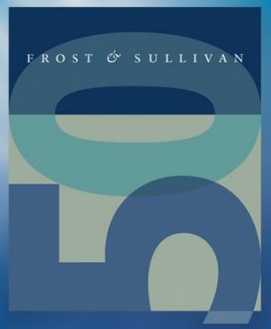
Global Autonomous Driving Market Outlook, 2018

The Global Autonomous Driving Market is Expected Grow up to $173.15 B by 2030, with Shared Mobility Services Contributing to 65.31%

Global Automotive & Transportation Research Team at Frost & Sullivan



K24A-18

March 2018

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Executive Summary

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2017 Key Highlights

Launch of level 3 (L3) automation, digitization of in-vehicle consoles, and improvements in hardware/software testing and simulation capabilities using AI are key trends in the autonomous driving (AD) ecosystem in 2017.

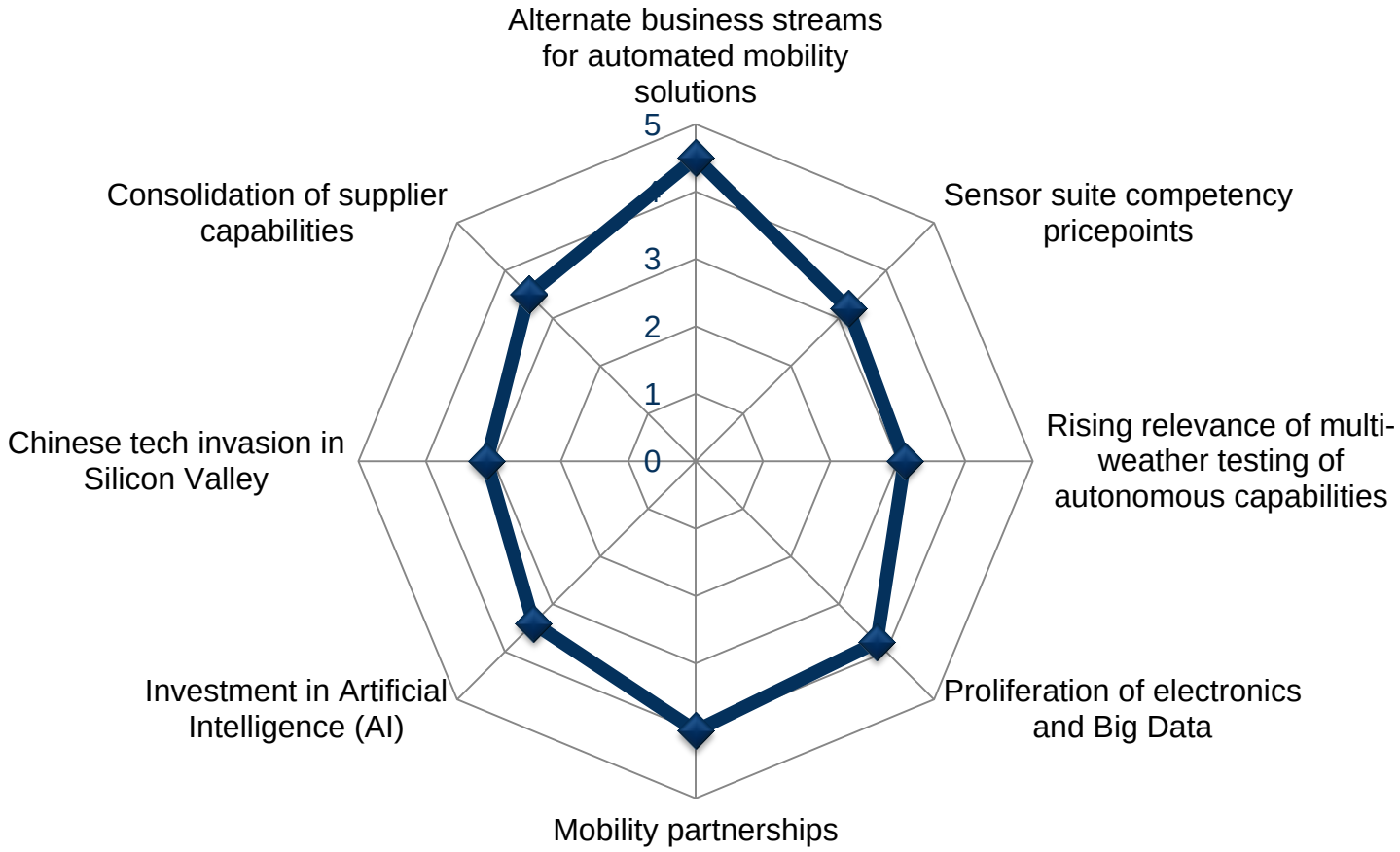
	What F&S Predicted For 2017	What Happened?
1	Launch of the first L3 Car	Audi is the world's first OEM to have unveiled a car with L3 capabilities – the 2018 A8 flagship launched in mid-2017 has all the necessary systems for hands-off highway driving. It is also the first car to feature a long-range LiDAR at the front. The L3 feature, currently not activated, is expected to be enabled by the OTA this year.
2	Compute power enhancement	The next generation of super computers enabling deep learning AI for object detection, classification and decision-making was introduced by Nvidia, Renesas, NXP, and Intel among others, and was tested by several of the top OEMs.
3	Strong growth expected in AD deployment in shared mobility (taxi) platforms	Top OEMs continued working toward having an autonomous vehicle shared mobility portfolio along with improving driver assistance features on their legacy product lines. Besides this, businesses around data-as-a-service are also being explored.
4	Improvement in Depth Sensing	Several start-ups and technology providers with capabilities in cost-effective depth sensing solutions best suited for AD emerged in 2017. The new generation of cost-effective LiDARs, far IR cameras, and combination sensors were also showcased.
5	Multiple approaches for AD development	The industry concurred that controlling automated vehicles with classical computer algorithms with if/then rules is enormously challenging, but not completely impossible. This prompted several OEMs and technology suppliers to invest time and money in researching more on AI to be the decision-making engines.
6	Electric vehicles/hybrids will be preferred over traditional IC engines for autonomous and connected driving	Learning that electric vehicles are becoming competitive in terms of cost effectiveness, maintenance, and charging infrastructure when compared to gas-powered vehicles, OEMs have been investing heavily and have also began testing all-electric/hybrid powertrains equipped with AD features.

Source: Frost & Sullivan

2018–2019 Top-of-Mind Issues for Senior Management

Unearthing the various monetization capabilities of AD beyond passenger vehicle sales is the key for tapping into the vast potential of the technology.

AD Market Outlook: Senior Management Top-of-Mind Issues, Global, 2018–2019



Note: Data collected over 2016-2017 interviews and discussions with Senior Managers to CEO-level executives of passenger vehicle OEMs and tier-I suppliers in North America, Europe, Asia-Pacific, China, India, Latin America, and other regions

