Status of Research Work of EEVC WG 15 **„Compatibility Between Cars“**

Eberhard Faerber on behalf
of EEVC WG 15

Draft for 41st WP.29/GRSP Geneva, May 07 - 11, 2007

Terms of Reference

The Terms of Reference of EEVC WG 15

are to develop test procedures to assess car frontal impact compatibility and establish criteria to rate frontal impact compatibility. The Working Group will report its findings and will propose candidate test procedures in June 2007.

The full version of the terms of reference can be found on the Web-site of EEVC WG 15

Membership

Actual membership of EEVC WG 15:

Member	Industry advisor
Eberhard Faerber / BAST (chairman)	Robert Zobel / VW
Tiphaine Martin / UTAC (secretary)	Richard Zeitouni/PSA
Giancarlo Della Valle / Elasis	Danilo Barberis / Fiat
Joaquim Huguet / IDIADA	
Richard Schramm / TNO	
Mervyn Edwards / TRL	Martin Harvey / Jaguar
Robert Thomson / Chalmers University	Anders Kling / Volvo

Observer

Pascal Delannoy / UTAC – Teuchos
David L. Smith / NHTSA / U.S.A.

Working Group Status

WG 15 has held meetings at least 4 times a year to discuss national and international research activities related to compatibility. WG15 has had joint meetings with relevant EEVC (WG 13, WG16) and IHRA working groups.

The draft report of the findings of EEVC WG 15 was submitted to the EEVC Steering Committee March 2007

Workplan

Main topic of WG 15 over the last 3 years:

In addition to serving as a focus for national research activities, WG15 served as a steering committee for the VC COMPAT project which started in March 2003 and was finalised February 2007.

The project was funded by the European Commission.

Objective of the VC COMPAT Project:

To draft legal test procedures to assess

- car to car crash compatibility *
- (EEVC WG 14: car to truck Compatibility) *

* Full report can be found on VC-COMPAT website (vc-compat.rtdproject.net)

Compatibility Test Requirements

- Integrated set of test procedures to assess a car's frontal impact protection (including compatibility)
  - Address partner and self protection without decreasing current self protection levels
  - Minimum number of procedures
  - Internationally harmonised procedures
- Both full width and offset tests required
  - Full width test to provide high deceleration pulse to assess the occupant's deceleration and restraint system
  - Offset test to load one side of car for compartment integrity
- Procedures designed so that compatibility can be implemented in a stepwise manner

VC-Compat Workplan

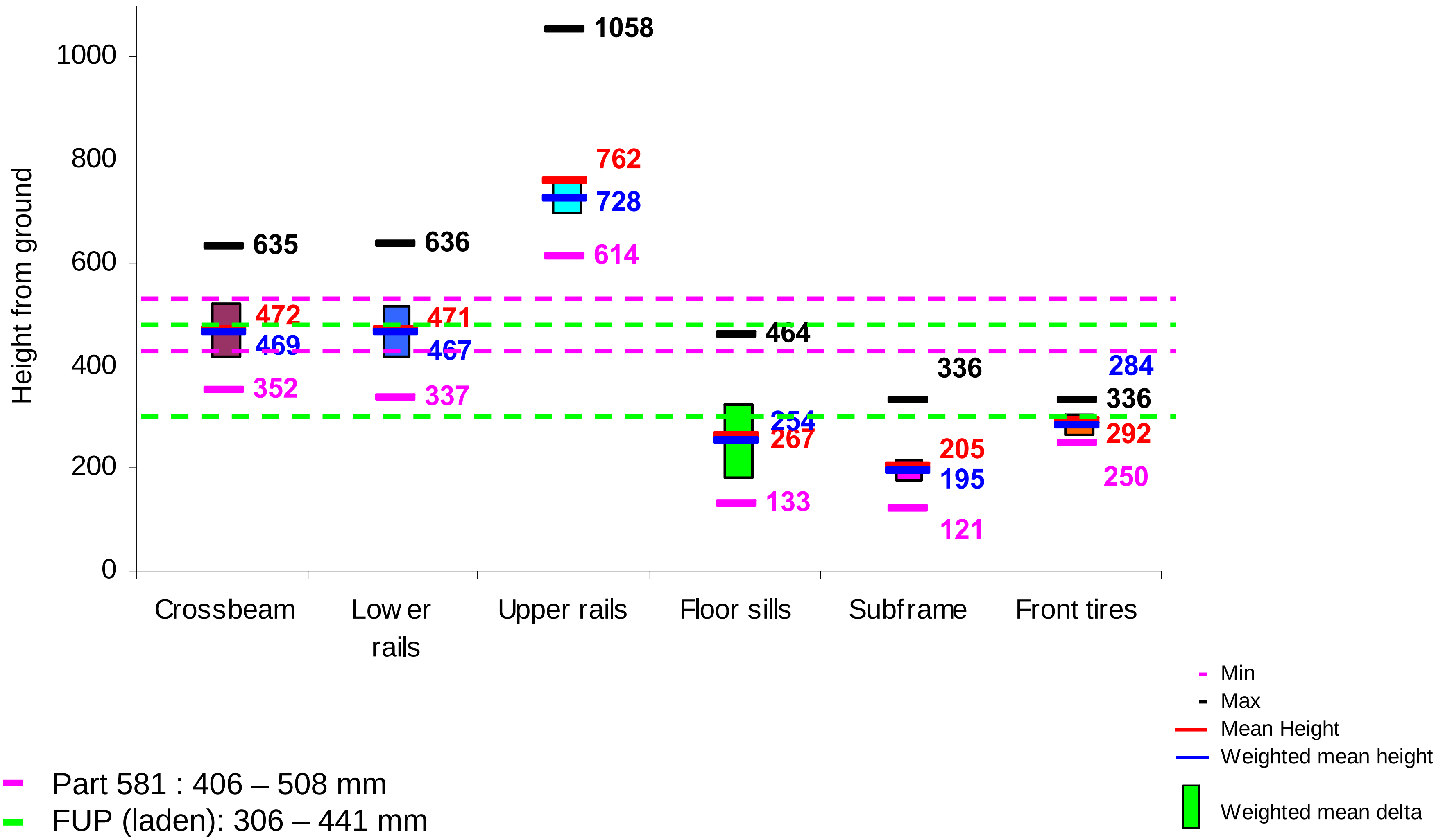
- WP 1: Structure analysis (UTAC)
- WP 2: Accident Analysis, Cost Benefit Analysis (BASt, TRL)
  - Accident Analysis, Benefit Analysis (TRL, BASt)
  - Cost Analysis (Fiat)
- WP 3: Crash Testing Test Programme (BAST, Fiat, TRL, UTAC, Chalmers, TNO)
- WP 4: Fleet Modelling (TNO, Chalmers)
- WP 5: Synthesis (TRL, all), finalised 02/2007

