FI-10-03

European Commission frontal impact accident analysis study: Summary of final results

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14th October 2010

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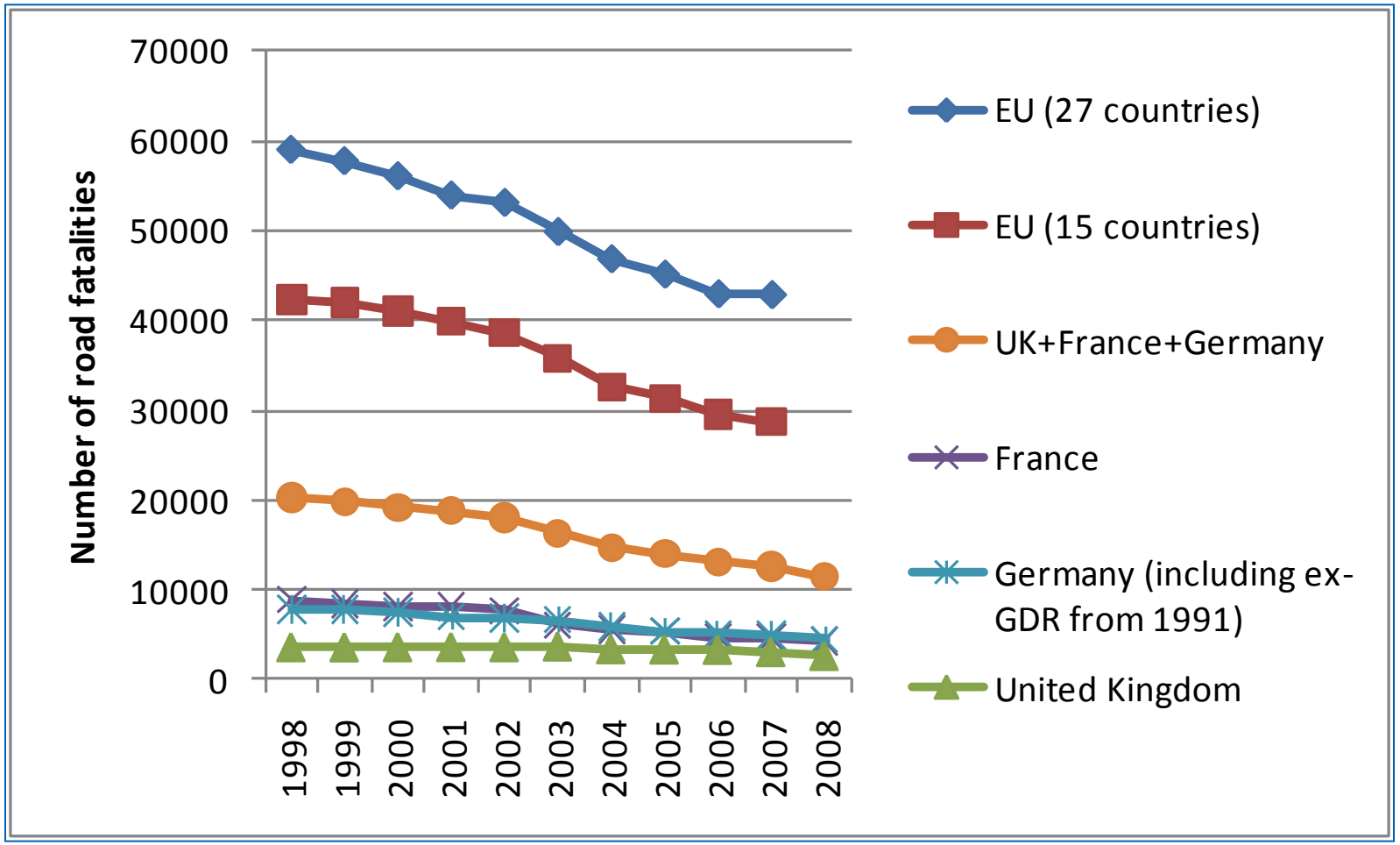
Overview

- Objectives
  - Identify the frontal impact taxonomy in Europe and quantify target populations for potential changes to frontal impact legislation
  - Perform detailed case analysis to investigate how well the current Regulation 94 test represents real-world accidents and help identify any modifications which should be made
  - Analyse car to other vehicle impacts to help understand the nature and magnitude of the compatibility problem in frontal impacts
- Data sources
  - European: CARE, Eurostat
  - UK: STATS19, CCIS, HVCIS, Heavy vehicle fatals
  - German: National, GIDAS
  - French: National, LAB
- Approach
  - Where appropriate only Regulation 94 compliant vehicles were included in the analyses to ensure results suitable to help set priorities for update of Regulation 94
  - Relationship between the detailed, national, and European data is known, so that the effect of possible changes can be scaled to the European picture

Tasks

1. Frontal impact taxonomy
2. Case analysis
3. Compatibility

Road casualties in EU



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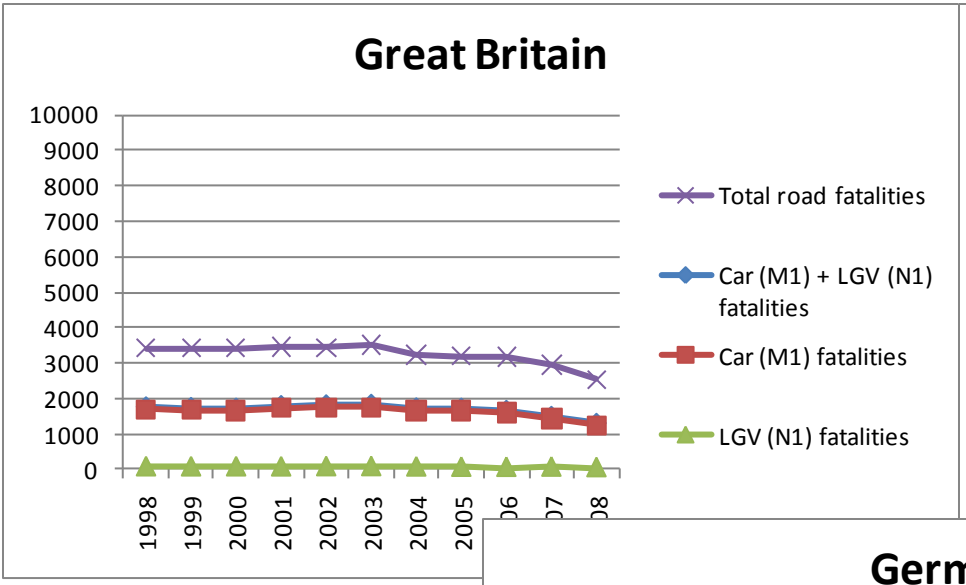
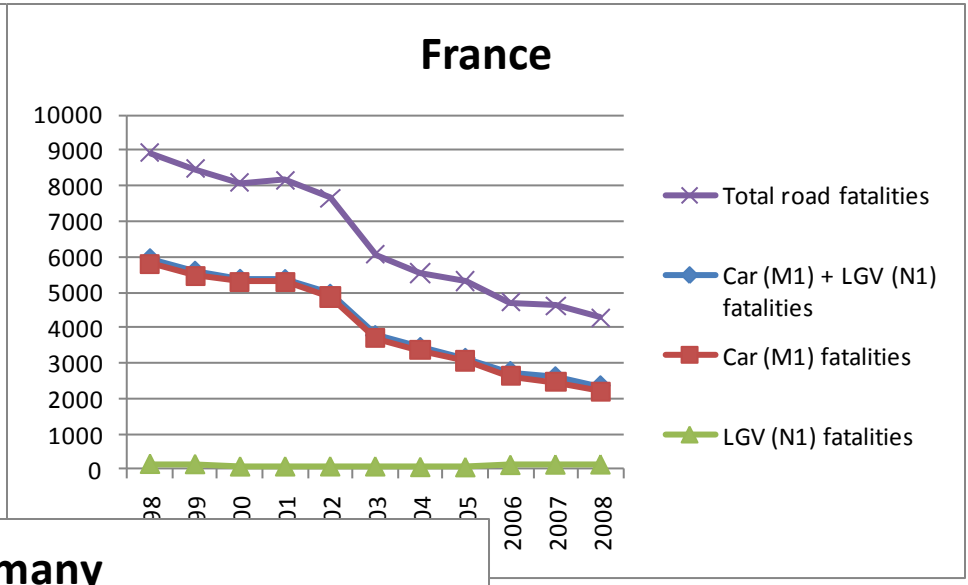
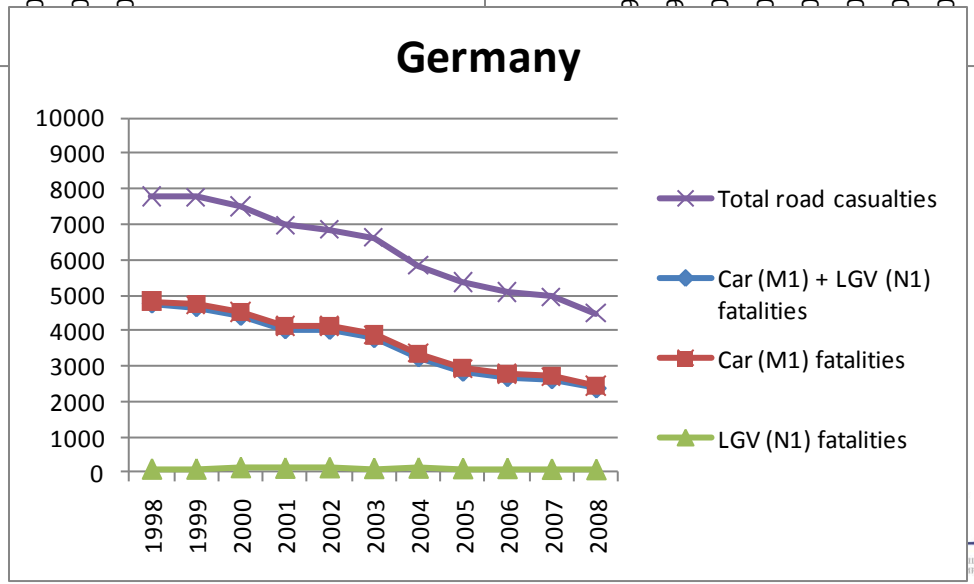
Road casualties in GB, France and Germany

