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Analysis of in-depth and mass crash data to inform the development of the Pole Side Impact Global Technical Regulation

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Overview of presentation

- Presentation split into 4 components

1. Analysis of UK CCIS, in-depth crash data
2. Examination of STATS19 (UK reported crashes)
3. Analysis of Australian Fatality data (2001-2006)
   – incidence and cost of pole side impact crashes
4. Analysis of Victorian crash data
   – effectiveness of SAB (real-world and NCAP) and fitment rates of SAB vehicle sales data
   – patterns of injury in NCAP 5* vehicles vs. 'the rest'
   – cost of injury estimates and incremental benefits, accounting for ESC

Background

- Analysis of Australian In-depth Crash data (presented in Washington, June 2011) showed:
  - a higher proportion of occupants in PSI crashes sustained serious AIS3+ head, chest, abdomen-pelvis, and lower extremity injuries
  - older age, shorter, and lighter occupants had increased risk of injury
  - Limitations of the analysis: small number of cases (42 V2V; 16 PSI)
- Analysis of TAC Claims data (214 pole; 880 vehicle)
  - significantly increased odds of AIS3+ head, chest, abdomen-pelvis and lower extremity injuries
- Identified need to replicate the analysis using alternative datasets to determine the generalisability of the Australian data to other contexts

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Part 1
Analysis of UK CCIS: examination of factors associated with injury severity in PSI & vehicle-vehicle crashes

CCIS: the UK in-depth crash study

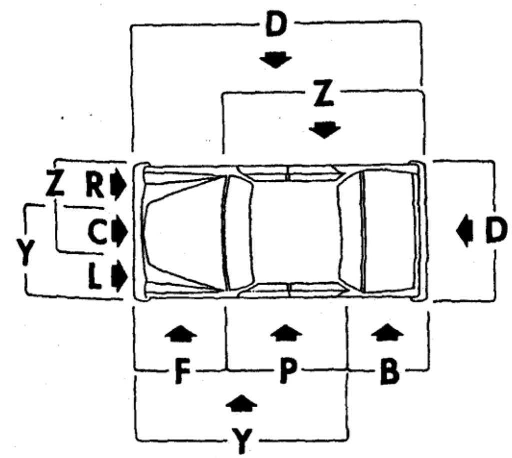
- CCIS is the UK in-depth crash investigation study
- In-depth crash data collected from 1983 to 2010 inclusive as part of the Co-operative Crash Injury Study (CCIS).
- The CCIS is managed by the Transport Research Laboratory
- Data collection: TRL (Crowthorne), Loughborough University, the University of Birmingham, and the Vehicle Inspectorate Agency
- The CCIS inclusion criteria:
  - crash occurred within a predefined geographic region;
  - The vehicle must be less than 7 years old;
  - the vehicle must be towed from the scene, and
  - The vehicle must have at least one injured occupant.
- A random stratified sampling system is used based on injury severity

Case selection criteria (1)

- The total number of cases (persons) available for analysis was 21,913 for crashes in the period 1998 – 2010
- Inclusion criteria
  - No rollover crashes, single impact (N=18,501)
  - MY 2000 onwards (*as a surrogate for meeting ECE95 (note 2003)*)
  - Side impact (n=7066; 32.2%) [frontal: 53.6%]
  - Struck-side
  - Known injury data
- After overlaying these criteria, there were **1735** cases available for analysis (right side: 1065; left side: 670) *[7.9% of total in CCIS]*
- Further restrictions
  - Front seat occupants: 1157 drivers & 362 front seat passengers
  - Collision partner was a car (n=543), or pole (narrow object impact)(n=57)
  - Removed unbelted occupants (less 36)

Case selection criteria (2)

- Impact profile with direct engagement with the occupant cabin.
  - Using the CDC damage profile, we select Zones **D, P, Y and Z**. This restriction results in the exclusion of 166 V2V impact cases and 10 pole impact cases, leaving **388 cases for analysis (V2V: 344; PSI: 44)**
- Crash severity index known – Equivalent Test Speed
  - excluded 8 PSI and 89 V2V impacts



Location	Classification
Distributed—side or end	D
Left—front or rear	L
Center—*front or rear*	C
Right—front or rear	R
Side front—left or right	F
Side center section—left or right	P
Side *rear—left or right*	B
Side or end—F + P or L + C	Y
Side or end—B + P or R + C	Z

Final sample: 299 cases available for analysis

<u>263 V2V impacts (88%) and 36 PSI (12%)</u>

Findings – occupant characteristics

Characteristic	Vehicle (N=263)	Tree / Pole (N=36)
Position		
Driver	213 (81%)	30 (83%)
Front left passenger	50 (19%)	6 (17%)
Number of occupants	263	36
Age (years)		
Mean (SD), years	42.5 (18.9)	27.3 (13.0) †
Mean - 95th% CL	40.1-44.8	22.8-31.8
Median, years	42.0	24.0
Min/Max	4-95	15-72
Sex		
Female	119 (45%)[b]	10 (28%)‡
Male	140 (55%)	26 (72%)

†‡p≤0.05

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Occupant height and weight

- Large proportion of cases where height and weight were unknown
  - Height: known for 119 (45.2%) V2V & 12 PSI cases (33%)
  - Weight: known for 119 (45.2%) V2V & 10 PSI cases (28%)

Characteristic	**Vehicle (N=119)**	**Tree / Pole (N=10)**
Weight (kg)		
Mean (SD)	73.2 (17.9) [a]	77.8 (26.1) [a]
Mean - 95th% CL	69.9-76.5	59.1-96.5
Median, kg	72.0	72.5
Min/Max	19-123	47-130
Height (m)	**Vehicle (N=119)**	**Tree / Pole (N=12)**
Mean (SD)	1.70 (0.11) [b]	1.76 (0.10) [b]
Mean - 95th% CL	1.68-1.72	1.69-1.82
Median (cm)	1.70	1.79
Min/Max	1.07-1.93	1.57-1.93

[a,b] $p \leq 0.05$

Vehicle details

Characteristic	Vehicle (N=263)	Tree / Pole (N=36)
Side airbag		
Not fitted / not activated	176 (66.9%)	27 (75.0%)
Curtain + thorax (+/- pelvis)	37 (14.1%)	1 (2.8%)
Combination – head+/ thorax (+/- pelvis)	15 (5.7%)	2 (5.6%)
Curtain only	29 (11.0%)	5 (13.9%)
Thorax only (+/- pelvis)	4 (1.5%)	1 (2.8%)
Tube + thorax (+/- pelvis)	2 (.8%)	Nil
R95 compliant		
Not compliant	48 (18.3%)	11 (30.6%)
Compliant	215 (81.7%)	25 (69.4%)

Crash severity

Characteristic	ALL INJURY SEVERITY Vehicle (N=263)	 Tree / Pole (N=36)
Crush - maximum		
Mean (SD) mm	21.8 (13.0)[b]	42.8 (23.6)[b]
Mean - 95th% CL	20.2-23.4	34.8-50.8
Median, mm	18.0	39.5
Min/Max	3-76	9-96
ETS		
Mean (SD) (km/h)	19.3 (10.7)[a]	28.4 (22.7)[a]
Mean - 95th% CL	18.0-20.6	20.7-36.1
Median, KM/H	17.0	24.0
Min/Max	5-72	4-133

[a,b] $p \leq 0.05$

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Injury severity

Characteristic	Unweighted Vehicle (N=263)	Unweighted Tree / Pole (N=36)	Weighted Vehicle (N=12,569)	Weighted Tree / Pole (N=1531)
Severity (CCIS rating)‡				
Killed	12 (4.6%)	7 (19.4%)	†102 (0.8%)	†60 (3.9%)
Seriously injured	75 (28.5%)	12 (33.3%)	1222 (9.7%)	195 (12.7%)
Slight	141 (53.6%)	16 (44.4%)	11245 (89.5%)	1276 (83.3%)
Uninjured	35 (13.3%)	1 (2.8%)	Unable to determine	Unable to determine
MAIS – whole body[(a)]				
0-uninjured	35 (13.3%)	1 (2.8%)	-	-
1-Minor	162 (61.6%)	16 (44.4%)	11587 (92.2%)[(cw)]	1213 (79.2%)
2-Moderate	35 (13.3%)	2 (5.6%)	562 (4.5%)	96 (6.3%)
3=Serious	15 (5.7%)	9 (25.0%)	237 (1.9%)	147 (9.6%)
4=Severe	9 (3.4%)	7 (19.4%)	116 (0.9%)	60 (3.9%)
5=Critical	4 (1.5%)	1 (2.8%)	42 (0.3%)	16 (1.0%)
6=Maximum	3 (1.1%)	0 (Nil)	26 (0.2%)	0 (-)

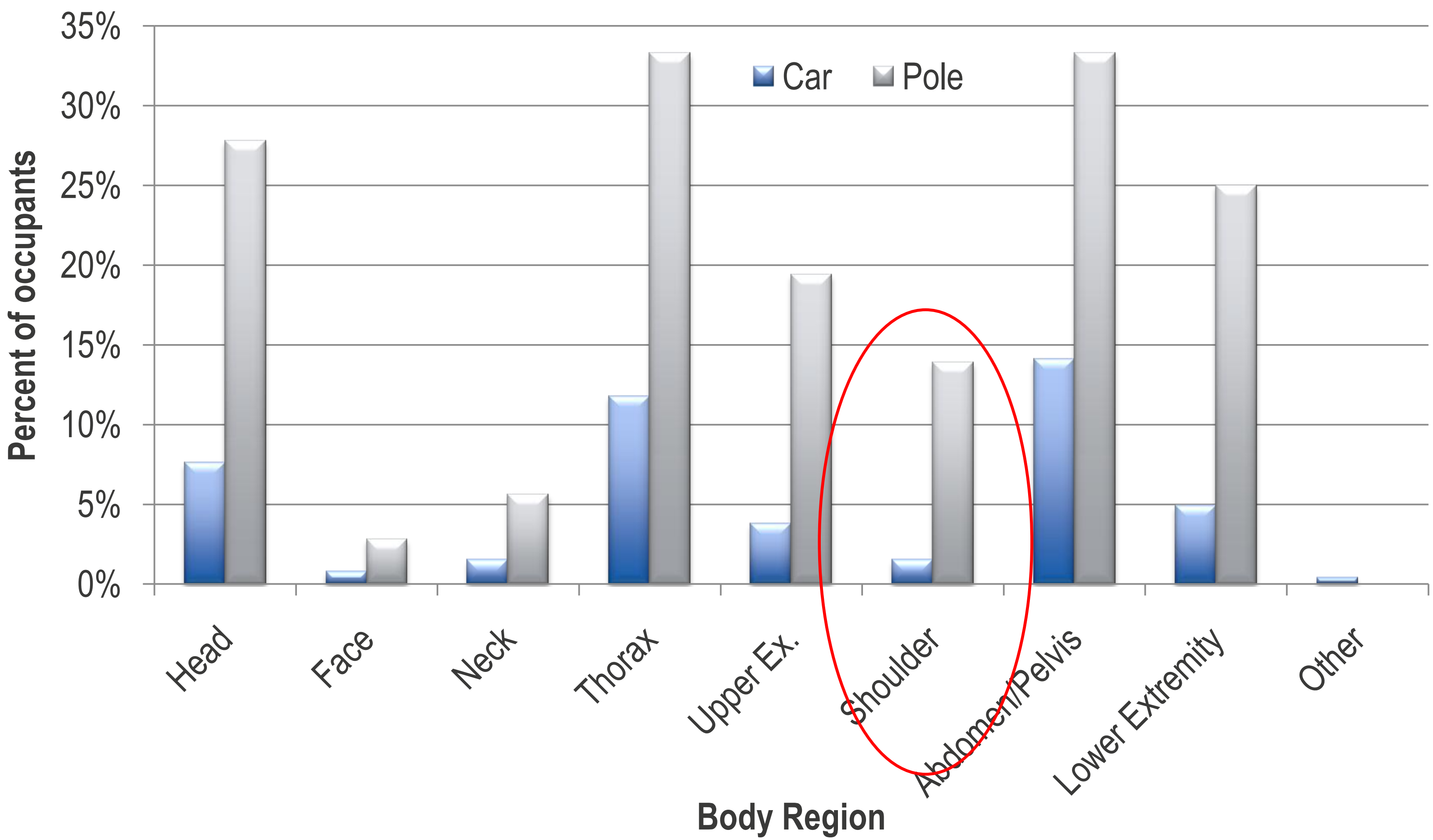
† ‡ ᵃ$p \leq 0.05$

Injury severity (2)

	Unweighted		Weighted	
Characteristic	Vehicle (N=263)	Tree / Pole (N=36)	Vehicle (N=12,569)	Tree / Pole (N=1531)
MAIS – 2 + (NUMBER, %) *(b)*				
MAIS <2	197 (74.9%)	17 (47.2%)	11587 (92.2%) *(dw)*	1213 (79.2%)
MAIS 2+	66 (25.1%)	19 (52.8%)	982 (7.8%)	319 (20.8%)
MAIS – 3 + (NUMBER, %) *(c)*				
MAIS <3	232 (88.2%)	19 52.8%)	12149 (96.7%) *(ew)*	1309 (85.4%)
MAIS 3+	31 (11.8%)	17 (47.2%)	420 (3.3%)	223 (14.6%)
Injury Severity Score *(d)*				
Mean (SD)	5.0 (10.9)	12.6 (10.9)	2.4 (5.3) *(fw)*	4.4 (8.6)
Mean - 95th% CL	3.67-6.35	7.44-17.88	2.37-2.55	4.00-4.86
Median	2.0	5.5	1.0	1.0
Min/Max	0-75	0-48	1-75	1-48
ISS category (major trauma) *(e)*				
Minor (<15)	243 (92.4%)	25 (69.4%)	12328 (98.1%) *(gw)*	1406 (91.8%)
Major (>15)	20 (7.6%)	11 (30.6%)	241 (1.9%)	125 (8.2%)

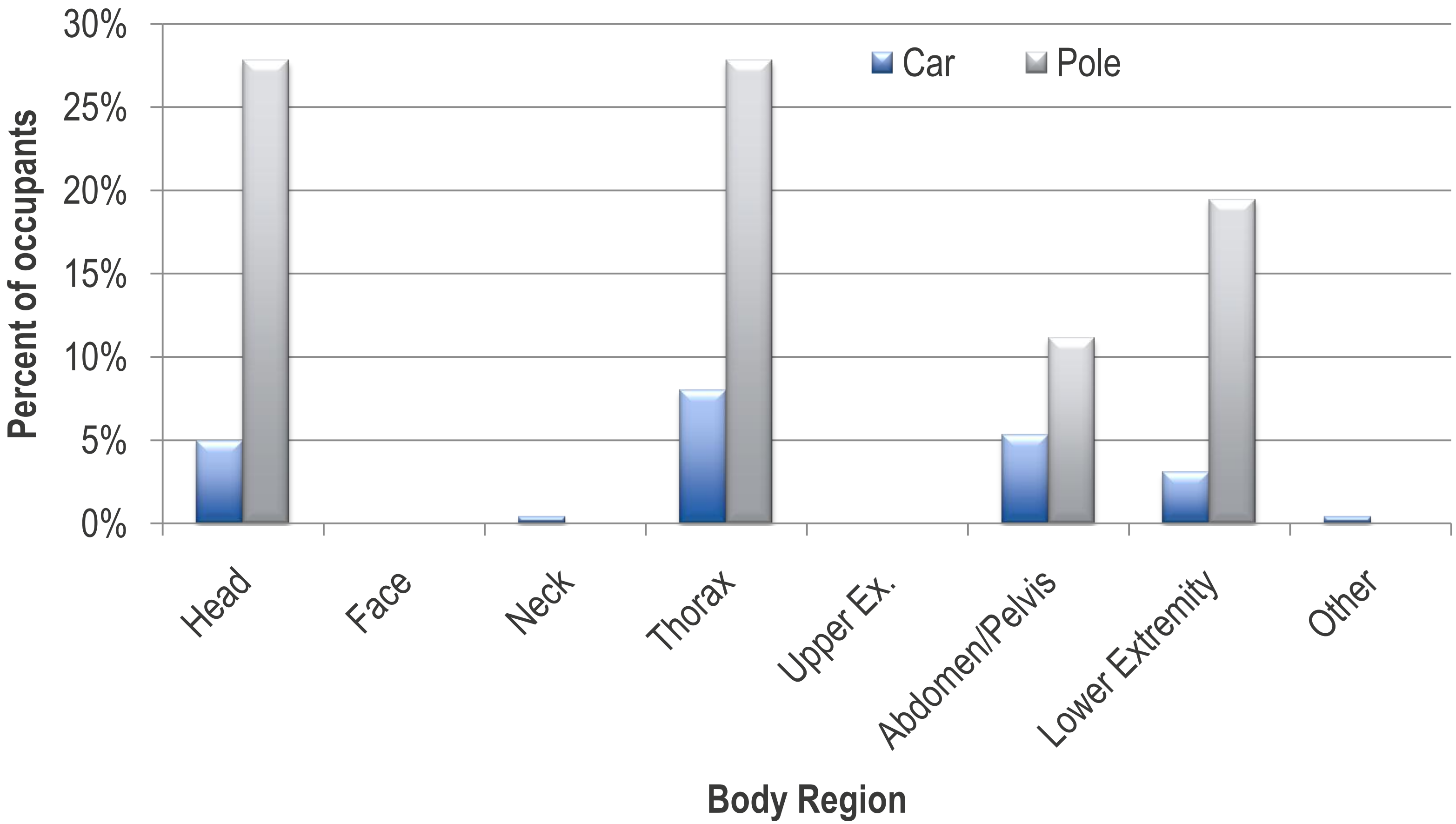
[b,c, d,e, dw,ew,fw,gw] $p \leq 0.05$

AIS 2+ injuries, by region and collision partner



Must consider that the mean ETS was higher in PSI than V2V crashes

AIS 3+ injuries, by region and collision partner



Of interest for prioritisation of regions, however must consider that the mean ETS was higher in PSI than V2V crashes

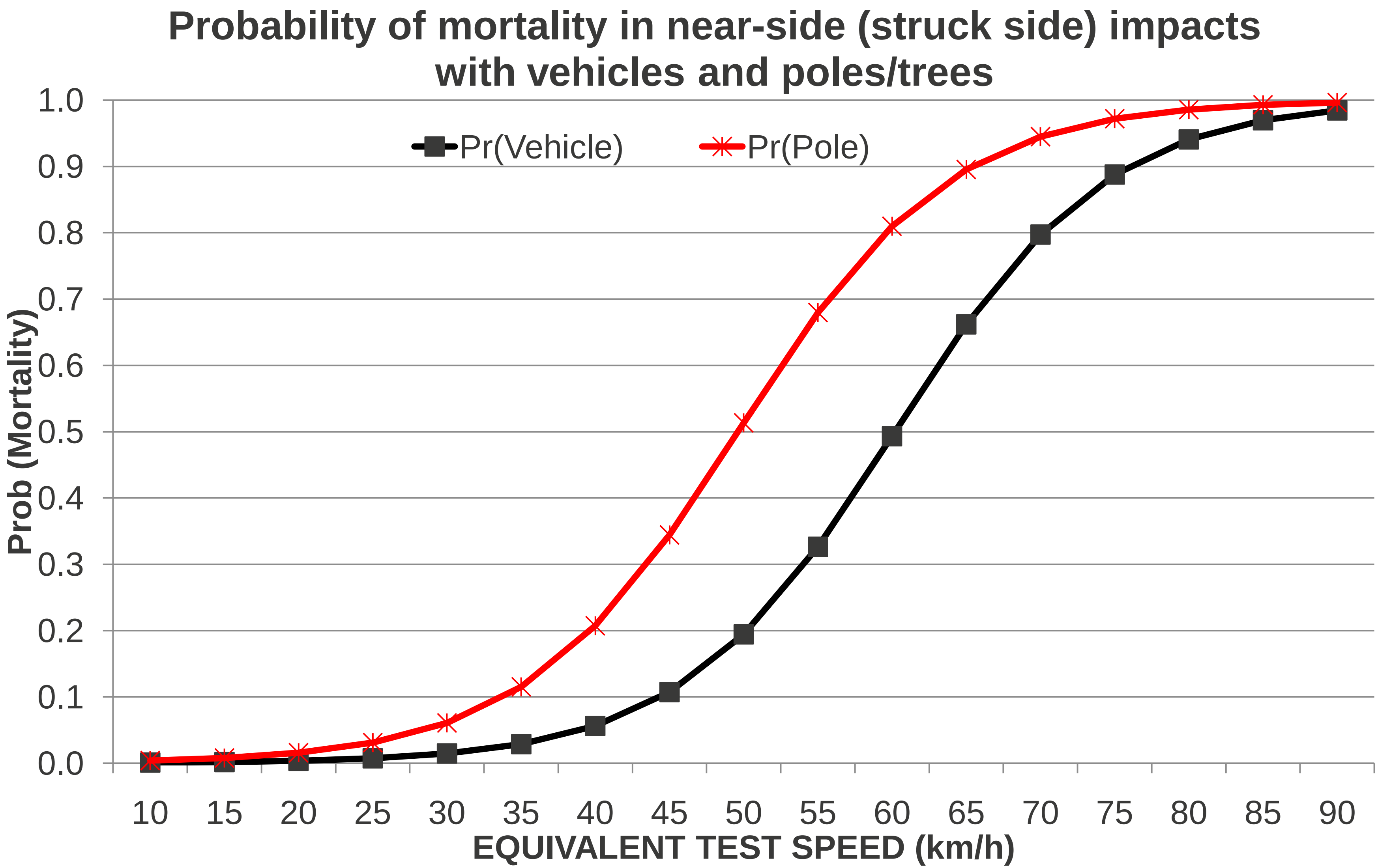
Mortality and Major Trauma

Principal question: difference in mortality and injury severity in PSI relative to vehicle side impacts

