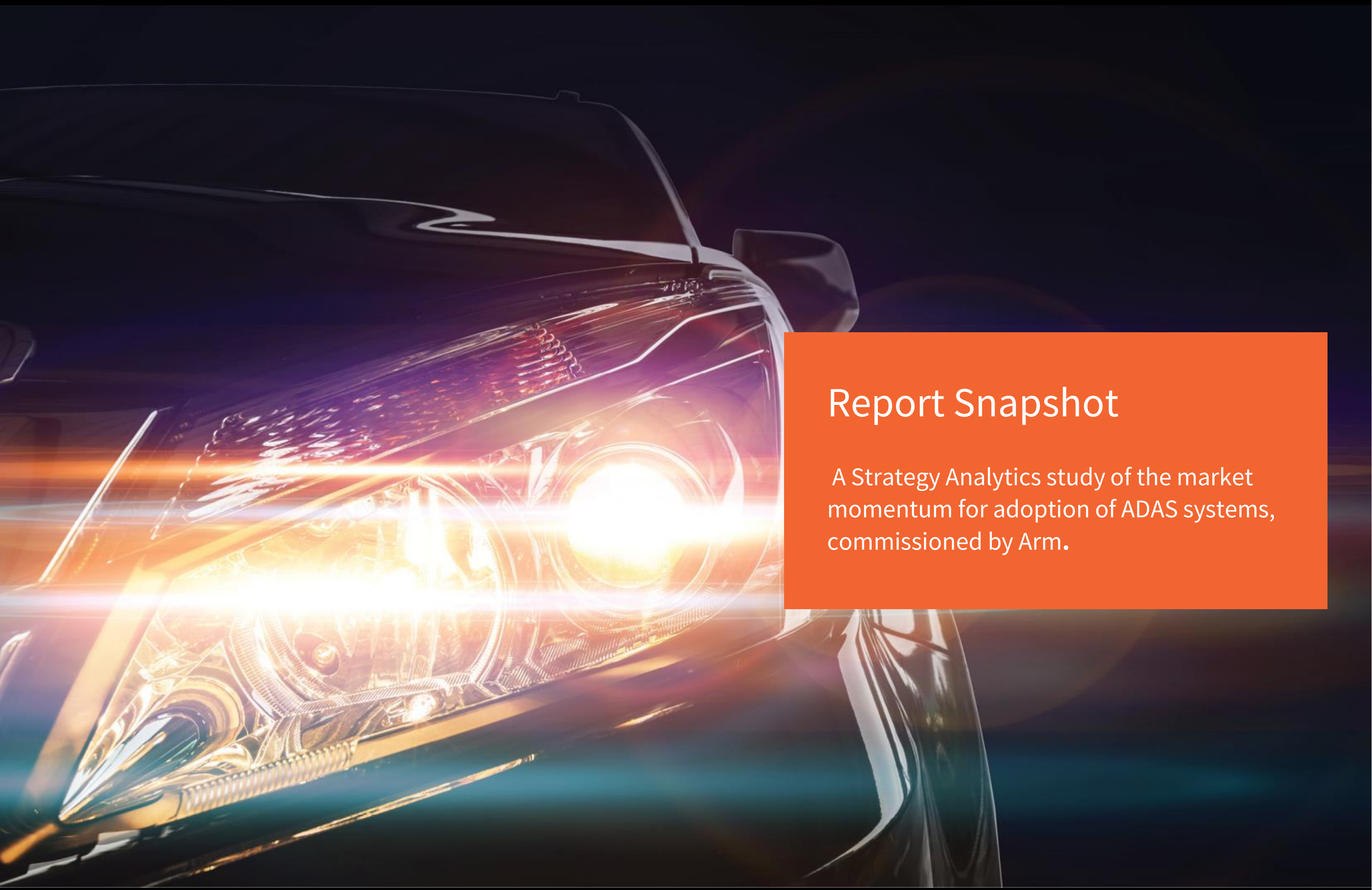
STRATEGY ANALYTICS
Celebrating 25 Years of Insights

The Evolution of ADAS



Report Snapshot

A Strategy Analytics study of the market momentum for adoption of ADAS systems, commissioned by Arm.

