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Further injury risk analysis and the cost-effectiveness of enhanced side impact protection in the form of a GTR for PSI crashes

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Held: 20^{th} June, 2012

Presentation structure

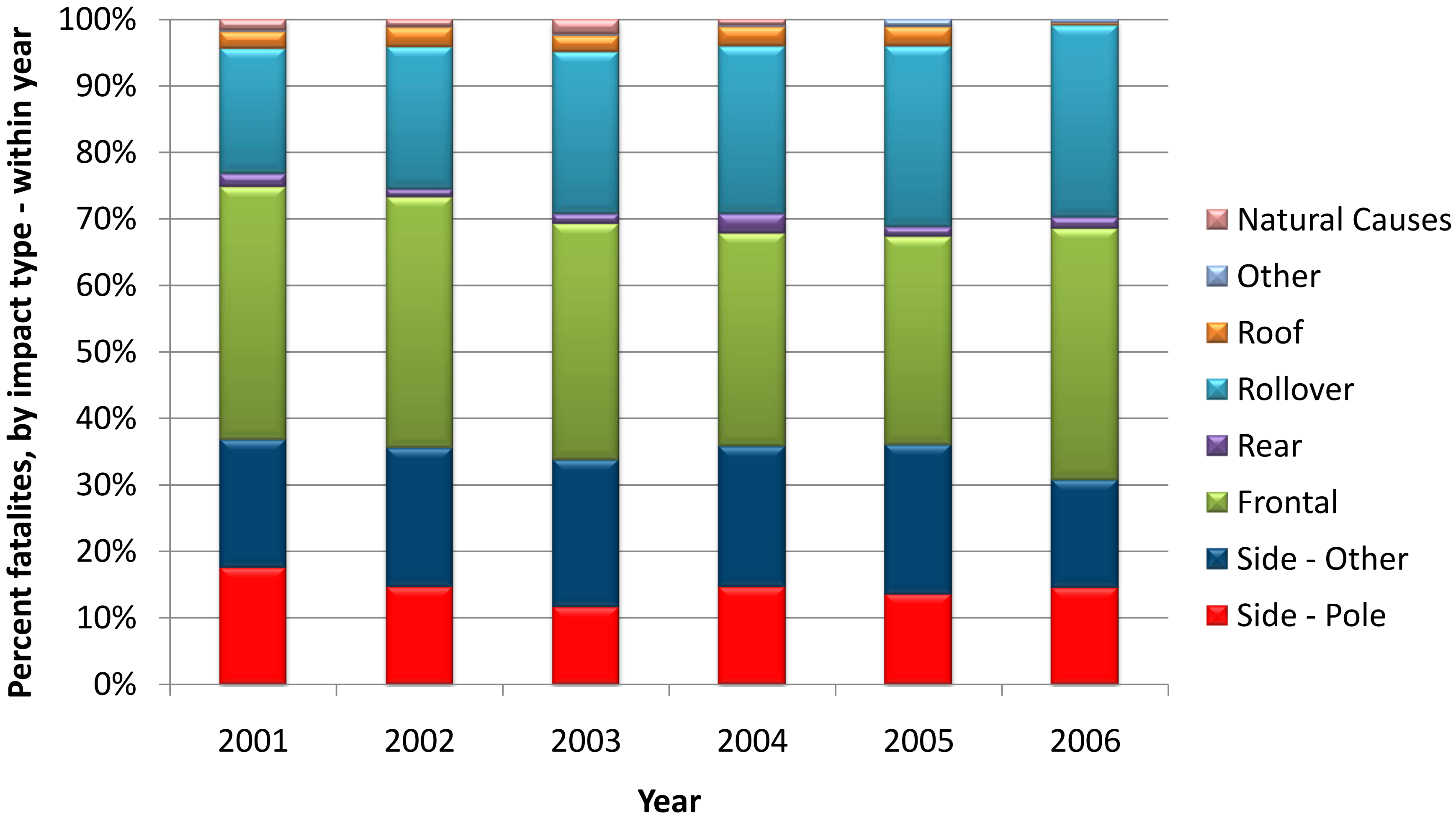
1. Side impact fatalities in Australia and Causes of Death in M1/N1 vehicles
2. Trends in AIS 3+ injuries in side impact crashes
3. Analysis of probability of AIS 3+ injuries in PSI and V2V crashes
4. Summary of risk factor modelling – UK, Australia, Germany
5. Modelling the benefits of the GTR

Side impact fatalities in Australia and Causes of Death in M1/N1 vehicles

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

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



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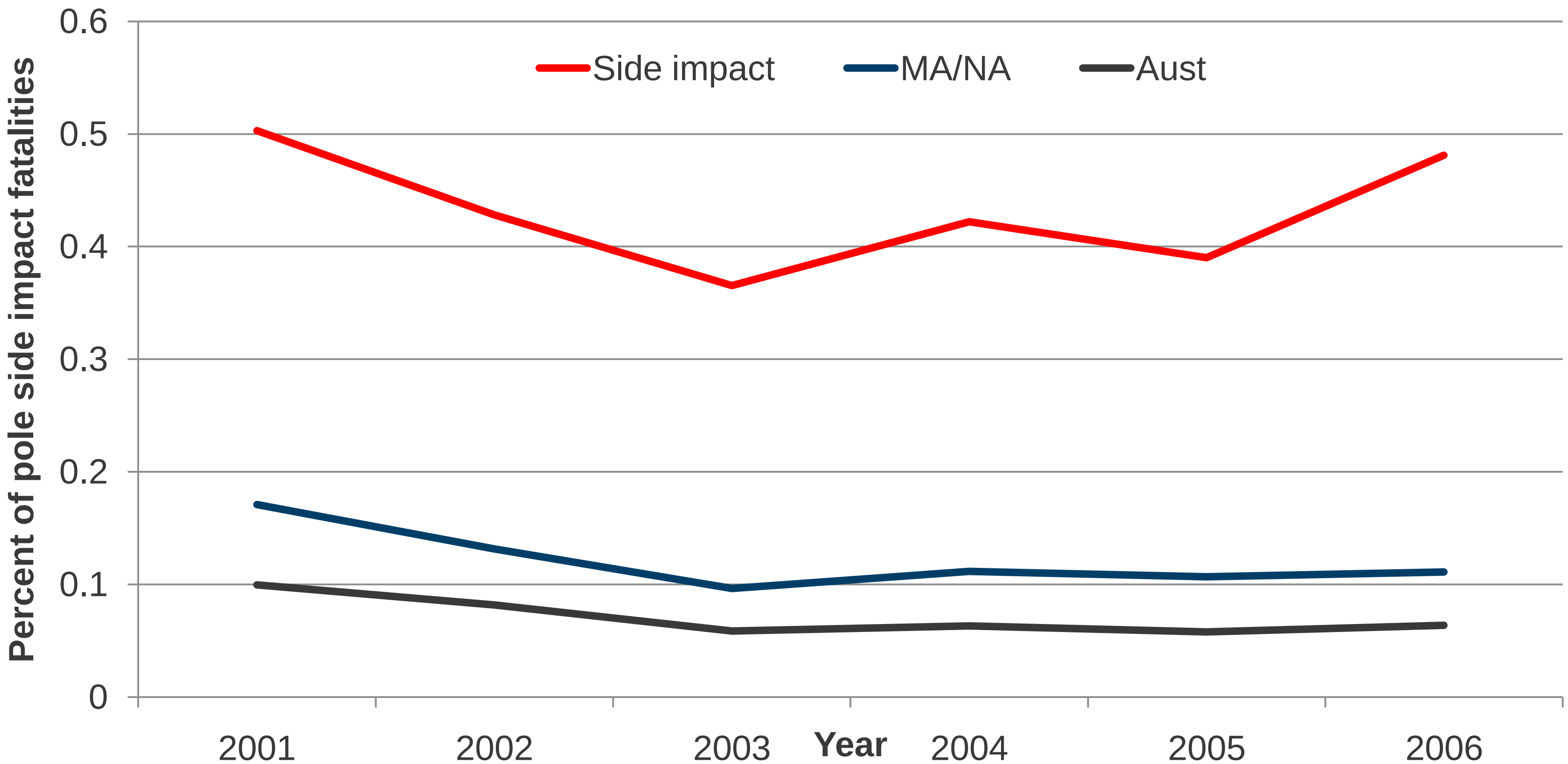
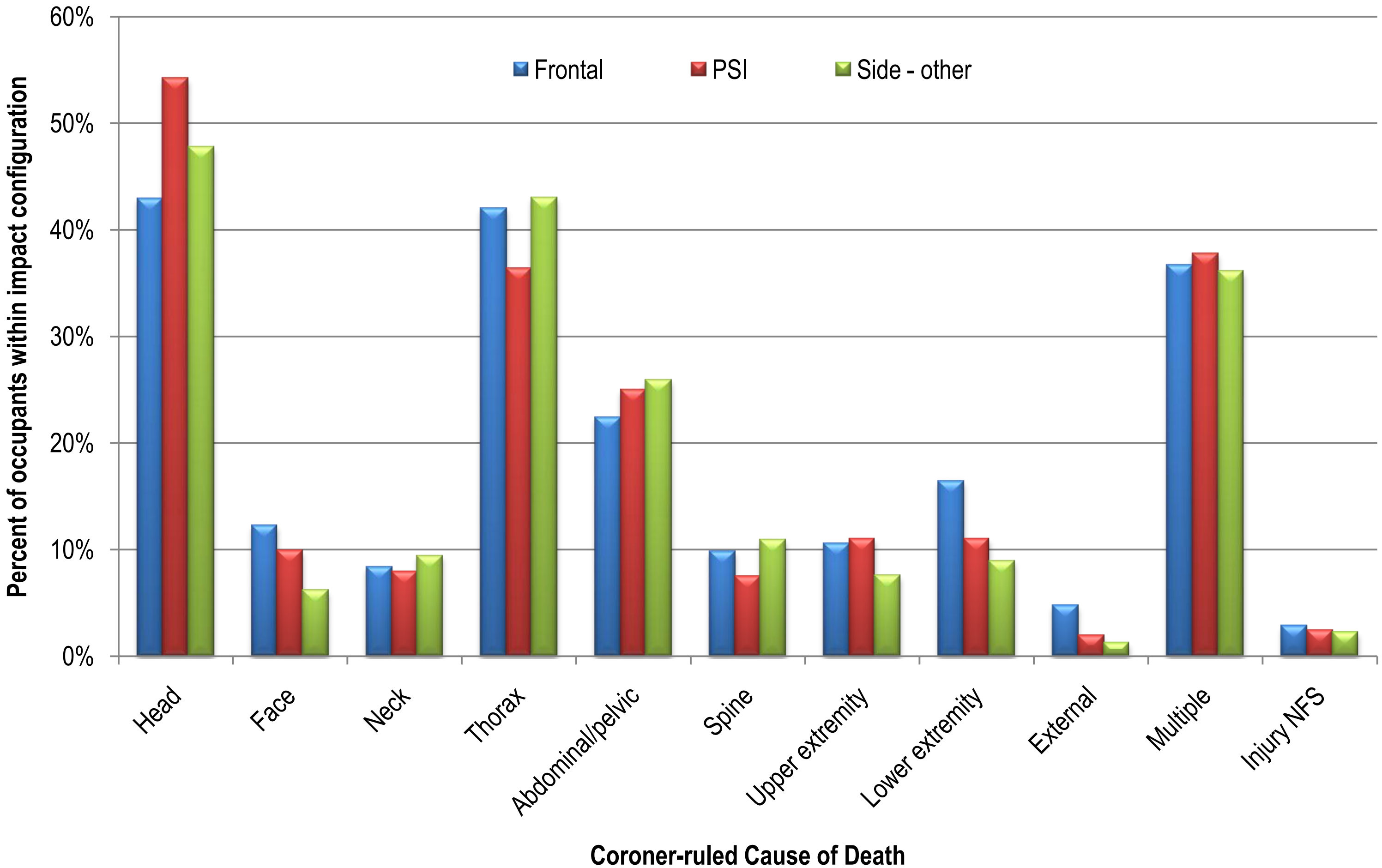
AU FRCD: Percent of Pole Side Impact fatalities



