IIHS crashworthiness evaluations for the protection of occupants in low-severity rear impacts

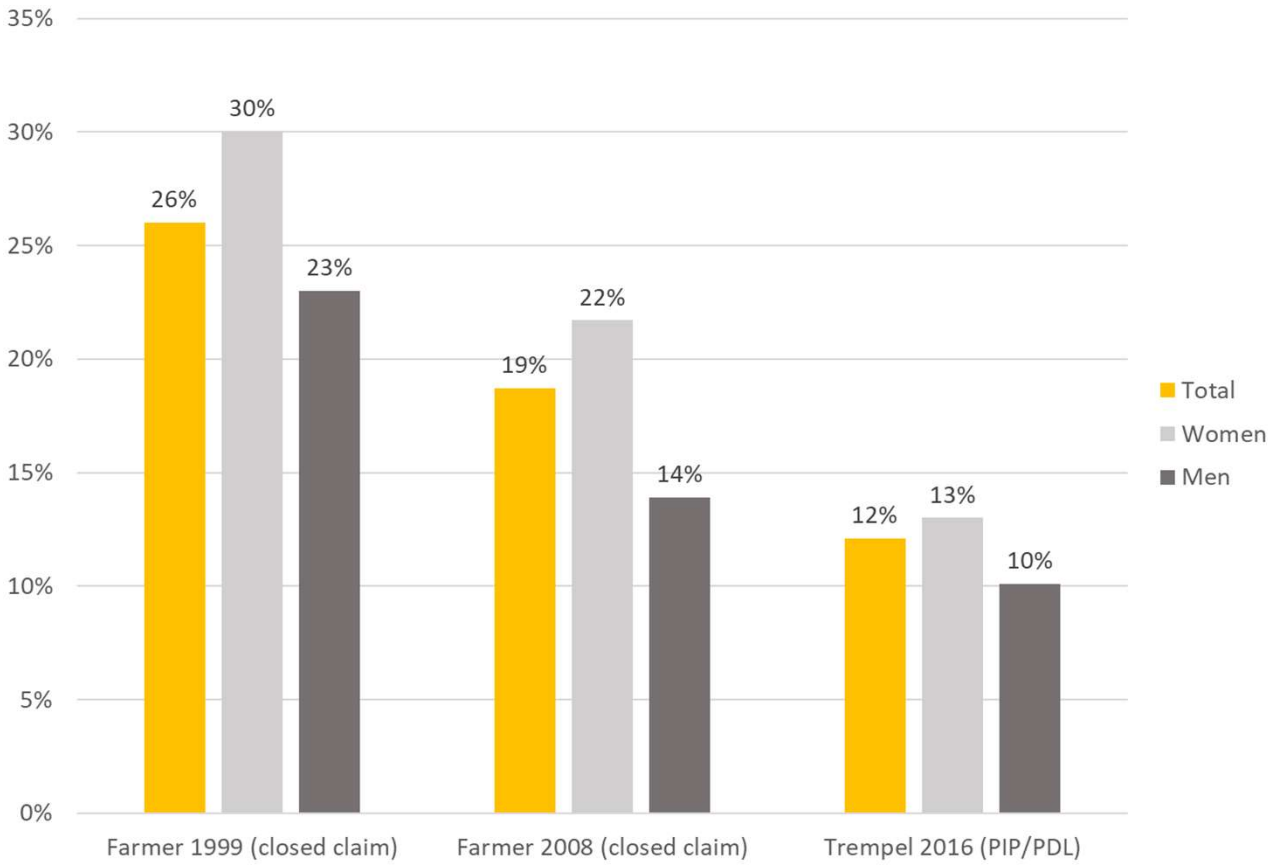
UNECE Ad-hoc working group

9/22/22

Marcy Edwards
Senior research engineer

Whiplash injury over time

Percent of rear struck drivers with neck (or any) injury



Geometry ratings

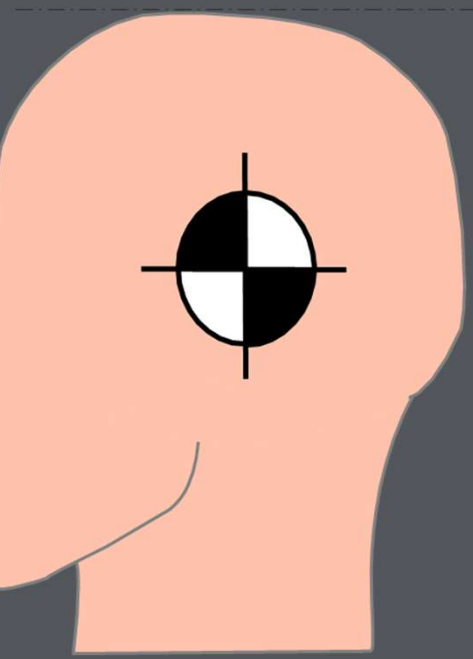
1995

Early model head restraints

Geometry ratings

Since 1995

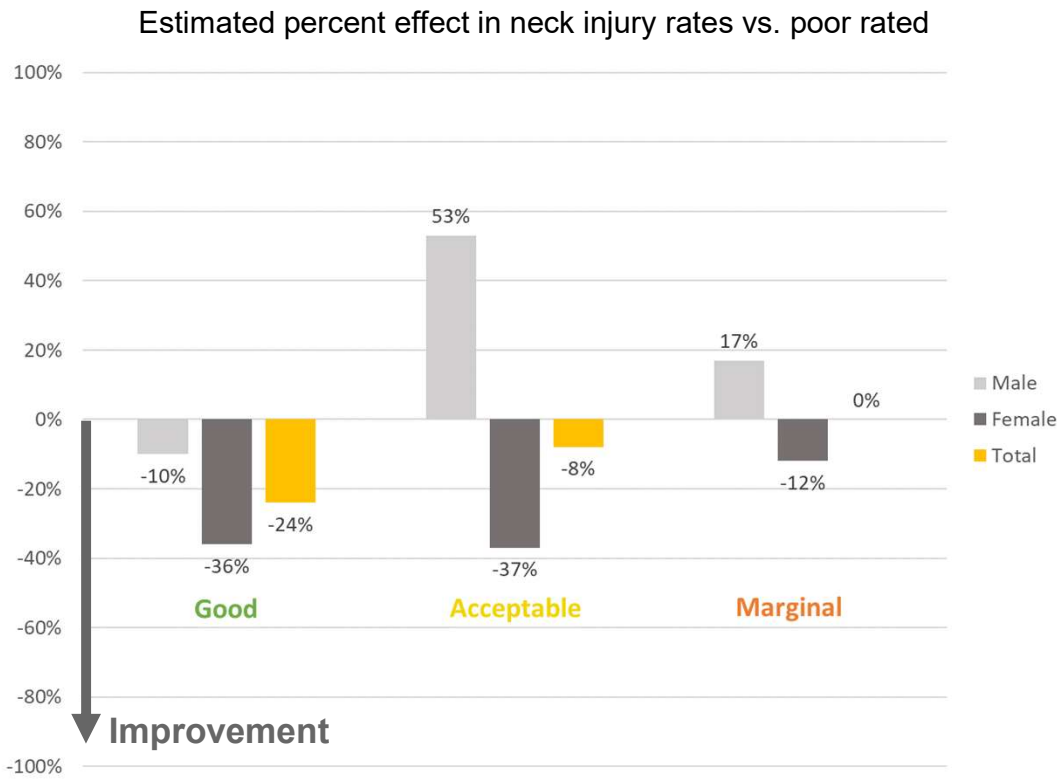
Implemented geometry ratings to get head restraints higher and closer to the head