		Mortality		Mortality (weighted)	
Collision partner		**Odds ratio**	**P**	**Odds Ratio**	**P**
Narrow object	vs.Vehicle	**4.37 (1.01-18.91)**	0.048	**4.43 (0.89-21.9)**	0.07
Equivalent Test Speed	km/h	1.14 (1.09-1.21)	<0.001	1.18 (1.13-1.24)	<0.001
Age	years	1.04 (0.99-1.07)	0.06	1.04 (0.999-1.08)	0.05

		Major trauma (ISS>15)		Major trauma (ISS>15) (weighted)	
Collision partner		**Odds Ratio**	**P**	**Odds Ratio**	**P**
Narrow object	vs. Vehicle	**4.17 (1.24-13.98)**	0.02	**3.44 (0.77-15.4)**	0.1
Equivalent Test Speed	km/h	1.16 (1.10-1.21)	<0.001	1.18 (1.12-1.23)	<0.001
Age	years	1.01 (0.98-1.04)	0.5	1.00 (0.97-1.04)	0.7

Note: by removing the uninjured in the weighted analysis, the uninjured occupants - all but 1 struck by a car, the denominator is biased, hence the non-statistically significant OR for the weighted analysis


Probability of mortality in near-side (struck side) impacts
with vehicles and poles/trees
Pr(Vehicle)
Pr(Pole)
Prob (Mortality)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
EQUIVALENT TEST SPEED (km/h)

Head injury

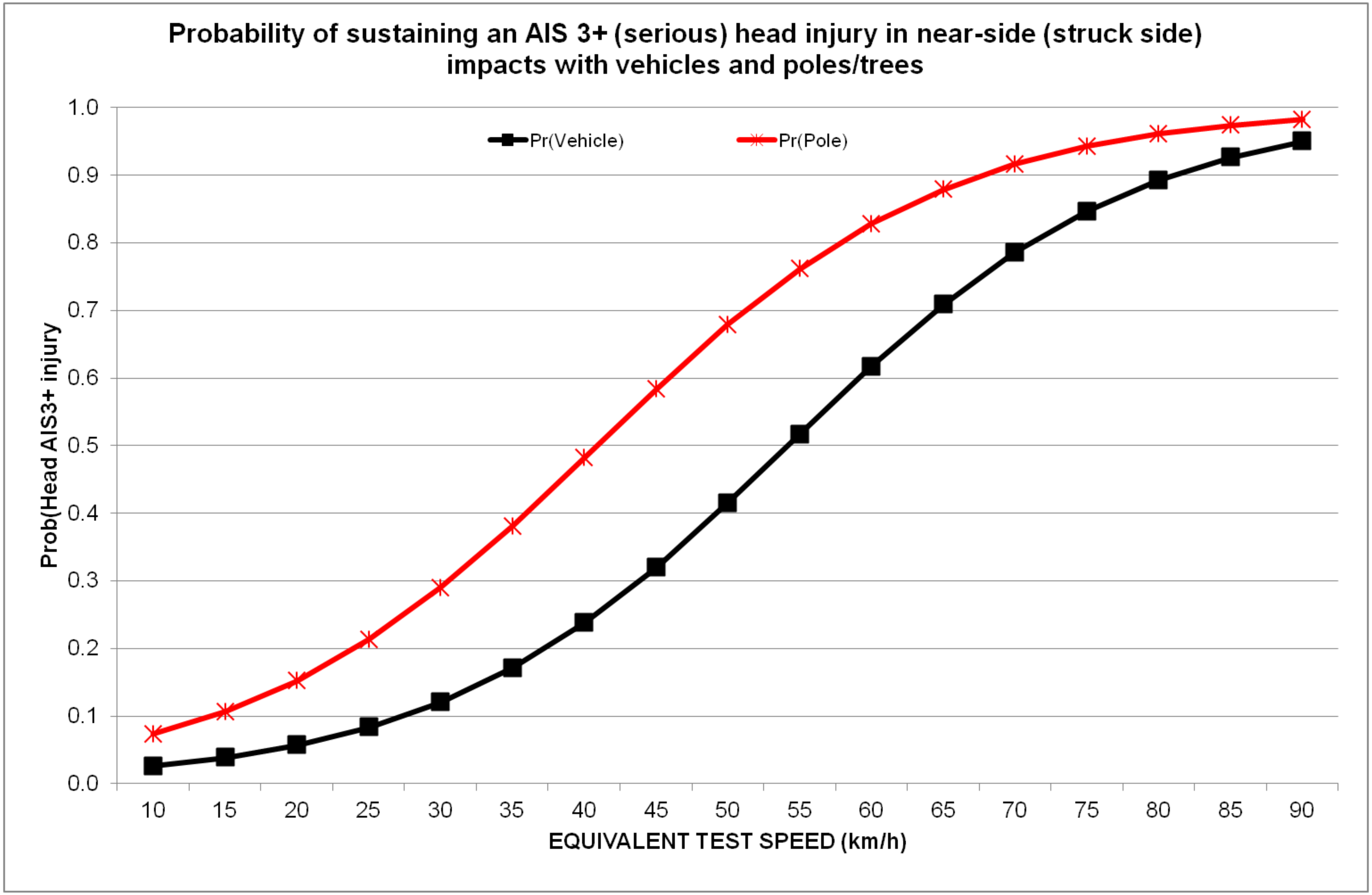
Principal question: difference in head injury in PSI relative to vehicle side impacts

		Head injury		Head AIS2+		Head AIS 3+	
		Odds ratio	P	Odds Ratio	P	Odds Ratio	P
Collision partner							
	Reference						
Narrow object	Vehicle	**2.38** (1.09-5.21)	0.03	**2.98** (1.10-8.05)	0.03	**5.15** (1.73-15.2)	0.003
Equivalent Test Speed	km/h	1.04 (1.02-1.07)	<0.001	1.08 (1.05-1.12)	<0.001	1.10 (1.06-1.14)	<0.001
Side airbag							
Curtain + Thorax	None	**0.27 (0.36-3.32)**	**0.04**	*Unable to model airbag as there were **no** AIS2+head injuries with a curtain + thorax SAB.*			
Combination (H+T)	None	1.09 (0.36-3.32)	0.9				
Thorax-only	None	0.70 (0.28-1.73)	0.4				
Curtain only	None	Omitted					
Tube	None	2.20 (0.13-36.4)	0.6				
SAB contrast							
Curtain+ Thorax	Combination	**0.25 (0.05-1.22)**	**0.09**				
Notes		• ***age, sex n.s;*** • ***assessed height and weight with 131 occupants – not predictors***					

Head injury (weighted analysis)

Principal question: difference in head injury in PSI relative to vehicle side impacts

			Head injury		Head AIS2+		Head AIS 3+	
			Odds ratio	**P**	**Odds Ratio**	**P**	**Odds Ratio**	**P**
Collision partner								
	Narrow object	vs. Vehicle	1.33 (0.47-3.74)	0.6	1.85 (0.58-5.85)	0.3	**3.98 (1.06-15.00)**	**<0.001**
Equivalent Test Speed		km/h	1.02 (0.99-1.06)	0.1	1.10 (1.07-1.14)	<0.001	1.12 (1.08-1.17)	<0.001
Age		years	0.98 (0.96-1.00)	0.1	0.98 (0.95-1.01)	0.2	0.99 (0.95-1.03)	0.7
Sex	Male	vs. Female	1.91 (0.85-4.31)	0.1	1.07 (0.39-2.95)	0.8	1.58 (0.44-5.62)	0.5
Notes			*weighted analysis - excludes 'uninjured' occupants as STATS19 does not report uninjured persons in crashes – hence no weight value available; unable to model side airbag system*					


Probability of sustaining an AIS 3+ (serious) head injury in near-side (struck side) impacts with vehicles and poles/trees
Pr(Vehicle)
Pr(Pole)
Prob(Head AIS3+ injury)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
EQUIVALENT TEST SPEED (km/h)

Chest injury

Principal question: difference in chest injury in PSI relative to V2V side impacts

		Chest injury		Chest AIS2+		Chest AIS 3+	
		Odds ratio	**P**	**Odds Ratio**	**P**	**Odds Ratio**	**P**
Collision partner							
Narrow object	Vehicle	1.22 (0.54-2.79)	0.6	**4.28 (1.07-1.15)**	<0.001	**3.87 (1.31-11.42)**	0.01
Equivalent Test Speed	km/h	1.06 (1.04-1.09)	<0.001	1.11 (1.07-1.15)	<0.001	1.09 (1.06-1.14)	<0.001
Age	years	1.03 (1.01-1.04)	<0.001	1.04 (1.02-1.06)	0.001	1.02 (0.999-1.05	0.05

- ***There is no difference in sustaining 'any injury' due to universally high proportion of occupants with a coded AIS 1 injury***
- ***At the higher AIS severities, the odds of sustaining an injury is significantly higher when the collision partner is a pole, relative to a vehicle***

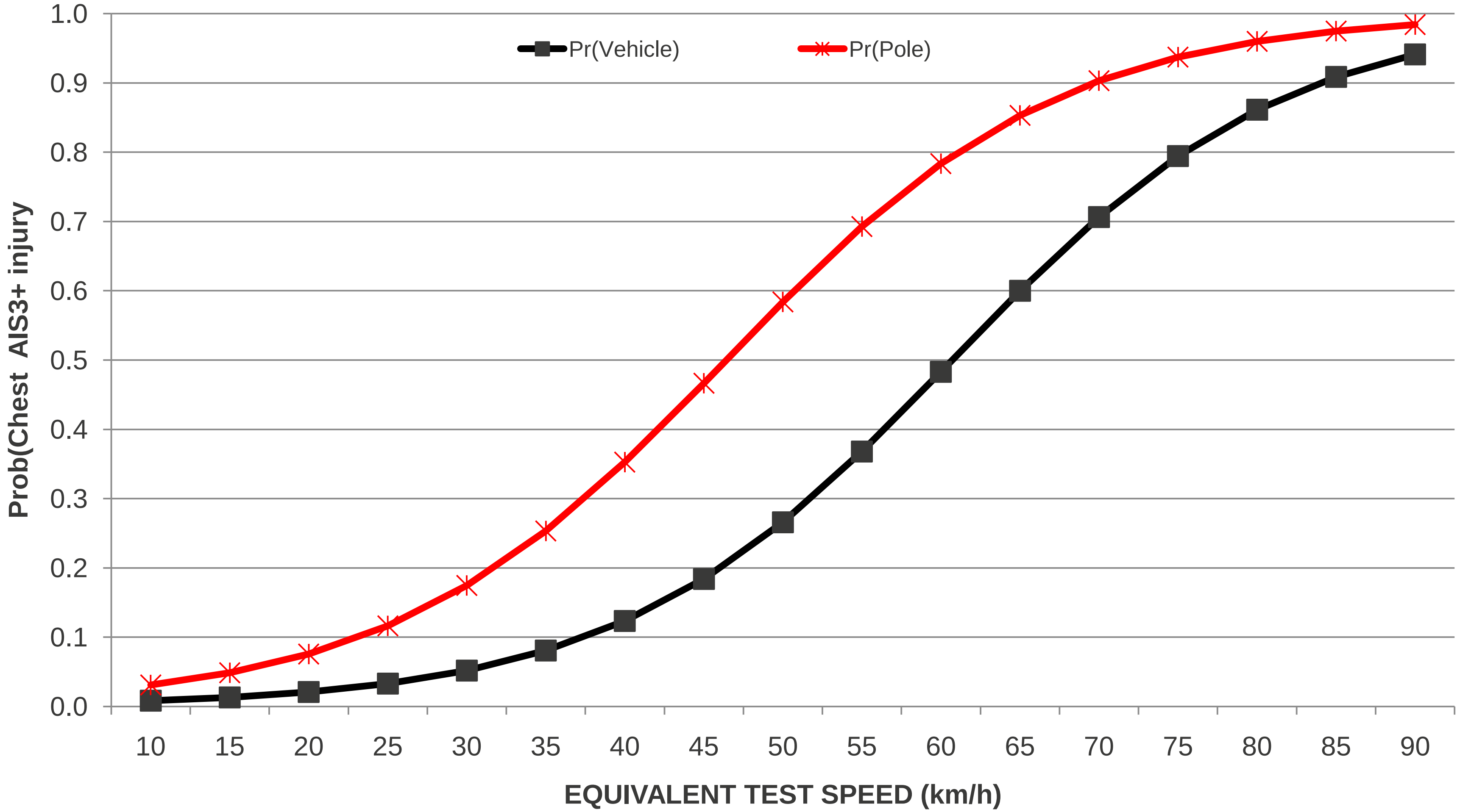
Chest injury (weighted)

Principal question: difference in chest injury in PSI relative to V2V side impacts

		Chest injury		Chest AIS2+		Chest AIS 3+	
		Odds ratio	**P**	**Odds Ratio**	**P**	**Odds Ratio**	**P**
Collision partner							
Narrow object	Vehicle	0.55 (0.21-1.44)	0.2	**3.27 (1.09-9.75)**	**0.03**	3.40 (0.97-11.9)	0.056
Equivalent Test Speed	km/h	1.03 (1.00-1.07)	0.03	1.13 (1.09-1.17)	<0.001	1.13 (1.08-1.17)	<0.001
Age	years	1.02 (1.00-1.04)	0.01	1.03 (1.01-1.05)	0.001	1.02 (1.00-1.05)	0.05

- ***Same pattern as for unweighted estimates, except for AIS3+ injuries – which was of borderline statistical significance; this is the consequence of the exclusion of the non-injured cases, which were all but 1 V2V impacts***

Probability of sustaining an AIS 3+ (serious) chest injury in near-side (struck side) impacts with vehicles and poles/trees



Abdominal – Pelvis injury

Principal question: difference in A-P injury in PSI relative to V2V side impacts

			Abdominal –pelvis injury		Abdominal –pelvis AIS2+		Abdominal –pelvis AIS 3+	
			Odds ratio	P	Odds Ratio	P	Odds Ratio	P
Collision partner								
	Narrow object	Vehicle	1.17 (0.49-2.77)	0.7	2.14 (0.76-6.01)	0.1	0.93 (0.19-4.44)	0.9
Equivalent Test Speed		km/h	1.08 (1.05-1.11)	<0.001	1.13 (1.09-1.17)	<0.001	1.11 (1.06-1.15)	<0.001
Age		years	1.01 (0.99-1.02)	0.1	1.01 (0.99-1.03)	0.3	1.01 (0.98-1.04)	0.6
Sex	Male	Female	**0.40 (0.23-0.70)**	**0.001**	0.51 (0.23-1.12)	0.09	0.43 (0.13-1.45)	0.2

- ***There was no difference in the odds of injury between PSI and V2V impacts***
- ***Males were less likely to sustain an injury of the abdomen and pelvis***

Abdominal – Pelvis injury (weighted)

Principal question: difference in A-P injury in PSI relative to V2V side impacts

			Abdominal –pelvis injury		Abdominal –pelvis AIS2+		Abdominal –pelvis AIS 3+	
			Odds ratio	**P**	**Odds Ratio**	**P**	**Odds Ratio**	**P**
Collision partner								
	Narrow object	Vehicle	1.01 (0.34-2.98)	0.9	1.69 (0.57-4.99)	0.3	0.52 (0.06-4.35)	0.5
Equivalent Test Speed		km/h	1.05 (1.02-1.09)	0.004	1.16 (1.11-1.20)	<0.001	1.16 (1.08-1.23)	<0.001
Age		years	1.01 (0.99-1.03)	0.2	1.01 (0.99-1.03)	0.3	1.00 (0.96-1.05)	0.8
Sex	Male	Female	**0.42 (0.20-0.88)**	**0.02**	0.50 (0.21-1.21)	0.1	0.43 (0.08-2.33)	0.3

- ***There was no difference in the odds of injury between PSI and V2V impacts***
- ***Males were less likely to sustain an injury of the abdomen and pelvis***

Shoulder injury

Principal question: difference in shoulder injury in PSI relative to V2V side impacts

		Shoulder injury		Shoulder AIS2	
		Odds ratio	P	Odds Ratio	P
Collision partner					
Narrow object	Vehicle	4.08 (1.73-9.59)	0.001	7.89 (1.85-33.5)	0.005
Equivalent Test Speed	km/h	1.03 (1.00-1.06)	0.02	0.99-1.06	0.1

- ***Significantly increased odds of shoulder injury in pole side impact crashes***

Lower Extremity injury

Principal question: difference in Lower Ex. injury in PSI relative to V2V side impacts

			Lower Extremity injury		Low Ex. AIS2+		Low Ex. AIS3+	
			Odds ratio	**P**	**Odds Ratio**	**P**	**Odds Ratio**	**P**
Collision partner								
	Narrow object	Vehicle	**2.07 (0.88-4.88)**	**0.09**	**4.13 (1.39-12.75)**	**0.01**	**4.79 (1.22-18.79)**	**0.02**
Equivalent Test Speed		km/h	1.06 (1.03-1.09)	<0.001	1.09 (1.05-1.13)	0.01	1.12 (1.07-1.17)	<0.001
Age		years	1.02 (1.00-1.03)	0.049	N.S		N.S	
Sex	**Male**	**Female**	**0.56 (0.31-1.00)**	**0.05**	N.S		N.S	
Side airbag								
Curtain + Thorax		None	1.60 (0.74-3.44)	0.2	*Airbag - no statistcal relationship with outcome demonstrated*			
Combination (H+T)		None	1.88 (0.61-5.83)	0.3				
Thorax-only		None	0.36 (0.11-1.09)	0.07				
Curtain only		None	1.43 (0.21-9.63)	0.7				
Tube		None	Omitted					

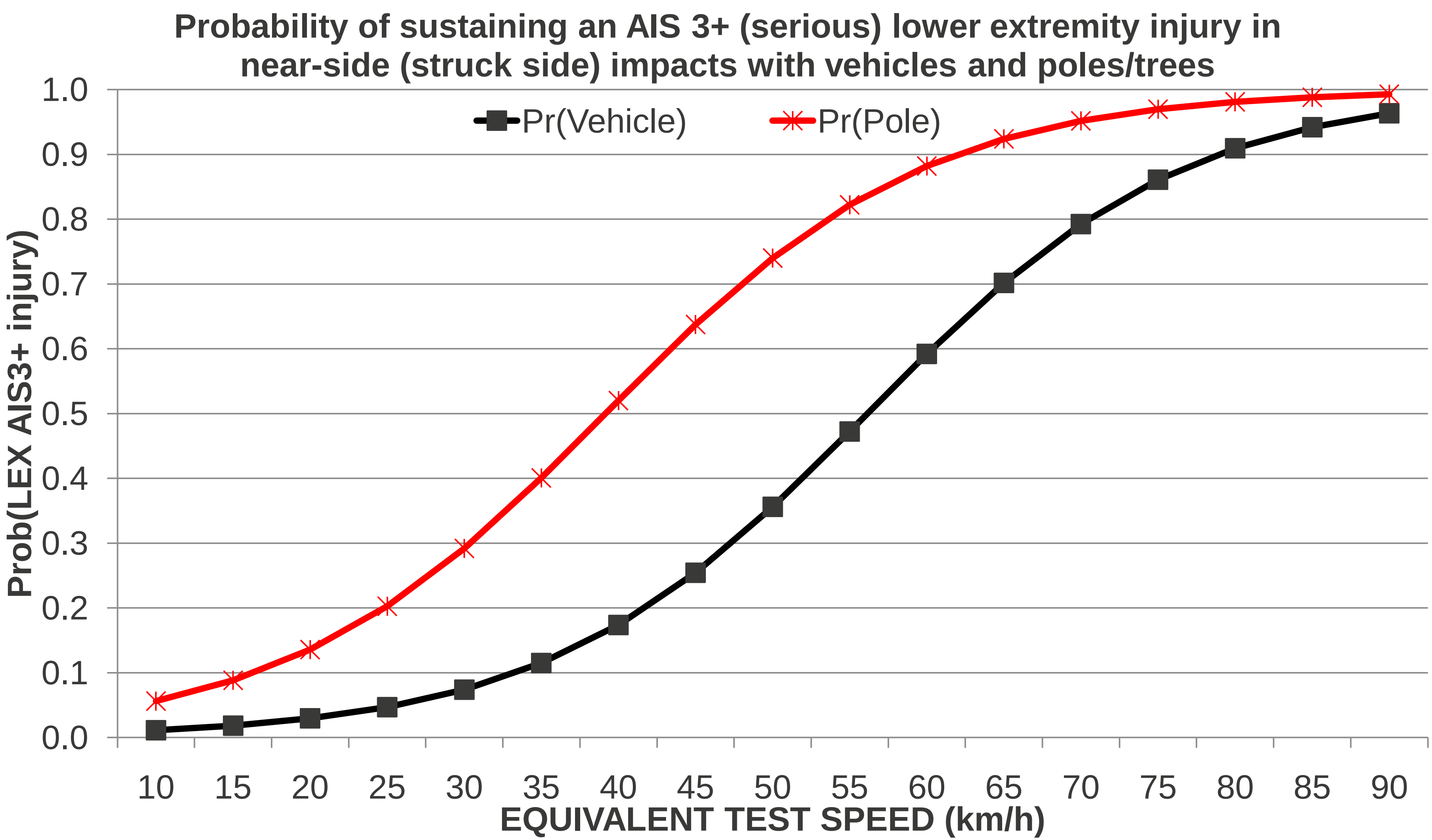
- ***Significantly higher odds of lower extremity injury in pole side impacts***
- ***Males were less likely to be injured, but no difference in higher severities between males and females***

