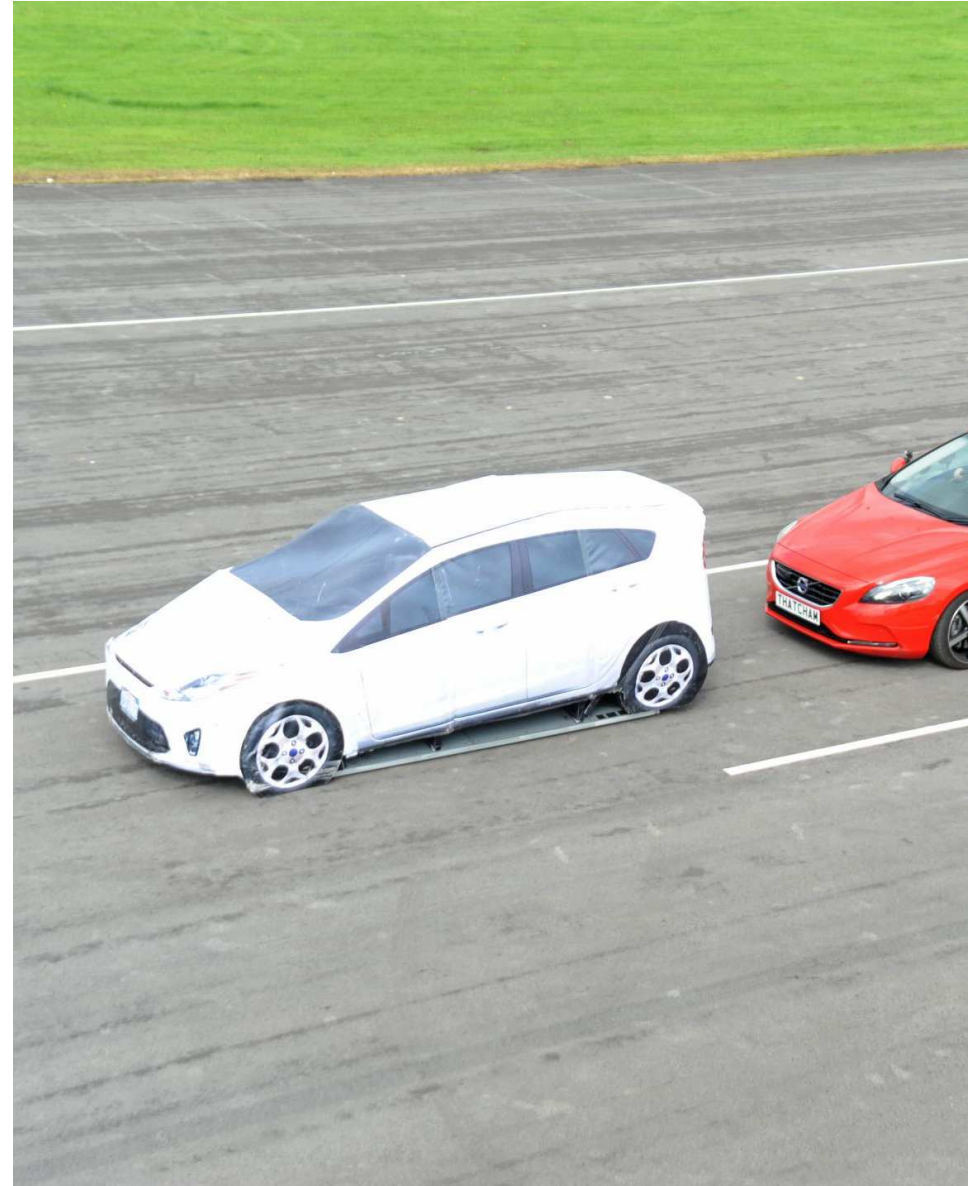


AEB at Thatcham Research and in Euro NCAP

Colin Grover

Principal Engineer – ADAS & Automated Driving

November 2017



Introduction

Introduction to Thatcham

AEB test development leading up to 2014 Euro NCAP implementation

Developments for 2018 AEB testing

Future Euro NCAP road map AEB developments

About Thatcham...

...“Safer cars, fewer crashes”

- Formed in 1969
- Funded by UK Motor Insurers
- Annual turnover £16m, not for profit
- Helping insurers control the cost of claims
- More recently, understanding risk



Thatcham Research

Core **Activities**

- Automated Driving
- Claim of the Future Modelling
- Enhanced Vehicle Data (ADAS)
- Vehicle Safety Research & Testing
- Repair Research (Methods & Times)
- Training & Accreditation
- Vehicle Security Research & Testing

Thatcham and AEB

10+ year relationship

- UK Government challenge to insurers – control cost of insurance
- Personal injury (whiplash) claims ever increasing despite great seat improvements
- AEB prevents collision and catalyst for insurance claim

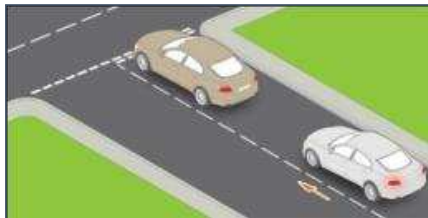


AEB Group



“To design and implement test procedures reflecting real world data that can encourage the development of autonomous braking technology that can help prevent or mitigate the effects of car-to-pedestrian and car-to-car crashes”

- Analyse real world accident data to define test scenarios
- Define and specify test methods and measurement equipment
- Define test metrics and rating process
- Publish results/ratings to inform consumers/stakeholders of technology capability
- Integrate into existing consumer test programs (RCAR)
- Offer to Euro NCAP PNCAP for consideration for future test program



Thatcham

Folksam®

INSURANCE INSTITUTE
FOR HIGHWAY SAFETY
VEHICLE RESEARCH CENTER

Unfallforschung
der Versicherer
GDV



LOUGHBOROUGH STUDY OF ALL UK CRASHES

Unique in-depth study commissioned by Thatcham investigating real world crashes and their causation factors to formulate realistic test scenarios that drive AEB functionalities suitable for Euro NCAP and Insurers

- 11,192 STATS19 CCR cases analysed
- 10,574 STATS19 CP cases analysed
- 50 OTS CCR cases analysed
- 175 OTS CP cases analysed