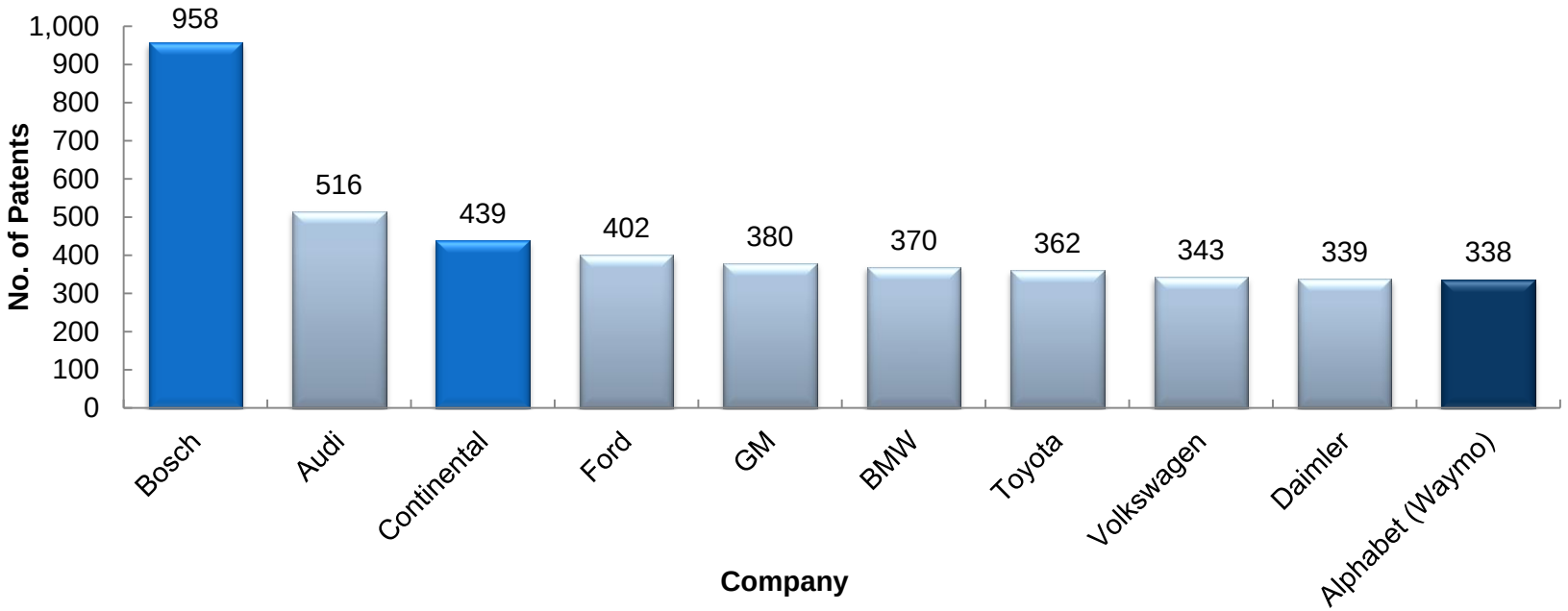
Scale: 0 means limited focus, 5 stands for top focus

Source: Frost & Sullivan

Leading Players in terms of AD Patents Filed in 2017

Out of the top 10 patent holders, 6 are German companies with Bosch leading the tally with 958 patents filed until 2017.

AD Market Outlook: Autonomous Driving Patent Race, Global, Until 2017



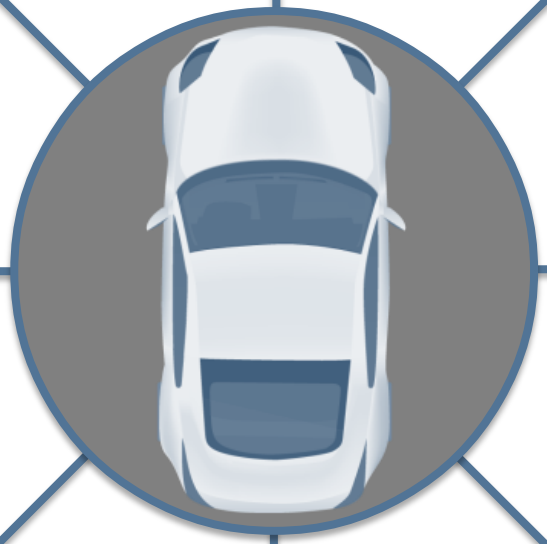
- 52% of the patents registered globally for AD are from German companies.
- Connectivity technology, AI, and human-machine interface are the main areas of probable AD related patent litigation in the next three years.
- OEMs generally have not used patents as a revenue-generator, but as they invest more in developing their own technology they could recoup this investment through licensing patents.
- Although Apple is currently not in the top 10 in terms of patents filed, it recently patented an autonomous navigation system, which would be dynamic and independent of any data received from any devices external to the vehicle, and any navigation data stored locally to the vehicle prior to any monitoring of navigation.

Disruptor OEM Supplier

Source: Cologne Institute for Economic Research - Based on the identified and analyzed 5,839 patents related to autonomous driving, as of August 2017; Frost & Sullivan

Sensors Currently Used Across Applications

Most ADAS solutions currently in use employ stereo/mono camera and LRR-based sensor fusion as it is the most preferred by many OEMs due to its simplicity and high cost benefits.



Long-Range Radar/ Forward Camera/ LiDAR

ACC, AEB Pedestrian Detection

LRR: HFOV 30°, Range: 150m
Tracking Features: Point Target

Forward Camera

Level 2 and 3 Automated Driving Features, Lane Keeping

FORWARD CAMERA: HFOV 45 °,
Resolution: 640x480/ 1280x780
Tracking Features: Vision Target

Forward Camera/LiDAR

Road Sign And Board Detection, Level 3 and 4 Automated Driving Features

LiDAR: HFOV 85~110°, VFOV: ~15°
Range: 100m
Tracking Features: Edge Target

GPS

Localized Vehicle Positioning/Lane Centering

SONAR

Stationary Obstacle Detection, Vacant Spot Detection

Short/Medium Range Radars

Blind Spot Detection/ Rear Cross Traffic Alert

SRR: HFOV 20° (near) 18° (far), Range: 60m (near)
Tracking Features: Point Target

Short-Range Radars/ Surround View Camera

Contextualized Pedestrian/ Cyclist/Moving Object Detection

SVC: HFOV 45° Resolution: 640x480
Tracking Features: Vision Target

Rear Camera/ SONAR

Rear- AEB, Park Assist

Source: Frost & Sullivan

Next Generations of Sensor Fusion

Highly automated and fully autonomous cars to have up to six radars and nine camera modules.

AD Market Outlook: Transformation in Industry Approach in Hardware and Software, Global, 2012–2025 and beyond

Level 1

Sensor – L1	#
Ultrasound	4
RADAR (LRR)	1
SRR	2
Camera/ Short- range LiDAR	1
Total	**~6-8**

Lateral or Longitudinal Assistance

2012

Level 2

Sensor -L2	#
Ultrasound	8
RADAR (LRR)	1
RADAR (SRR)	2-4
Camera	2-4
Total	**~17**

Observation of Environment

2016

Level 3

Sensor – L3	#
Ultrasound	8
RADAR (LRR)	2
RADAR (SRR)	4
Camera (LR)	2
Camera (Sur)	4
Camera (Stereo)	1
µbolo	1
LIDAR	1
Dead reckoning	1
Total	**~24-26**

Awareness for Take Over

2018

Level 4

Sensor – L4	#
Ultrasound	8
RADAR (LRR)	2
RADAR (SRR)	4
Camera (Stereo/Trifocal)	2/3
Camera (Sur)	4
Camera (Stereo)	1
µbolo	1
LIDAR	2/4
Dead reckoning	1
Total	**~25-28**

No Driver Interaction

2020

Level 5

Sensor – L5	#
Ultrasound	8-10
RADAR (LRR)	2
RADAR (SRR)	4
Camera (LR)	2/3
Camera (Sur)	4
Camera (Stereo)	2
µbolo	1/2
LIDAR	4
Dead reckoning	1
Total	**~28-32**

No Driver

>2025

#: Average sensor count in respective levels; µbolo: Thermal camera/IR Sensor for Night Vision Approximation based on number of features supported

Source: Frost & Sullivan

Future Approach in Hardware and Software toward L5 Automation

With the automotive industry expected to have shorter product life cycles, successful business models for autonomous solutions would need to incorporate on-demand OTA update services.

AD Market Outlook: Transformation in Industry Approach in Hardware and Software, Global, 2017–2023

Shift in the industry - Manufacturing of vehicles with all the necessary ADAS sensors to support higher levels of automation rather than refreshing the suite as the levels of automation increase.

This will result in more investment and collaborations in digital technologies.

