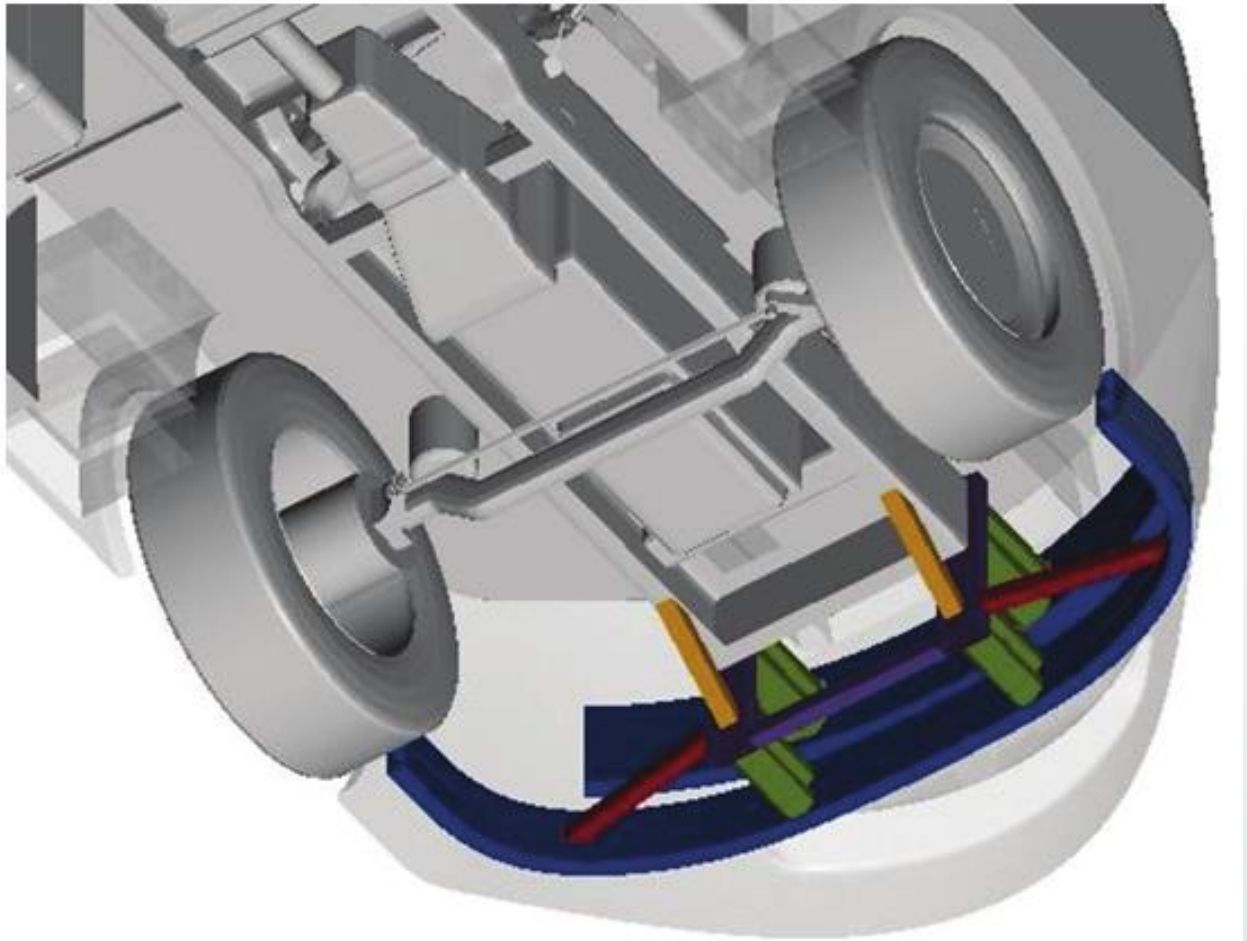


Front Underrun Protection: What is it & how is it managed in Europe?

