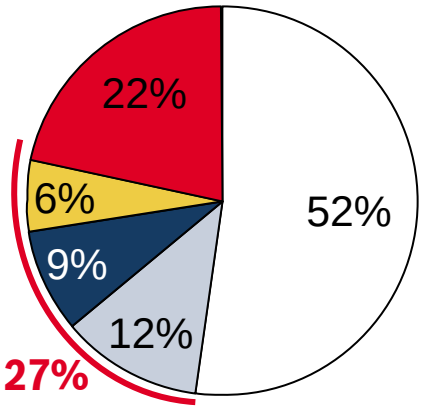
(n=635 accidents: rear end crashes with car as main causer, hitting opponent from the rear)

GIDAS German In-Depth Accident Study
(weighted and reconstructed, 2001-2004)

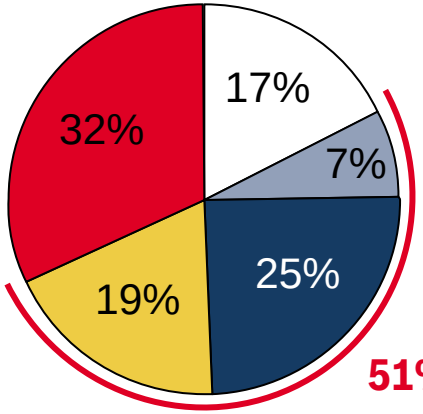
Steering as a reaction in critical situations*

*: As a result of a study in cooperation with Daimler AG´s driving simulator **. Number of persons participating in the study: 70

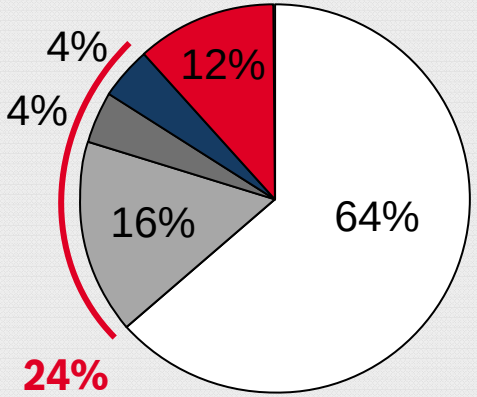
Rear-end collision on highway



Entering vehicle @ intersection



Lane changing vehicle up-front



- braking to full stop (w/o steering)
- braking to full stop & steering
- evasion (w/o braking)
- collision
- collision despite steering
- braking
- braking & steering left
- braking & steering right

→ Steering and evasion are drivers' options in order to avoid collisions

** from: H. Schittenhelm, *Fahrverhalten und Reaktionszeiten in kritischen Situationen*, VDI-Bericht 1911, Düsseldorf, 2005

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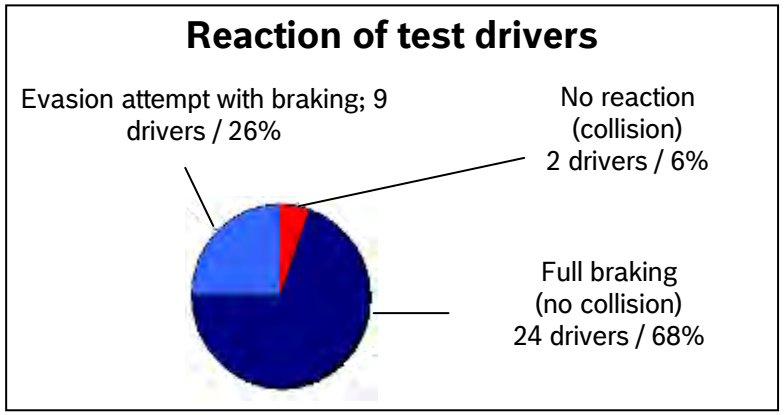
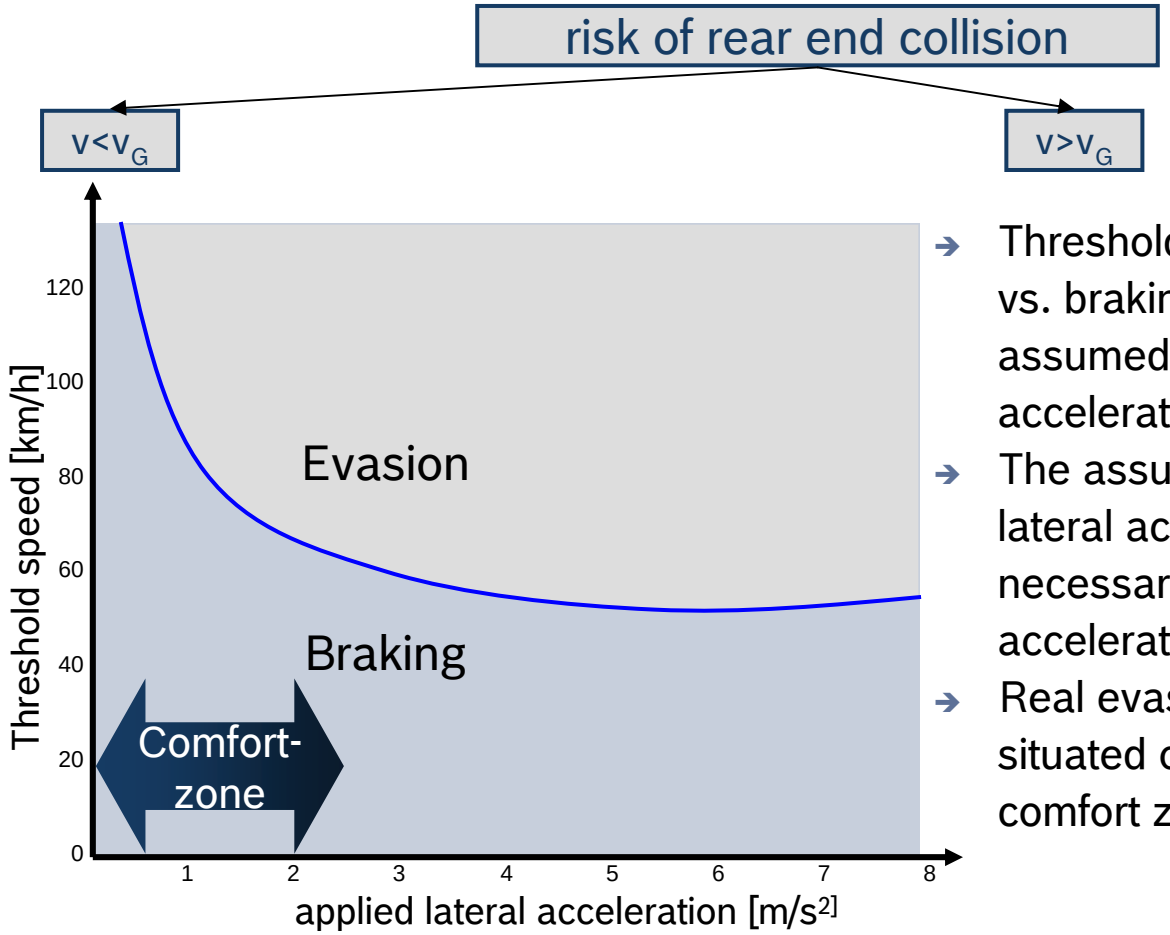
Evasive Steering: Studies with untrained drivers