Next Generation Hardware

- Trifocal Camera
- LiDAR
- LiDAR combined with Camera
- Longer-range Radar
- Thermal Imaging
- Improved Cameras

OTA Updates (Service)

- Subscription based
- Region and Legislation specific Options
- Encrypted
- Real-time Data Monitoring Vehicle Performance

Features (On Demand)

- Automatic Steering with Lane Changing
- Fully Automatic Parking
- Autonomous Pedestrian and Cyclist Braking

Higher Levels of Vehicle Automation

Saves cost and time for the customer and enhances customer experience

OEM Perspective: Hardware sale once in life, followed by selling services as features over the vehicle's lifetime.

Source: Frost & Sullivan

Level 3 Automated Vehicles—What could be new?

While piloting features have significant consumer-centric value-add, current challenges with DMS applications and HMI-ADAS integration limit the deployment of L3 systems.

AD Market Outlook: Expected New Technologies for L3, Global, 2017–2023

Traffic Jam Pilot

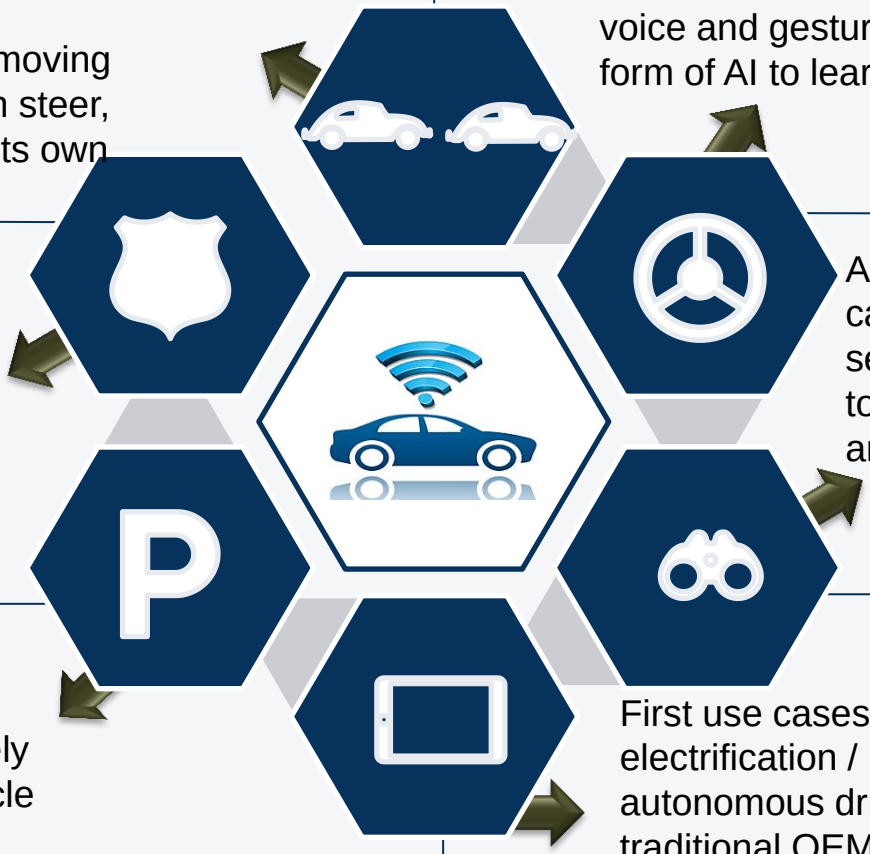
For maneuvering in slow-moving traffic, wherein the car can steer, accelerate, and brake on its own

More interactive infotainment system with voice and gesture commands, using basic form of AI to learn user patterns

Infotainment and HMI

Highway Pilot

For driving, lane centering, lane changing in highway speeds, wherein the car can steer, accelerate, and brake on its own



An inward-facing stereo camera and capacitive sensors on the steering wheel to monitor driver attentiveness and also estimate driver health

Driver Monitoring System

Pilot Parking

Parking the vehicle remotely by using an app. The vehicle can be summoned by the same app

Hands and Eyes-off Systems

First use cases where the convergence of electrification / hybridization and autonomous driving is possible with traditional OEMs. For example, the Audi A8, BMW iNext vehicle

Electrification/Hybridization

Source: Frost & Sullivan

2018 Top 5 Predictions

Development in E/E architectures and further test deployments in shared AD applications are expected to improve the robustness of edge case data for future L4 applications.

AD Market Outlook: Top 5 predictions, Global, 2018

1	**Rise of Virtual Voice Assistants:** Several Technology giants such as Amazon, IBM, and others are expected to introduce interesting voice assistants for in-car use. Most of them would not require a consistent internet connection.
2	**Centralized Domain Architectures:** Tier-1 suppliers such as Autoliv, Continental, and others are expected to introduce centralized E/E architectures for the enablement of true L3 and L4 autonomous driving as the process of continually adding ECUs for each feature (driver assistance or autonomous driving) no longer seems viable as it adds unnecessary cost to the vehicle's E&E architecture and also increases the complexity.
3	**Improved Vision and Depth Sensing Solutions:** Besides improvements in the detection range and cost effectiveness of LiDARs, 2018 is expected to be the year that would see the advent of several types of vision sensors including 4D cameras, far IR sensors, 360-degree radars, and trifocal cameras for better object detection and classification. Several Tier-1 players are expected to introduce mass-production worthy LiDARs in 2018. Inward cameras to monitor driver behavior are expected to gain traction in L3 systems.
4	**Shared Mobility Platforms:** OEMs have realized that the introduction of Level 4 tech is most certainly going to be in a geo-fenced ride-hailing service, prompting them to collaborate with / acquire start-ups with capabilities in fleet management software and cyber-security.
5	**Artificial Intelligence Powering Development, Testing and Validation:** With increasing amounts of data being captured and processed and with better learning capabilities, AI in cars is anticipated to grow exponentially, eventually leading to real-world AD autonomous driving. Technology development through the deep reinforcement learning approach is likely to be the most sought out technique for mapping; hardware and software testing and simulation; and for making improvements to the human-machine interface.

Source: Frost & Sullivan

Research Scope and Segmentation

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Research Scope

Base Year	2017
Study Period	2017-2023
Forecast Period	2018-2030
Vehicle Type	Passenger vehicles

Detailed Geographical Scope

North America	
Developed countries	USA, Canada
Emerging countries	Mexico
Europe	
Developed countries	Belgium, Denmark, Finland, France, Greece, Germany, UK, Ireland, Italy, Luxembourg, Netherlands, Norway, Austria, Portugal, Sweden, Switzerland, Spain
Emerging countries	Czech Republic, Ukraine, Hungary, Russia, Poland, Estonia
Rest of Europe	Canary Islands, Romania, Slovenia, Slovakia, Croatia, Lithuania, Estonia, Rest of Eastern, Europe
South America	
Emerging countries	Argentina, Brazil, Chile, Colombia
Rest of SAM	Rest of South/Middle America
Africa	
Emerging countries	Egypt, Morocco, Algeria, South Africa, Tunisia
Rest of Africa	Rest of Africa
ASEAN	
Emerging countries	India, Indonesia, Malaysia, Philippines, Thailand, Vietnam
Rest of Asia-Pacific	Rest of Asia-Pacific
China	China + Hong Kong
Rest of World	
Developed countries	Australia, Japan, New Zealand, Singapore, South Korea
Emerging countries	Israel, Saudi Arabia, Turkey, Taiwan, Rest of the World