Aim for 4-6 clusters
≥75% of cases

	Clusters							Total
	1	2	3	4	5	6	7-18	Total
Cluster representativeness (%)								
Slight	30	19	13	12	8	5	13	100
Serious	21	10	12	30	9	4	14	100
Fatal	21	0	0	53	0	11	16	100
Total	30	18	13	13	8	5	14	100
Accident severity								
Slight	3249	2025	1401	1293	890	523	1463	10944
Serious	69	32	41	100	28	12	47	329
Fatal	4	0	0	10	0	2	3	19
Total	3322	2057	1442	1403	918	537	1513	11192
Speed limit (mph)								
10-30	1966	1199	932	364	541	236	827	6064
40-50	582	365	236	190	171	117	274	1925
60-70	774	503	274	849	206	185	412	3203
Total	3322	2057	1442	1403	918	537	1513	11192
Junction detail								
Not at junction	1162	679	85	1403	0	363	633	4325
Roundabout	513	528	140	0	257	174	283	1895
Junction	1647	850	1217	0	661	0	597	4972
Total	3322	2057	1442	1403	918	537	1513	11192
Light conditions								
Daylight	2973	1932	1264	1007	747	399	518	8800
Darkness	349	125	178	396	171	178	995	2392
Total	3322	2057	1442	1403	918	537	1513	11192
Weather conditions								
Fine	3040	1983	1227	1096	840	0	833	9019
Not fine	282	74	215	307	78	537	680	2173
Total	3322	2057	1442	1403	918	537	1513	11192
Vehicle A manoeuvre (striking vehicle)								
Going ahead	3312	0	1225	1403	888	537	515	7880
Stopping, starting, held-up	0	2057	162	0	24	0	735	2978
Turning	10	0	55	0	6	0	263	334
Total	3322	2057	1442	1403	918	537	1513	11192
Vehicle B manoeuvre (struck vehicle)								
Going ahead	0	72	0	1403	918	46	145	2584
Stopping, starting, held-up	3322	1985	0	0	0	491	1088	6886
Turning	0	0	1442	0	0	0	280	1722
Total	3322	2057	1442	1403	918	537	1513	11192
Vehicle directions								
Following	3223	2007	463	1386	869	525	1326	9799
Diverging	63	28	909	8	21	5	124	1158
Converging	36	22	70	9	28	7	63	235
Total	3322	2057	1442	1403	918	537	1513	11192

Example

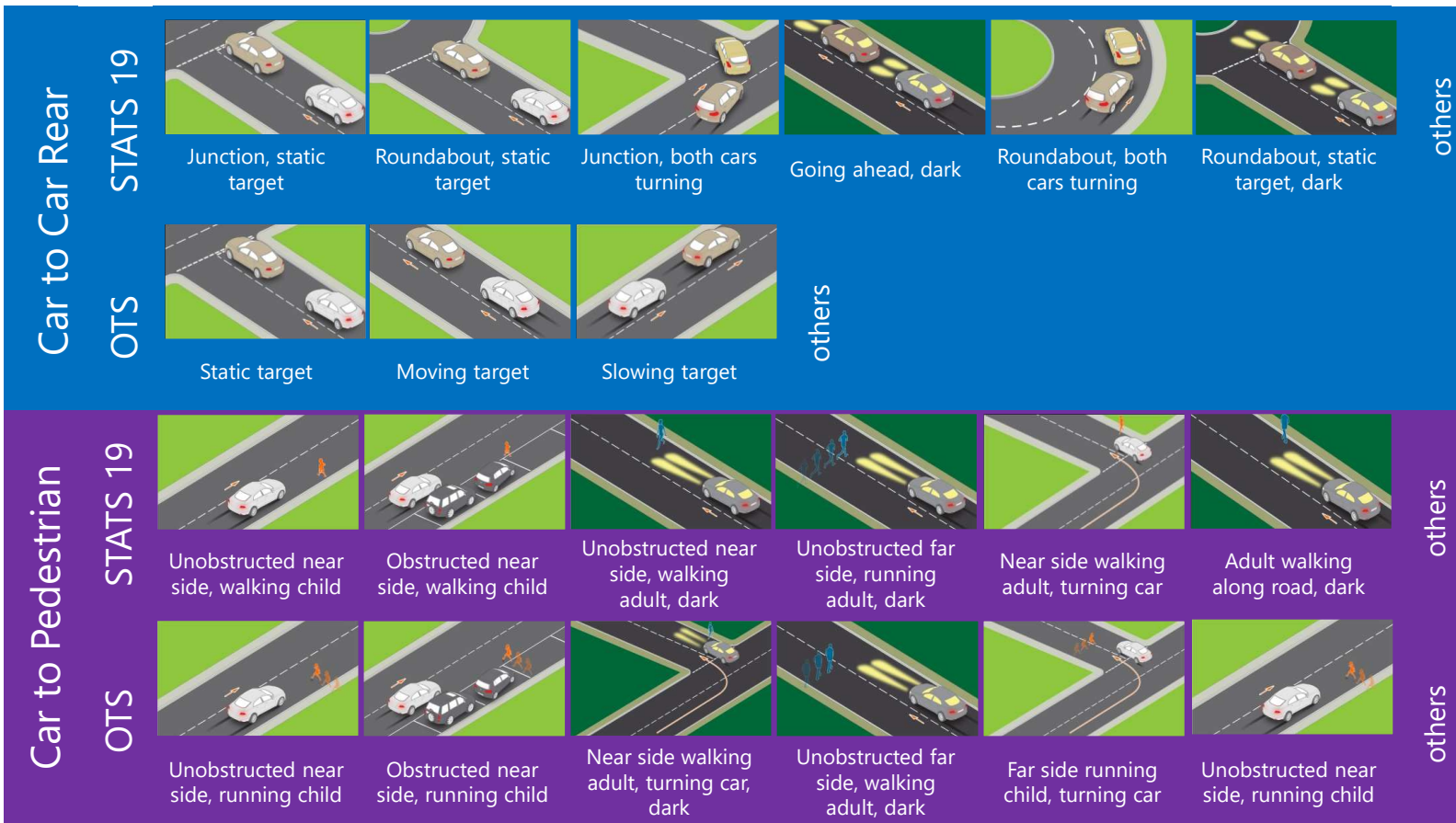
Cluster 1

- 30% of cases
- Lower speeds
- At junction
- Daylight
- Fine weather
- Vehicle A going ahead
- Vehicle B stop/starting
- Following traffic

REAL WORLD DATA



UK ACCIDENT CLUSTERS: WIDE VARIETY OF ACCIDENT TYPES



REAL WORLD DATA



UK ACCIDENT CLUSTERS: WIDE VARIETY OF ACCIDENT TYPES



Car to Car Rear

STATS 19



Junction, static target

Roundabout, static target

OTS



Static target

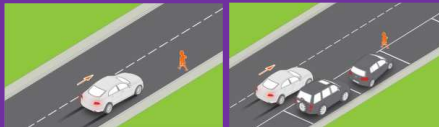
Moving target

Slowing target

Too many scenarios to be feasible for testing, so select scenarios based on real world frequency

Car to Pedestrian

STATS 19



Unobstructed near side, walking child

Obstructed near side, walking child

OTS



Unobstructed far side, running adult, dark




Near side walking adult, turning car

Adult walking along road, dark

REAL WORLD DATA



TEST SCENARIOS SELECTED TO REPRESENT GREATEST FREQUENCY OF REAL WORLD CRASHES

Combining accident data from other international sources			UK	UK	Germany
			STATS 19 n=34,764 cluster analysis rear-end collisions	OTS n=50 cluster analysis rear-end collisions	UDV n=285 (N=30,155) 3rd party vehicle claims 2002-2006 rear-end collisions
CITY & URBAN	Car drives into stationary vehicle		61%	56%	52%
URBAN	Car drives into slower moving vehicle			30%	10%
URBAN	Car drives into braking vehicle			14%	6%



In addition to real world data scenarios are also selected using engineering judgements. CCR 2 is situation noted from track testing where some AEB systems appear to fail. This scenario is under investigation, not yet tested due to limitation of 3D appearance of target.