STRATEGY ANALYTICS
Celebrating 25 Years of Insights

Contents

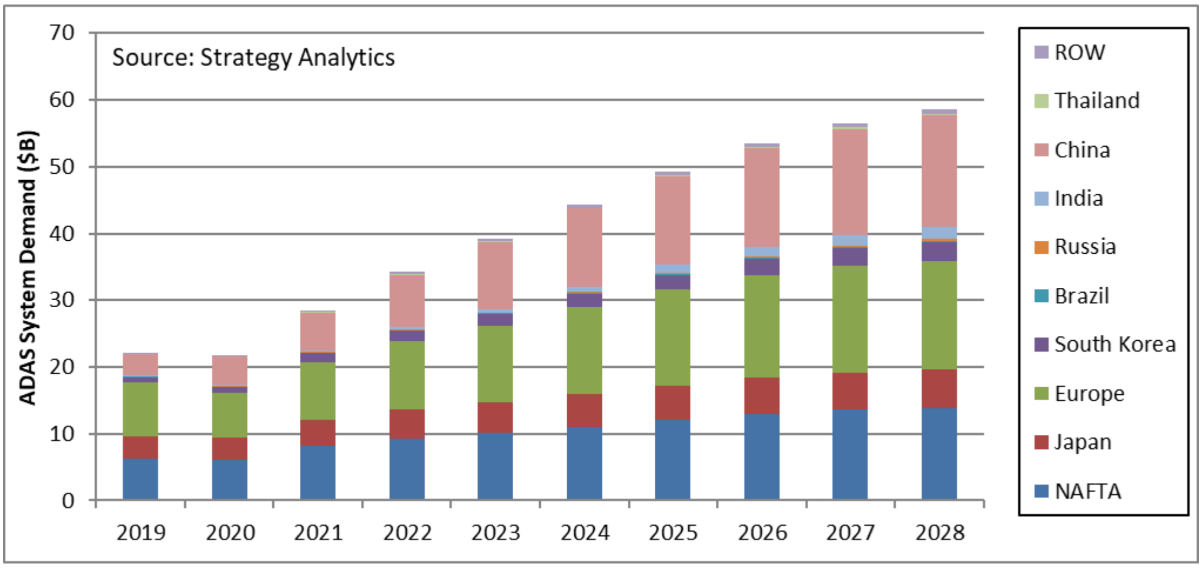
Table of Exhibits

1. ADAS Market Status

1.1 Post pandemic recovery in motion

After the unprecedented fall in the ADAS market in 2020, 2021 will see a return to growth. By 2025, the market for ADAS at a system level is thus forecast to grow to $49.3 billion, representing a dollar CAAGR (Compound Average Annual Growth Rate) of 17.7% over the period 2020 to 2025, increasing to $58.6 billion by 2028.

Exhibit 1.1 ADAS system demand by region ($Billions)

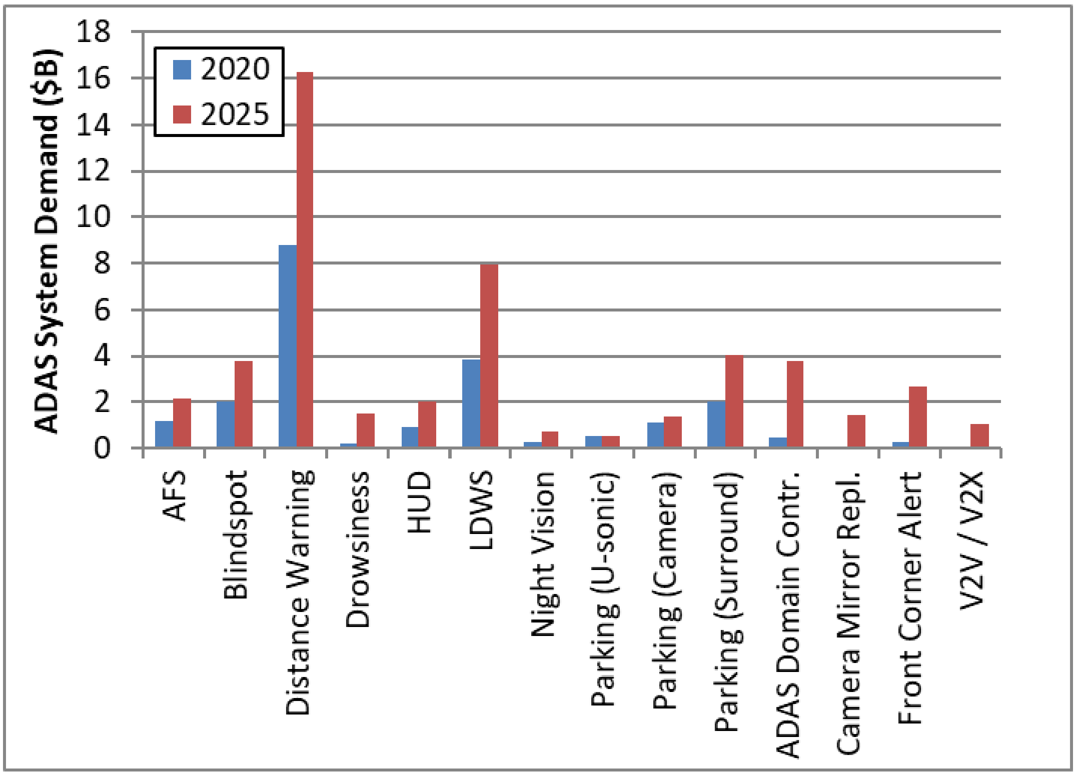


Source: Strategy Analytics

Distance Warning to see a good combination of growth and market size.

- Distance Warning systems cover all forward-looking features and applications. Strategy Analytics does not split out separate demand for functions such as Adaptive Cruise Control (ACC), Automatic Emergency Braking (AEB) etc., as these are typically becoming “just” software functions running on the same hardware platform.
- ACC used to dominate this category, but the most prevalent driving feature now is AEB due to mandates such as the European New Car Assessment Program (Euro NCAP), as well as associated functions such as pedestrian and vulnerable road user (VRU) detection.

Exhibit 1.2 ADAS system demand by application ($Billions)



Source: Strategy Analytics

As technologies such as AEB start to become near ubiquitous, there are now three challenges for OEMs and suppliers:

- Firstly, reducing the cost of these relatively low-end ADAS technologies to allow them to be brought to dedicated markets and many vehicle classes.
- Secondly, attempting to leverage the mass of research undertaken for automated driving into the higher-end ADAS market. One important issue is finding a cost-effective way to combine longitudinal and lateral control of the vehicle (the longitudinal controller is responsible for regulating the vehicle's cruise velocity while the lateral controller steers the vehicle's wheels for path tracking) – essentially joining-up today's mass-market lane-keeping, distance control and blind spot technologies.
- Thirdly, managing the software required across a range of implementations, from discrete solutions with a dedicated ECU, to the growing approach of integrated solutions, where the function is one of many housed in an ADAS domain controller and receiving inputs from multiple sensors.