- 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%]***

AU FRCD: Causes of death in side impact crashes



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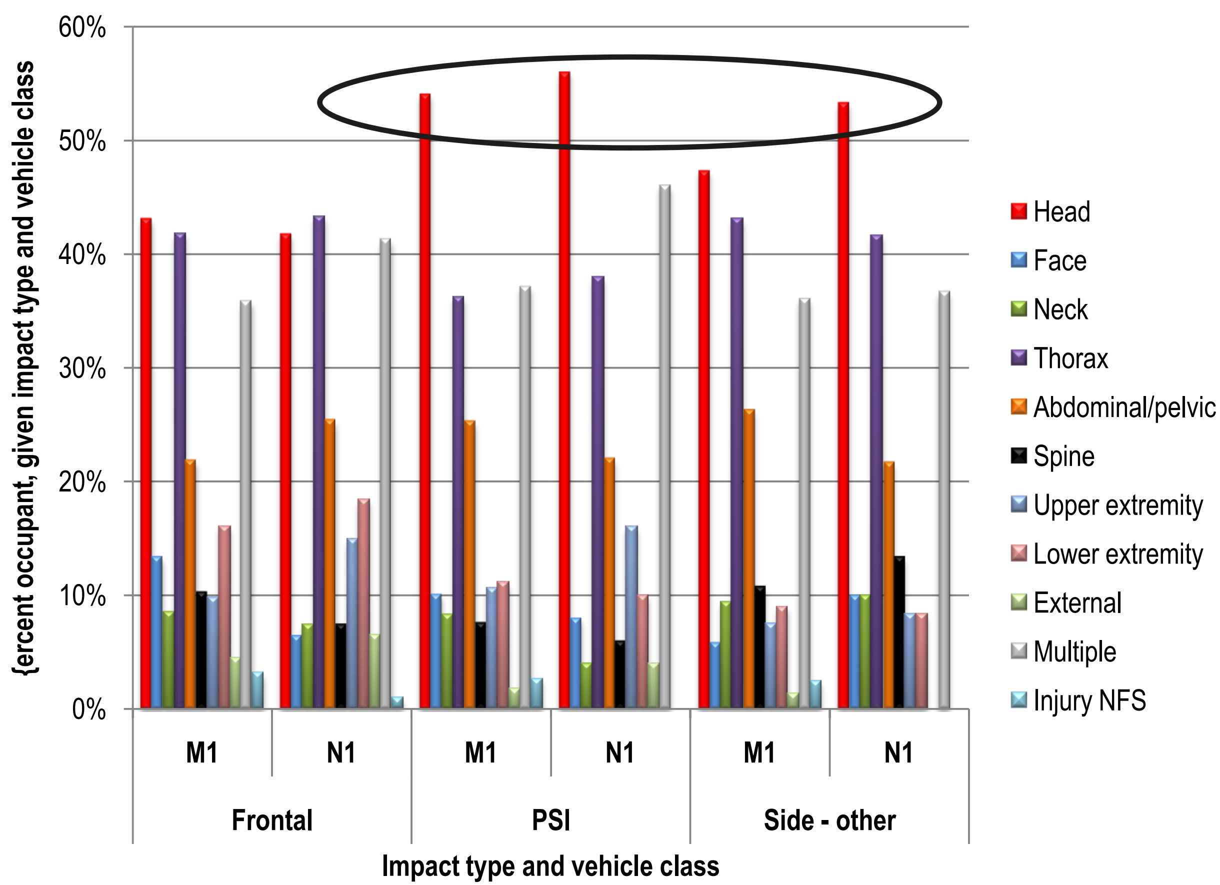
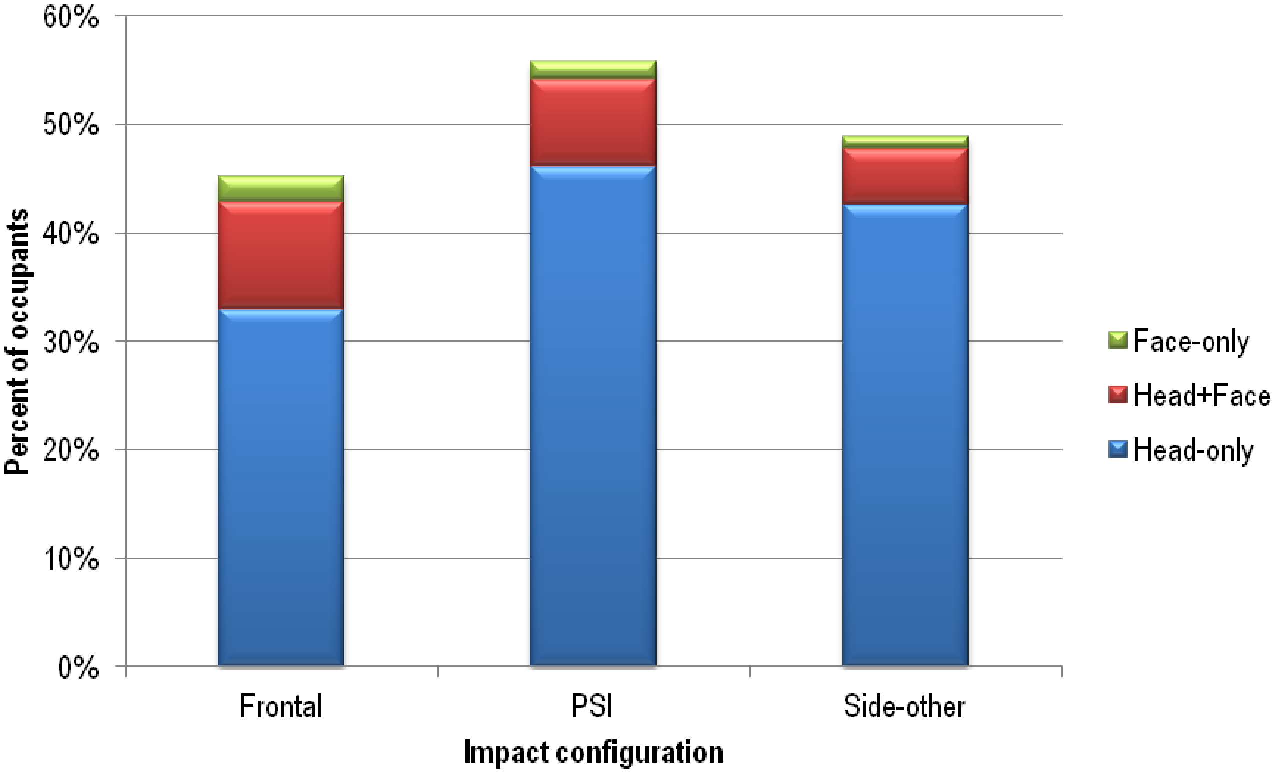
Causes of death by vehicle class and impact