Car (M1) and LGV (N1) occupant fatalities 1998-2008 (CARE and national data)







Identification of target populations

Great Britain, 2008, cars

Rollover	
Fatal	Serious
297 (23.7%)	1706 (16.0%)

All cars	
Fatal	Serious
1250	10643

Front	
Fatal	Serious
731 (58.5%)	6995 (65.7%)

Side	
Fatal	Serious
438 (35.0%)	2738 (25.7%)

Rear	
Fatal	Serious
57 (4.6%)	700 (6.6%)

Other/unknown	
Fatal	Serious
24 (1.9%)	210 (2.0%)

Impact side: first point of impact, regardless of rollover

Rollover: regardless of first point of impact

France, 2008, cars

Rollover	
Fatal	Serious
132 (6.0%)	741 (5.2%)

All cars	
Fatal	Serious
2205	14127

Front	
Fatal	Serious
1398 (63.4%)	9968 (70.6%)

Side	
Fatal	Serious
491 (22.3%)	1763 (12.5%)

Rear	
Fatal	Serious
130 (5.9%)	1239 (8.8%)

Other/unknown	
Fatal	Serious
186 (8.4%)	1157 (8.2%)

Impact side: first point of impact, regardless of rollover

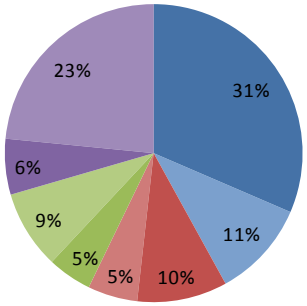
Rollover: regardless of first point of impact

Impact partner, rollover, belt use

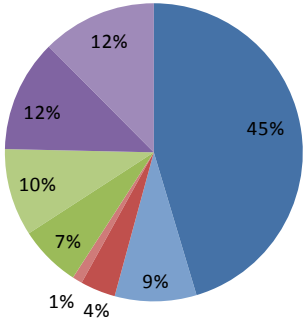
Frontal impacts
Regulation 94 compliant vehicles
All car occupants

Great Britain – CCIS scaled to STATS19 2008

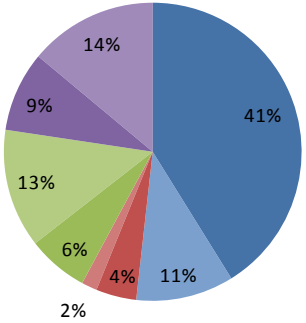
Fatal
n = 704



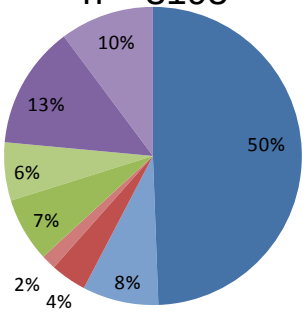
Serious
n = 6230

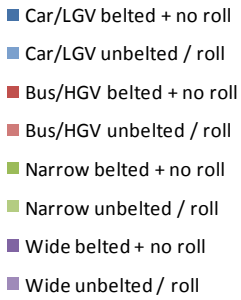


MAIS 3+
n = 1801



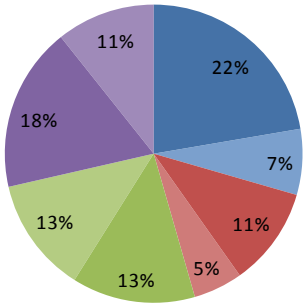
MAIS 2
n = 3195



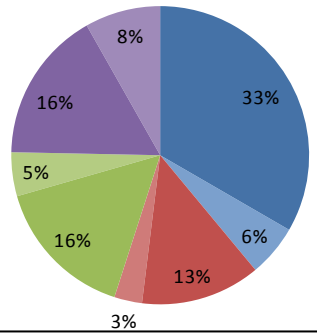


Germany – 2008 national casualties represented by GIDAS

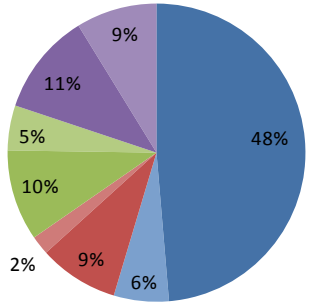
Fatal n=1096

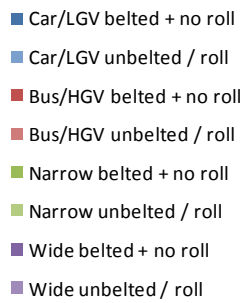


MAIS 3+ n=3017



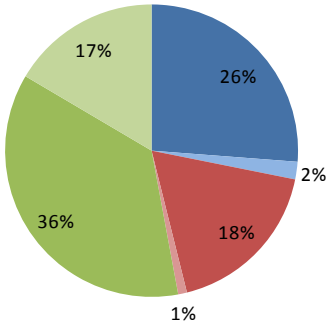
MAIS 2 n=12892



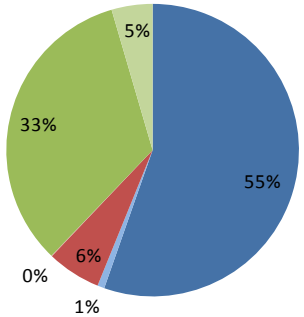


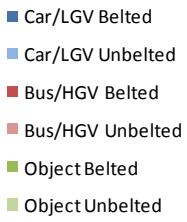
France – 2008 national casualties in R94 compliant vehicles defined as 2004+

Fatal n=213*



Serious n=1694*





Note:* unscaled

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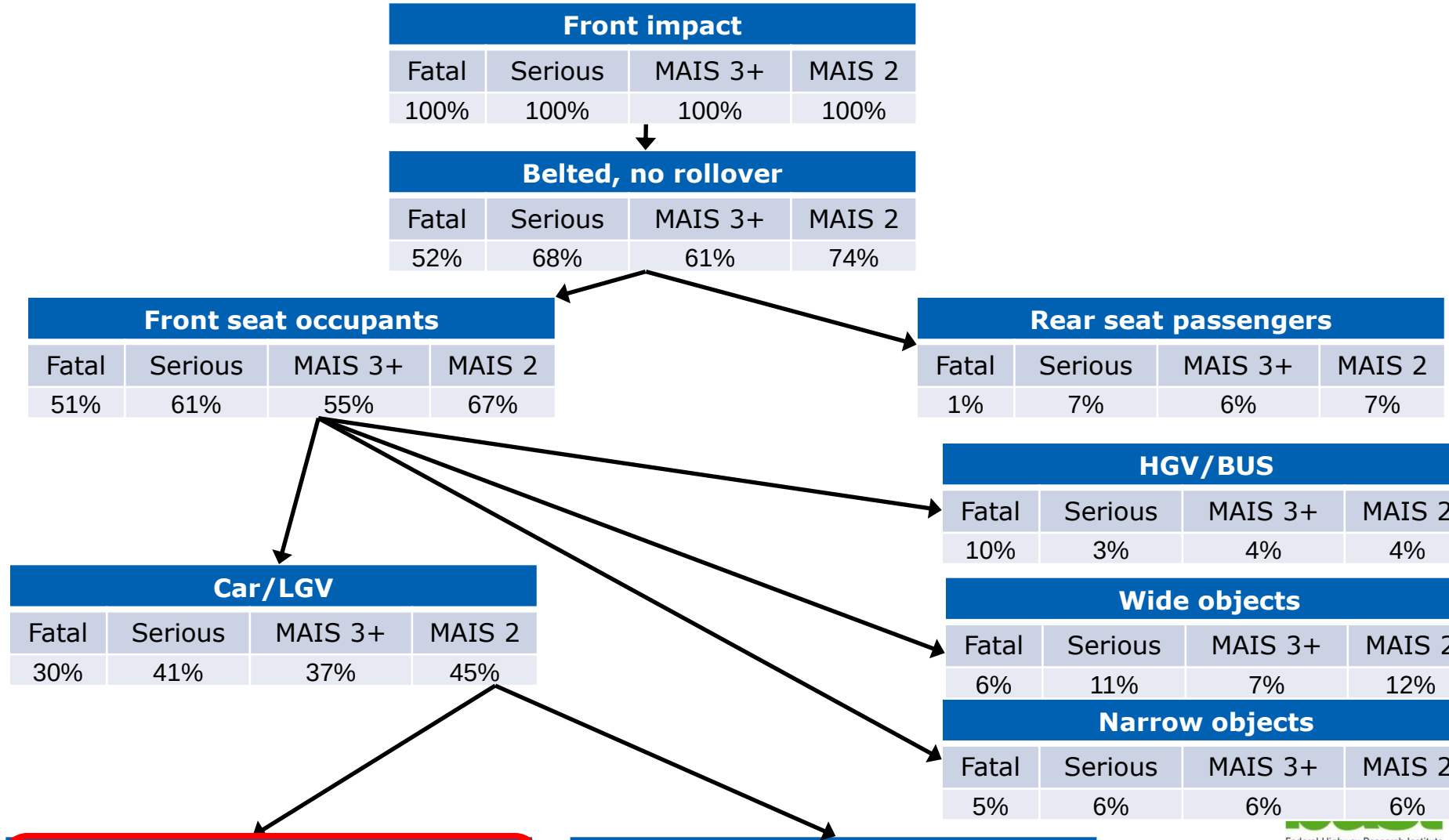
Identification of target populations – in depth data scaled to adjusted national data - GB