Source: Frost & Sullivan

Vehicle Segmentation

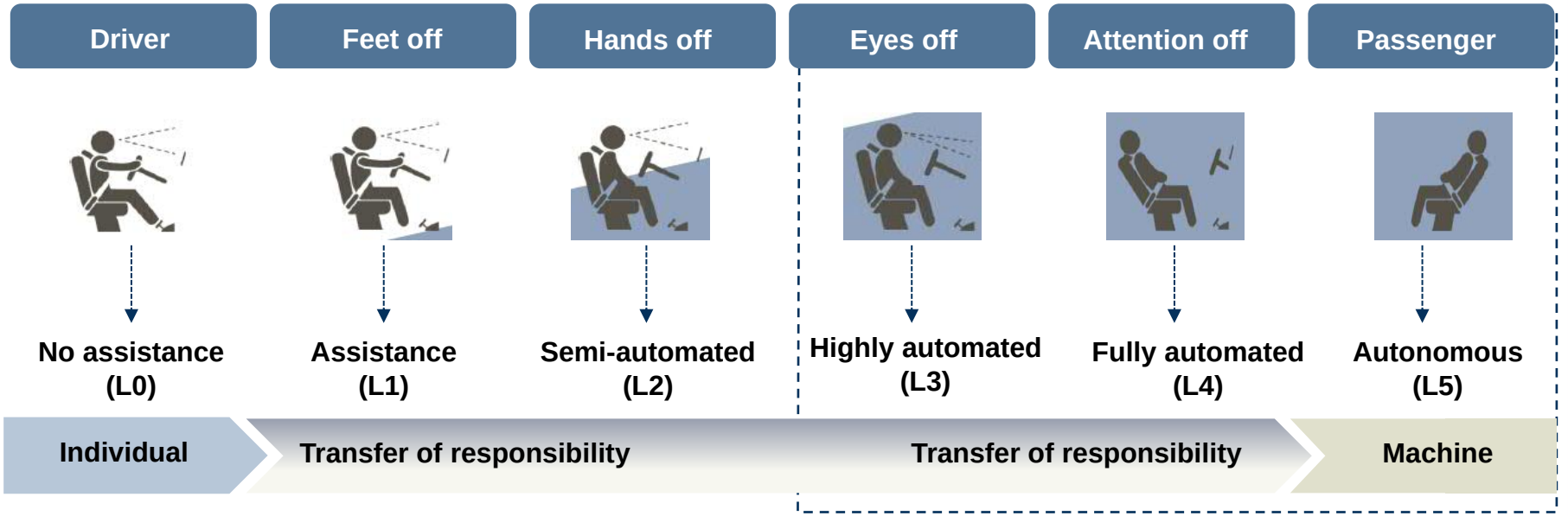
Class	Description	Global Traditional Segment	Example
Small	A—Basic	Basic	C1, Fiat 500, Panda, 107, Twingo, Up!, Isetta, Fortwo
	B—Small	Sub-Compact	Audi A1, Logan, Punto, Fiesta, Fusion, Clio, Fabia, Polo, Mito
Medium	C—Lower Medium	Compact	Audi A2, A3, Q3, BMW X1, BMW 1 Series, Golf, Focus, Mercedes A&B Class, Astra, Fluence, Jetta
	D—Upper Medium	Mid-Size	BMW 3 Series, Audi A4, Mondeo, C-Class, Superb, Passat
High End	E—Executive	Large	BMW 5 Series, Audi A6, E-Class
	F—Luxury	Large Plus	BMW 7 Series, S-Class, Audi A8
	G—Sports	Sport	Brera, BMW 6 Series, A5, A7, Mercedes SLK, Mercedes CLS, Porsche 911
Van	MPV	MPV	Galaxy, V-Class, Sharan
	SUV	SUV	Audi Q5, Q7, BMW X3, X6, Ford Explorer, Touareg
	Van	Van	Berlingo, Transit, Partner

Source: Frost & Sullivan

Market Definition—Rise of Automation

Level 3 vehicles will be a turning point for technology testing, opening the gateway to mass-market adoption of automated technology.

AD Market Outlook: Definition Of Levels of Vehicle Automation, Global, 2017–2030



Source: BMW Group

Key Questions this Study will Answer

AD Market Outlook: Key Questions this Study will Answer, Global, 2017–2023

What are the top trends that will drive the autonomous driving market in 2018? What impact will these trends have on the market?
What are the key developments in the autonomous driving market to watch out for in 2018? What are the major companies to watch in 2018?
What was the size of the total autonomous driving market in 2017; how is it expected to grow in 2018 and by 2023?
What is the impact of regulatory and macro-economic trends on market growth?
What are the opportunities available for technology providers, suppliers, and OEMs in 2018?

Source: Frost & Sullivan

Impact of Autonomous Vehicles Driving Development of Vital Facets in Business and Technology

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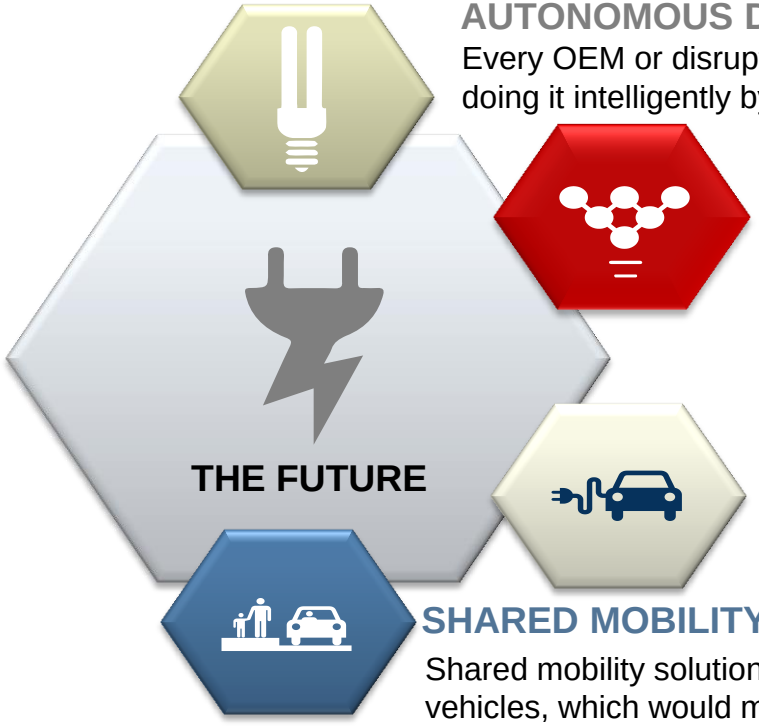
Transformational Impact of Automation on the Industry

Based on a user's preferences and activities, customized services and solutions would be offered enabling a technology-driven lifestyle that will revolutionize the way people function.

AD Market Outlook: Convergence of Vital Influencers, Global, 2017–2023



AUTONOMOUS DRIVING

Every OEM or disruptor working toward the development of autonomous technology is doing it intelligently by sensor fusion. These sensors gather massive amounts of data.

CONNECTIVITY

Connecting autonomous vehicle to the ecosystem of personalized services (for example, connected parking) to the customer, based on data collected from autonomous cars, infrastructure, and other devices

ELECTRIFICATION

Going forward, OEMs are expected to prefer high-mileage hybrid and fully electric powertrains over IC engines for autonomous vehicles

SHARED MOBILITY

Shared mobility solutions in the next decade are expected to be autonomous – electric- connected vehicles, which would make it an extremely cost-effective option when compared to pure ownership

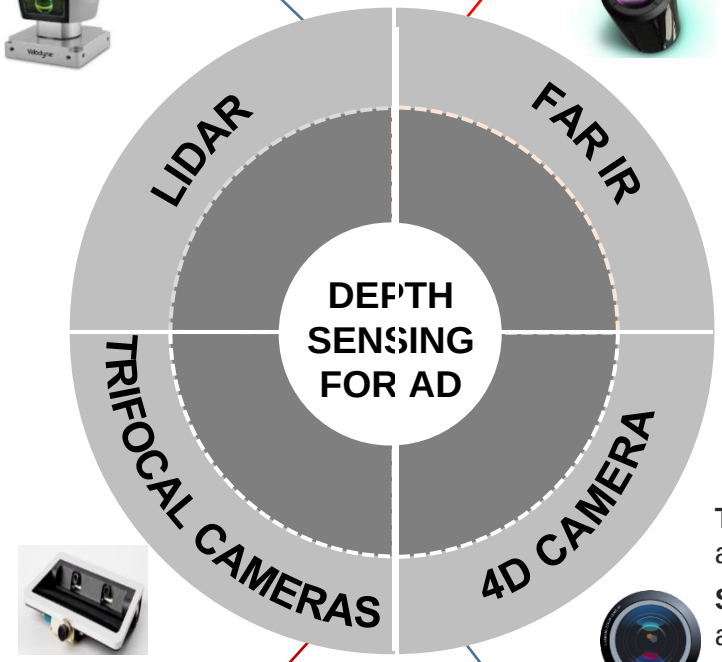
OEM Leading Convergence	General Motors	Mercedes Benz	Volkswagen Group
Where they are today?	Ahead in the race currently, continuously testing 130+ Bolt EV prototypes in different parts of the US Connectivity- ON, Autonomous- CRUISE, Shared- MAVEN	Newly introduced strategy, expected to bring new ACES vehicles on an entirely new platform by 2020	Introduced the "Sedric" concept - an electric, connected autonomous vehicle with no steering wheel or pedals aimed at shared mobility

Source: Frost & Sullivan

Impact on the Development of Next-Generation Depth Sensing

Enhancing vision is a key element of every OEM autonomous driving roadmap because the biggest obstacle today is high definition object detection and classification for accurate path planning.