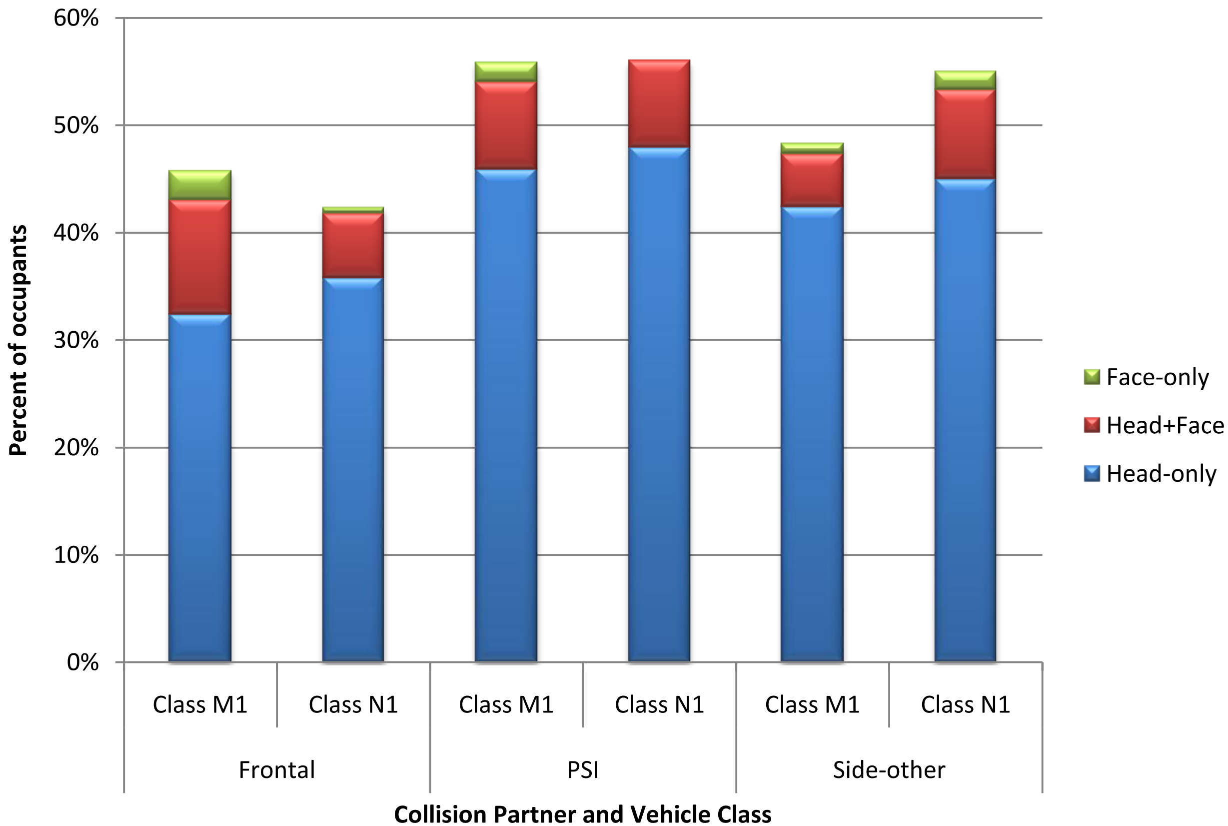
- High rates of head injury in PSI in both M1 and N1
- High rate head injury as COD in N1, other side impact
- ‘Multiple injuries’ mostly also include head injury

Head / Face injuries as a Cause of Death



- PSI have the highest rate of head / face injuries than any impact type
- Injuries are amenable to curtain airbags as the key countermeasure
- Different patterns in M1 / N1

Head / Face injuries as Cause of Death, by vehicle class and impact type



- Little difference in percent occupants with head/face injuries as COD in M1 and N1 PSI
- Head / Face injuries as COD in other side impact crashes as high as PSI
- Clear target for enhanced side impact countermeasures

Key points

- Pole Side impact crashes account for:
  - 43% of all side impact fatalities
  - 15% of passenger vehicle fatalities, and
  - 9% of all fatalities in Australia.
- Numeric terms:
  - 898 individuals killed
  - $AUD 4.4 billion. (£2.96 billion) over the period 2001-2006
  - Average 150 people killed and $AUD 0.7 billion per annum.
- 55% of PSI deaths sustaining a ‘fatal’ head injury (c.f frontal: 44%) and ‘other side impact crashes (49%)
- The pattern of injuries was similar in Class M1 and Class N1 vehicles, BUT higher head injury as COD for N1 ‘other side impact types

Trends in AIS 3+ injuries in side impact crashes

Trends in injury severity - Victoria

- Observation has been made in Victoria of ‘severity category shifting’, meaning fatalities decreasing but hospital admissions increasing
- Mechanisms
  - improvements in passive safety systems
  - infrastructure investment, including speed limit reductions
  - high level of enforcement on key risk behaviours
- Implications
  - points to avenues for countermeasure development
  - cost of injury implications

Data source – Mass Claims Data

- The *Transport Accident Commission* is a government-run compulsory third-party insurer
- No-fault basis
- Covers all medical and like expenses, rehabilitation, loss of earning and other benefits
- Data source has multiple components
  - Crash information
  - Vehicle information (and linked to NCAP data)
  - Hospital / rehabilitation information, and local Doctor
  - Injuries sustained **(coded in ICD, and mapped to AIS)**
  - Cost of injury
  - Ambulance and Police reports where attended

Data analysis

- Aim: inform the safety situation with regards to vehicles that would meet the existing side impact standard ECE R 95, known in Australia as ADR72.
- *Inclusion criterion -*
  - Vehicle Model year 2000, as surrogate for ADR72 (ECE R 95) compliant;
  - The initial point of impact being the front or rear side passenger door;
  - The collision partner being a tree / pole, or other vehicles for vehicle-to-vehicle side impact crashes;
- Exclusion criteria -
  - Impact point of front, front / rear side corner, rear, rollovers
  - Collisions with ‘other’ types of partners (e.g., animals, trains etc…)