Evasion CarClinic :

- Tests carried out with 35 untrained test drivers
  - Approx. 26% tried to evade the suddenly appearing obstacle
  - All test persons applied the brakes

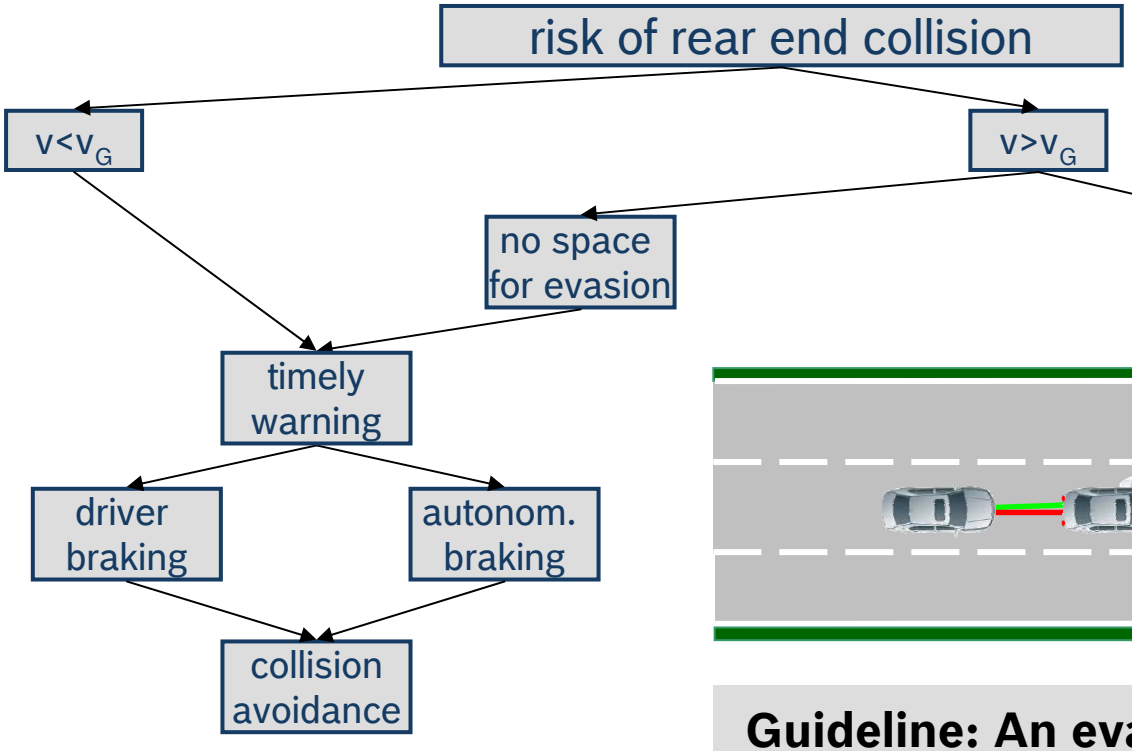


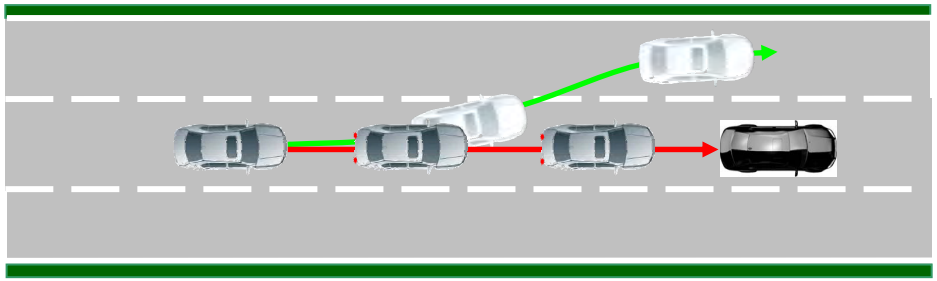
Topology of evasive maneuvers



- Threshold speed for evasion vs. braking depends on assumed maximum lateral acceleration
- The assumed maximum lateral acceleration is not necessarily the physical limit acceleration
- Real evasion usually is situated outside the driver‘s comfort zone