OBJECTIVES WP 1:

⇨ The objective of WP1 was to measure and create a database containing dimensions of the main car and truck/trailer structures that are involved in front and side collisions

⇨ This database was used to study current car-to-car and car-to-truck geometric incompatibility.

SYNTHESIS WP 1:



Part 581 : 406 – 508 mm

FUP (laden): 306 – 441 mm

Structure Analysis

CONCLUSION WP 1:

- The purpose of this WP1 is to give information about the main car structures that are involved in front and side collisions

  (Structure Data were used to select car models to be tested)
- 55 vehicles were measured in this survey
- Data represent 61% of the European sales in 2003
- The investigation area of frontal structure interaction may be positioned at 180 mm from the ground to 800 mm.

Benefit Analysis

Databases for UK and Germany are different:

UK:

- tow away accidents
- more severe accidents
- mostly retrospective analysis

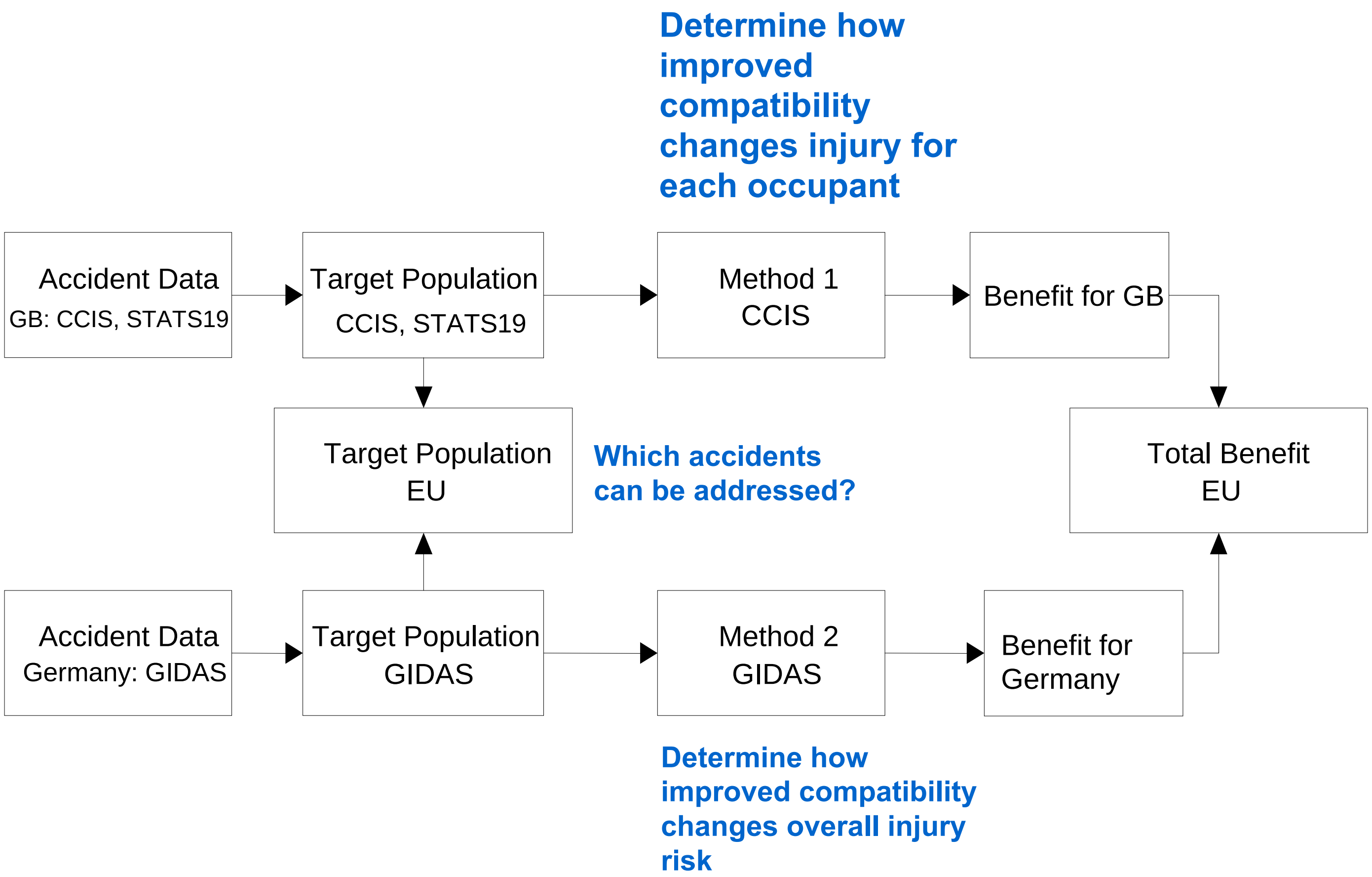
Germany:

- analysis on the spot
- representative for Germany

Consequences:

- UK data contains more severe accidents
- German data contains only few very severe accidents
- → **different approaches!**

Approach to Estimate Benefit for EU 15



Benefit Methodology - assumptions for GB

<u>Assumptions</u>

- Pessimistic (lower)
  - – Eliminate injuries caused by contact with an <u>**intruding**</u> front interior structure if ETS < 56 km/h
- Optimistic (upper)
  - – Eliminate injuries caused by <u>**contact**</u> with the front interior (with or without intrusion) if ETS < 56

Benefit Analysis Germany

Compatibility Benefit Effect on Injury Risk

Euro NCAP tests at 64km/h show, that most car models:

- do not show any structural collapse
- show only minor compartment intrusions

Car to car tests of WG 15 however show, that structural collapse and compartment intrusions start at velocity changes (rebound velocity included) between 50 and 56km/h.

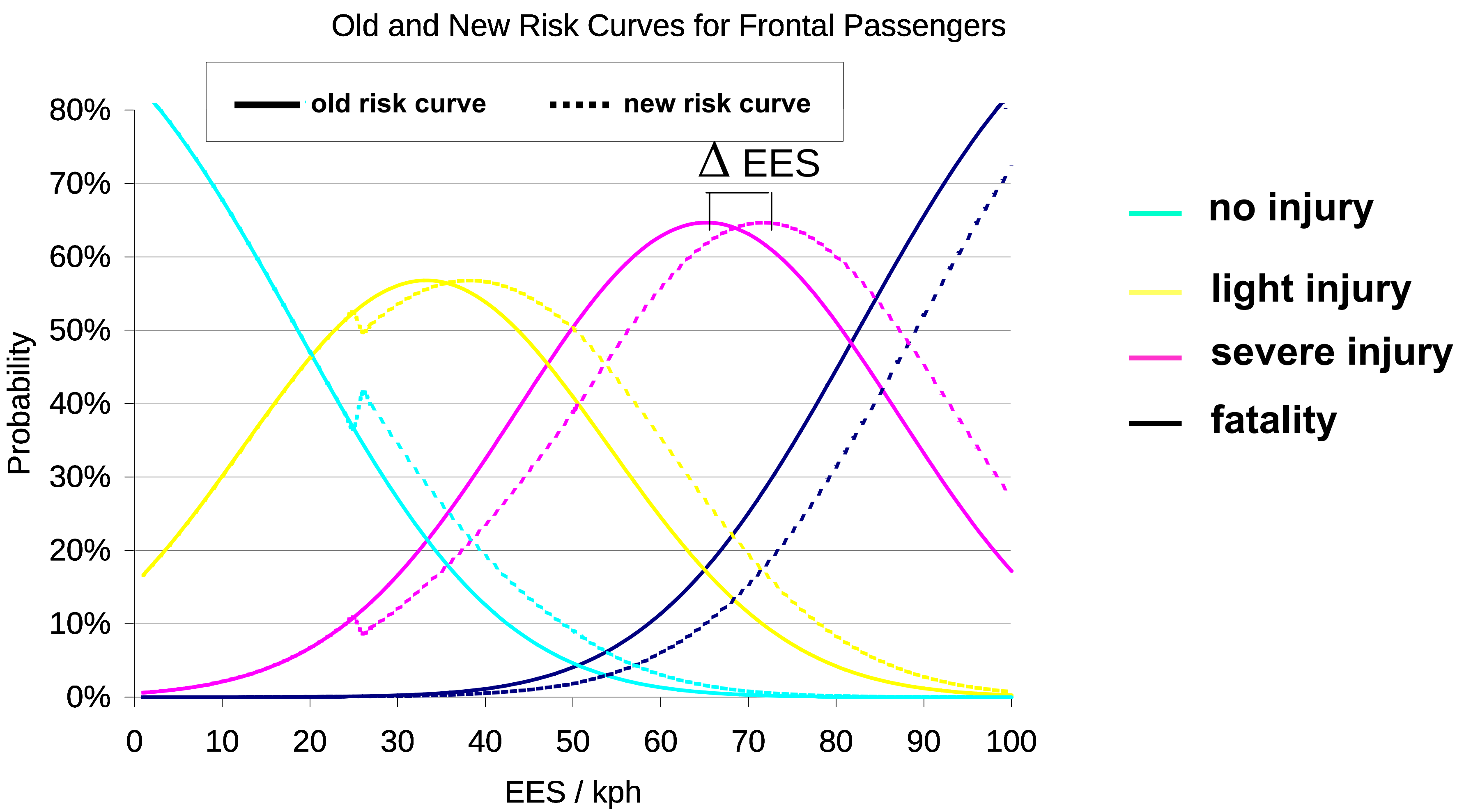
Cars with good compatibility could absorb more energy in car to car crashes showing similar deformation depth

- **ΔE = about 45kJ or**
- **$\Delta E/E$ = about 30% higher energy-absorption!**

Compatibility Benefit Effect on Injury Risk

Passenger cars with good compatibility could be impacted in car to car tests at <u>higher energy equivalent speed (EES)</u> showing the same compartment loading as in Euro NCAP tests.

