Status of Research Work of EEVC WG 15

„Compatibility Between Cars“

Eberhard Faerber on behalf
of EEVC WG 15

38th WP.29/GRSP Geneva, 06 - 09 December 2005

Terms of Reference

The <u>Terms of Reference of EEVC WG 15</u>

are to develop a test procedure to assess car frontal impact compatibility and establish criteria to rate frontal impact compatibility. The Working Group will report its findings and will propose a test procedure in November 2006.

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)	Dr. Robert Zobel/VW
Tiphaine Martin, UTAC (secretary)	Richard Zeituni/PSA Peugeot Citroen
Pascal Delannoy/UTAC (substitute)	
Giancarlo Della Valle/Elasis	Federico Pasqui/Fiat
Jaoquim Huguet/IDIADA	
Cor van der Zweep/TNO	
Dr. Mervin Edwards/TRL	Martin Harvey/Jaguar
Robert Thomson/Chalmers University	Anders Kling/Volvo

Observer

None (invited David L. Smith/NHTSA)

Workplan

Current Main topic at the moment:
Give advice to and guide the VC COMPAT project commenced in March 2003 for a period of 3,5 years. The project is funded by the EU-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)

Workplan

VC COMPAT Workplan

WP 1: Structure Analysis - UTAC	
Car Fleet - UTAC	Truck Fleet - CIC

WP 2: Accident Analysis & Cost-Benefit Analysis - BASt	
Car to Car Impact - BASt	Car toTruck Impact - GDV

WP 3: Crash Testing & Analysis - TRL

WP 4: Car to Car & Car to Barrier Crash Modelling - TNO

WP 5: Synthesis of Test Procedure for Car to Car Impact - TRL

WP 10: Industrial Liaison and Dissemination - TNO	
Car to Car Impact - ChUT	Car toTruck Impact - TNO

WP 11: Project Management -TRL	
Car to Car Impact - TRL	Car toTruck Impact - TNO

Workplan

Status December 2005:

- WP 1: Structure analysis (UTAC) completed
- WP 2: Accident Analysis, Cost Benefit Analysis (BASt, TRL)
  - Accident Analysis, Benefit Analysis (TRL, BASt) completed
  - Cost Analysis (Fiat) to be done
- WP 3: Crash Testing Test Programme (BAST, Fiat, TRL, UTAC) completed
- WP 4: Fleet Modelling (TNO) drafted
- WP 5: Synthesis (TRL, all) to be done 01/2006 to 09/2006

Structure Analysis

OBJECTIVES:

- ⇨ The objective of WP1 is 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 will be used to study current car-to-car and car-to-truck geometric incompatibility.

Structure Analysis

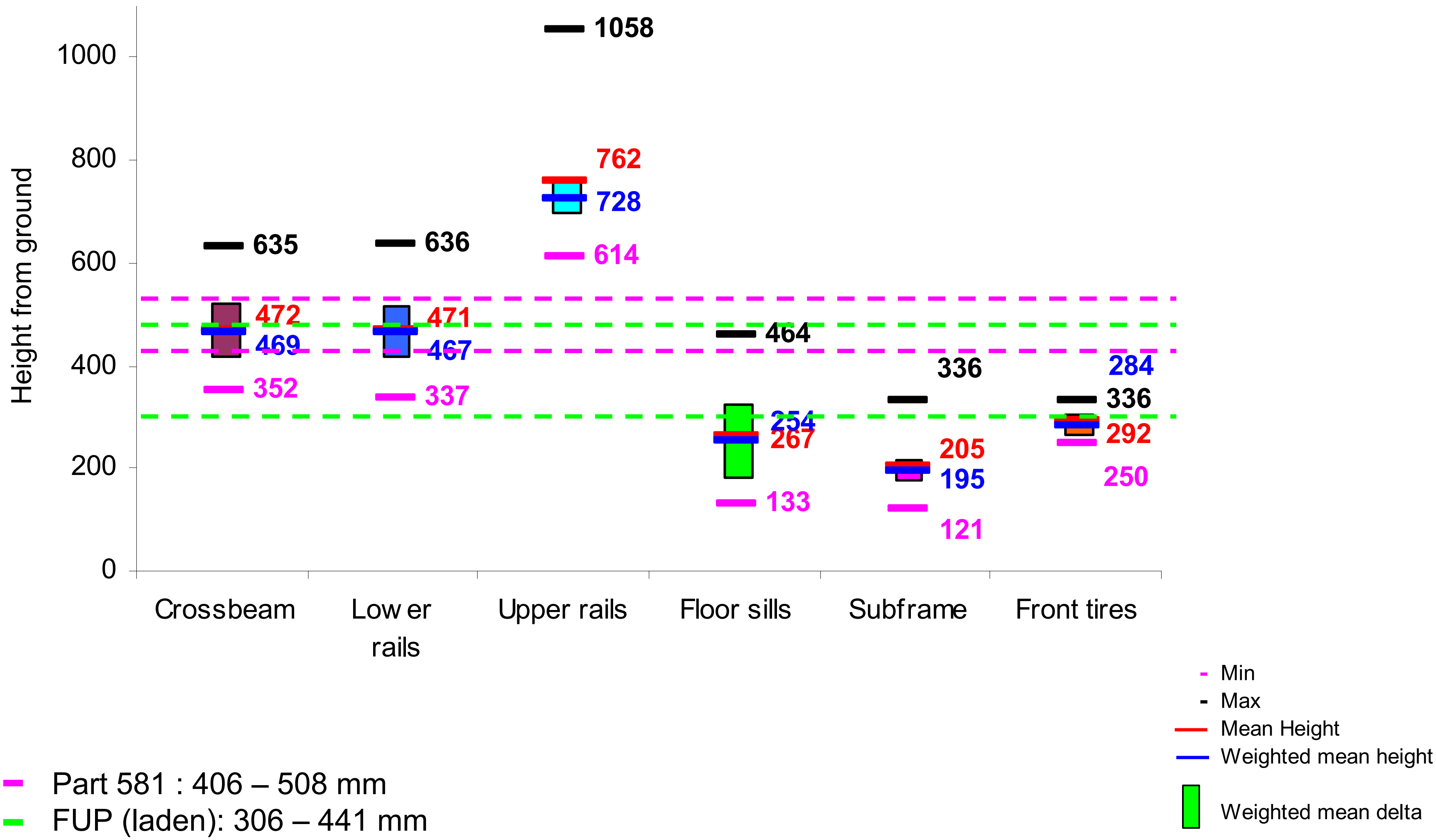
CAR SELECTION:

A segment			B segment			C segment			D segment			D/E segment		
n°	name	%	n°	name	%	n°	name	%	n°	name	%	n°	name	%
1	Citroën C2	0,21	6	Citroën C3	1.85	15	PT Cruiser	0.13	25	Saturn Ion	0	34	Mercedes Eclass	1.18
2	Renault Twingo	0.7	7	Opel Corsa	2.6	16	Ford Focus	2.83	26	Ford Mondeo	1.22	35	Renault Velsatis	0.08
3	Smart	0.07	8	Renault Clio	3.11	17	Opel Astra	2.16	27	Mazda 6	0.57	36	Volvo S80	0.09
4	Toyota Yaris	1.32	9	VW Polo	2.12	18	Peugeot 307	2.81	28	Opel Vectra	1.08			
5	Citroën Saxo	0.44	10	Peugeot 206	3.53	19	Renault Megane	1.86	29	Renault Laguna	1.13			
			11	Fiat Punto	2.32	20	Audi A3	0.81	30	Rover 75	0.24			
			12	Ford Fiesta	2.5	21	BMW 3 series	1.99	31	VW Passat	1.62			
			13	Seat Ibiza	1.14	22	VW Golf	3.61	32	Audi A4	1.61			
			14	Mercedes Aclass	0.9	23	Mercedes Cclass	1.36	33	Citroën C5	0.62			
						24	Fiat Stilo	0.96						
F segment			**Small MPV**			**MPV**			**4WD**			**LCV**		
n°	name	%	n°	name	%	n°	name	%	n°	name	%	n°	name	%
37	BMW 7series	0.09	40	Opel Meriva	0.67	46	Citroën C8	0.16	49	Honda CRV	0.19	54	Renault Trafic	0.32
38	Mercedes S class	0.11	41	Citroën Picasso	1.94	47	Renault Espace	0.39	50	Nissan Xtrail	0.28	55	Ford Transit	0.84
39	VW Phaeton	0.02	42	Opel Zafira	1.38	48	VW Sharan	0.27	51	Freelander	0.27			
			43	Renault Scenic	1.86				52	Volvo XC90	0.11			
			44	VW Touran	0.0004				53	Range Rover	0.08			
			45	Renault Kangoo	1.05									

⇨ 55 vehicles measured: representative of 61% of European sales in 2003

Structure Analysis

SYNTHESIS:



Part 581 : 406 – 508 mm
FUP (laden): 306 – 441 mm

Structure Analysis

CONCLUSIONS:

- 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 representative from 61% of the European sales in 2003
- The investigation area of frontal structure interaction may be positioned at 180 mm from the ground to 650 mm.

Benefit Analysis

Benefit Analysis to be carried out by TRL and BASt

Database

- UK: CCIS

  UK in-depth Co-operative Crash Injury Study

    detailed and accurate information, including AIS codes

    crashes from June 1998 – present

- UK: STATS19

  UK national accident database

    includes all injury accidents that are reported by or to the police

    broad in scope, limited detail

- Germany: GIDAS

  German in Depth Accident Study

    representative for Germany

- Germany: German national traffic accident data

    similar to UK data

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

Target Population for GB

- Definition
  - Casualties likely to experience reduced risk of injury as a result of improved compatibility
- Methodology
  - Select accidents where improved compatibility likely to help injury outcome
  - Count front seat occupant casualties

Selection Criterion	Lower Estimate	Upper Estimate
Impact location	frontal	frontal
Seat belt usage	only belted occupants	only belted occupants
Occupant position	only frontal occupants	only frontal ocupants
Overlap	> 30 %	> 20 %
PDOF	11..1 o'clock	10..2 o'clock
ETS	all accidents up to 48 km/h	all accidents up to 56 km/h

- Target population estimate
  - 20% (343) to 31% (543) fatally injured car occupants
  - 41% (8,130) and 52% (10,504) seriously injured car occupants

Benefit Analysis

Benefit Methodology - assumptions for GB

Aim of compatibility

- Predictable performance to absorb impact energy in frontal structure
- Little compartment intrusion
- Optimum deceleration pulse

Assumptions

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

Benefit Analysis

Results - Estimated Proportional Benefit for GB

- Pessimistic (lower)
  - Save 12% of fatalities & 9% of seriously injured casualties
- Optimistic (upper)
  - Save 25% of fatalities & 18% of seriously injured casualties

Benefit Analysis

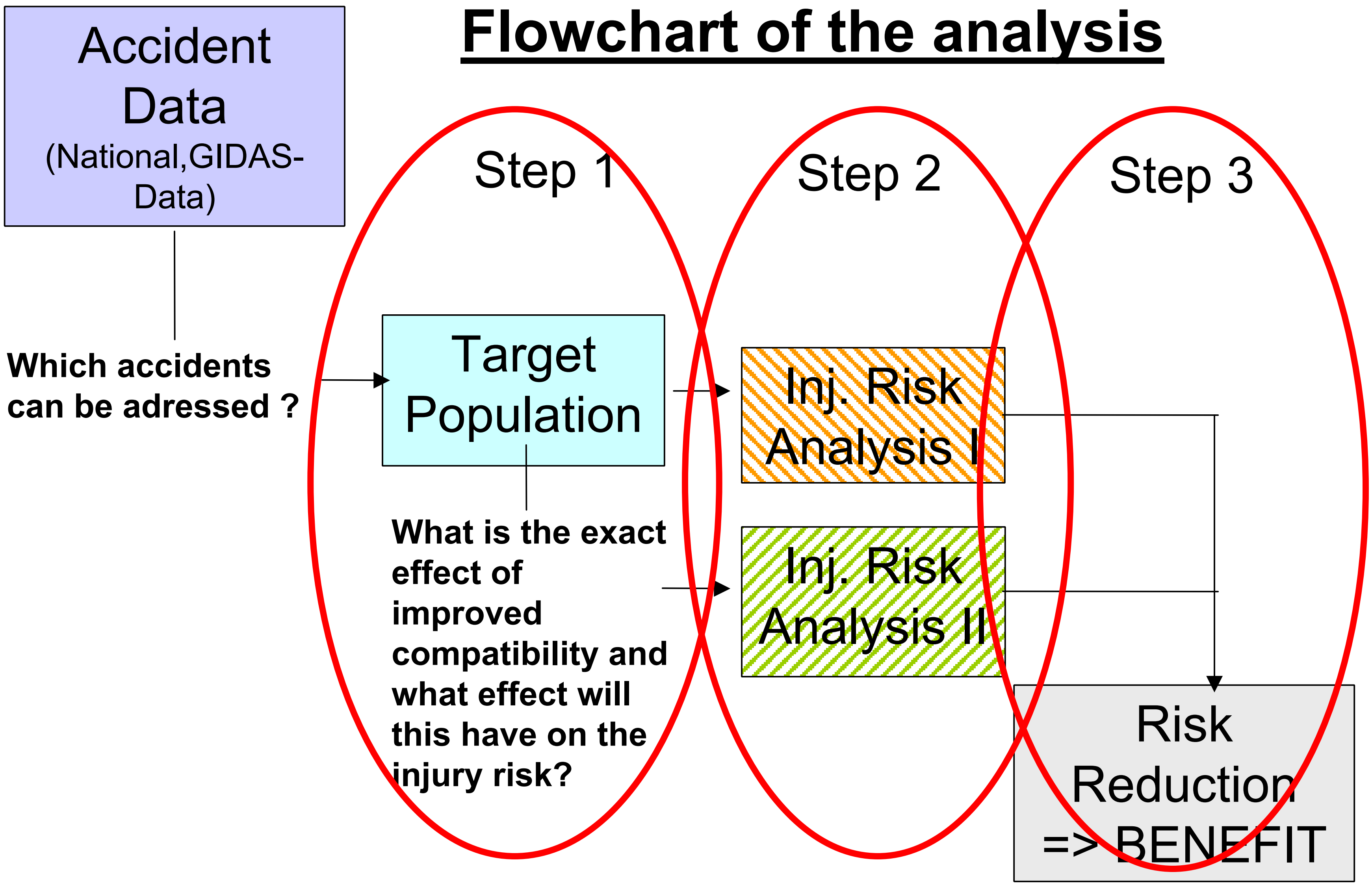
Results – Estimated Benefit for GB

- STATS19 (1999 - 2003) - adjust to remove cars registered before 1996
  - Occupants in frontal impacts seated in front of car
    - 898 killed on average per year
    - 10,056 seriously injured on average per year
- Pessimistic Estimate (Preventing Intrusion Injuries)
    - Save 108 fatalities per year
    - Save 905 serious casualties per year
- Optimistic Estimate (Preventing Contact Injuries)
    - Save 225 fatalities per year
    - Save 1,810 serious casualties per year