Apollo Vehicle Safety

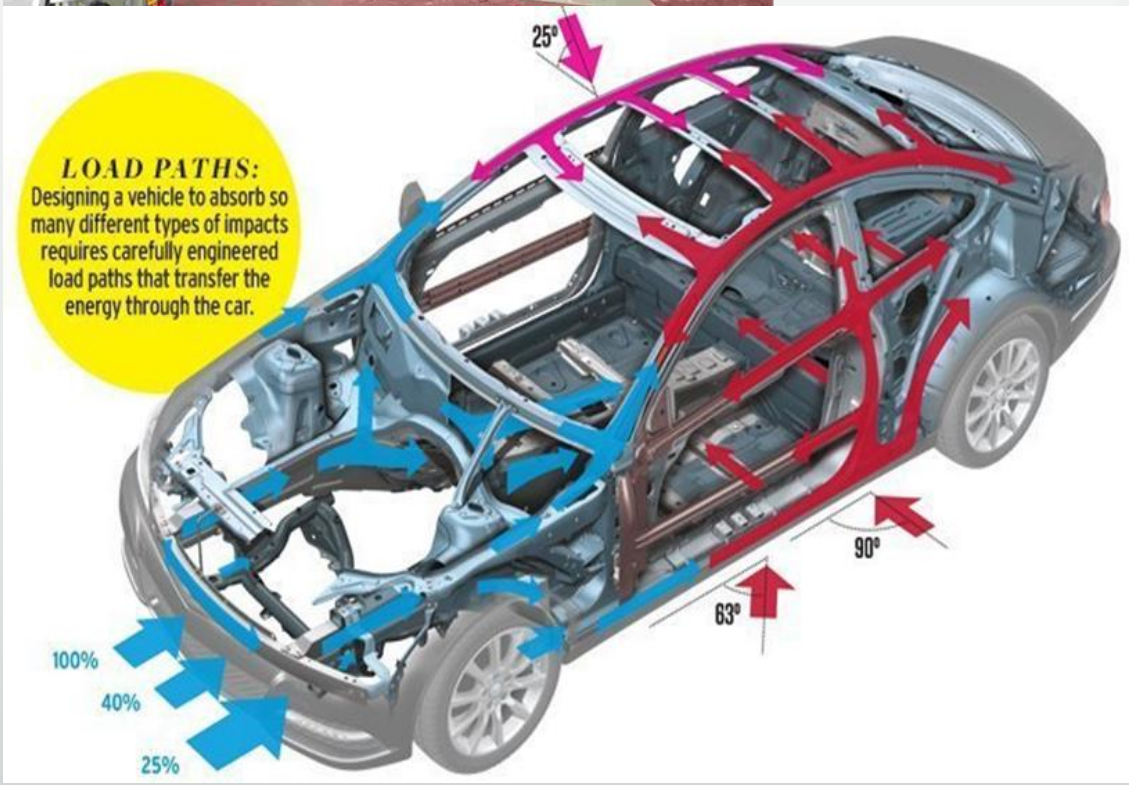
What is underrun?

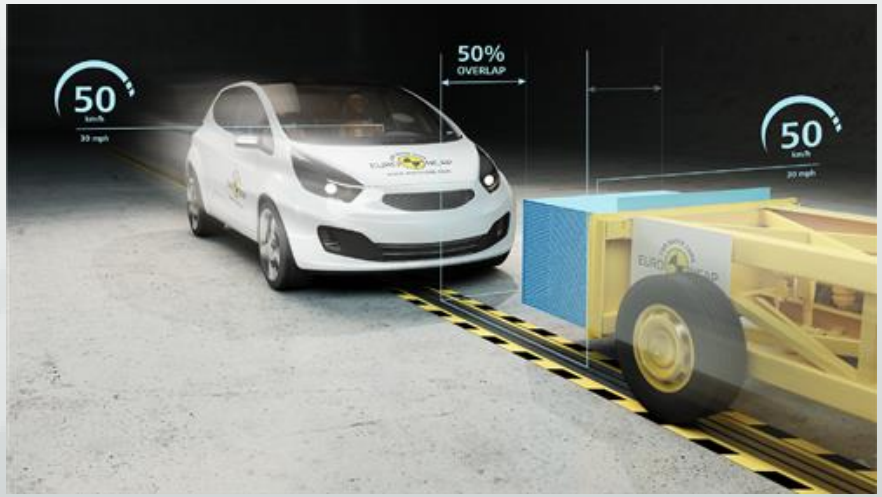
What is underrun?

- Simply, a crash where the structures of one vehicle run underneath the structures of the other

Why is underrun bad?