Real-world benefit of improved head restraint geometry

- Driver of vehicles with good rated head restraints are 24% less likely to suffer neck injury than those in poor rated vehicles
- For every rating category, females have a greater benefit from improved head restraint geometry

Farmer 1999



Advanced seat designs

2003

Active head restraint examples

Volvo WHIPS

Saab AHR

Advanced seat/head restraint designs

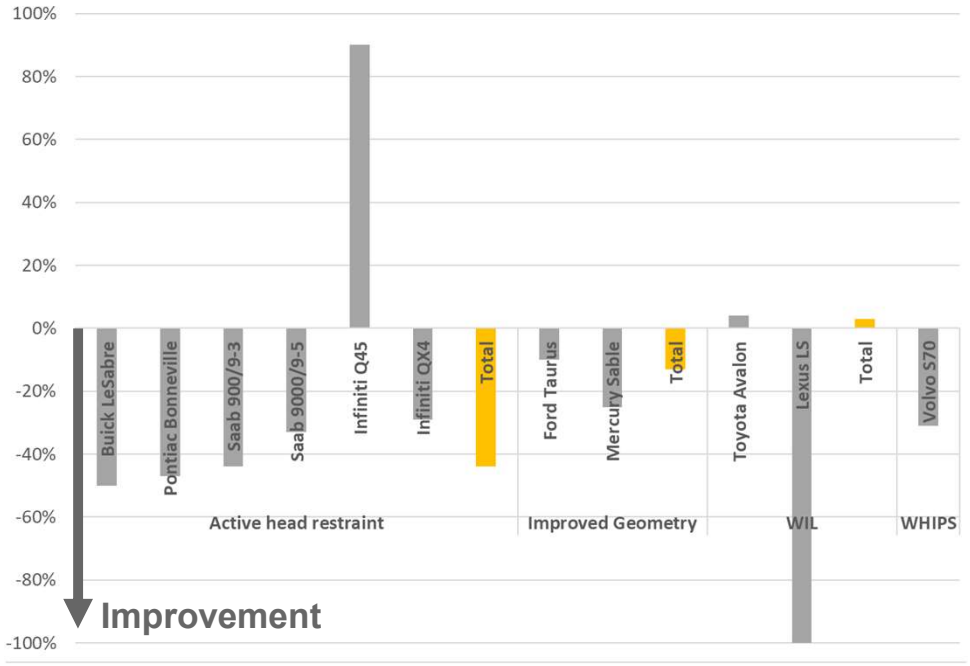
Seating system design change	Vehicle model
Active head restraint	Buick LeSabre
	Pontiac Bonneville
	Saab 900/9-3
	Saab 9000/9-5
	Infiniti Q45
	Infiniti QX4
Improved geometry	Ford Taurus
Advanced seating system	Mercury Sable
	Toyota Avalon
	Lexus LS 430
	Volvo S70

Real-world benefit of advanced seat designs

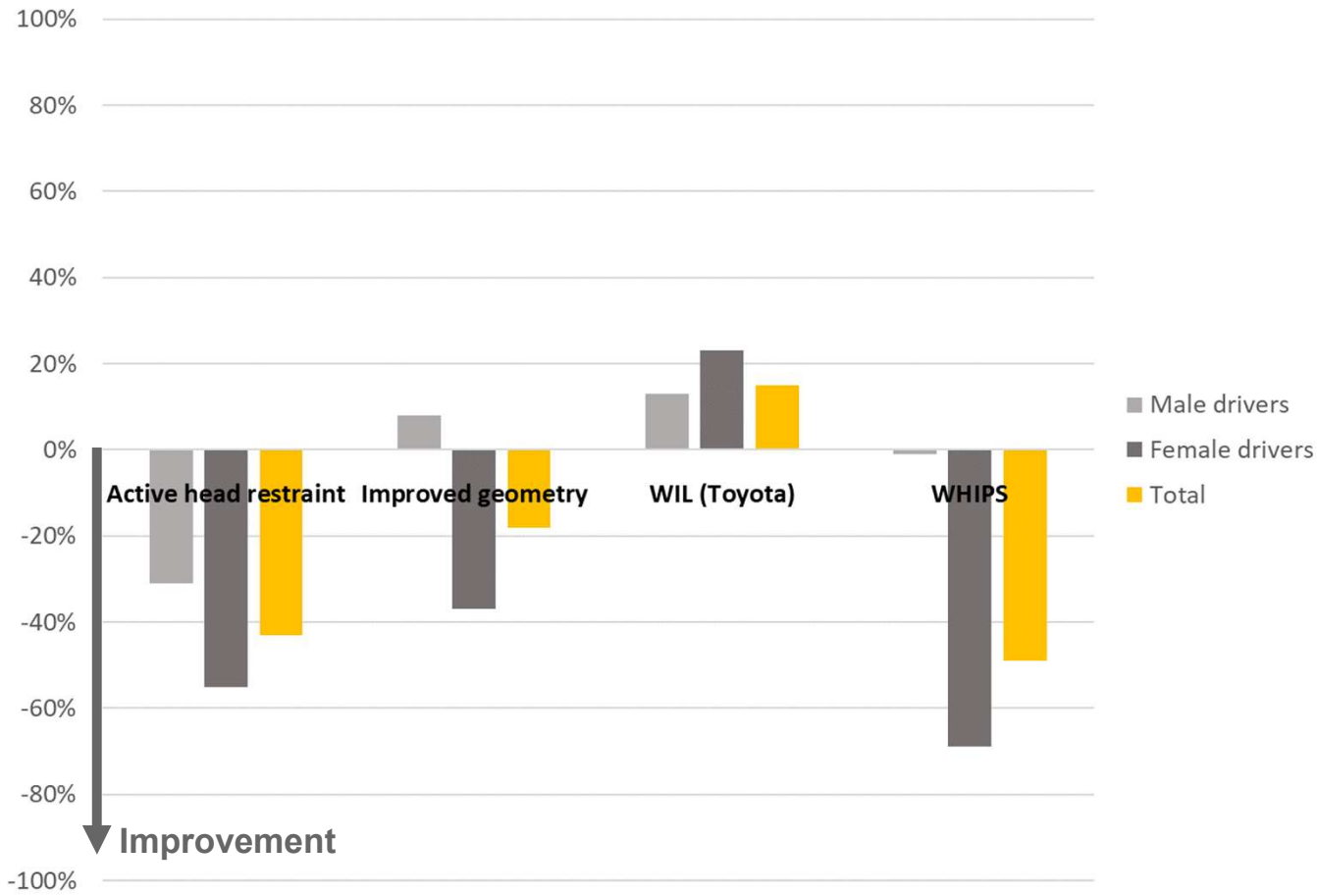
- Active head restraints had an overall 44% reduction in neck injury rates
- Improved geometry had a 13% reduction in neck injury rates
- Toyota WILS design had a 3% increase in neck injury rates
- Volvo WHIPS had a 31% decrease in neck injury rates