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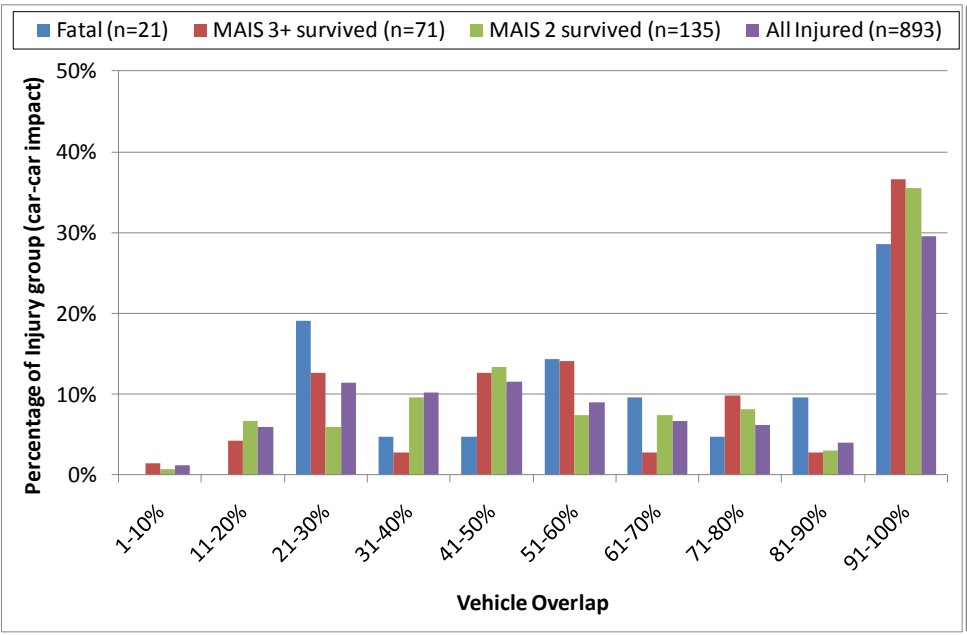
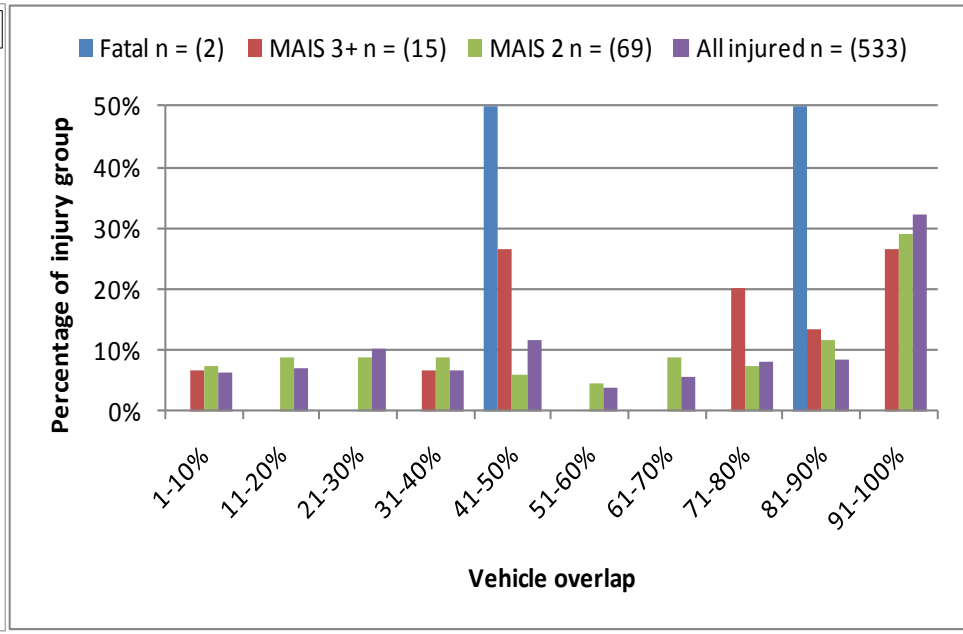
Overlap

Frontal impacts
Regulation 94 compliant vehicles
No rollover, belted, no unbelted occupant behind
Car-car/LGV impacts

GB – CCIS - drivers



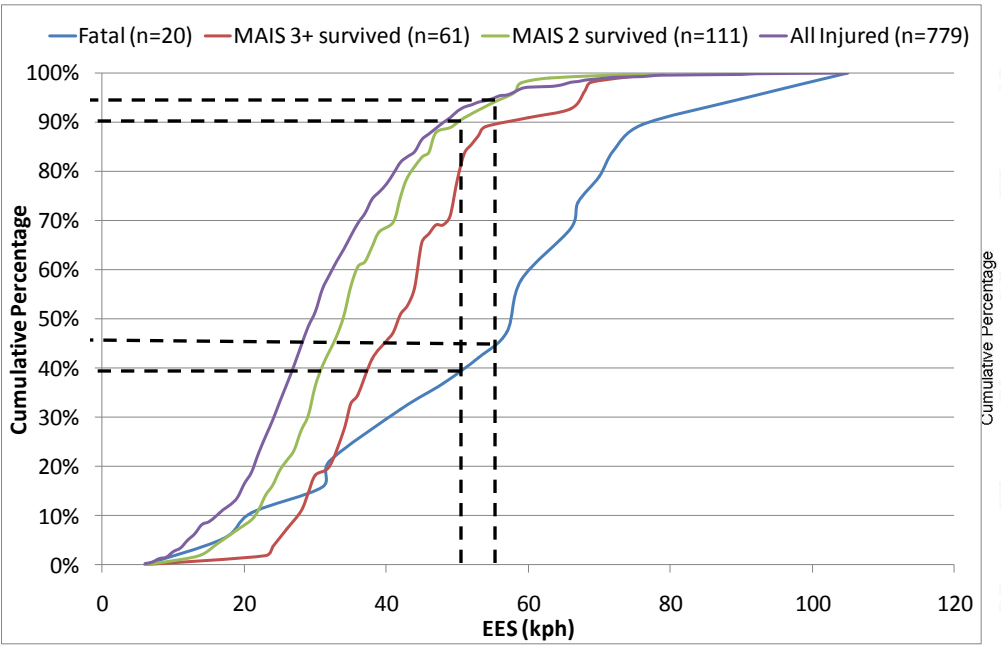
Germany – GIDAS – front row occupants



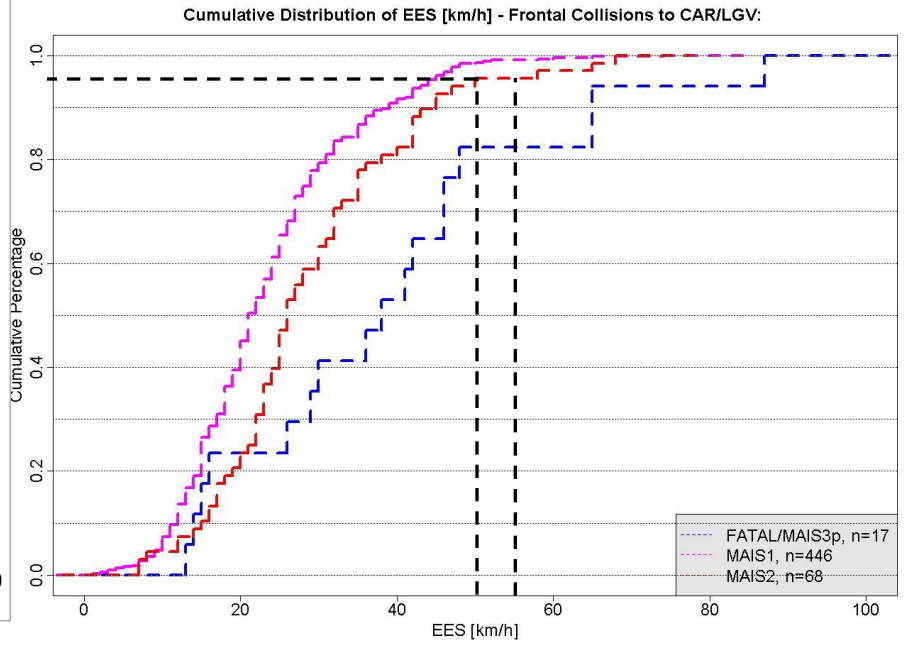
Speed

Frontal impacts
Regulation 94 compliant vehicles
No rollover, belted, no unbelted occupant behind
Car-car/LGV impacts