- Modern cars have developed to have excellent crashworthiness.
  - Crumple Zone provides ride down
  - Rigid passenger cell prevents intrusion
  - Complex restraints manage loads on occupants
- Achieved through structural members and load paths designed around collision with other cars & barriers
- When cars underrun an HGV it is loaded in places not designed for it – e.g. HGV chassis to A-pillar



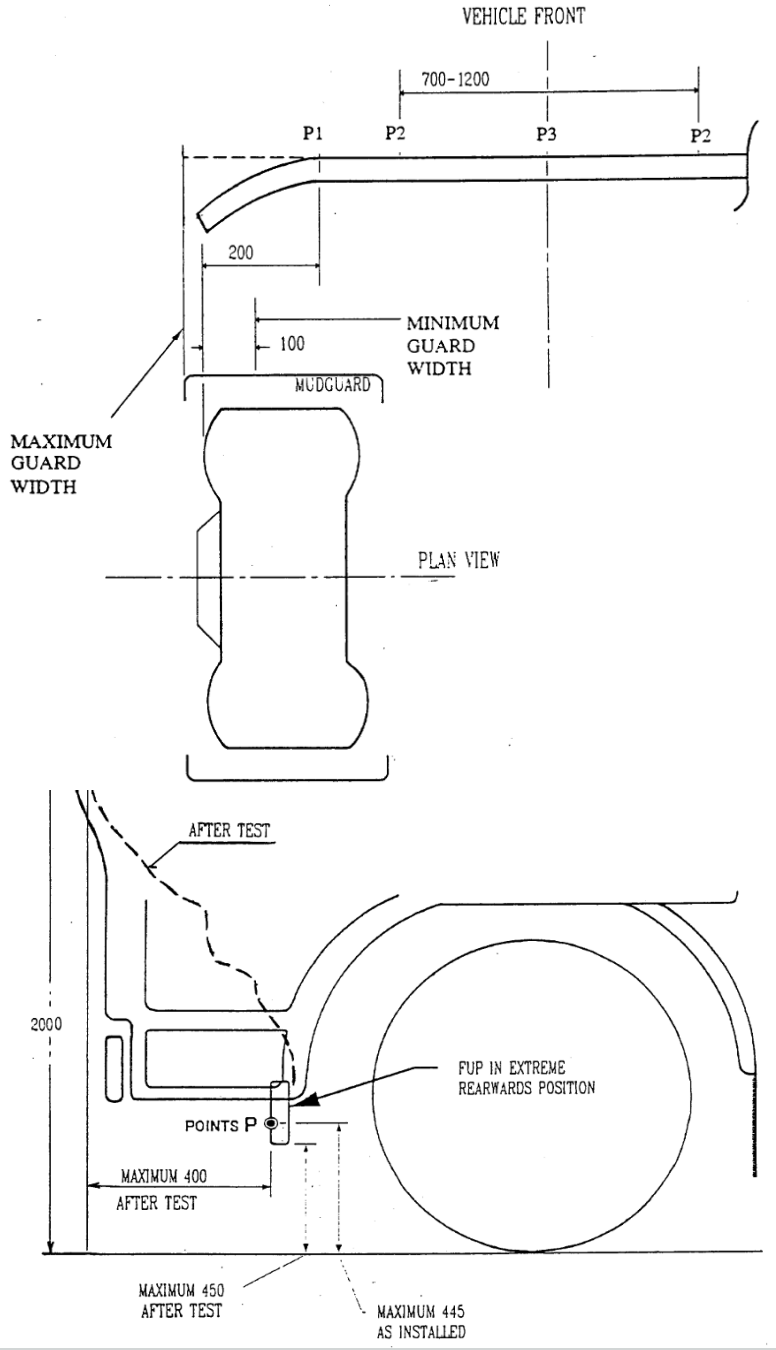


What Front Underrun Protection is required in Europe?

Is the problem solved?