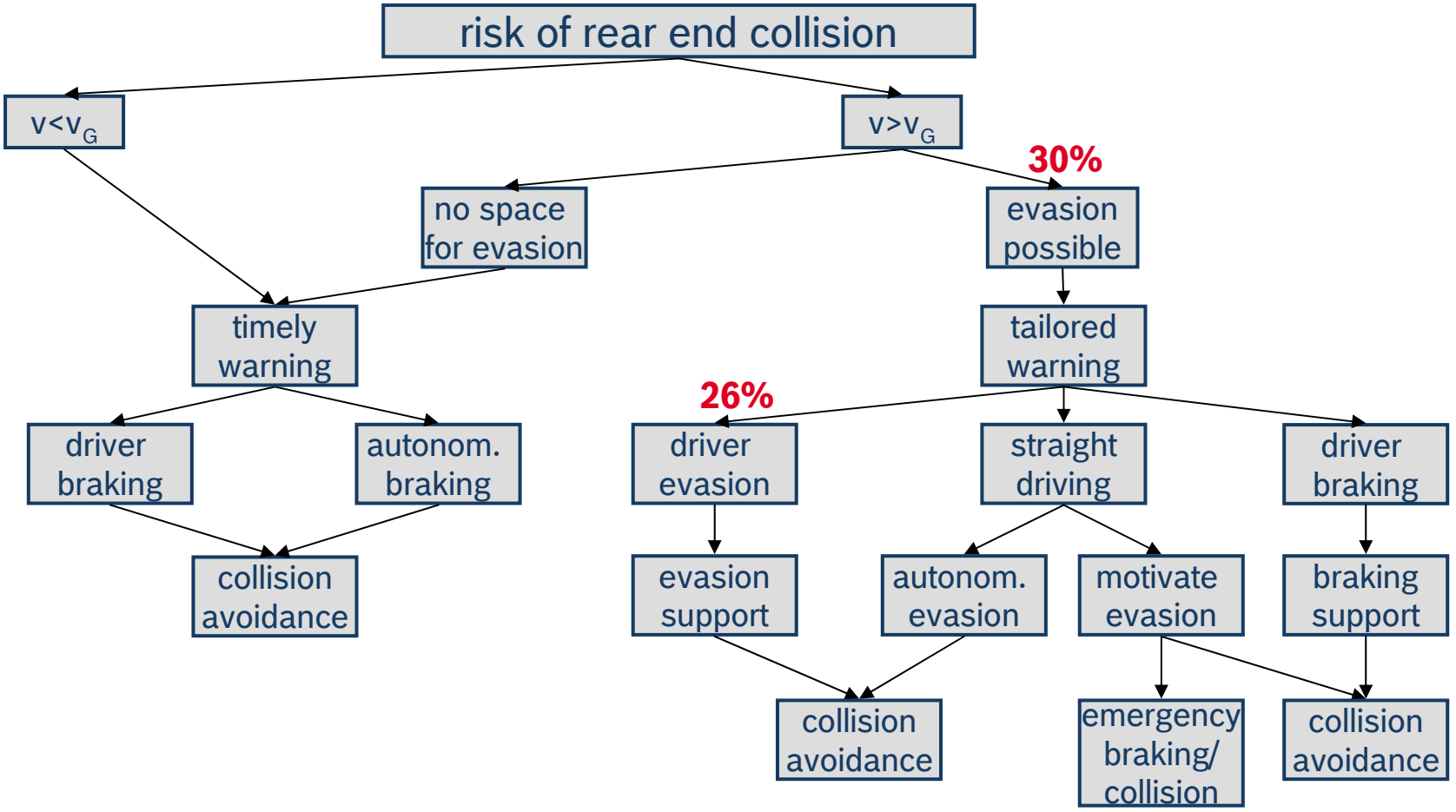
Topology of evasive maneuvers



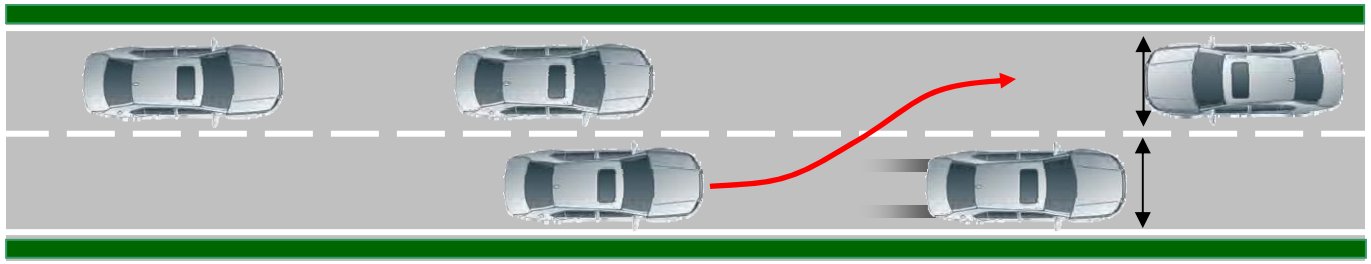


Guideline: An evasive maneuvre shall not be undertaken unless the collision is unavoidable by braking

