Development of a Full Width Frontal Impact Test for Europe

GRSP Informal Working Group on Frontal Impact

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on behalf of APROSYS WP1.2 consortium

Overview

- Requirement
- Objective
- Main questions
- Accident analysis
- Test results
- Cost benefit analysis

Requirement – Frontal Impact

EEVC WG15

- Integrated set of test procedures to assess a car's frontal impact protection (including compatibility)
- 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

Objective

- To develop a full width high deceleration test for Europe
  - Advanced European Full Width (AE-FW) test
- To perform associated cost benefit analysis

Main Questions

- Test speed?
- Dummy specification?
  - Size and injury criteria?
- Rear occupants?
- Deformable face and Load Cell Wall?
  - For compatibility measures?

Approach

- Define draft test protocol
  - Accident analysis
  - Consideration of other similar procedures, e.g. FMVSS208
- Evaluate draft test protocol
  - Full scale crash testing
- Perform cost benefit analysis

Accident Analysis

- Analysis performed for GB and Germany, using CCIS and GIDAS databases
- Case selection criteria

CCIS

- Frontal impact, no rollover
- Occupant belted
- Where possible (test speed and injury type analyses)
  - New vehicle – build year 2000 onwards
  - Overlap > 33%

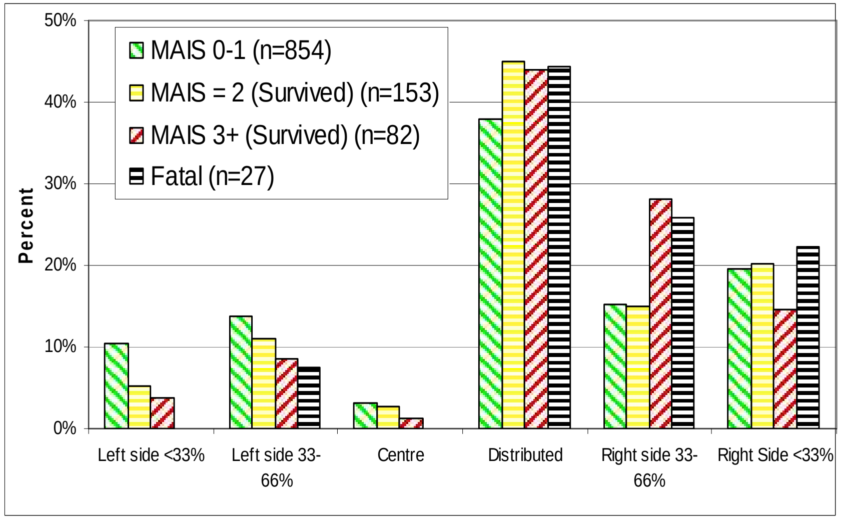
GIDAS

- Frontal impact, no rollover
- Occupant belted
- Where possible (test speed and injury type analyses)
  - New vehicle – build year 1997 onwards
  - Overlap all

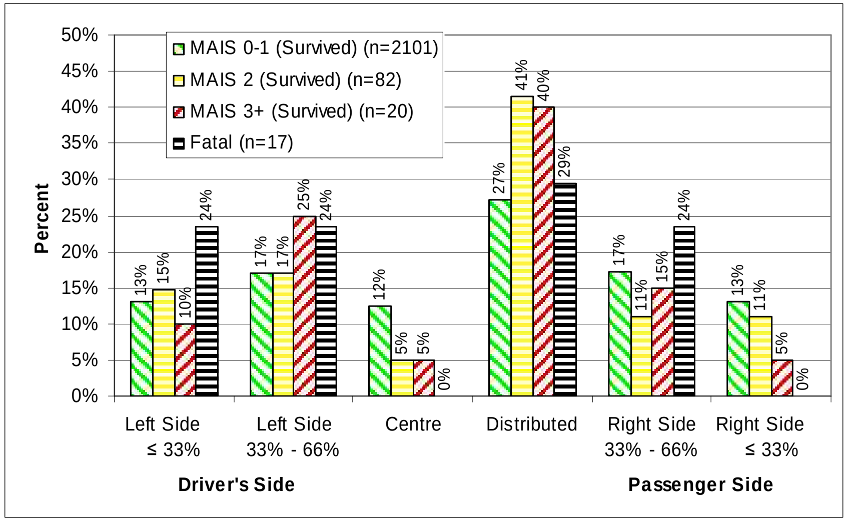
Test Overlap?

Location of Damage for Belted Drivers

CCIS

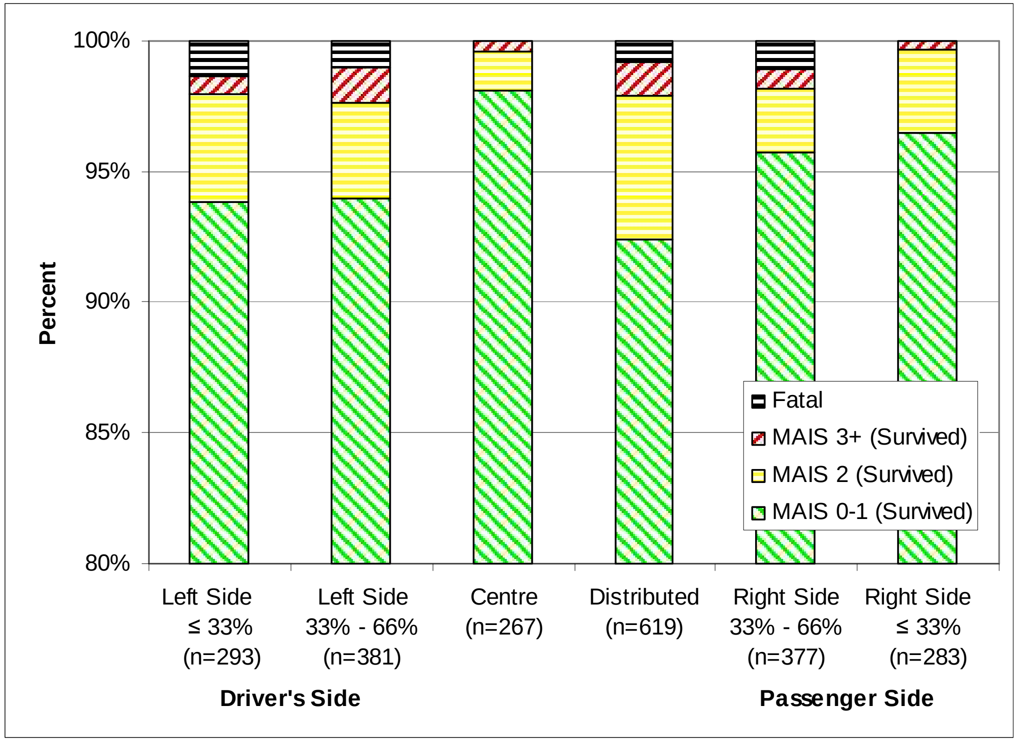


GIDAS



- Distributed damage most frequent for all injury levels

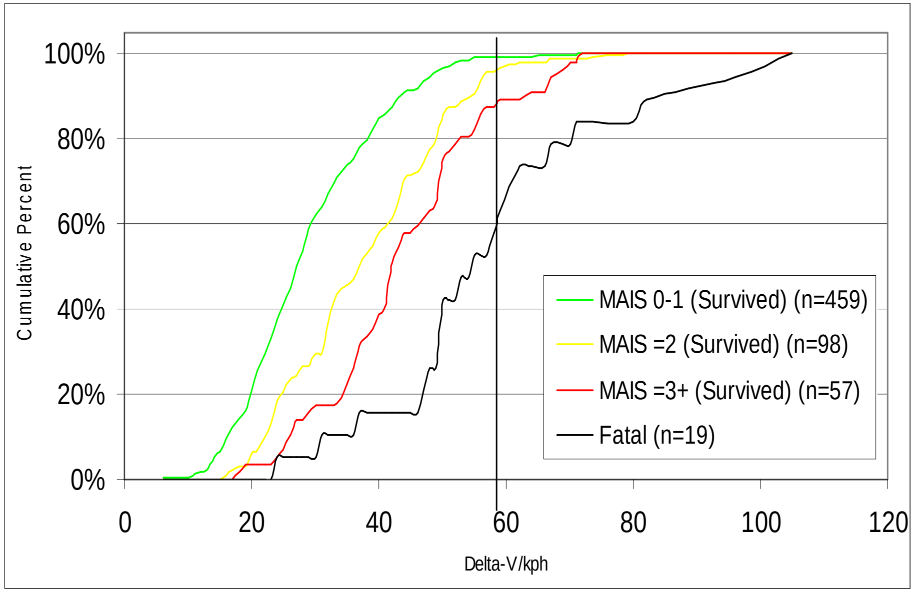
Risk of Injury with Location Damage for Belted Drivers (GIDAS Data)



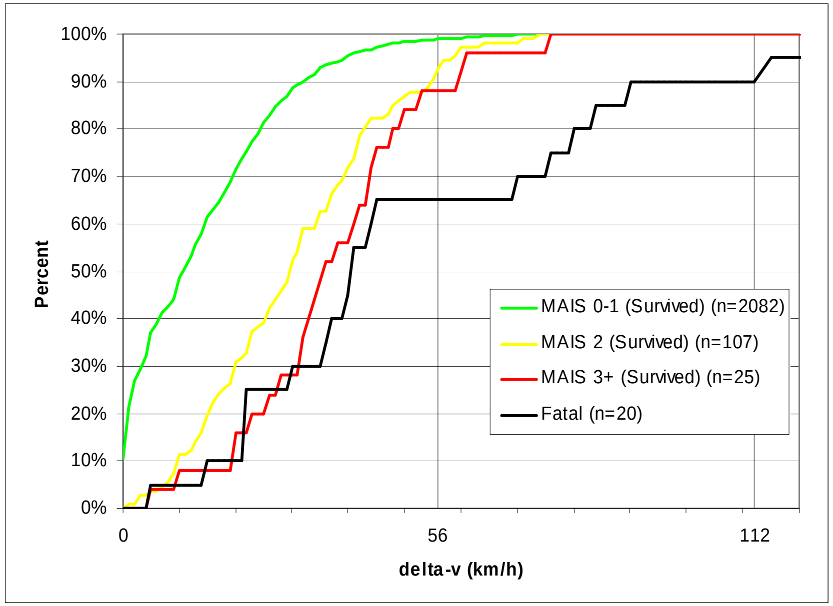
- Distributed damage has highest MAIS 2+ injury risk

Test Speed?