European Regulatory Requirements

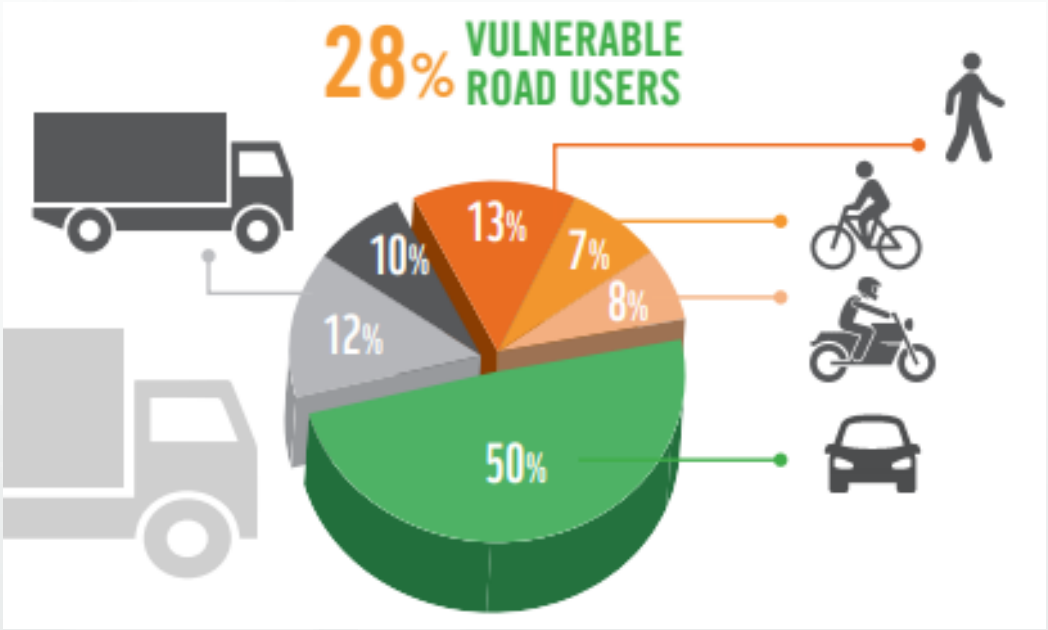
- Since 2005 Mandatory for most new trucks to fit front underrun protection complying with UNECE Regulation No. 93
  - Rigid barrier 120mm tall, near full width of vehicle
  - Maximum ground clearance 400mm
  - Must be located no more than 400mm rear of the foremost point of the vehicle after application of the test loads
  - Quasi-static loads applied sequentially to points P1, p2, P3
    - P1 and P3 - 80 kN
    - P2 – 160 kN
- So, problem solved right?....



Recent casualty levels

- Around half of all those killed in collisions involving at least one HGV are car occupants.
- Example data from GB suggests priorities are
  - Head-on collisions
  - HGV front to car side
  - Car front to HGV rear
- Still a lot of people killed…

Source: EU data according to ETSC 2020



Car Occupant Fatalities		Car Impact Point				
		Front	Back	Side	Other /NK	All
HGV Impact point	Front	42%	7%	21%	0%	70%
	Back	19%	0%	1%	0%	20%
	Side	6%	0%	5%	0%	10%
	Other/Unknown	0%	0%	0%	0%	0%
	All	67%	7%	26%	0%	100%