Topology of evasive maneuvers

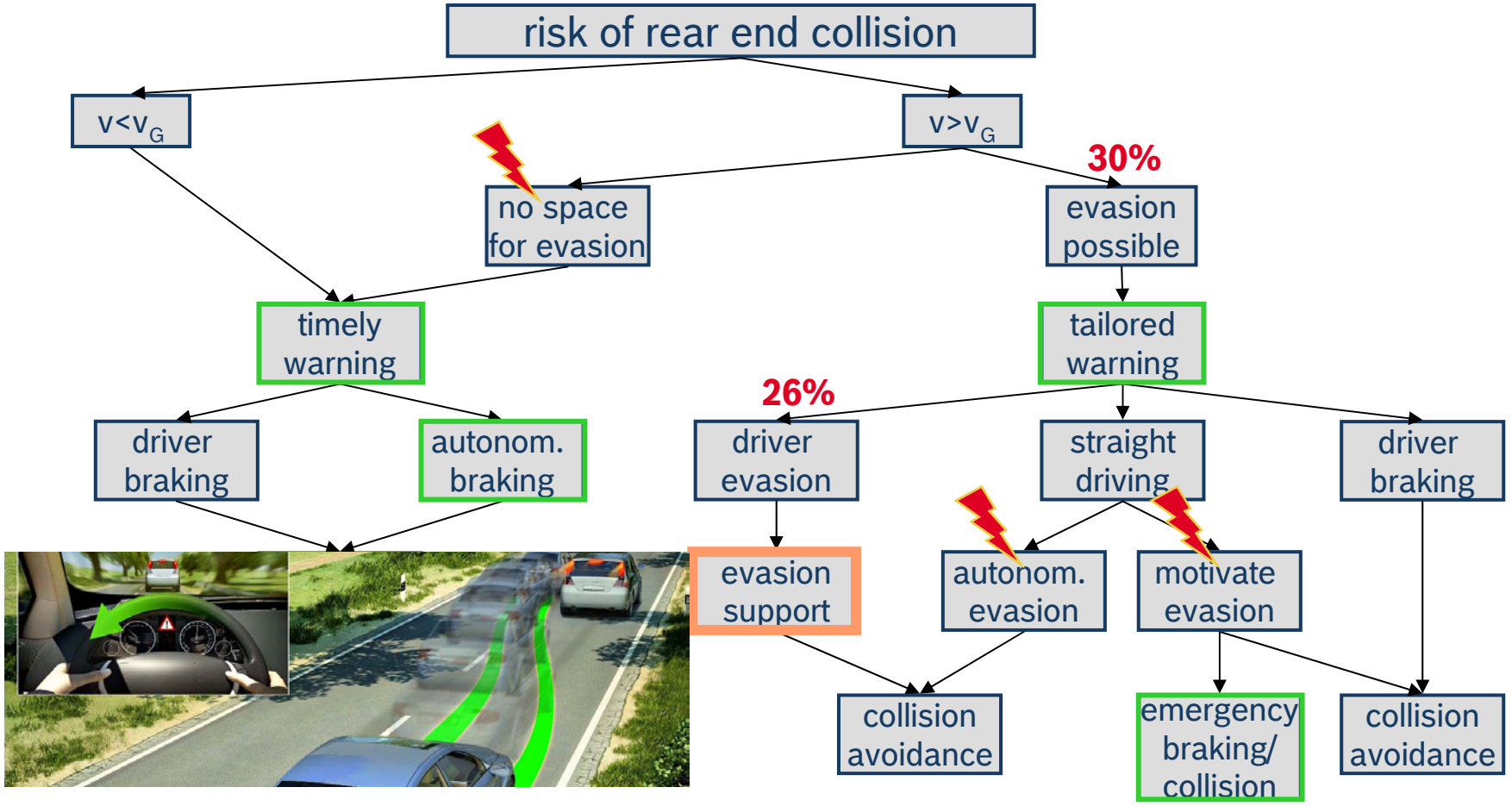


Challenges for automatic evasion maneuvers

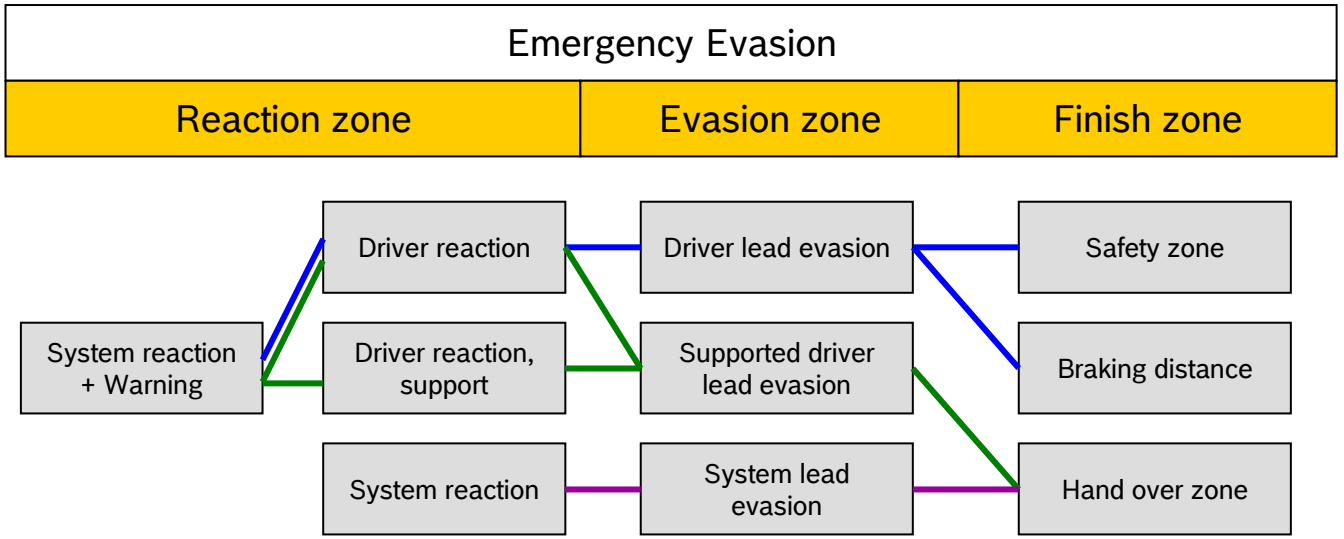


- Detection of oncoming traffic
- Detection of fast following traffic
- Detection of blind spot
- Detection of geometry of evasive path
    - e.g. Width of obstacle, width of evasion lane, …

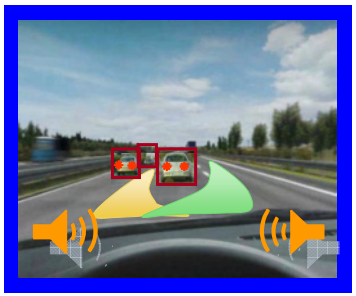
Topology of evasive maneuvers



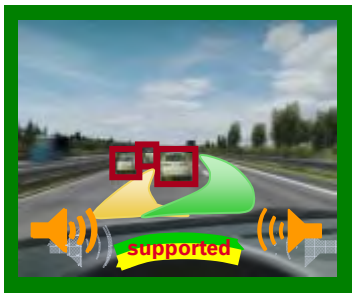