Lower Extremity injury (weighted)

Principal question: difference in Lower Ex. injury in PSI relative to V2V side impacts

			Lower Extremity injury		Low Ex. AIS2+		Low Ex. AIS3+	
			Odds ratio	**P**	**Odds Ratio**	**P**	**Odds Ratio**	**P**
Collision partner								
	Narrow object	Vehicle	1.50 (0.58-3.88)	0.4	**8.27 (2.00-34.1)**	**0.003**	**6.69 (1.51-29.64)**	**0.01**
Equivalent Test Speed		km/h	1.05 (1.01-1.09)	0.004	1.11 (1.07-1.15)	<0.001	1.16 (1.09-1.23)	<0.001
Age		years	1.00 (0.98-1.02)	0.7	N.S		N.S	
Sex	Male	Female	0.51 (0.24-1.07)	0.08	N.S		N.S	
Side airbag								
Curtain + Thorax		None	2.22 (0.87-5.64)	0.09	*Airbag - no statistcal relationship with outcome*			
Combination (H+T)		None	1.95 (0.46-8.18)	0.4	*demonstrated*			
Thorax-only		None	**0.21 (0.05-0.94)**	**0.04**				
Curtain only		None	.092 (0.12-7.36)	0.9				
Tube		None	Omitted					

- ***Significantly higher odds of lower extremity injury in pole side impacts at AIS2+/3+***
- ***Thorax-only bag was associated with lower odds LEX injuries***



Probability of sustaining an AIS 3+ (serious) lower extremity injury in near-side (struck side) impacts with vehicles and poles/trees
Pr(Vehicle)
Pr(Pole)
Prob(LEX AIS3+ injury)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
EQUIVALENT TEST SPEED (km/h)

Summary – probability of injury and OR

	Probability		Pole relative to Vehicle impact	
	Pole	Car	OR (95% CI)	P
Killed	0.15	0.03	4.37 (1.01-18.91)	0.048
Major Trauma	0.31	0.07	4.17 (1.24-13.98)	<0.001
Head AIS 2+	**0.38**	**0.13**	**2.98 (1.10-8.05)**	**0.03**
Head AIS 3+	0.34	0.07	5.15 (1.74-15.29)	0.003
Face 2+	**0.03**	**0.02**	**2.09 (0.11-36.44)**	**0.6**
Neck 2+	**0.06**	**0.03**	**1.98 (0.25-15.5)**	**0.5**
Shoulder AIS2	**0.24**	**0.03**	**7.89 (1.85-33.5)**	**0.005**
Chest 2+	**0.72**	**0.17**	**4.28 (1.07-1.15)**	**<0.001**
Chest 3+	0.46	0.12	3.87 (1.31-11.42)	0.01
Ab-Pelvis 2+	**0.76**	**0.35**	**2.14 (0.76-6.01)**	**0.1**
Ab-Pelvis 3+	0.10	0.11	0.93 (0.19-4.44)	0.9
Upper Ext. 2+	**0.30**	**0.07**	**4.05 (1.31-12.47)**	**0.01**
Lower Ext. 2+	**0.30**	**0.07**	**4.13 (1.39-12.27)**	**0.01**
Lower Ext. 3+	0.13	0.03	4.79 (1.22-18.79)	0.02

Key messages

- PSI represented 12% of cases in the side impact crashes within the case selection criteria in the UK CCIS database
- Pole side impact crashes are associated with significantly higher likelihood of injury and death than vehicle-to-vehicle side impacts
  - Serious head, chest, upper extremity and lower extremity injuries
  - 4 times higher odds of death and major trauma (ISS>15)
- The probability of injury varies across the body regions
  - as high as 0.72 for AIS2+ chest injuries in pole impacts (cf. 0.17)
  - other regions of concern
    - Head AIS2+ of 0.38 in PSI cf. 0.13 in V2V
- Probability of death was 0.15 in PSI cf. 0.03 in V2V
- While representing a small proportion of crashes, pole / tree side impact crashes have a higher risk of mortality and serious injury

Acknowledgements

- Dr Fitzharris wishes to acknowledge and thank Mr Richard Cuerdon and Ms Brenda Watterson at TRL for their assistance, for facilitating access to the CCIS dataset and for their gracious welcome. Thanks to Mr Bernie Frost (DfT), for facilitating access to CCIS.
- This report used accident data from the United Kingdom Co-operative Crash Injury Study (CCIS) collected during the period 2000-2010. CCIS was managed by TRL (Transport Research Laboratory), on behalf of the Department for Transport (Transport Technology and Standards Division, DfT) who funded the project along with Autoliv, Ford Motor Company, Nissan Motor Company, and Toyota Motor Europe. Previous sponsors of CCIS have included Daimler Chrysler, LAB, Rover Group Ltd, Visteon, Volvo Car Corporation, Daewoo Motor Company Ltd and Honda R&D Europe (UK) Ltd. Data were collected by teams from the Birmingham Automotive Safety Centre of the University of Birmingham; the Transport Safety Research Centre at Loughborough University; TRL and the Vehicle & Operator Services Agency of the Department for Transport.

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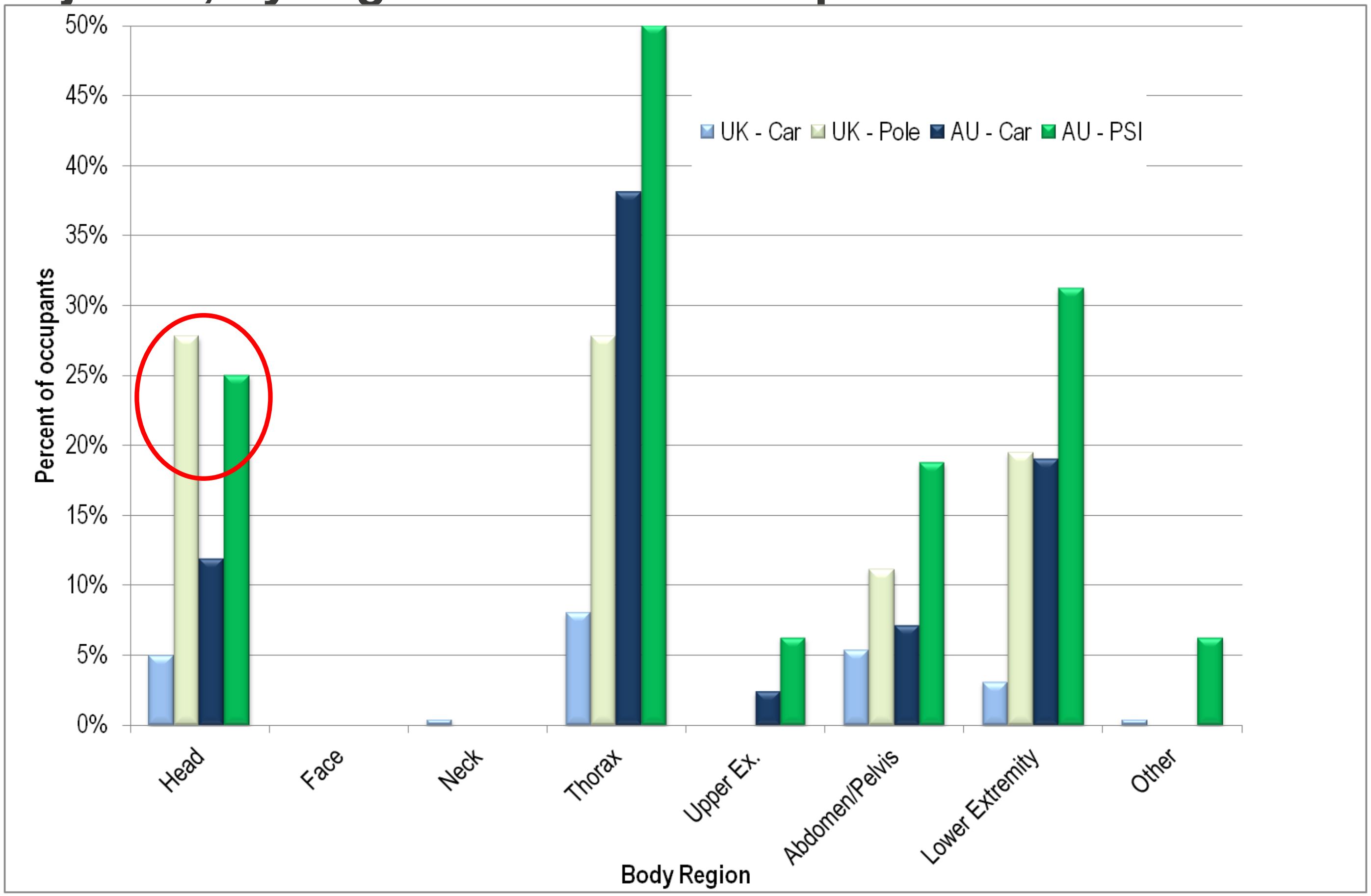
Quick comparison between UK and Australian data

AIS 3+ injuries, by region and collision partner: UK cf. Australia



- Comparable proportion with Head AIS3+ injuries
- The % occupants with thorax, ab/pel, and lower extremity injuries is higher in Australia, the difference between the proportion of occupants injured in PSI relative to V2V is clear

Summary – Comparison of CCIS, ANCIS and Victorian Mass Casualty data

	UK CCIS		ANCIS	Victorian Mass Data analysis*
	OR (95% CI) Unweighted	OR (95% CI) Weighted	OR (95% CI)	OR (95% CI)
Head AIS 3+	5.15 (1.74-15.29)	3.98 (1.06-15.00)	2.53 (0.49-13.17)	1.92 (1.12-3.27)
Chest 3+	3.87 (1.31-11.42)	3.40 (0.97-11.9)	3.51 (0.90-13.6)	2.57 (1.68-3.91)
Ab-Pelvis 3	0.93 (0.19-4.44)	0.52 (0.06-4.35)	1.46 (0.18-11.4)	3.6 (1.72-7.71)
Lower Ext. 3+	4.79 (1.22-18.79)	6.69 (1.51-29.6)	1.78 (0.34-9.41)	7.41 (3.35-16.36)

- CCIS and ANCIS have similar entry criteria (vehicles <=7 years), however CCIS has a broader crash severity profile (killed, admitted to hospital, not admitted and uninjured) than ANCIS, which is restricted to hospitalised patients.
- *The Victorian Mass Dataset includes all persons involved and eligible to make a claim for ‘compensation’; the data therefore includes persons with minor injuries who were not hospitalised

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Part 2
Analysis of UK STATS19 – Trends in side impact crashes, and associated cost of injury

Dr Michael Fitzharris

Accident Research Centre & Injury Outcomes Research Unit

Monash Injury Research Institute

STATS19 – *Reported Road Casualties, GB*

- STATS19 is the data system that contains all police reported crashes in the UK
- Requires police attendance or informed of, for crashes occurring on public roads
- Data on fatality and injury crashes, involving one or more vehicles
- Data supplied by DfT, for the period 2000-2009
- Definitions
  - Fatalities: died within 30 days of the accident
  - Serious injury: in-patient at hospital, or where any of the following injuries (irrespective of hospital in-patient status): fractures, concussion, internal injuries, crushings, burns (excluding friction burns), severe cuts, severe general shock requiring medical treatment

STATS19 (2) – Vehicle categories & impact direction

- Vehicle categories
  - 'cars' which is broadly synonymous with 'M1', but may include a small number of (M2) minibuses or 3 wheeled bodied vehicles.
  - Also, some larger M1 vehicles such as motor caravans may not be classed as cars in GB statistics.
- Side impacts
  - the first point of contact is the nearside or offside of the vehicle
  - Pole side impacts are where the first point of impact is a pole type object, hence SVA (excludes second impact into a pole)
  - Caveat: there may be cases where the initial pole strike does not cause the injury, and the injury is caused by a secondary impact
- .

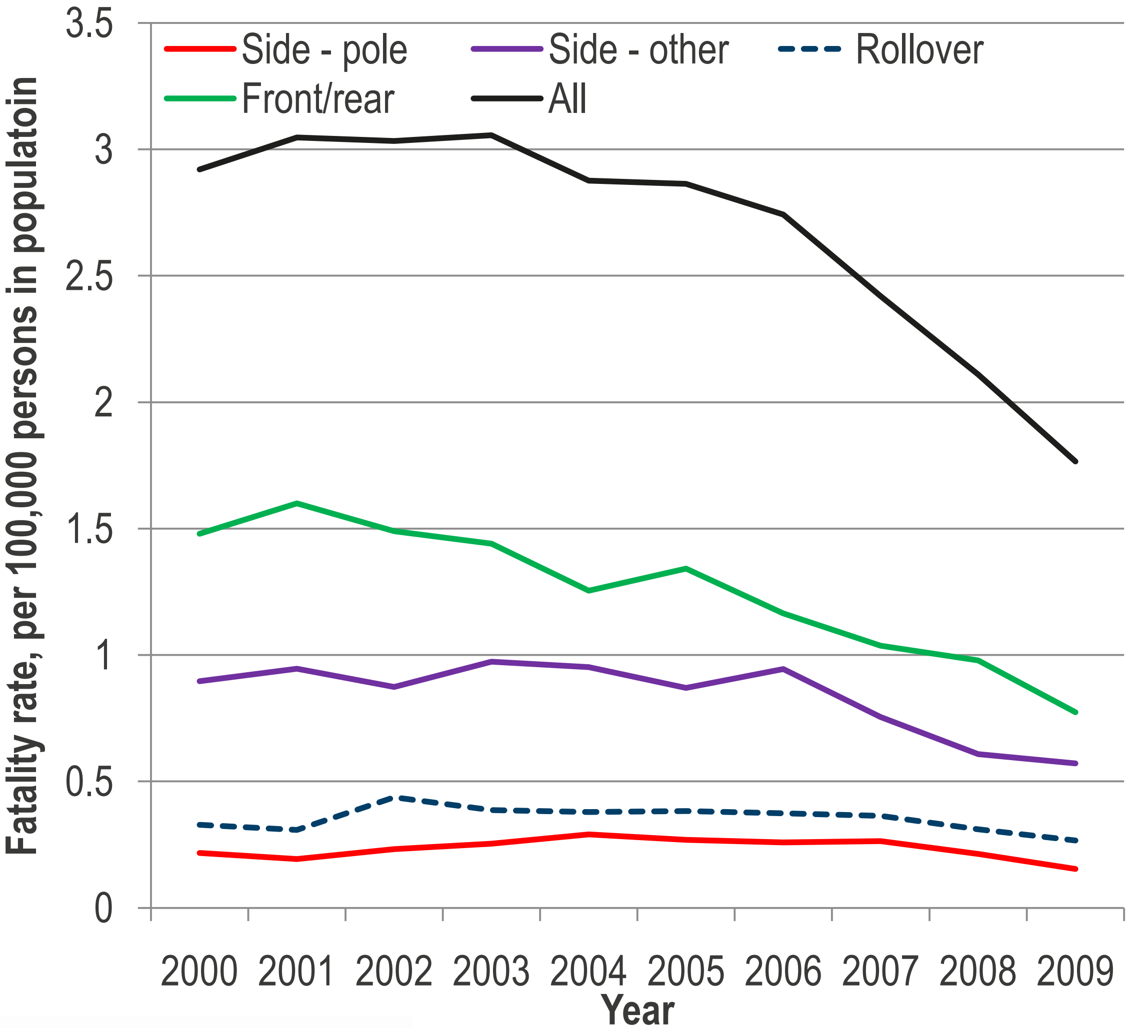
STATS19 – Fatalities and Serious Injuries, 2000-09

- Pole side impact fatalities and serious injuries cost the UK community £3.10 billion over period 2000-2009
  - of those involved in PSI, 20.9% were killed (cf. 10% other side impacts; 9% overall)
  - fatality costs account for 70% of the burden of PSI (cf. 47% overall)
- The cost of side impact fatalities was £6.25 bn., with PSI accounting for 21% of costs
- PSI account for 8.8% of passenger car fatalities and 3.7% of serious injuries (& 6.2% M1 cost)

	Fatalities				Serious Injury				Totals and Summary measures			
	N	% M1	Rate (pop)	Cost (bn.)	N	% M1	Rate (pop)	Cost (bn.)	Total (bn.)	Prop. Killed	% costs fatal	% costs, of M1
Side -pole	1369	8.8%	0.23	£2.17	5190	3.7%	0.89	£0.92	£3.10	20.9%	70.1%	6.2%
Side-other	4890	31.3%	0.84	£7.75	44237	31.3%	7.57	£7.88	£15.63	10.0%	49.6%	31.3%
Rollover	2064	13.2%	0.35	£3.27	14770	10.5%	2.53	£2.63	£5.90	12.3%	55.4%	11.8%
Front/ Rear	7313	46.8%	1.25	£11.59	77075	54.6%	13.20	£13.73	£25.33	8.7%	45.8%	50.7%
M1 - fatalities	15636	100%	2.68	£24.79	141272	100%	24.19	£25.17	£49.96	10.0%	49.6%	100%
UK fatalities	31,098		5.32	£49.31	312,203		53.45	£55.62	£104.93	9.1%	47.0%	