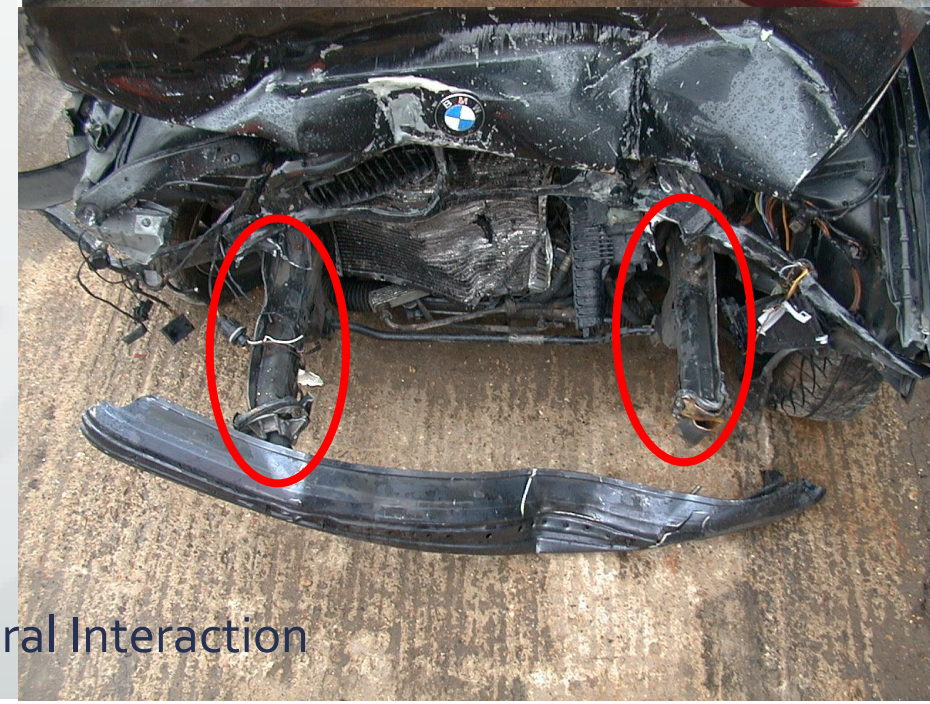
GB 2010-2018 data as an example

What limits the effectiveness of devices

Structural Interaction

- If key structural elements of the car are not engaged then:
  - ‘Crumple Zone’ does not absorb enough energy
  - Passenger cell will have to absorb it – intrusion & higher decel
  - Deceleration profiles not as expected – airbags or pretensioners may not fire at optimal times