CCIS



GIDAS

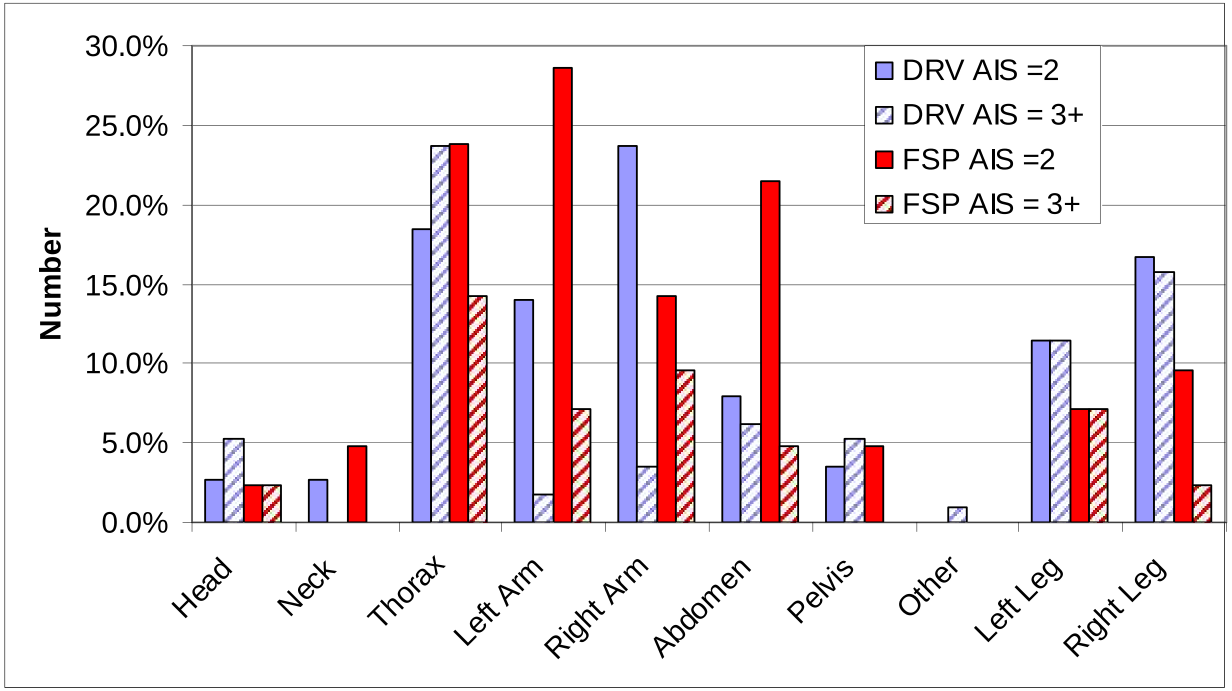


- Proposed test speed of 56 km/h covers large proportion of serious injuries
  - 83% of MAIS 3+ based on CCIS (new vehicles)
  - 88% of MAIS 3+ based on GIDAS (new vehicles)

Note: for belted occupants only

Type of Injuries?

Body Region Injured when Occupant had MAIS 2+ Injury (CCIS Data)

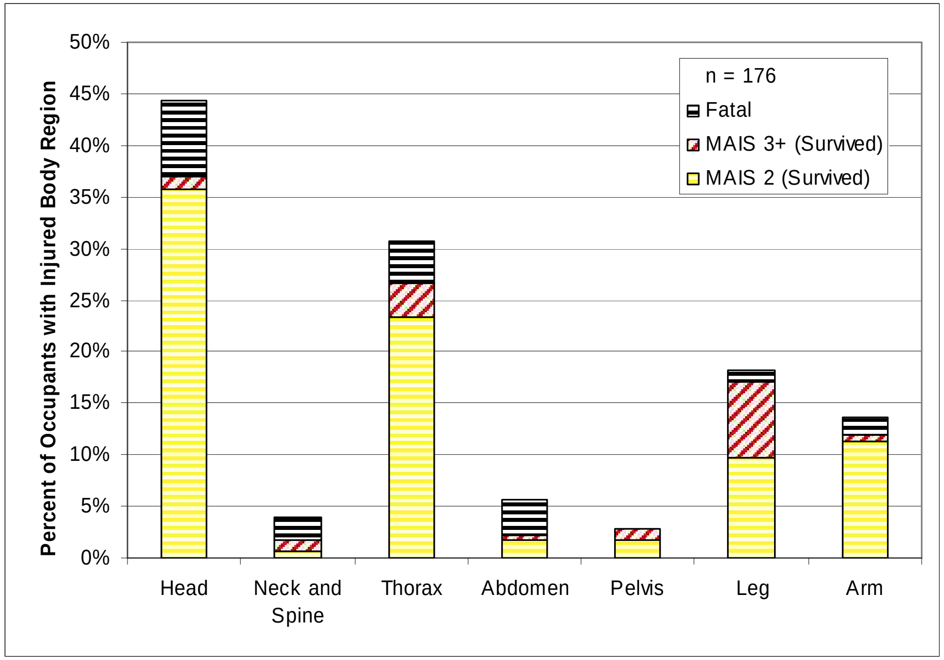


Body regions to protect:

- For AIS 2 injuries are thorax and clavicle for DRV and FSP and legs for DRV
- For AIS 3+ injuries are thorax for DRV and FSP and femur for DRV

Type of Injuries?

Fatal Injuries or Most Severe Injuries (GIDAS data)

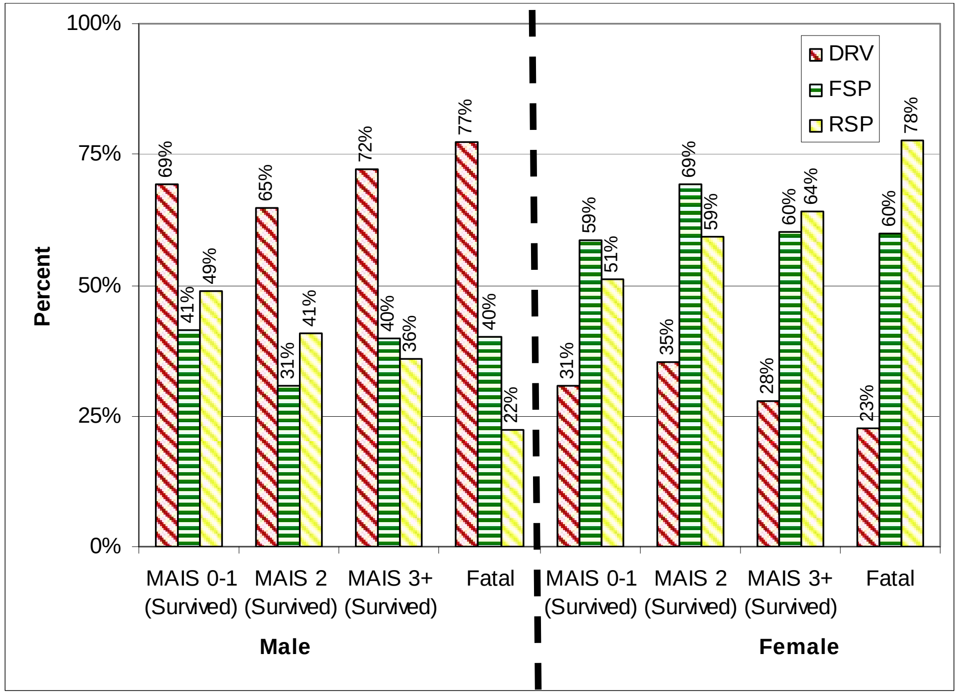


* Note that more than one injury may be recorded as being Fatal or Most Severe for each occupant

- Body regions to protect are head and thorax
- Leg and arm injuries are rarely fatal, despite high frequency at MAIS 2 and MAIS 3 level
- GIDAS data shows significantly higher frequency of head injury than CCIS

Occupant Gender?

Gender Ratio for Belted Occupants in Frontal Impacts (GIDAS)



- For driver majority male (65 – 77%), increases with increasing severity
- For front seat passenger majority female (59 – 69%), does not change with severity
- For rear seat passenger majority female

Note: CCIS gives similar results for Driver and Front Seat Passenger

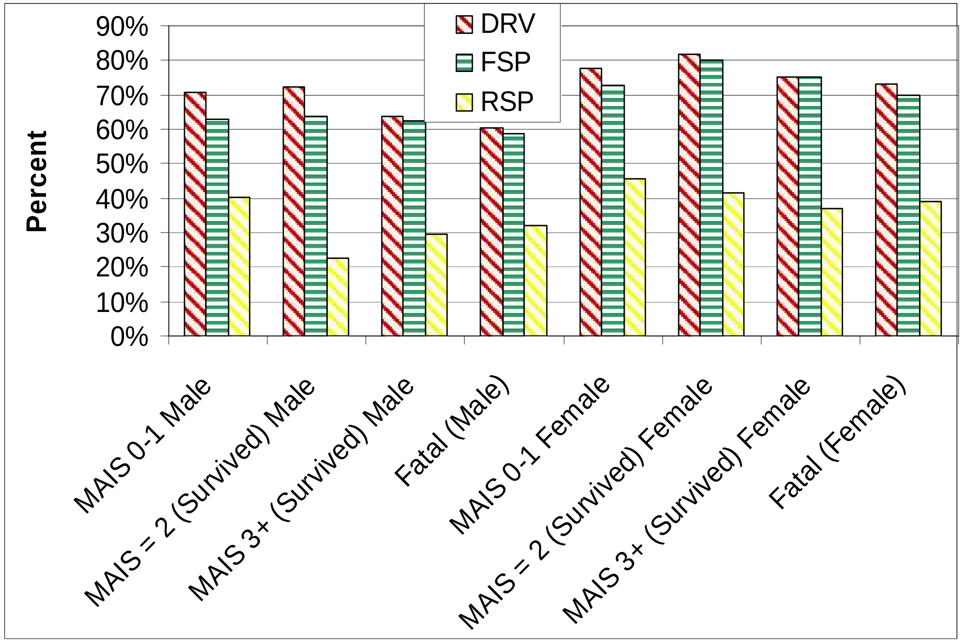
Other Occupant characteristics?

