



Advanced Driver Assistance Systems Report

This insightful and thorough 180 page report considers the technologies, applications and OEM implementations that define Advanced Driver Assistance Systems – ADAS. The recent growth in installations of ADAS is set to accelerate and provide opportunities for those innovative suppliers participating.

This report examines in detail sensor technologies, liaisons and co-operations around ADAS applications and the new and additional features that are improving road safety.

Furthermore the report looks at ADAS implementations with examples from Audi, BMW, Daimler, Ford, General Motors, Honda, Jaguar / Landrover, Nissan, Mazda, PSA Peugeot-Citroën, Subaru, Toyota, Volkswagen and Volvo.

Background to this research

In recent years, active safety systems – such as ABS, traction control, ESP – have become commonplace across most car segments. Typically these technologies temporarily enhance the vehicle control that drivers have as they encounter potential hazards and are regarded as preventative safety systems.

ADAS technologies differ in that they are more advanced preventative safety systems, which can monitor and predict potential collision scenarios, warn the driver and can take automatic corrective action to either mitigate the collision, or avoid it completely. Many ADAS warning features like adaptive cruise control, lane-departure warning, night vision and blind spot monitoring are commonplace and have typically been marketed as “comfort and convenience” optional features. However, active ADAS features that intervene in the control of the car to assist drivers in avoiding accidents are now coming into production, moving ADAS clearly into the “Safety” category. These applications include collision avoidance systems that can automatically apply a car s brakes and lane-departure prevention to steer a vehicle back on track.

Table of Contents

INTRODUCTION 10

ADAS Technology 11
ADAS and Safety 12

SENSOR TECHNOLOGIES 15

Radar 15
Automotive Radar Applications 18
Impulse Radar / Ultra-wideband radar 18
Range-Gated Radar 19
Camera Systems 21
Edge Detection 21
Vehicle recognition and tracking 21
Pedestrian Detection 22
Traffic Sign Recognition 22
Stereo Vision Systems 22
Multi-functional camera systems 23
Advantages and Disadvantages of Camera-based Systems 23
Night Vision Systems 24
Night Vision Applications 25
lidar 26
Ultrasonic Sensors 28
ADAS Navigation / Mapping Information 29
Example Application: Adaptive Speed Recommendation (ASR) 32
Sensor Fusion 32
Connected Vehicle and Roadway Sensors 33

OVERVIEW OF LIAISONS AND CO-OPERATIONS 36

Vehicle-to-Vehicle (V2V) Communications for Safety 36
Vehicle-to-Infrastructure (V2I) Communications for Safety 37
Connected Vehicle Programme 38
Crash Avoidance Metrics Partnership 38
CAR 2 CAR 39
Cooperative Forward Collision Warning 40
Pre-Crash Sensing/Warning 40
Hazardous Location V2V Notification 40
Traffic Efficiency 40
Enhanced Route Guidance and Navigation 40
Green Light Optimal Speed Advisory 40
V2V Merging Assistance 41
Approaching Emergency Vehicle Warning 41
Other C2C ADAS Related Use Cases 42
DRIVE C2X 43
Traffic jam ahead warning 44
Road works warning 44
Car breakdown warning 44
Approaching emergency vehicle 44
Weather warning 45
Emergency electronic brake lights 45
Slow vehicle warning 45
Post-crash warning 45
Obstacle warning 45
In-vehicle signage / Speed limit 45

GLOSA (Green Light Optimized Speed Advisory) 45
Traffic information 45
Insurance and Financial Services 45
Dealer Management 45
Point of interest notification 46
Fleet management 46
Transparent leasing 46

ADAS APPLICATIONS 47

Adaptive Cruise Control (ACC) 47
Adaptive Headlights with cornering 51
Autonomous Emergency Braking 54
Car Company AEB Implementations and ADAS Activity 57
Backup Cameras 59
Blind Spot Warning / Lane Change Assistant 60
Cooperative Intersection Safety Systems (CISS) 64
Curve Speed Warning 67
Emergency Call / Mayday / ACN 68
Forward Collision Warning / Avoidance 71
Toyota A-PCS Case Study 72
Front & Rear Side View Cameras 76
Lane Departure Warning / Lane Keeping Systems 77
Night Vision 78
Night Vision Applications 79
Pedestrian Detection and Avoidance 82
Self-Parking Systems 87
Speed Limit Recognition 88
Stop & Go City Drive (Stop & Go Adaptive Cruise Control) 89
Vehicle Platooning and Road Trains 92