REAL WORLD DATA



TEST SCENARIOS SELECTED TO REPRESENT GREATEST FREQUENCY OF REAL WORLD CRASHES

Combining accident data from other international sources		UK	UK	Germany	USA	
		STATS 19 n=10,574 cluster analysis frontal collisions	OTS n=175 cluster analysis frontal collisions	UDV n=234 (N=18,571) 3rd party vehicle claims 2002-2006 frontal collisions	IIHS 1997-2006 FARS & GES all car-pedestrians	
PEDESTRIAN	Pedestrian walks from nearside	51%	59%	32%	27%	
	Pedestrian walks out from behind obstruction	14%		7%		
	Pedestrian runs out from the far side	9%	37%	28%		
	Pedestrian walks along in the dark	3%	5%	8%		9%
	Pedestrian walks out into the path of turning car	6%	Overall: going ahead 87%, Turning 13%	18%		-

Darkness scenarios are not yet tested, but closest possible scenario is under investigation
For example CP4 is tested as stationary pedestrian, but not in darkness

INTERNATIONAL ACCIDENTOLOGY



FURTHER INTERNATIONAL CP STUDIES

Vehicle Manoeuvre	Pedestrian	Scenario	Germany		China (Beijing, Shanxi & Chongqing)		Australia (Victoria, New South Wales & Queensland)
			Passenger car to pedestrian collisions	Excluding reversing	Passenger car to pedestrian collisions	Vehicle to pedestrian collisions	
							vFSS
							GIDAS
							184 accidents investigated (similar to OTS)
							Police reported collisions
							2006-2008
							Pre 1997
Straight	Cross from near side		45.0%	50.0%	84.2% on straight roads	82.1% crossing road arbitrarily	45.7% on roads and at junctions
Straight	Cross from near side - obscured						12.4% near and far side combined
Straight	Cross from far side		29.3%	32.6%			26.9% on roads and at junctions
Straight	Cross from far side - obscured						12.4% near and far side combined
Straight	Walking along or in road		3.3%	3.7%			17.9% walking along or generally in road
Turn to far side	Cross from near side		7.9%	8.8%	10.8% on crossroads	82.1% crossing road arbitrarily	Collisions at junctions not specifically identified
Turn to far side	Cross from far side						
Turn to near side	Cross from near side		3.3%	3.7%			
Turn to near side	Cross from far side						
Reversing	-		10.0%	-	-	-	-
Others	-		1.2%	1.3%	5.0%	-	4.6%
Total			100.0%	100.0%	100.0%	100.0%	100.0%

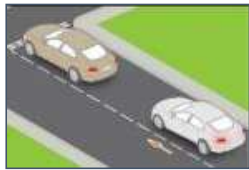
•Overall the clusters derived from STATS 19 and OTS data for both CP and CCR data appear to be reasonably representative of other international accident distributions

•Scenarios were therefore considered to be globally representative

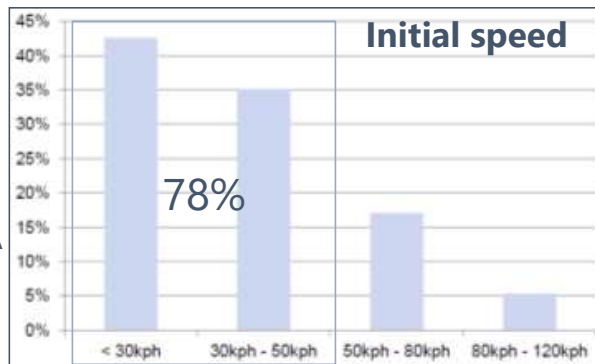
REAL WORLD DATA



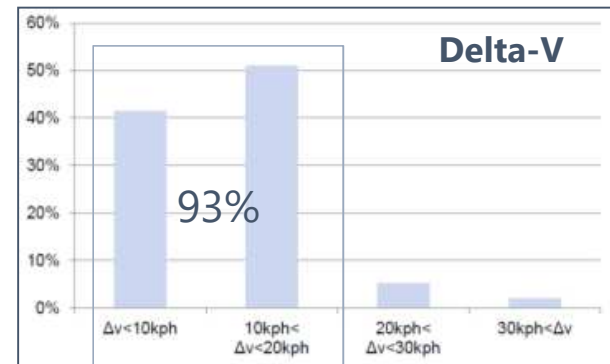
INITIAL SPEEDS AT START OF COLLISION



EDR data – AXA
Switzerland



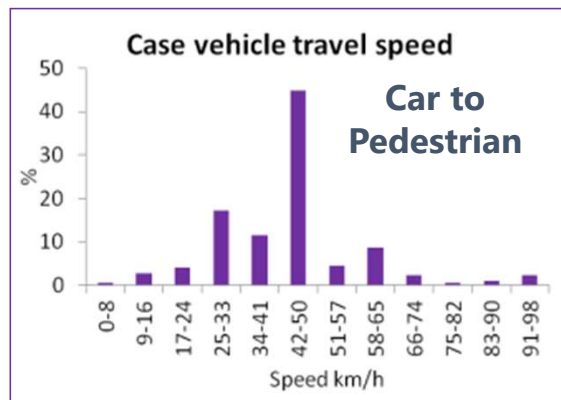
Initial speed prior to braking was below 50km/h for 78% of cases