<u>Characteristics of belted occupant involved in frontal impact (GIDAS)</u>

- 50th percentile driver
  - Male
  - 34 years
  - 175 cm
  - 74 kg
- 50th percentile passenger
  - Female
  - 30 years
  - 169 cm
  - 67 kg
- 50th percentile male dummy most closely matches these characteristics (175 cm, 78 kg)

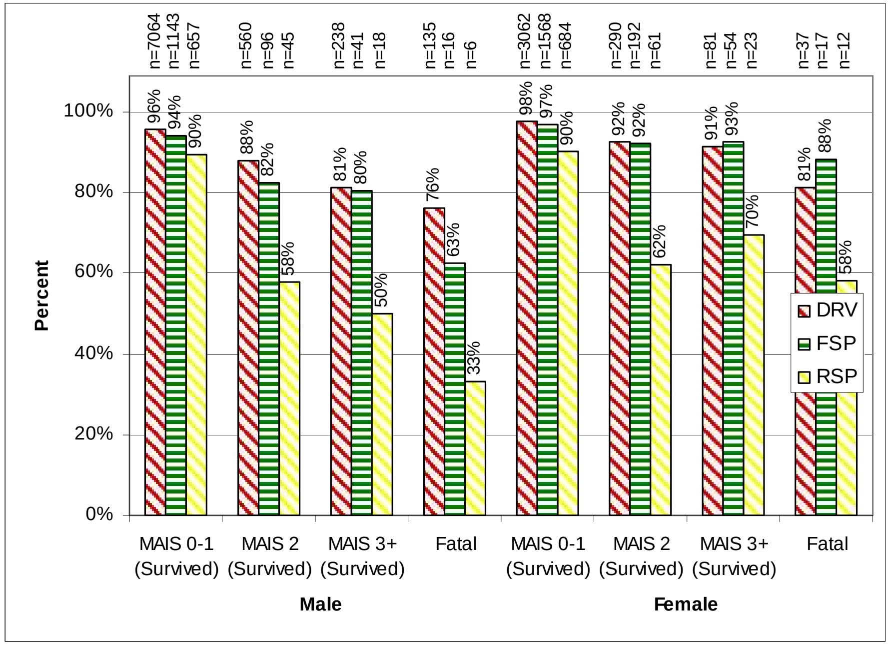
Rear Seated Occupants - Seat Belt Usage

CCIS



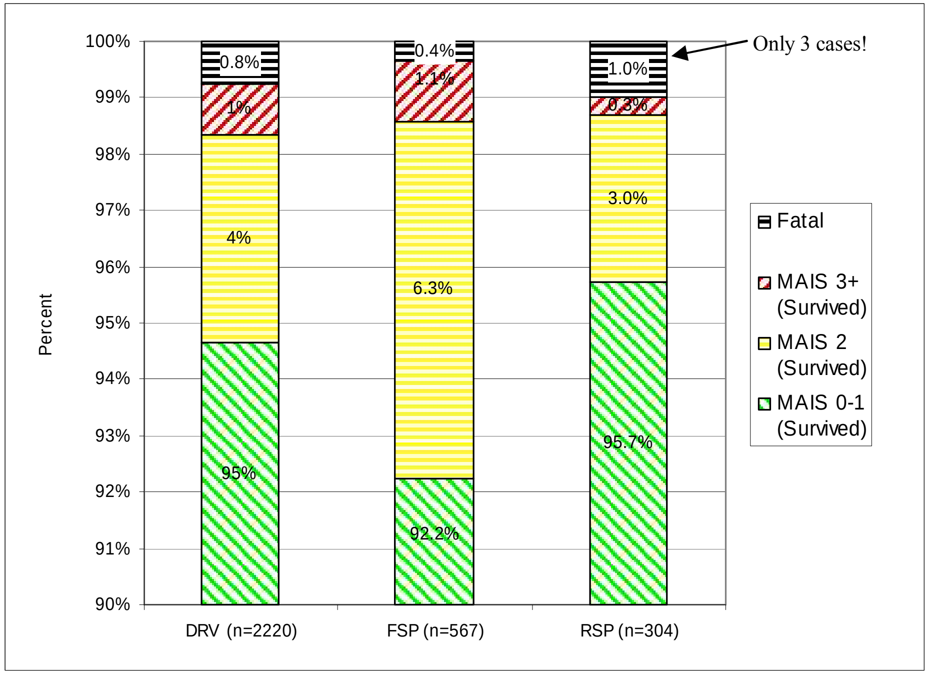
GIDAS

* All Build Years



- Rear seat occupants have low seat belt usage compared to front seat occupants
  - Male lower than female

Rear Seat Occupants – Risk of injury



Risk of injury or fatality for occupants of passenger vehicles with build years 1997 - 2006

- **Belted rear seat occupants have lower risk of injury than front seat occupants**

Summary

- Test speed - 56 km/h
  - Covers a large proportion of serious injuries
  - Same as FMVSS208
- Dummy specification – 50^{th} percentile driver and passenger
  - Male driver, female passenger; mass and height of driver and front seat passenger close to 50^{th} %tile dummy
  - Injury – body regions to focus on to reduce serious injuries are thorax and head and legs (for the driver)
- Rear seat occupant – optional
  - Seat belt usage rate much lower than front seated occupants and overall number low (CCIS & GIDAS); risk of injury lower than for front seated occupants (GIDAS)
- Deformable face - optional
  - EEVC compatibility work not sufficiently well progressed to decide whether or not deformable face required for compatibility measures

Evaluation of Draft Test Protocol

- Objectives
  - Effect of including the deformable face
  - Effect of including rear seated dummies
  - Repeatability / reproducibility
  - Practicality / robustness

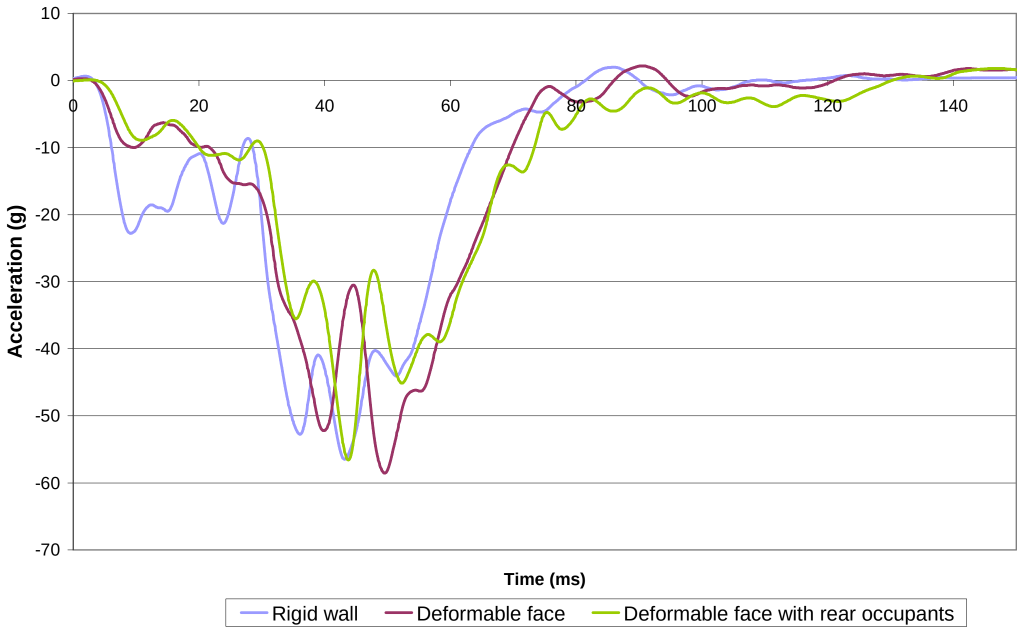
Test Matrix

Vehicle	Test Configuration	
	Rigid Wall	**Deformable Face**
	Test Objective	**Test Objective**
Supermini 1	Baseline	Baseline
		Reproducibility
Supermini 2	Baseline	Baseline
		Rear occupants
Small Family 1	Baseline	Baseline
	Rear occupants	Rear occupants
		Repeatability
		Reproducibility

Effect of Deformable Face

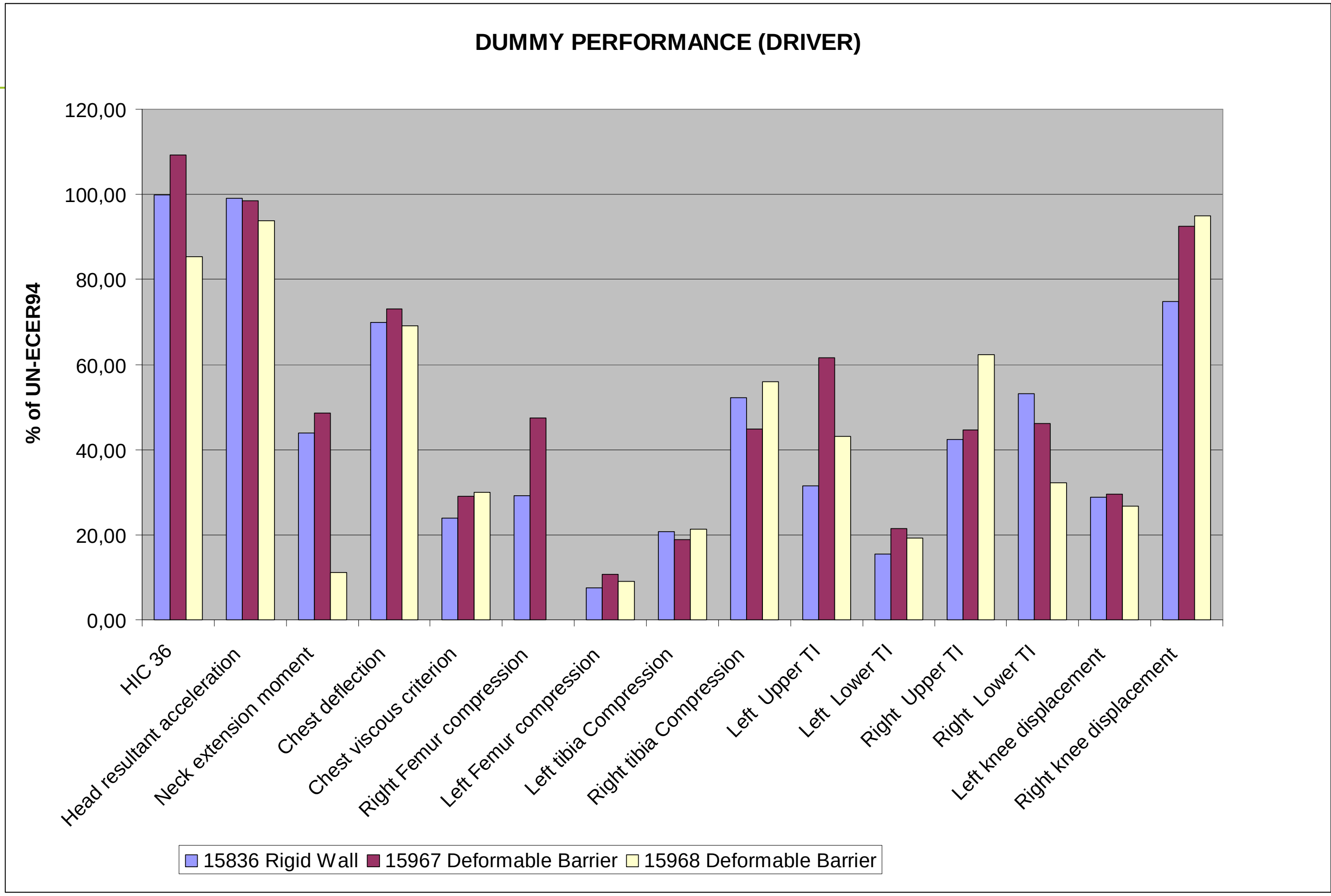
- Deformation of vehicle
  - Substantial difference of the car's frontal structures, especially front of lower rails and bumper crossbeam
- Deceleration of vehicle
  - Lower compartment decelerations at beginning of impact
- Airbag firing time
  - Large difference for Supermini 2, little difference for others
- Dummy injury criteria values
  - Similar apart from Supermini 2 test
- Load Cell Wall results
  - Substantial differences such as attenuation of engine inertial 'dump' loading seen in rigid wall test