Farmer 2003

Percent change in driver neck injury risk
by seat and seat design change



Estimated percent effect of seating design changes on driver neck injury risk

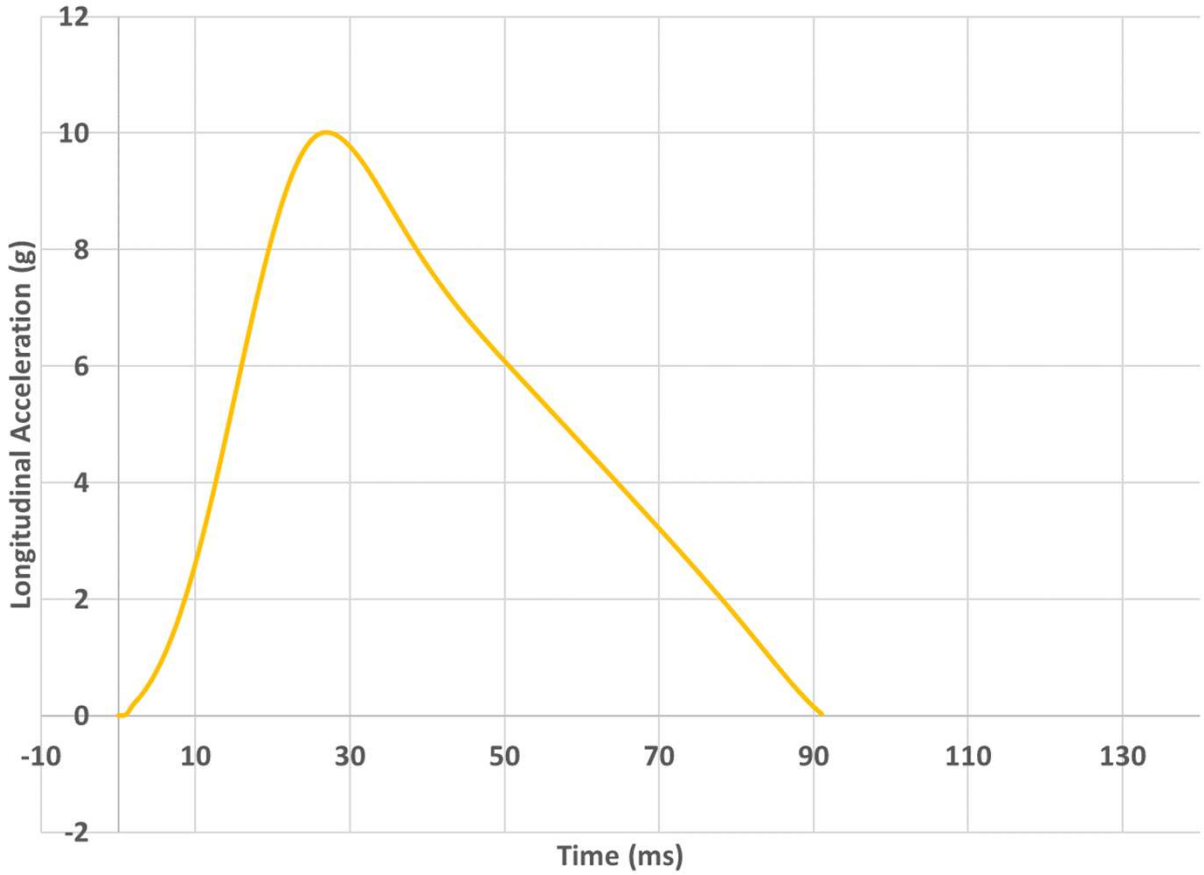


Dynamic testing

2004

IIWPG sled pulse

16 km/h



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Rating table

Geometric Rating	Dynamic Rating	Overall Rating
Good	Good	Good
	Acceptable	Acceptable
	Marginal	Marginal
	Poor	Poor
Good Height →	Good	Good
Acceptable		Acceptable
	Acceptable	Acceptable
	Marginal	Marginal
	Poor	Poor
Marginal	No dynamic test	Poor
Poor	No dynamic test	Poor