AD Market Outlook: Development of Next-Generation Depth Sensing, Global, 2017–2023



Trend: Less than $500 Lidar by 2020

Sub Trend: Internalize vs. externalize Lidar Technology

OEM Partnerships: Toyota-Luminar, GM-Strobe

Impact to AD: Use of Lidars for HD mapping and localizations to fast-track deployment

Key Companies: Photive, Cepton

Trend: Improvement of night and bad weather vision

Sub Trend: Deep learning based vision sensors

OEM Partnerships: NA

Impact to AD: Early impact of AI in autonomous driving beyond path planning

Key Companies: AdaSky, Brightway

Trend: Increasing FoV for pedestrian and sign recognition

Sub Trend: Traditional suppliers increasing competence in t he camera market to compete with MobilEye

OEM Partnerships: Tvolvo-Autoliv, BMW-Continental

Impact to AD: Use of trifocal cameras for special use cases like pedestrian and sign recognition

Key Companies: Continental, LG

Trend: Integration of autonomous driving and AR

Sub Trend: Motion tracking in video for autonomous vehicles

OEM Partnerships: NA

Impact to AD: Video tracking based features for location services

Key Companies: TetraVue

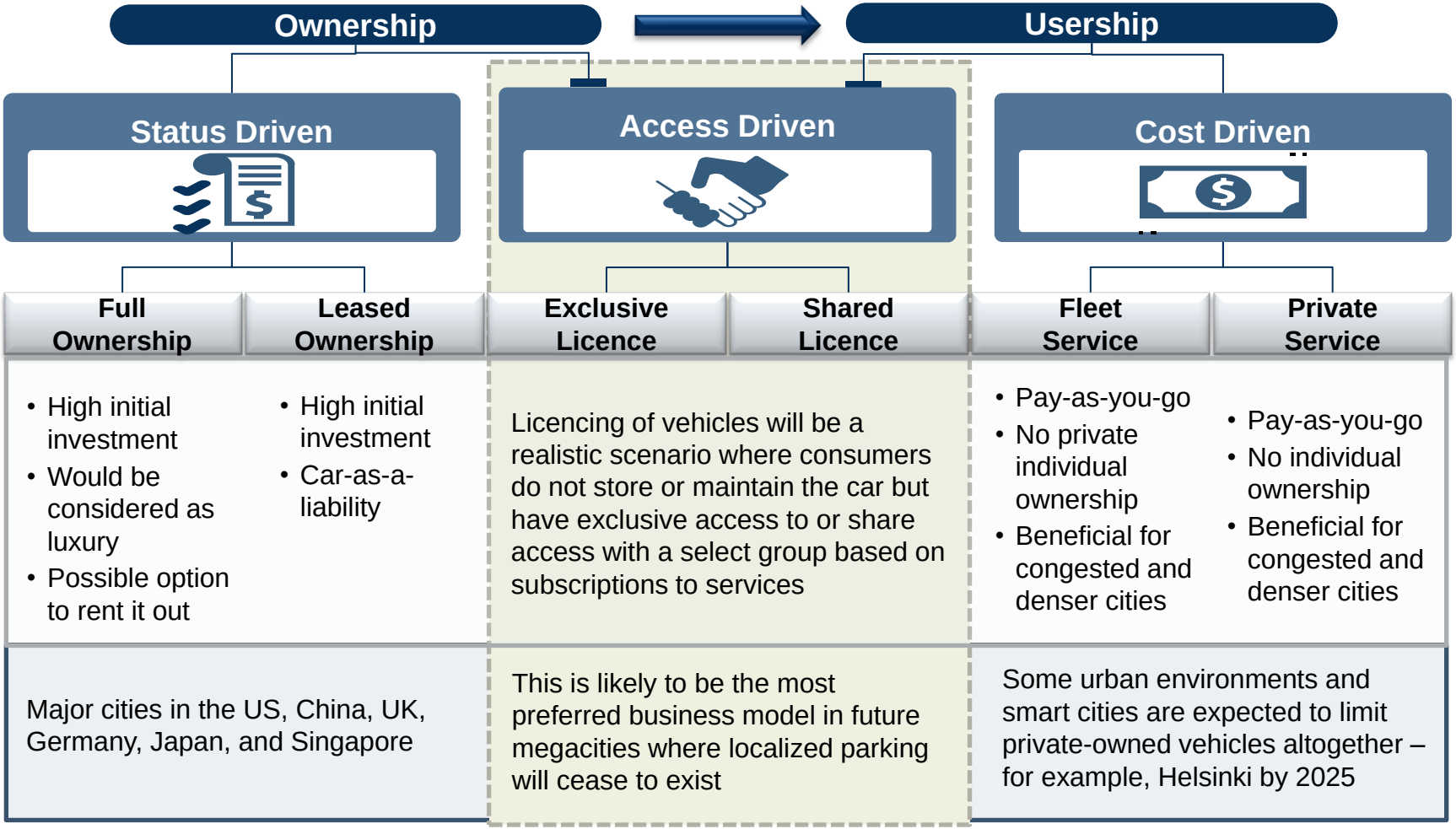
Image Source: Velodyne, AdasSky, Continental

Source: Frost & Sullivan

Impact on Ownership and User-ship Structures

Autonomous vehicles will likely rebalance the shift to a paradigm of co-existence as accessibility of vehicles sways from ownership to user-ship.

AD Market Outlook: Ownership and User-ship Structures In an Autonomous Ecosystem, Global, 2017–2030



Source: Frost & Sullivan

Impact of Autonomous Driving on Future Vehicle Design

The future cockpit and cabin of passenger vehicles will be largely influenced by OEMs trying to design components that would be in line with the fast-changing trends.

AD Market Outlook: Impact of Autonomous Driving on Future Vehicle Design, Global, 2017–2023

Augmented Reality

- Cars with augmented interactive games using the physical world seen through the windshield
- High-Definition HUDs and AD displays that would be responsive to touch and other inputs

Steering Columns

- Retractable when vehicle is on fully autonomous mode
- Advanced Biometrics Touch Steering Wheel (Brainwave, Alcohol Detection)
- Drowsiness and Distraction Detection Using Facial and Eyelid Monitoring

Fitness

- Gym equipment built into the seats and floor
- Built-in monitor displays video tutorials of various workouts
- Small fridge where drinks can be stored
- Compartment for aromatherapy

Swivelling Seats

- Equipped with self aligning, reclining calf and foot rests
- Self-adjusting seats with advanced biometrics features

Health, Wellness And Wellbeing

- Beyond Wellness (health monitoring, diagnosis, and treatments)
- Biosensors
- Condition monitoring (heart rate, blood pressure)
- Real-time alerts

Interior Lighting

- Light Diffusing Fiber
- Ultra Thin Panels (center console and doors)
- Transparent Roof with Solar-powered OLEDs
- Alive Geometry –system mounted on dashboard and side panels