B-pillar Deceleration and Airbag Firing Time (Supermini 1)

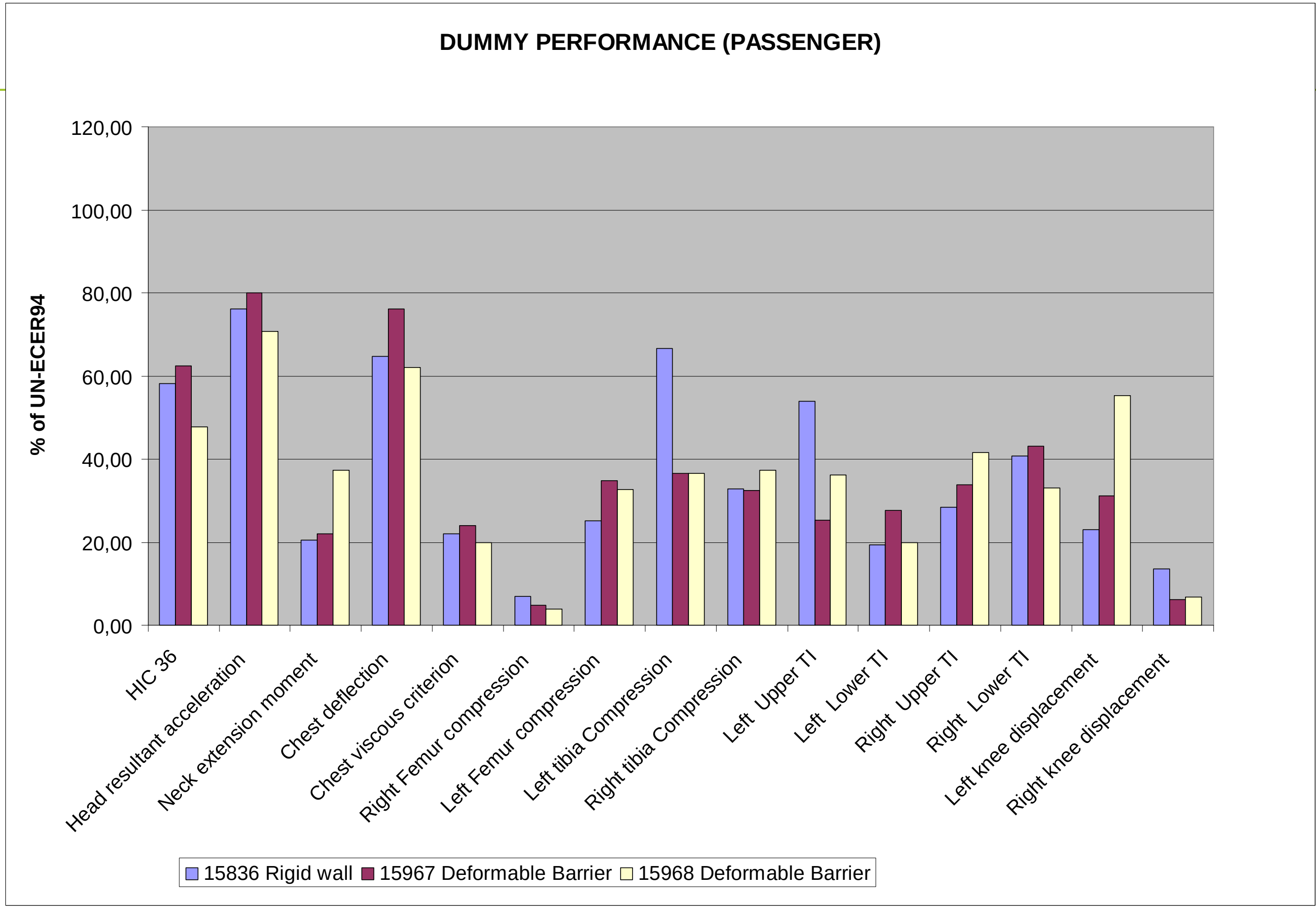


	Driver	Passenger
Baseline rigid wall	12ms	12ms
Baseline deformable element	33ms	33ms
Deformable element with rear occupants	35ms	35ms

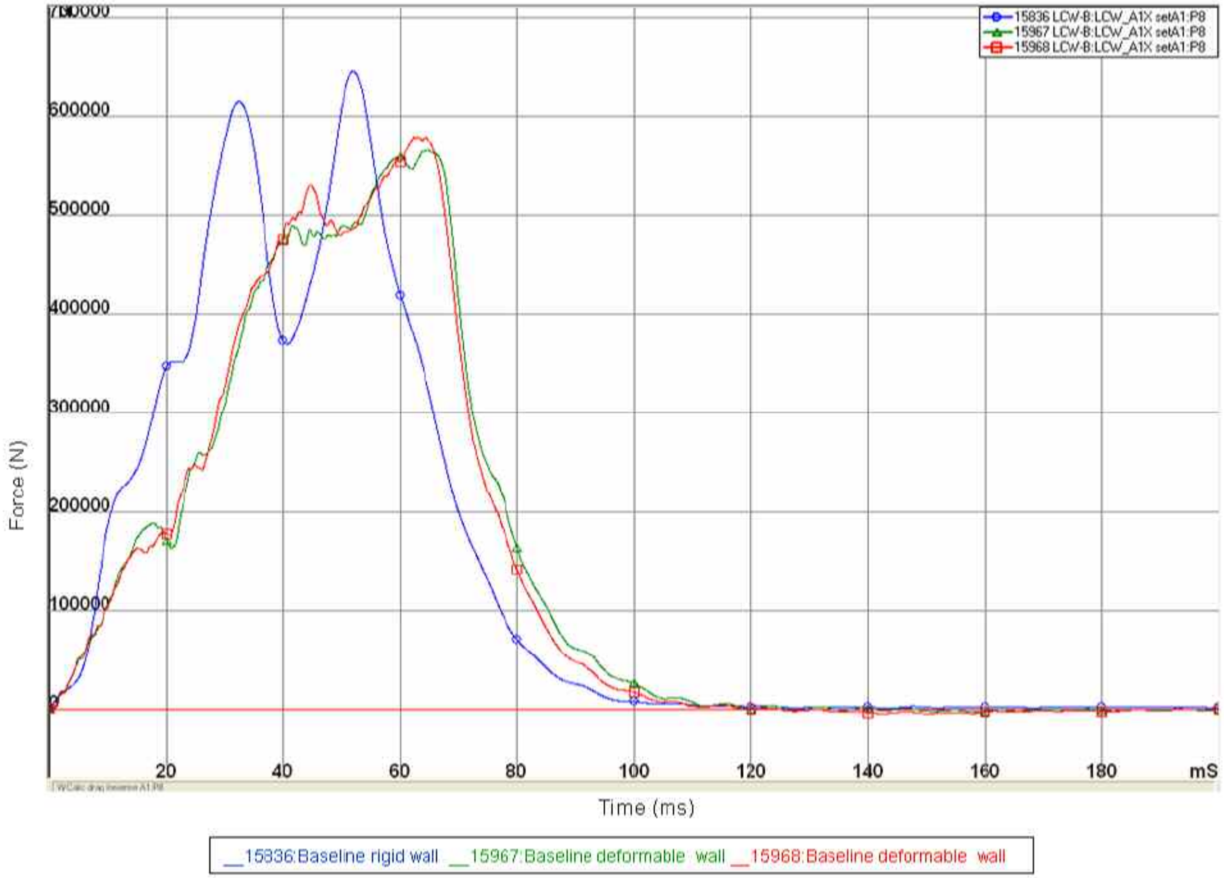
Dummy Performance (Small Family)



Dummy Performance (Small Family)

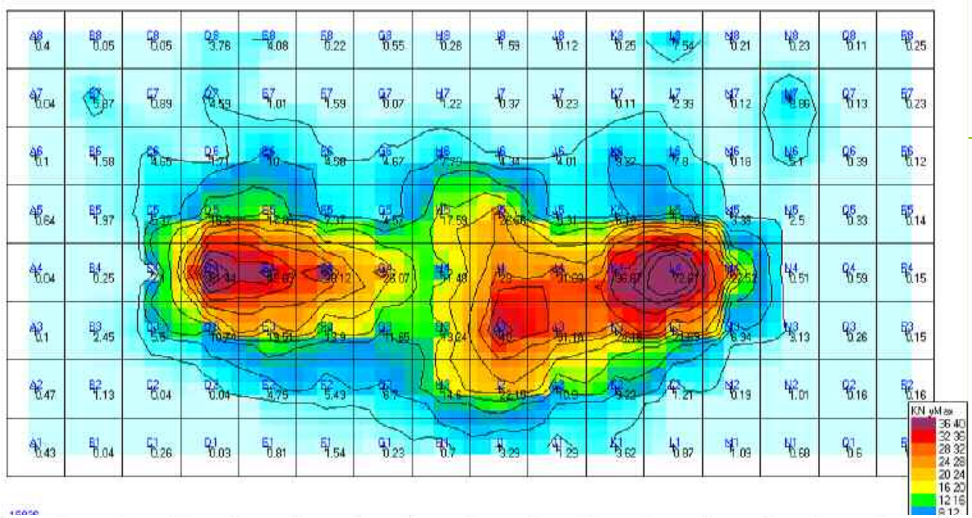


Load Cell Wall (Small Family 1)

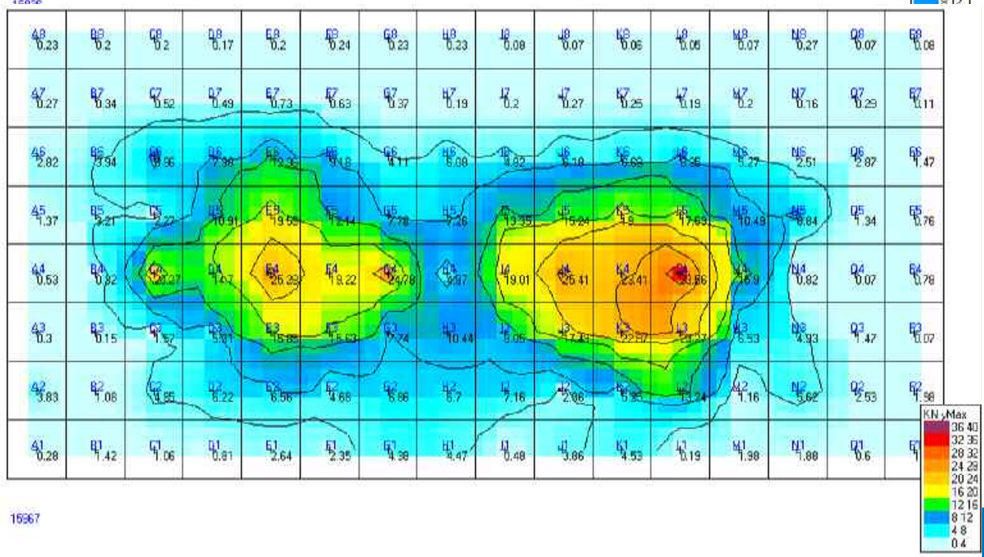


Load Cell Wall (Small Family 1)