93% of all accidents had a delta-v of less than 20km/h



OTS case reconstructions
– UK



Initial speed prior to braking was below 60km/h for majority of cases

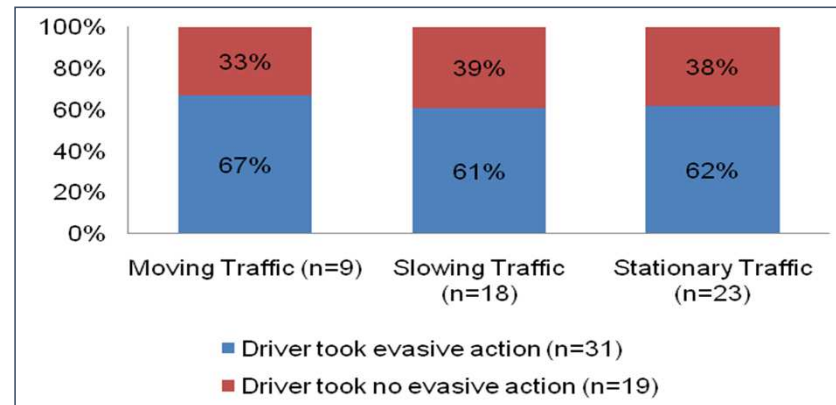
REAL WORLD DATA



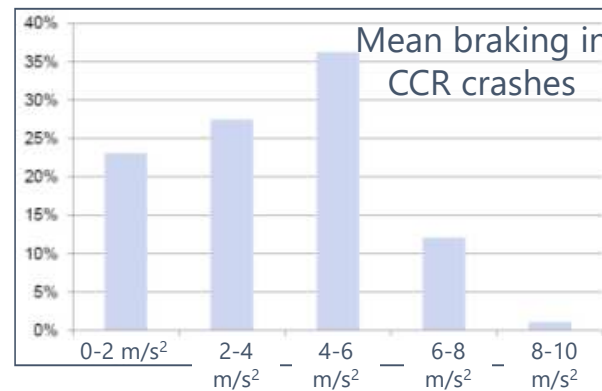
BRAKING LEVELS DURING COLLISION



OTS case
reconstructions
– UK



EDR data – AXA
Switzerland

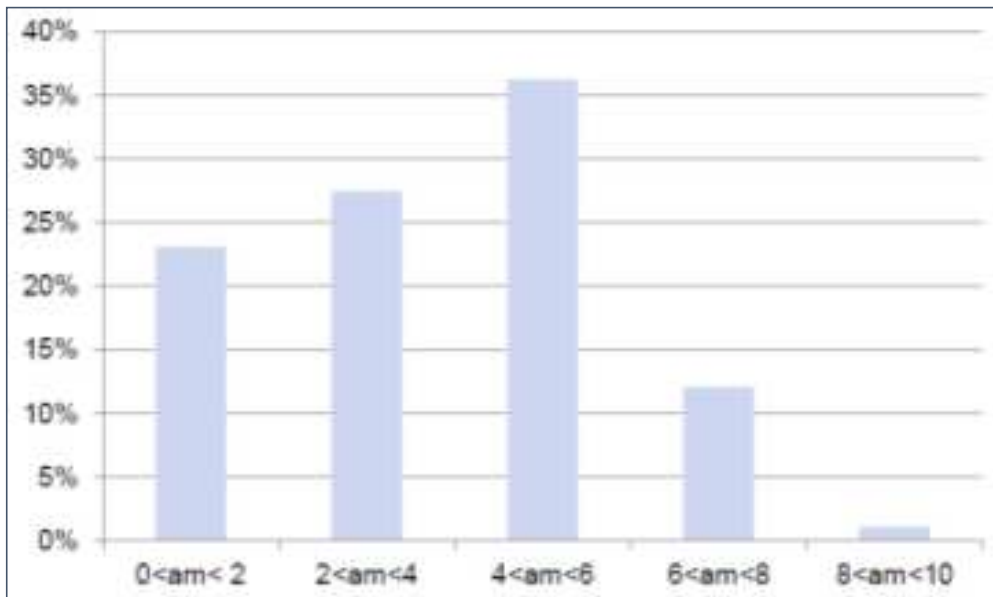


86% of drivers braked before the accident

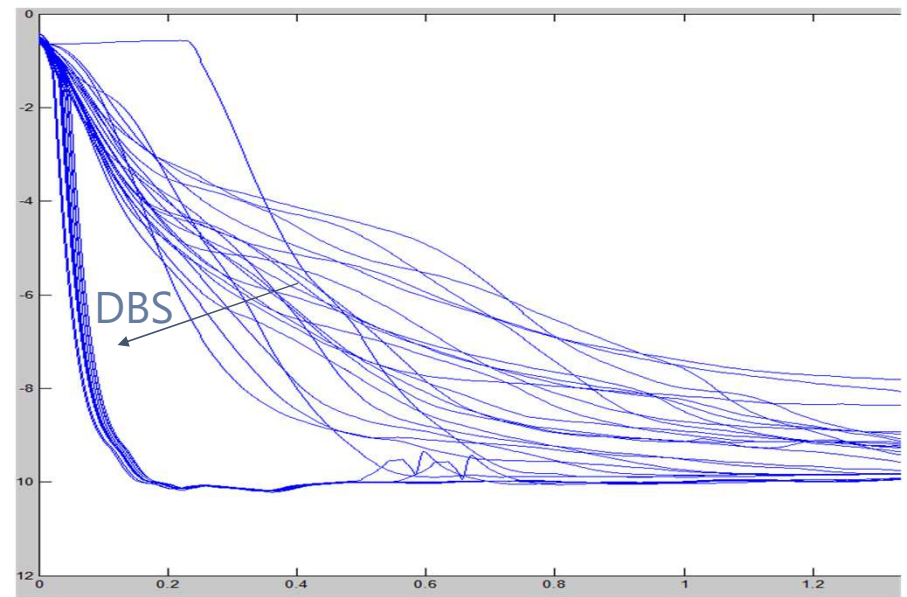
Majority of drivers did not brake hard enough

Dynamic Brake Support (DBS)

In conjunction with Forward Collision Warning (FCW)










Mean deceleration in rear end crashes
62 to 86% of drivers brake, but only moderately



DBS boosts driver braking response in
emergency situations

AEB Test Scenarios

Car & Pedestrian

Car-to-Car Rear (CCR)		Car-to-Pedestrian CP	
	CITY Lead Vehicle Stopped <50km/h		CP1 Unobscured nearside walking pedestrian
	INTER-URBAN Lead Vehicle Stopped 30-80km/h		CP2 Obscured walking nearside pedestrian
	INTER-URBAN Slower Lead Vehicle Target 20km/h Test 30-80km/h		CP3 Unobscured farside pedestrian
	INTER-URBAN Lead Vehicle Decelerating 50km/h		

WHAT TARGET?



COMPARISON OF DIFFERENT TEST TARGETS

RADAR and Camera Systems

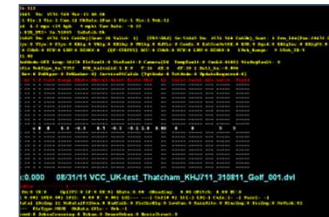


Car

Assessor - Tyres

Assessor - Ground

Balloon Car



Rabbit & Assessor

Rabbit & Suzuki

ABsessor



Adult

Pedestrian target

Rabbit (Landrover Discovery with radar shielding) is not acquired as a target by the system