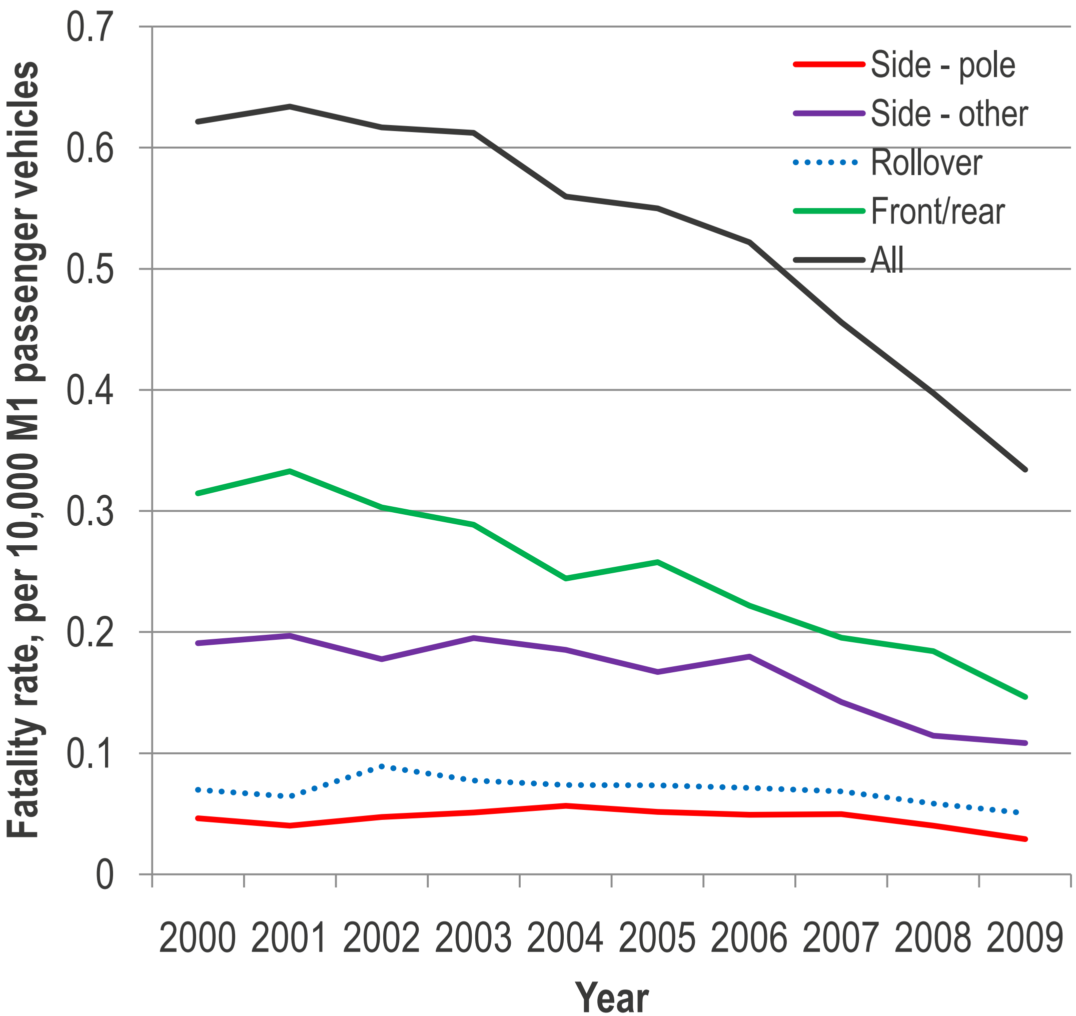
Note: Costs from *'A valuation of road accidents and casualties in Great Britain in 2010',* DfT (2009 costs) / excludes 'slight' injury

STATS19: Trends in persons killed, per population



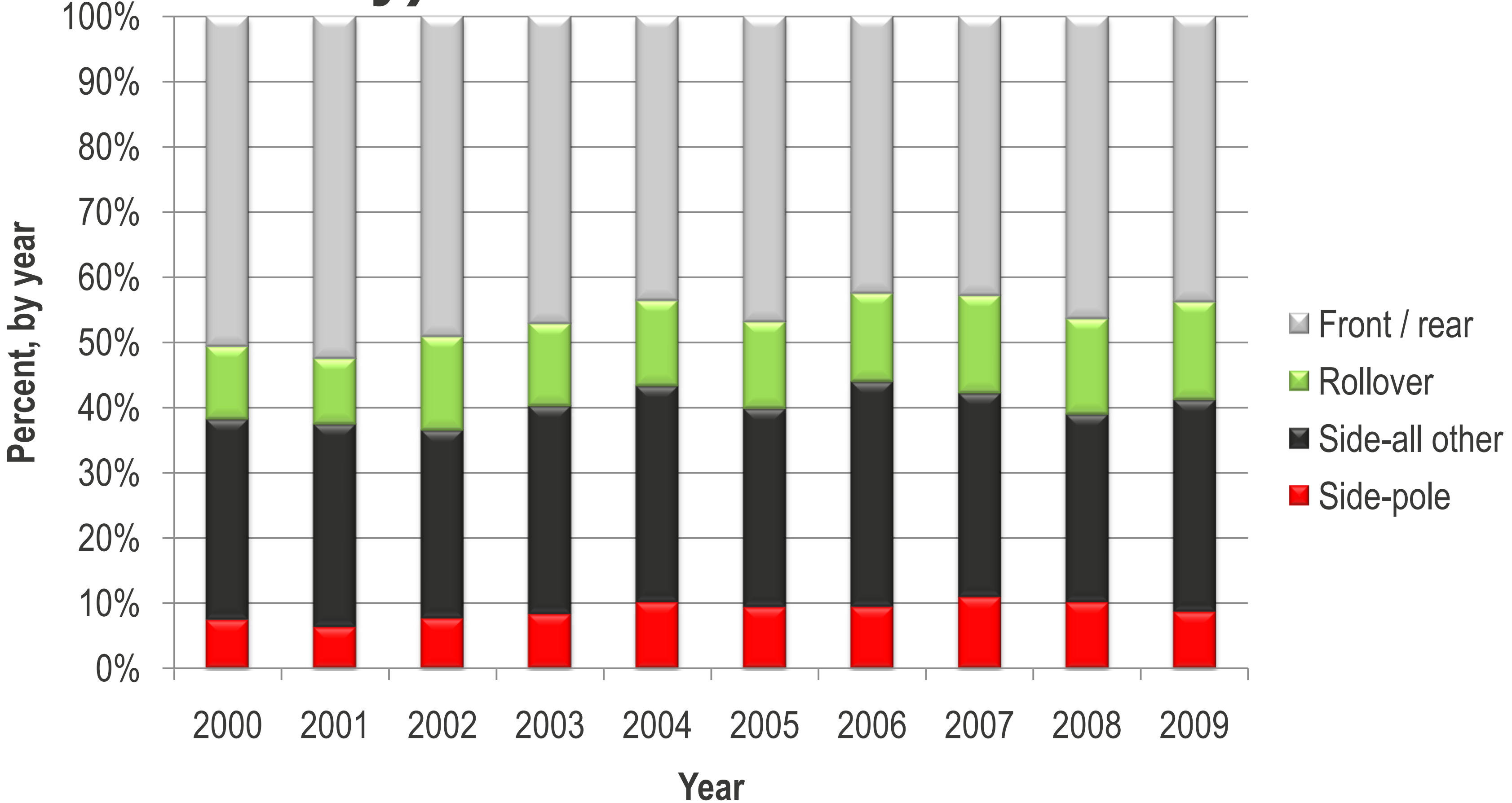
- Visible reduction in the overall M1 vehicle fatality rate (IRR:0.95, 95%CI:0.83-1.08, p=0.4)
- 6.5% p.a. ↓ in front/rear fatalities (IRR: 0.935, 95%CI: 0.93-0.94, p<0.001)
- 4.4% p.a. ↓ in side impact fatalities (IRR: 0.956, 95%CI: 0.95-0.96, p<0.001)
- **NO CHANGE IN PSI fatalities** (IRR: 0.99, 95%CI: 0.97-1.01, p<0.4
- 1.7% p.a. ↓ in rollover fatalities (IRR: 0.98, 95%CI: 0.97-0.99, p=0.03)
- Poisson regression, accounting for population; M1 vehicles only

STATS19: Trends in persons killed, per vehicle (M1)



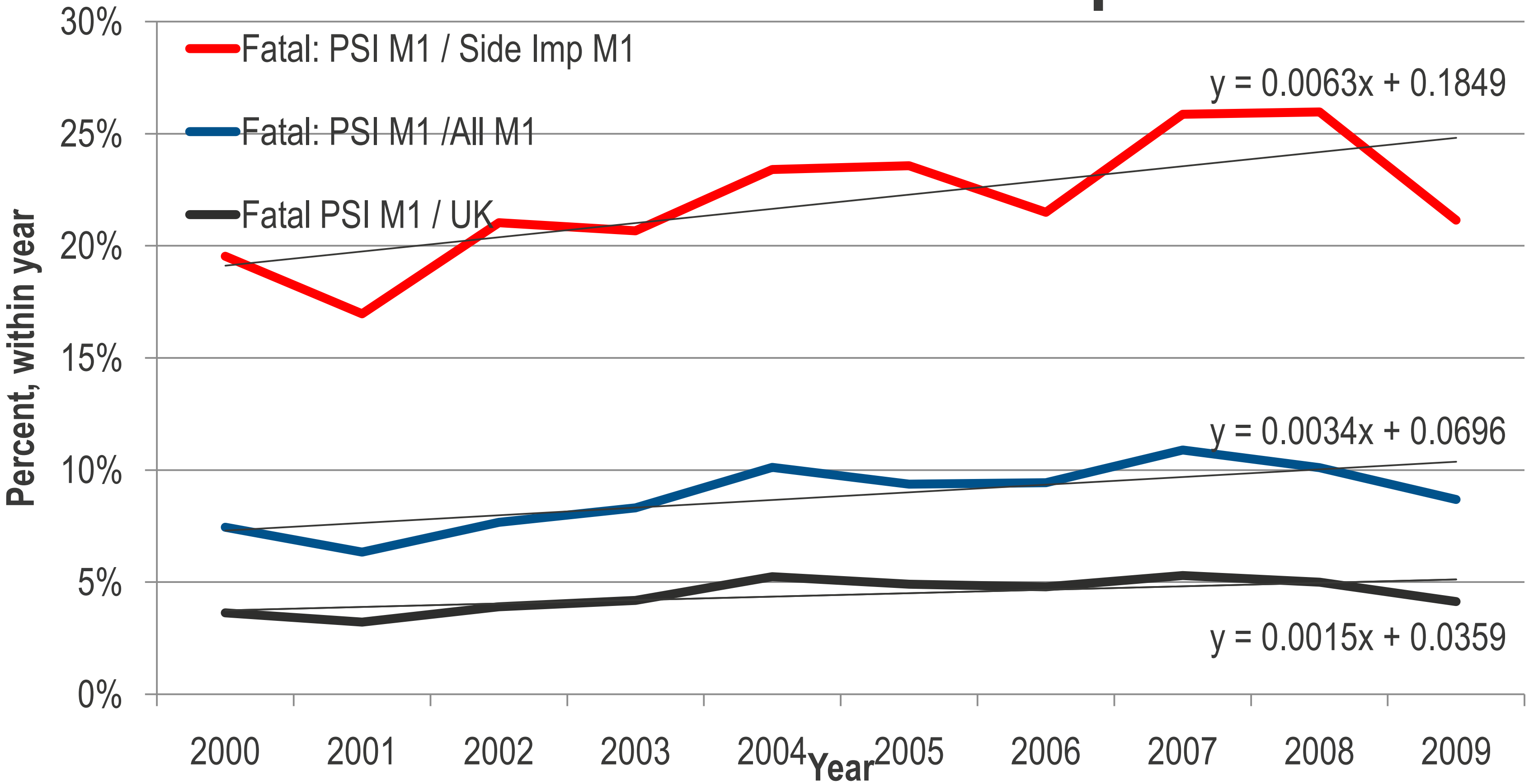
- Visible reduction in the overall M1 vehicle fatality rate (IRR:0.93, 95%CI:0.82-1.07, p=0.3)
- 8% p.a. ↓ in front/rear fatalities (IRR: 0.92, 95%CI: 0.91-0.93, p<0.001)
- 6% p.a. ↓ in side impact fatalities (IRR: 0.94, 95%CI: 0.93-0.95, p<0.001)
- **2% p.a. ↓ IN PSI fatalities** (IRR: 0.98, 95%CI: 0.96-0.99, p=0.02
- 3.1% p.a. ↓ in rollover fatalities (IRR: 0.98, 95%CI: 0.95-0.98, p=0.03)
- Poisson regression, accounting for number of M1 category vehicles

STATS19 – proportion of fatalities, by year(M1 vehicles-only)



- For M1 vehicles only: approximately 10% fatalities are PSI crashes (increasing proportion)

STATS19: Percent of Pole Side Impact fatalities



- Among side impact fatalities, PSI proportionately increasing (av: 20%)
- PSI represent ~10% all fatalities in M1 vehicles
- PSI represent 4.5% all fatalities in UK (10-year average)

Key messages

- PSI cost the UK community £3.10 billion over period 2000-2009
- PSI are more severe, with 20% occupants involved in PSI killed (cf. 10%) and 70% of costs being 'fatality costs'
- On a population basis, PSI fatalities have not reduced over the last decade, but reductions in fatalities in all other impact configurations (up to 6.5%)
- On a per-vehicle basis, there has been a 2% per annum reduction in PSI fatalities, cf. 8% and 6% reduction in frontal / rear and other side impact crashes
- Proportionately, the importance of PSI fatalities is increasing, and represents approximately 20% of side impact fatalities and 10% of fatalities in all M1 vehicles

Acknowledgements

- Dr Fitzharris wishes to acknowledge and thank Mr Bernie Frost and the DfT for supplying the STATS19 data.

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Part 3
Analysis of Australian Fatality data (2001-2006) - incidence and cost of pole side impact crashes

Background

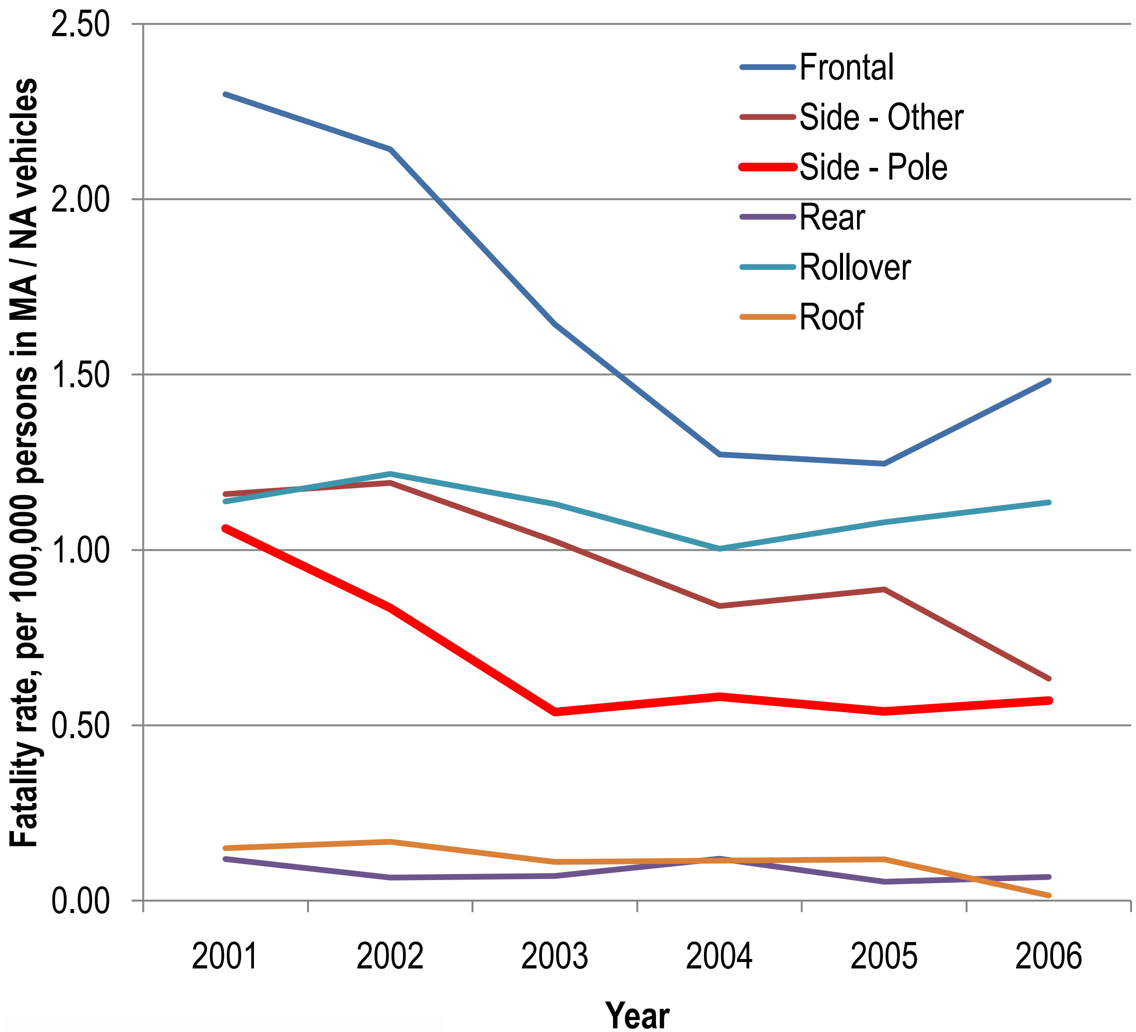
- Analysis of the Australian Fatal Road Crash Database for the period 2001-2006
- All road deaths in Australia
- Data derived from a range of sources, with cause of death noted by the State Coroner
- Provides the basis for understanding the relative burden of PSI

Number & Cost of fatalities in Australia, 2001-2006 – Class MA/NA

	Period 2001 - 2006				Per Annum		Summary (2001-2006)		
Impact direction	**N**	**Percent**	**Cost (period) (bn., $AU)**	**Cost (period) (bn., £GBP)**	**Number**	**Cost ($AUD)**	**As % all deaths**	**Rate (pop)**	**Rate (MA/NA vehicles)**
Frontal	1909	33.1%	$9,430	£6,298	318	$1,571	19.3%	1.59	0.26
Side - Other	1197	20.8%	$5,914	£3,950	200	$0.985	12.1%	1.00	0.16
Side - Pole	**898**	**15.6%**	**$4,434**	**£2,961**	**150**	**$0.739**	**9.1%**	**0.75**	**0.12**
Rear	123	2.1%	$0.605	£0.404	20	$0.100	1.2%	0.10	0.02
Rollover	1367	23.7%	$6,751	£4,509	228	$1,125	13.8%	1.14	0.18
Roof	163	2.8%	$0.805	£0.538	27	$0.134	1.7%	0.14	0.02
Other	15	0.3%	$0.074	£0.050	3	$0.012	0.2%	0.01	0.00
Natural Causes	89	1.5%	$0.437	£0.291	15	$0.072	0.9%	0.07	0.01
Total	5761	100.0	$28,453	£19,004	960	$4,742	58.3%	4.79	0.77

* Department of Finance and Deregulation. Best Practice Regulation Guidance Note: Value of statistical life. Canberra: Office of Best Practice Regulation, Australian Government, 2010.