Results

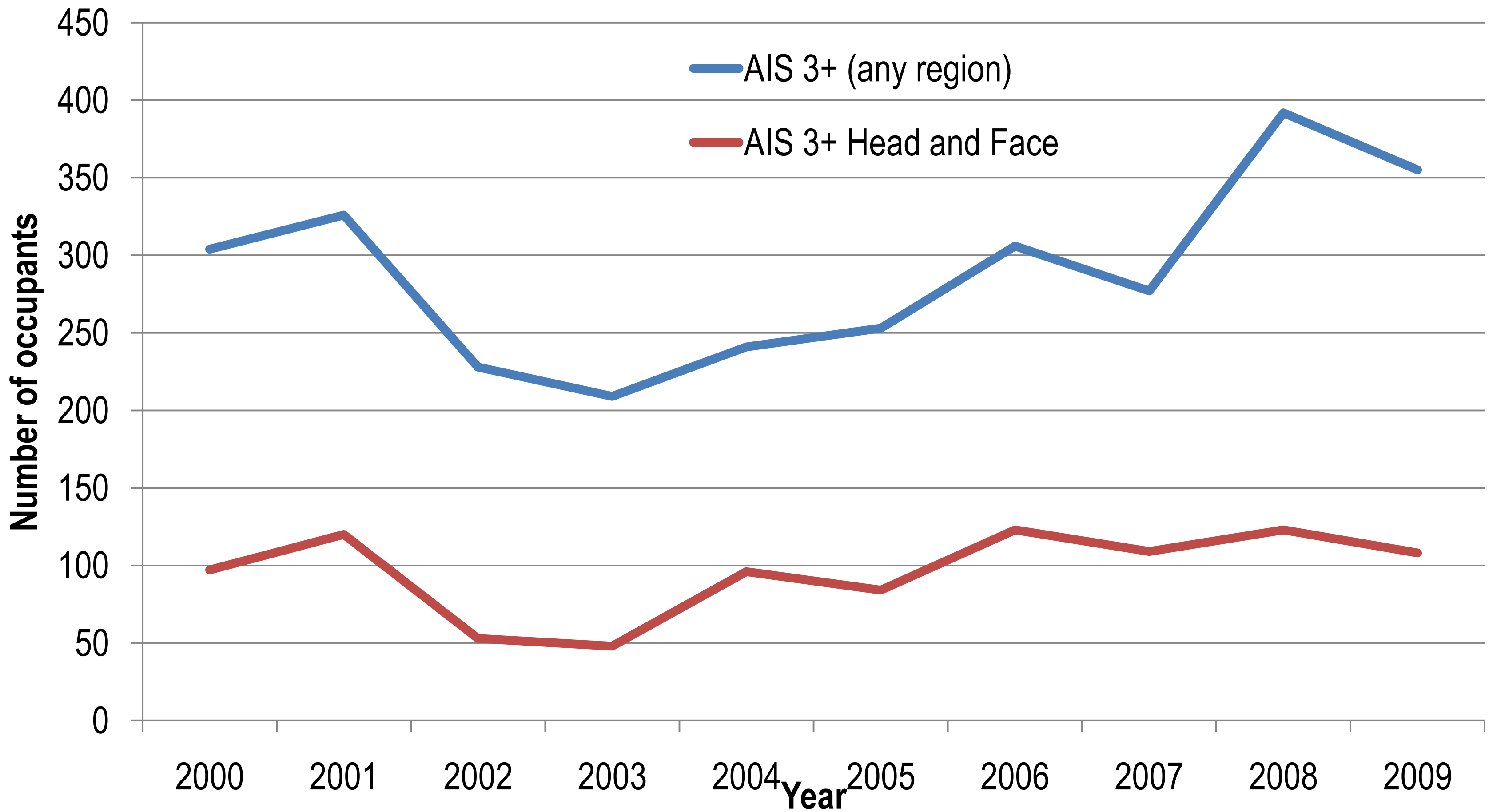
- Data on 174,233 road users, of which 127,254 were four-wheeled vehicle occupants (10 years, 2000-2010)
  - killed: 2482, 1.95%; injured: 124,772, 98.05%
  - frontal impacts (n=49,695), and side impact (n=51,101)
- Mortality rate:
  - 2.3% for side impact vs. 1.9% for frontal
- Side impact crashes: 48.6% of fatalities cf. Frontal (39%)
- Side impact injuries (excluding killed occupants):
  - AIS 3+ injury: 2891 occupants (5.7%)
  - AIS 3+ thorax: n = 1571, 3.1%
  - AIS 3+ head: n=959, 1.9%

Overall cost of injury (M1) – all occupants

	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)

AIS 3+ injuries over time



Estimates of persons with AIS3+ injuries, Australia

- Victoria, with 25% of the population and vehicles registered represents a strong basis to extrapolate injuries in Australia
- The second lowest fatality rate in Australia

AIS 3+ injury	Occupants injured in side impact crashes, Australia			
	Population estimate†		Vehicles registered estimate‡	
	10-year period	Per annum	10-year period	Per annum
	n	n	n	n
Any region	11,673	1167	11,156	1116
[redacted]				
Head	3872	387	3701	370
Face	24	2	23	2
Neck	*Defaults to spine, region specific location, or external in mapping from ICD to AIS*			
Thorax	6343	634	6063	606
Abdomen-Pelvis	1389	139	1328	133
Spine	1022	102	976	98
Upper extremity	291	29	278	28
Lower Extremity	2063	206	1972	197

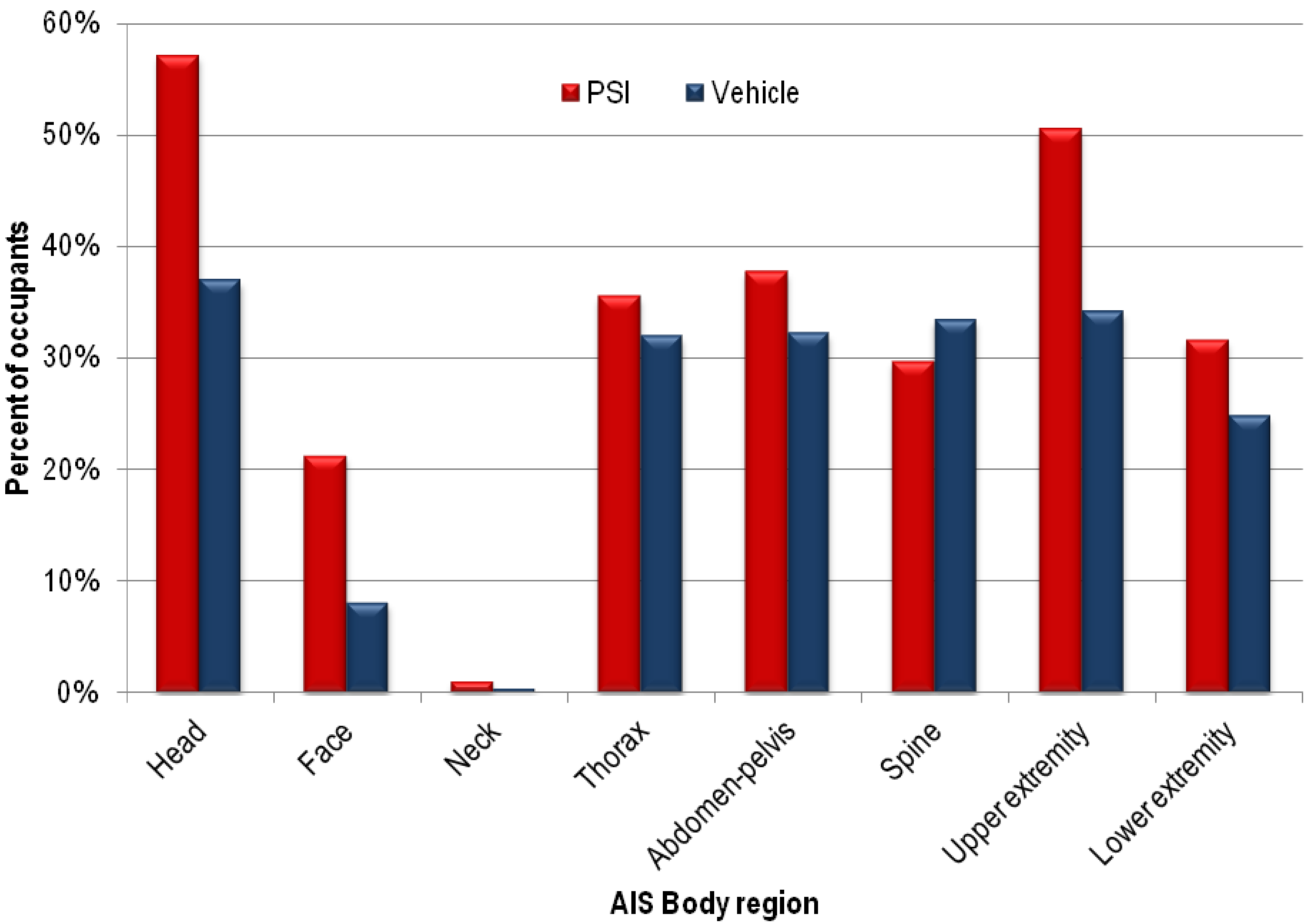
Analysis of probability of AIS 3+ injuries in PSI and V2V crashes

Injuries in PSI and V2V crashes

- Previously reported extensive analysis of injuries from multiple data sources on differential risk of injury for occupants involved in PSI crashes
- Further analysis of data on 194 PSI and 794 vehicle-to-vehicle side impact crashes, on occupants of M1 vehicles in near-side impacts
- Injury in severity in PSI higher than V2V impacts

ISS	Pole	Vehicle
% Major Trauma (ISS>15)	22.2%	9.3%
Mean (SD),	9.4 (8.9)	5.1 (6.6)
95^{th}% CI of mean	8.1-10.6	4.7-5.6
Median	6.0	3.0
Range	0-43	0-43

Injuries to body regions, by impact type



- AIS 1 + injuries presented
- In PSI, head and upper extremity is prominent
- Difference in percent with face injuries