Full paper: medwards@trl.co.uk

Benefit Analysis

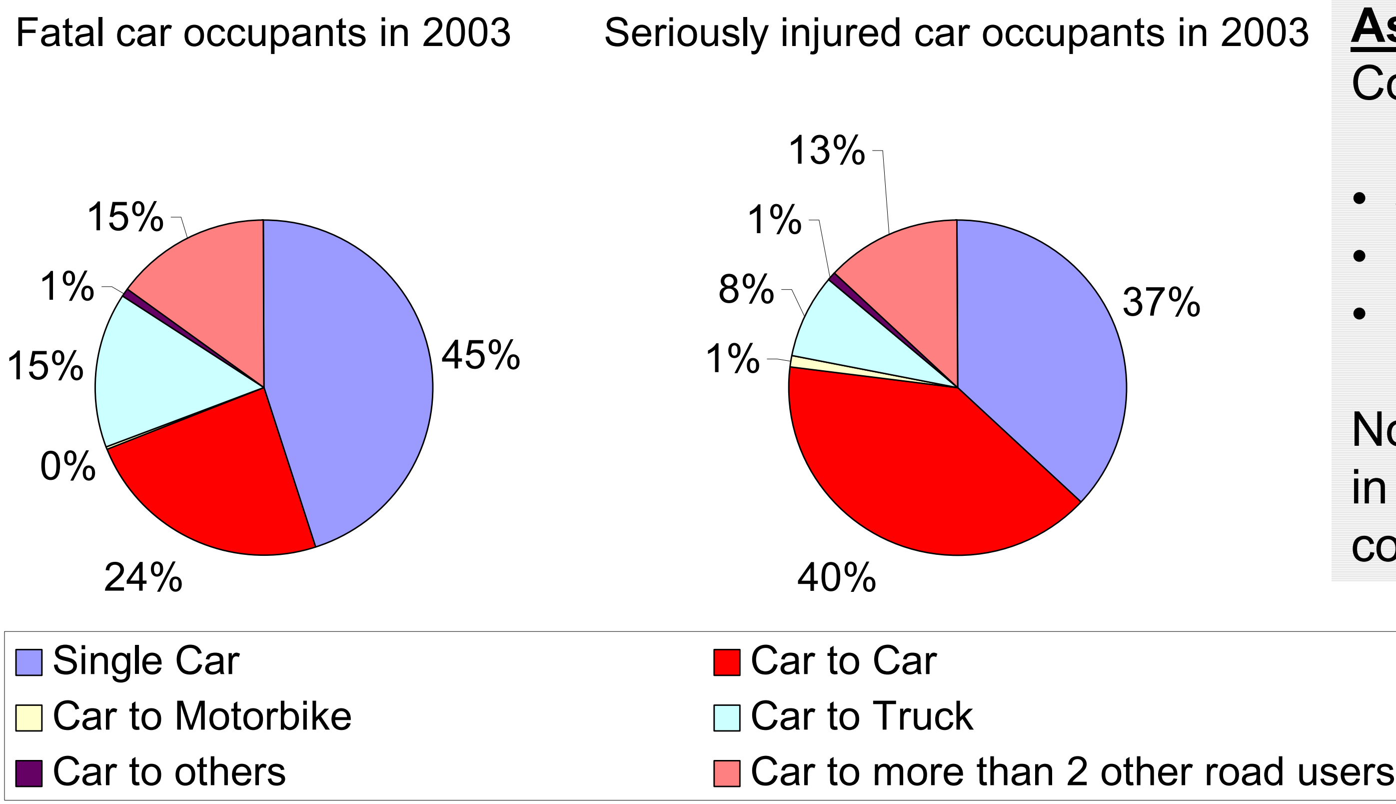
Flowchart of the analysis



Benefit Analysis

STEP 1: Estimation of Target Population

Target Population



Assumption:
Compatibility improves

- **Single Car**
- **Car to Car**
- **Car to Truck**

No improvement in multiple vehicle collisions

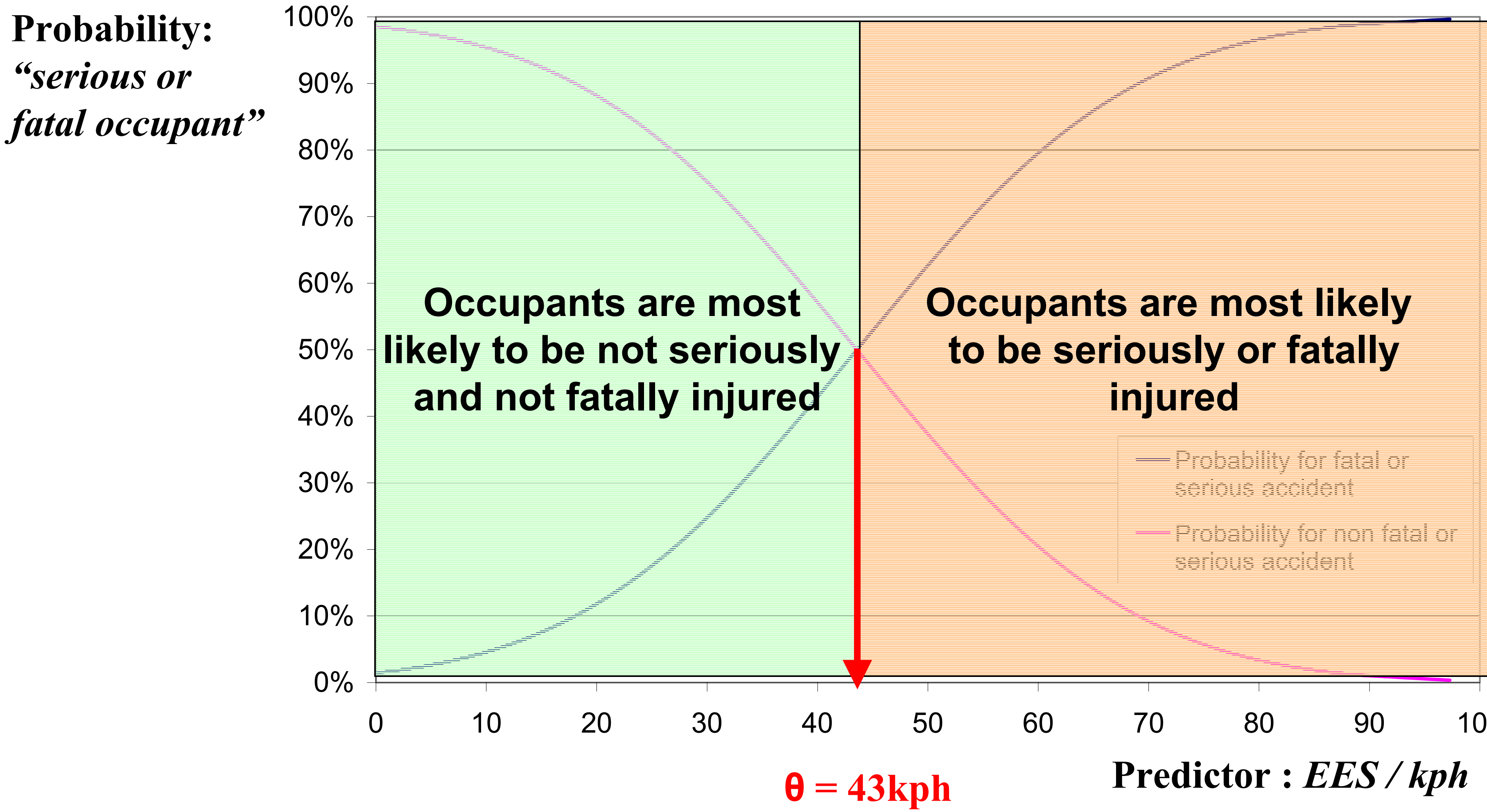
Compatibility can address 84% of all fatal and 85% of all serious accidents