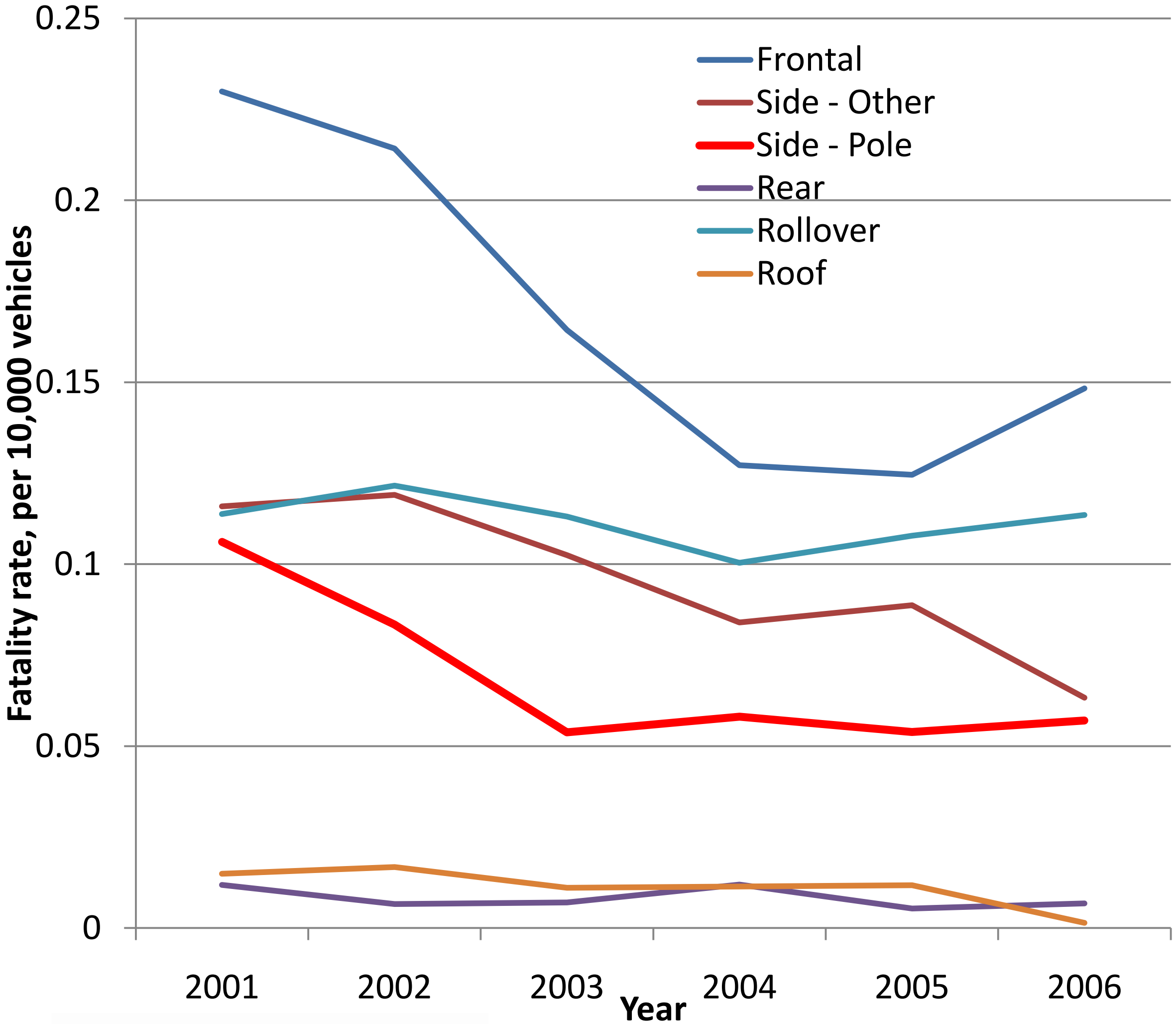
AU FRCD: Trends in persons killed, per population



- 5% Reduction in the overall vehicle fatality rate
  (IRR:0.95, 95%CI:0.94-0.97, p<0.001)
- 12% p.a. ↓ in front fatalities
  (IRR: 0.88, 95%CI: 0.86-0.92, p<0.001)
- 11% p.a. ↓ in side impact fatalities (IRR: 0.89, 95%CI: 0.86-0.92, p<0.001)
- **13% p.a. ↓ IN PSI fatalities but driven by 2001-2003, and no change 2003-2006**
  (IRR: 0.87, 95%CI: 0.83-0.91, p<0.001)
- 2% p.a. ↓ in rollover fatalities
  (IRR: 0.98, 95%CI: 0.96-1.01, p=0.4)

- Poisson regression, accounting for number persons in population

AU FRCD: Trends in persons killed, per vehicle (MA/NA)



- 5% Reduction in the overall vehicle fatality rate (IRR:0.95, 95%CI:0.94-0.97, p<0.001)
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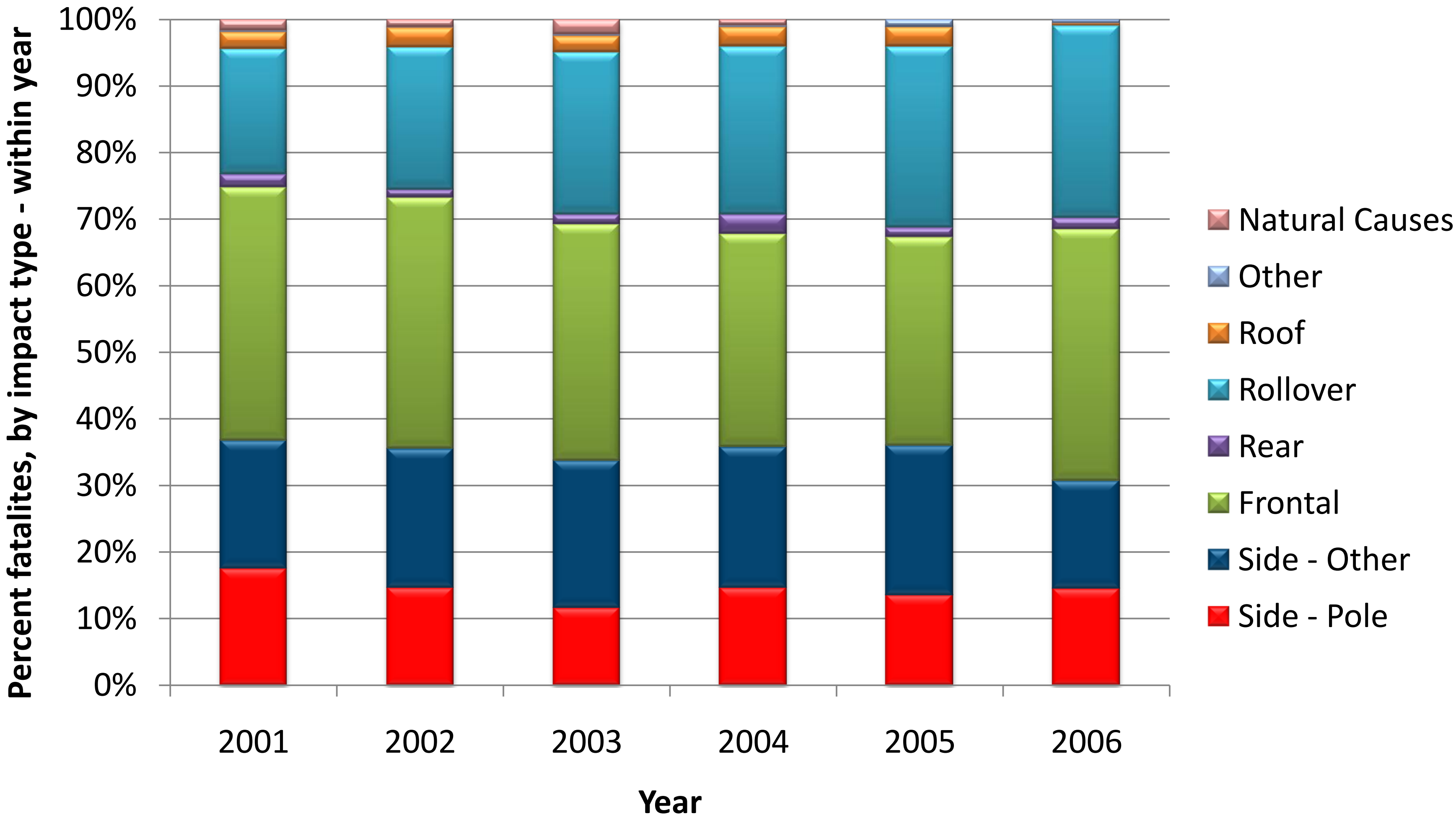
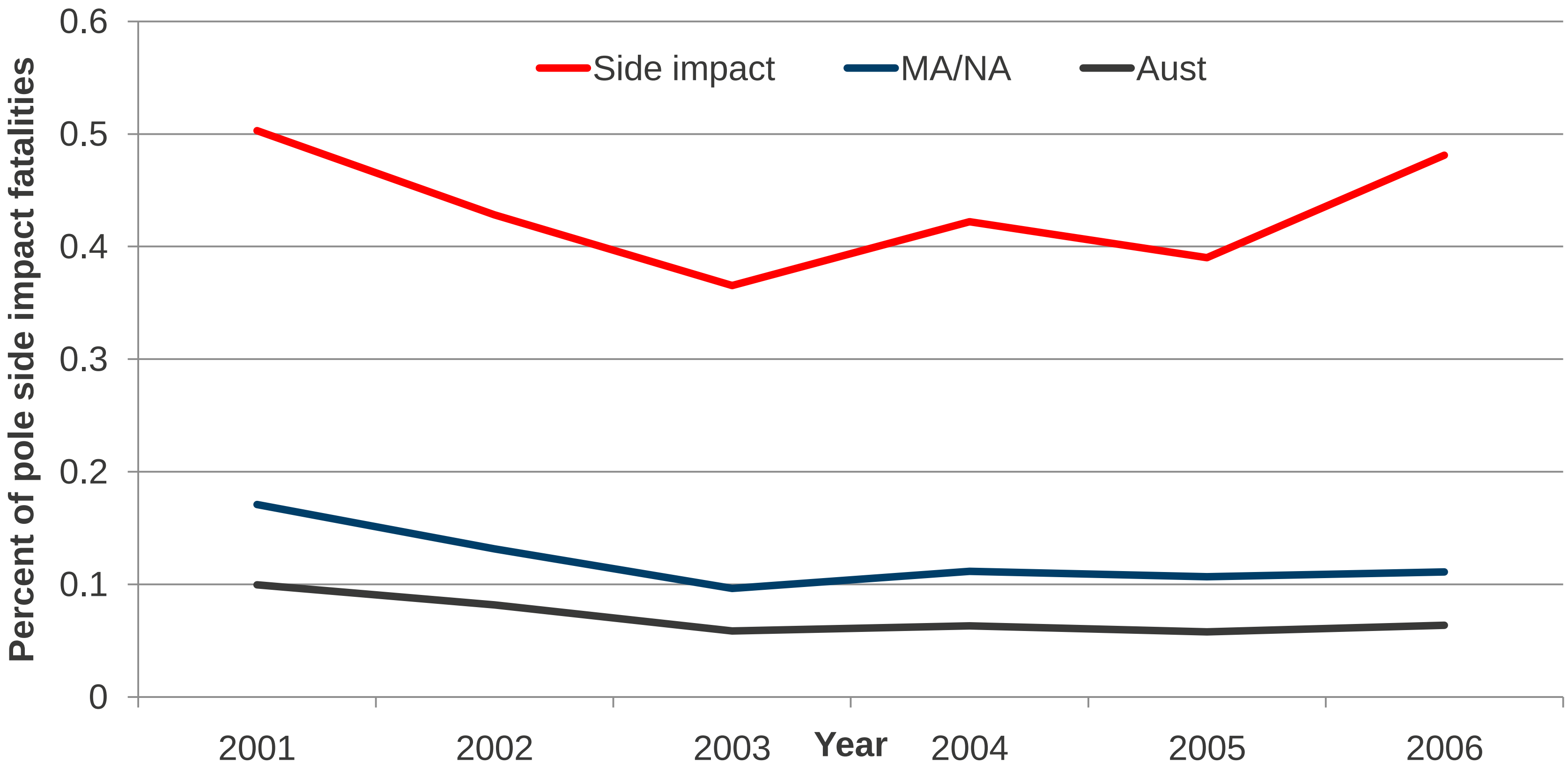
- 2% p.a. ↓ in rollover fatalities (IRR: 0.98, 95%CI: 0.96-1.02, p=0.4)

- Poisson regression, accounting for number persons in population

AU FRCD – Proportion of fatalities by year (MA, NA)



AU FRCD: Percent of Pole Side Impact fatalities

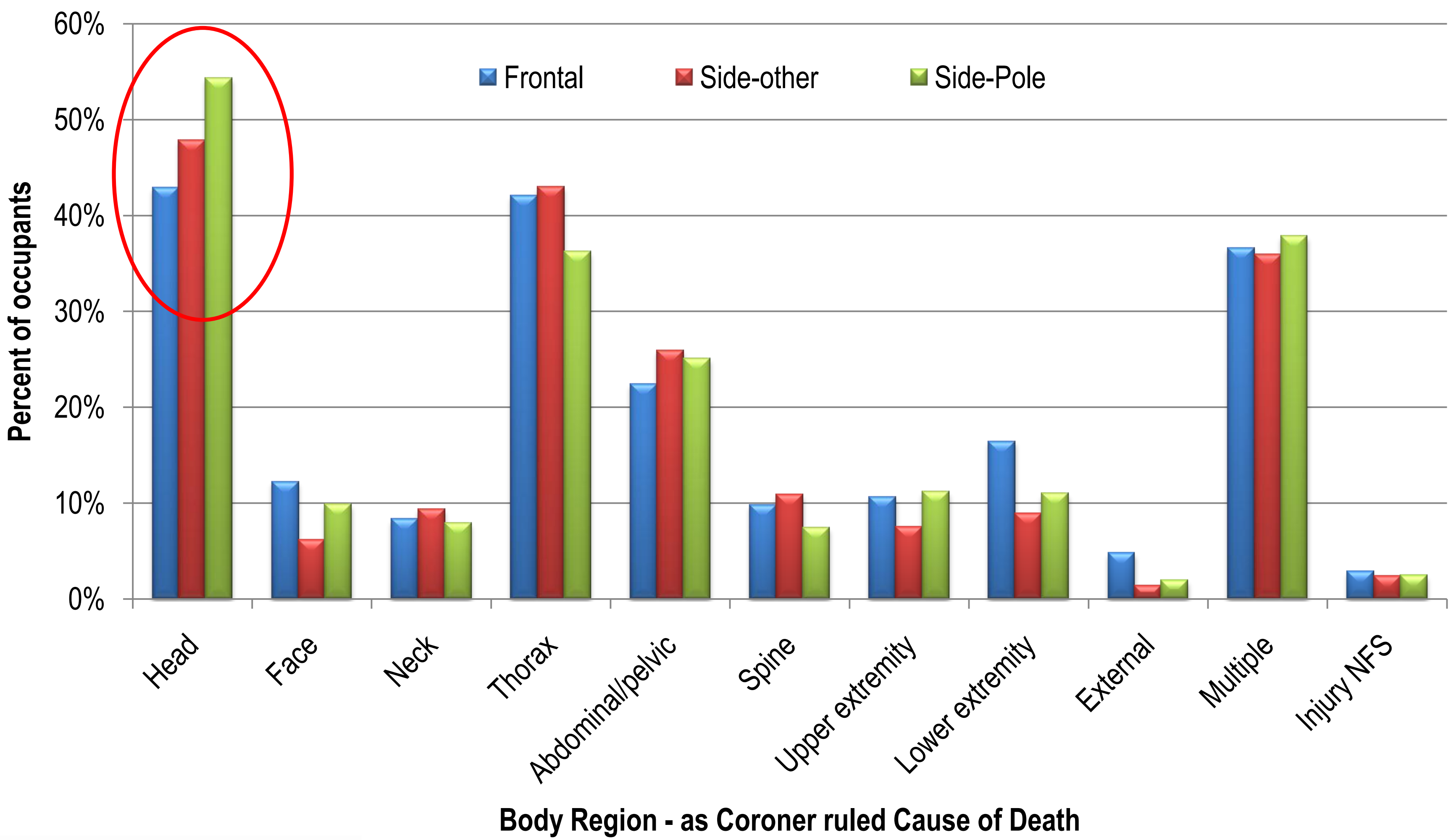


- Among side impact fatalities, PSI represent 45% of deaths [***cf. UK 20%]***
- PSI represent ~12% all fatalities in MA/NA vehicles [***cf. UK 10%]***
- PSI represent 9.1% all fatalities in Australia [***cf. UK 4.5%]***

Side airbag system availability

- SAB system availability and deployment *very low*
- *Known to have been available and deployed for 5 side impact cases in total*
  - *3 vehicle to vehicle impacts*
  - *2 pole side impacts*
- *Establishes an important baseline for prioritisation of countermeasures*
- *Evident that* **head injury** was the leading cause of death as ruled by the Coroner
  - this was the case for **both** **PSI and other side impact crashes**, and with few exceptions, none side impact protection

Coroner ruled 'Cause of death'



Key messages

- PSI cost the Australia community $AU4.4 bn. (£2.96 bn) over period 2001-2006
- 898 people killed in PSI in the 6 year period; average 150 killed per annum ($AU0.7bn.)
- On a population basis & per vehicle basis, reduction in the rate of PSI was evident, but stable since
- PSI represent
  - ~ 43% all side impact fatalities (cf. UK: 20% in M1 vehicles]
  - ~15.5% (average) in MA/NA fatalities (cf. UK: 10% in M1 vehicles]
  - ~9% all fatalities in Australia [cf. UK 4.5%]

Key messages

- Side airbags known to be available and deployed in only 0.3% of fatalities (n=5)
  - represents a base case against which the effects of new safety can be assessed
- Head injuries were the most common cause of death, according to the Coroner 55% head as the cause in PSI, cf. 44% frontal, & 49% side impact in V2V
- Chest injuries also prominent in crashes
- ‘Multiple regions’ category is also important, as the Coroner uses this to refer to head, chest and abdominal injuries, or head+chest injuries as COD

Acknowledgements

- Dr Fitzharris wishes to acknowledge and thank Ms Joanna Cotsanis, Victorian Institute of Forensic Medicine (Melbourne, Australia) with assistance with the Fatal Road Crash Database (FRCD)

- The FRCD is maintained by the VIFM on behalf of the Commonwealth Department of Infrastructure, Transport and Regional Development.

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Part 4
Analysis of Victorian (Aus) crash data

1. Effectiveness of SAB (real-world and NCAP) and vehicle sales data on fitment rates of SAB
2. Patterns of injury in NCAP 5* vehicles vs. 'the rest'
3. Cost of injury estimates and incremental benefits, accounting for ESC

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Part 4-1
Effectiveness of SAB (real-world and NCAP) and vehicle sales data on fitment rates of SAB

1. Analysis of NCAP and EuroNCAP Side Impact performance parameters, by airbag fitment and type
2. Review of research into SAB systems
3. New vehicle sales and side-airbag & ESC fitment

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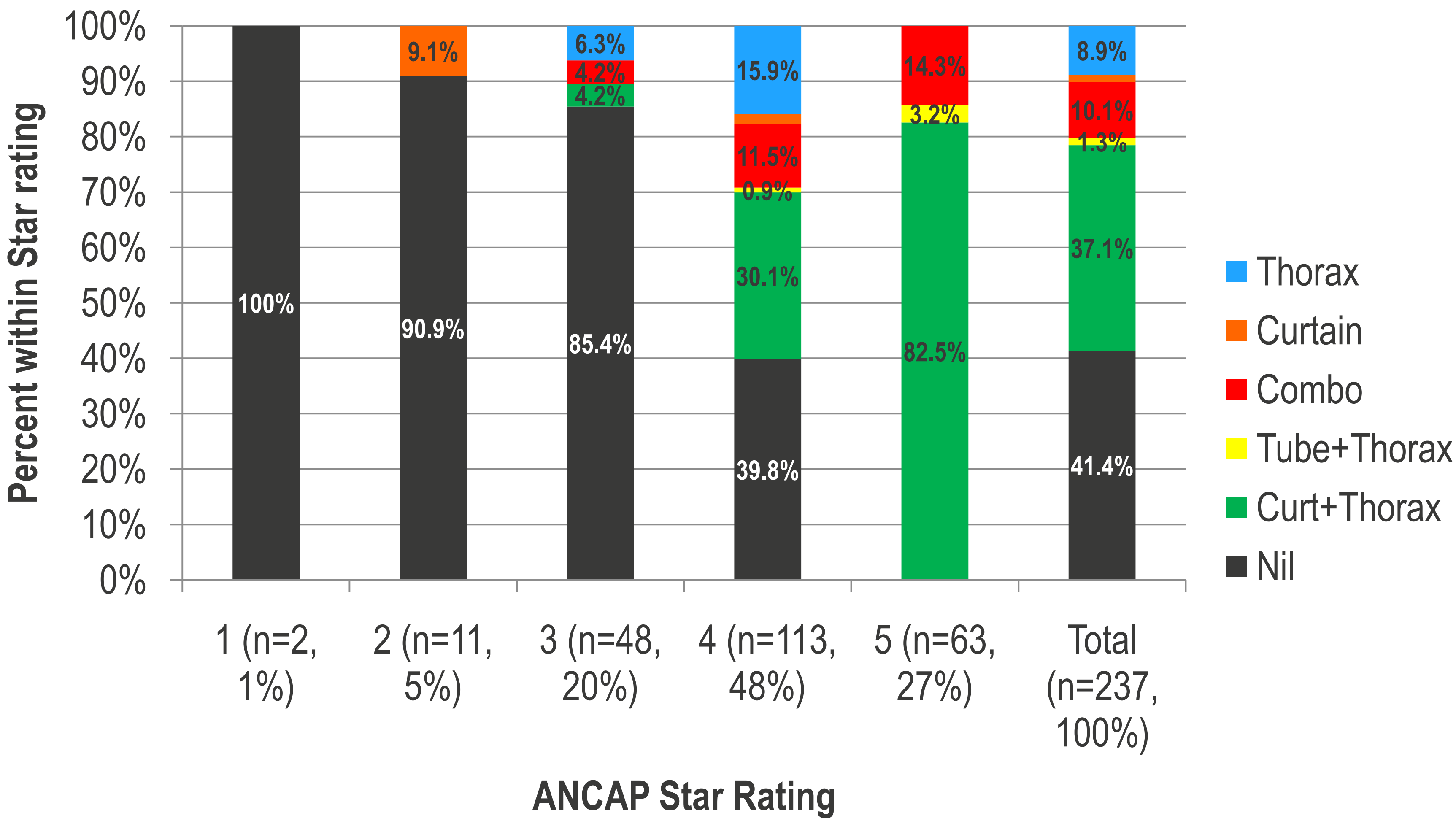
Part 4-1 (i)
Analysis of ANCAP and EuroNCAP Side Impact performance parameters, by airbag fitment and type

Examination of Anthropometric Test Dummy (ATD) performance in NCAP side-impact test, by airbag system