Meeting Room

- Beyond just swivelling seats, interiors will be a ‘Digital Living Space’
- Automatic retractable coffee table
- Equipped with self aligning, reclining calf and foot rests

Infotainment

- Retractable tray with tablet PC for rear passengers
- 10” to 12” rear passenger screen behind front seats
- Smart touch inner cabin door surface
- Internet browsing, social media, apps, video calls, entertainment

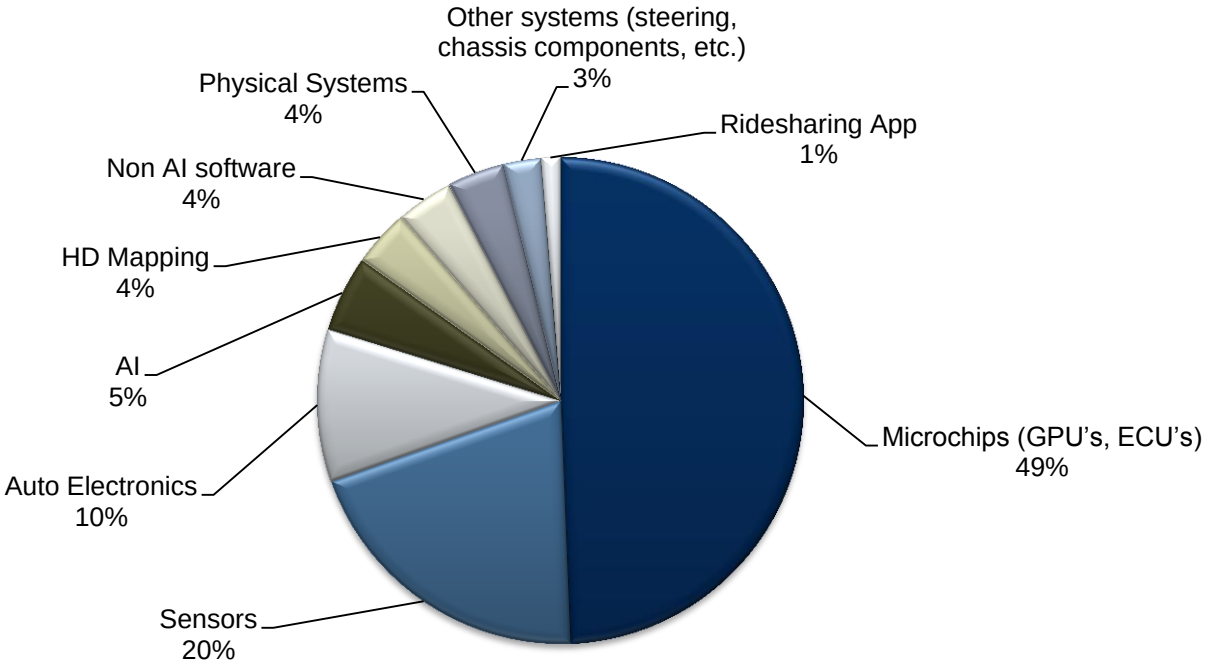
Source: Frost & Sullivan

Impact of Investments on Technology Development

Around $80 billion was invested in all forms* for the development of AD technology between 2014 and 2017; this figure is expected to increase by a further twofold from 2018 to 2022.

AD Market Outlook: Impact of Investments on Technology Development, Global, 2017–2023

Investment (Global)- primarily US, UK, Israel, Germany, China (in US$ Billion)



- 2016 was the year sparking a growth in investment
- The above investments are expected to be a positive sign of things to come in fields like natural language processing, image recognition, and others.

*Includes investment by OEMs and tech companies in the form of development, partnerships, acquisitions - primarily in auto electronics, artificial intelligence, microchips, ride sharing apps, mapping, non-AI software, sensors, and physical systems

Source: Corporate SEC Filings, Crunchbase, Brookings Institution; Frost & Sullivan

Major Market and Technology Trends in Automated Driving—2018

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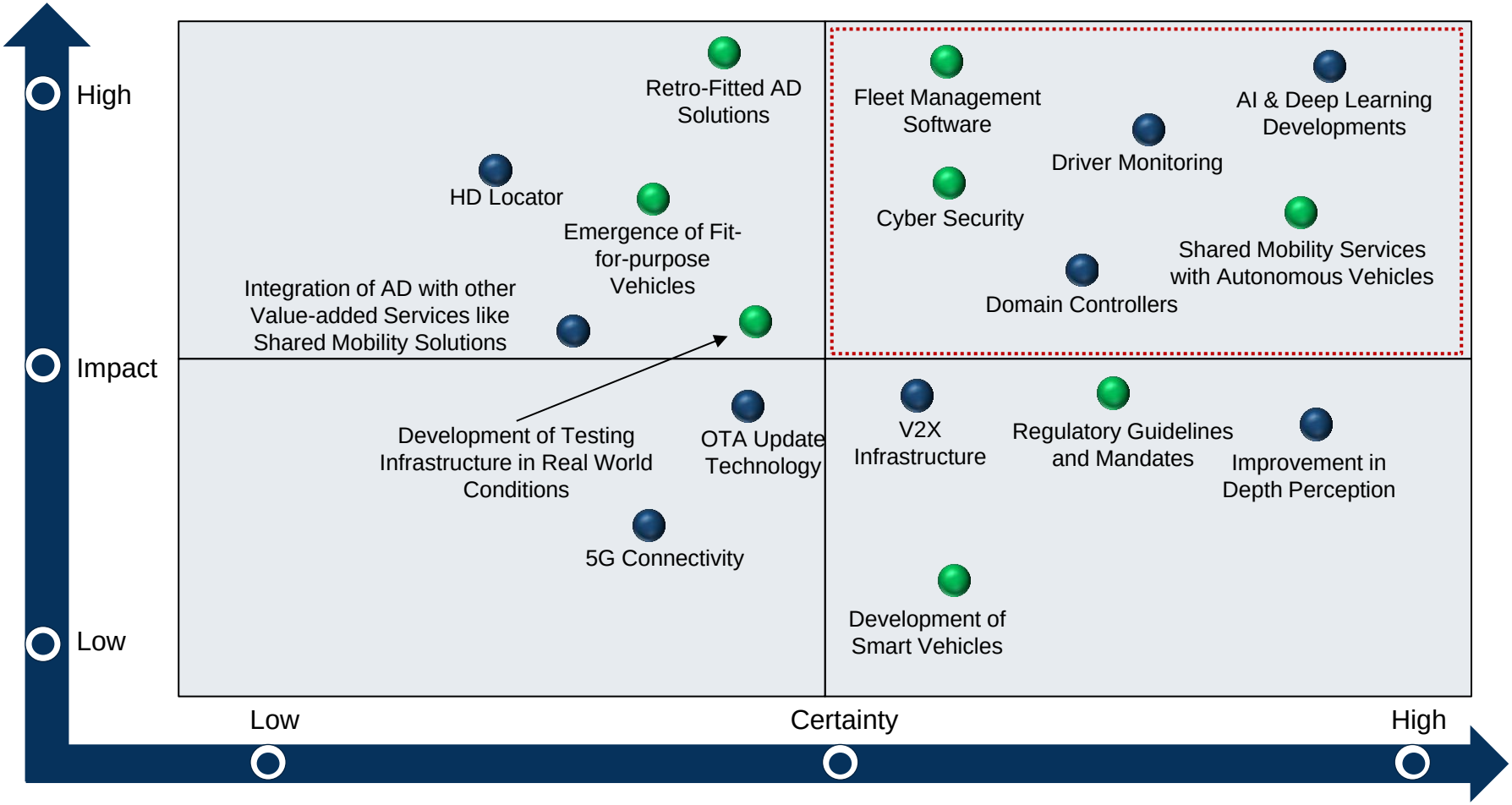
Top Trends Driving the Autonomous Driving Market—2018

2018 is expected to be the year of L3 automated vehicles for highway use and L4 testing and implementation of autonomous vehicles for limited, controlled and well-defined scenarios.