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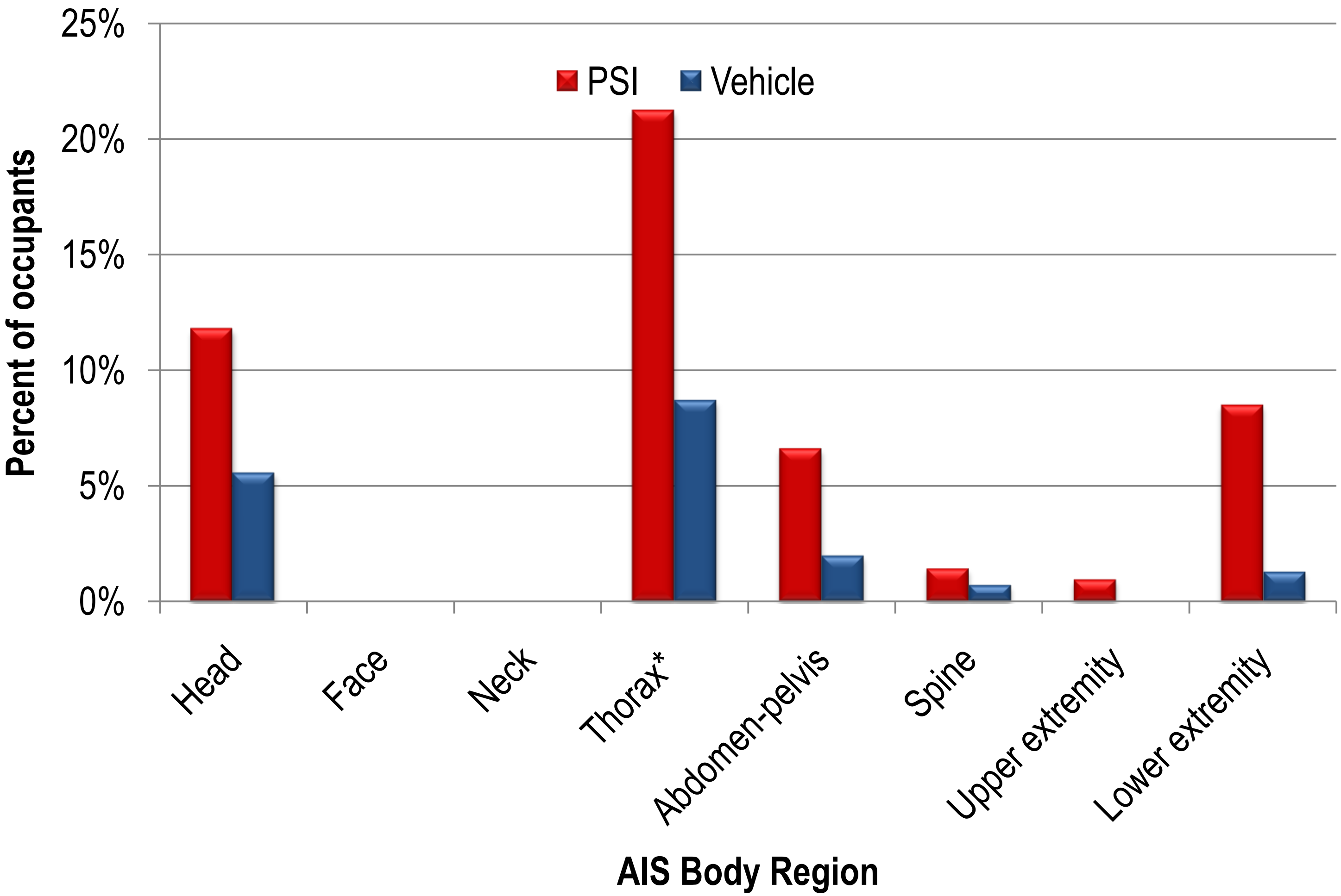
AIS 3+ Injuries to body regions, by impact type



- Core body regions injured
- Upper extremity injuries AIS 1 or 2
- Face injuries drop out
- Consistent with all previous analysis

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Adjusted probability of AIS 3 + injuries

Region / Severity	*Pole / tree*	*Vehicle*	*Absolute difference in Pr(Head, pole) to Pr(Head, vehicle)*		*% difference pole to vehicle*
	Adj. Prob. (95th% CI)	*Adj. Prob. (95th% CI)*	*Adj. Prob. diff. (95th% CI)*	P	
AIS 3+					
Head	0.11 (0.07-0.16)	0.05 (0.04-0.07)	0.06 (0.01-0.11)	0.008	+54.5%
Face	Nil injuries	Nil injuries	N/A		
Neck	Nil injuries	Nil injuries	N/A		
Thorax	0.21 (0.16-0.27)	0.08 (0.07-0.10)	0.13 (0.07-0.18)	0.001	+61.9%
Abdomen-Pelvis	0.07 (0.03-0.10)	0.02 (0.01-0.03)	0.04 (0.01-0.08)	0.009	+71.4%
Spine	0.02 (0.00-0.03)	0.01 (0.00-0.01)	0.008 (-0.01-0.02)	0.4	+50%
Upper extremity	*Cannot calculate*	Nil injuries			
Lower extremity	0.08 (0.05-0.12)	0.01 (0.005-0.02)	0.07 (0.03-0.11)	<0.001	+87.5%

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Logistic model adjusted using side airbag status and occupant position (front or rear seat)

Other factors related to injury risk

- Models also demonstrate role for age and gender depending on body region
- Irrespective of impact partner (adjusted models, also accounts for speed zone)
- Findings
  - Males at higher risk of AIS 3+ head & thorax injuries
  - Females at higher risk of AIS 3+ spine injuries
  - Increased age is associated with AIS 3+ thorax injuries

Summary of risk factor modelling – UK, Australia, Germany

AIS 3+, body region	United Kingdom			Australia						Germany[d]	
	CCIS[a]			TAC Mass Claims data[b]			ANCIS[c]			GIDAS[d]	
	PSI (n=36) relative to V2V (n=263)			PSI (n=212) relative to V2V (n=865)			PSI (n=16) relative to V2V (n=42)			PSI (n=15) relative to V2V (n=88)	
	OR	95th % CI	P	OR	95th % CI	P	OR	95th % CI	P	OR	P
Head	**5.15**	1.74-15.29	0.03	**2.26**	1.36-3.76	<0.001	**1.41**	0.24-8.39	0.7	**3.10**	0.1
Thorax	**3.87**	1.31-11.42	0.01	**2.83**	1.89-4.24	<0.001	**2.13**	0.21-4.62	0.3	**3.09**	0.04
Ab-Pelvis	**0.93**	0.19-4.44	0.9	**3.55**	1.72-7.33	<0.001	**1.88**	0.19-18.35	0.6	**2.20**	0.4
Lower Extremity	**4.79**	1.22-18.79	0.02	**7.27**	3.37-15.66	<0.001	**1.81**	0.09-1.75	0.2		

Modelling the incremental benefits of the GTR

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?

Both M1 and N1 vehicles are of interest

Modelling the incremental benefit of the GTR

Requires numerous inputs, including:

1. Projections of the future number of crashes, given the population estimates and vehicle registrations
2. Account for ESC fitment, penetration into the fleet and effectiveness in reducing crashes
3. Account for curtain side airbag fitment, penetration into the fleet and effectiveness in reducing crashes
4. Assess the 'incremental benefit', commencing 2015
    1. Apply the incremental benefit of improved protection (with appropriate cost of injuries)
    2. Apply the incremental cost of fitment

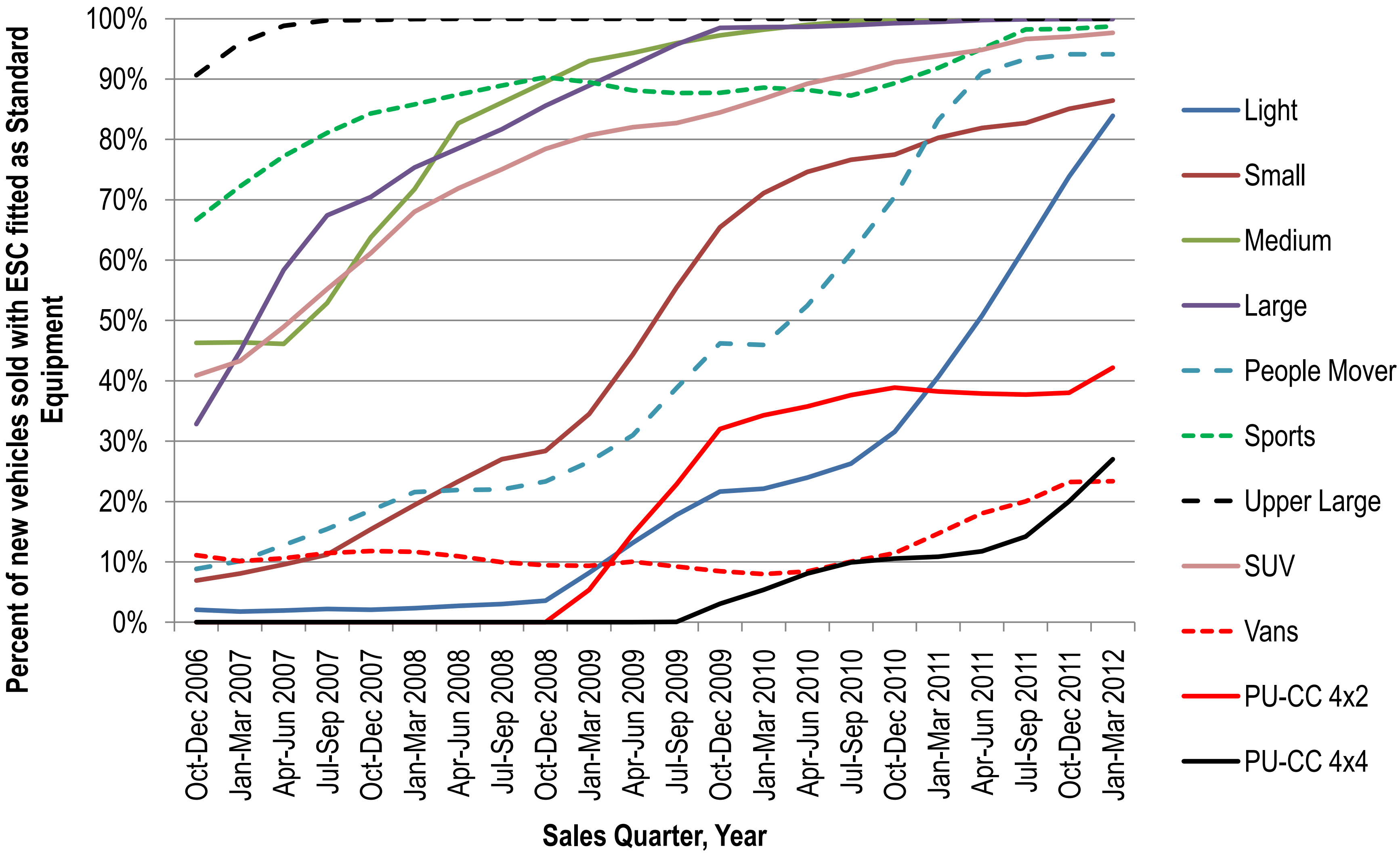
Use Victoria as the basis for estimation – extremely robust vehicle and injury data