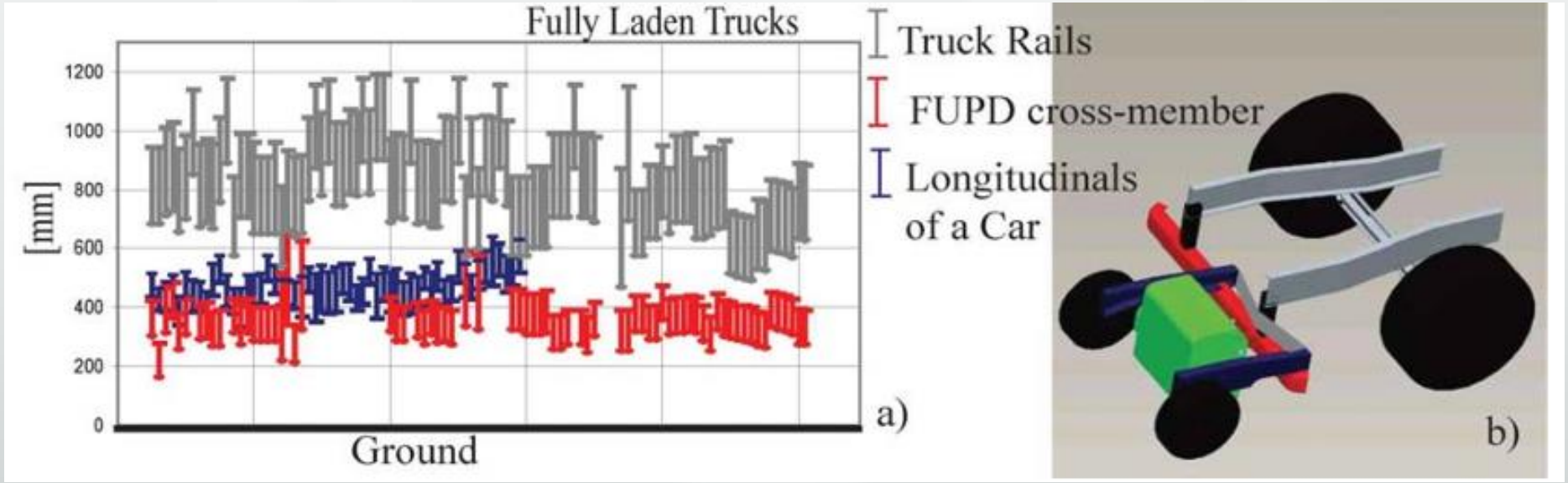
- Good Structural Interaction



- Poor Structural Interaction

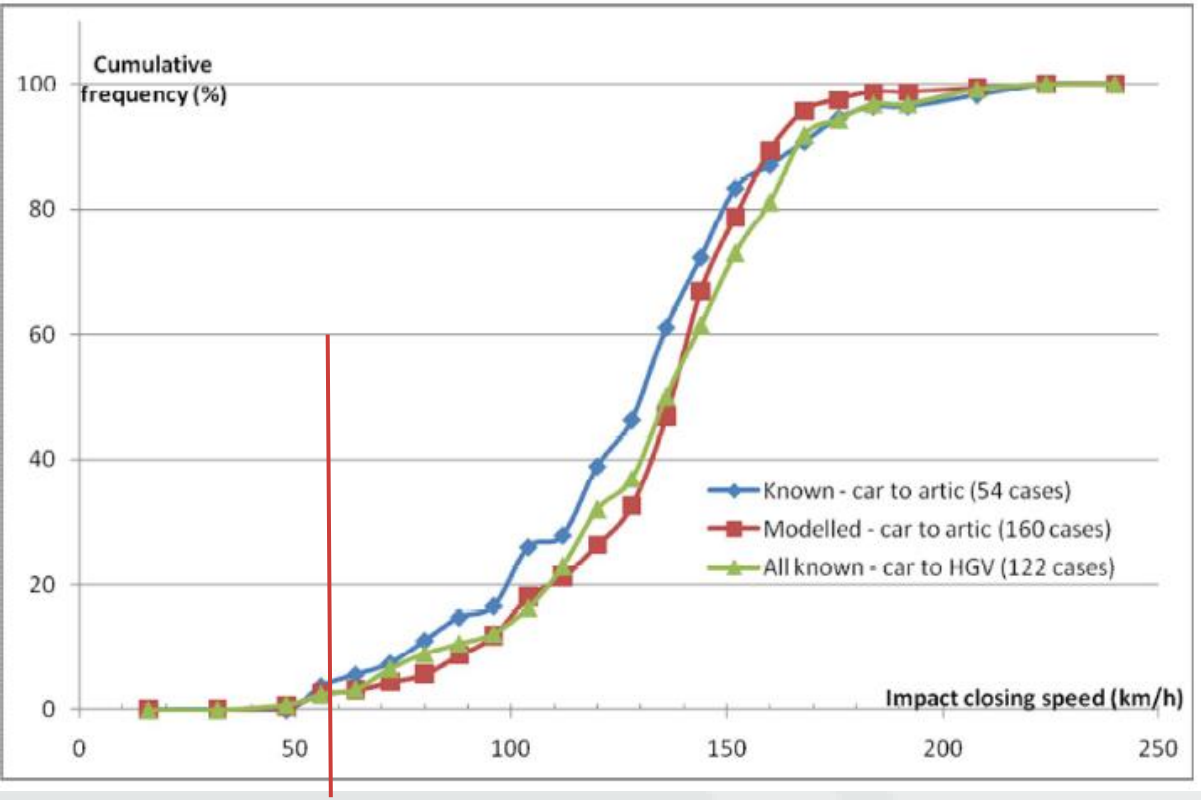
Structural Interaction 2

- 400mm is a height limit
- Manufacturers tend to fit a standard FUP component involving drop arm from each chassis rail and cross member
- Chassis height varies with wheel/tyre size, suspension type, operational need.
- In real world FUP tends to be lower than regulated limit of 400mm
- Car structures can now run between chassis rails and FUP cross member to some degree
- If FUP retains integrity, underrun prevented, but may not engage car crumple zone in optimum way