Demand for surround view systems using multiple cameras is expected to grow from its current value of around $2.0 billion in 2020 to $4.1 billion in 2025, a dollar CAAGR of 14.7%. The penetration rate is also expected to grow, from 14% to 24% over the same period.

- Vehicles built in NAFTA are expected to form the largest single regional demand for surround view throughout the forecast period, accounting for 44% of all systems fitted in 2020 and 39% in 2028. This is a function of legislation mandating back-up cameras in the US (and thus meaning surround view has to be fitted to achieve any significant differentiation) as well as the large number of full-size light trucks in the US market, which can be difficult to maneuver in tight spaces.
- Europe is the second largest region of fitment at present, but China is closing the gap.

The US National Highway Traffic Safety Administration (NHTSA) required backup cameras to be fitted to all new vehicles sold in the US since May 2018. Strategy Analytics assesses that this is leading to demand for more advanced surround-view systems. If all models are required to have a basic reversing camera, then upscale brands and model variants will need to offer something more sophisticated.

Other systems showing growth include:

- Drowsiness Detection or Driver Monitoring
- Head-up displays (HUD)
- Vehicle to everything (V2X) communication solutions, including vehicle to vehicle (V2V), vehicle to infrastructure (V2I) and vehicle to cloud (V2C).

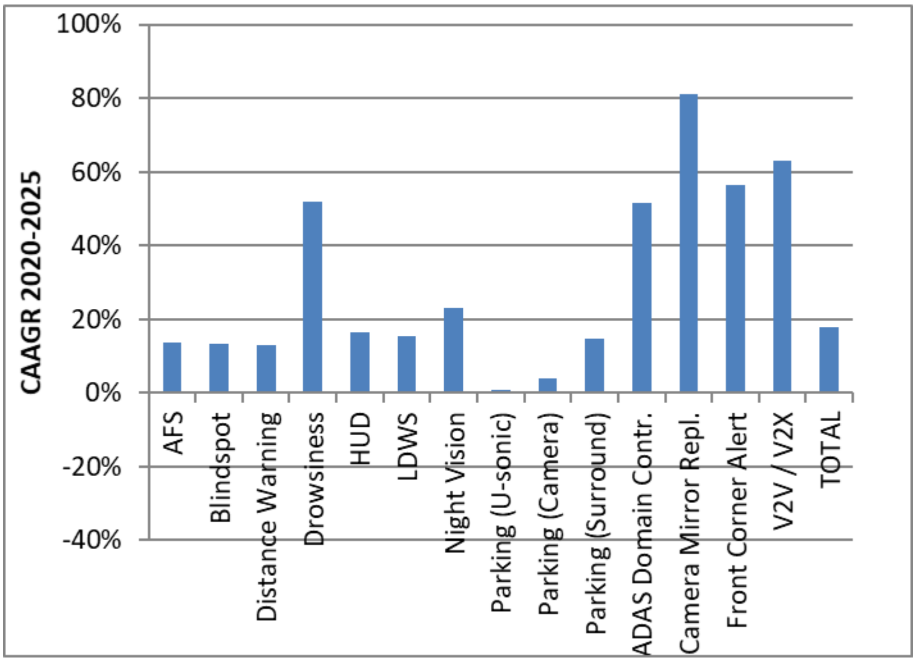
ADAS content-per-vehicle is expected to grow at a CAAGR of 10.7% over 2020 to 2025 – well above the level of vehicle production growth, which is forecast at a CAAGR of 6.3%

- Europe is currently the largest single region of demand (based on the location of end-vehicle manufacture), but due to the higher current fitment rates, is one of the slowest growing. Despite this, it will remain the largest single market for most of the forecast period, being overtaken by China in 2028.
- China will see strong growth from only 10% of the global total ADAS demand in 2012 to 29% by 2028.

The fastest growth applications (with unit CAAGRs in excess of 50% over 2020 to 2025) are Adaptive Matrix Lighting Systems, ADAS Domain Controllers, Camera Mirror Replacement Systems, Front Corner

Alert and V2V/V2X. Although these growth rates are very high, these systems are still low in volume and thus growing from a very small base level.

Exhibit 1.3 ADAS system growth



Source: Strategy Analytics

- Night Vision systems will also see strong growth from current low fitment levels, with a unit CAAGR of around 23% a year over 2020 to 2025.
- Drowsiness systems will see strong dollar growth (52% CAAGR), but the unit growth rate is much lower (31%). The dollar growth thus reflects the strong increase in more expensive camera-based systems.
- Premium vehicles currently make up over 32% of ADAS system-level dollar demand, despite only accounting for around 13% of vehicle production.

1.2 Legislation – Pressure from governments globally

The automotive industry is undergoing rapid changes in the development of ADAS and AD solutions. Vehicle OEMs and suppliers are promoting and advancing applications for vehicle comfort and safety. These developments take a global perspective to such an extent that the entire automotive value chain is involved.