IIHS HLDI

Early model head restraints

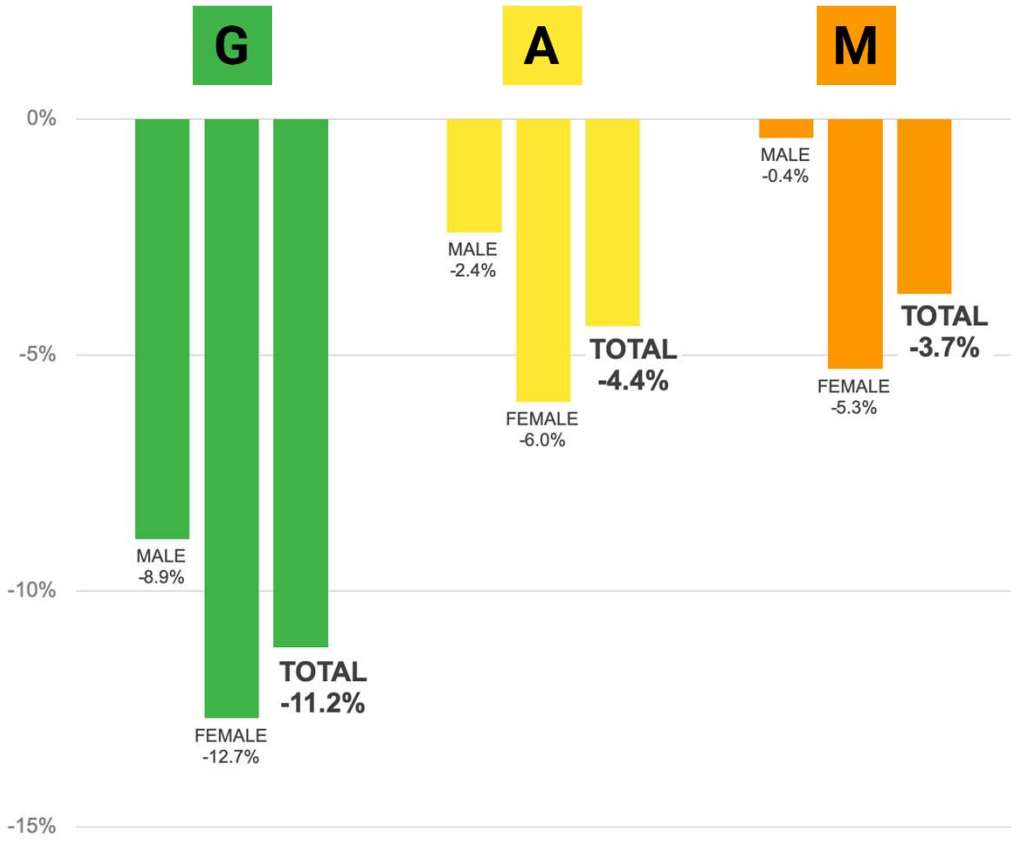
Early model head restraints

Dynamic testing

2016 Analysis

IIHS whiplash evaluation

Percent reduction in injury claim rates vs. poor-rated seats



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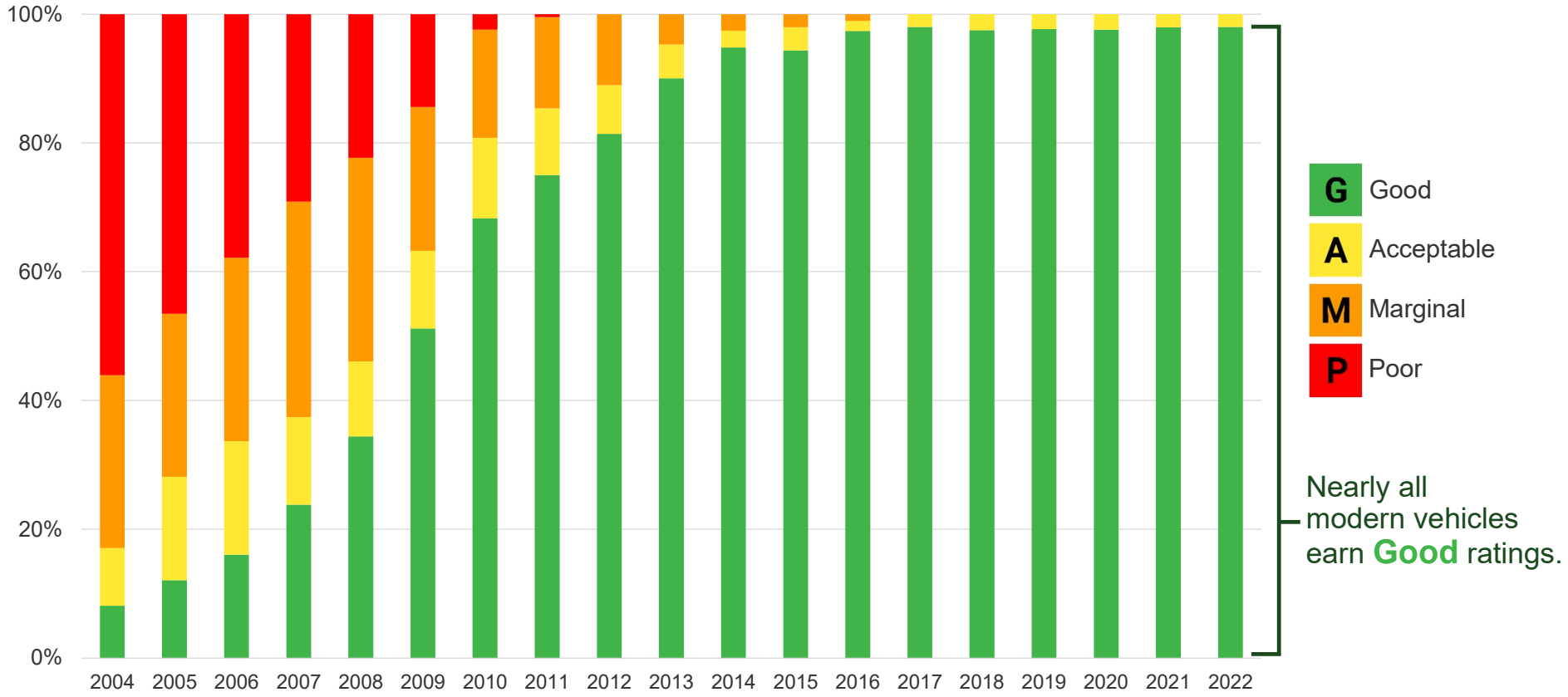
Additional outcomes

- Newer vehicles had lower injury rates than older vehicles