GB – CCIS - drivers



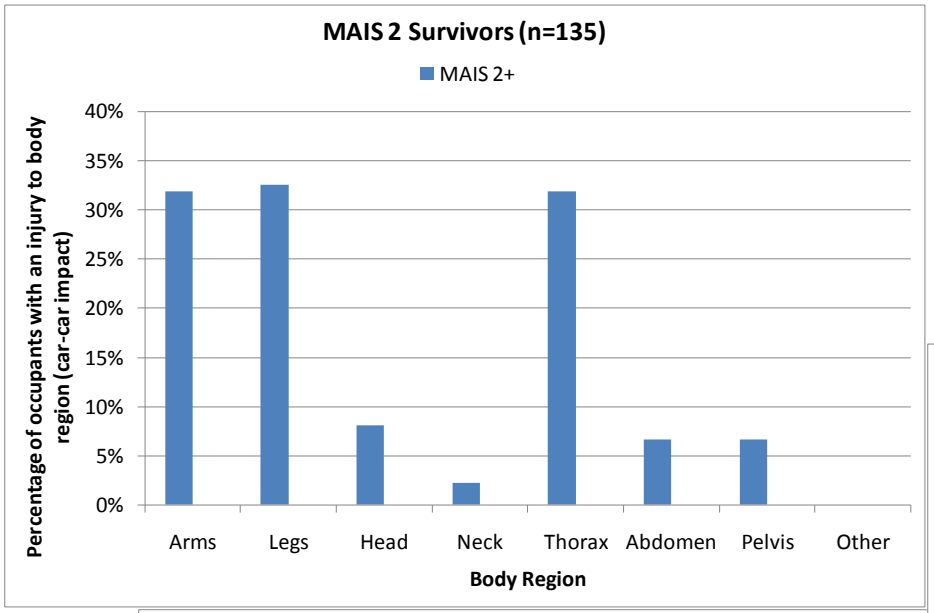
Germany – GIDAS – front row occupants

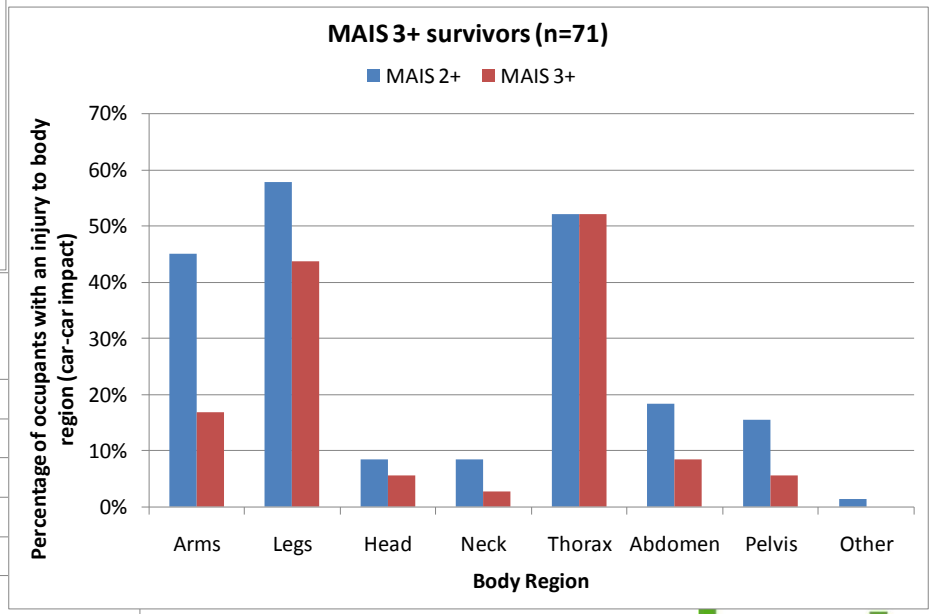


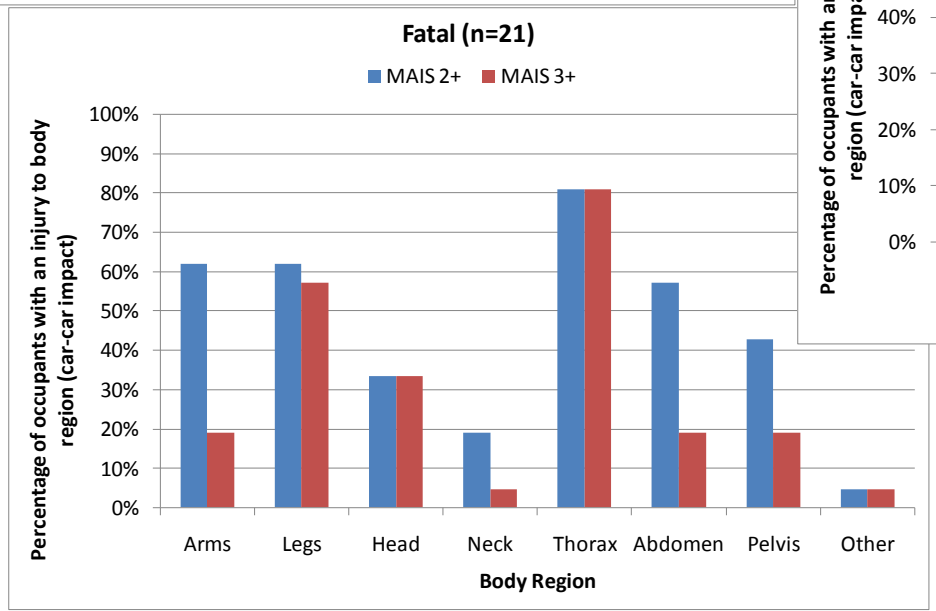
Injury distribution

Frontal impacts
Regulation 94 compliant vehicles
No rollover, belted, no unbelted occupant behind
Car-car/LGV impacts

GB – CCIS - drivers





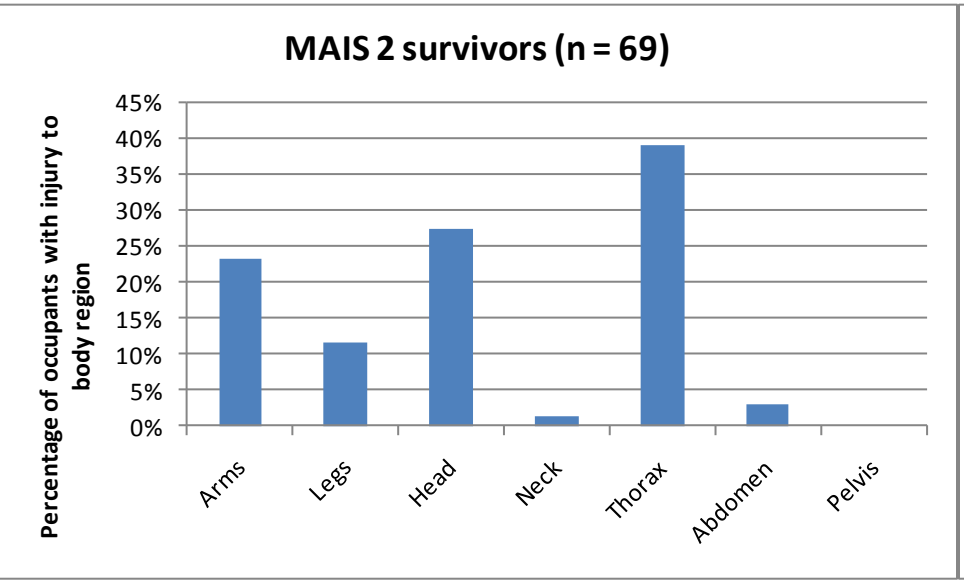


Injury distribution

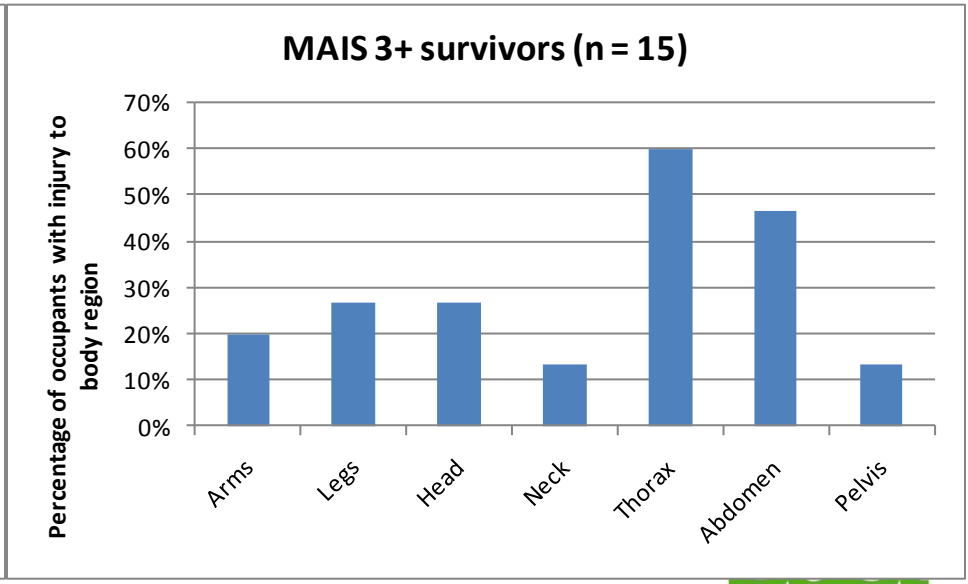
Frontal impacts
Regulation 94 compliant vehicles
No rollover, belted, no unbelted occupant behind
Car-car/LGV impacts