AD Market Outlook: Top Trends, Global, 2017–2023



Source: Frost & Sullivan

Market Trends

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1. Autonomous Shared Mobility Solutions

The coming together of autonomous driving and shared mobility solutions is expected to result in the convergence of e-hailing and car sharing business models.

AD Market Outlook: Autonomous Shared Mobility Solutions, Global, 2017–2023

Autonomous Driving

Shared Services

Shared Connected Autonomous Vehicles

Transformative Mobility Experience

Why are SAVs important? Cost per mile of shared AVs in 2022 = $0.35* as there is no driver (80% of the total** cost per mile) involved in the mobility-as-a-service business

Key Enablers Infrastructure → Smart networks and connectivity → Platform (OS) for car and ride sharing

Carsharing

- One owner-multiple users
- End-to-end business model is enticing for global OEMs, new mobility providers, dealer groups, rental agencies etc. to enter into the autonomous vehicle service market

Ridesharing

- End-to-end service business wherein autonomous vehicles would comply with automated ride requests, autonomous dispatch, intelligent routing, and real-time tracking and payment handling
- Real-time data collection and analytics for expanding business models

Public Transit

- End-to-end service business for shuttles designed for low-speed, private-road environments
- Best suited for self-driving shuttle service in a college campus, corporate park, or residential community in the near future

*Lyft; **-as compared to non autonomous shared mobility solution

Key: SAV—Shared Autonomous Vehicles

Source: Frost & Sullivan

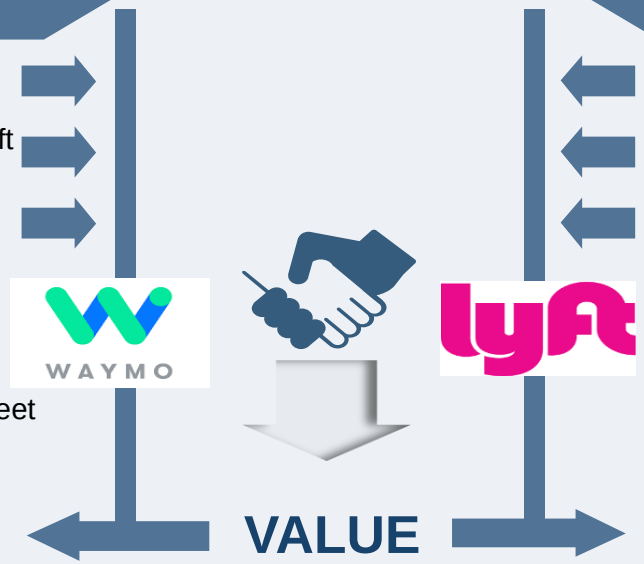
Case Study—Waymo

Waymo is expected to play a major role in the autonomous shared mobility industry by 2030, with it offering autonomous hardware/software and FCA building cars/minivans, and with Lyft managing the fleet.

AD Market Outlook: Autonomous Shared Mobility Solutions, Waymo, Global, 2017–2023

WAYMO (Autonomous Shared Mobility Software)

- Early rider program is expected to provide a fillip to Waymo to expand into the shared mobility space with Lyft
- Waymo has designed its hardware and software enabling autonomous driving, while also offering important elements such as detailed 3D HD maps, cyber security, and safety features
- Staying clear of maintaining vehicle fleet
- Data collected from cars lead to new avenues of business opportunities
- Slice of revenue from ride-sharing business



LYFT (Fleet Management)

- Waymo autonomous cars are expected to run under the Lyft banner; more shared mobility companies to partner with Waymo
- Additional revenue stream from data-based service in addition to core services
- Need not spend time and money on autonomous tech development
- Offer data-based services to clients; improve customer satisfaction
- Increase return on investment and improve competitive advantage

Waymo also plans to start its own ride-hailing service with its fleet of driverless Chrysler Pacifica minivans. Expected Location - Phoenix, Arizona

Why Waymo Leads The Shared Mobility Space?

- Waymo has conducted more than 3.5 million miles of on-road testing. This means its software is tried and tested for the widest range of use cases, enabling faster commercialization.
- A Waymo-powered ride-sharing vehicle is expected to offer personalized solutions like targeted ads. Waymo's revenue from ads could allow it to offer ride sharing services for lower prices.

Source: Frost & Sullivan

2. Collective Intelligence for Fleet Management

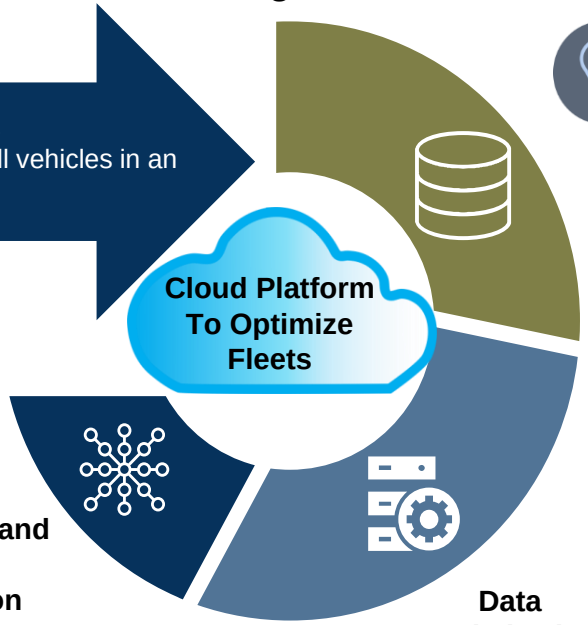
For effective fleet management, organizations need to manage both the hardware and software with all the algorithms, big data and apps, the expertise for which still lies with a handful of companies.

AD Market Outlook: Collective Intelligence for Fleet Management, Global, 2017–2023

Autonomous Vehicle Fleet Management
Centralized brain for communication with all vehicles in an autonomous fleet network

Potential Application Areas

- Transit Agencies
- Private Sites (University campuses, industrial sites, airports, resorts)
- Taxi Operators
- Vehicle OEMs
- Tourist Sites



Vehicle production will rest in the hands of OEMs

- Vehicles Telemetry
- Timetable
- Traffic Info
- Weather
- Live Demand (via smartphone app)

Software

1. Tracking

The system tracks the position of the vehicles in real-time with perfect accuracy

2. Optimizing

Complex and state-of-the-art fleet management algorithms

3. Controlling

The system sends back commands to the vehicles, giving coherence to the whole fleet

Benefits

1. **New Mobility Schemes**
   A flexible public transportation system that automatically adapts to end-user demand
2. **High Efficiency, Low Costs**
   Transport operators benefit from increased efficiency and lowered costs: Vehicles are in use only when needed but are potentially available 24/7.
3. **New Mobility Schemes**
   Shared autonomous vehicles will increase safety of pubic transport and reduce the number of accidents that happen.

Source: Frost & Sullivan

Case Study—BestMile

BestMile's cloud platform (world's first) enables the intelligent operation and optimization of autonomous mobility services, managing fixed-route and on-demand services, regardless of the vehicle brand or type.

AD Market Outlook: Collective Intelligence for Fleet Management, Bestmile, Global, 2017–2023

Fleet Operator
- Passenger info
- Easy-to-use software platform designed for fleet operators

BESTMILE'S CLOUD INTELLIGENCE
TRACKING→OPTIMIZING→CONTROLLING

Road Infrastructure

Autonomous Shuttles

Control Center

Customers can choose between a turnkey solution and a fully modular approach

Traditional Buses

Smartphone

User hails service using Bestmile app **(World's first)**

Algorithms (vehicle agnostic) optimize autonomous vehicle fleets in real-time and according to the standards of public transportation

Operational as usual

Local Motors Olli- Washington
- Olli, developed by Local Motors based on the IBM Watson platform, is a 3D printed autonomous car running in Washington DC
- Watson acts as the interface between passengers and the vehicle. Bestmile provides the software for ride hailing and route optimization.