Source: VC-COMPAT project

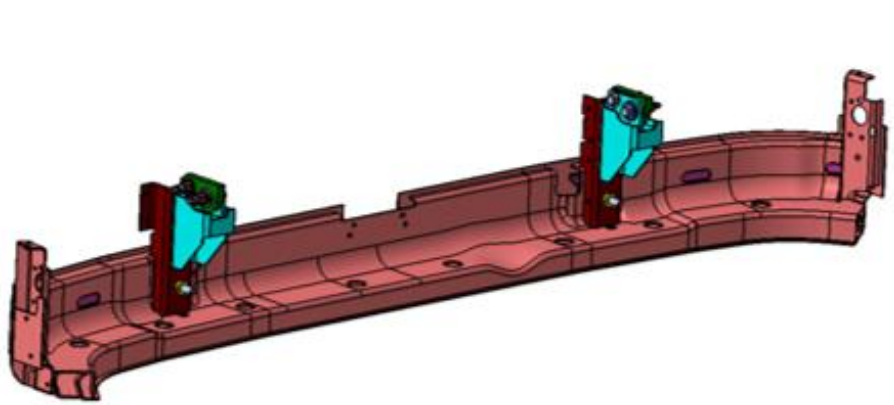
Speed, Stiffness & Energy Absorption

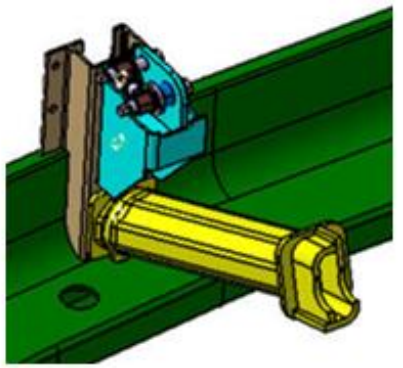


- Regulation sets survivable car speed @ 56 km/h. Euro NCAP extends 64 km/h, reality for some may be higher
- Mass ratio - car sees c 98% of the closing speed
- Many fatalities occur above survivable speeds. HGV needs a 'crumple zone' too if these are to be brought into scope
- Energy absorption is proportional to stiffness and square of deformation length
- Stiffness needs to be between car front & passenger cell
- Space between front and axle on an EU HGV small
- Length constrained by law (16.5/18.75m) and commercial need to maximise load space
- Frontal structure must meet many competing needs. Protect truck occupant, car occupant, pedestrian, support engine, axle, cab loads, provide space for lights, cooling

Structural Interaction 3

- How can energy absorption be implemented?
  - One example is a 'crash can' behind the beam
- However, if the cars structural members do not interact well with the cross member, they may not apply enough force to crush the can
- The area around the FUP has to be free of other stiff components obstructing the cross member movement or engaging with other car structures
- Its become a highly complex problem: not just "underrun" anymore - Need to consider **Crash Compatibility**
- Previous efforts have not been able to optimise the solution



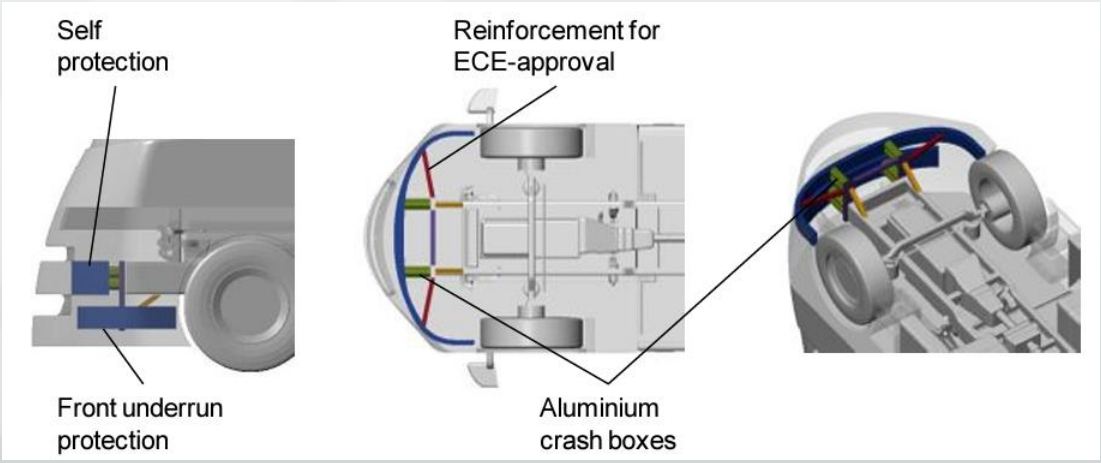


The opportunity provided by additional length

The 'Elongated Cab' concept

- The European 'Cab over engine' design driven by strict length limits, standardisation of load units, productivity etc.
- Sub-optimal for aerodynamics, car occupant protection, pedestrian protection & driver comfort
- EU Regulations amended to remove length limit if it improves aerodynamics, safety and comfort, provided manoeuvrability criteria still met & load length remains the same (capacity neutral).
- In theory, a max of 900mm extension in cab length could be achieved with highly curved profile
- In practice Daf and Volvo have brought out 'elongated' cabins with c 300mm extra at rear of cab for comfort <240mm extra at front for safety.
- Increases potential deformation length available for car crash compatibility

Source: Volvo



Source: FKA Aachen