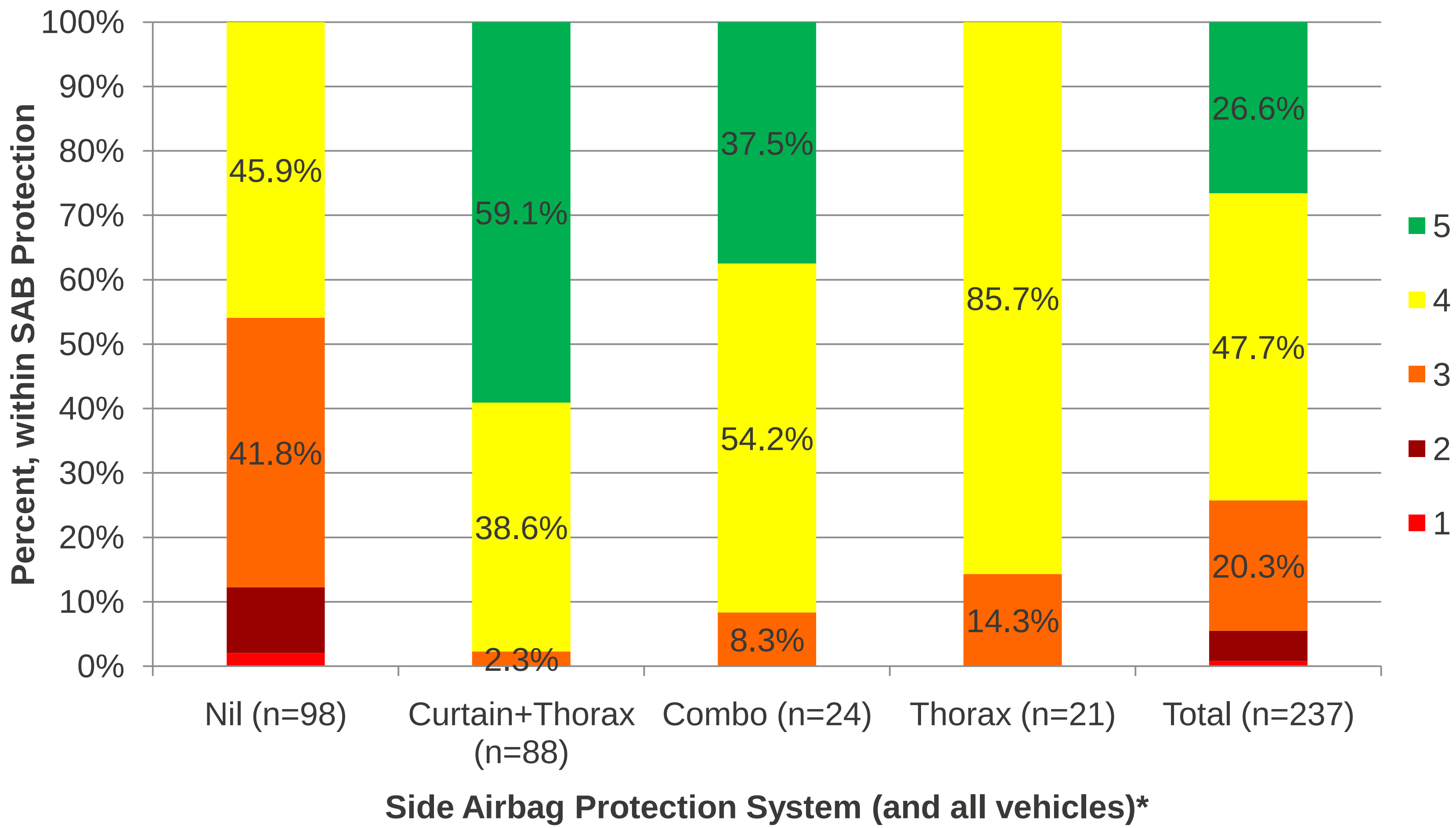
- Analysis performed to examine differences in performance criteria
- Sets context for assessment of relationship of ATD assessment and mass data analysis
- Established a database of 238 vehicles tested by ANCAP and EuroNCAP
  - Used published data for 200 vehicles from ANCAP & 38 (16%) from EuroNCAP
- Included overall Star Rating, Point Scores (occupant, safety assist)
- ATD performance available for 173 vehicles (all ANCAP)

ANCAP Star Rating & Side impact AB system



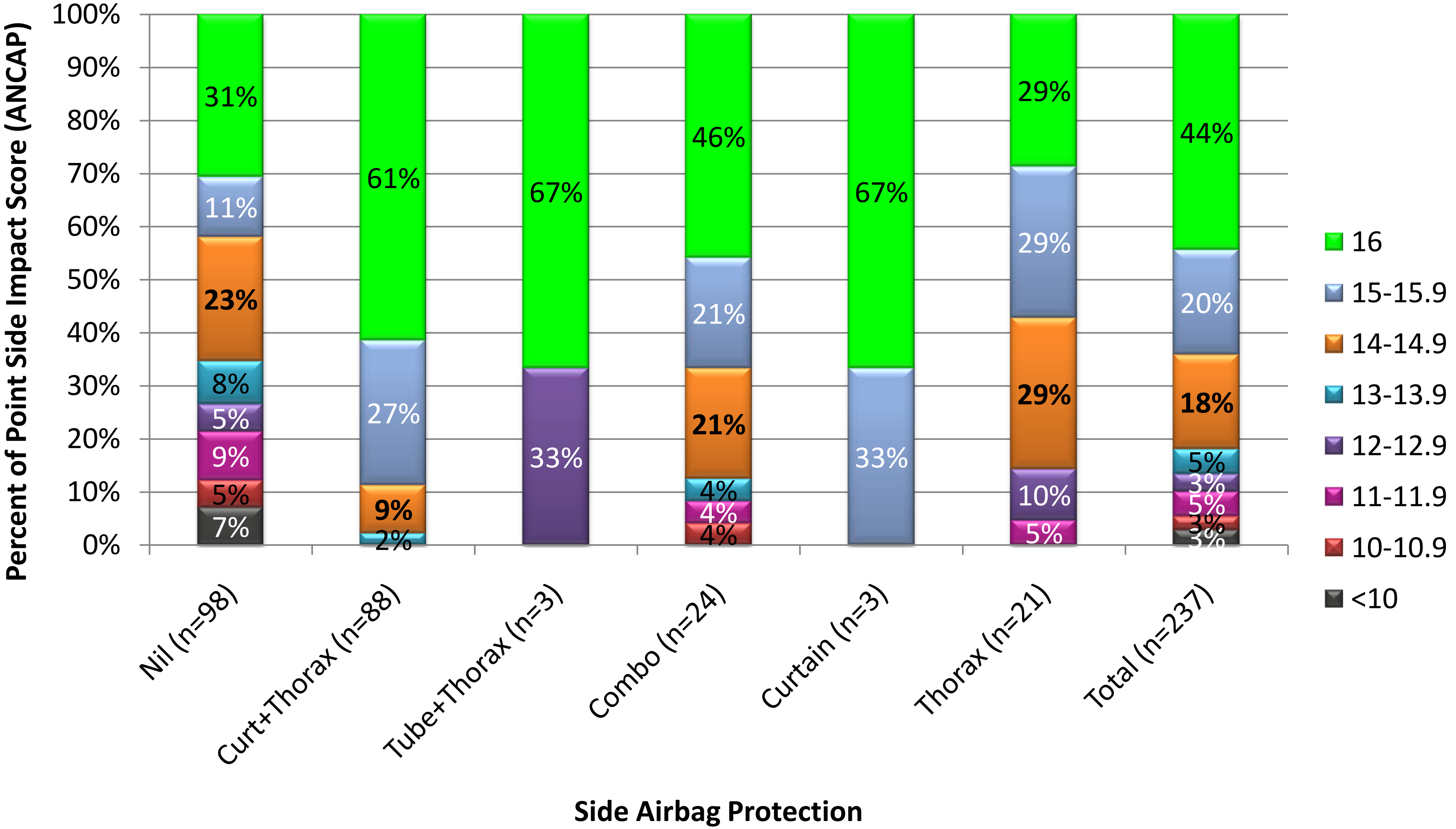
Of the 5* rated vehicles, 82% had curtain + separate thorax SAB fitted

Side impact AB system & NCAP Star Rating



*3 curtain-only & 3-tube+thorax not shown

Side impact AB system & ANCAP Side Impact Points



Side impact ATD Head performance (side barrier)

- Analysis of 173 ANCAP tests, by SAB system

SIDE IMPACT NCAP TEST PARAMETER	None n=71	Curtain + Thorax SAB n=62	Head / Thorax (Combo) n=22	Thorax-only n=16	Tube + Thorax n=2	Curtain-only n=2
Head - HIC						
Mean (SD)	146.0 (90.7)	48.7 (36.9)	122.09 (164.5)	115.03 (72.0)	40.04 (26.9)	55 (18.3)
Median	124.0	44.0	65.0	100.7	40.0	55.0
95%CI	124.5-167.4	39.3-58.2	49.2-195.0	76.6-153.4	-	-
Min / Max	21-431	3-273	25-778	24-300	21 / 59	42 / 68
Head - Acceleration (g for 3ms)						
Mean (SD)	47.1 (14.7)	22.9 (7.4)	34.5 (17.3)	39.6 (15.7)	20.3 (7.9)	27.2 (2.8)
95%CI	43.6-50.6	21.1-24.8	26.6-42.4	31.2-47.9	-	-
Median	46.6	22.7	30.3	37.9	-	-
Min / Max	22.3-86.0	6.9-44.3	16.2-78.1	15.7-64.9	14.7 / 25.8	25.2 / 29.2

Side impact ATD Chest performance

	None	Curtain + Thorax SAB	Head / Thorax (Combo)	Thorax-only	Tube + Thorax	Curtain-only
Chest - Compression (mm)						
Mean (SD)	25.9 (11.9)	17.9 (6.0)	20.5 (8.2)	24.7 (6.0)	17.7 (13.0)	17.5 (4.2)
95%CI	23.0-28.7	16.3-19.4	16.8-24.3	21.5-27.9	-	-
Median	27.6	18.0	20.3	24.4	17.7	17.5
Min / Max	1.2-48.5	2.8-32.0	8.9-39.7	15.5-39.9	8.5 /26.9	14.5 / 20.4
Chest - Viscous Criterion (m/s)						
Mean (SD)	0.37 (0.34)	0.12 (0.09)	0.17 (0.13)	0.24 (0.17)	0.11 (0.13)	0.16 (0.05)
95% CI	0.29-0.45	0.10-0.15	0.11-0.23	0.15-0.33	-	-
Median	.30	.10	.15	.19	.11	.16
Min / Max	0-1.77	0.01-0.38	0.04-0.58	0.04-0.70	0.02 / 0.20	0.12 / 0.19

Side impact ATD Abdomen & Pelvis performance

	None	Curtain + Thorax SAB	Head / Thorax (Combo)	Thorax-only	Tube + Thorax	Curtain-only
Abdomen - Force (kN)						
Mean	1.15 (0.54)	0.66 (0.32)	0.71 (0.31)	0.98 (0.24)	1.02 (1.05)	0.81 (0.44)
95% CI	1.02-1.28	0.58-0.74	0.57-0.85	0.86-1.11	-	-
Median	1.10	0.63	0.62	1.00	1.02	.81
Min / Max	0.25-3.23	0.10-1.34	0.28-1.56	0.60-1.36	0.28 / 1.76	0.50 /1.12
Pelvis - Force (kN)						
Mean	2.43 (0.95)	1.45 (0.71)	2.03 (0.83)	2.09 (0.76)	1.54 (1.59)	0.73 (0.28)
95% CI	2.21-2.66	1.27-1.63	1.65-2.41	1.69-2.50	-	-
Median	2.32	1.35	1.86	2.09	1.54	.73
Min / Max	0.47-5.40	0.01-2.80	0.69-3.59	1.0-3.34	0.41 /2.66	0.53 / 0.93

Key messages

- Of the vehicles fitted with a curtain + thorax SAB, 60% achieved a 5* rating
- Of the vehicles without a SAB system fitted, none achieved a 5* rating
- Of the 5* vehicles, 82.5% had a curtain + thorax SAB fitted
- Performance differences
  - HIC & Head *acceleration* significantly < in Curtain + Thorax SAB cf. Nil, Combo, & Thorax-only)
  - Head acceleration < in Combo bag cf. Nil
  - Chest compression < in C+T SAB cf. Nil and Thorax only (just)
  - Chest VC < in C+T cf Nil, and Combo vs. Nil
  - Adbo kN < in C+T cf. Nil & Thorax-only; < in Combo cf. Nil
  - Pelvis kN < in C+T cf. Nil, Combo & Thorax-only

Acknowledgements

- Dr Fitzharris wishes to acknowledge and thank Mr Michael Paine (ANCAP) for providing test details, and to Miss Amy Allen for research assistance

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Part 4-1 (ii)
Review of research into SAB systems

Background

- Research conducted on the effectiveness of SAB and FMVSS-214
- Published studies provide the basis for understanding risk reductions associated with side impact crashes, and effectiveness of countermeasures
- Literature review
  - Fatality reductions: 4 studies [all US, used FARS, GES]
  - Injury reductions: 9 studies
  - *Examined different side airbag type*

Published estimates on SAB fatality reductions

Braver and Kyrychenko (2004)	FARS 1999-2001 GES 1999-2001	Passenger cars 1997-2002	Relative driver fatality rate per near side impact Adjusted for front/rear impact fatality rate **Compared to vehicles without SIA)**	**Torso only**	**11%** (ns) adj RR=0.89 (95%CI 0.79-1.01)
				Torso + head	**45%** adj RR=0.55 (95%CI 0.43-0.71)
McCartt and Kyrychenko (2007) *Replication of Braver & Kyrychenko	FARS 1999-2001 GES 1999-2001 FARS 2000-2004 GES 2000-2004	Passenger cars 1997-2002 Passenger cars 2001-2004		**Torso only** 1997-2002 veh 2001-2004 veh Combined MY	**25%:** Adj RR=0.75 (95%CI 0.64-0.89) **27%** Adj RR=0.73 (95%CI 0.61-0.87) **26%** Adj RR=0.74 (95%CI 0.66-0.84)
				Torso + head 1997-2002 MY 2001-2004 MY Combined MY	**47%:** Adj RR=0.53 (95%CI 0.43-0.65) **31%** Adj RR=0.69 (95%CI 0.60-0.80) **37%** Adj RR=0.63 (95%CI 0.56-0.71)

Injury reduction estimates with SAB

- Reviewed 9 studies focused on injury
- Variation in the injury outcome of interest
- Studies generally did not distinguish between SAB type
- Most studies did not distinguish between the struck object
- The UAB CIREN Center study provides the best approximation for our purposes (presented in Table; MY2000-2009)
- Require highly specified analysis to be undertaken

SIA system and injury	OR (adjusted)
Head SIA/Head AIS2+ - Near side impact (n=163 pairs)	
Vehicle to vehicle	0.68 (0.29-1.58)
Vehicle vs. Fixed object	0.57 (0.17-1.96)
Torso SIA/Thorax AIS2+ - Near side impact (n=293 pairs)	
Vehicle to vehicle	0.99 (0.61-1.61)
Vehicle vs. Fixed object	1.09 (0.49-2.43)

1998MY vehicles+; front seat occupants; Adjusted for delta v, and matched for driver age, gender, object hit, direction of force, seat position, area of damage, vehicle type
Data source: CIREN data + NASS CDS
Source: UAB Ciren Center (2011)

Acknowledgements

- Dr Fitzharris wishes to acknowledge and thank Ms Karen Stephan for playing a lead role in the literature review

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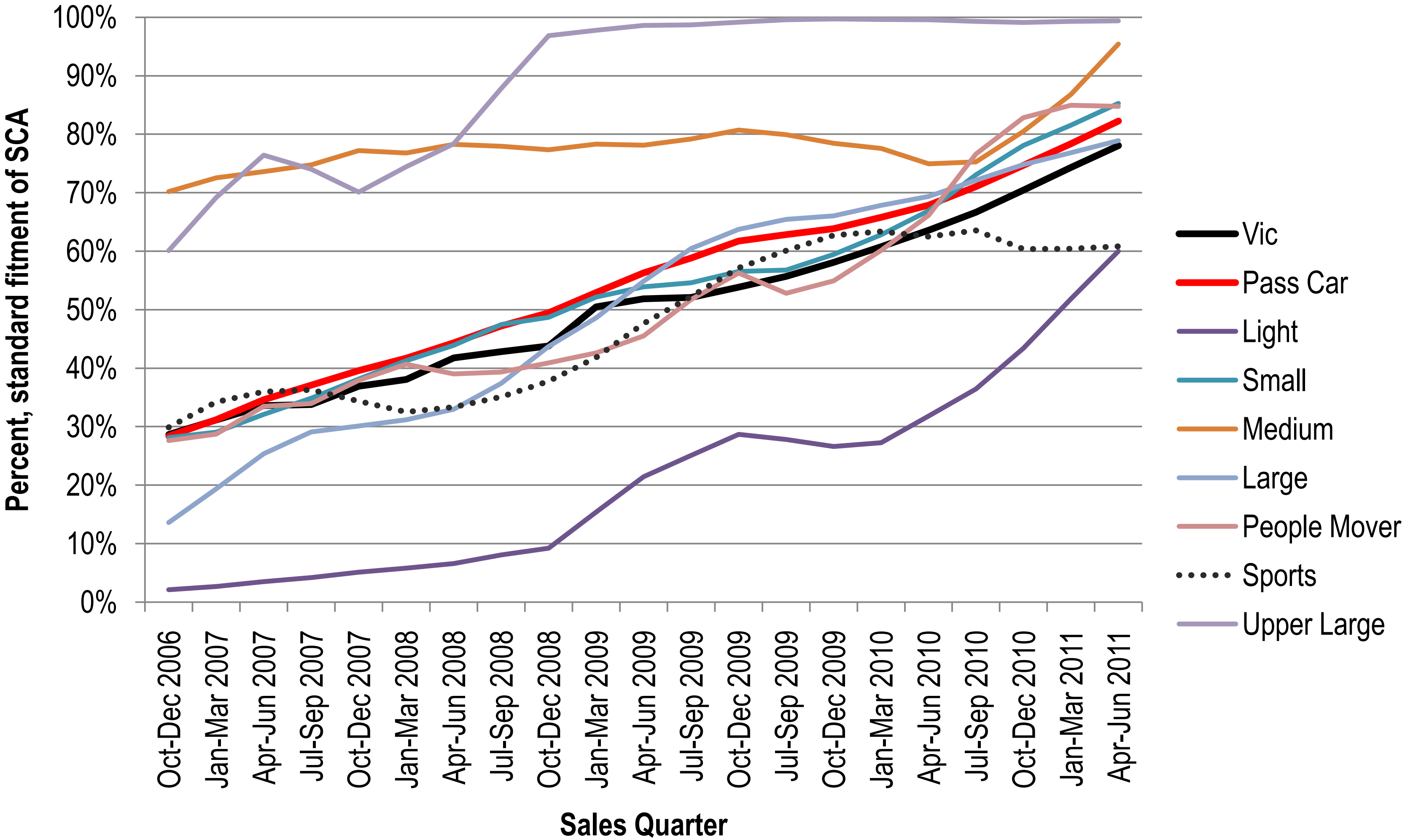
Part 4-1 (iii)
New vehicle sales and side-airbag & ESC fitment