ADAS IMPLEMENTATIONS 94

Audi 94

Adaptive Cruise Control, Braking Guard and Pre-Sense 94
Adaptive Headlights 96
Audi Lane Assist 96
Audi parking system 96
Audi side assist 97
Night vision assistant with Pedestrian Detection 98
Autonomous Audi TTS 98

BMW 100

Adaptive Headlights 101
Night Vision 101
Active Cruise Control and "Stop & Go" 101

Lane Departure Warning / Collision Warning 103
Lane Change Warning 104
Surround View / Side View 104
Park Distance Control 106
Active Park Distance Control / Park Assist / Parking Assistant 106
Remote Controlled Parking 107
BMW Automated Driving Prototypes 107
Autonomous Emergency Braking / Pedestrian Detection Development 108
Interview with Christian Gruber 109

Daimler 113

PRE-SAFE and PRE-SAFE Brake 113
Automatic emergency braking 114
DISTRONIC PLUS 114
Blind Spot Assist 115
Active Lane Keeping Assist 116
Night View Assist Plus with Pedestrian Detection 117
Intelligent Light System / Adaptive High Beam Assist 117
Speed Limit Assist Plus 117
Active Parking Assist 118
Attention Assist 119
Future Developments 120

Ford 121

Curve Control 122
Adaptive Cruise Control with Brake Support & Forward Alert 124
Active City Stop 126
Driver Alert System 127
Lane Keeping Aid / Alert 128
Traffic Sign Recognition 128
Blind Spot Information System 128
Auto High Beam 129
Speed Limiter System 129
Active Park Assist 130

General Motors 131

Adaptive Cruise 131
Lane Departure Warning 131
Side Blind Zone Alert 131
GM's EN-V Concept: Future Urban Mobility - Special Report 132
Interview with Dr Chris Borroni-Bird – Director for Advanced Vehicle Concepts, General Motors 137

Honda 138

Lane Keeping Assistance System 138

Adaptive Cruise Control 138
Collision Mitigation Braking System 138

Jaguar / Land Rover 140

Adaptive Front Lighting 140
Blind Spot Monitor 140
Adaptive Cruise Control 140
Advanced Emergency Brake Assist 141

Nissan 142

Around View Monitor with Parking Guide 142
Moving Object Detection (MOD) 143
Back-up Collision Intervention (BCI) System Overview 144
Intelligent Cruise Control 144
Distance Control Assist System 144
Intelligent Brake Assist 144
Lane Departure Warning / Prevention 145
All-around "Collision Free" Prototype 145

Mazda 146

Rear Vehicle Monitoring System 146

PSA Peugeot-Citroën 147

Lane Departure Warning System (LDWS) 147
Citroën Blind Spot Warning 147

Subaru 148

Crash Avoidance / Crash Damage Reduction 149
Driving Load reduction 149
Active Safety 149
Testing ADAS Systems & Interview with David Dello Stritto 150

Toyota 153

Pre-Collision System (PCS) 153
Advanced Pre-Collision System 155
Lane Keep Assist System 158
Adaptive Cruise Control (ACC) / Radar Cruise Control 158
Driver Monitoring System 159
Night View system 160
Intelligent Parking Assist 160
Blind-Corner Monitor 162
Multi-Angle Monitor 162

Interview with Maminirina Ranovana, Toyota 163

Volkswagen 166

Lane Assist 166

Adaptive Cruise Control 166

Front Assist 167

Side Assist 168

ParkPilot 168

Park Assist 168

Rear Assist 168

Area View 169

Dynamic Light Assist 169

Sign Assist 169

City Emergency Braking 170

Future mobility developments 170

Volvo Car Corporation 172

City Safety System 172

Adaptive Cruise Control 173

Collision Warning with Full Auto Brake and Pedestrian Detection 173

Blind Spot Information System 174

SARTRE - Safe Road Trains for the Environment 174

Testing ADAS Systems & Interview with Thomas Broberg, Senior Safety Advisor, Volvo 175

ABOUT THE AUTHOR 178

List of Figures:

Figure 1: Automotive Radar Apps 16

Figure 2: Bosch ACC Sensor (Source: Bosch) 17

Figure 3: Delphi Electronically Scanning Radar (Source: Delphi) 17

Figure 4: DELPHI ESR RADAR COVERAGE 17

Figure 5: Impulse radar and range gates (Source: Cambridge Consultants Ltd) 19

Figure 6: Impulse radar coverage zones from 4 sensors 20

Figure 7: Lane detection - 21

Figure 8: Continental Stereo Camera 22

Figure 9: BMW Night Vision System 25

Figure 10: ADAS Horizon Determination 30

Figure 11: Map based ADAS Architecture 31

Figure 12: Approaching Emergency Vehicle Warning 41

Figure 13: Use case scenarios for Approaching Emergency Vehicle Warning (Source: VANET) 42