- The oldest rated drivers had the lowest injury rates
- The vehicle group with the lowest curb weight had the highest injury rate

The future of IIHS whiplash evaluations

Head restraint ratings by model year

As of August 15, 2022



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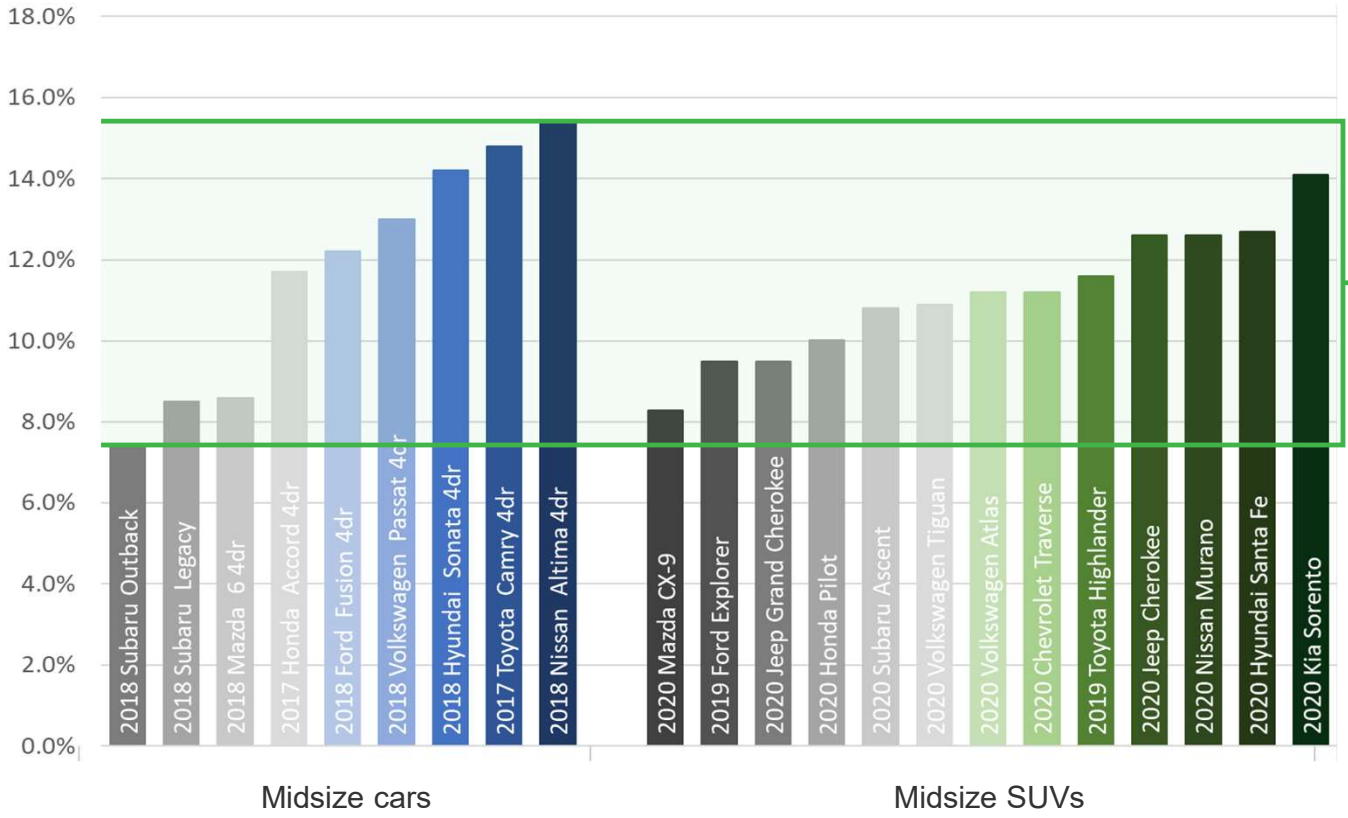
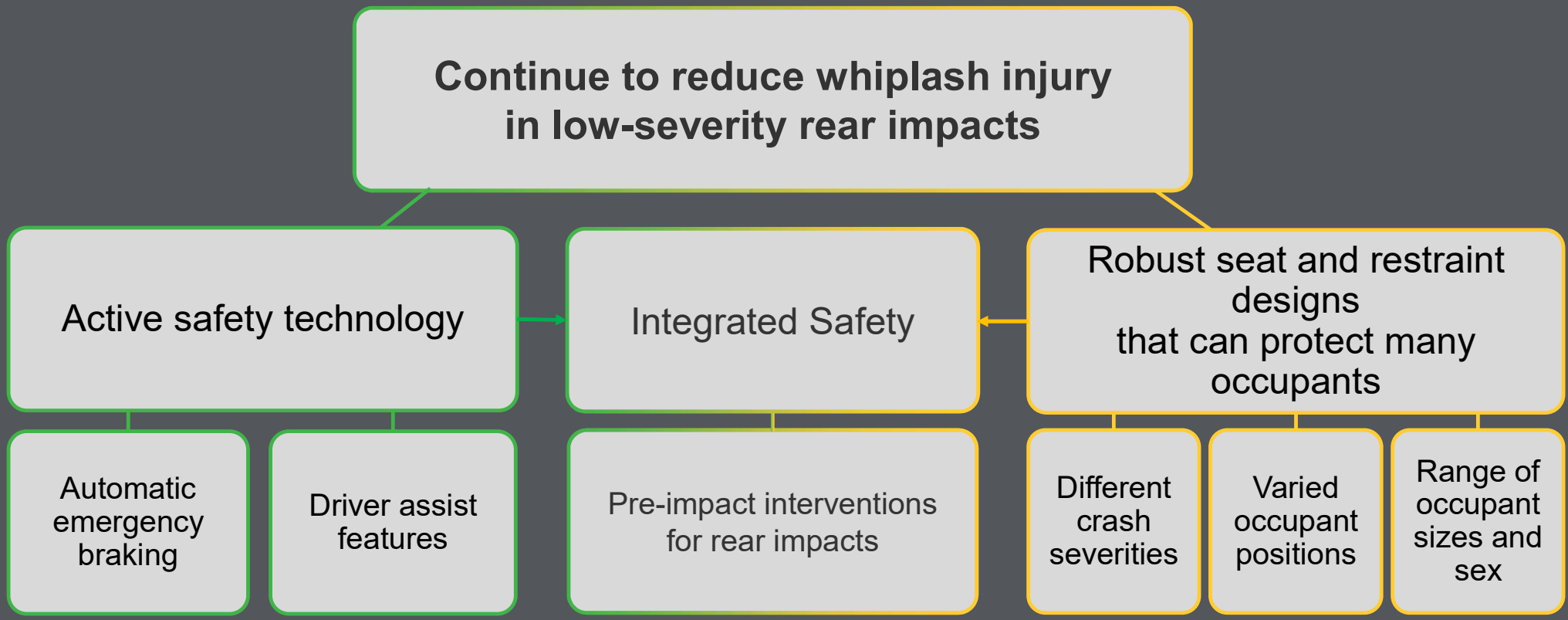
Current IIHS ratings vs. real-world data