- Europe takes the lead in assessment efforts via the Euro NCAP and associated automotive industry consortia.
    - Euro NCAP includes a Safety Assist score that is determined from tests to the most important driver assist technologies that support safe driving to avoid and mitigate accidents. In these tests, Euro NCAP assesses system functionality and/or performance during normal driving and in typical accident scenarios. ADAS applications tested include AEB, occupant status monitoring, speed assistance and lane support (LKA and ELK).
    - From 2024, all new vehicles sold must include AEB, ability to facilitate DADSS (Driver Alcohol Detection System for Safety), DMS, event data recorder (EDR)/black box, and LKA.
- In North America, the USA takes the leading effort through the NHTSA, Department of Transportation (DoT) and various support groups from the automotive industry.
    - Pending mandates for AEB, BSD, DADSS, DMS, EDR, LKS and child presence detection are being voted on for 2024 implementation.
- In Asia, Japan is at the forefront of advancing automotive applications through the Ministry of Land, Infrastructure, Transport and Tourism (MOLIT), JNCAP, among others. Also, in Asia, China is constantly issuing, updating and refining their automotive roadmaps for ADAS and autonomous driving.

Governments provide the necessary regulatory framework on which all automotive technologies operate. It is also the governments and other bodies working closely with the government that set standards for requirements.

- Governments typically do not specify sensor types or sensor performance but rather overall system functionality. As an example, for AEB, it is the capability that is specified and not whether it is implemented with RADAR, cameras, and other sensors stack.

1.2.1 Roadmaps by nations: USA, China, Europe, Japan, South Korea

All involved governments have their own visions for the future of automotive applications. However, the actual implementation will depend on the speed at which automakers, and in turn automotive suppliers and Tier Ones can produce the necessary supporting sensor technology. For example, lane detection systems would not be realized without the necessary image acquisition technologies such as computer vision. Even with the sensor technology available, the reliability of the processed sensor data is critical. A system that produces a lot of false alarms due to the lack of sophisticated and mature algorithms, neural networks, machine learning or deep learning software will be unacceptable to most drivers.

Today, the general consensus is that we are moving from ADAS to autonomous driving and this transition will slowly be achieved in the next ten to twenty years.

As can be seen in the roadmaps below, full automation can be expected on the roads in the 2030s or later.

1.2.1.1 Governmental Roadmap for Autonomous Driving in China

In October 2016, China's "Technology Roadmap for Energy-Saving and New Energy Vehicles" was released. This roadmap includes intelligent and connected vehicles (ICV) as important future mobility solutions, aiming for an installation rate of driving assist and partial autonomous driving of 50% in 2020, 10-20% highly automated vehicles in 2025 and 10% full automation in 2030.

Furthermore, the Chinese government and the Society of Automotive Engineers of China (SAEC) have issued a roadmap for intelligent and connected vehicles that could have semi or fully autonomous vehicles on sale as early as 2021.

1.2.1.2 Governmental Roadmap for Autonomous Driving in Europe

In April 2016, at an informal Transport and Environment Council meeting in Amsterdam, 28 EU Ministers endorsed the Declaration of Amsterdam to work towards a more coordinated approach enabling the introduction of connected and automated driving. Close cooperation between member states, the European Commission (EC) and industry partners is seen as an important prerequisite for the widespread introduction of innovative and interoperable connected and automated driving technologies and services in Europe.

The Declaration of Amsterdam on connected and automated driving was an important first step towards a common European strategy in this field and includes a joint agenda for further action to support the shared objectives. Key action points for member states involve the need to address legal and practical barriers to the testing and deployment of connected and automated vehicles. The Declaration of Amsterdam also called for the establishment of a high level structural dialogue for member states to exchange views and best practices regarding the development of connected and automated driving and to monitor progress.

Different European countries are responsible to work at different technologies for autonomous driving, thus the timelines and roadmap for fully autonomous driving are not yet clear. The German government have taken steps towards allowing SAE Level 4 automated vehicles to operate on public roads, demonstrating clear progress following the legislation the Bundestag passed, including a draft law "to amend the Road Traffic Act and the Compulsory Insurance Act - Act on Autonomous Driving" in May 2021.

1.2.1.3 Governmental Roadmap for Autonomous Driving in Japan

Japan's cross-ministerial Strategic Innovation Promotion Program (SIP) initiated a research and development plan in May 2014 called Innovation of Automated Driving for Universal Services (ADUS) as one of eleven priority policy issues. The plan included a budget of 2.8 billion yen for 2018. Initial targets included SAE Level 2 systems in 2017, SAE Level 3 from 2020 and Level 4 from 2025.

The first phase of SIP-ADUS was completed at the end of 2018 and the second phase has been approved in July 2018 and started in 2019. While the first phase has been focusing on developing technologies, the second phase gives more attention to services and looks at how to ensure the safety of automated driving systems both for the vehicle side and infrastructure side.

Japan is constantly revising its laws for autonomous driving, in April 2021, traffic laws were revised to allow SAE level 3 vehicles to operate on public roads. Honda has already released 100 SAE Level 3 AV cars in the highways of Japan and testing geofenced Level 4 self-driving technology.

1.2.1.4 Governmental Roadmap for Autonomous Driving in the USA

The NHTSA NCAP currently only provides crashworthiness (Front, Side and Rollover) ratings; it does not rate advanced safety technologies, such as forward collision warning (FCW) or AEB nor pedestrian/VRU safety.