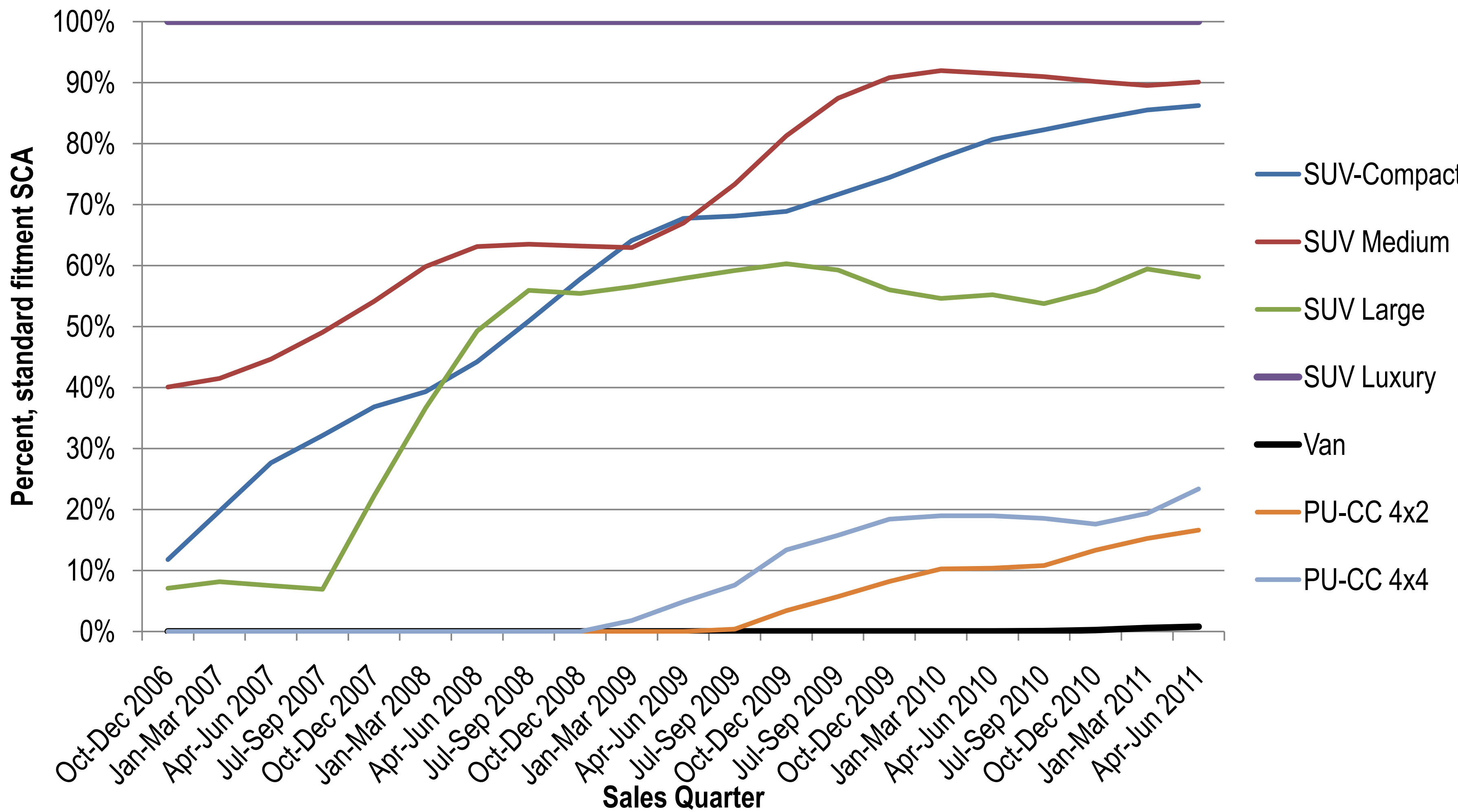
Background

- Analysis of the standard fitment of side curtain airbags is of interest, and importance
- Basis of understanding the ‘market’
- Permits estimation of time-to-penetration of SCA into the fleet, and hence, for benefits to be realised
- Understanding the standard fitment of ESC also important for benefit estimation
- Examine *all vehicle sales,* and, by *vehicle class*

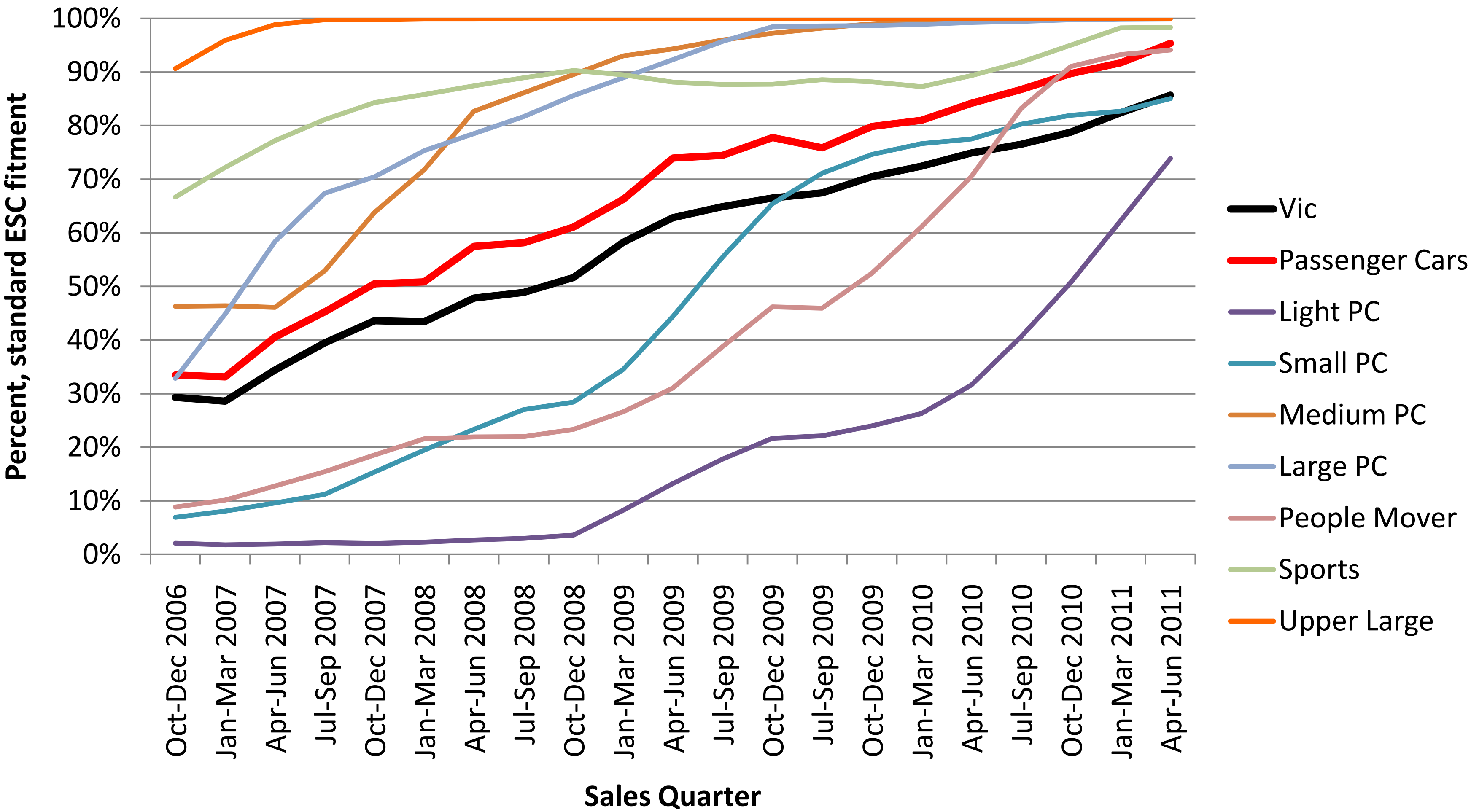
Front Side Curtain Airbags – New Car Sales



Front Side Curtain Airbags – New SUV / Van / Commercial Sales



ESC standard fitment – New Car Sales



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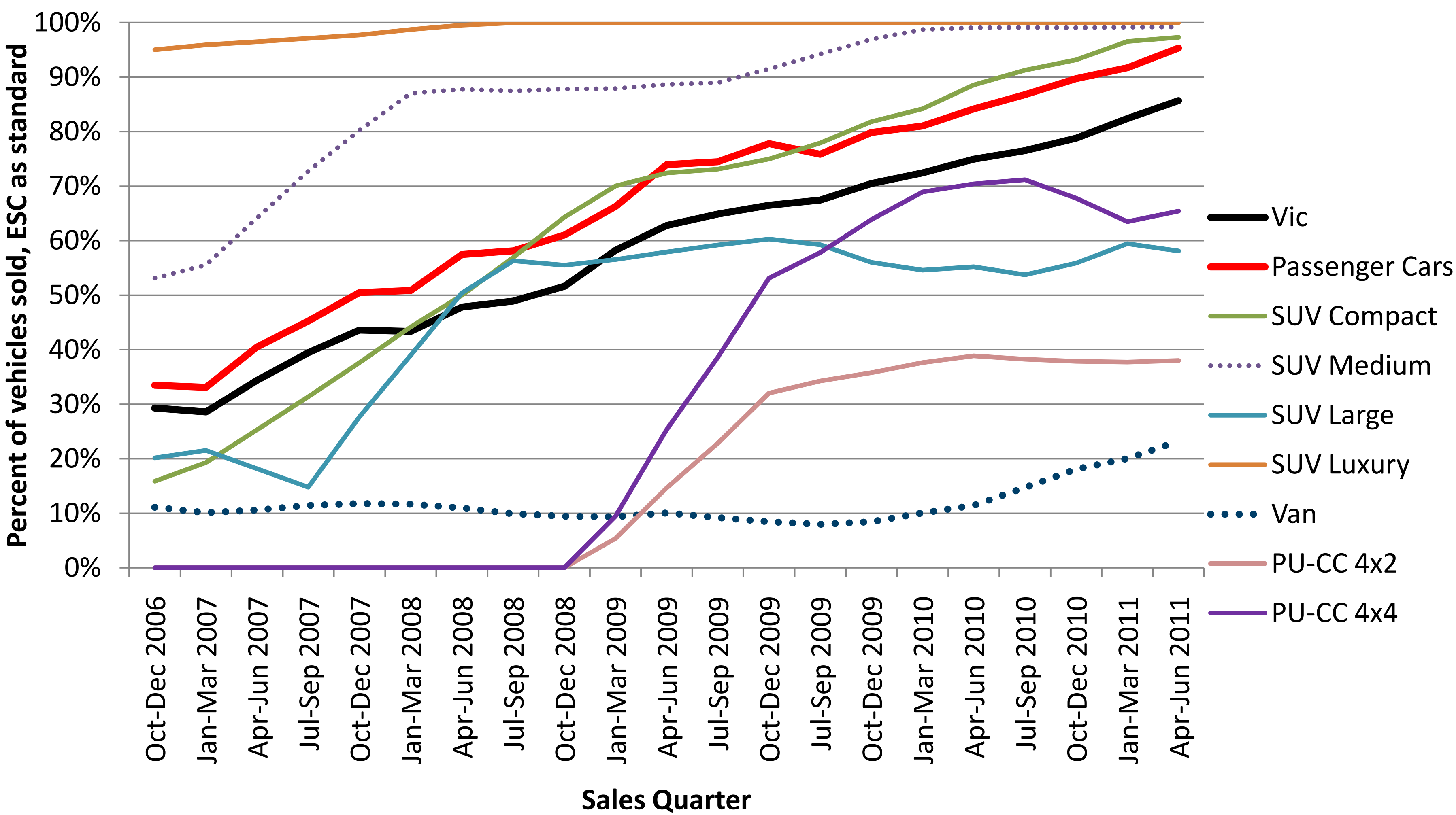
ESC standard fitment – – New SUV / Van / Commercial Sales



Key messages

- On average, front side curtain airbags fitted to ~80% all new passenger car sales
  - variation from 60% (light) to 100% (upper large) in last available sales ¼
- Apart from SUV light (~85%) and SUV medium (~90%), standard fitment of SCA into larger SUV (except luxury) and commercial vehicles is low
- ESC standard fitment rates around 95% in last quarter
  - rapid acceleration in standard fitment by mid-2011
  - high fitment in SUV compact and SUV luxury, but poor in 4x2, 4x4 and vans & rapid growth in standard fitment of ESC in SUV medium

Acknowledgements

- Dr Fitzharris wishes to acknowledge and thank Mr Michael Nieuwesteeg, Ms Renee Shuster, and Ms Jodi Page-Smith for assistance with the TAC Claims data, and for supplying the vehicle sales data; all are employees of the *Transport Accident Commission, Victoria.*

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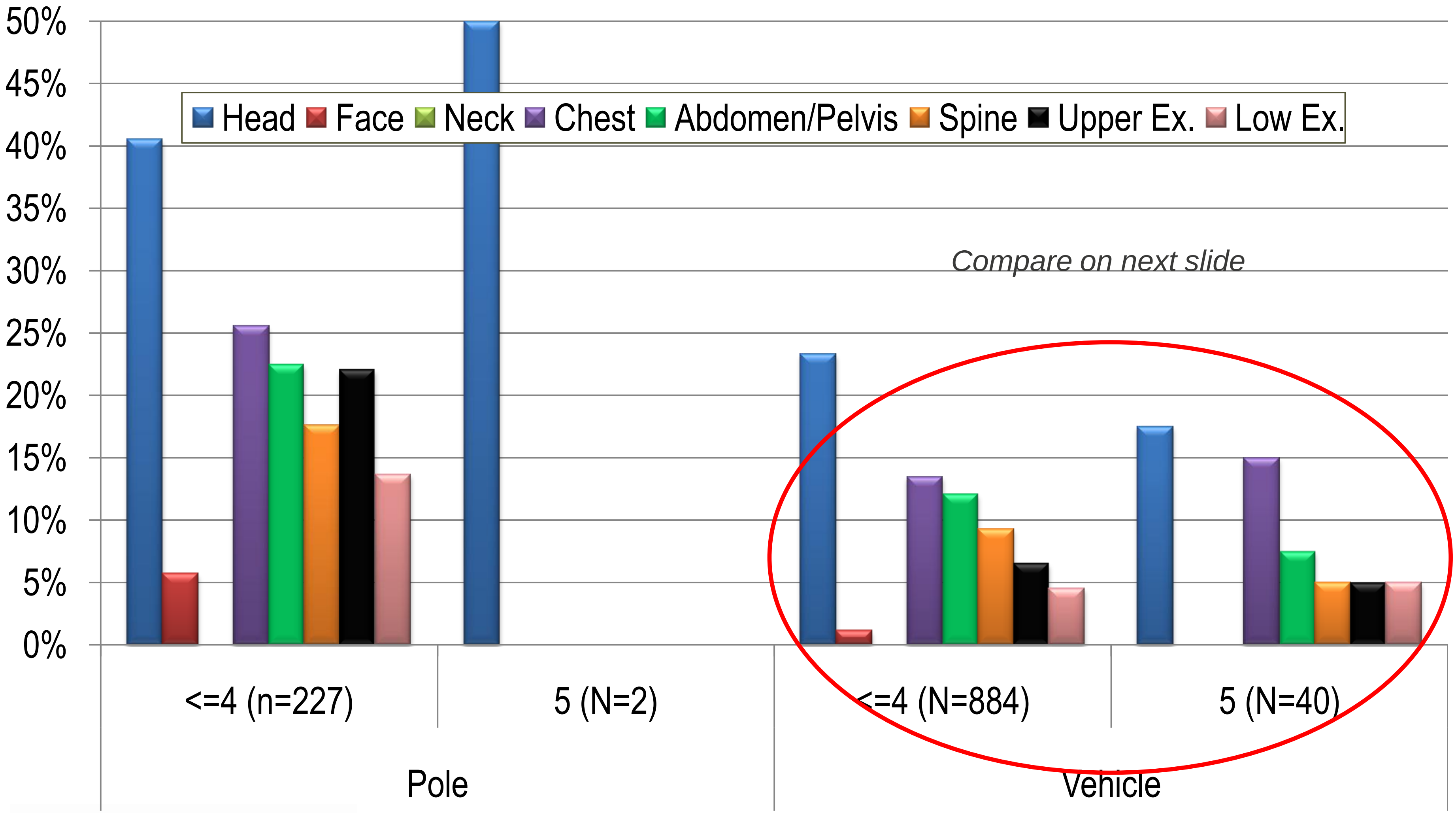
Part 4-2
Patterns of injury in NCAP 5* vehicles vs. ‘the rest’ (& SAB effectiveness)

Background

- In Washington (June 2011), presented mass data analysis for Victoria
- Cases were: side impact, MY2000+, near-side, period 2000-2010
- Results found significantly higher odds AIS3+ head, chest, abodomen/pelvis, and lower extremity injuries in Pole Impacts relative to V2V
- Further analysis of the TAC Claims data presented in Washington (June,2011) was warranted to arrive at the incremental benefit of improved side impact protection via a PSI GTR, in particular
  - Differentiation on NCAP staff rating in the patterns of injury in PSI
  - Cost of injury
  - Effectiveness of different types of side-airbag systems

Injury (AIS2+) differences between impact type / ANCAP *



Effect of 5* vs. <=4* for injury risk for vehicle-to-vehicle side impacts

- In car-to-car side impact collisions, no statistically significant reduction in injury risk for 5* vehicle cf. <=4 star vehicles

Region, severity	<=4* (n=884)	5* (n=40)	OR	OR 95% CI	P
Head 2+	23.3%	17.5%	0.92	0.78-1.08	0.3
Face 2+	1.1%	0.0%	N/A		
Neck 2+	0.0%	0.0%	N/A		
Chest 2+	13.5%	15.0%	1.01	0.85-1.21	0.8
Ab/Pel 2+	12.1%	7.5%	0.88	0.69-1.13	0.3
Spine 2+	9.3%	5.0%	0.86	0.64-1.15	0.3
Up. Ex 2+	6.6%	5.0%	0.93	0.70-1.25	0.7
Low Ex 2+	4.5%	5.0%	1.02	0.76-1.37	0.8

Adjusted for speed zone

Costs of injury

- Analysis of cost is an important part of the overall burden of the different crash types
- Essential for the benefits estimation, particularly in looking at the reductions possible
- Cost information
  - Fatality cost @ $4.938,964 million per incident case
    - Best Practice Regulation Guidance Note: Value of statistical life. Canberra: Office of Best Practice Regulation, Australian Government, 2010.
  - Serious & Minor injury cost: $804,618.00 & $29,709 per incident case respectively
    - Cost of road crashes in Australia 2006, Report 118. Canberra: Department of Infrastructure, Transport, Regional Development and Local Government, 2010.
  - Head injury cost: severe $4.8m. (AIS4+,GCS3-8); moderate $3.7m. (AIS3; GCS 9-11)
  - Spinal cord injury costs: paraplegia - $5m. per incident case
    - The economic cost of SCI and TBI in Australia. Access Economics, 2009

Overall cost of injury

	Collision with fixed object				Collision with vehicle			
Cost category	**Persons**	**% N**	**Cost (total)**	**% cost**	**Persons**	**% N**	**Cost (total)**	**% cost**
Fatality	6	2.6%	$29,633,784	12.9%	12	1.3%	$59,267,568	11.1%
Severe TBI	15	6.6%	$72,000,000	31.4%	30	3.2%	$140,802,000	26.4%
Moderate TBI	6	2.6%	$15,000,000	6.5%	18	1.9%	$45,000,000	8.4%
Paraplegia	1	0.4%	$5,000,000	2.2%	0			0.0%
Serious injuries, other regions	131	57.2%	$105,405,060	46.0%	340	36.8%	$273,570,385	51.2%
Minor injuries, other regions	70	30.6%	$2,079,630	0.9%	524	56.7%	$15,567,516	2.9%
Total	229	100.0%	$229,118,474	100.0%	924	100.0%	$534,207,469	100.0%
Mean cost			$1,000,517				$578,146	
% of cases			19.9%				80.1%	
% of cost			30.0%				70.0%	

Analysis: 72% higher costs in pole impacts than V2V (p<0.001)

Cost differences between impact type / NCAP *

- Sub-analysis indicates a significant difference in cost of injury in PSI <4* cf. V2V crashes
- Only two 5* cars involved in PSI

	Vehicle			Pole			All		
	<=4	**5**	**All**	**<=4**	**5**	**All**	**<=4**	**5**	**All**
Mean	$588,773	$343,312	$578,147	$1,005,657	$417,164	$1,000,517	$673,951	$346,829	$662,035
95% CI									
Lower	$519,636	$181,571	$511,591	$829,690	-$4,505,917	$825,888	$740,275	$190,749	$597,800
Upper	$657,909	$505,052	$644,702	$1,181,625	$5,340,245	$1,175,147	$477,815	$502,909	$726,270
Total cost	$520,474,991	$13,732,478	$534,207,469	$228,284,146	$834,328	$229,118,474	$748,759,137	$14,566,806	$763,325,943
N	884	40	924	227	2	229	1111	42	1153
% N	76.7%	3.5%	80.1%	19.7%	0.2%	19.9%	96.4%	3.6%	100%
% cost	68.2%	1.8%	70.0%	29.9%	0.1%	30.0%	98.1%	1.9%	100%