Rigid



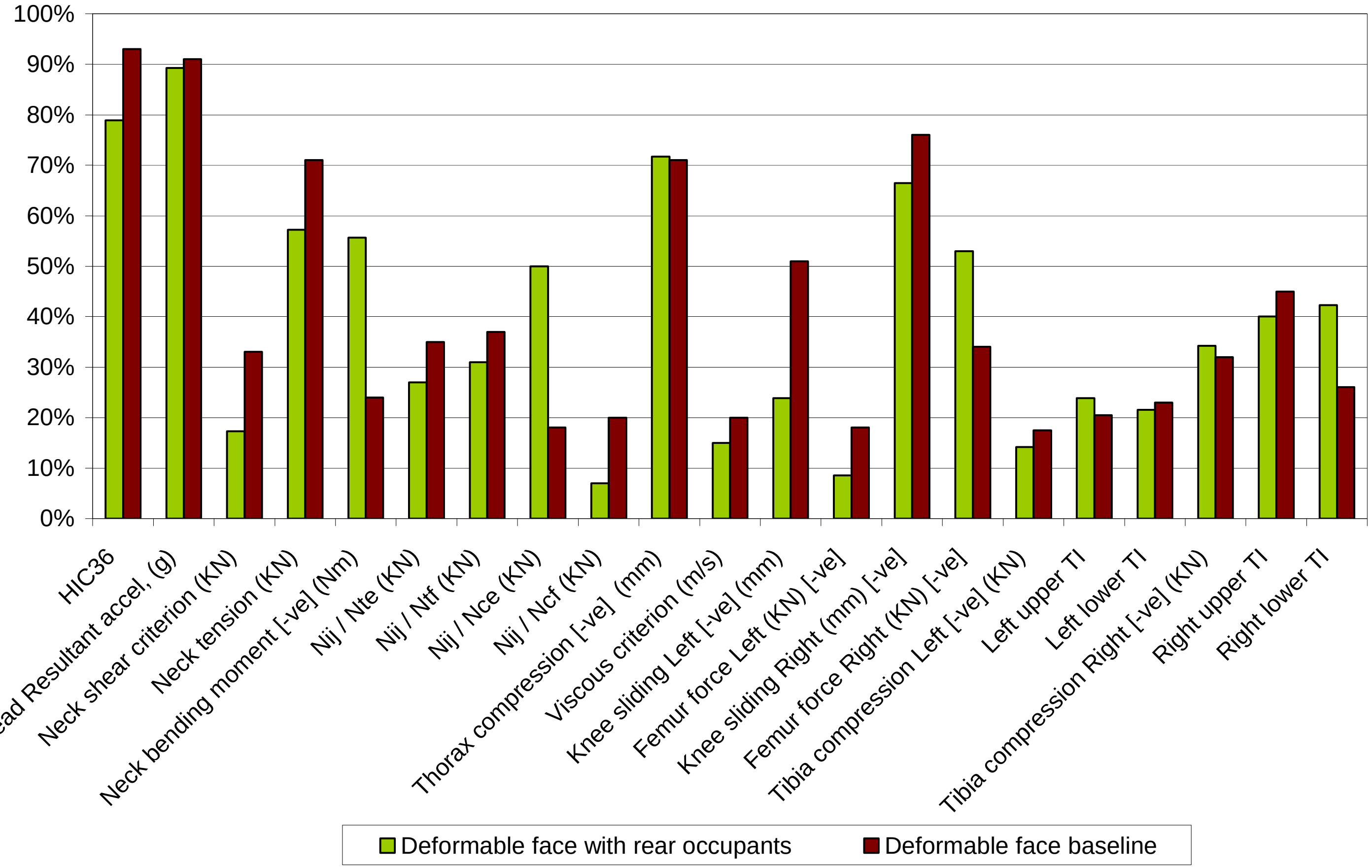
Deformable Face



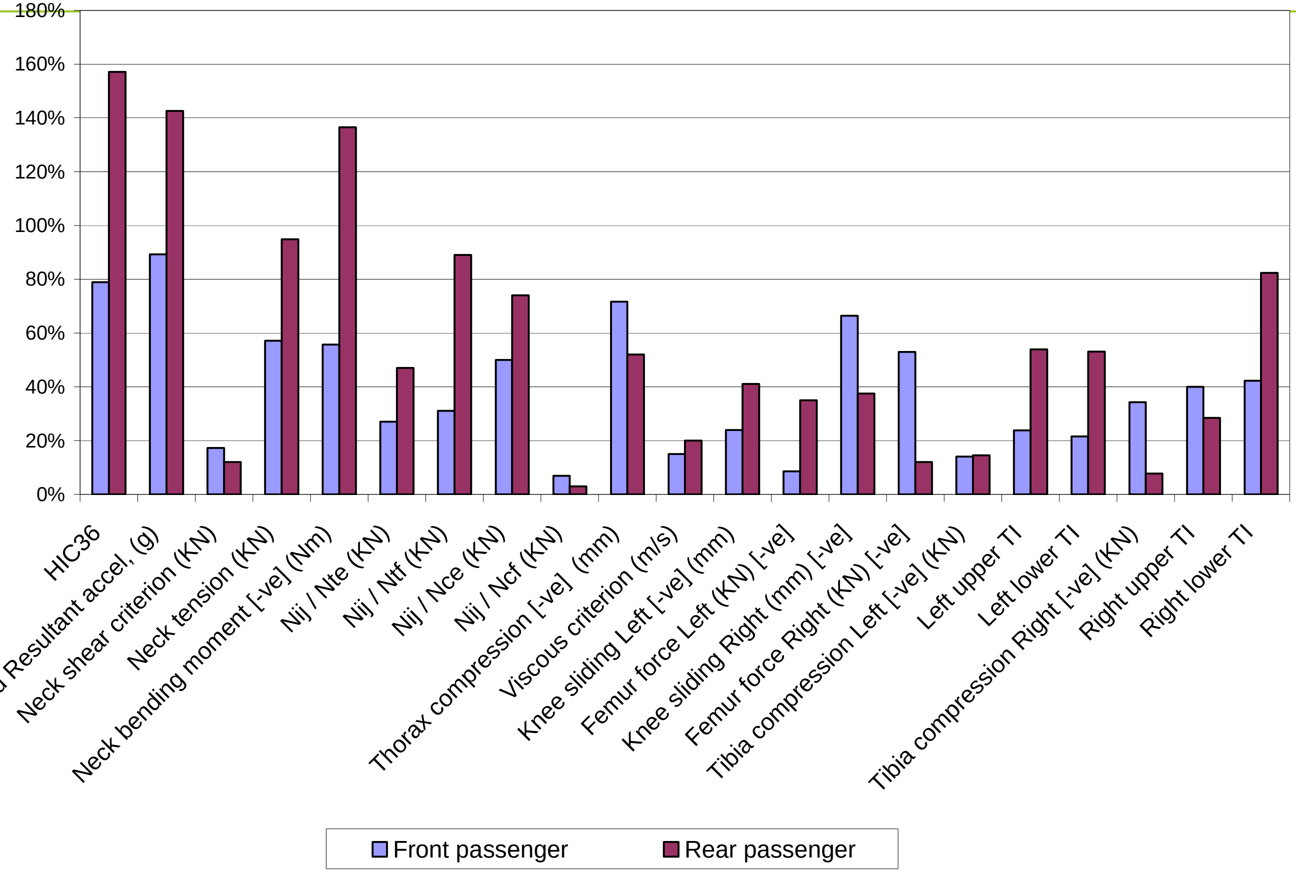
Effect of Rear Seat Dummies

- Performance of front seated dummies
  - Little effect on overall performance
  - Differences could be explained by additional weight and / or factors within range of test repeatability
- Performance of rear seated dummies compared to front seated dummies
  - Significant differences for head, neck and lower tibia body areas
  - Evidence of submarining with small family car

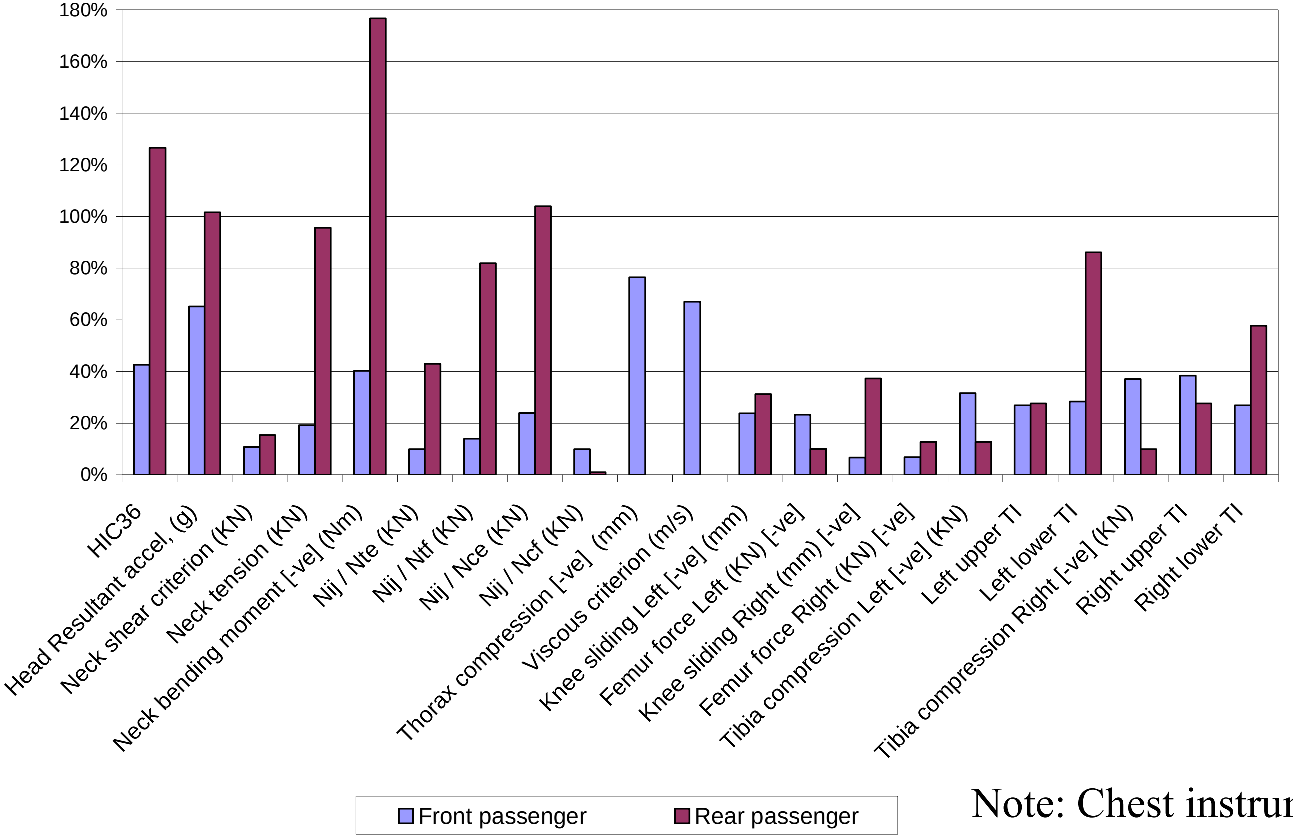
Driver performance with and without rear dummies (Small Family 1)