The rollout of ADAS systems in the US is driven by market demand and OEM voluntary implementation, rather than mandates from NHTSA.

Current NHTSA mandates and recommendations for ADAS systems include:

- **Rearview Video Systems** – As of May 2018: required on all new vehicles sold in the US
- **Automatic Emergency Braking –** NHTSA recommended for Dynamic Brake Support (DBS) & Crash Imminent Braking (CIB). OEMs have agreed to install AEB on all 2022+ vehicles
- **Forward Collision Warning** – NHTSA recommended
- **Lane Departure Warning Systems -** NHTSA recommended

- **Automatic Crash Notification** – NHTSA has not set performance specifications for this technology
- **Lane Keeping Support –** NHTSA has not set performance specifications for this technology
- **Pedestrian Automatic Emergency Braking –** NHTSA has not set performance specifications for this feature but recognizes this as a promising technology that may be added to the 5-Star Safety Ratings list of recommended technologies in the future
- **Blind Spot Detection -** NHTSA has not set performance specifications for this feature but recognizes this as a promising technology

The USDOT published the Intelligent Transportation Systems (ITS) Strategic Plan 2015-2019 describing "Realizing Connected Vehicle Implementation" and "Advancing Automation" as the primary technological drivers of current and future ITS work. The Automation Program is organized along 5 major research areas and includes 3 capability-based tracks:

- Human-in-the-loop (HITL) Connected Driving Assistance
- Conditional Automation Safety Assurance
- Limited Driverless Vehicle Operations

Recently the USDOT released its updated 3rd iteration of its new Federal guidance for automated vehicles building upon Automated Driving Systems 2.0 – Preparing for the Future of Transportation: Automated Vehicles 3.0.

The guidance establishes a clear and consistent Federal approach to shaping policy for automated vehicles based on 6 principles: prioritize safety, remain technology neutral, modernize regulations, encourage a consistent regulatory and operational environment, prepare proactively for automation, protect and enhance the freedoms enjoyed by Americans.

Five implementation strategies have been defined to translate these principles into actions: stakeholder engagement, best practices, voluntary standards, targeted research and regulatory modernization. It provides guidance for States to consider for the training and licensing of test drivers as well as guidance for testing entities to consider driver engagement methods during testing.

1.2.1.5 Governmental Roadmap for Autonomous Driving in South Korea

The South Korean government has designated autonomous vehicles as one of its top 13 Industrial Engine Projects. The focus is put on converging industries covering IT and automotive technologies.

The Ministry of Land, Infrastructure and Transport (MOLIT) revised the Automobile Management Act, making it possible for self-driving vehicles to be tested on designated routes on five national highways. The Ministry provides temporary license plates to OEMs, universities and research laboratories.

The main research activities in South Korea are evolving from the car manufacturers. Hyundai for example planned to set aside KRW 2 trillion to develop and commercialize fully autonomous vehicles by 2030. This will be done by testing different autonomous car technologies in the Uiwang Choongang Laboratory (Hyundai's central research center) and the Namyang R&D Center. Besides Hyundai, Unmanned Solution manufactured test cars for automated driving. The Connected & Automated Public TrAnsport INnovation (CAPTAIN) project, focusses on connected and automated driving (CAD) systems for public transport, including both large transit buses and smaller cut-away shuttle vehicles.

2. ADAS Today

2.1 Sensor technologies and requirements, challenges

A variety of sensors are used to provide environmental (including object detection and tracking) and localization perception inputs for ADAS and automated driving route planning and vehicle control. Typical sensors used for autonomous driving include ultrasonic, camera, RADAR and LiDAR.

Exhibit 2.1 ADAS sensor comparison

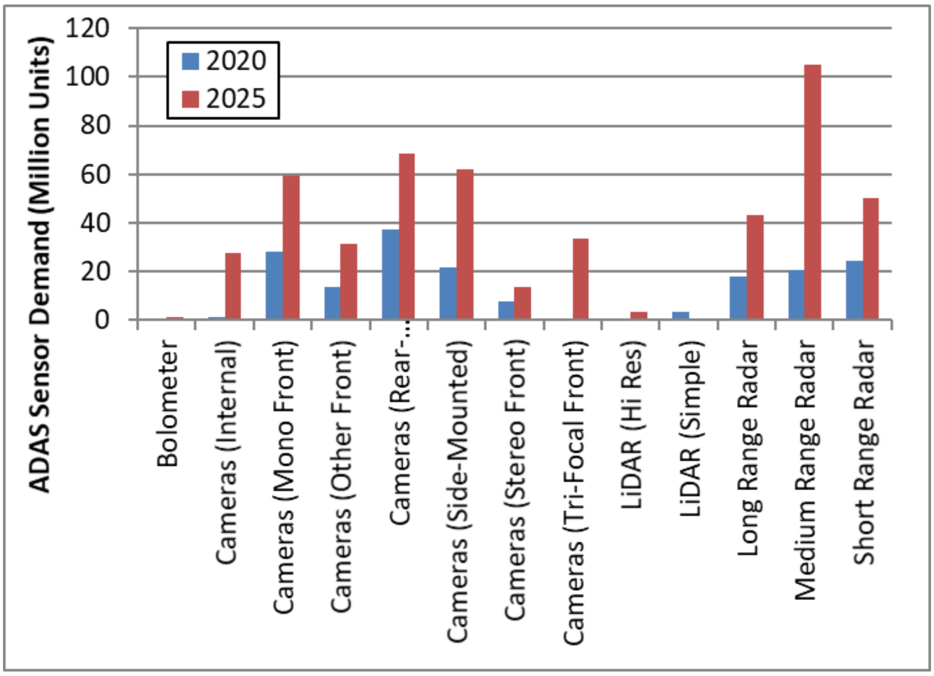
Sensor Type	Cost	Weather Sensitivity	Low Light Performance	Range	Resolution	Sensor Size
Ultrasonic	Very low	Low	Good	Short	Low	Small
Camera	Low	Medium	Poor	Medium Long <100m	High	Small
RADAR	Medium	Low	Good	Long 200m+	Medium	Medium
LiDAR	High	Medium	Good	Long 200-300m+	High	Large