Insurance injury claim rates (PIP/PDL by class and vehicle)

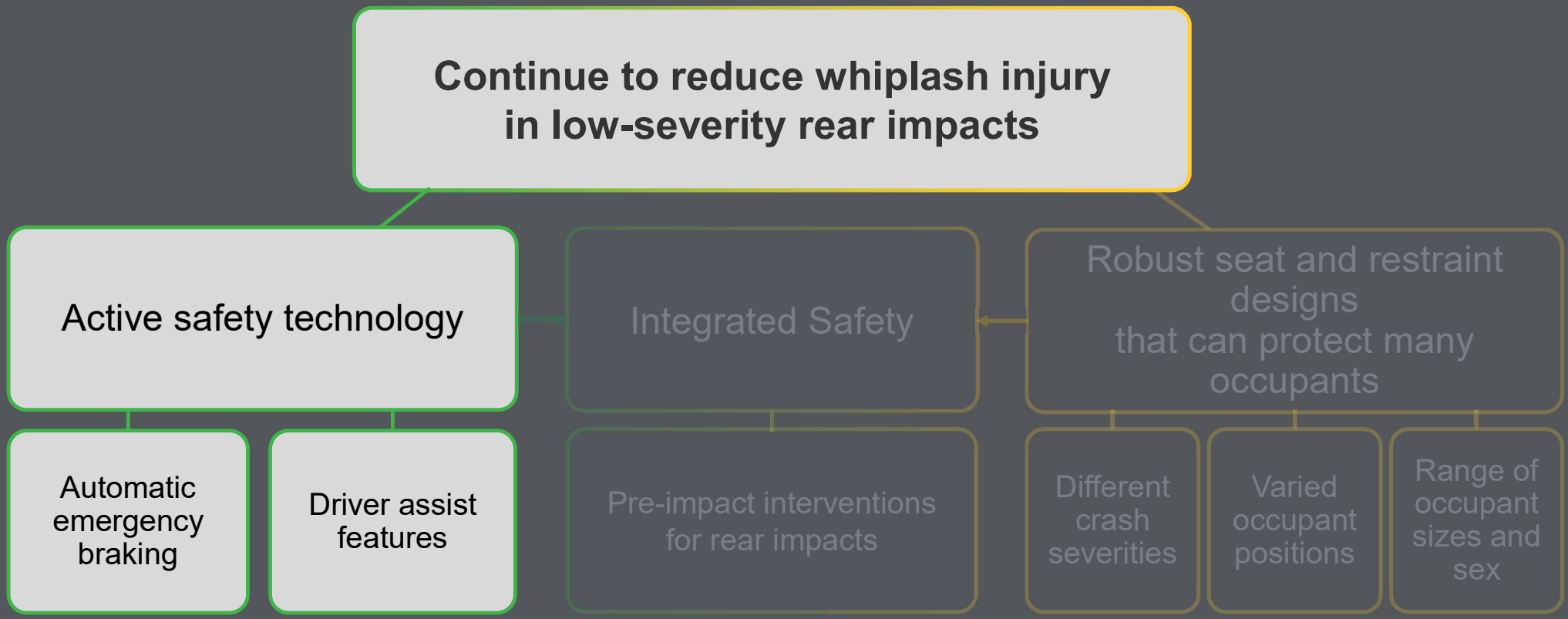


IIHS HLDI

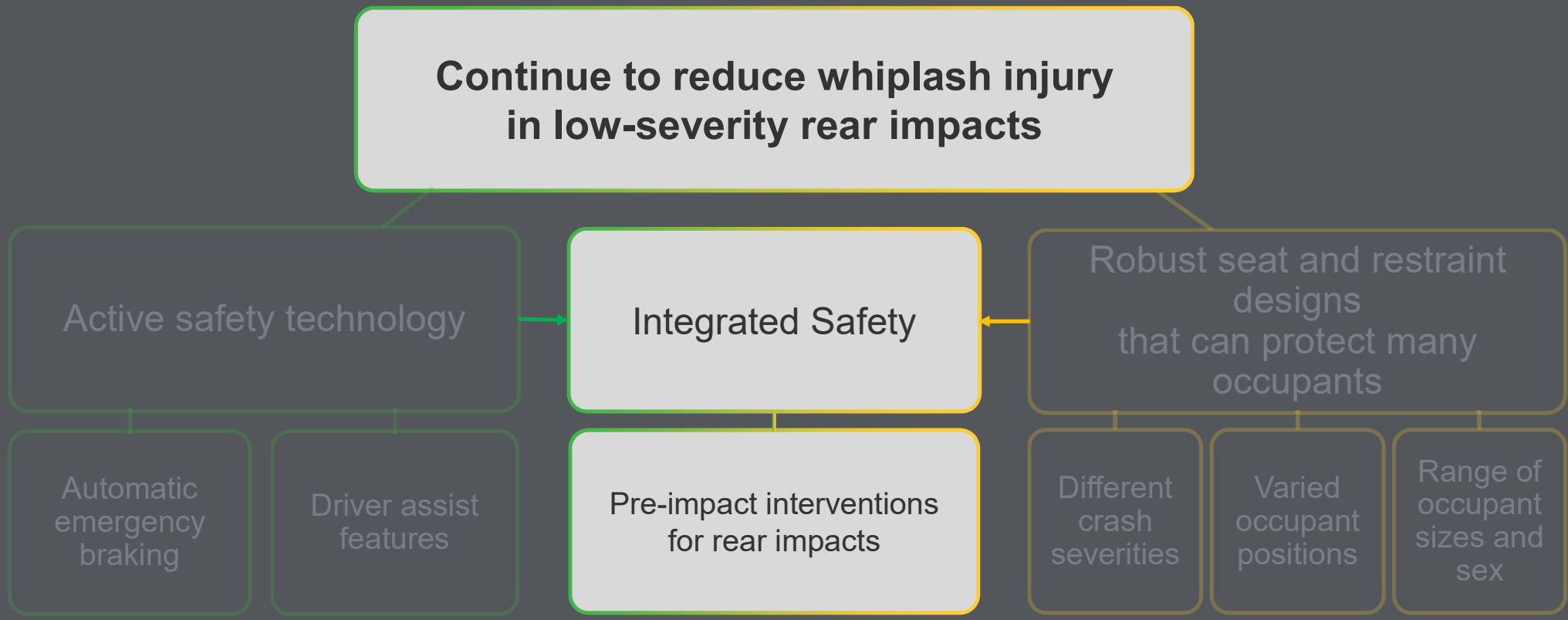
IIHS whiplash safety research goals



IIHS whiplash safety research goals



IIHS whiplash safety research goals



Pre-impact interventions for rear impacts

Pre-impact interventions

IIHS is exploring the potential benefit of systems like Volvo's occupant positioning and Windsor Machine Group's (WMG) active head restraint

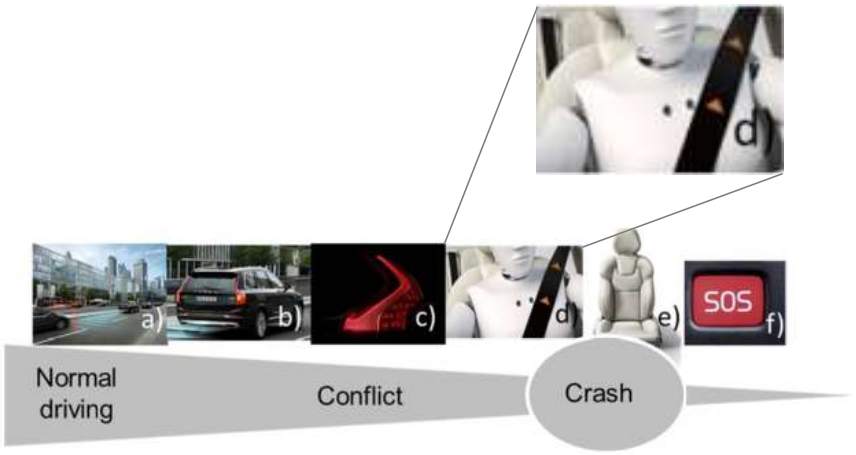


Fig. 1. Rear-end impact sequences: a) detection + activation; b) warning; c) braking; d) occupant pre-positioning; e)WHIPS generation 2; f) eCall.

Volvo pre-impact occupant positioning*

WMG pre-impact active head restraint

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**Jakobsson 2015*

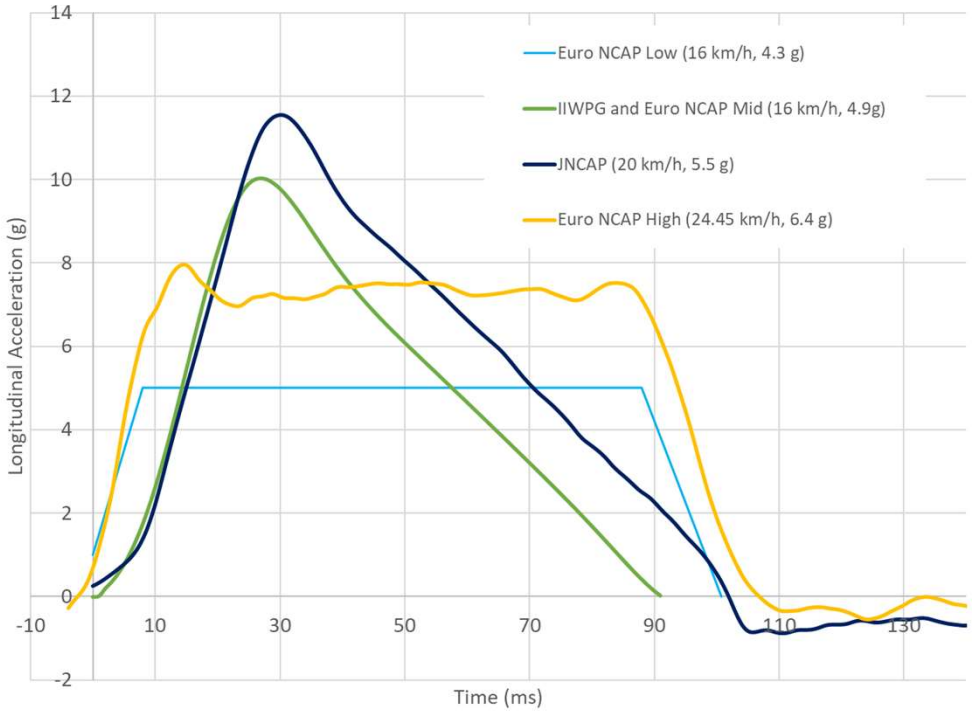
IIHS whiplash safety research goals

NCAP rear impact research review

Current assessment program pulses

	IIHS	Euro NCAP < 2020	Euro NCAP 2020+	JNCAP
Euro Low	-	✓	-	-
IIWPG/ Euro mid	✓	✓	✓	-
JNCAP	-	-	-	✓
Euro High	-	✓	✓	-

Euro NCAP, JNCAP and IIWPG acceleration pulses



Protocol dynamic rating parameters

IIWPG	EuroNCAP < 2020	JNCAP	Euro NCAP 2020 +
Upper Neck Rearward Shear	Upper Neck Rearward Shear	Upper Neck Rearward Shear	**Upper Neck Shear (+/-)**
Upper Neck Tension	Upper Neck Tension	Upper Neck Tension	**Upper Neck Tension**
Head Contact Time	Head Contact Time		Head Contact Time
Maximum T1 Acceleration	Maximum T1 Acceleration		Maximum T1 Acceleration
	NIC	NIC	**NIC**
	Max NKM		Max NKM
	Head Rebound Velocity		Head Rebound Velocity
		Upper Neck Flexion	Upper Neck Flexion
		Upper Neck Extension	Upper Neck Extension
		Lower Neck Rearward Shear	Lower Neck Shear (ABS)
		Lower Neck Tension	Lower Neck Tension
		Lower Neck Flexion	Lower Neck Flexion
		Lower Neck Extension	Lower Neck Extension
			Seatback dynamic deflection