Cost considerations: curtain side airbag and ESC fitment rates

- Must account for ESC fitment and hence penetration into the fleet
  - influences an increasing range of crashes over time, until complete penetration into the fleet is achieved
  - reaches an equilibrium state on crash risk
  - acts each year to reduce the 'pool' of side impact crashes amenable to GTR effects

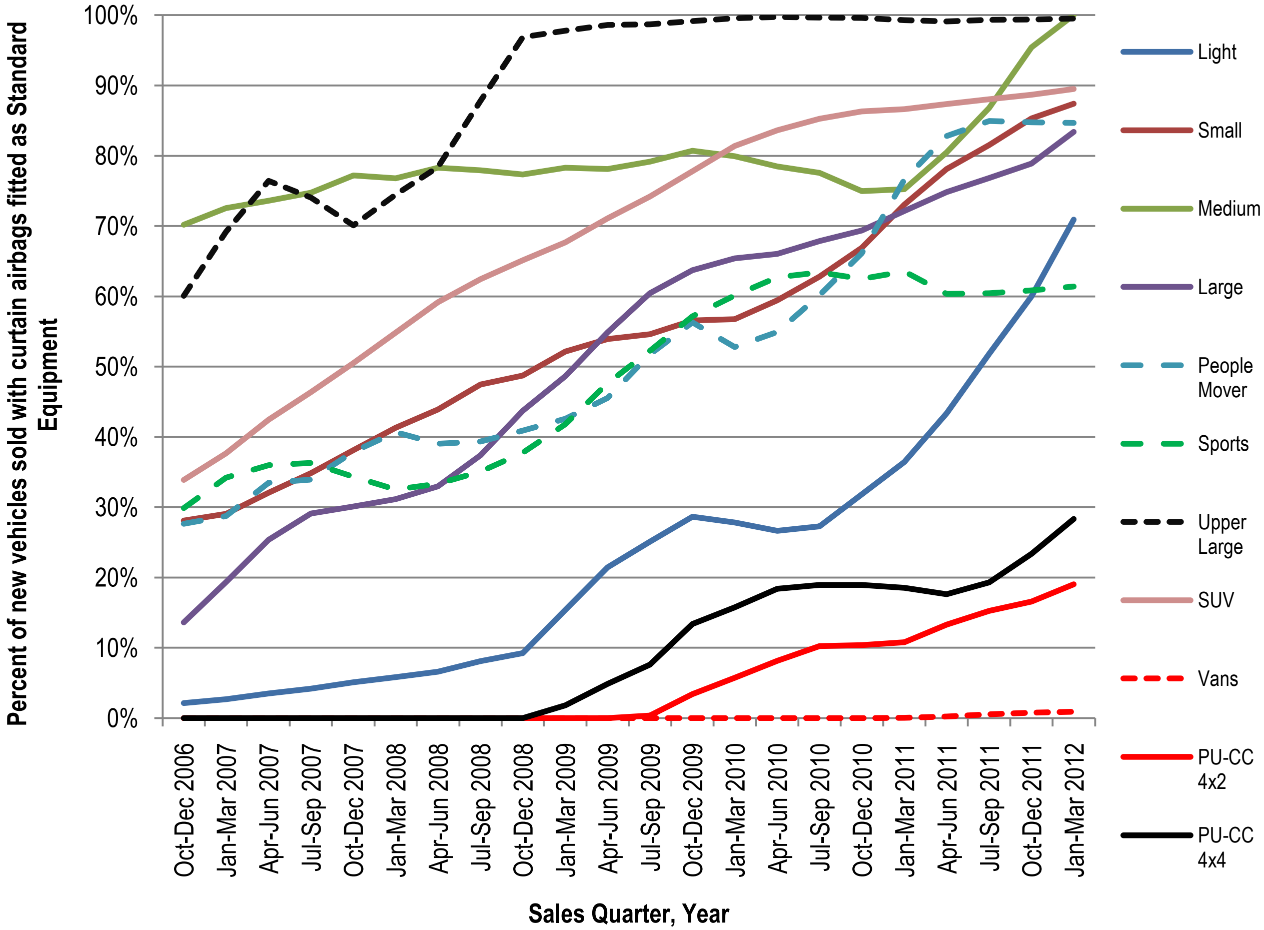
- Fitment of side curtain airbags is critical
  - direct influence on community benefits realised
  - time-lag must be accounted for into the fleet
  - safety performance has a direct bearing on 'increment'

ESC fitment



Percent of new vehicles sold with ESC fitted as Standard Equipment
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Oct-Dec 2006
Jan-Mar 2007
Apr-Jun 2007
Jul-Sep 2007
Oct-Dec 2007
Jan-Mar 2008
Apr-Jun 2008
Jul-Sep 2008
Oct-Dec 2008
Jan-Mar 2009
Apr-Jun 2009
Jul-Sep 2009
Oct-Dec 2009
Jan-Mar 2010
Apr-Jun 2010
Jul-Sep 2010
Oct-Dec 2010
Jan-Mar 2011
Apr-Jun 2011
Jul-Sep 2011
Oct-Dec 2011
Jan-Mar 2012
Sales Quarter, Year
Light
Small
Medium
Large
People Mover
Sports
Upper Large
SUV
Vans
PU-CC 4x2
PU-CC 4x4

Curtain Side Airbag Fitment



High levels of curtain side airbag standard fitment in M1 vehicles

Poor level of fitment to N1 vehicles

Project time point of complete fitment and complete fleet penetration

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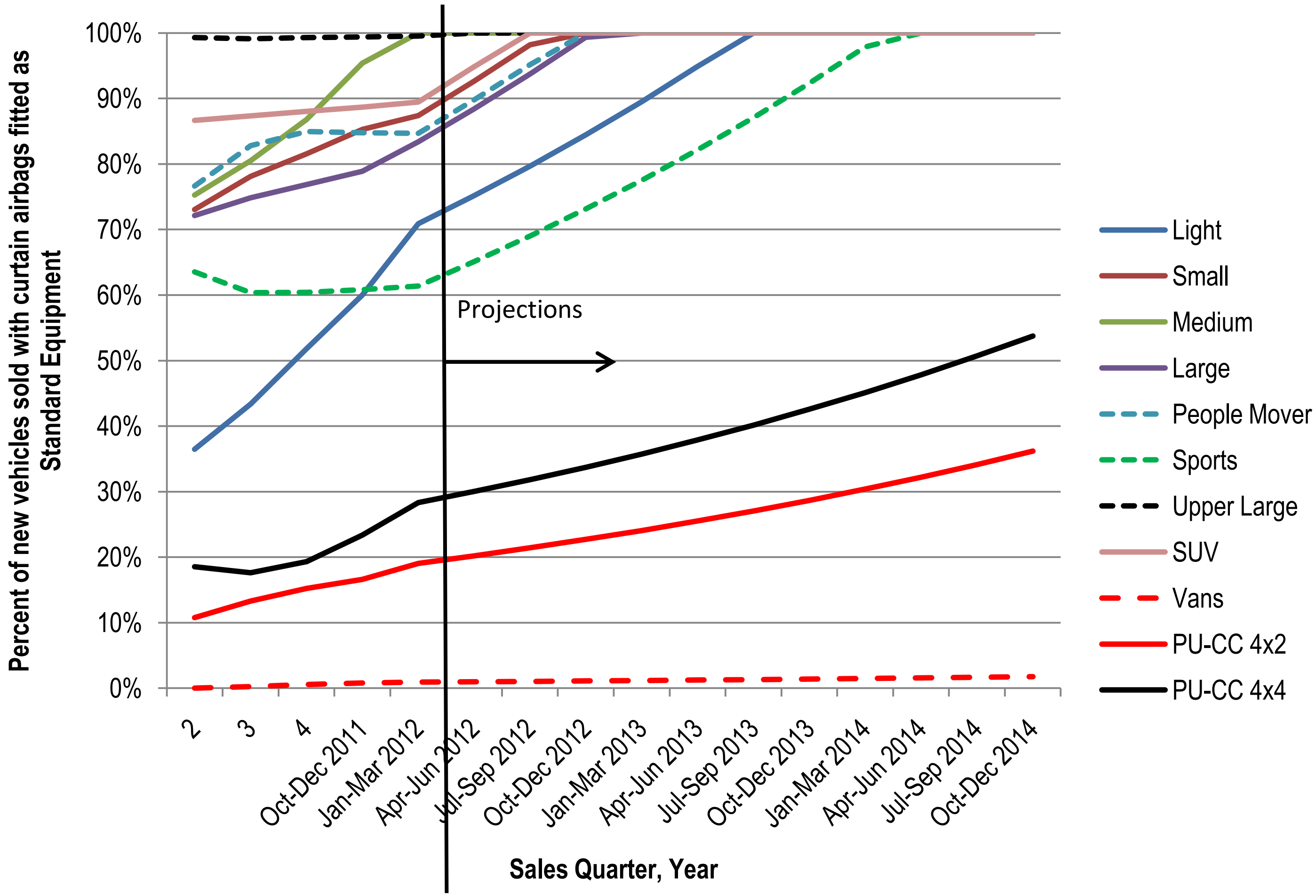
Projected fitment of curtain side airbags