Source: Strategy Analytics

Typical ADAS systems today rely on camera and RADAR inputs for features such as AEB. As more automated features such as lane keeping assistance systems (LKAS) and dynamic driving assistance technologies such as traffic jam assist and highway pilot/chauffeur systems are implemented, LiDAR inputs will augment camera and RADAR sensor inputs. The ability to detect objects such as pedestrians, cyclists, and vehicles in high resolution from short to long distances makes LiDAR an attractive solution to round out an automated vehicle's sensor suite.

2.1.1 Sensor types – Cameras, LiDAR, RADAR

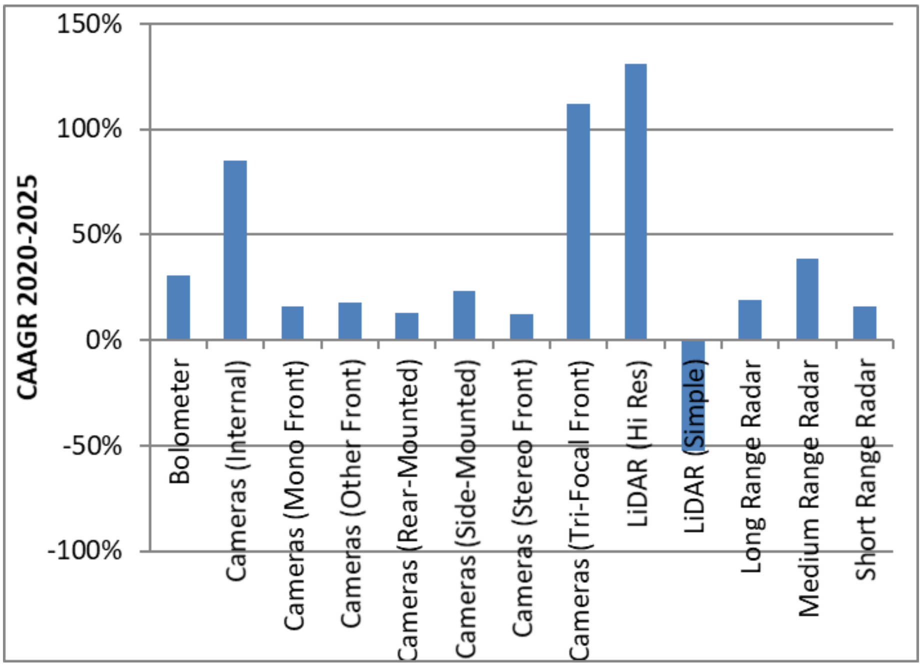
Exhibit 2.2 ADAS sensor unit demand (MU)



Source: Strategy Analytics

- Overall camera unit growth slower than RADAR due to maturity of rear-camera applications.
- Fall in usage of simple LiDAR sensors (e.g., Continental SRL-1 type) is not being significantly compensated for by increase in high-end scanning LiDARs in the 2025 timeframe, which are only coming to market in small volumes compared with other sensor types.

Exhibit 2.3 ADAS sensor unit growth



Source: Strategy Analytics

2.1.2 Camera sensors and image processing

Total demand for camera sensors across all covered applications is expected to grow from around 111 million units worth $3.0 billion in 2020 to 296 million units worth $7.3 billion in 2025. This represents a dollar CAAGR of 19.2%.

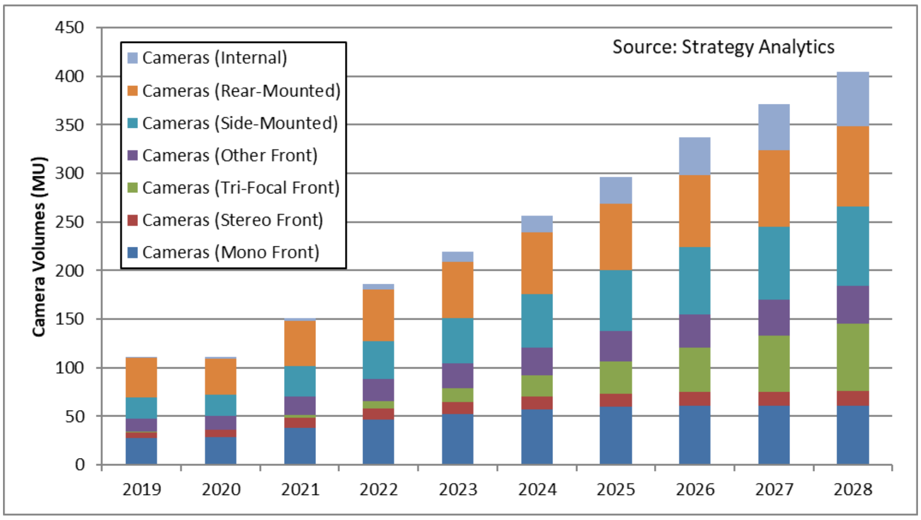
Cameras are the base sensor used in ADAS solutions allowing multiple features to be implemented using a single sensor type. As ADAS solutions become more advanced, vehicles will require multiple sensor types to adequately perceive the vehicle's environment.