STEP 1: Estimation of Target Population

		Car to Car Category	Car to Truck Category	Single Car Category	**Total**
Proportion of fatal Occ.		24%	15%	45%	**84%**
Proportion of serious Occ.		40%	8%	37%	**85%**
Share of frontal impacts		60%	58%	51%	**---**
Compatibility Relevant Accidents		68%	50%	20%	**---**
TARGET P.	**Fatalities**	9%	4%	5%	**18%**
	Serious Inj.	16%	2%	4%	**22%**

Target Population = „Proportion“ x „Share of frontal impacts“ x „Relevant Accidents“

STEP 2: Injury Risk Curves (Binary Data)



STEP 2: Compatibility effect on injury risk

ECE R.94, Euro NCAP:

Assumption: Offset block fully compatible

Vehicle: 1500kg, Δv = 64km/h, 5 stars

E_{kin} = 240kJ, $E_{def.\ Elem.}$ = 35kJ, **$E_{Vehicle\ R94}$ = 205kJ**

Car to Car Impact:

Assumption: Start of compartment collapse at 50 - 56km/h

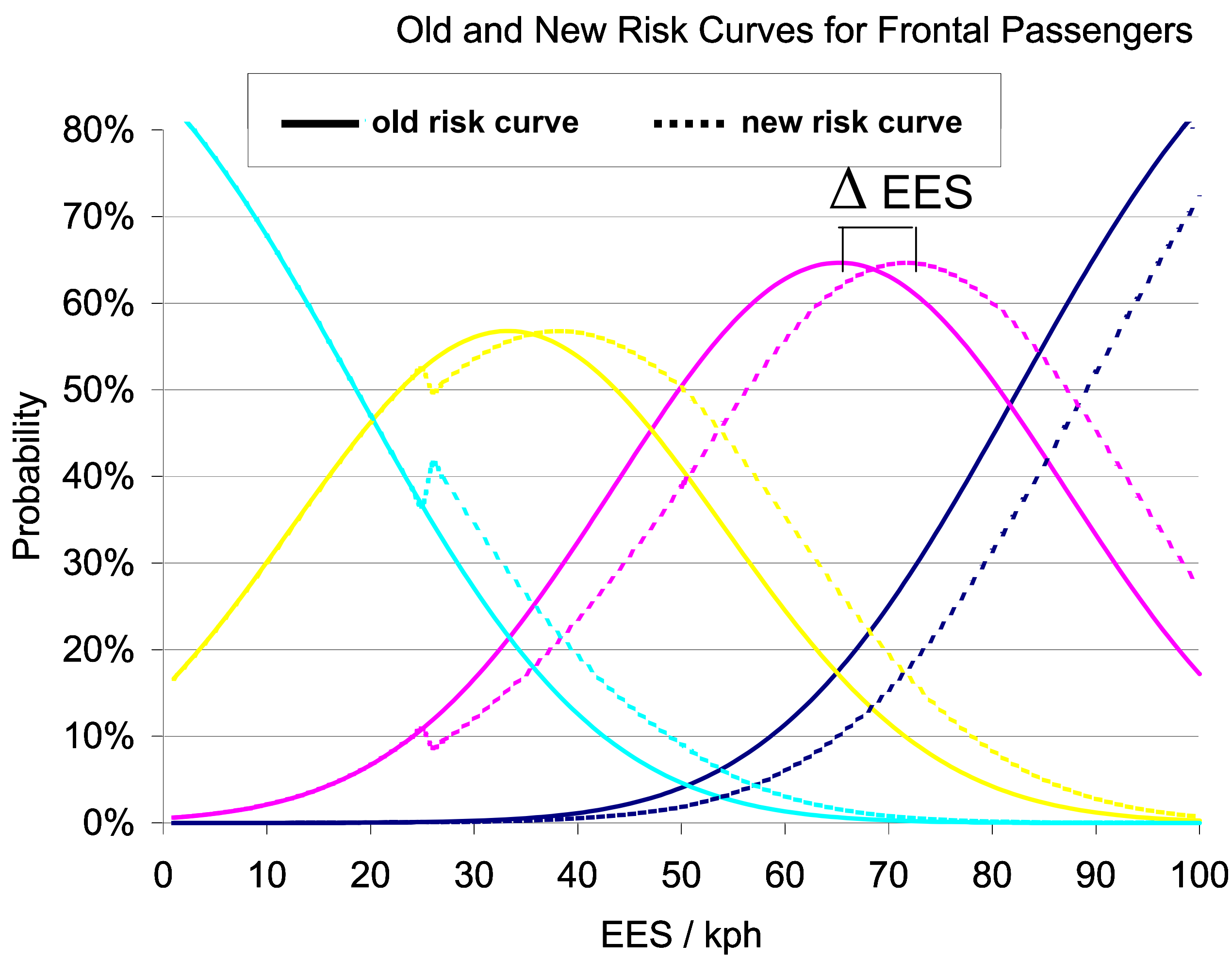
Vehicle = 1500kg, Δv = 53km/h, **$E_{Vehicle\ c2c}$ = 160kJ**

Cars can absorb more energy showing similar deformation depth

- **ΔE = 45kJ or**
- **ΔE/E = 28% higher energy-absorption!**

Inj. Risk Analysis II

STEP 2: Injury Risk Estimation



Benefit Analysis

Risk Reduction
=> BENEFIT

STEP 3: BENEFIT Estimation

Proportion of	Old Risk Curve	New Risk Curve	CHANGE
Fatalities	0,81%	0,45%	**45%**
Seriously Inj.	13,77%	11,21%	**19%**
Slightly Inj.	43,40%	43,81%	**-1%**
Uninjured	42,00%	44,52%	**-6%**

		Car to Car Category	Car to Truck Category	Single Car Category	**Total**
Target P.	**Fatal Occ.**	9%	4%	5%	**18%**
	Serious Occ.	16%	2%	4%	**22%**
CHANGE	**Fatal Occ.**	45%	45%	45%	**---**
	Serious Occ.	19%	19%	19%	**---**
BENEFIT	**Fatal Occ.**	4%	2%	2%	**8%**
	Serious Occ.	3%	0,5%	0,7%	**4,2%**

Benefit Analysis

Conclusion …

- 8 % of all fatal car occupants will take advantage of compatible frontal car structures
- 4.2 % of all seriously injured car occupants will benefit from compatible frontal car structures
- Socio-Economic saves of 500 M€ per anno can be expected.