Comparison of front and rear seated dummy performance - Driver side (Small Family 1)

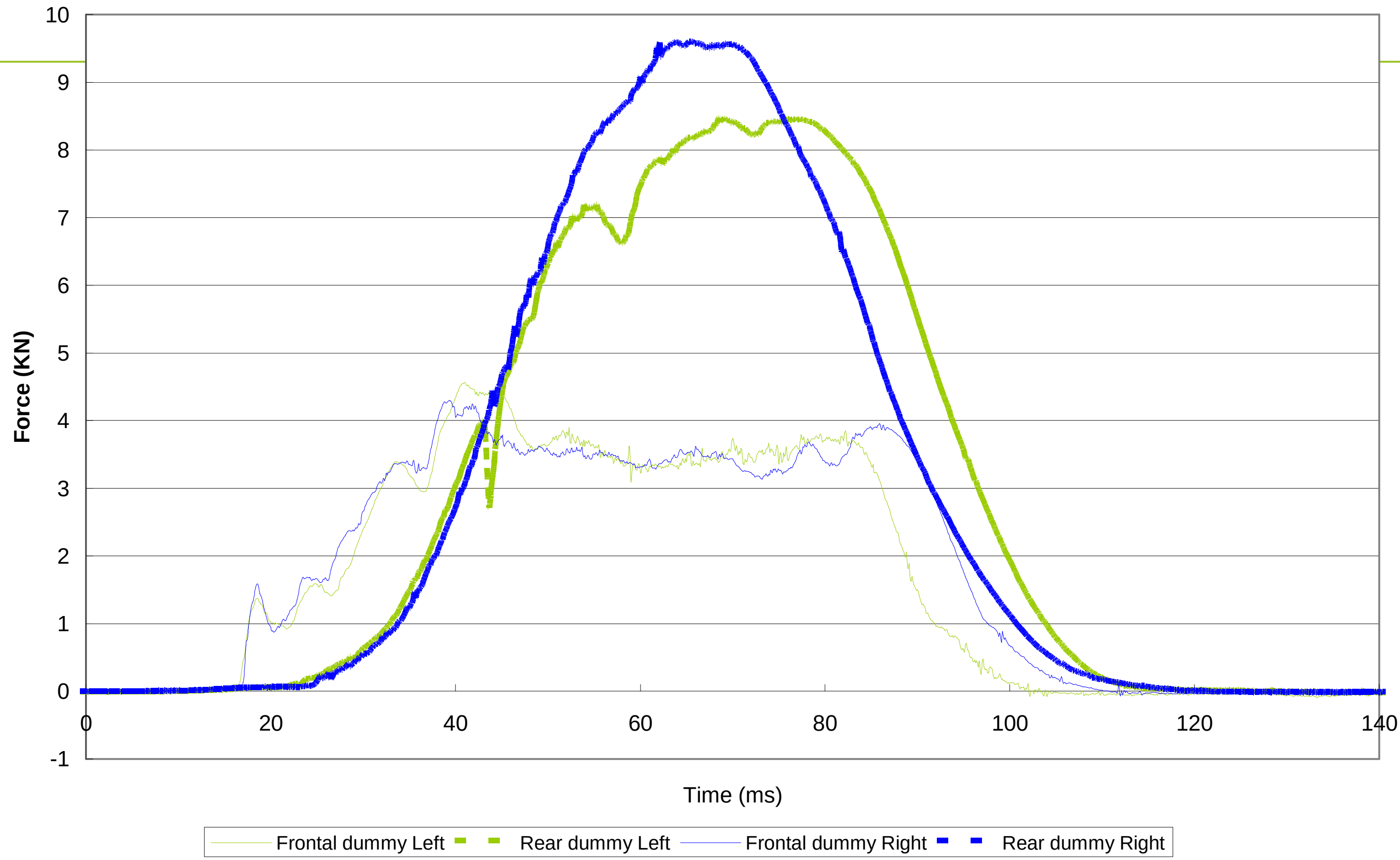


Comparison of front and rear seated dummy performance - Passenger side (Small Family 1)



Note: Chest instrumentation failure

Shoulder Belt Loads - Driver side (Small Family 1)



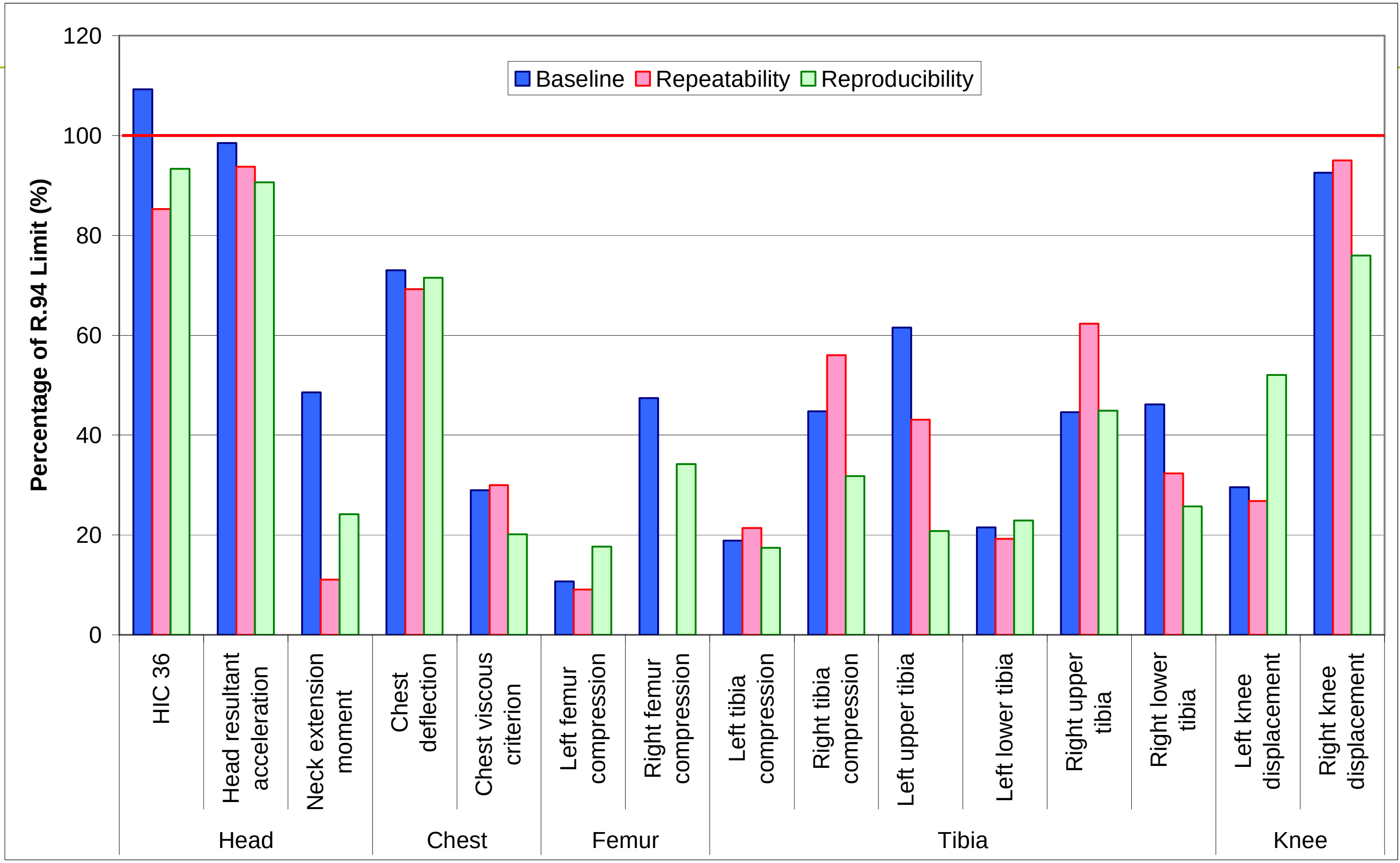
Evidence of submarining (Small Family 1)