CAR & PEDESTRIAN TEST TARGETS



COMPARISON AT APPROACH SPEED \approx 20KM/H

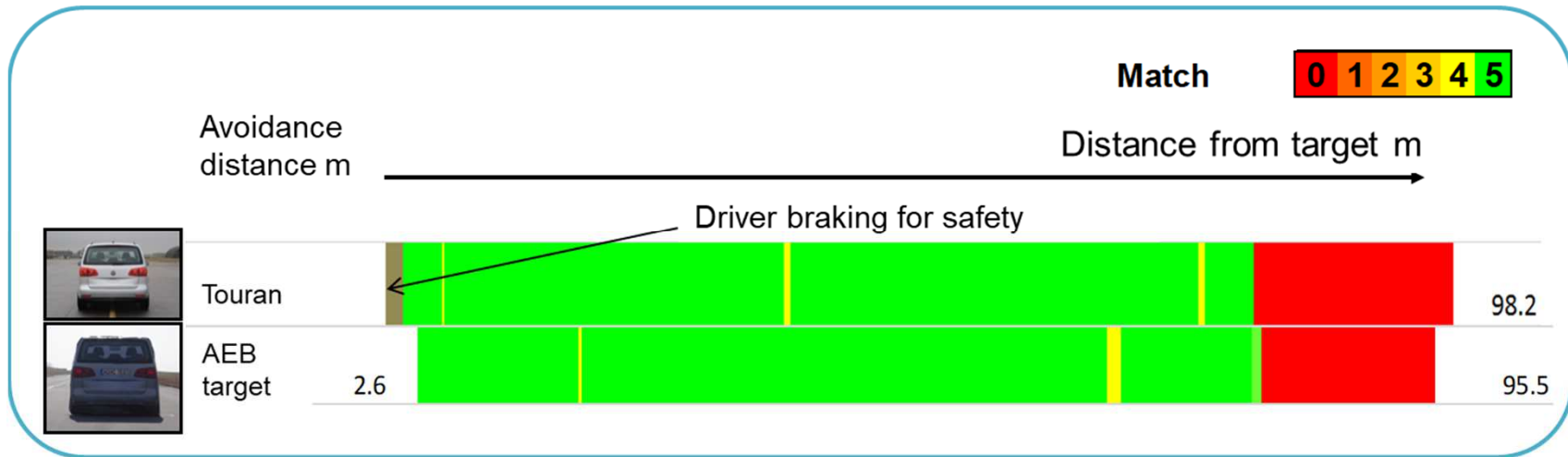


- System outputs confidence level of an object based on radar and visual attributes
- Scored on a scale of 0-5 with 5 being the higher confidence (green)
- Score of 0 indicates insufficient visual detail to confirm the object (red)



Euro NCAP Vehicle Target

EVT



2014 City AEB Test

Car to car stationary



- Stationary target
- Test speeds 10 to 50km/h in 5km/h steps
- Preconditions:
 - Front seat whiplash score: ≥ 1.5 points (good)
 - Full avoidance at 10, 15 and 20km/h
- Reward for AEB only (FCW not considered)
- Full points for avoidance
- Mitigation rewarded proportionally to speed reduction

- Precondition: AEB system default ON at start of every journey
- Points awarded if deactivation NOT possible with a single button push

2014 City AEB Test

Car to car stationary



2014 Inter-urban AEB Test

AEB & FCW

Stationary



Moving



Braking



- **Precondition: AEB and/or FCW operate up to at least 80km/h**

- Stationary target
- Test speeds ranging from 30 to 80km/h
- Reward for Forward Collision Warning (FCW)
- No reward for AEB
- Mitigation rewarded proportionally to speed reduction

- Moving target 20 km/h
- Test speeds AEB 30 to 70 km/h
FCW 50 to 80 km/h
- Reward for AEB and FCW
- Mitigation rewarded proportionally to speed reduction
- Maximum points awarded for AEB avoidance

- Test target and test vehicle initially driving at 50km/h
- 12m and 40m headways, target deceleration 2 and 6m/s²
- Reward for AEB and FCW
- Mitigation rewarded proportionally to speed reduction

2014 Inter-urban AEB Test

Car to car stationary FCW



Subaru Outback CCR1 60k run 7

2014 Inter-urban AEB Test

Car to car moving






2014 Inter-urban AEB Test

Car to car braking



Inter-urban HMI points

Pre-conditions – no one button off switch, FCW must be 'loud and clear'

Activation	Supplementary Warning for FCW	Reversible pre-tensioning of belt (pre-crash phase)
Points awarded if deactivation NOT possible with a single button push	e.g. head-up display, brake jerk, other haptic feedback	Belt is pre-tensioned if critical crash situation detected
2 points	1 point	1 point
		

Modern AEB Performance

AEB City

Euro NCAP see a 38% overall reduction in real-world, rear-end crashes

- Volvo
- Mercedes
- VW/Audi/Skoda/Seat
- BMW
- Toyota/Lexus
- Nissan/ Infiniti
- Alfa Romeo
- Mazda
- Honda
- Peugeot
- Opel/Vauxhall
- Jaguar/Land Rover
- Hyundai/Kia



Modern AEB Performance

Cars achieving 50km/h AEB City collision avoidance

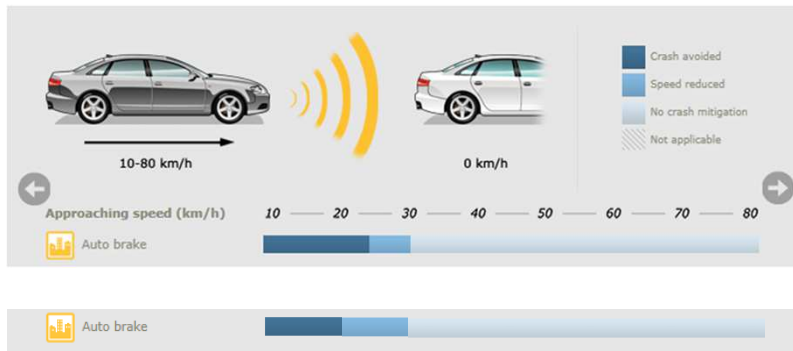
- Alfa Romeo Giulia, Stelvio
- Audi Q2, A4 Q7 & A8
- BMW X3, 5 Series & 6 Series
- Honda Civic
- Hyundai i30, Ioniq, Tucson, Jonathan
- Infiniti Q30, QX30,
- Jaguar XF, F Type, XJ , E-Pace,
- Kia Moro, Picanto, Stinger, Stonic, Sportage
- Range Rover Evoque, Velar
- Mazda 3, CX3, CX5
- Mercedes GLA, CLS, E-Class
- Nissan Micra
- Opel Grandland X
- Peugeot 3008, 5008
- Seat Arona, Ateca, Ibiza, Karoq, Kodiaq, Octavia
- Toyota Yaris, Prius, CHR, RAV4, Verso, Pro Ace Verso, Hilux
- VW Polo, Passat, Arteon, Tiguan, T-Roc, Crafter
- Volvo XC60, XC90, S90, V90