Germany – GIDAS – front row occupants

MAIS 2 occupants – AIS 2 injuries



MAIS 3+ occupants – AIS 2+ injuries



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Target population sizes: MAIS 2 surviving car occupant casualties in GB

	Population	Proportion of subset						Proportion of target population						
		Car-car/LGV		Car-HGV/bus	Car-wide	Car-narrow	Car-all	Car-car/LGV		Car-HGV/bus	Car-wide	Car-narrow	Car-all	All
		DRV	FSP	DRV+FSP	DRV+FSP	DRV+FSP	RSP	DRV	FSP	DRV+FSP	DRV+FSP	DRV+FSP	RSP	All
		-	-	-	-	-	-	-	-	-	-	-	-	-
		n=135	n=49	n=24	n=32	n=13	n=22							
Impact configuration	PDOF = 12	66%	65%	79%	75%	66%	68%	22%	7%	3%	9%	4%	5%	50%
	No long. loading	10%	8%	33%	19%	10%	13%	3%	1%	1%	2%	1%	4%	12%
	1 long. loaded	50%	59%	50%	35%	50%	36%	17%	6%	2%	4%	3%	3%	35%
	2 long. loaded	39%	33%	17%	44%	39%	50%	13%	4%	1%	5%	2%	4%	29%
	>90% overlap	35%	31%	29%	38%	35%	50%	12%	3%	1%	5%	2%	4%	27%
	EES <= 50 kph	90%	97%	90%	94%	90%	90%	31%	11%	4%	11%	5%	6%	67%
	EES <= 56 kph	95%	100%	95%	96%	95%	94%	32%	11%	4%	12%	6%	7%	70%
	Represented by R94 test	33%	29%	N/A	27%	N/A	N/A	11%	3%	N/A	3%	N/A	N/A	18%
Casualties and their injuries	Gender: female	41%	85%	25%	35%	41%	54%	14%	9%	1%	4%	2%	4%	35%
	Age: elderly (66+)	17%	28%	8%	34%	17%	9%	6%	3%	0%	4%	1%	1%	15%
	Head AIS 2+	8%	2%	25%	10%	8%	4%	3%	0%	1%	1%	0%	0%	6%
	Thorax AIS 2+	32%	39%	16%	25%	32%	28%	11%	4%	1%	3%	2%	2%	23%
	Leg AIS 2+	33%	12%	13%	15%	33%	4%	11%	1%	1%	2%	2%	0%	17%
	Arm AIS 2+	32%	31%	42%	31%	32%	54%	11%	3%	2%	4%	2%	4%	25%
	Abdomen AIS 2+	7%	16%	5%	19%	7%	19%	2%	2%	0%	2%	0%	1%	8%
	Intrusion	15%	4%	17%	13%	15%	N/A	5%	0%	1%	2%	1%	N/A	9%
	All	100%	100%	100%	100%	100%	100%	34%	11%	4%	12%	6%	7%	74%

Target populations: MAIS 2 surviving car occupant casualties in Germany

	Population	Proportion of subset		Proportion of target population	
		Car-car/LGV DRV+FSP n=69	All All -	Car-car/LGV DRV+FSP -	All All -
Impact configuration	PDOF = 12	51%	51%	25%	40%
	No long. loading	-	-	-	-
	1 long. loaded	-	-	-	-
	2 long. loaded	-	-	-	-
	>90% overlap	29%	29%	14%	23%
	EES <= 50 kph	95%	95%	47%	74%
	EES <= 56 kph	96%	96%	47%	75%
	Represented by R94 test	27%	20%*	13%	16%*
Casualties and their injuries	Gender: female	55%	55%	27%	43%
	Age: elderly (66+)	19%	19%	9%	15%
	Head AIS 2+	27%	27%	13%	21%
	Thorax AIS 2+	39%	39%	19%	30%
	Leg AIS 2+	11%	11%	5%	9%
	Arm AIS 2+	23%	23%	11%	18%
	Abdomen AIS 2+	3%	3%	1%	2%
	Intrusion	4%	4%	2%	3%
	All	100%	100%	49%	78%

Conclusions

- Overall
  - Road accident fatalities in the EU27 and in particular car occupant fatalities have reduced by approximately 30% in the period 1998 to 2007
  - Car occupant fatalities still account for about half of all road accident fatalities (EU27 in 2007: 42,854) and hence remain a substantial problem
  - Fatality reduction in Germany and France is substantially higher than in Great Britain (26% in Great Britain, 50% in Germany, 62% in France). However Great Britain has the lowest number of fatalities per head of population.

Conclusions

- Overall
  - Once unbelted occupants etc. are removed from the sample, the proportions of casualties who could benefit from changes to Regulation 94 are as follows:
    - Fatalities – 52% in Great Britain, 64% in Germany, 80% in France
    - MAIS 3+ survived – 61% in Great Britain, 78% in Germany
    - MAIS 2 survived – 74% in Great Britain, 78% in Germany
  - Measures to improve protection to those excluded from the target population should be considered strongly

Conclusions

- Impact configuration
  - Impact partner
    - Impacts with cars or LGVs are generally the largest target population group in all three countries and at all injury levels. This indicates that car-to-car / car-to-LGV compatibility should be an important consideration for potential changes to Regulation 94.
    - The size of the target population group for narrow objects (< 41 cm wide, e.g. poles, small diameter trees) is small; 5-6% of casualties for GB and 10-16% of casualties for Germany. This gives an indication that the benefit of the introduction of a frontal pole test into Regulation 94 would likely be low and hence should not be considered as a high priority.
  - Overlap
    - Direct loading to only one longitudinal (like the current offset test) accounts for a larger proportion of impacts than other impact types
    - The next most frequent impacts are direct loading both longitudinals, followed by low overlap impacts with no direct loading to the longitudinals
    - The introduction of a full width overlap test into Regulation 94 should be an important consideration for potential changes to Regulation 94.

Conclusions

- Impact configuration
  - Severity
    - Increasing the Equivalent Energy Speed (EES) from 50 kph to 56 kph (which approximately relate to the severity of Regulation and Euro NCAP tests respectively) increases the target population by 3-5% of all frontal impact casualties in Great Britain depending on severity, although this increase is smaller in Germany (about 1%)
    - For GB over half of fatalities are in impacts with a higher severity than both these speeds
    - There are also a large proportion of fatalities at relatively low severities, the majority of which are elderly occupants
    - The potential benefit to Regulation 94 to increase the test severity to that of the Euro NCAP test may not be that high

Conclusions

- Population injured
  - Age
    - In Great Britain and France, the national data showed that elderly occupants (aged 66 or over) make up 20% of car fatalities in frontal impacts
      - However, it should be noted that the largest proportion of fatalities are aged 12-25 years, which account for 34% of fatalities in Great Britain and 29% in France
    - Although elderly occupants are over-represented in the GB CCIS sample, the German analysis showed that elderly occupants could make up 15% of the target population of MAIS 2 surviving occupants – the same proportion as for MAIS 2 surviving occupants in Great Britain.

Conclusions

- Population injured
  - Seating position
    - Drivers are a much larger proportion of the target population than front seat passengers. In car-car/LGV impacts alone in Great Britain, the target population of driver casualties is 23-34% of all frontal impact casualties depending on severity, compared to 7-11% for front seat passengers
    - The proportion of rear seat passengers in the target population is much smaller than both, partially because of the low seat belt wearing rates in the rear
    - The age and gender of occupants in different seating positions is substantially different:
      - The majority of front seat passengers are female, and a large proportion of these are elderly
      - A large proportion of rear seat passengers are children or young adults
    - A suitable dummy to represent the most frequently injured casualty in the front passenger seat would represent a female or elderly female, while a suitable dummy in the rear would represent a child or young adult.

Conclusions

- Frequency and severity of injury
  - In Great Britain, for all injury severities, injuries to the thorax, arms, and legs are the most frequent. For fatalities, injuries to the abdomen are also frequent.
  - The dummy used in any regulatory test should be capable of measuring injury criteria in all of these regions, and better protection should be provided for these body regions
  - The target population of MAIS 2 casualties with head injuries in Germany is 21%, compared to 6% in Great Britain, suggesting that measurement of head injury is also important.