Figure 14: ACC sensor path prediction 48

Figure 16: VEHICLE CUT-IN SCENARIO FOR ACC 49

Figure 15: ACC in operation. (Source - Ford Motor Company) 49

Figure 17: Adaptive headlamps around corner 52

Figure 18: BMW Graphic showing adaptive headlamp capability 52

Figure 19: Graphic showing cornering lights (Source: BMW) 53

Figure 20: Sequence of warning and AEB activities pre-crash (graphic courtesy Toyota) 54

Figure 21: Car to car rear collision AEB test scenarios 55

Figure 22: Car to pedestrian AEB test scenarios 56

Figure 23: Volvo radar sensor hidden behind the grill 57

Figure 24: Subaru stereo cameras and image identification 58

Figure 25: Rear view from Lexus LS250 59

Figure 26: Vehicles in blind spot of mirrors 60

Figure 27: Zones Covered by Blind Spot Monitor 61

Figure 28: Continental implementation of Blind Spot Detection 61

Figure 29: Ford BLISS (Blind Spot Information System) Available on Galaxy and SMAX since 2010 61

Figure 30: Ford s Blind Spot Information System (Source: Ford) 62

Figure 31: Delphi Rear and Side Detection System. Source: Delphi 62

Figure 32: Blind spot indicator on Jaguar XF 63

Figure 33: CISS Vehicle Sensing Systems 64

Figure 34: CISS Junction Scenarios 65

Figure 35: Left Turn Scenario 65

Figure 36: Sensor technologies on BMW CISS Prototype 65

Figure 37: Motorcycle view of left turning vehicle 66

Figure 38: Showing how the EU eCall would work 68

Figure 39: ERTICO approach to eCall 70

Figure 40: Current eCall implementation using Telematics Service Provider 70

Figure 41: Ford s Collision Warning With Brake Support (Source: Ford Motor Company) 72

Figure 42: Toyota Advanced Pre Crash Safety Detail (Source: Toyota) 74

Figure 43: Driver facial monitoring system (Source Toyota) 74

Figure 44: Toyota approach to collision warning, avoidance and mitigation 75

Figure 46: Showing rear and side sensing system coverage (Source: Ford Motor Company) 76

Figure 45: BMW Side view camera integrated into wheel arch (Prototype) 76

Figure 47: BWM 7 Series Night Vision 80

Figure 48: Mercedes Active Night View Assist Plus 81

Figure 49: Pedestrian Recognition 82

Figure 50: Showing Horizon line 83

Figure 51: Pedestrian Detection Algorithm: Source: 85

Figure 52: Siemens VDO "Park Mate": Source Siemens 87

Figure 53: BWM Head Up display showing speed limit 88

Figure 54: ACC with Stop & Go Scenario 90

Figure 55: BMW in Stop & Go mode, showing icon in cluster. (Source BMW.com) 90

Figure 56: Stop & Go showing instrument detail (Source Volvo) 91

Figure 57: Vehicle Platooning - Source: Volvo 92

Figure 58: Audi Display showing menu for various ADAS and other optional systems 94