Injury Risk Benefit Estimation



Injury Reduction Estimation in EU 15

	Frontal car casualties	Predicted Reduction in EU-15 Casualties		
		CCIS intrusion model	CCIS contact model	German model
Fatal	16,014	721	1,332	1,281
Serious	122,084	5,982	15,383	5,128

Monetary Benefit in EU 15

	Benefit per person		Predicted Total benefit		
	Fatal	Serious	CCIS: Intrusion	CCIS: Contact	German model
RCGB 2005 (€)	2,136,262	240,043	2,976,180,313	6,538,077,822	-
German (€)	1,161,885	87,269	-	-	1,936,005,641

Cost Analysis for EU15

- Costs calculated by estimating cost to modify existing car
  - 4 star EuroNCAP car – worst case
    - Structural interaction and compartment strength
  - 5 star EuroNCAP car – best case
    - Structural interaction only

Cost per Car

Manufactured cars (n_cars)	WORST CASE (4 stars car) (€)	BEST CASE (5 stars car) (€)
100.000	281,85	143,51
500.000	228,37	106,53
1.000.000	221,68	101,90

Cost for EU15

	Cost per Car	No. of Cars Registered p.a.	Total Cost p.a. [€]
Best Case Scenario	102	14,211,367	1,449,550,394
Worst Case Scenario	282	14,211,367	4,007,605,383

Benefit/Cost Analysis

Benefit/Cost Ratio in EU 15

	Ratio of financial benefits to implementation costs		
	CCIS intrusion model	CCIS contact model	German model
Best case scenario	2.05	4.51	1.34
Worst case scenario	0.74	1.63	0.48

Conclusions:

⇒ **Benefit/Cost Ratio > 1**

⇒ **For New Car Models Lower Costs**

Crash Test Procedures

Two favourite test procedure candidates:

- <u>Full Width Test</u> with deformable element and high resolution load cell wall

- <u>Offset Deformable Barrier Test</u> with Progressive Deformable Barrier and high resolution load cell wall

Test procedure : FWDB

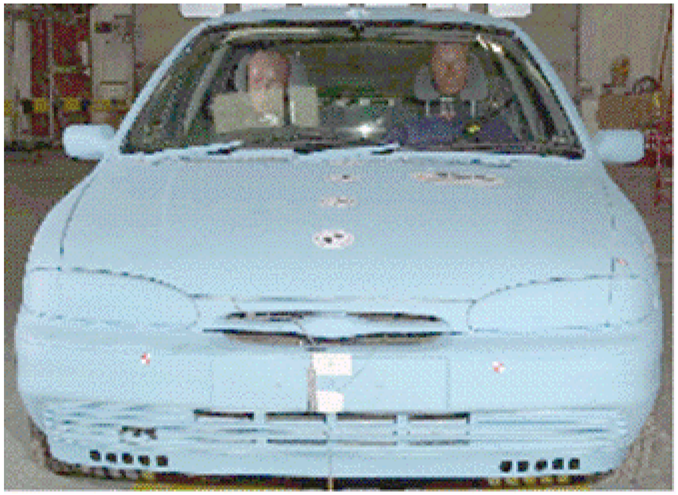
Full Width Barrier With Deformable Element and Load Cell Wall