Accident avoidance by evasion – System pattern



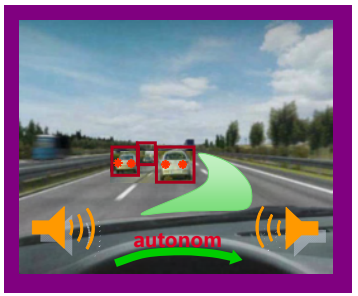
Warning w/o support



Warning w/ support



Autonomous

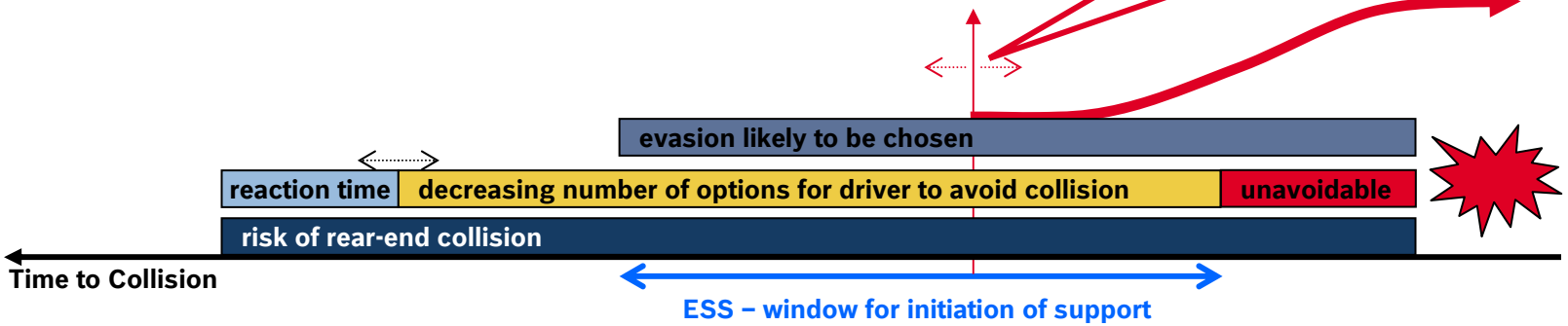


Evasive Steering Support (ESS) - Principles

critical driving situation

potential driver intention:
avoidance by evasion

evasion support
***triggered** by driver*



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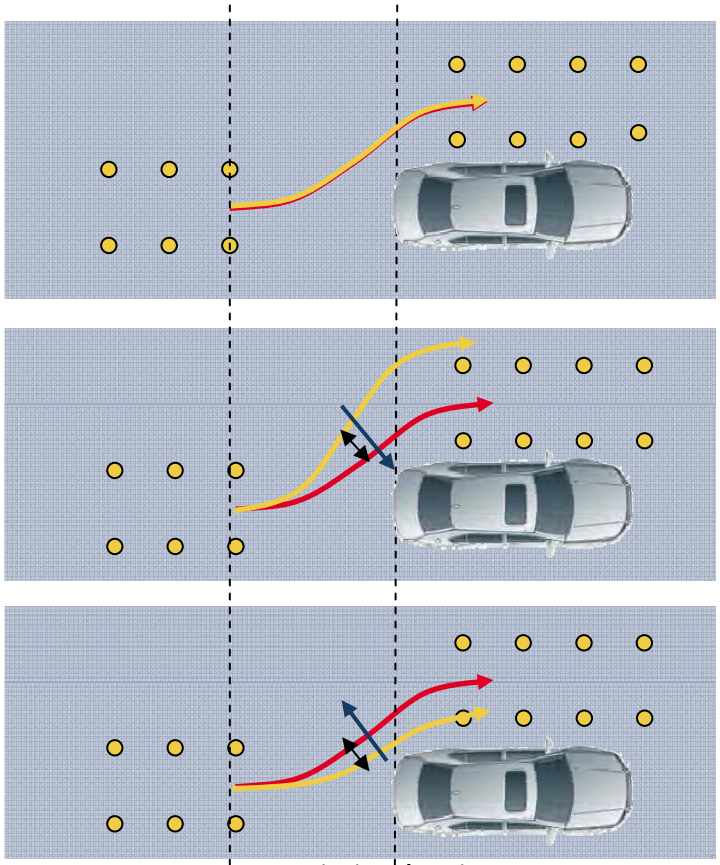
Technical characteristics – Support strategy