Conclusions

- Injury mechanisms
  - the injury mechanisms are related to both the injury severity and the individual body regions
    - For MAIS 2 surviving drivers, injuries to the thorax are generally related to the restraint system, injuries to the legs are related to contact with non-intruding structures, and injuries to the arms are related to a combination of both these causes
    - As the injury severity becomes more severe, a larger proportion of injuries are related to contact with intruding structures. For fatalities, the majority of injuries to all body regions (with the exception of the abdomen) are related to contact with intruding structures.
  - The proportion of MAIS 2 casualties receiving thorax injuries is greatest for elderly casualties

Tasks

1. Frontal impact taxonomy
2. Case analysis
3. Compatibility

Detailed case analysis (GB data only)

- Fatal injuries
  - Determine factors which caused fatal injuries
    - Accident, vehicle or occupant characteristics
- Impacts with configuration similar to Regulation 94 test
  - Determine how well R94 test represents real-world accidents by review of the structural performance of the vehicle and injuries received by the occupants against that expected from test experience
    - Vehicle test performance (Euro NCAP)
    - Accident characteristics
    - Occupant characteristics

Case Findings – Fatal occupants

There were 48 fatal occupants. The primary factors which caused the fatal injuries have been put into bins as follows:

•**Severe crash / anomaly**	**17**
•EES > 65 kph	11
•56 kph < EES <= 65 kph	5
•Anomaly	1
•**Vulnerable occupant**	**13**
•Elevated occupant age	13
•**Underride**	**10**
•HGV front	4
•HGV rear	3
•LCV front	1
•SUV front	1
•Car front	1
•**Limited horizontal structural engagement**	**4**
•With underride	2
•Without underride	2
•**Other**	**4**
•Post crash fire	2
•Oblique impact	1
•Unknown	1

Fatal Occupants – Example

A Fiat Punto overtook a Suzuki and collided with a Peugeot 206 travelling in the opposite direction in a head-on collision

2002 Fiat Punto
PDoF: 12 o'clock
Overlap: 73%
EES: 32 kph
Mass ratio: 1.08

O/S long direct
N/S long indirect

2003 Peugeot 206
PDoF: 12 o'clock
Overlap: 85%
EES: 33 kph
Mass ratio: 0.92

O/S long direct

FSP compartment intrusion: none

Front seat passenger, Female Age: 76 Height: 1.55m Mass: 56kg

Injuries (AIS 2+): head(3), multiple thorax injuries (highest:5)

Primary factor: elevated occupant age
Secondary factor: seat belt related injury

Case Findings – Like reg. occupants

There were 25 occupants in impacts similar to the regulatory test. In some of these impacts, the structural performance and/or occupant injuries were worse than expected:

Structural performance:

•**Worse than expected**	**8**
•Possible compatibility issue (poor structural interaction)	3
•Possible compatibility issue (poor structural interaction / low overlap)	2
•Poor structural interaction (low overlap)	1
•Overridden by SUV, large mass difference	1
•EES possibly an underestimate	1

Occupant injuries:

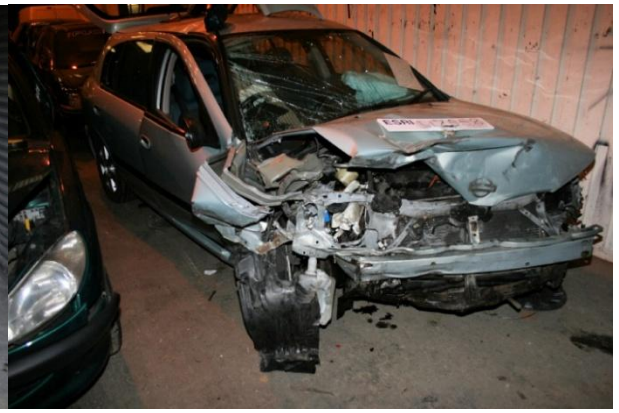
•**Worse than expected**	**2**
•Large intrusion – compatibility issue (poor structural interaction / low overlap)	1
•Medium intrusion – poor structural interaction (low overlap)	1
•**Fatal**	**3**
•Large intrusion – overridden by SUV	1
•Large intrusion – EES possibly an underestimate	1
•Medium intrusion – possible compatibility issue, age of occupant	1

Like Reg. Occupants – Example

A Nissan lost control whilst negotiating a left hand bend and crossed onto the opposite carriageway, colliding with an oncoming Fiat Punto

2001 Fiat Punto
PDoF: 12 o'clock
Overlap: 35%
EES: 51 kph
Mass ratio: 1.35

O/S long direct
N/S long indirect



2001 Nissan Almera
PDoF: 12 o'clock
Overlap: 36%
EES: 36 kph
Mass ratio: 0.74

O/S long direct
N/S long indirect

Intrusion: steering wheel up 3cm, inboard 42cm, backwards 33cm, knee 35cm, footwell, 53cm, o/s facia 37cm

Driver, Female Age: 17 Height: unknown Mass: unknown

Injuries (AIS 2+): multiple thorax injuries (highest:2), multiple limb fractures (highest:2)

Structural performance: worse than expected. Large intrusion (e.g. Footwell 53 cm)
Injury outcome: worse than expected
Reasons: large mass difference. Possible compatibility issue (poor structural interaction)

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Conclusions

Detailed case analysis

- Of 48 fatalities in Regulation 94 compliant cars, the main reasons in order of importance were:
  - High severity of the crash
  - Elevated age of the occupant
  - Underride and limited horizontal structural engagement with partner vehicle
- 25 occupants in impacts similar to the Regulation 94 test were identified, and compared to what was expected from EuroNCAP tests:
  - The injury outcome was only assessed as “worse than expected” when the car’s structural performance was also assessed as “worse than expected”, related to issues of poor compatibility and structural interaction
  - This highlights the importance of considering potential changes to Regulation 94 to improve a vehicle’s compatibility and structural interaction potential

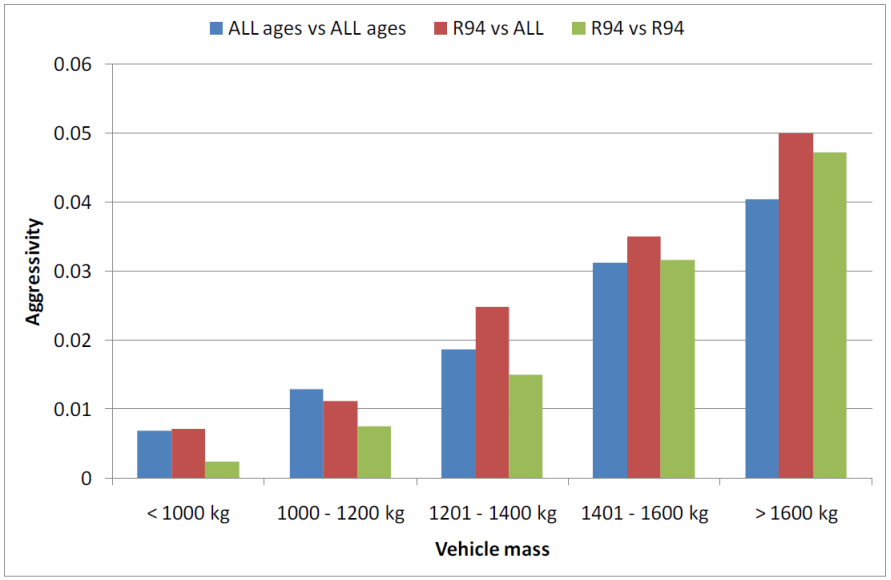
Tasks

1. Frontal impact taxonomy
2. Case analysis
3. Compatibility

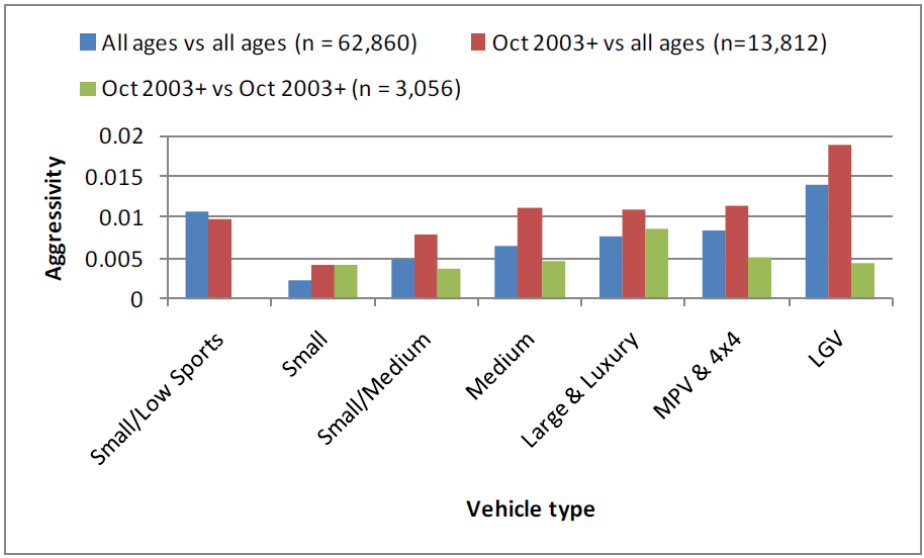
Aggressivity (partner protection)

$$Aggressivity = \frac{Driver\ fatalities in collision\ partner}{Number\ of\ crashes\ of\ subject\ vehicle}$$