(full paper: pastor@bast.de or faerber@bast.de)

Crash Test Programme

Two favourite test procedure candidates:

- **Full Width Test** with high resolution load cell wall
- **Offset Deformable Barrier Test** with progressive deformable barrier and load cell wall

other considered test procedures:

- ODB with standard deformable barrier
- Overload test
- Offset mobile deformable barrier (OMDB)

Crash Test Programme

Full Width Barrier With Deformable Element and Load Cell Wall

Crash Test Programme

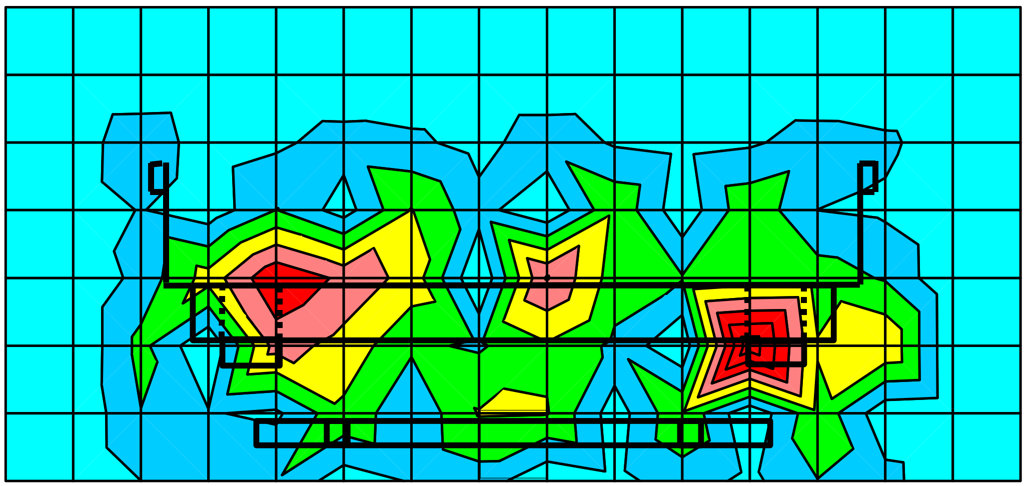
Full Width Test With Deformable Element

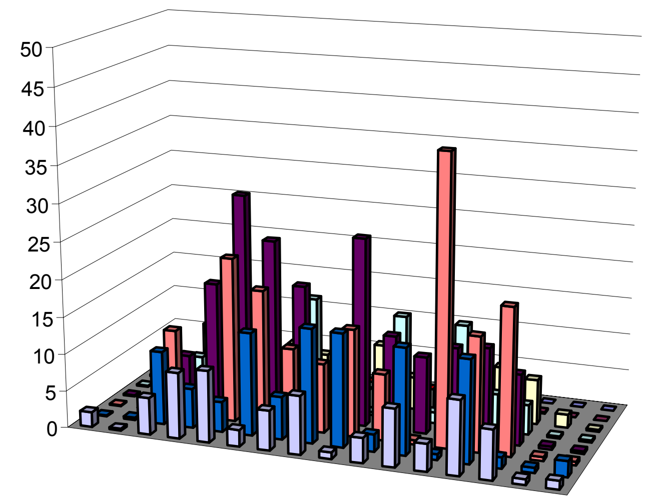
Pre and post test front view, Resultant barrier deformation

Full Width Test With Deformable Element

Maximum Force Distribution Behind Deformable Element

150mm 0.34MPa & 150mm 1.71MPa





Full Width Barrier Evaluation

HOMOGENITY ASSESSMENT

- Cell homogeneity
  - Overall force distribution
- Row homogeneity
  - Vertical force distribution
- Column homogeneity
  - Horizontal force distribution

Crash Test Programme

Full Width Barrier Evaluation

CELL HOMOGENEITY

$$V_c = \frac{\sum_{i=1}^{n_c} (L - f_i)^2}{n_c}$$

V_c = Cell homogeneity assessment

L = Target load level

f = Peak cell force

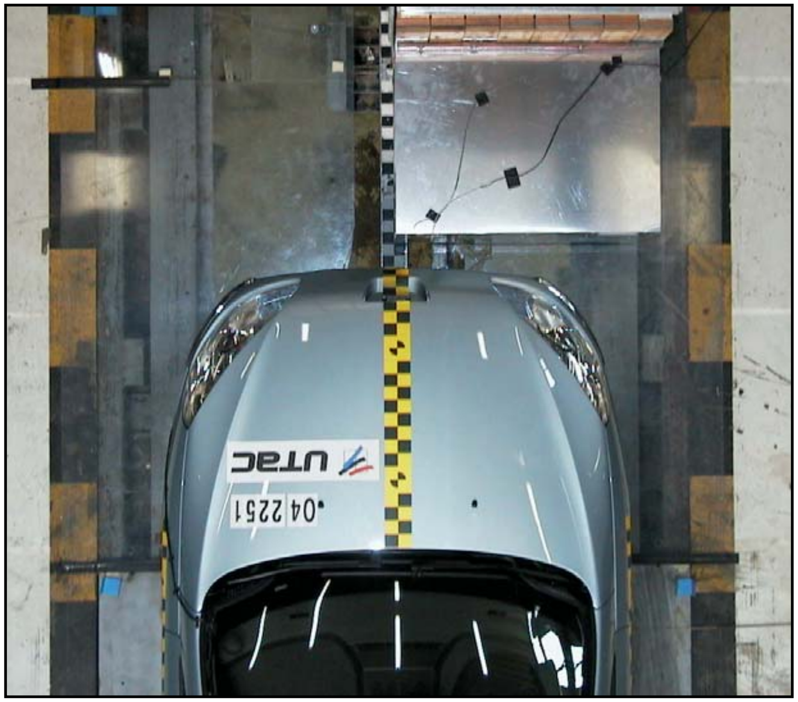
n_c = Number of cells in the smoothed footprint

- Indicates the overall force distribution

Under Revision

PDB Approach

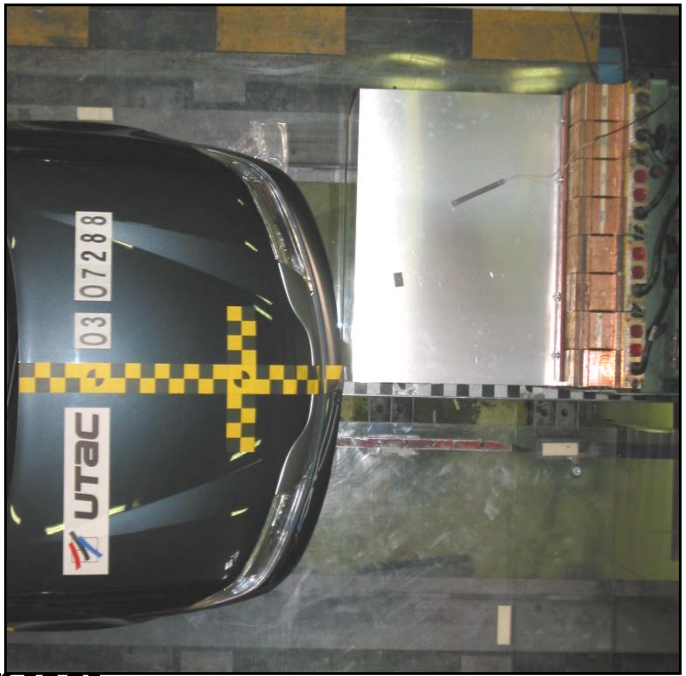
(Progressive Deformable Barrier)