Optimized trajectory
Drivers reaction without ESS

The driver steers on the optimal evasion trajectory

What ESS does:

- ESS provides no support at all as long as the driver does not decide to perform an evasive maneuver

The driver overreacts

What ESS does:

- **Corrective torque** on the steering wheel

The driver underreacts

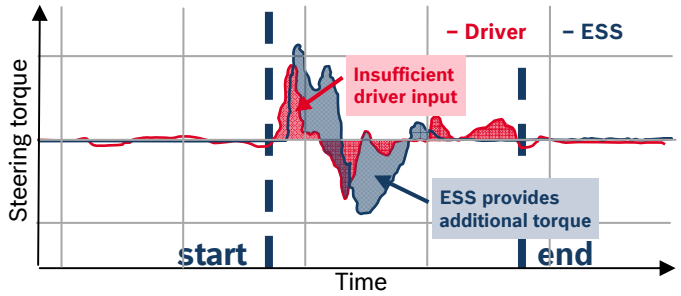
What ESS does:

- Supports the driver during evasion with **additional torque** on the steering wheel

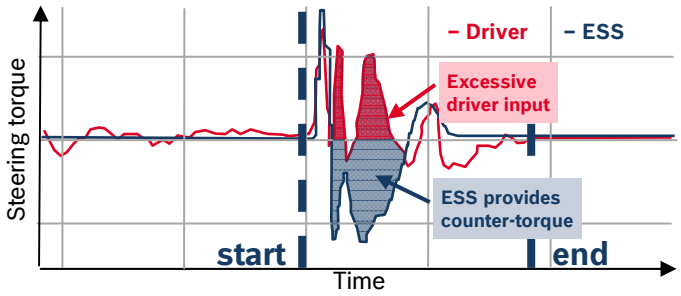
ESS controller deviation
Direction of ESS torque intervention

Demonstrations: over and under-reaction

1. Driver under-reacts (with ESS)



2. Driver over-reacts (with ESS)



➔ ESS corrects the driver's insufficient input in case n°1 and the excessive reaction in case n°2. In both cases the right amount of steering torque is finally input. The obstacle is safely avoided.

Please keep in mind: the following examples are for demonstration purposes only and do not represent the actual performance of the system in a real danger situation.

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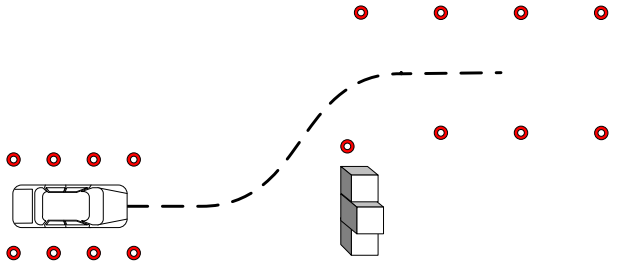
Effect and benefit of ESS

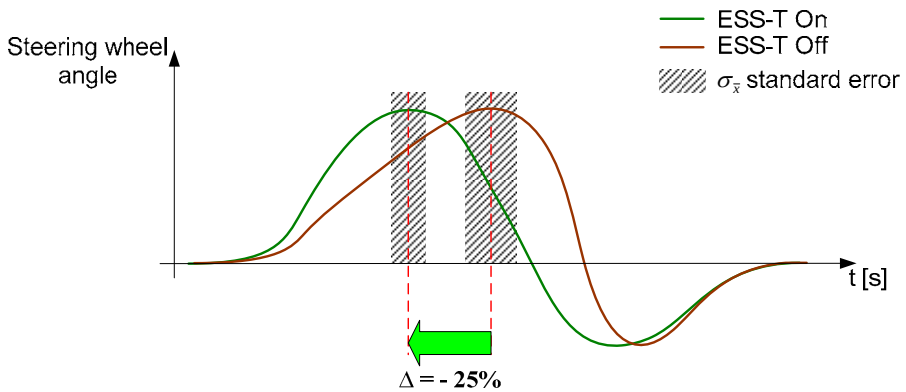
Method

- Internal study using prototype vehicle
- Number of persons participating: 41
- Evasion maneuver with 60 kph