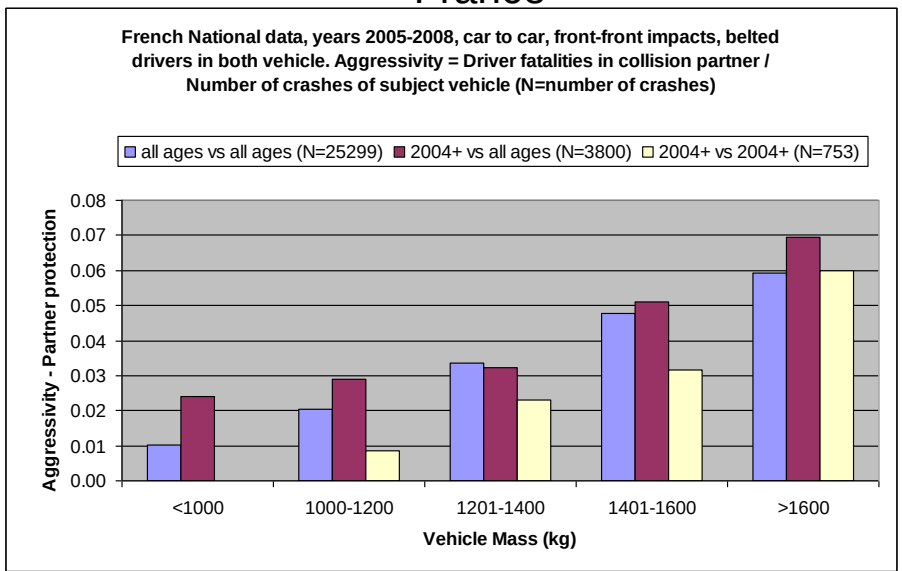
Germany



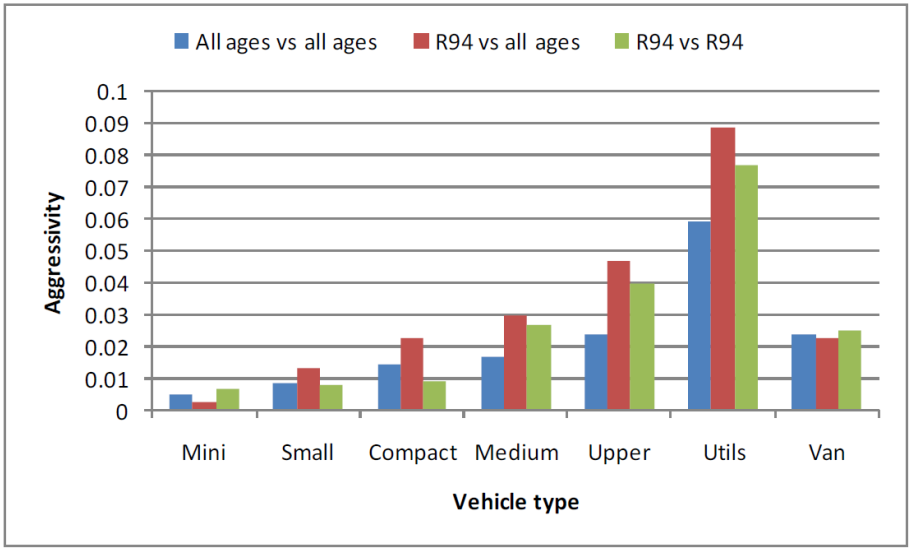
GB



France



Germany



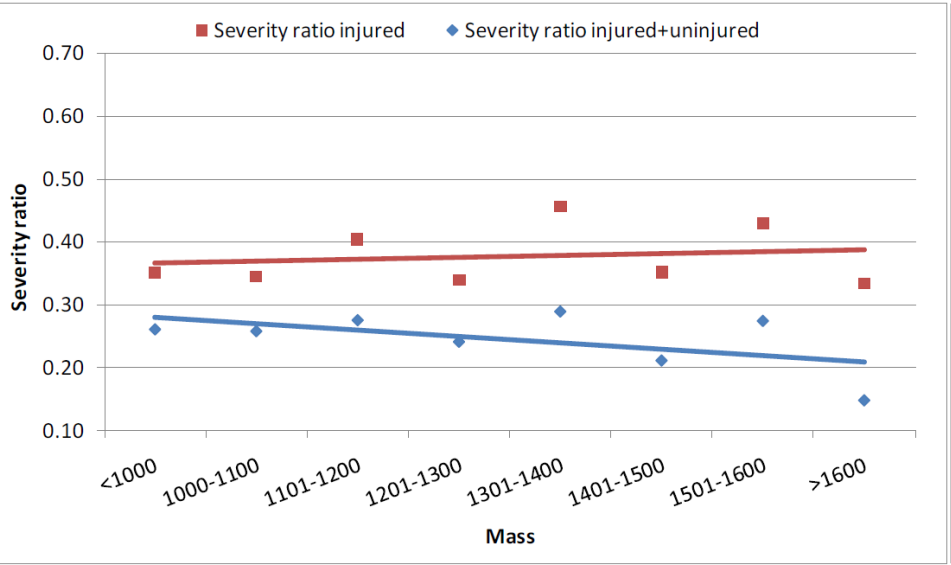
Severity proportion (self protection)

$$Severity\ proportion = \frac{Driver\ fatalities + Seriously\ injured\ drivers}{Fatal + Serious + Slight\ drivers}$$

$$Severity\ proportion = \frac{Driver\ fatalities + Seriously\ injured\ drivers}{Fatal + Serious + Slight + uninjured\ drivers}$$

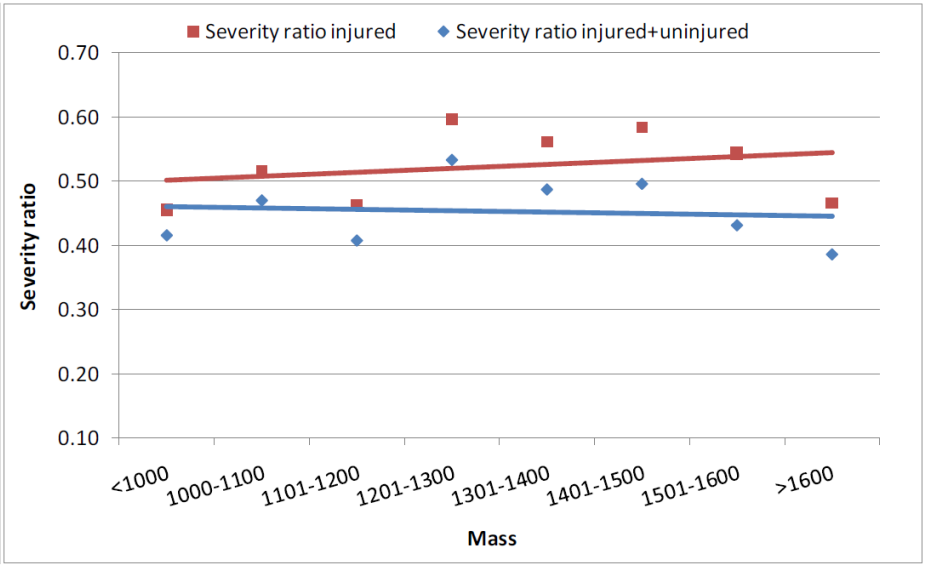
Car –to-car

France – R94 vs R94



Car –to-object

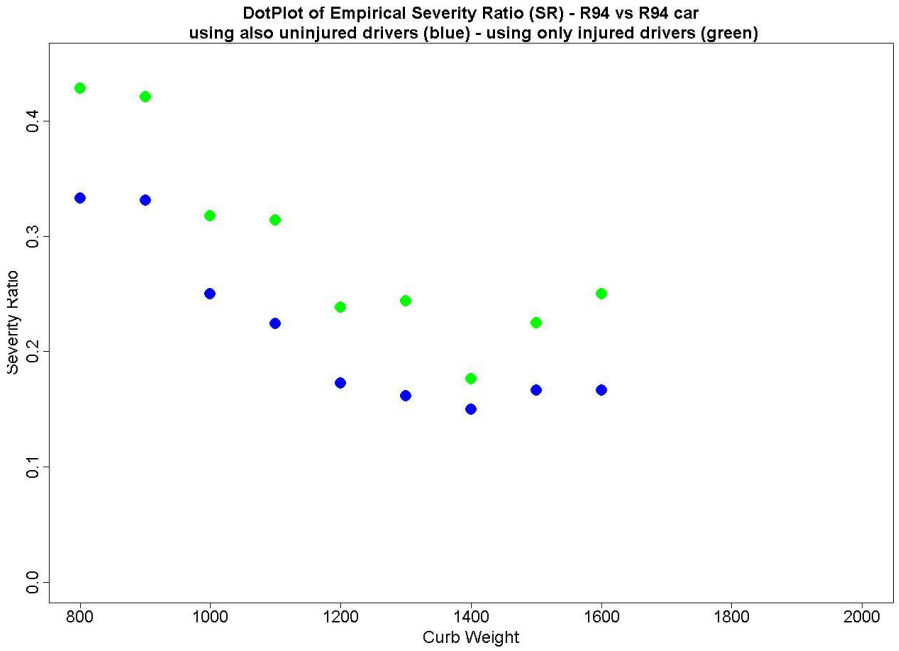
France – R94 vs object



Severity proportion (self protection)