PDB TEST PROCEDURE : CONFIGURATION

French proposal: update current R94 Frontal ODB test

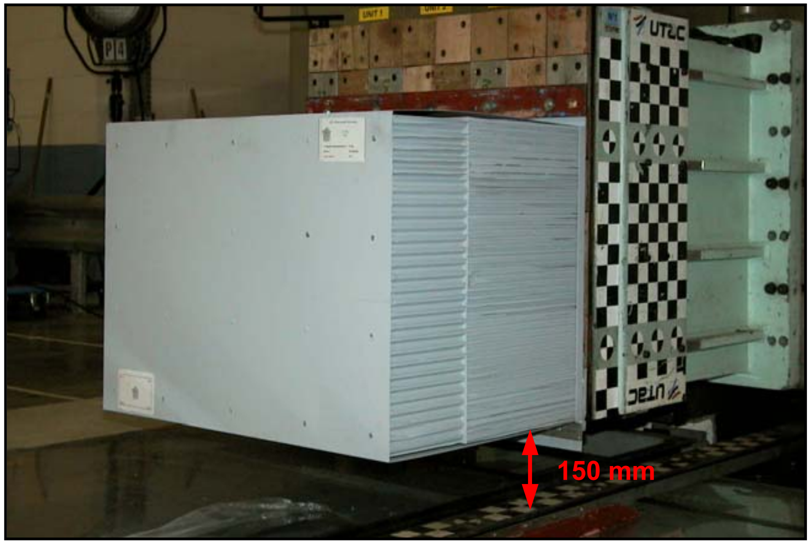
3 parameters are changed:

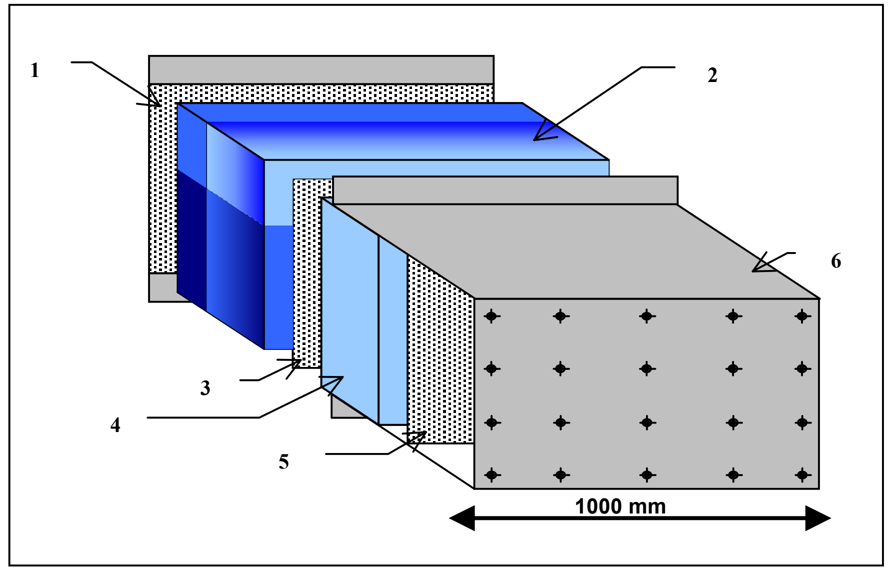


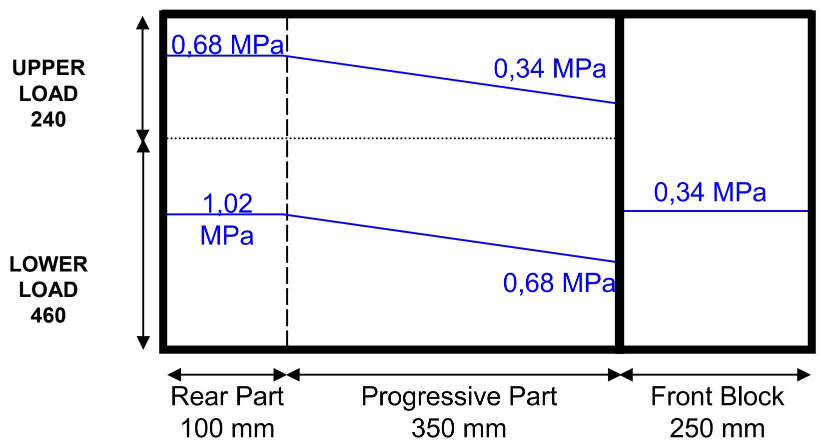
- **OBSTACLE : PDB Barrier**
  - ➢ To avoid bottoming out, more stable
- **SPEED: 60 km/h**
  - ➢ to check compartment strength
- **OVERLAP: 50%**
  - ➢ To check half width and be close to car to car test

⇨ More realistic test configuration

PDB TEST PROCEDURE : PDB BARRIER







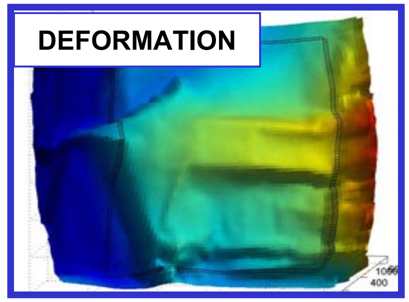
⇨ PDB looks like a car

Crash Test Programme

PDB TEST PROCEDURE: TOOLS AND MEASUREMENT

TOOLS | **MEASUREMENTS** | **ASSESSMENTS (First step)**

STRUCTURAL INTERACTION

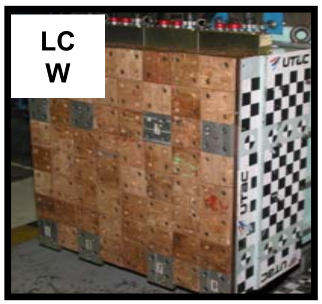


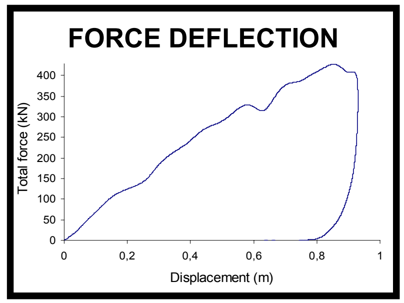
AHOD: Average Height of Deformation ?

ADOD: Average Depth of Deformation ?

Homogeneity ?

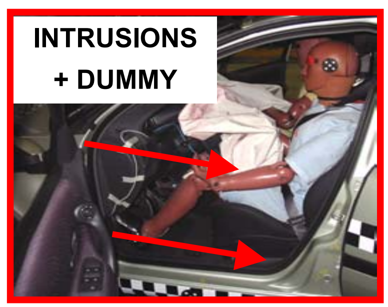
FRONT END FORCE





Force level ?

COMPARTMENT STRENGHT



dummy criteria

Intrusion level ?