Aluminium honeycomb layers: 150mm 0.34MPa & 150mm 1.71MPa

Test procedure : FWDB

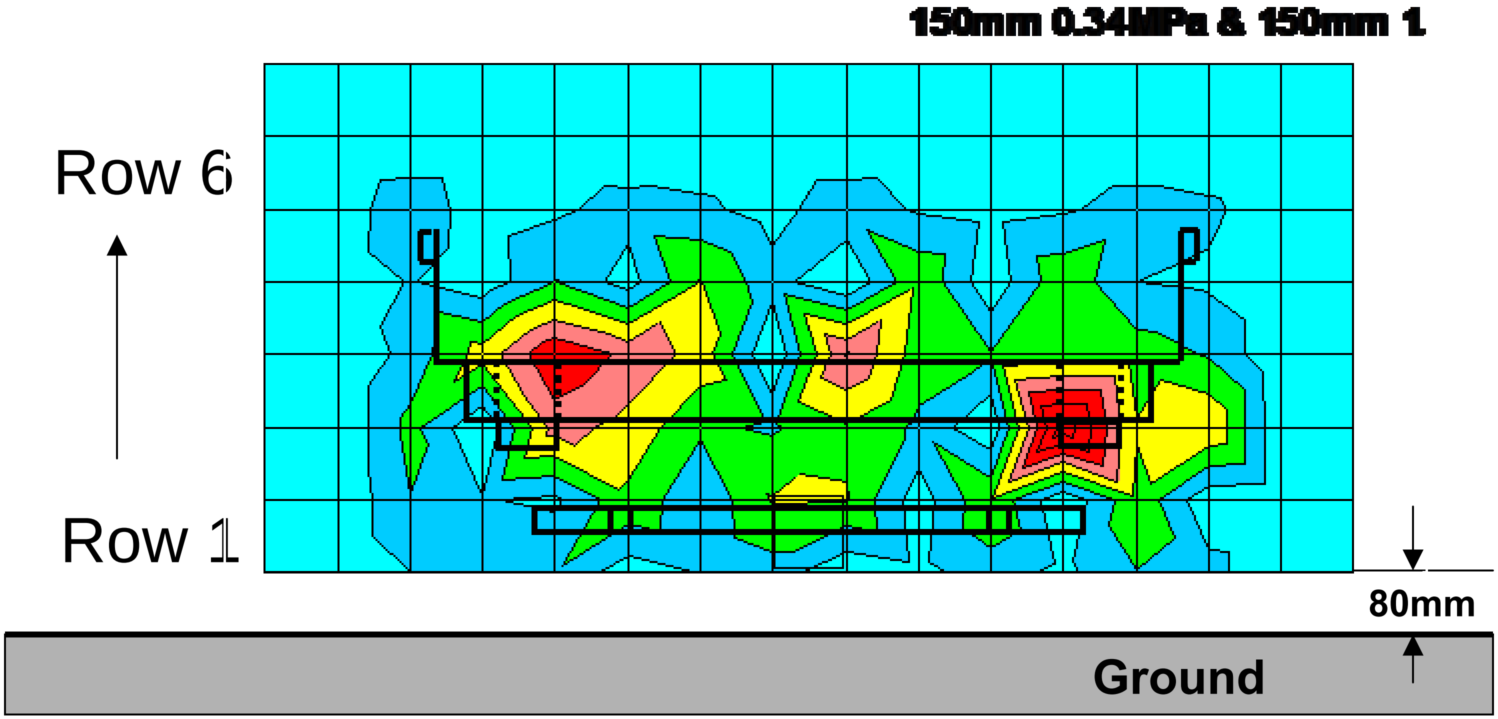
Full Width Test With Deformable Element

Pre and post test front view, Resultant barrier deformation



Test procedure : FWDB

Full Width Barrier Evaluation



Full Width Barrier Evaluation

Assessment criteria should encourage:

- Load paths below main rail (greater vertical force distribution)
- upper/lower rail connections
- strong vertical connections between load paths
- greater horizontal force distribution

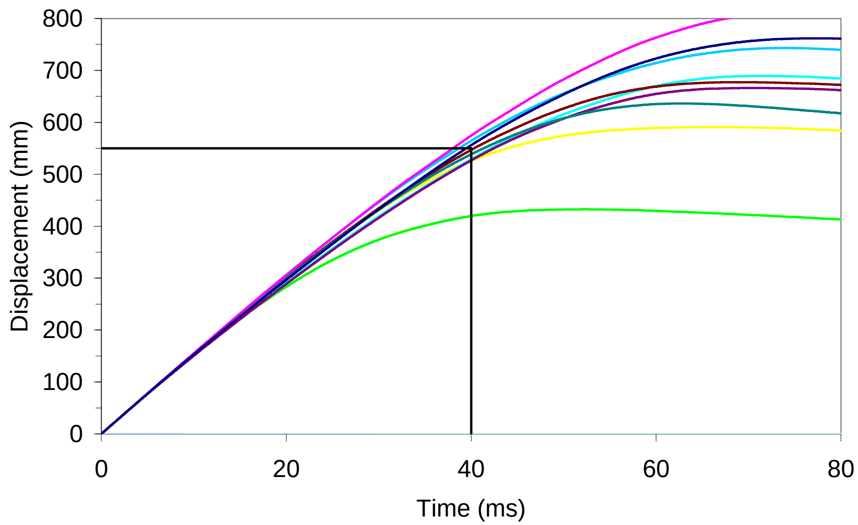
Full Width Barrier Evaluation

A Structural Interaction (SI) Critieria was developed to:

- Encourage better vertical force distribution (multi-level load paths)
- Encourage better horizontal force distribution (crossbeams)
- Ensure adequate structure in alignment with a common interaction area
- Be applied in a stepwise manner to allow manufacturers to gradually adapt vehicle designs