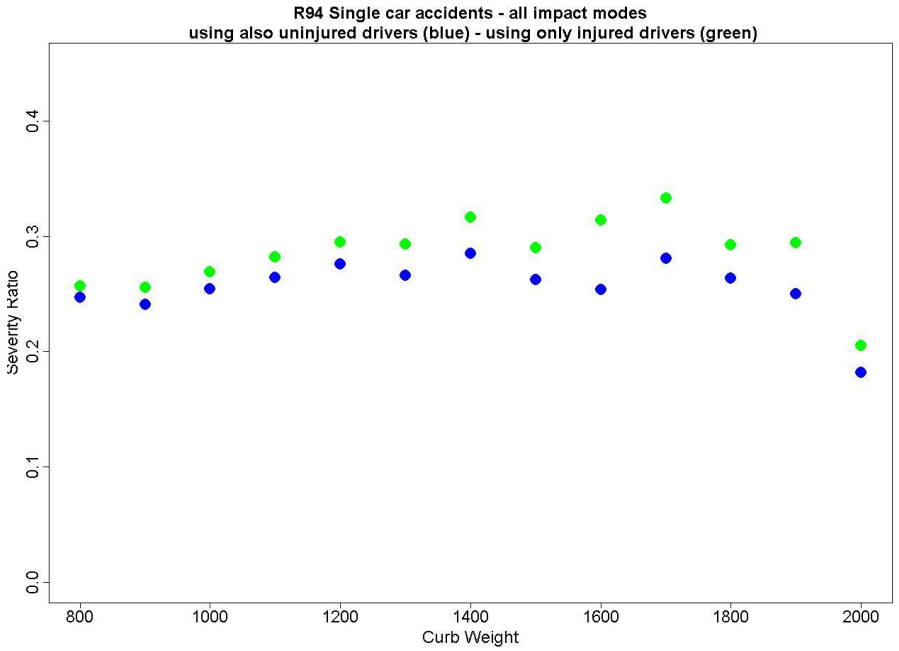
Car –to-car

Germany – R94 vs R94



Car –to-object

Germany – R94 vs object



Green: injured drivers only

Blue: includes uninjured drivers

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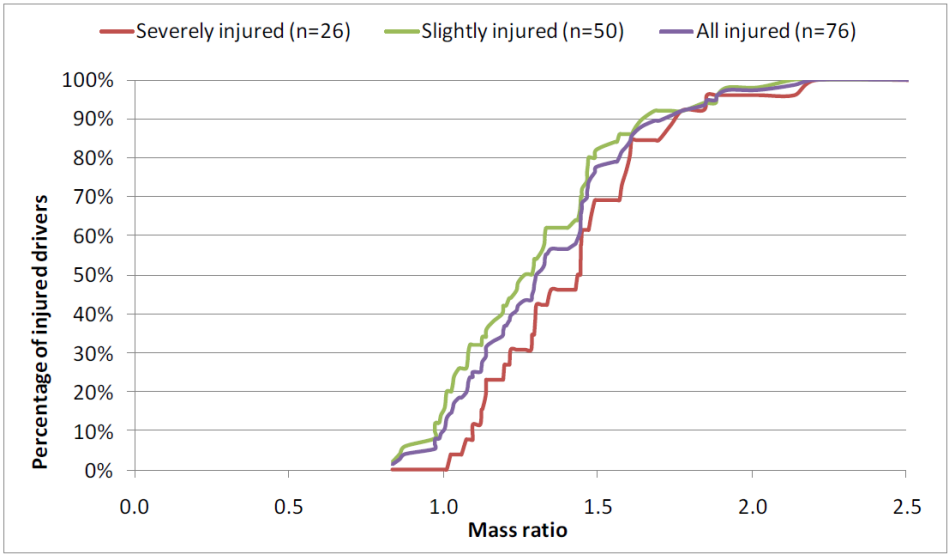
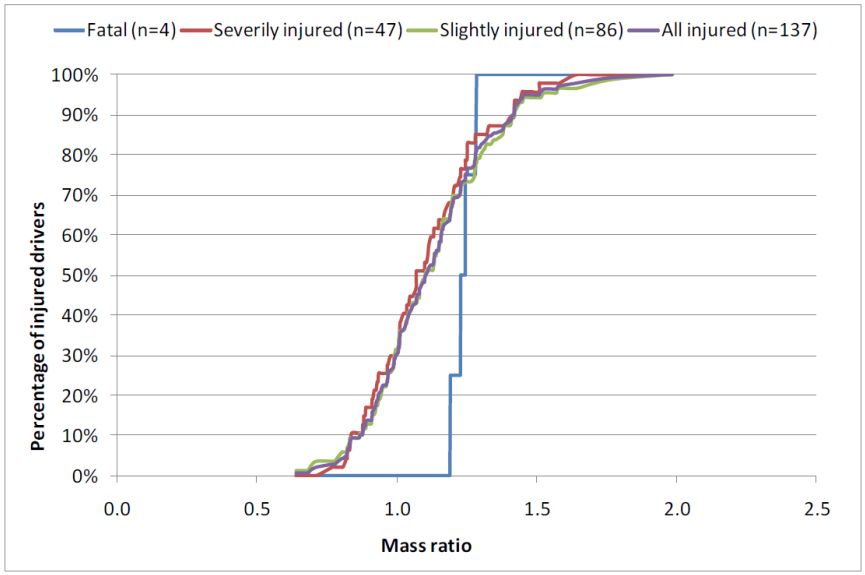
Mass ratio – France national data

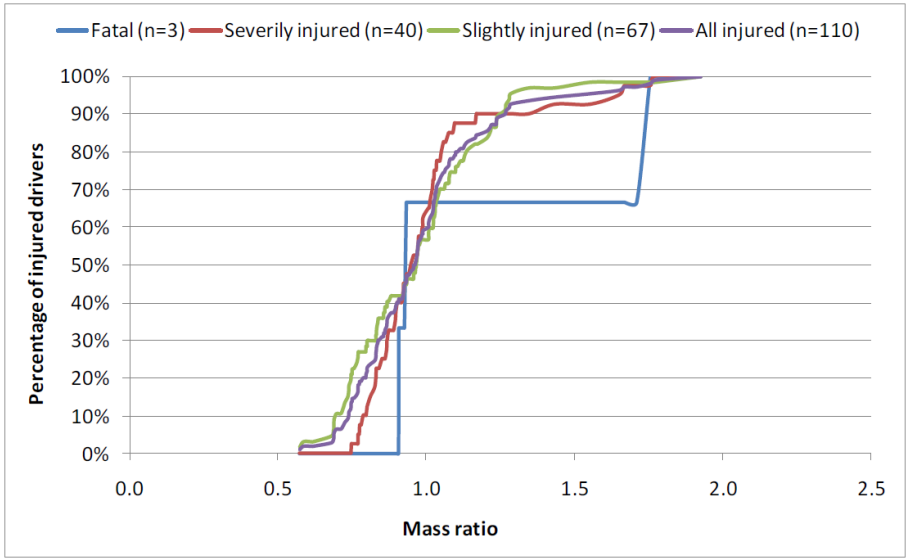
Cars < 1000 kg



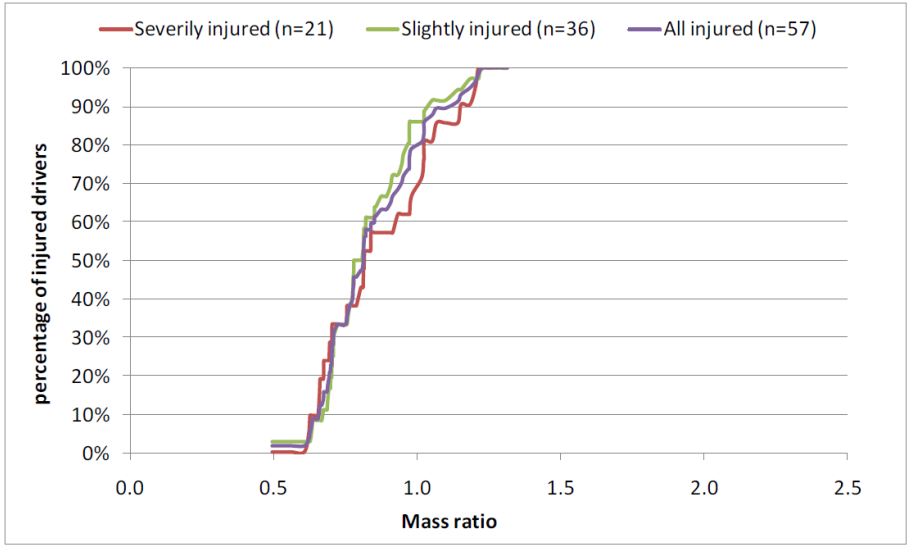
Cars 1000-1200 kg



Cars 1200-1400 kg



Cars 1400-1600 kg



Conclusions

- A three part analysis was performed using accident data from Great Britain, Germany and France, which found:
  - as vehicle mass or size increases, aggressivity also increases. This suggests that there is a compatibility problem
  - The relationship between self protection (severity proportion) was unclear. It is recommended that a different approach is tried in which confounding factors could be removed, for example a matched pair type of analysis
  - The relationship between the mass ratio of the vehicles involved in the impact and the injury severity of the drivers in the vehicles suggest a trend that increasing mass ratio (i.e. the subject vehicle has smaller mass than the impact partner) gives an increasing rate of fatal or severe injury
    - If a new test is developed in which the mass ratio can be altered (e.g. a Mobile Deformable Barrier test), the cumulative mass ratio curves can be used to help choose a suitable mass ratio for testing vehicles in different mass categories to address a given percentage of the casualties.

Thank you

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Report reference:

http://ec.europa.eu/enterprise/sectors/automotive/documents/calls-for-tender-and-studies/index_en.htm

ENTR 05/17: Technical assistance and economic analysis in the field of legislation pertinent to issue of automotive safety: Final Report: Provision of information and services on the subject of accident analysis for the development of legislation on frontal impact protection (July 2010)