Looking at the type of cameras deployed in vehicles, the largest single category is currently for rear-mounted cameras, as shown in Exhibit 2.4. However, their share is rapidly falling. These cameras accounted for 62% of unit demand in 2014 and had fallen to 34% by 2020. By 2025, they are expected to account for only 23% of camera unit demand, falling further to 20% by 2028.

In Exhibit 2.4 the demand shown against stereo and trifocal cameras is for the *number of camera chips present in the design*. To get to the number of camera modules you will need to divide by two and three respectively.

- Fastest growth will be for tri-focal and internal cameras. Combined, these will rise from less than 1% of camera unit demand in 2019 to over 31% by 2028.

Exhibit 2.4 Camera demand by camera type (MU)



Source: Strategy Analytics

Due to the high volume of camera applications in parking solutions it can be seen that these play a large part in the market. However, amongst the fastest growth application areas (excluding the very low volumes for camera mirror replacement) are the drowsiness detection category, driven by systems to monitor the driver during automated driving and to ensure that the driver is paying attention to the road.

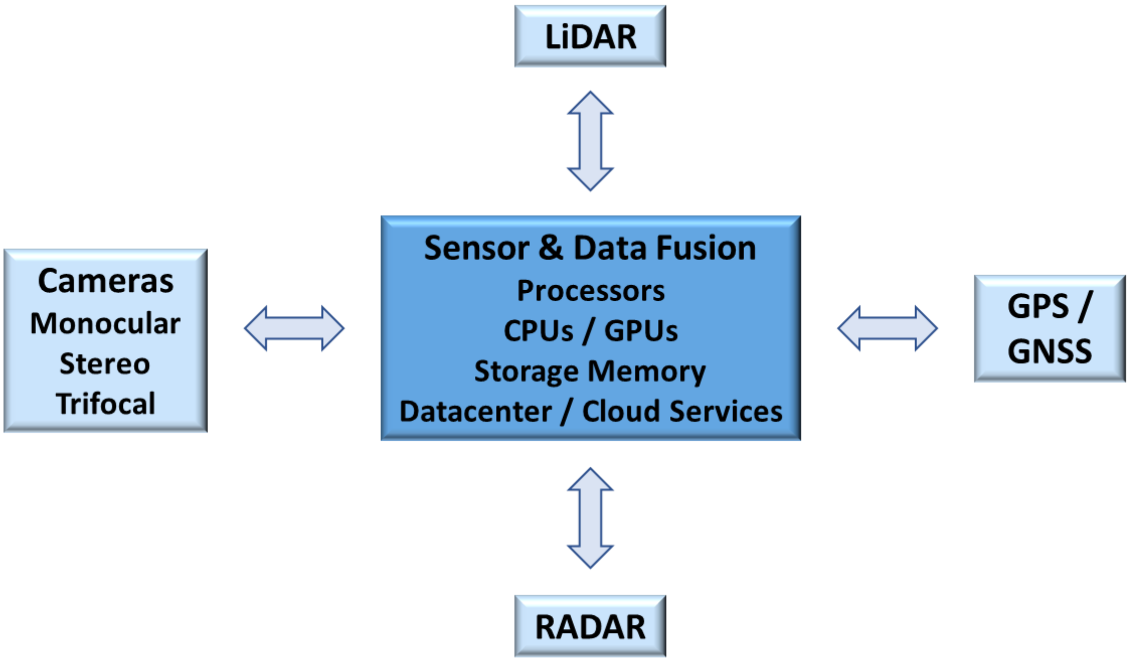
2.1.3 Sensor fusion and getting the most out of signals, images

While camera sensors are the primary inputs to many ADAS functions, data from multiple cameras as well as LiDAR, RADAR and ultrasonic sensors create a sensor suite collating rich data that is fused together to generate a 360 degree view of the environment.

Advances in automotive technology will continue to drive more computing power, more sensors (sensor and data fusion), more functionality and safety-related environments (ISO 26262), more ADAS systems and more autonomous driving technology into cars.

It is observed that most autonomous R&D vehicles are using the same sensor technology as the one that it is being used in the geospatial/mapping ecosystem. These sensors consist of cameras (monocular, stereo, tri-cameras, infrared and other combinations), RADAR, LiDAR, navigation (GNSS, GPS) etc., the use of which can have a potentially disruptive impact on the information industry.