- Project 100% fitment into M1 vehicles by mid 2014
- N1: late 2010
- Volume sellers have high fitment in 4x4 range

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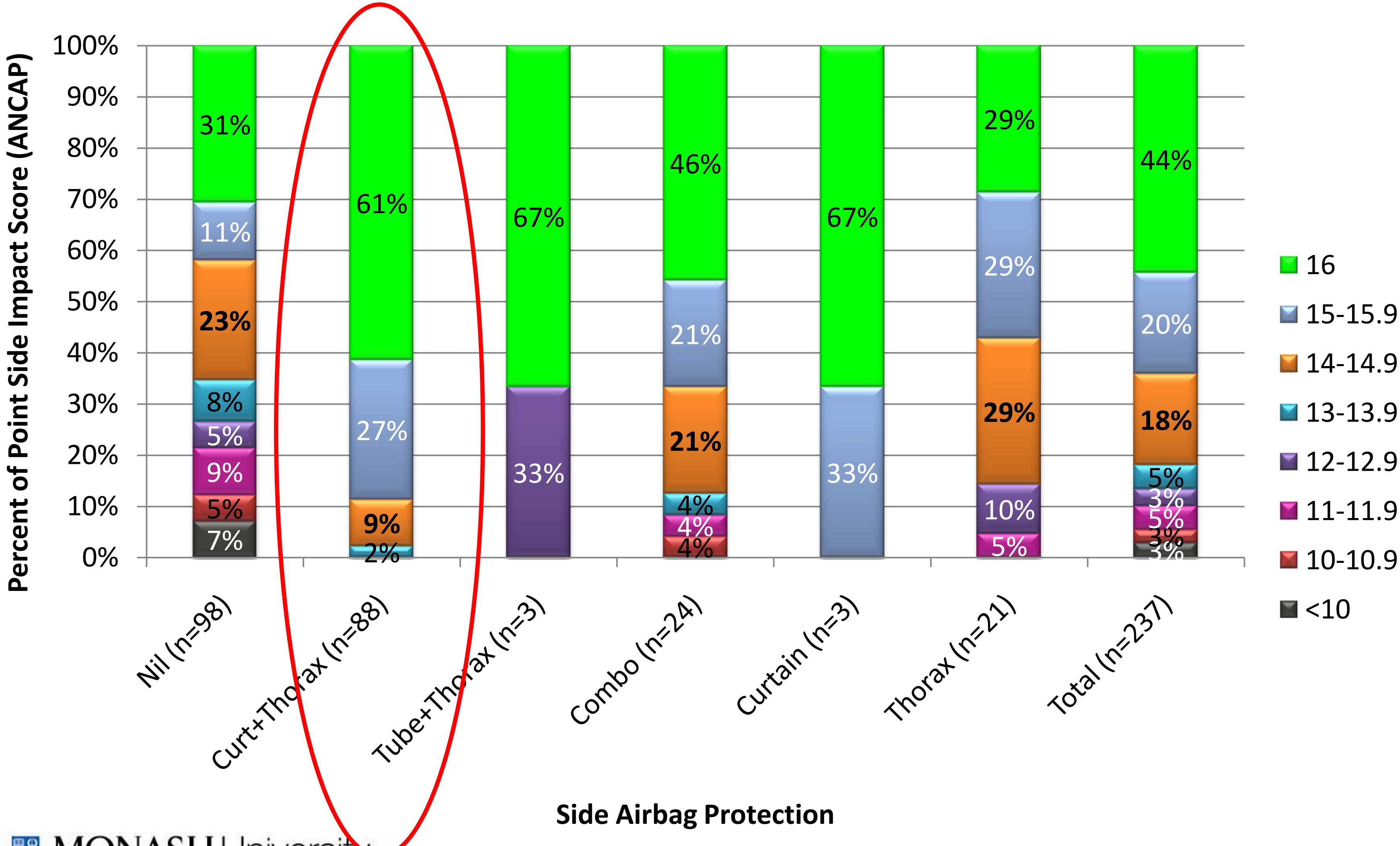
What will the side impact performance of new vehicles be?

- Based on past NCAP test results, assessed whether the EEVC ‘low cost’ is reasonable for Victoria in 2015
- 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)
- It is known all new M1 vehicles will have curtain + thorax SAB fitted by mid-2014, so question is, how might they score on 2008 barrier test?

Side impact AB system & ANCAP Side Impact Points



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Vehicle safety performance and cost

- Safety of new vehicles at the time of GTR increment implementation is critical
- Has implications for the nature of the ‘increment’ and the associated cost
- EEVC specified a ‘low’ cost of €121, using 2007 values
  - the value reflected vehicles achieving ‘maximum points’ in he 2008 side impact protocol
  - Implicit assumption that vehicles fitted with curtain airbags
  - using standard discount rates of 7%, in 2015 terms the value is approximately €70.
- NHTSA stated in their ‘Amending Report’ for side impact protection incremental costs ranging from $USD 33 to $USD 66, in 2004 values
- Advice to the researcher indicated a proximate value of ‘about $70’ to achieve the increment

Vehicles requiring full or increment cost

- **M1 vehicles**: 100% fitment of curtain SAB, so increment only cost
- N1 vehicles: by commencement of 2015, 40% will have SAB fitted as standard, hence 60% will require full implementation cost ($140)

N1 vehicle class	Percent of N1 new vehicle sales	Side airbag fitment rate, end 2014	N1 requirements to meet GTR (2015 for 1 year only, thereafter increment only	
			% requiring full implementation cost (2015) ($140)	% requiring incremental cost only ($40)
Vans	16.97%	1.7%	16.69%	0.28%
PU-CC 4 x 2	30.23%	36.2%	19.29%	10.94%
PU-CC 4 x 4	52.8%	53.74%	24.43%	28.37%
N1 vehicles	100%	-	60.41%	39.59%

Derivation of GTR benefit

- The improved side impact protection translates to lives saved and injuries mitigated for each year using the following parameters
- M1
  - ESC effectiveness of 18% for SVA, run-off-road; nil for other side impact
  - SAB effectiveness
    - Fatal: 32% reduction
    - Injury: 34% reduction
  - GTR offers 50% improvement on these published, averages
  - All costs and benefits @ 7% discount rate
- N1
  - as above, except ESC has 45% crash reduction benefit