PDB TEST PROCEDURE: CONCLUSIONS

Proposal:

Replace the current barrier by PDB one to update R94 test protocol

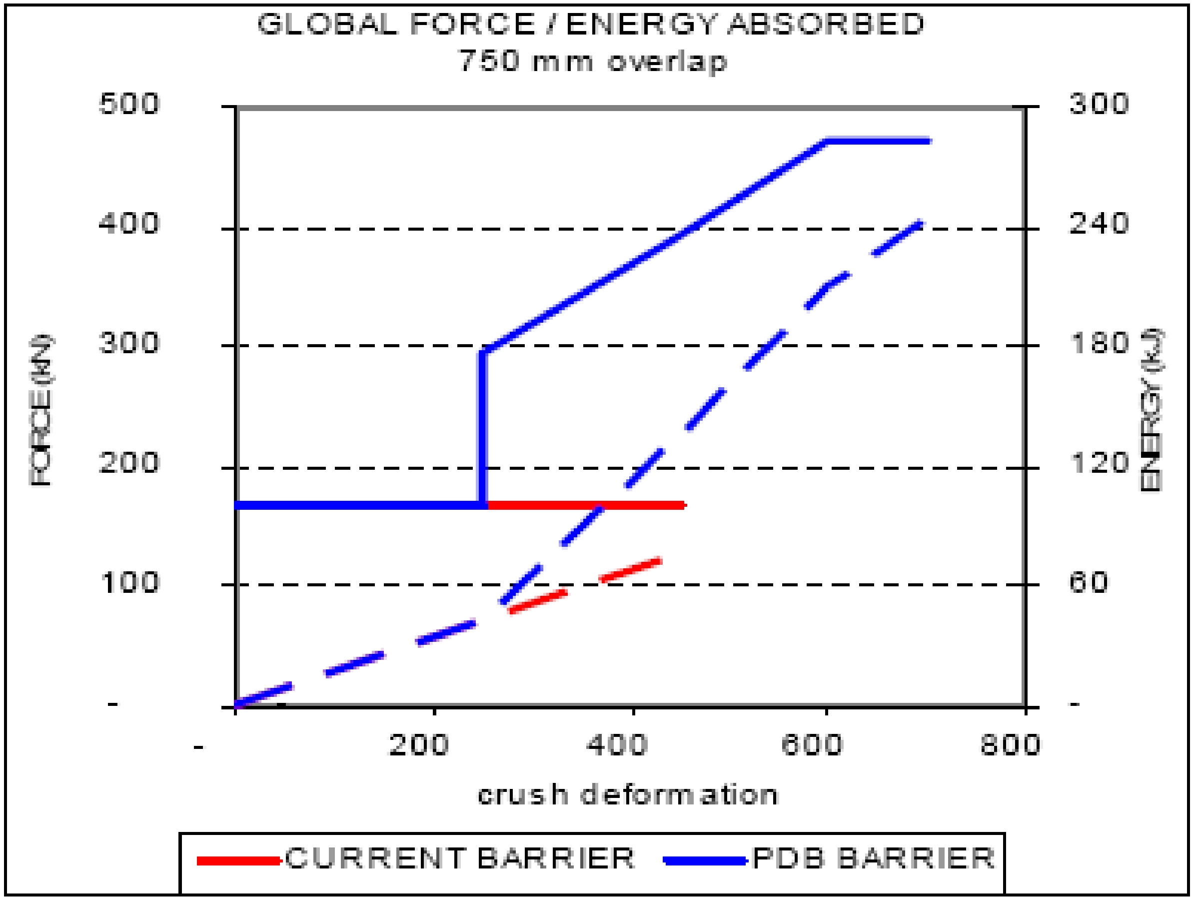
Influence on vehicle design

- **Harmonize severity for all mass range**
- **improve self protection of light cars**
- **limit increasing stiffness of heavy cars**
- **improve partner protection of heavy cars**

PDB Barrier is closer to new safety requirements and car design.

Crash Test Programme

PDB and R.94 Barrier, Force-Deflection & Energy Absorption Capability



Crash Test Programme

Crash Test Programme Phase 1 and 2

:

PDB Tests	FWDB Tests	Car to Car Tests
Volvo XC90	Volvo XC90	Focus vs Focus
Honda CRV	Honda CRV	Focus vs Astra
Mercedes E-Class	Mercedes E-Class	
	MMC Smart	
	Ford Focus (raised LCW)	
Golf V	Golf V	Golf V vs Golf V (60mm ride height diff.)
Astra MY 04	Astra MY 04	Astra vs Astra (60 mm ride height diff.)
Focus		

st

Crash Test Programme Phase 3 and 4

Car 1	**Car 2 / Barrier**	**Comment**	**Purpose**	**Test Lab**
To date: 6 PDB, 7 FWDB, 4 CtC (21 of 43 units)				
Astra '04MY	64km/h ODB		Frontal force level measurement, compartment intrusion measurements	BASt
Astra '04MY	Golf MkV	Golf bumper crossbeam must be lower than Astra Requires similar frontal force level. Closing speed 112 km/h	Demonstrate improved structural interaction of Golf due to Astra subframe load path. (Golf cf lowered Golf)	TRL
Investigate impacts with mass ratio difference (less than 2.0)				
Panda	Panda	Raised / lowered to give 60 mm ride height difference Closing Speed 112 km/h	To establish structural interaction performance of Panda and compartment strength	Fiat
Decision Point 1 (16 crash test units remaining)				
Panda	Golf MkV	Closing Speed 112 km/h	To investigate if performance of small car is improved against car with two load path levels (Panda 850 / A 1240(1.46) G 1200 (1.41))	BASt
Panda	Astra '04MY	Closing Speed 112 km/h		UTAC
Panda	FWDB	Test speed 56 km/h		TRL
Panda	PDB	Test speed 60 km/h		UTAC
VW Touareg	Golf	Closing Speed 112 km/h		BASt
VW Touareg	Astra	Closing Speed 112 km/h		TRL

Further Progress:

Both favourite test Procedures are under critical consideration and further development:

- November 2005 :
  - Collating crash test data
  - Summary of crash test results
- January 2006:
  - Finalising summary of crash test results
  - EEVC WG 15 establish conclusions
  - Commence of drafting the test procedure/ set of test procedures.

Conclusions:

Both favourite test Procedures are under critical consideration and further development:

- PDB:
  - deformation assessment
  - assessment criteria
- Full Width:
  - deformable element stiffness
  - homogeneity criteria
  - definition of area to be assessed