AEB Effectiveness

Test performance & claims data

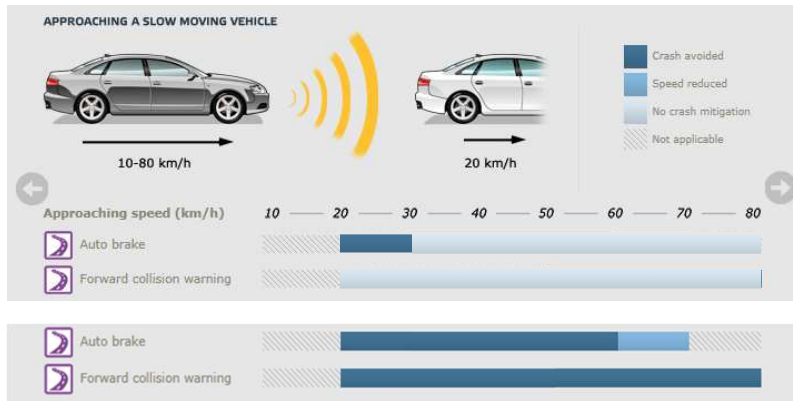
Testing

Low Speed



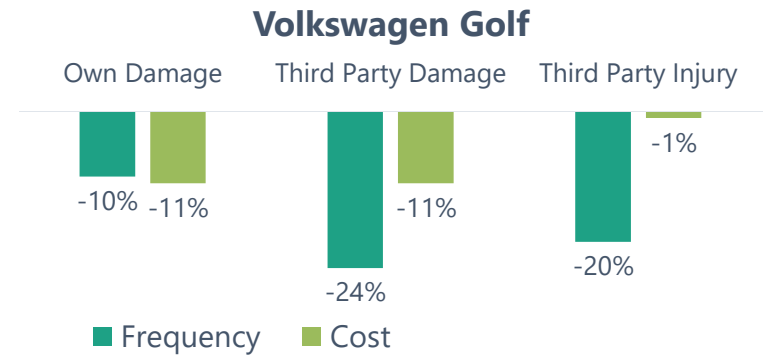
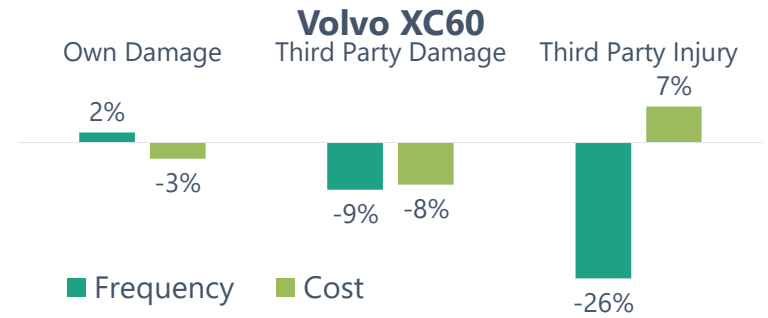
Volvo XC60
VW Golf

High Speed



Volvo XC60
VW Golf

Real-world insurance analysis



AEB Effectiveness

City safety reduces insurance claims

Updated study of US insurance claims by Insurance Institute for Highway Safety (IIHS)

Weighted averages applied to US findings to represent UK market:

- Injury reduction 26%
- Damage reduction 15%



Summary of studies:

Insurance claims study from Switzerland;
31% reduction in 3rd party rear-end claims

Insurance claims study from Germany;
9% reduction in all claims

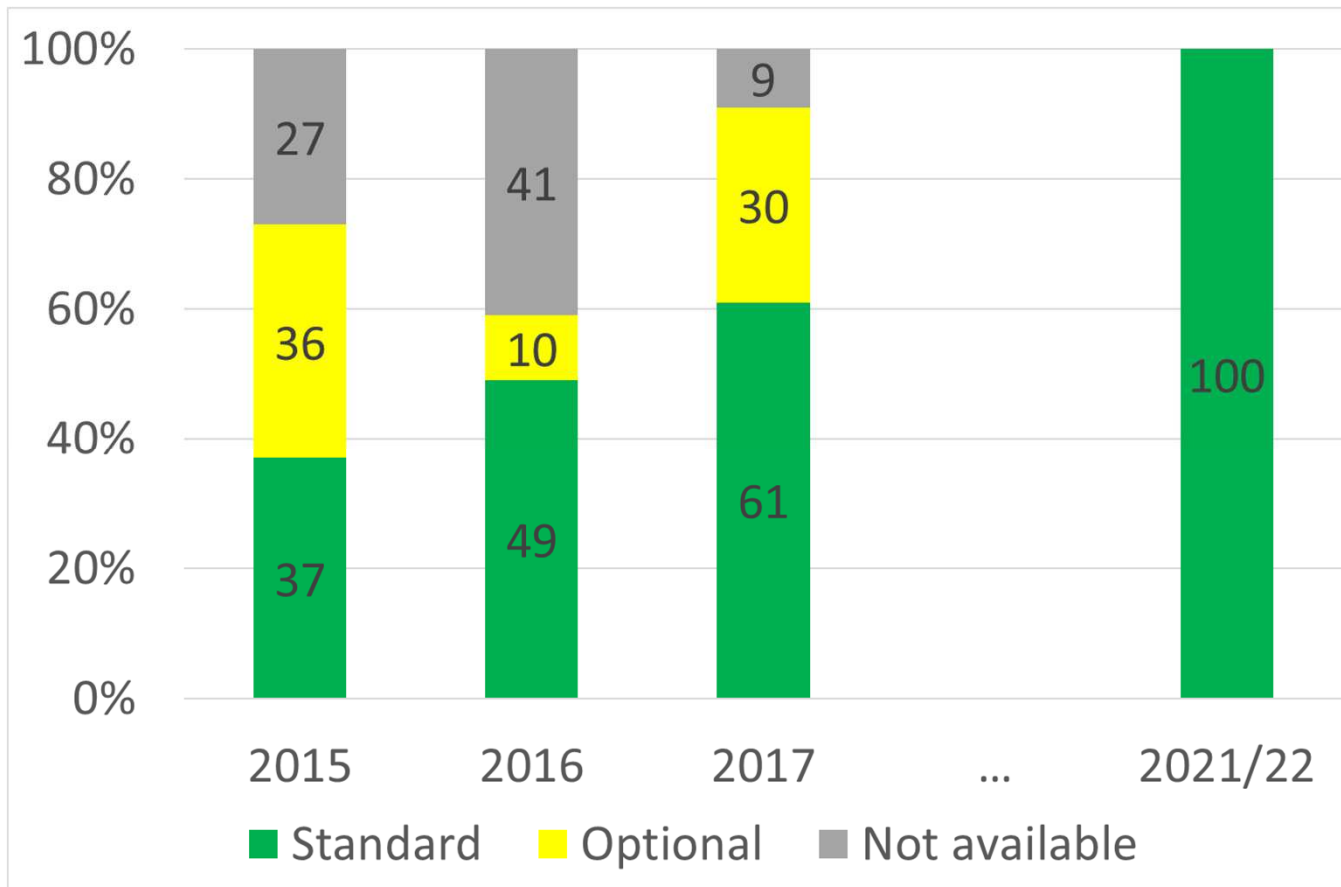
Tristar worldwide (chauffeur fleet standard fit); 27% reduction rear impacts

Volvo study of real world crashes in GIDAS; 19% were avoidable with City Safety

TREND: AEB is reducing collisions in the real world

AEB availability on new cars

New cars launched in...



**Early 2020s -
AEB mandated
by regulation**

AEB on Other Vehicle Types

HGV



EU Regulation No. 347/2012 - All vehicles > 8000 kg



Vulnerable Road Users

Pedestrian 2016 Implementation

13% of all road casualties

Test scenarios based on top 3 pedestrian collisions



Unobscured nearside walking adult



Obscured running nearside child



Unobscured farside adult



Subaru Levorg CVNA -75 20k

Many VRU systems only work in daylight
Day light testing Euro NCAP in 2016, Night testing likely 2018