Cost of injury values and translation to GTR benefits

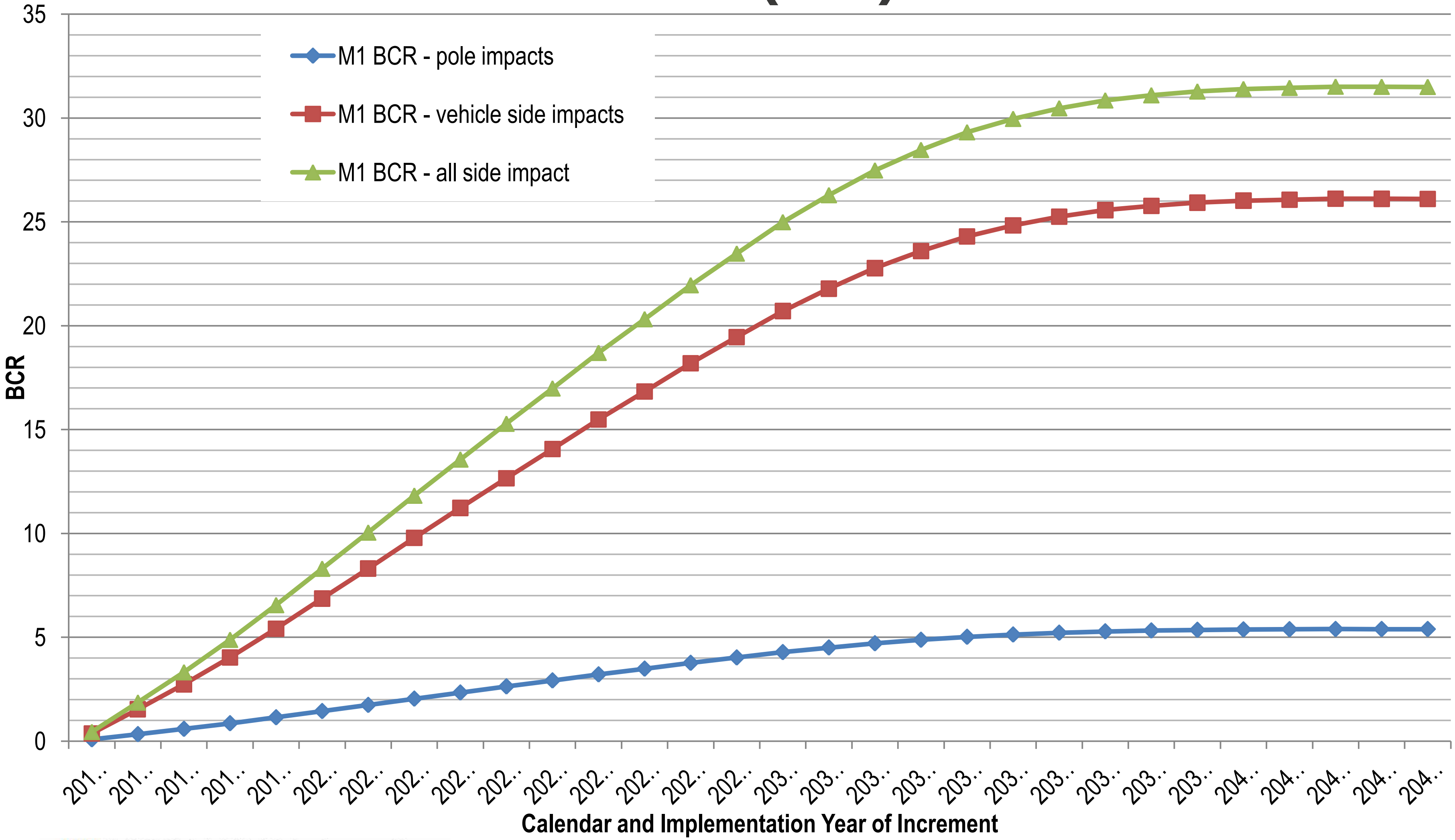
- **Fatality values:** value of statistical life being $AUD 4.938,964 million per incident case.
- **Injury values – applied on basis of known injury distributions:**
  - 'Serious' : $AUD 804,618.00
  - 'Minor' injuries: $AUD 29,709
  - Severe TBI: $AUD 4.8 million per incident case, and taken to be AIS 4+ injuries and / or a Glasgow Coma Score of 3-8
  - Moderate TBI: $AUD 3.7 million per incident case, and taken to be AIS 3 and / or GCS 9-11
  - SCI - paraplegia: $AUD 5 million per incident case

GTR and M1 vehicles

Findings – Incremental benefits of a GTR (Victoria)

Incremental benefits	Pole impacts	Vehicle-to-Vehicle	All
Additional Fatalities avoided	82	124	206
Additional TBI-severe avoided	129	722	851
Additional TBI-moderate avoided	51	288	339
Additional Paraplegia avoided	7	48	55
Additional Serious injuries avoided	1125	6305	7430
Additional Minor injuries avoided	602	3371	3973
Financial benefits, 2015-2043	$605,651,954	$2,921,340,152	$3,526,992,106
GTR requirement cost@ $70 per vehicle	$215,050,759	$215,050,759	$215,050,759
BCR @ incremental $70	2.82	13.58	16.40
BCR in Yr 30	5.39	26.11	31.50

M1 BCR for increment ($70)



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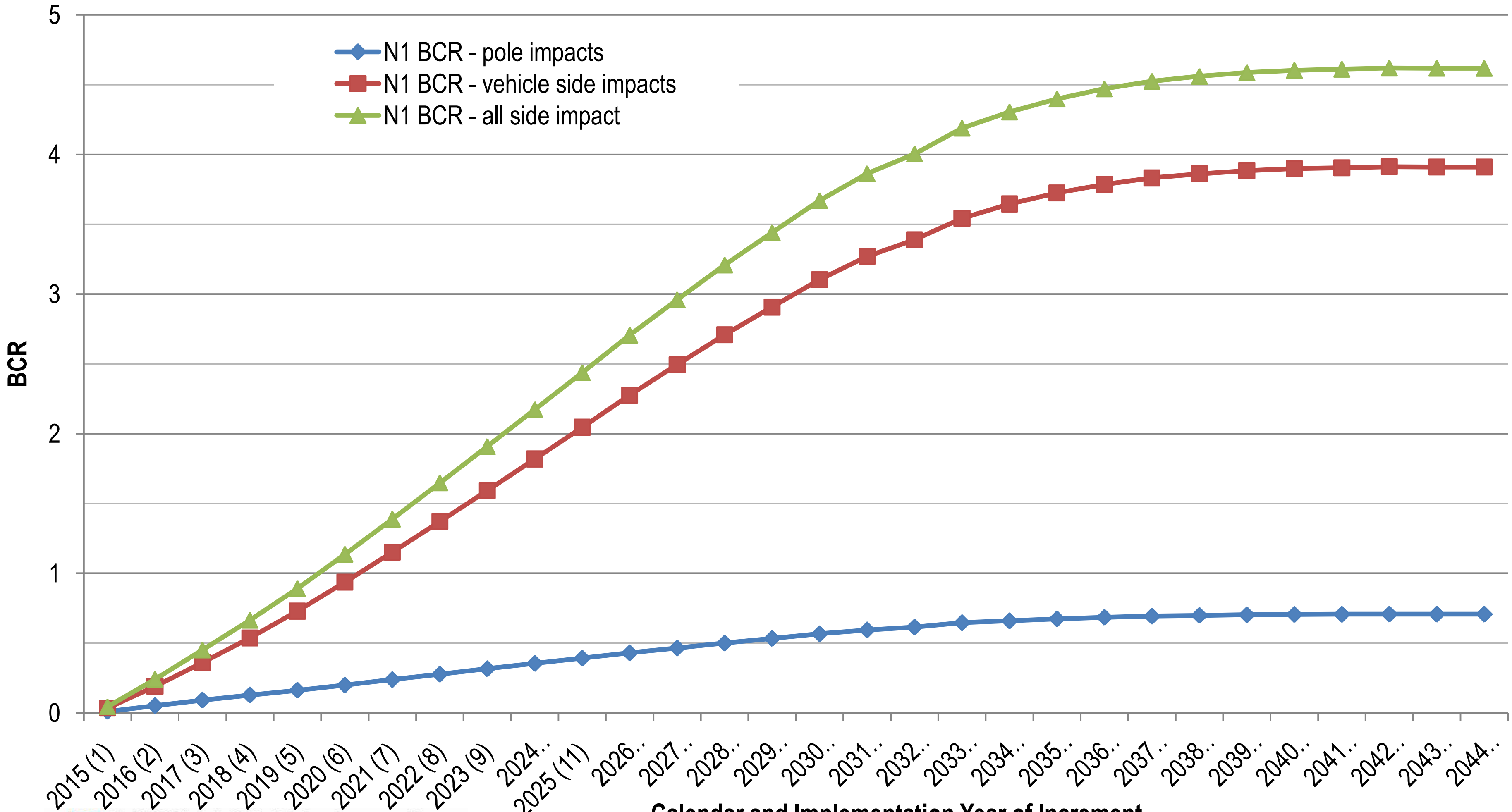
GTR and N1 vehicles

Findings – Incremental benefits of a GTR (Victoria)

Incremental benefits	Pole impacts	Vehicle-to-Vehicle	All
Additional Fatalities avoided	5	20	25
Additional TBI-severe avoided	11	60	71
Additional TBI-moderate avoided	4	24	28
Additional Paraplegia avoided	1	4	5
Additional Serious injuries avoided	93	525	618
Additional Minor injuries avoided	49	280	329
Financial benefits, 2015-2043	$47,965,927	$254,578,777	$302,544,704
GTR requirement cost@ $41.53 per vehicle	$127,586,543	$127,586,543	$127,586,543
BCR @ incremental $41.53	0.38	2.0	2.37
BCR in Yr 30	0.71	3.91	4.62

N1 BCR for increment (@ $40 + full cost year 1 ($140)



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Thank-you for your attention

Questions?