Possible Sets of Legal Frontal Impact tests to Assess Compatibility

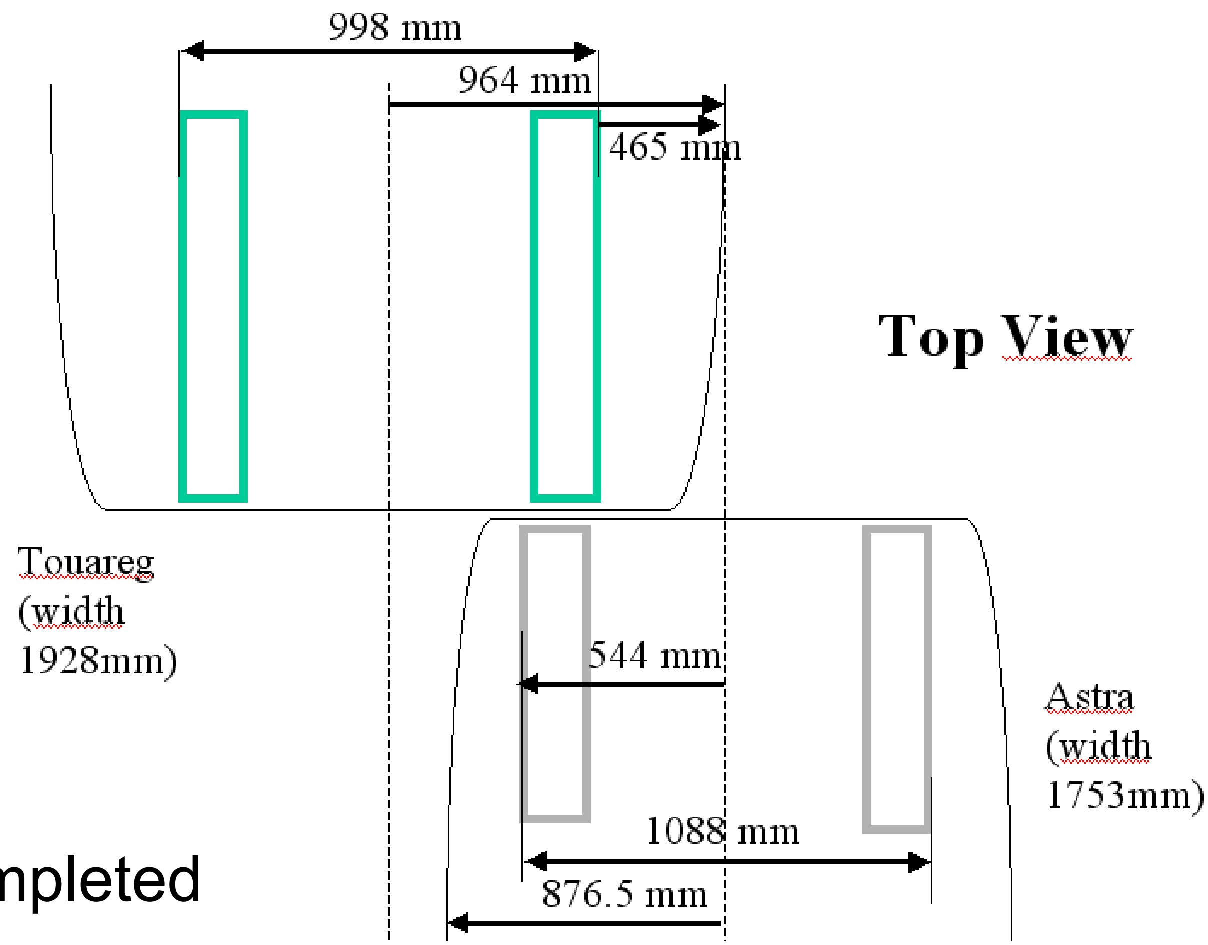
Set 1:
- PDB Test Procedure replacing ECE R.94 (structure test) with barrier deformation analysis
- Maintain or/and improve restraint system tests

Set 2:
- Maintain ECE R. 94 (structure test)
- Full Width Barrier Test With Deformable Front Face (restraint test, additional airbag sensing).

Set 3:
- PDB Test Procedure replacing ECE R.94 (structure test)
- Full Width Barrier Test with or without Deformable Front Face

Illustration of Compatibility Problem

Horizontal Geometrics



Note: to be completed

Illustration of Compatibility Problem

Vertical Alignment

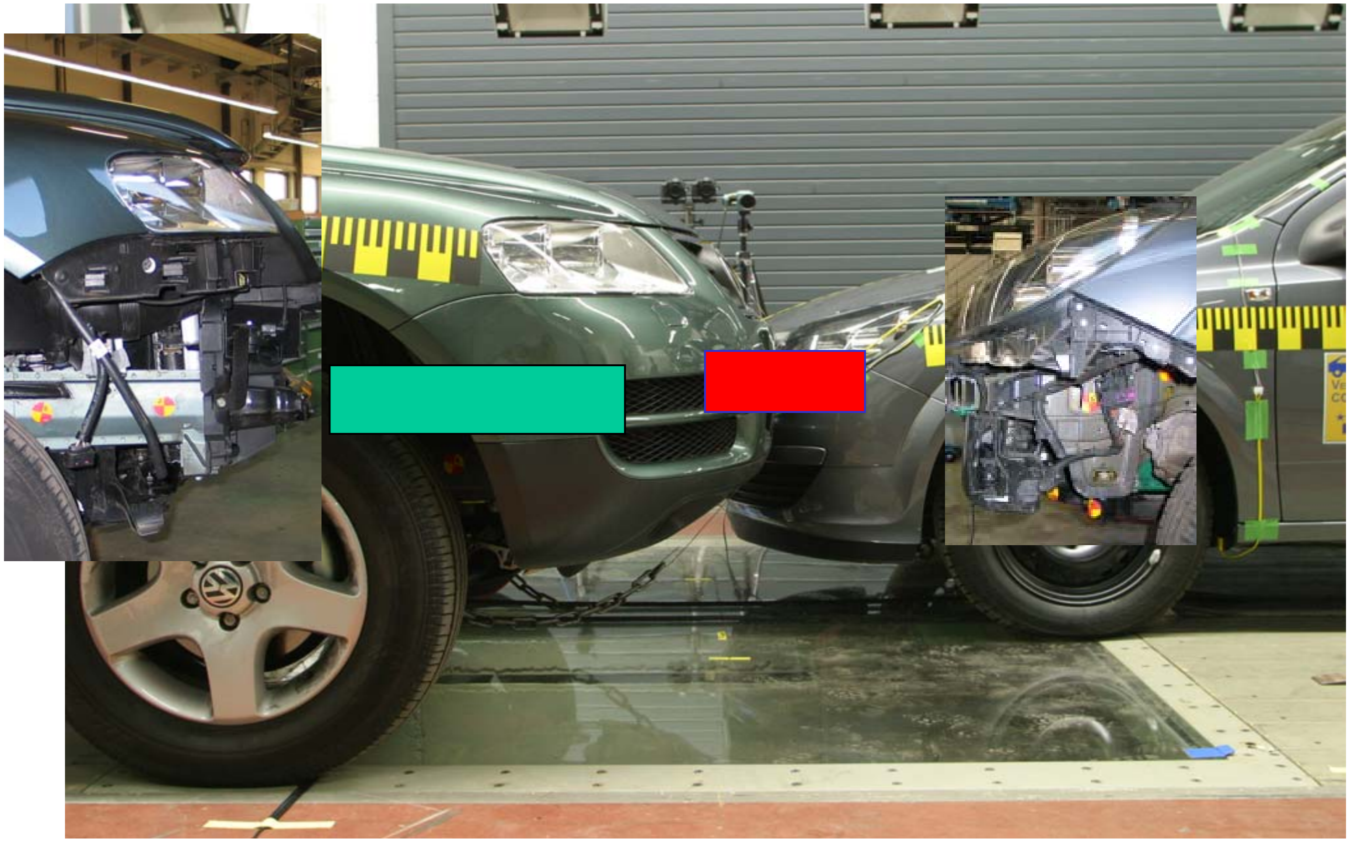


Illustration of Compatibility Problem

Photo Astra

Illustration of Compatibility Problem

Photo Touareg