SI Metric Basis

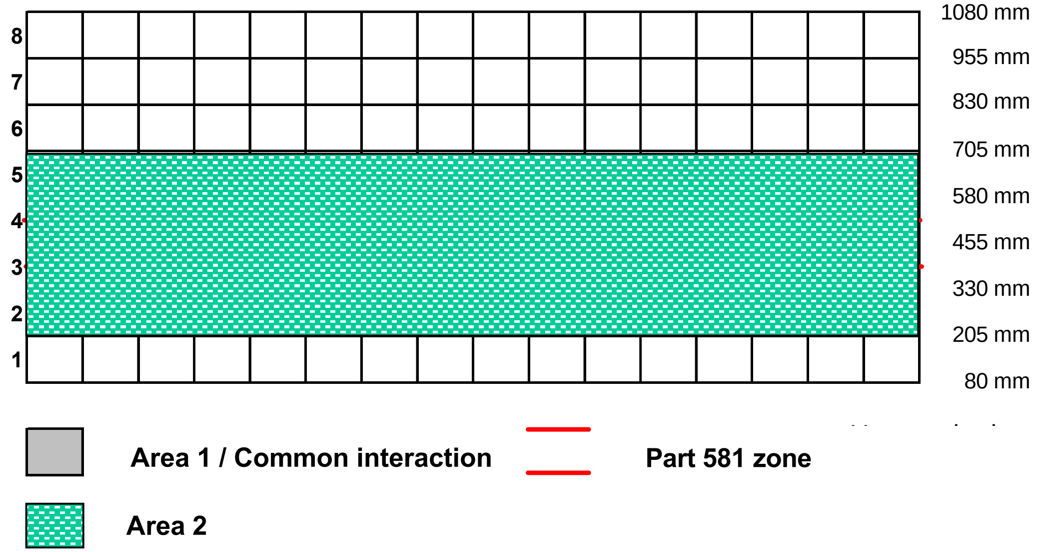
- Calculated from peak cell forces < 40 ms (550 mm displacement)



- Why?
  - Minimises loading from structures further back in vehicles enabling better assessment of interaction at beginning of impact
  - Aligns with other proposals (NHTSA AHOF400 & KW400)
  - Still able to detect subframes (reaches ~400mm into vehicle)

SI Metric Basis

- Assessed over 2 areas which allows adoption in step-wise manner
  - Area 1 - common interaction area, rows 3 & 4 (330mm to 580mm)
    - Ensure all vehicles have adequate structure in alignment with common interaction zone
  - Area 2 – rows 2,3,4 & 5 (205mm to 705mm)
    - Encourage vehicles to distribute structure to reduce under/override and fork effect



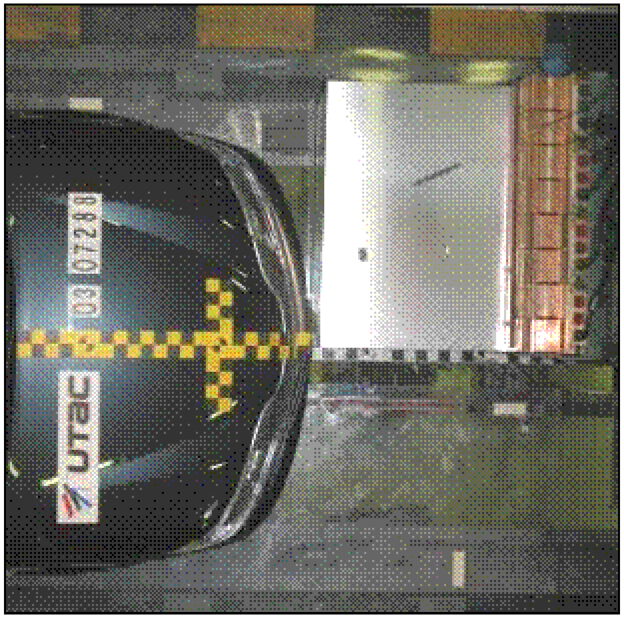
- Has Vertical (VSI) and Horizontal (HSI) components

Test procedure : PDB

PDB TEST PROCEDURE : CONFIGURATION

Compared to current R.94 Frontal ODB test

3 parameters are changed:



- **OBSTACLE : PDB Barrier**
- **SPEED: 60 km/h**
- **OVERLAP: 50%**

Test procedure : PDB

PDB TEST PROCEDURE : AIM

To control partner protection in addition of self-protection on the same test:

Test configuration

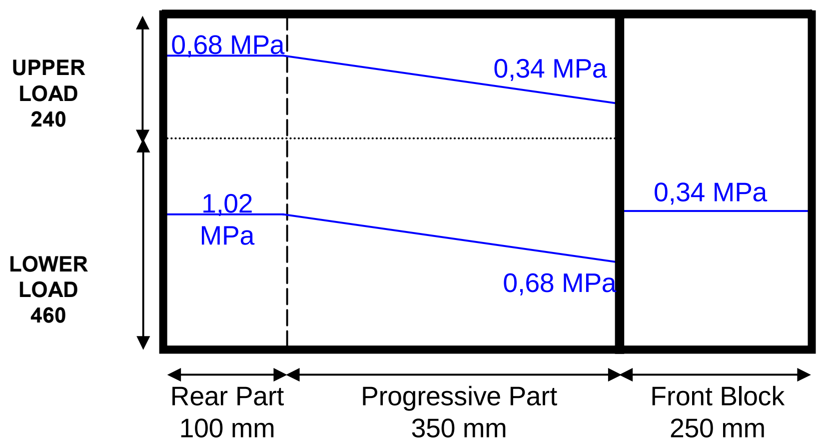
- ⇨ harmonize test severity for all vehicle mass range (closer EES)
- ⇨ adapt offset test protocol to compatibility requirements
- ⇨ adapt offset test protocol to new generation of vehicles