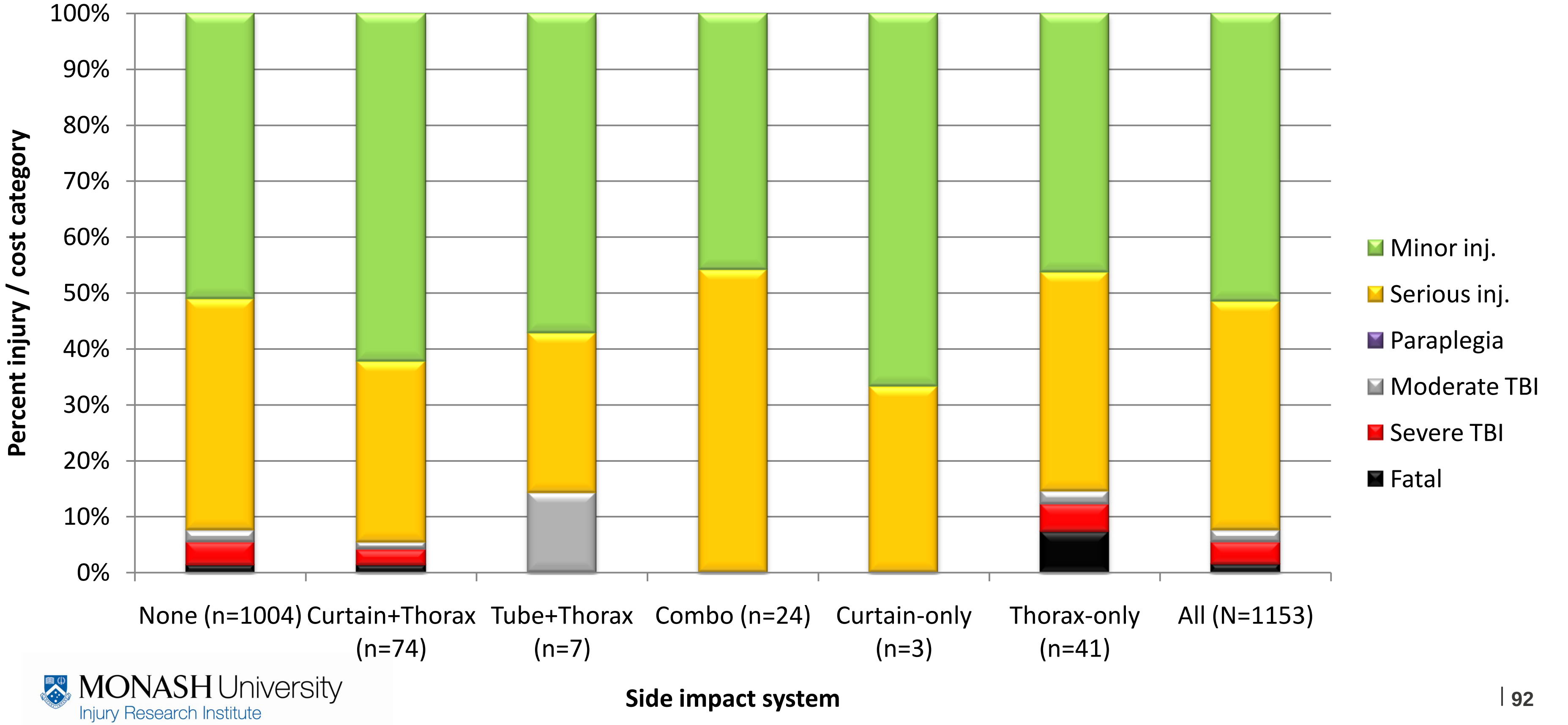
Injury cost category by impact object and 5* ANCAP status

- In V2V crashes, there is a difference in the injury distribution to the less severe end of the injury spectrum

Cost Category	Pole side impact				Vehicle-to-vehicle side impact				*For V2V impacts*		
	≤4 STARS		5 STARS		≤4 STARS		5 STARS		RR	95% CI	P
Fatal	6	2.6%	Nil	Nil	12	1.4%	Nil	Nil	N/A		
Severe TBI	15	6.6%	Nil	Nil	30	3.4%	Nil	Nil	N/A		
Moderate TBI	6	2.6%	Nil	Nil	17	1.9%	1	2.5%	1.30	0.18-9.5	0.8
Paraplegia	1	0.4%	Nil	Nil	Nil	Nil	Nil	Nil	N/A		
Serious injury – other regions	130	57.3%	1	50%	327	37.0%	13	32%	0.88	0.56-1.38	0.5
Minor injury – other regions	69	30.4%	1	50%	498	56.3%	26	65%	1.15	0.91-1.46	0.4
Total	227	100%	2	100%	884	100%	40	100%	-		

Injury cost category by Side Airbag system

- Differences in the severity level across the SAB system types, with highest proportion fatalities being thorax-only
- Important to note cases of moderate & severe TBI with curtain & thorax SAB
- Small numbers prevent assessment of benefit for Curtain+Thorax vs. Combination SAB



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Key messages

- Important differences in injury for pole impacts cf. V2V
- Trends evident for reduced injury risk in ANCAP-rated 5* cars cf. ≤4* in vehicle-vehicle side impacts
- In cost estimations, essential to capture appropriate lifetime incident costs, which are high in for traumatic brain injury and SCI
  - Fatality rate and severe TBI are significantly higher in PSI, and coupled with high costs, represent a larger % of the total cost to the community
  - PSI represent 20% of occupants, but 30% of total cost of side impacts
  - Mean PSI cost is ~$1million, cf. $560k for other side impacts (i.e, 72% ↑)
  - 5* ANCAP rating, on average, had half the mean cost cf. <=4*
  - Pole impacts were, on average, double the cost of V2V (4 star cars)

Key messages

- Differences in cost categories represented within SAB type
  - *Note: fatalities and severe TBI in Curtain+Thorax airbag fitted car*
- The relatively small numbers means that it is not yet possible to estimate key benefit reductions given a 5* vehicle with C+T striking a pole given the small number of cases
  - This could be used as the basis for setting an ‘incremental benefit’ for the GTR cost-benefit analysis
  - Important clues from CCIS on SAB effectiveness for head injury, the literature plus the important cost differences presented here
  - Essential to capture the appropriate lifetime costs consistent with the injury severity by applying known proportions to ‘mass data’ and future projections
  - Must model the ‘incremental benefit’ in terms of savings as well as the ‘incremental cost’ associated with meeting the requirements of the GTR

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Part 4-3
Cost of injury estimates and incremental benefits, accounting for ESC

Modelling the incremental benefit of the GTR

- The principal question is:

What is the incremental benefit of the GTR in terms of lives saved, injuries avoided, and the cost-benefit, given ESC fitment, over and above the current safety implementation process?

Requires numerous inputs, including:

1. Projections of the future number of crashes, given the population estimates
2. Understand the severity distribution, and apply appropriate costs
3. Incorporate the *additional benefit* than is already the case by improved safety features (such as ESC) **BUT** also the introduction of airbag systems in their current schedule
4. Include an estimate of the *incremental, additional* cost to achieve the additional benefit

- We use Victorian data as the basis of estimation; accounts for approximately 25% of all fatalities and injuries in Australia

Projecting the future number of crashes

- We use actuarial methods to determine the future number of crashes using
  - Projected population, 30 years into the future (Australian Bureau of Statistics)
  - Historical patterns in the number of registered vehicles
  - We use the historical vehicle involvement rate in *side impact* fatalities to establish the 'fatalities per registered vehicle' (& for serious injuries) [fatalities per registered vehicle]
  - We use the vehicle ownership rate per population

    thus: Predicted(fatalities, 2012-20401)=

    (Estimated Pop2012-2041(Vehicles/person))* pr(Fatalities per vehicle))*
- *We also know from our analysis that PSI crashes account for **43%** of fatal side impact crashes and **24.5%** of injury crashes (& the complement for V2V side impacts)*
  - ***Hence, we split apart the future number of crashes into PSI and V2V crashes***

Accounting for ESC in reducing the crashes a GTR can influence

- A step in the estimation process is the derivation of the number of crashes that ESC is likely to prevent
  - We then use this % reduction on the project number of crashes in the future
  - It is necessary to determine the proportion of crashes *by impact object* that are likely to be influenced by ESC
- There are two sub-steps:
  1. Determine the proportion of PSI is likely to effect
     - Assume that all PSI crashes are amenable to ESC, as they departed the road as single vehicle accidents
     - Assume that none of the vehicle-to-vehicle impacts are amenable to ESC as they are intersection crashes in most instances
  2. Determine an *ESC crash reduction effectiveness value*

Accounting for ESC: reducing crashes influenced by the GTR

- Determine an *ESC crash reduction effectiveness value*
- *Monash completed an evaluation on ESC using* police-reported crash data from five Australian states and NZ which had been collected as part of the Monash University Accident Research Centre's (MUARC's) *Used Car Safety Ratings* project
- *MY 1998+:* ESC fitted (n=27,252); not fitted (n=439,543); 175 vehicle models
- ESC was associated with an **18.6% reduction** in single vehicle crashes in Australia

	# vehicles	% Crash reduction			95% CL	
SVA: Passenger cars	with ESC	Unadjusted	Adjusted	Stat. sig.	Lower	Upper
All severities	9,354	23.60	**18.60**	<.0001	13.06	23.78

For side impact crashes (multiple vehicles), the evaluation showed no benefits of ESC

MVA-side impact Passenger cars	# vehicles with ESC	Unadjusted	Adjusted	Stat. sig	Lower	Upper
All severities	12,053	1.59	-3.56	0.1	-8.53	1.17
Driver injury	2,234	13.32	1.13	0.8	-10.40	11.47
Driver ser. inj.	153	12.52	-13.72	0.5	-71.05	24.39

Source: Scully et al., 2010

Accounting for ESC: reducing crashes influenced by the GTR

Rules for applying ESC effectiveness

1. **ESC will reduce all PSI crashes by 18.6%**
2. ESC will have **no influence on vehicle-to-vehicle side impact crashes**

This could be considered a very stringent approach as other ESC evaluations globally have reported effects across a range of crash types ***HOWEVER*** *we use the jurisdiction specific estimate*

- *Must also consider the implementation schedule of ESC, as it will not reach 100% of the fleet until 2030*
  - *We use the age of the vehicle fleet, and attrition to determine the proportion of vehicles in the first year of life in the fleet, etc..to see the movement of the technology into the fleet over time, given its current fitment rate*
  - ***Accounts for the fact ESC will not reach its full 18% per annum benefit in PSI until in EVERY vehicle***
  - *Gives us PSI fatalities saved due to ESC, so the difference is what the GTR can influence*

Accounting for ESC: deriving the number of POLE SIDE IMPACT fatalities able to be influenced by improved side impact protection

- Application of process

Year	Fatalities Predicted	**Fatalities due to PSI (*43%)**	ESC penetration into the fleet (prop of fleet with ESC)	ESC effectiveness (18% reduction multiplied by ESC penetration)	ESC benefit per annum (PSI lives saved)	Amenable to Improved Side Impact Protection
2012	58	25	0.6077	0.109	3	22
2013	59	25	0.6697	0.121	3	22
2014	60	26	0.7174	0.129	3	22
2015	61	26	0.7637	0.137	4	22
...	....	...	...	....	...	...
2041	87	38	1.0	0.180	7	31
TOTAL	**2157**	**928**			**157**	**771**

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Accounting for ESC: deriving the number of POLE SIDE IMPACT <u>injuries</u> able to be influenced by improved side impact protection

- Application of process

Year	Injuries Predicted	**Injuries due to PSI (*24.5%)**	ESC penetration into the fleet (prop of fleet with ESC)	ESC effectiveness (18% reduction multiplied by ESC penetration)	ESC benefit per annum (PSI injuries saved)	Amenable to Improved Side Impact Protection
2012	741	182	20	162	741	182
2013	753	184	22	162	753	184
2014	765	187	24	163	765	187
2015	776	190	26	164	776	190
...	....	...	...	....	...	...
2041	1118	274	49	225	1118	274
TOTAL	27629	6769	1145	5624	27629	6769

Accounting for ESC: deriving the number of POLE SIDE IMPACT fatalities able to be influenced by improved side impact protection

- Using the crashes left post-ESC, we have the number per annum that could be influenced by *improved side impact protection (i.e., they still occur)*

	(A)menable to Improved Side Impact Protection	
Year	Fatalities	Injuries
2012	22	182
2013	22	184
2014	22	187
2015	22	190
...	...	...
2041	31	274
TOTAL	**771**	6769

Must account for penetration of SAB into the fleet

SAB fitment rates were presented, as was ESC

B	Open to influence from SAB	
SAB vehicle penetration multiplier	C Fatalities	D Injuries
0.473	10	77
0.589	13	96
0.670	15	109
0.717	16	118
...	...	...
1.0	31	225
	710	5181

Columns C and D are the number of fatalities and serious injuries that SAB systems can influence in PSI crashes

Overlay the % benefits from published studies to arrive at 'savings'

Modelling current improvements in vehicle safety on PSI fatalities and injuries

1. *Overlay current SAB effectiveness values in reducing mortality and injury:*
   - *Fatality reduction benefit of SAB* ***(32% ↓) (C)***
   - *Injury reduction* ***(34%↓) (D)***
     - *Reduction values based on the literature*
     - *CCIS analysis indicated a 75% reduction in serious head injury in curtain +thorax SAB, which was in turn 75% better than the combination SAB*
2. *FOR THE INCREMENTAL BENEFIT*
   - *Estimate the benefit reduction associated with the GTR*
     - *estimated <u>additional</u> 50% reduction in fatalities – hence, 0.32+ (0.5*0.32)=0.48*
     - *estimated <u>additional</u> 50% reduction in fatalities – hence, 0.34+ (0.5*0.32)=0.51*
3. ***The difference in the savings is the*** **Incremental frequency count savings**

The same benefits are expected in V2V impacts, given the high rates of head injury

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Modelling current improvements in vehicle safety on PSI fatalities and injuries, and the incremental GTR benefit

Year	Savings with SAB introduction as now (excl first 2 years)		Benefits under GTR (SAB + Added GTR reductions)		Incremental benefit of GTR (additional savings)	
	Fatality reduction	Injury reduction	Fatality reduction	Injury reduction	Fatalities	Injuries
2012	3	26	*Phase-in*	*Phase-in*	0	0
2013	4	33	*Phase-in*	*Phase-in*	0	0
2014	5	37	7	56	2	19
2015	5	40	8	60	3	20
...	...	...	...	...	...	...
2041	10	76	15	115	5	38
Period	220	1762	330	2555	**110**	**852**

- **Over the 30-year period, the GTR would result in 110 fewer PSI fatalities, and 852 fewer persons injured – but we reduce this by subtracting the fatalities, who we assume will sustain minor injuries, hence 742 fewer in Victoria**
- **Hence, for Australia – estimate 440 fewer fatalities, and 2968 fewer persons injured**

Modelling incremental improvements

- *The fatality and injury savings represent the incremental benefit, given a start date of 2015*
- *Using the injury distribution reported earlier, we can* ***disaggregate*** *the INJURY savings into their severity categories, to* ***account for cost differences*** *in traumatic brain injury from 'other serious' and 'minor' costs*
- *Necessary to reflect the differential lifetime care costs associated with TBI and SCI, over and above 'serious' injuries avoided*
- *For benefit calculations:*
  - *Assume that a fatality and serious injury occupant would be 'minor injured'*
  - *Assume minor injured are 'uninjured'*

Injury category	Pole %	V2V %
Severe TBI	6.7%	3.3%
Moderate TBI	2.7%	2.0%
Paraplegia	0.4%	0.0%
Serious injuries, other regions	58.7%	37.3%
Minor injuries, other regions	31.4%	57.5%
Total	100%	100%

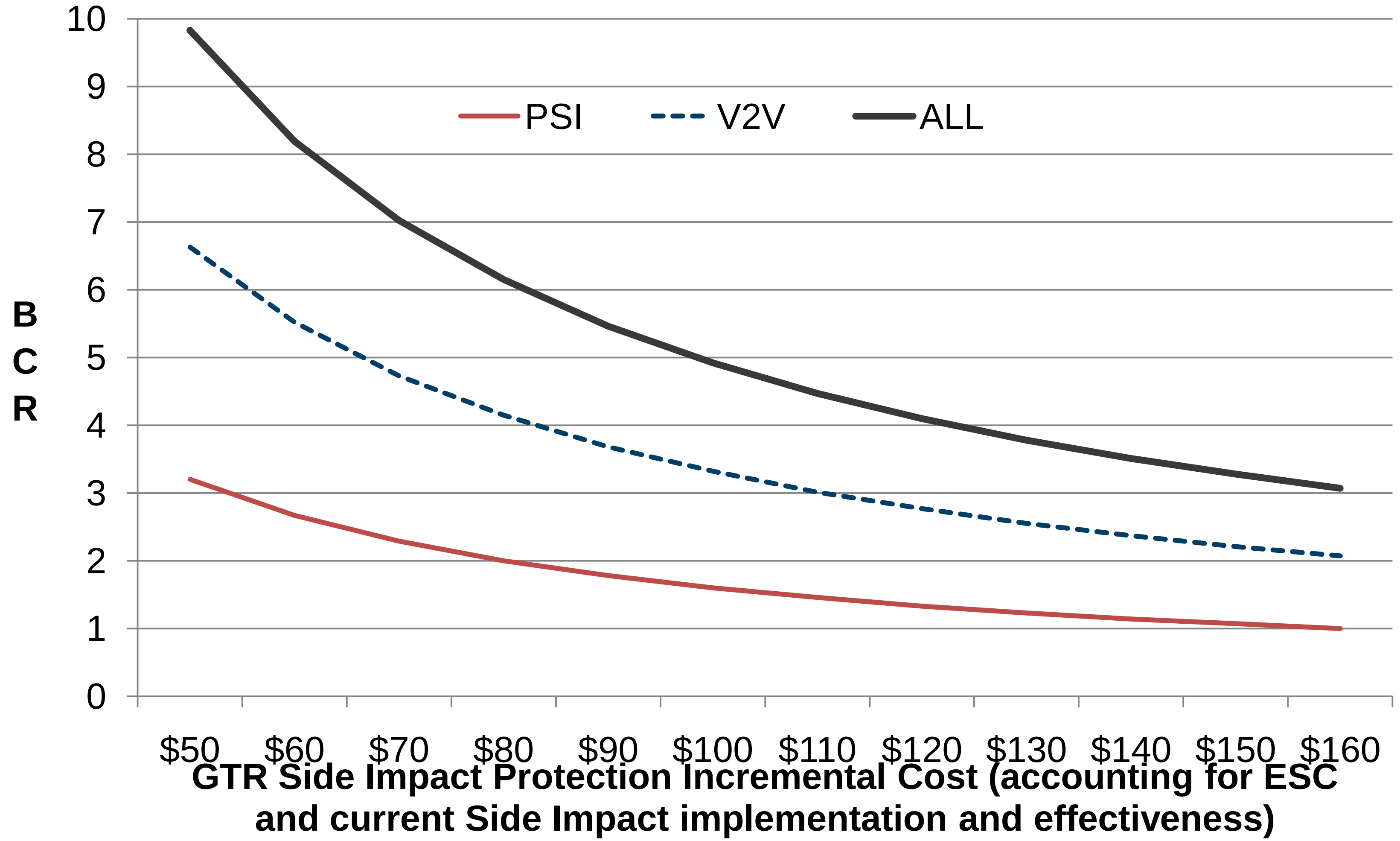
Modelling incremental improvements

- *Using the appropriate costs for each injury severity, & fatalities we determine the $ amount associated with:*
  1. *SAB implementation (as Business-As-Usual [BAU])*
  2. *SAB + GTR implementation benefit*
  3. ***The difference in savings, which is the incremental benefit***
- *On COSTS, we model:*
  1. *Cost of SAB fitment, of $AU220 (on all new registered vehicles, as BAU)*
  2. *Cost of meeting the GTR, of an **additional** $AU120 per unit (on all new registered vehicles, from 2015)*
  3. ***The difference in cost, which is the incremental cost***
- *As the benefits and costs are projected into the future, we discount both at 7%, to reflect the value of today's dollar 'tomorrow'*
- *We derive a BCR for every year, and for the entire 30 year period*

Findings – Incremental benefits of a GTR, over and above BAU of SAB installation (Victoria)

Incremental benefits	Pole impacts	Vehicle-to-Vehicle	All
Additional Fatalities avoided	110	176	286
Additional TBI-severe avoided	53	98	151
Additional TBI-moderate avoided	21	59	80
Additional Paraplegia avoided	4	9	13
Additional Serious injuries avoided	466	1108	1574
Additional Minor injuries avoided	249	1707	1956
Financial benefits, 2015-2041	$375,981,006	$778,988,640	$1,154,969,646
GTR requirement cost@ $120 per vehicle	$281,874,206	$281,874,206	$281,874,206
BCR @ incremental $120	1.33	2.76	4.10
BCR in Yr 30	1.68	3.48	5.14

BCR range, given variable incremental costs



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Findings

- Introduction of a GTR for PSI would be cost-effective, with a break-even incremental cost of $A160, per unit
- Incremental benefits, over and above current side impact improvements, apply to vehicle-to-vehicle impact crashes
- Given the assumptions stated, significant number of additional lives saved in Victoria, and Australia due to the incremental benefit of the GTR, given ESC and current side impact protection

Incremental benefits	AUST.	AUST. p.a
Fatalities avoided	1144	41
TBI-severe avoided	604	22
TBI-moderate avoided	320	11
Paraplegia avoided	52	2
Serious injuries avoided	6296	225
Minor injuries avoided	7824	279
Financial benefits, 2015-2041	$4,619,878,584	$164,995,663†
GTR requirement cost@ $120 per vehicle	$1,127,496,824	$40,267,743

†over 28 years implementation

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Thank-you