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Test matrix

MY Begin	MY End	Make	Model	PDL #	PIP #	PIP/PDL	Euro Low	IIWPG/ Euro mid	JNCAP	Euro High
Mid-size cars										
2015	2018	Subaru	Outback	3071	227	7.4%	-	✓	✓	✓
2015	2018	Subaru	Legacy	1288	109	8.5%	-	✓	✓	✓
2014	2018	Mazda	6 4dr	3214	276	8.6%	-	✓	✓	✓
2013	2017	Honda	Accord 4dr	24961	2909	11.7%	-	✓	✓	✓
2013	2018	Ford	Fusion 4dr	8802	1075	12.2%	-	✓	✓	✓
2012	2018	Volkswagen	Passat 4dr	7981	1035	13.0%	-	✓	✓	✓
2015	2018	Hyundai	Sonata 4dr	5555	790	14.2%	-	✓	✓	✓
2012	2017	Toyota	Camry 4dr	30441	4498	14.8%	-	✓	✓	✓
2013	2018	Nissan	Altima 4dr	19351	2979	15.4%	-	✓	✓	✓
Mid-size SUVs										
2016	2020	Mazda	CX-9	957	79	8.3%	-	✓	-	✓
2011	2020	Jeep	Grand Cherokee*	21662	2063	9.5%	-	✓	-	✓
2018	2019	Ford	Explorer	1260	120	9.5%	-	✓	-	✓
2016	2020	Honda	Pilot	5569	555	10.0%	-	✓	-	✓
2019	2020	Subaru	Ascent	305	33	10.8%	-	✓	-	✓
2018	2020	Volkswagen	Tiguan	1275	139	10.9%	-	✓	-	✓
2018	2020	Volkswagen	Atlas	807	90	11.2%	-	✓	-	✓
2018	2020	Chevrolet	Traverse	1265	142	11.2%	-	✓	-	✓
2014	2019	Toyota	Highlander	10199	1188	11.6%	-	✓	-	✓
2015	2020	Nissan	Murano	2789	351	12.6%	-	✓	-	✓
2014	2020	Jeep	Cherokee**	9424	1187	12.6%	-	✓	-	✓
2013	2018	Hyundai	Santa Fe	2211	280	12.7%	-	✓	-	✓
2018	2020	Kia	Sorento	1075	152	14.1%	-	✓	-	✓

*** Proactive** **** Reactive**

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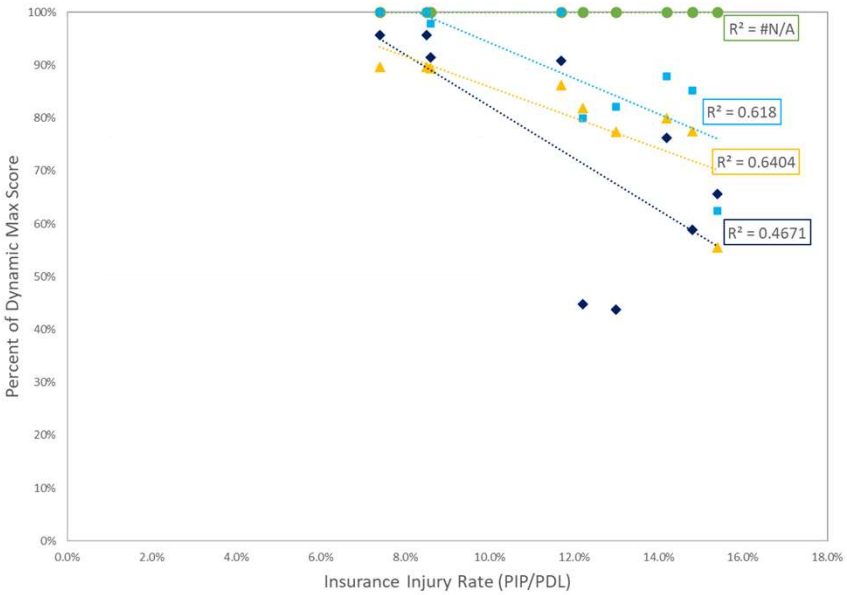
Overall ratings

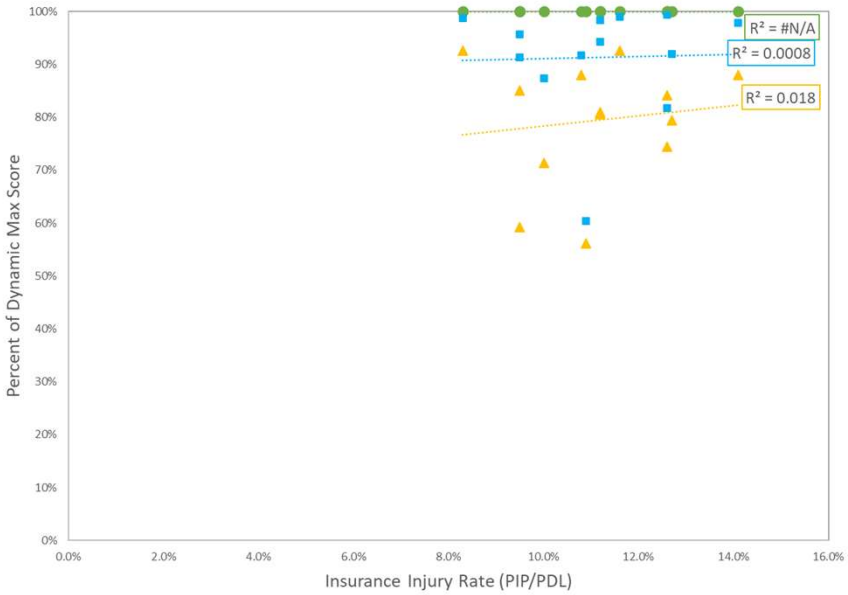
Midsize cars

NCAP rating vs. injury claim rate



Midsize SUVs

NCAP rating vs. injury claim rate



IIHS rating JNCAP rating Euro NCAP < 2020 overall rating Euro NCAP 2020+ overall rating

Individual Injury metrics evaluated

Upper Neck Shear	Upper Neck Flexion
Upper Neck Tension	Upper Neck Extension
Head Contact Time	Lower Neck Shear
Maximum T1 Acceleration	Lower Neck Tension
NIC	Lower Neck Flexion
Max NKM	Lower Neck Extension
Head Rebound Velocity	Pelvis Displacement

Individual Injury metrics evaluated

Upper Neck Shear	Upper Neck Flexion
Upper Neck Tension	**Upper Neck Extension**
Head Contact Time	Lower Neck Shear
Maximum T1 Acceleration	Lower Neck Tension
NIC	Lower Neck Flexion
Max NKM	Lower Neck Extension
Head Rebound Velocity	Pelvis Displacement

Summary and next steps

- Overall rating correlations seen in the mid-size car dataset are not apparent in the midsize SUV data set
- Individual metrics upper extension moment, Max NKM and T1 acceleration showed correlations worth further investigation
- Individual metrics were less likely to show correlations with the injury claim rates with the IIWPG pulse than the Euro NCAP high pulse
- Continued analysis on individual metrics of interest
- Look at the effect of mass disparity in the midsize SUV class on results (e.g. 2WD vs. 4WD)