Exhibit 2.5 Example of sensor integration architecture



Source: Strategy Analytics

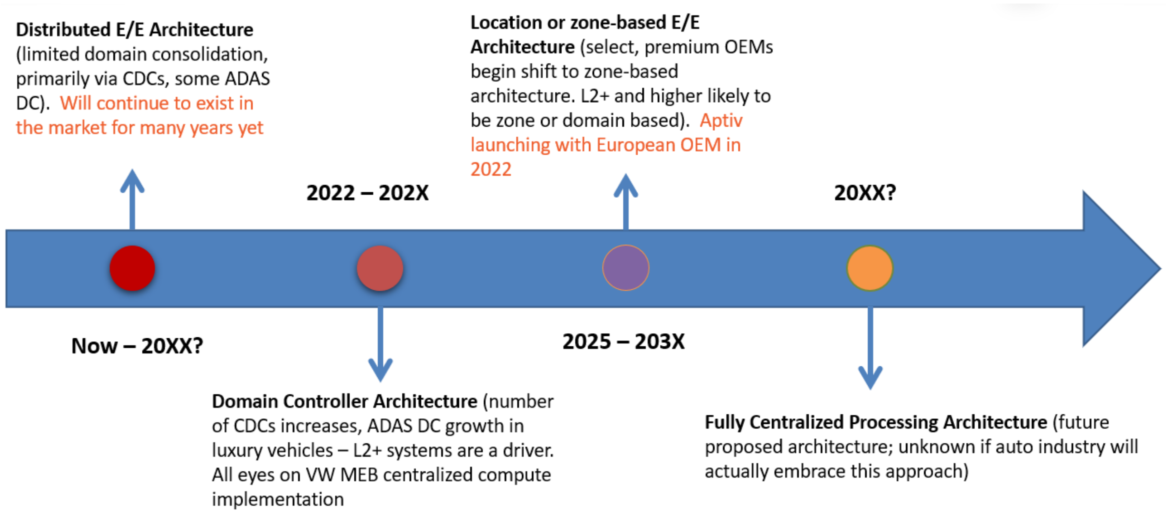
3. ADAS Systems of Tomorrow

3.1 Move to domain controllers

The motivation to move from a decentralized to centralized architecture is to reduce the number of decision-making ECUs and corresponding software implementations. This reduction in ECUs in turn, lowers complexity in vehicle design, decreases cabling requirements and corresponding weight.

Centralized architecture also allows automakers to leverage advancements in processing, memory, software and high bandwidth networking technologies to meet future ADAS and autonomous driving performance requirements such as reliability/fault tolerance, latency, redundancy, security, flexibility, over-the-air (OTA) updates and cost.

Exhibit 3.1 Vehicle architecture adoption timeline



Source: Strategy Analytics

4. Conclusions

4.1 ADAS becoming prevalent in more vehicles

The ADAS market is still expected to expand at a CAAGR of 17.7% over 2020 to 2025 driven by consumer demand, government mandates and expansion to more capable ADAS technologies.

- ADAS content-per-vehicle is expected to grow at a CAAGR of 10.7% over 2020 to 2025 – well above the level of vehicle production growth, which is forecast at a CAAGR of 6.3%

4.2 OEMs differentiate through technological innovations

Over the past 12 to 18 months, more and more industry players, from software and semiconductor companies, through Tier 1s to automakers, have been stressing the importance of developing "L2+" or "L2 Max" solutions

- This emergence of L2+ is widely seen as one response to the industry's failure to bring more highly automated solutions to market in an earlier time frame.
- There is no standards-based or industry-agreed definition of L2+
- Currently deployed L2 typically only offers these features at either **highway speed** (as in Tesla Autopilot) or **parking speeds** (as in many automated parking solutions)

4.3 Compute on path to centralization

The reduction of the number of ECUs in vehicles lowers ECU design and maintenance efforts, decreases cabling requirements and corresponding weight. Centralized architecture also allows automakers to leverage advancements in processing, memory, software and high bandwidth networking technologies to meet future ADAS and autonomous driving performance requirements.

- Strategy Analytics expects demand for central processing units to emerge mainly on higher-end vehicles and premium brands offering a significant degree of automated driving technology, or heavily integrated ADAS functionality to differentiate their premium products from the broader mass market.

5. Glossary

ACC	Adaptive Cruise Control	LiDAR	Light Detection and Ranging
AD	Autonomous Driving	LKAS	Lane Keeping Assistance Systems
ADAS	Advanced Driver Assistance Systems	LKS	Lane Keeping Support
AEB	Automatic Emergency Braking	MOLIT	Ministry of Land, Infrastructure, Transport and Tourism
ASIL	Automotive Safety Integrity Level	NAFTA	North American Free Trade Agreement
CAAGR	Compound Average Annual Growth Rate	NCAP	New Car Assessment Program
CAD	Connected and Automated Driving	NHTSA	National Highway Traffic Safety Administration
CAPTAIN	Connected & Automated Public TrAnsport INnovation	OEM	Original Equipment Manufacturer
CIB	Crash Imminent Braking	OTA	Over the Air
CPU	Central Processing Unit	RADAR	Radio Detection and Ranging
DBS	Dynamic Brake Support	SAE	Society of Automotive Engineers

DoT	Department of Transportation
EC	European Commission
ECU	Electronic Control Unit
FCW	Forward Collision Warning
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPU	Graphics Processing Unit
HITL	Human-in-the-Loop
HUD	Head-up Display
ICV	Intelligent and Connected Vehicles
ISO	International Organization for Standardization
ITS	Intelligent Transportation Systems
LDW	Lane Departure Warning
SAEC	Society of Automotive Engineers of China
SaFAD	Safety First for Automated Driving
SIP	Strategic Innovation Promotion Program
SLAM	Simultaneous Localization and Mapping
SOTIF	Safety of the Intended Functionality
V2C	Vehicle to Cloud
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VRU	Vulnerable Road User