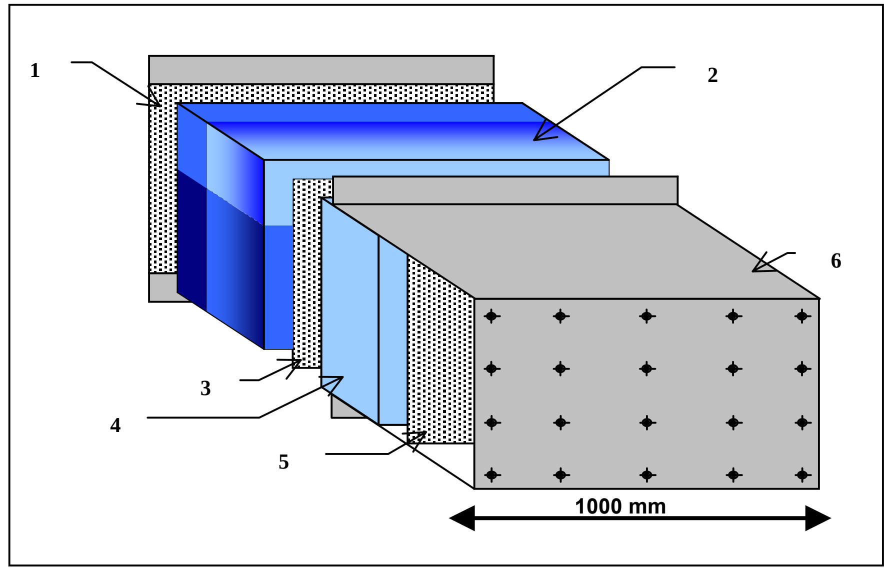
Car design influence

- ⇨ improve self protection of light cars
- ⇨ improve partner protection of heavy cars without compromise self protection
- ⇨ limit increasing stiffness of heavy cars

Test procedure : PDB

PDB TEST PROCEDURE : PDB BARRIER





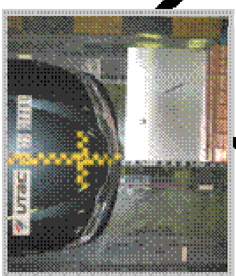
⇨ PDB is more representative of a car than the ODB