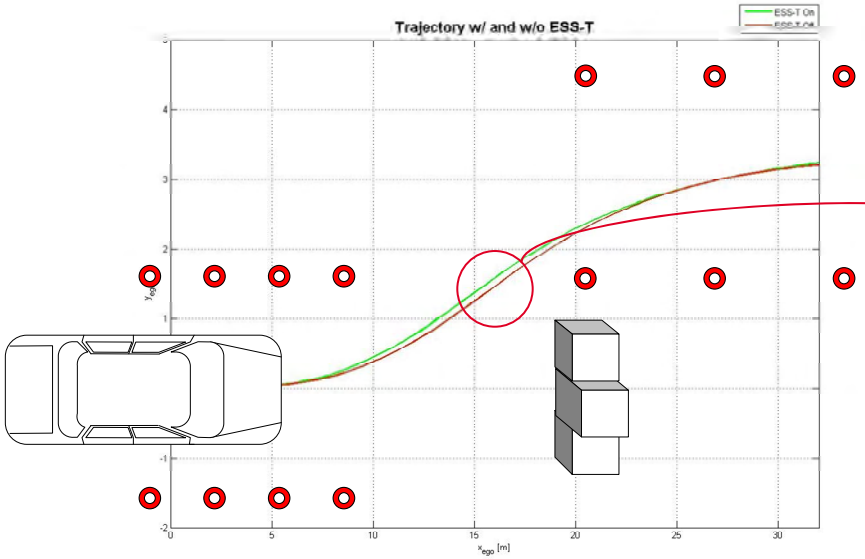
Result

- The Maximum steering wheel angle reached 25% earlier (Mean values)
  - higher steering wheel angular velocity
  - More calm steering behaviour



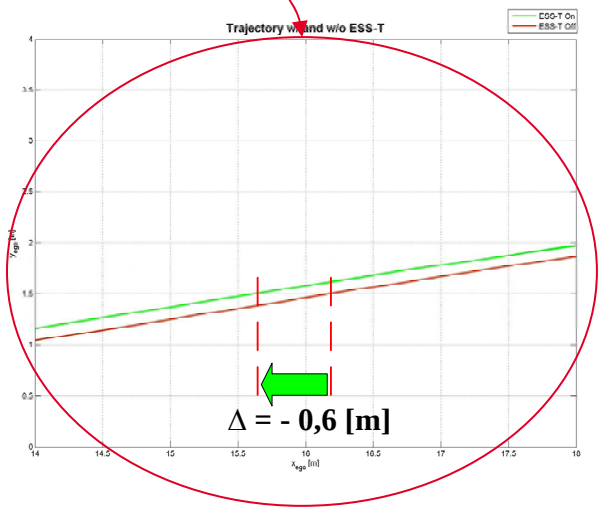
Drivers' steering reaction is improved by ESS

Result of the improved steering behaviour



➔ Same lateral position is reached 60 [cm] earlier

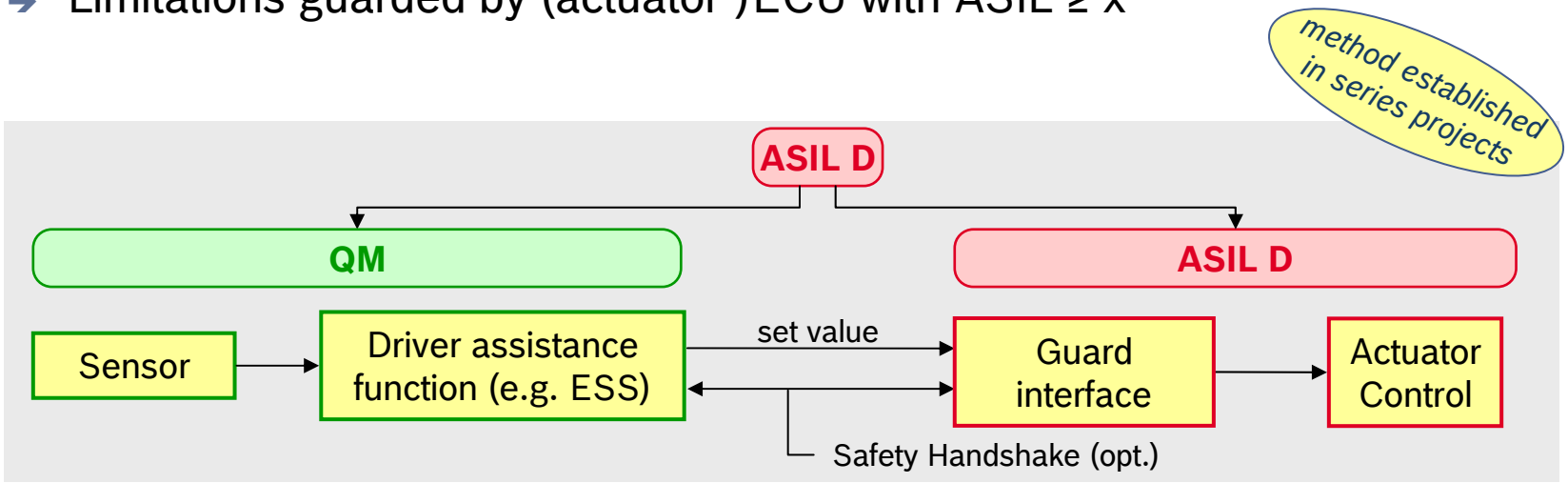
- Increased degree of freedom to avoid a collision with the obstacle



Evasion trajectory is improved by ESS

Safety decomposition of ESS

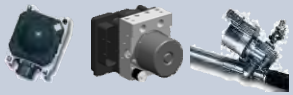
- Introduction of functional limitations
- Limitations guarded by (actuator-)ECU with ASIL ≥ x



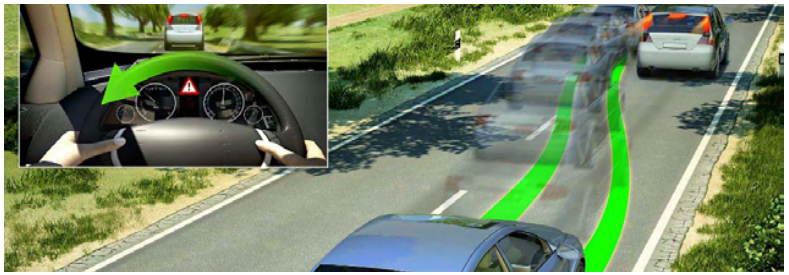
Guard interfaces are essential for functional safety