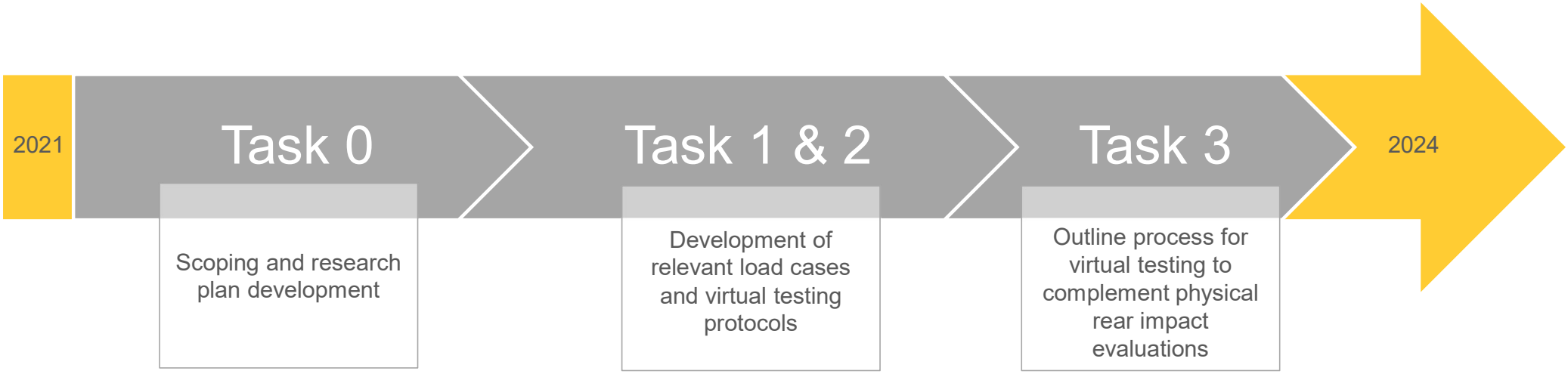
IIHS whiplash safety research goals

Virtual testing for rear impacts

Research motivations

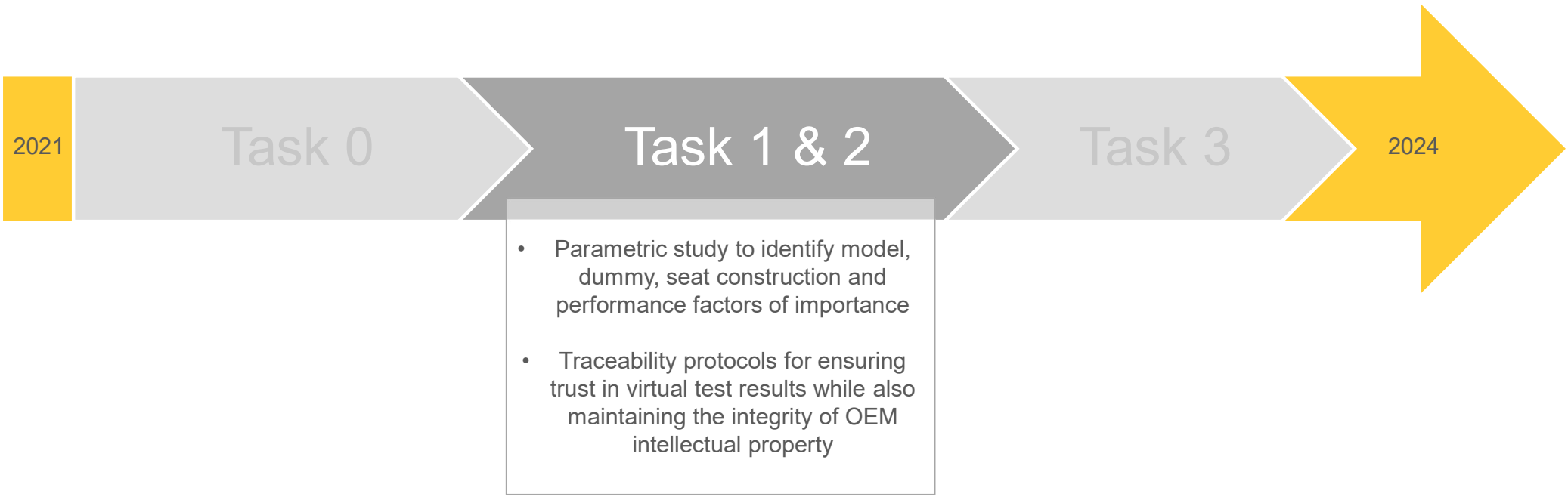
- Develop a virtual testing framework that can be used to promote seat safety robustness for a range of occupant size, sex, and seating position
- Lay groundwork for the possible use of human body models to evaluate rear impact whiplash
- Gain organizational experience with virtual testing and explore opportunities where virtual testing could be feasible and beneficial
- Develop a framework for the certification and validation of automaker seat models and/or automaker simulation results, data sharing with automakers and a workflow for virtual testing

Virtual testing research plan



Virtual testing research plan

Virtual testing research plan



Research Item 1 – Overview

What affects rear impact responses?

Parameter exploration

Automated simulations

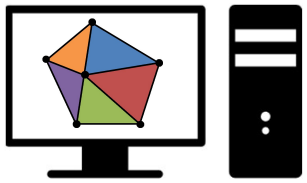
Outcomes

Factors that influence response

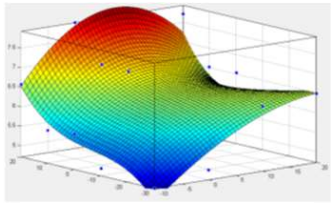
Inform future validation cases

Recommendations on injury metrics

Seat and restraint



Modeling factors



Response models
Data analysis

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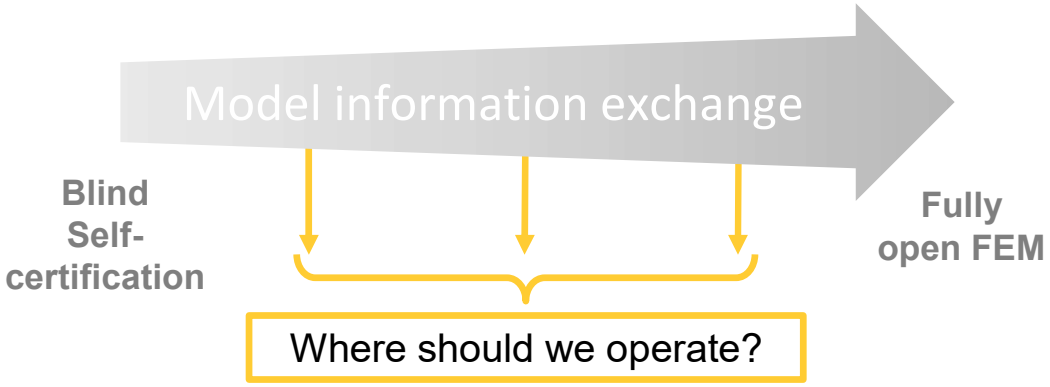
Research Item 2 – Model traceability

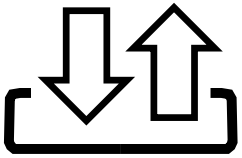
Sharing information without compromising IP concerns

How much information needs to be exchanged?



How do we protect IP concerns?

Fingerprinting



Input-output
checker report

Key takeaways

- Current evaluation tools have reduced injuries in rear impacts for both men and women and reduced the gap in risk of injury
- Women are still at a higher risk for whiplash injury than men
- Virtual testing provides opportunities to address equity and robustness in crashworthiness evaluations

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THANK YOU

Marcy Edwards
Senior Research Engineer
medwards@iihs.org