Figure 59: Audi ACC controls and display 94

Figure 60: Audi pre-programmmed headway settings 95

Figure 61: View from inside vehicle of back-up screen 97

Figure 62: Back-up camera located in Audi trunk lid 97

Figure 63: Audi Side Assist 97

Figure 64: Audi Night Vision and Pedestrian Detection System 98

Figure 65: BMW Connected Drive 3-level model 100

Figure 66: Night vision display in cluster 101

Figure 67: BMW Icon for ACC Active 101
Figure 68: ACC stalk control and cluster icons in 7 series 102
Figure 69: Lane Departure Monitoring 103
Figure 70: LDW on Head-up display 103
Figure 71: Info Display LDW icon 103
Figure 73: BMW Surround View 104
Figure 72: BMW Lane Change Warning 104
Figure 74: BMW Side View 105
Figure 75: Park Distance Control Display 106
Figure 76: Parking Assistant Display 106
Figure 77: BMW Remote Controlled Parking 107
Figure 78: BMW Pedestrian detection prototype with HUD 109
Figure 79: Combination of short and long range sensors for DISTRONIC PLUS 114
Figure 80: Cluster display for DISTRONIC plus 115
Figure 81: Blind Spot Assist 115
Figure 83: Active Lane Assist icon 116
Figure 82: Camera processing showing out of lane 116
Figure 84: Mercedes Night Vision System 117
Figure 85: Adaptive High Beam Cluster 117
Figure 87: B Class cluster showing Parking Assist engaged 118
Figure 86: Speed limit Assist Camera 118
Figure 88: View from reversing camera 119
Figure 89: Attention Assist Display 119
Figure 90: Sensing Systems on European Focus 121
Figure 91: Overview of Ford s Curve Control 123
Figure 92: Ford s ACC implementation 124
Figure 93: ACC Icons on Ford Focus 124
Figure 94: Ford s Collision Warning and Brake Support 125
Figure 96: Ford Dearborn Testing Facility for ACC with Braking 125
Figure 95: Forward alert icon - Focus 125
Figure 98: Ford Focus Active City Stop using Forward lidar 126
Figure 97: Components of Active City Stop 126
Figure 100: More foam block testing for Autonomous Emergency Braking 127
Figure 99: Post incident message 127
Figure 101: Driver Alert Display 127
Figure 102: Ford Lane Keeping Icon 128
Figure 103: Ford Lane Keeping Aid 128
Figure 104: Ford BLIS - Blind Spot Info System 128
Figure 105: Steering wheel controls for Focus Speed Limiter 129
Figure 106: Various screen displays 129
Figure 107: Focus Ultrasonic Parking Sensors 130
Figure 108: LaCrosse Side Blind Zone Alert 131
Figure 109: Activation Switchgear for Honda ADAS 138
Figure 110: Honda ACC Controls and Display 138
Figure 111: Jaguar blind spot alert 140
Figure 112: ACC Control Switches - Land Rover 140
Figure 113: Jaguar XF Cluster Display showing ACC 140
Figure 114: Jaguar / Land Rover ACC Radar and fitting details 141

Figure 115: Nissan Parking Guide screens 142
Figure 116: Showing the synthesis between cameras 143
Figure 117: Nissan s Moving Object Detection System 143
Figure 118: Nissan Seatbelt Tensioner 145
Figure 119: Nissan "All-round Collision Free" vision 145
Figure 120: Mazda RVM Alert 146
Figure 121: On/Off switch for Peugeot LDWS 147
Figure 122: Blind Spot Warning 147
Figure 123: Subaru Stereo Cameras for Eyesight 148
Figure 124: Testing Autonomous Emergency Braking - view inside and outside the car 150
Figure 125: Testing Pedestrian Avoidance at Thatcham. 151
Figure 126: Radar and Camera views 153
Figure 127: Toyota PCS System Overview 154
Figure 128: Toyota s Pre-Crash Safety Functions 155
Figure 129: Fusion of stereo cameras and millimetre-wave radar 156
Figure 130: Toyota A-PCS System Overview 156
Figure 131: Sequence of warning and AEB activities pre-crash (graphic courtesy Toyota) 157
Figure 132: Toyota Lane Keep Assist Icon - Avensis 158
Figure 133: LKA Key Components 158
Figure 135: Toyota Driver Monitoring System 159
Figure 134: Toyota Radar Cruise Setting 159
Figure 136: Toyota Pedestrian Detection in Night View 160
Figure 137: Toyota Night View in cluster 160
Figure 138: Selection of Intelligent Parking Assistant 161
Figure 139: Toyota IPA Screen 161
Figure 140: Toyota s Blind Corner Monitor 161
Figure 141: Toyota Multi-Angle Monitor 162
Figure 142: How to safely test pedestrian avoidance 164
Figure 143: VW Lane Assist Icon 166
Figure 145: VW ACC "On" Display 167
Figure 144: VW ACC Switchgear 167
Figure 146: VW ACC and Front Assist Radar 167
Figure 147: VW Side Assist Coverage 167
Figure 149: VW Parking Aid Display 168
Figure 148: VW Parking Sensors 168
Figure 150: Park Assist 168
Figure 151: Rear Assist 168
Figure 152: Area View - showing left and right from front cameras 169
Figure 153: Area View display 169
Figure 154: VW Traffic Sign Recognition 170
Figure 155: 2005 Grand Challenge Winner 170
Figure 156: City Safe Display 172
Figure 157: Volvo Radar behind radiator grille 173
Figure 158: Volvo BLIS camera 174
Figure 159: Testing Pedestrian Avoidance for dummies 175