Test procedure : PDB

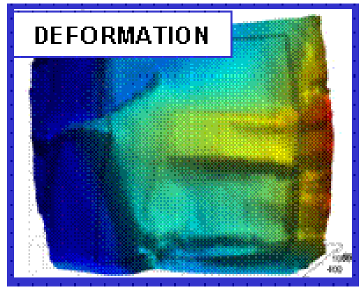
PDB TEST PROCEDURE: TOOLS / MEASUREMENT / ASSESSMENT PARAMETERS

TOOLS | **MEASUREMENTS** | **ASSESSMENTS PARAMETERS**

Test severity
Harmonisation



STRUCTURAL INTERACTION

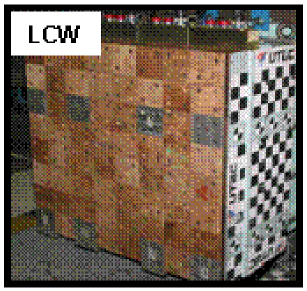


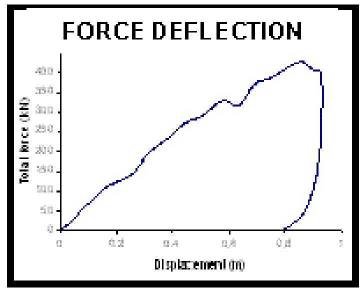
AHOD: Average Height of Deformation

ADOD: Average Depth of Deformation

Homogeneity

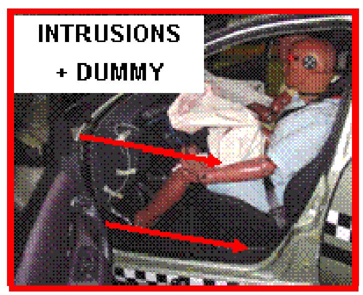
FRONT END FORCE





Global Force level

COMPARTMENT STRENGHT

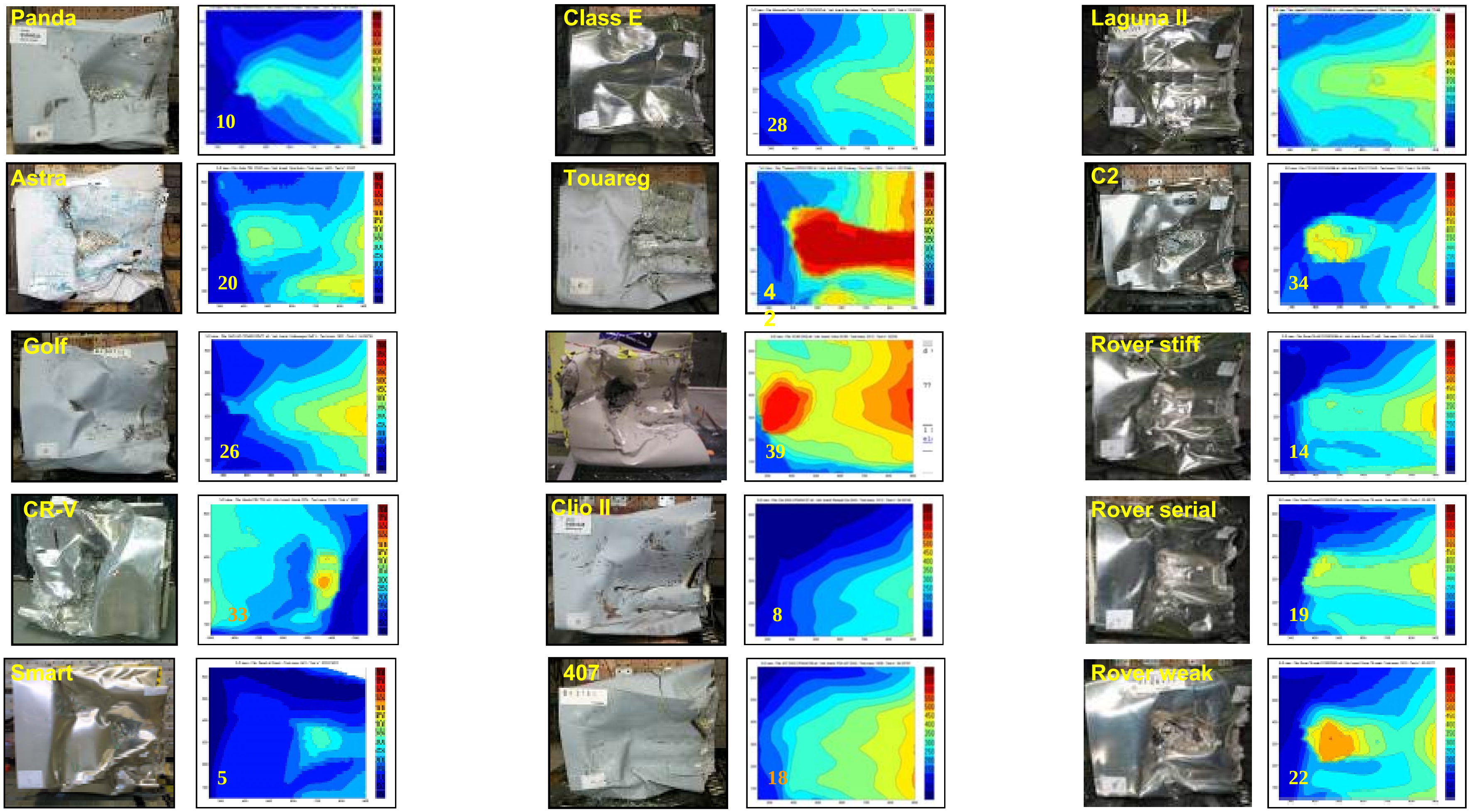


dummy criteria

Intrusion level

Test procedure : PDB

PDB TEST PROCEDURE : TOOL / MEASUREMENT VALIDATION



⇨ Barrier deformation and measurement detect different front end design

Possible Sets of Test Procedures

Approach 1:

- Full Width Deformable Barrier (FWDB) Test
  - Structural interaction
  - High deceleration pulse
- Offset Deformable Barrier Test (ODB)
  - Frontal force levels
  - Compartment integrity

Approach 2:

- Full Width Rigid Barrier Test
  - High deceleration pulse
- Progressive Deformable Barrier (PDB) Test
  - Structural interaction
  - Frontal force matching
  - Compartment integrity

A Possible Further Approach:

- Combination of FWDB and PDB

Open Questions

General open questions

FWDB

- Assessment criteria available but not validated
- Investigate relation of honeycomb deformation - load cell forces
- Confirm all important vehicle structures detected
- Confirm repeatability of test results

PDB

- No assessment criteria available
- Validate calculation of absorbed barrier energy to find EES value
- Validate that PDB introduces a minimum EES severity for all vehicles
- Confirm repeatibility of test results

ODB

- Does barrier instability affect results
- Does it accurately assess force levels
- Which test speed is required

Future Work

Global Issues:

- Finalise the test severity (EES) for regulation test(s)
- Further in depth accident analysis in relation to advanced restraint systems
- Finalise objective assessment procedures to analyse results of car to car tests with respect to:
    - Good structural interaction
    - Good compartment strength
    - Compatible car characteristics
    - Importance of width of frontal structures
- Identify critical injury mechanisms
- Finalise assessment criteria for regulation test(s) and prepare an impact assessment.

Future Work

FWDB

- Test repeatability / reproducibility
- Link between honeycomb deformation and load cell measurements
- Confirm detection of all important vehicle structures
- Sensitivity of load cell forces to vertical vehicle alignment

PDB

- Test repeatability / reproducibility
- Propose and validate assessment criteria
- Validate EES calculation method
- Validate that PDB guarantees a minimum EES test severity for all vehicles.

Future Work

Combination of Test Approaches FW(DB)* - PDB

- Investigate the potential to develop and propose complementary assessment criteria for a combination of the two test procedures

* Full width test with or without deformable element

Analyse of potential benefit of a mobile deformable barrier test

- Does a MDB provide a more realistic loading for both a lighter and heavier car

End

Thank You for Your Attention!

Extra Slide

VSI and HSI

- Vertical (VSI) and Horizontal (HSI) components
- VSI
  - Area 1
    - Assess if adequate structure in alignment with area by measuring if target load [100 kN] applied to each row
  - Area 2
    - Assess if adequate structure in alignment with area by measuring if target load [100 kN] applied to each row
    - Assess if structure is distributed well vertically by measuring row load distribution using Coefficient of Variance
- HSI
  - Area 1 and 2
    - Assess rail / crossbeam strength balance by measuring how well row load distributed over centre cells
    - Option – Assess structural width for low overlap impacts by measuring how well row load distributed over outer cells