Evasive Steering Support (ESS) – Comparison

ESS by Torque



- ESS by (steering) torque as haptic support
- Limited steering torque below safety level guarantees controllability by driver
- Can be combined with partial braking intervention



ESS-B by brake

- ESS by (brake) yaw torque directly improves vehicle handling
- Limited yaw torque below safety level guarantees controllability by driver
- Can be combined with partial braking intervention

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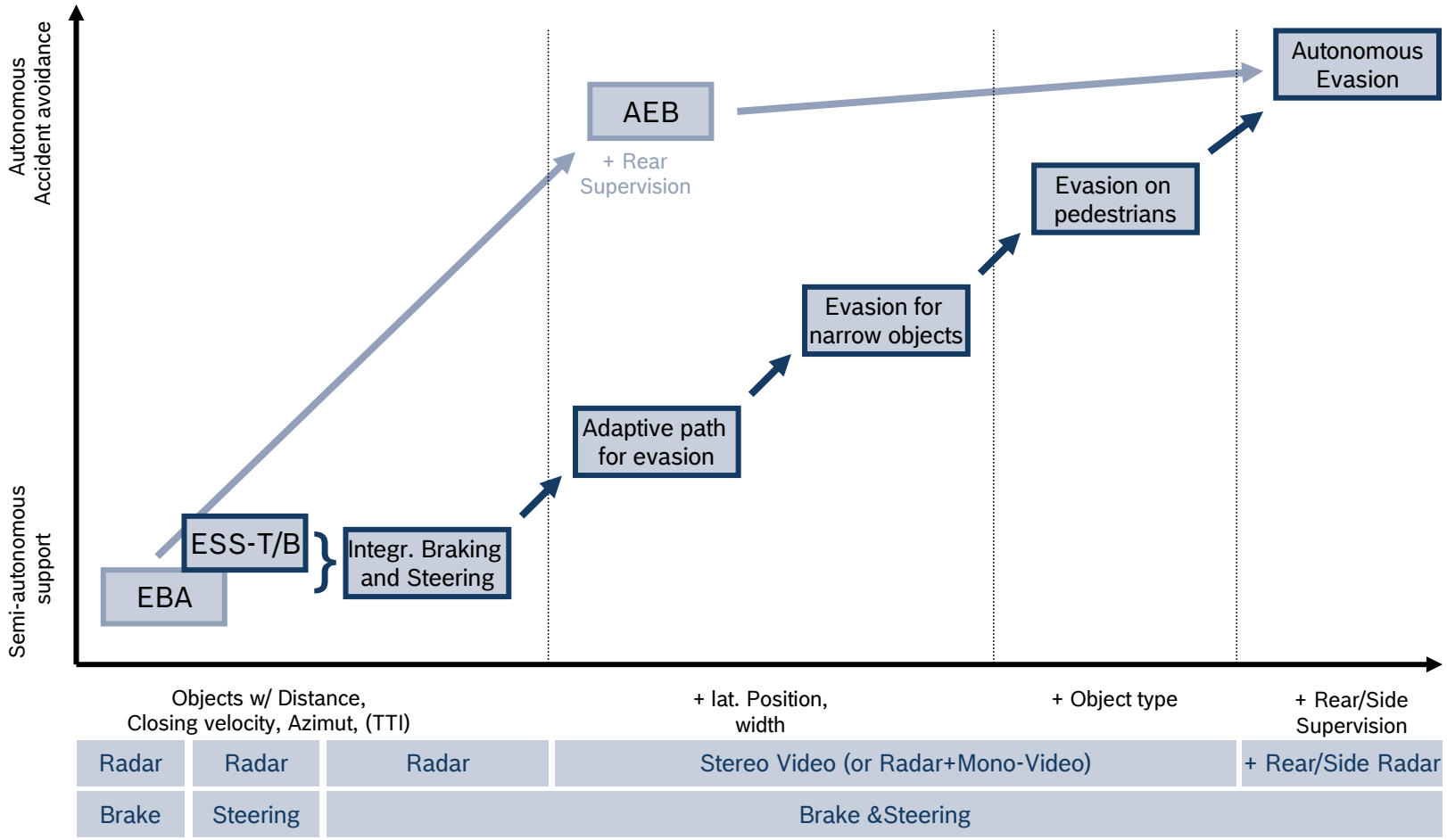
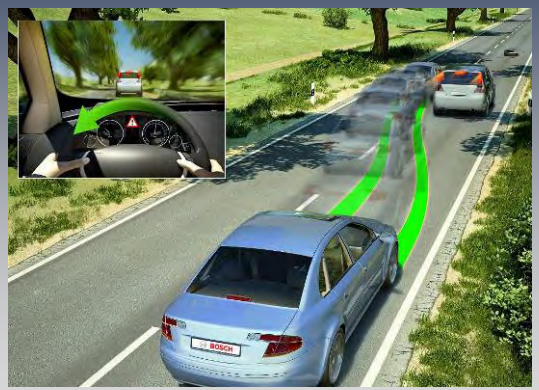
Development strategy for evasion functions



VMS
Vehicle Motion and Safety



Accident Avoidance by Evasive Manoeuvres

Thank you for your attention.

Questions?

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