	 
Rear occupant right before test	Rear occupant right after test

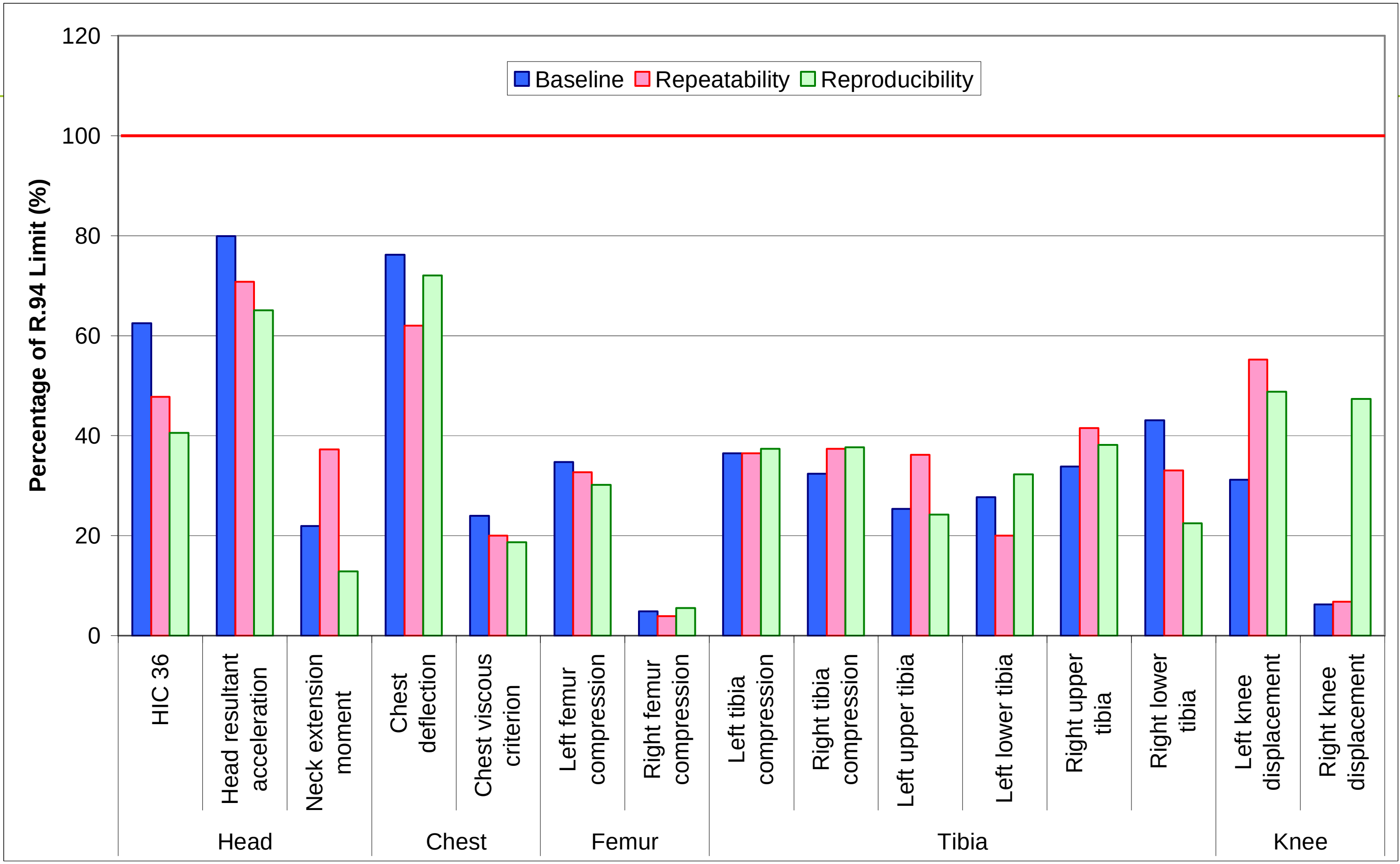
Repeatability / Reproducibility

- Repeatability / reproducibility of test with deformable face at least as good existing ECE-R94 offset procedure
- Load Cell Wall force
  - Global force repeatable / reproducible
  - Force distribution not repeatable in tests with Small Family 1 due to different longitudinal collapse modes
- Compatibility Structural Interaction (SI) metric
  - Vertical component (VSI) over common interaction zone repeatable / reproducible
  - Horizontal component (HSI) over common interaction zone not repeatable / reproducible
    - High sensitivity to small variations in individual cell loads

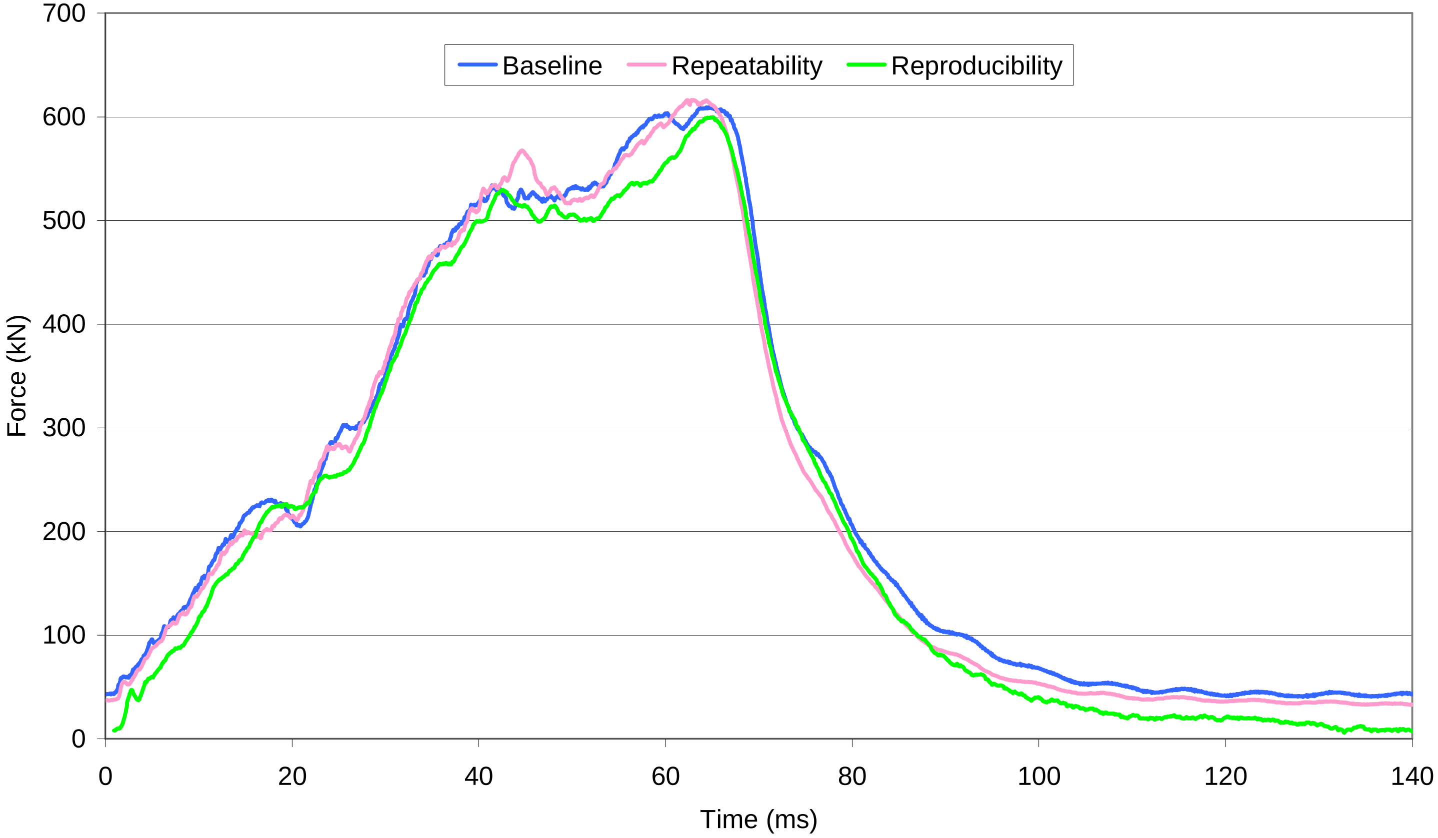
Driver Dummy performance (Small Family 1)



Passenger Dummy performance (Small Family 1)

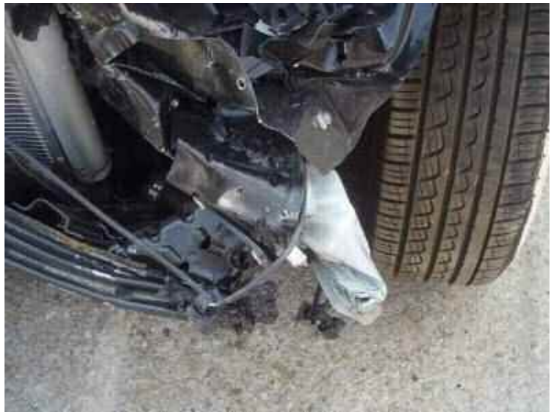


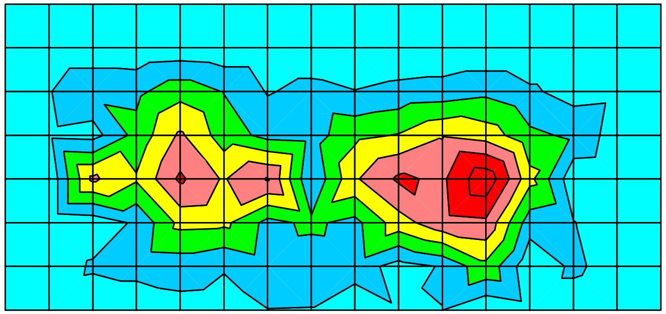
LCW Global Force (Small Family 1)



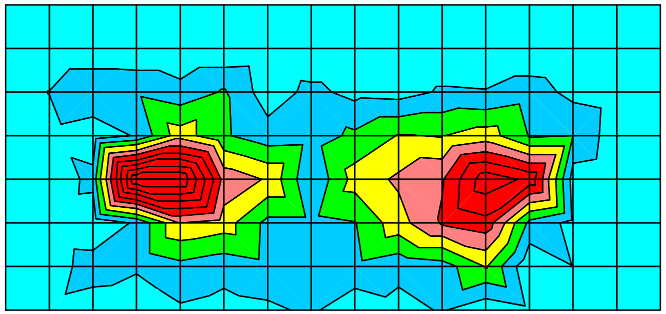
LCW Force Distribution (Small Family 1)