Vulnerable Road Users

Cyclist 2018 Implementation

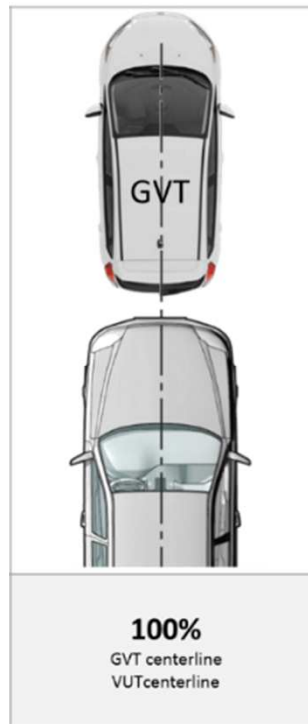
Cyclists 11% of all road casualties

Pedal cycle traffic increasing: 13% higher than 2005-9 average



2018 Euro NCAP AEB Testing

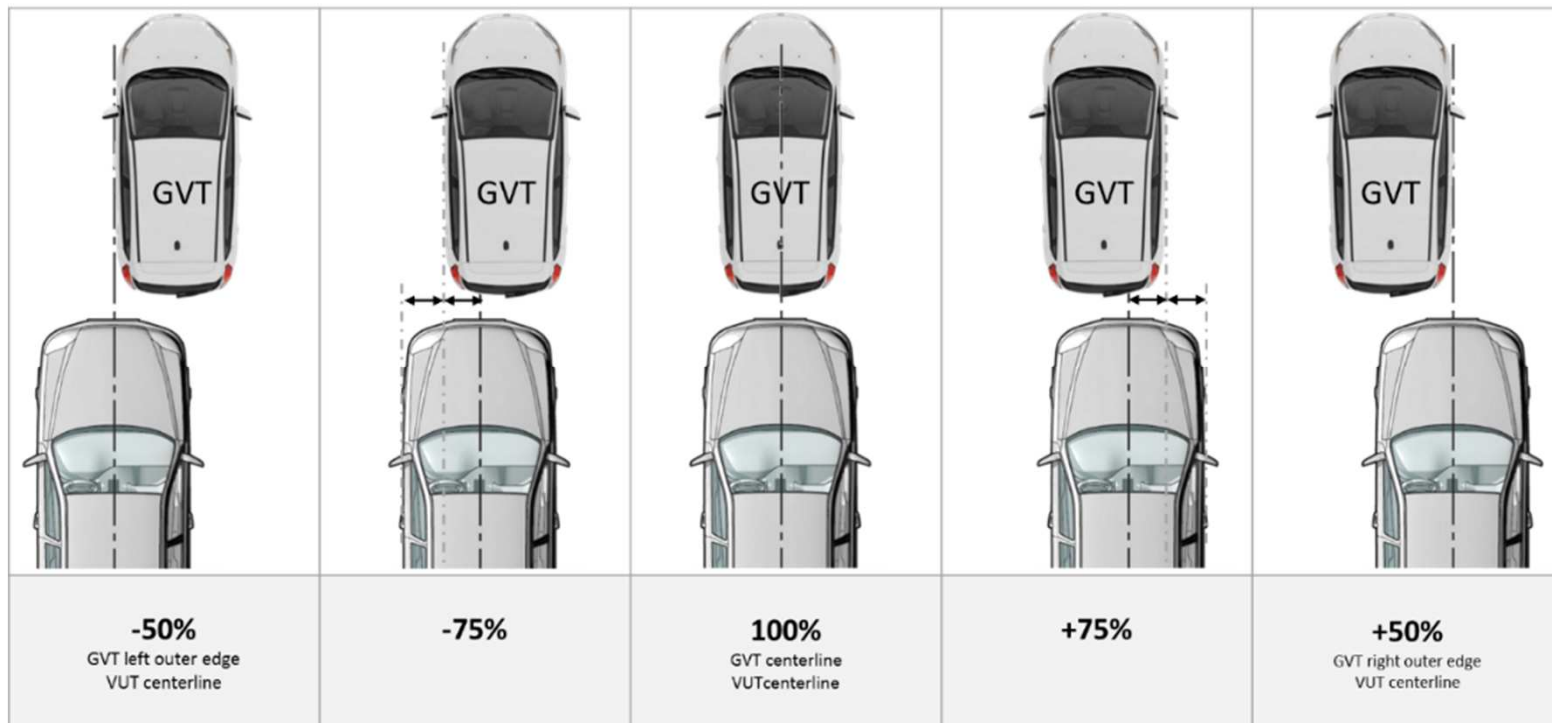
Additional tests and new target



2018 Euro NCAP AEB Testing

Additional tests and new target

City & Inter-Urban with 100, 75 and 50% overlap



2018 Euro NCAP AEB Testing

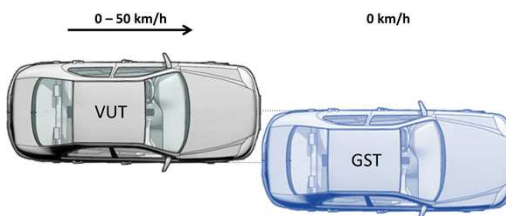
Additional tests and new target

UK insurance claims data analysis

	3rd party rear damage	1st party striking
Speed	~50% stationary, 40% up to 30km/h	More than 90% up to 50km/h
Direction	More than 95% 6 o'clock, remainder 5 and 7	More than 95% 12 o'clock, remainder 11 and 1
Overlap	2/3 central or full width, 1/6 half to two thirds, 1/6 less than one third	

AEB Offset Testing

Additional tests and new target



Make & Model	Sensor technology	Target	Overlap	10	15	20	25	30	35	40	45	50
Mercedes E-Class	Radar & camera	GST	100%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Mitigate	Mitigate	mitigate
			50%	Avoid	Avoid	Avoid	mitigate	No effect	No effect			
Prototype vehicle	Radar & camera	GST	100%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid
			50%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid
Volvo V40	Lidar	EVT	100%	Avoid	Avoid	Avoid	Avoid	Avoid	Mitigate	Mitigate	mitigate	No effect
			50%	Avoid	Avoid	Avoid			Mitigate			
Honda Jazz	Lidar	EVT	100%	Avoid	Avoid	Avoid	Avoid	Mitigate	No effect			
			50%	Avoid	Avoid	Avoid	Avoid	mitigate	No effect			
Toyota Prius	Radar & camera	EVT	100%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid
			50%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Mitigate	
Volvo V40	Lidar, radar & camera	EVT	100%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	Mitigate	Mitigate
			50%	Avoid	Avoid	Avoid	Avoid	Avoid	Avoid	(Avoid)		

Vehicle Testing Targets

GVT

Current vehicle testing targets

Representation

Suitable for full overlap rear end only

Manoeuvrability

Straight line driving only

Impactability

Low to moderate speeds, full overlap only

Different designs

Increases development and confirmation workload



Euro NCAP Vehicle Target (EVT)



NHTSA Strikeable Surrogate Vehicle (SSV)

New target requirements

Representation

Full 360° perimeter representation – radar, camera, lidar

Manoeuvrability

Use stationary and travelling at speed – stability

Impactability

Impactable at speed – minimal damage

Different designs

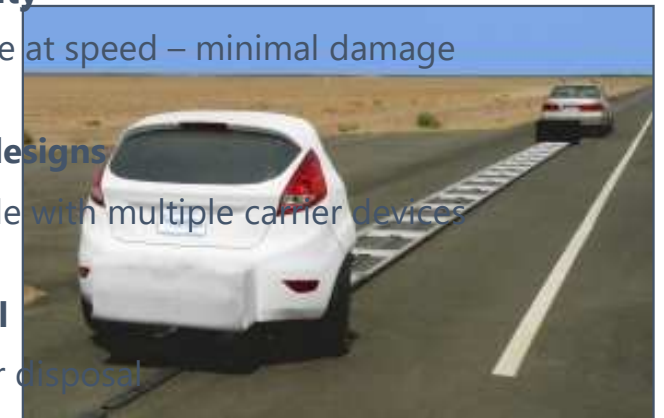
Compatible with multiple carrier devices

Economical

Durable or disposal



Euro NCAP Vehicle Target (EVT)



NHTSA Strikeable Surrogate Vehicle (SSV)

GVT Development Process

GVT

Achieving appropriate RCS

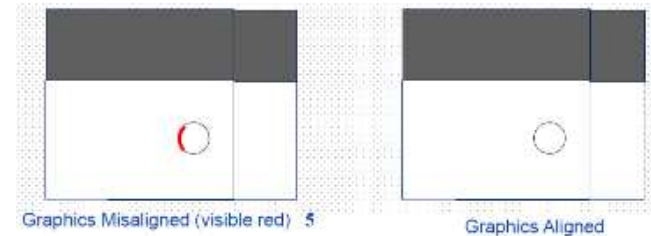
- Minimising platform effect – 22° edges, bulkheads and skirts
- Internal reflections – enclosing target
- dB return – increasing reflection whilst maintaining GPS
- Wheel well and wheels – separate wheel blocks

Visual representation

- Surface wrinkling – stiffeners added
- Repeatable construction – telltale circles/windows

Light reflective elements

- Applied to lights and licence plate



GVT Construction

Global Vehicle Target

Thatcham
Research
Safer cars, fewer crashes

Global Vehicle Target
(GVT)

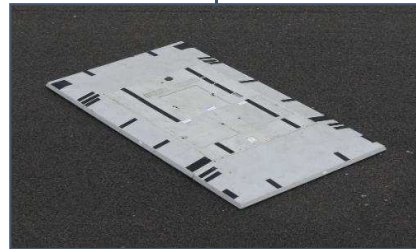
Target Interoperability

GVT

DRI Soft Car 360



DRI Low Profile Robotic Vehicle (LPRV)



DSD Ultraflat Overrunable robot (UFO)



ABD Guided Soft Target (GST)

ISO WG developing target attributes specification – referenced by Euro NCAP

2018 Inter-urban AEB

Car to car moving



Lane Support Systems

Emergency Lane Keeping



2020 Junction Collision Protection

Crossing and Turning

3/4 of all injurious accidents involving a car and another vehicle occur at junctions
2/3 occur where the vehicle fails to give way to vehicles approaching from the right

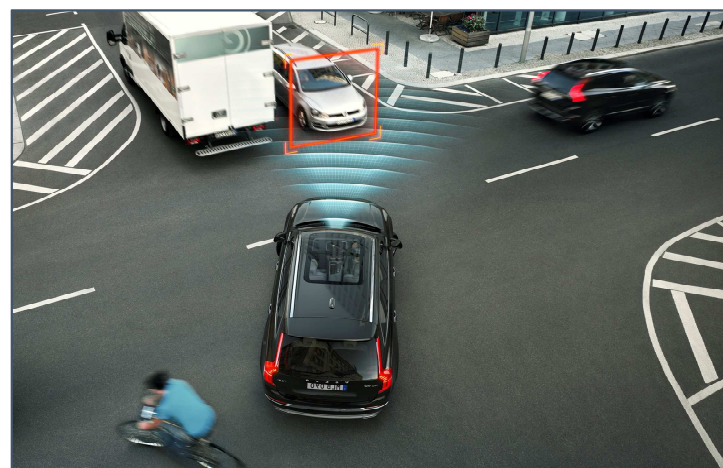
Mercedes E-Class

Cross Traffic Function
Up to 22mph



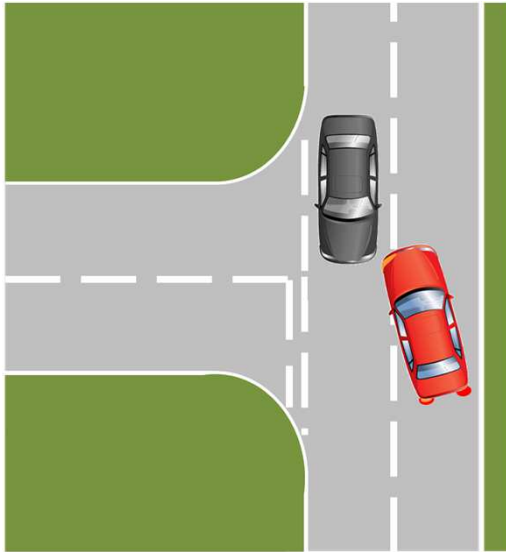
Volvo XC90 S90 V90 XC60

City Safety including braking in intersection
Up to 31mph

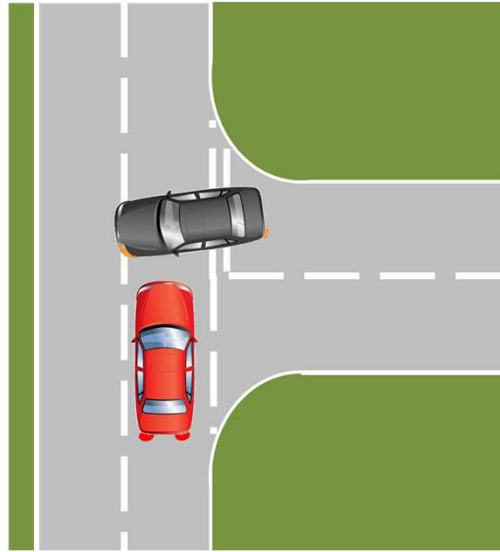


Example Junction Test Scenarios

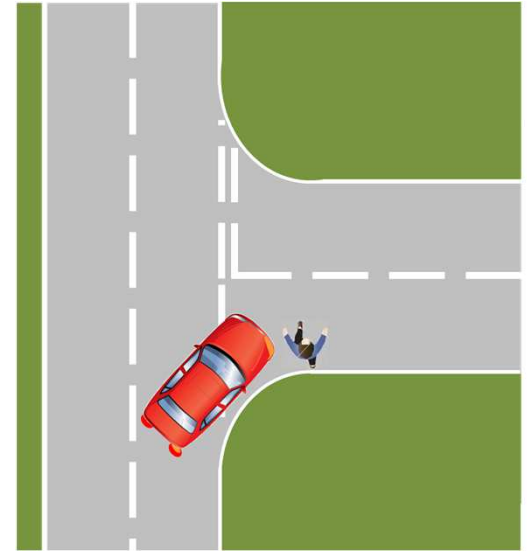
Turn Across Path



Crossing Traffic



Pedestrian



Junction Collision Protection

Volvo XC90



Junction Collision Protection

Mercedes E-Class



2020 Reversing Pedestrian AEB

Proposal

- ~1 in 6 pedestrian collisions are reversing
- ~1 in 3 MAIS 3+ injuries – upper leg and head
- Typically collisions with elderly pedestrians and children
- Speeds <10km/h
- Drivers rarely brake



AEB at Thattham Research and in Euro NCAP

Colin Grover

Principal Engineer – ADAS & Automated Driving

November 2017