Baseline

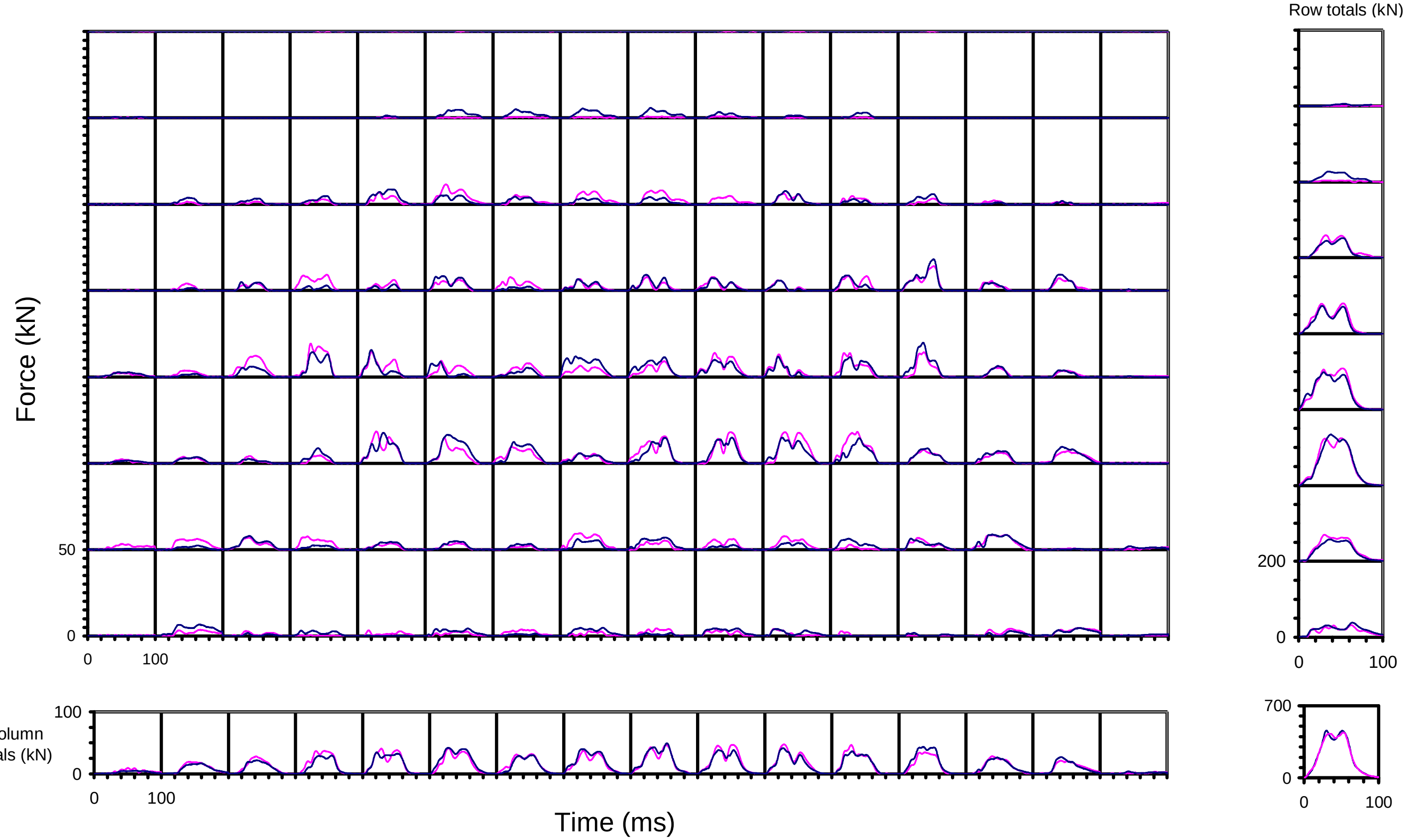




Repeatability



Compatibility SI Metric – LCW force distribution (Supermini 1)



Compatibility SI metric (Supermini 1)

	VSI	HSI
Test 1 - Baseline	0	4.93
Test 2 - Reproducibility	0	3.26

Note: Borderline score between good and poor performing bumper crossbeams is of the order of 2 to 4

Poor reproducibility of HSI metric

Practicality / Robustness

- Positioning of rear seated dummies
  - With 3 door cars possible dummy access problems for taking measurements such as pelvic angle
- Deformation measures
  - Cannot correct for deformation behind B-pillar as with offset test
  - Careful positioning of reference points needed if there is deformation behind B-pillar

Way Forward

- Deformable face?
  - Advantages, e.g. more realistic in particular for restraint triggering
  - Disadvantages, e.g. not included in current regulation / consumer tests
  - Compatibility issues / harmonisation?
- Rear seated dummies?
  - No major technical obstacles
  - Low number of casualties, cost benefit?
  - Chest injury criteria measurements?
  - Dummy size, 50th?

Cost Benefit Analysis

- Initial analysis as performance requirements for test not determined yet
- Benefit analysis performed for GB (CCIS) and Germany (GIDAS)
  - GB analysis results scaled to give benefit estimate for Europe because confounding factor found in German analysis which probably caused under-estimate of benefit for Germany
- Cost analysis
  - Performed by industrial partner based on costs to modify existing car

Benefit Analysis (GB)

- Assumption
  - Introduction of full width test will enforce improved restraint systems which will reduce restraint induced injury
  - Reduce chest and abdominal injury in frontal impacts by up to two AIS levels where occupant belted, ETS $\leq$ 56 km/h, intrusion $\leq$ 5 cm and occupant age $\leq$ 65 years
- Methodology
  - Using CCIS data set, estimate benefit in terms of MAIS for each individual casualty within target population
  - Transform MAIS injury to Police casualty severity measures
  - Scale STATS19 using benefit proportions calculated from CCIS data set

Calculation of MAIS Benefit

- Calculate 'Revised MAIS' for each casualty within CCIS data set using assumptions noted above

MAIS	Original data set	Data set with benefit	Change
0	296	296	0
1	1084	1195	+111
2	280	206	-74
3	135	114	-21
4	37	26	-11
5	35	30	-5
6	2	2	0
Total	1869	1869	-

Transform to Police Severity Scale

MAIS	Fatal	Serious	Slight	Uninjured	Not known
0	0.0	1.4	1.0	95.9	1.7
1	0.1	9.2	90.2	0.1	0.4
2	0.4	97.1	2.5	0.0	0.0
3	5.2	94.8	0.0	0.0	0.0
4	48.6	51.4	0.0	0.0	0.0
5	85.7	14.3	0.0	0.0	0.0
6	100.0	0.0	0.0	0.0	0.0

Transfer function derived using data in CCIS data set

Scale to GB Benefit using STATS19

Annual Reduction in Car Occupant Casualties

	National benefit		
	Original Number	**Reduction**	**% Reduction**
Fatalities	1695	47	2.77
Serious casualties	14512	812	5.60

Note: the % reduction of fatalities is increased to approx 6% if target population
Is expanded to include occupants aged over 65

European Benefit

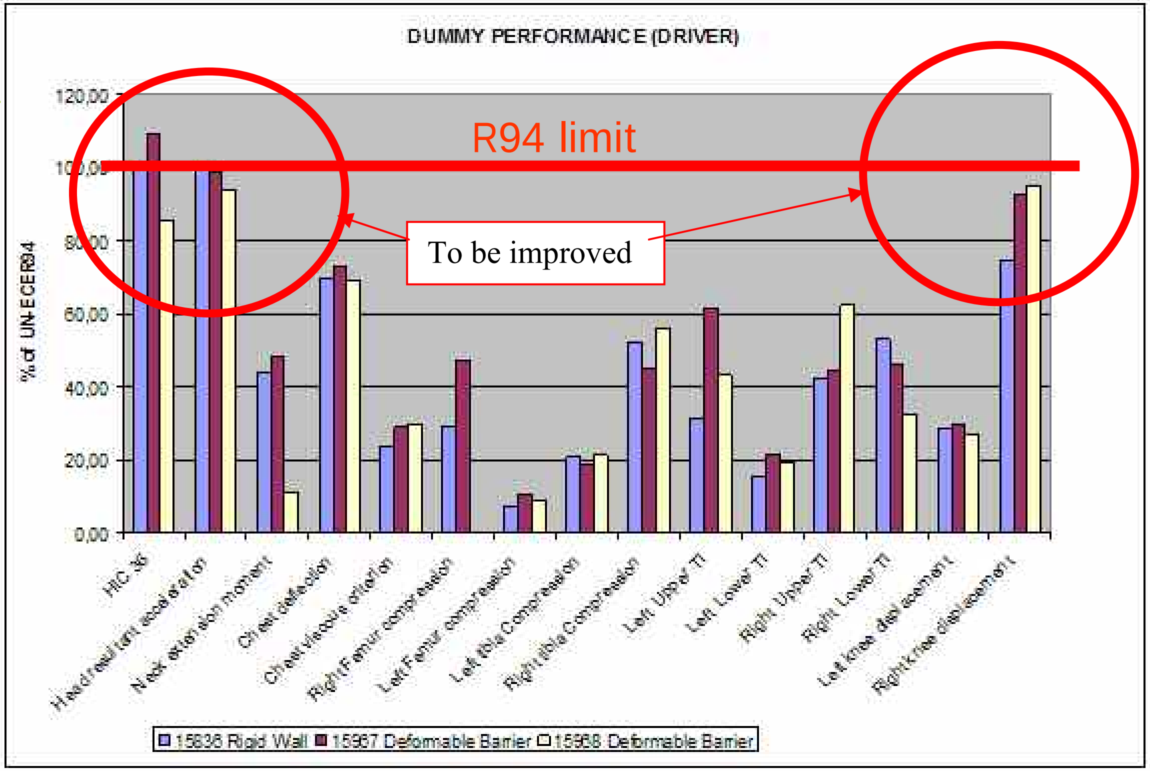
	Casualties Prevented		Financial Benefit per casualty		Financial Benefit (£Million)		
	Fatal	**Serious**	**Fatal**	**Serious**	**Fatal**	**Serious**	**TOTAL**
EU-15	430	6,017	£1,489,450	£167,360	£640M	£1,007M	£1,647M
EU-25	574	8,038	£1,489,450	£167,360	£855M	£1,345M	£2,200M
EU-27	625	8,756	£1,489,450	£167,360	£932M	£1,465M	£2,397M

For EU15 potential benefit is up to £1,674M *1.2 = €1,976M

Cost Analysis

- Based on costs to modify typical European car not designed to meet current FMVSS208 requirements
  - Small Family 1
- Performance requirements assumed for test
  - Equivalent to FMVSS208
  - Equivalent to ECE R94
- Estimate costs to modify 'Small Family 1' to meet requirements
  - Determine modifications – restraint changes
  - Determine cost of modification
    - Development costs
    - Tooling costs
    - Variable costs – additional parts, etc

Cost per Car – ECE R94 requirements



- Modifications
  - Degressive load limiter (head)
  - Double pretensioner (Hard knee contact)
  - Collapsible steering column (chest)

Costs per year for EU15

Performance Requirement	Cost per Car	Cost for EU15 per year
FMVSS208	17€	242M€
R94	32€	455M€

Assume 14,221,978 new cars registered per year in EU15

Note: Cost estimate likely to be high as many European cars sold in US where they have to meet FMVSS208 and hence likely to perform better than 'Small Family 1' chosen to represent typical European car

Cost Benefit for EU15

- Potential benefit
  - Up to about €2,000Million per year
- Costs
  - FMVSS208 - €242Million per year
  - R94 - €455Million per year

- Note: More stringent performance requirements above R94 may be needed to deliver all the potential benefit, which may require additional modifications to the car, which would increase the cost

Way Forward - Summary

- Test configuration?
  - Deformable face?
  - Rear seated dummies?

- Performance criteria and limits?
  - Further cost benefit analysis required to determine appropriate limits

References

- www.aprosys.com
  - D121 ‘Draft test and assessment protocol for Advanced European Full Width (AE-FW) Test’
  - D122 ‘Evaluation of Advanced European Full Width (AE-FW) Test’
  - D123A ‘Accident Analysis for Specification of Advanced European Full Width (AE-FW) Test’
  - D123B ‘Cost Benefit Analysis for Introduction of Advanced European Full Width (AE-FW) Test’

Acknowledgements

- European Commission DG-TREN
- APROSYS WP1.2 partners
  - TRL, VW, Toyota, TNO, FIAT, IDIADA, BASt, Nissan, TUG

The End

Questions?