Smartshuttle – Sion Switzerland
- Launched in 2016
- Over 21,500 people transported in autonomous shuttles in the city center

Citymobil2 – Lausanne Switzerland
- Operational on the EPFL campus from 16 April 2015 to 30 June 2015
- Was aimed at supporting existing public transport solutions for "last mile" problems
- Undergoing testing for commercialization

Image Source: Local motors, Navya, EasyMile

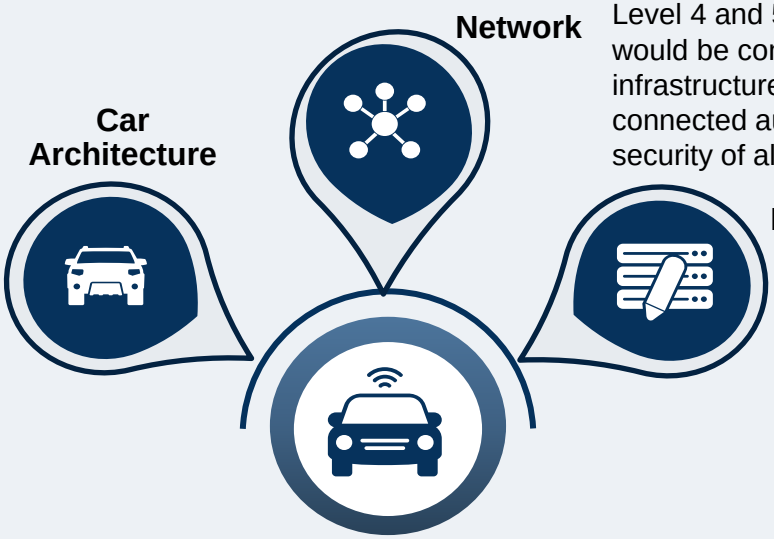
Source: Frost & Sullivan

3. Cyber Security of Autonomous Cars

The quality of intelligent in-vehicle security analytics and the threat detection capability of security solutions are expected to attract significant interest from OEMs, thus prompting collaborations in 2018.

AD Market Outlook: Major Threat Areas for Autonomous Vehicles, Global, 2017–2023

There is a possibility of hackers disabling an autonomous vehicle's brakes or steering, shut down the powertrain, or manipulate other on-board systems through denial of service attacks (DDoS). The software updates delivered over the air or at a service center create a chance of potential malicious activity and violations of organizational policies. Besides this, there could be forceful physical intrusion to override the system.



Major Threats to Connected Autonomous Vehicles

Level 4 and 5 autonomous vehicles (especially fleet) would be connected with each other and also the infrastructure. Any vulnerability in one system in such a connected autonomous car can compromise the security of all cars in that network.

Data Transmissions in IoT Ecosystem

The telemetry data transmitted through the on-board diagnostics (OBD II) port can be compromised through unauthorized sources. The data is being carried to internal control systems through complex networks, dashboard displays, and devices.
The data can also be exchanged with other connected vehicles and connected roadside entities, such as streetlights, in an IoT environment.

Major Players

- Karamba Security
- Irdeto
- Argus
- Advanced Telematic Systems (ATS)
- Harman
- Movimento

- ECU providers and over-the-air (OTA) updates vendors are collaborating with Tier-I partners and security companies to offer OEMs a holistic security solution.
- Tesla is ahead of the curve, disrupting the automotive industry by offering OTA security updates with its architecture—with no legacy systems. It has successfully enabled Autopilot using firmware OTA (FOTA) updates.

Source: Frost & Sullivan

Case Study—Karamba Security

Karamba's Carwall seamlessly integrates into the software development environment and hardens the ECU's software run-time environment to detect and prevent all attempted attacks.

AD Market Outlook: Autonomous Cyber Security, Karamba Security, Global, 2017–2023

Connected Autonomous Car Network

Cyber Security: Vital for autonomous shared mobility solutions

Industry Challenge

Autonomous vehicles will be interconnected with each other for communication, and so the chances of a vehicle getting hacked is quite high.

Currently, cars are equipped with advanced electronic systems that manage cruise control, braking, and navigation, and lane changing.

Embedded security systems are not sophisticated enough to fight evolving cyber threats, which highlights the need for a security solution that can provide 24x7 protection.

Recommended Solution

Karamba's flagship product, Carwall, provides a security solution at the level of the vehicle's ECU program code.

The solution stabilizes ECU's software run-time environment to detect and prevent all types of attacks that are trying to communicate with the car's system.

The solution locks the vehicle's ECU, by allowing only the running of operations that comply with the ECU's factory settings, thus making it difficult for an intruder to find loopholes in the software and gain control of the vehicle.

Need for autonomous security software

Reports malicious activities and classifies exploits by attack path

Source: Frost & Sullivan

Technology Trends

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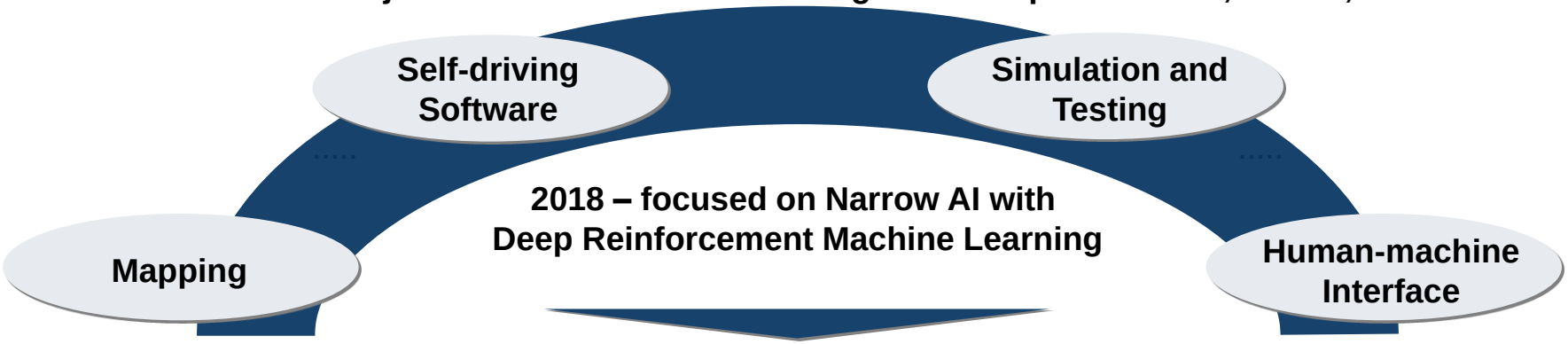
1. Convergence of Artificial Intelligence and Automated Driving

Most OEMs and Tier-1 suppliers such as BMW, Mobileye, and Tesla are working with reinforcement learning as a stepping stone to higher levels of artificial intelligence required for Level 5 autonomous driving.

AD Market Outlook: Major Avenues for AI Contributing to Development of AD, Global, 2017–2023



Narrow AI (Machines exhibit intelligence in limited and well-defined domains)

Mapping

Sensor data also gathers deep understanding of the physical environment. Taking this data and adding salient information that includes traffic control information, such as the lengths of crosswalks, the locations of traffic lights, and relevant signage, highly detailed 3D maps are created. The software also detects a change in road conditioning by cross-referencing sensor data with on-board maps.

Software

PERCEPTION

Uses data from the vehicle sensors to detect and classify objects on the road, while also estimating their speed, heading, and acceleration over time

Behavior Prediction

The software can model, predict, and understand the intent of each object on the road

Path Planner

It considers all the gathered information from perception and behavior prediction, and plots out a path for the vehicle.

S&T

Initial Scenario

High detailed virtual replica of say, an intersection, is built with in-house sensors

Multiple Added Elements to Scenario

such as flashing yellow lights or cars moving in the wrong way are built into the simulation. This is practiced several times to refine the response of the algorithm. More variations are added.

Validation

The new learned skill becomes part of the knowledge base of autonomous driving.

HMI

Interaction Intelligence

AI will be used to understand driver and occupant emotions and make it an empathetic companion.

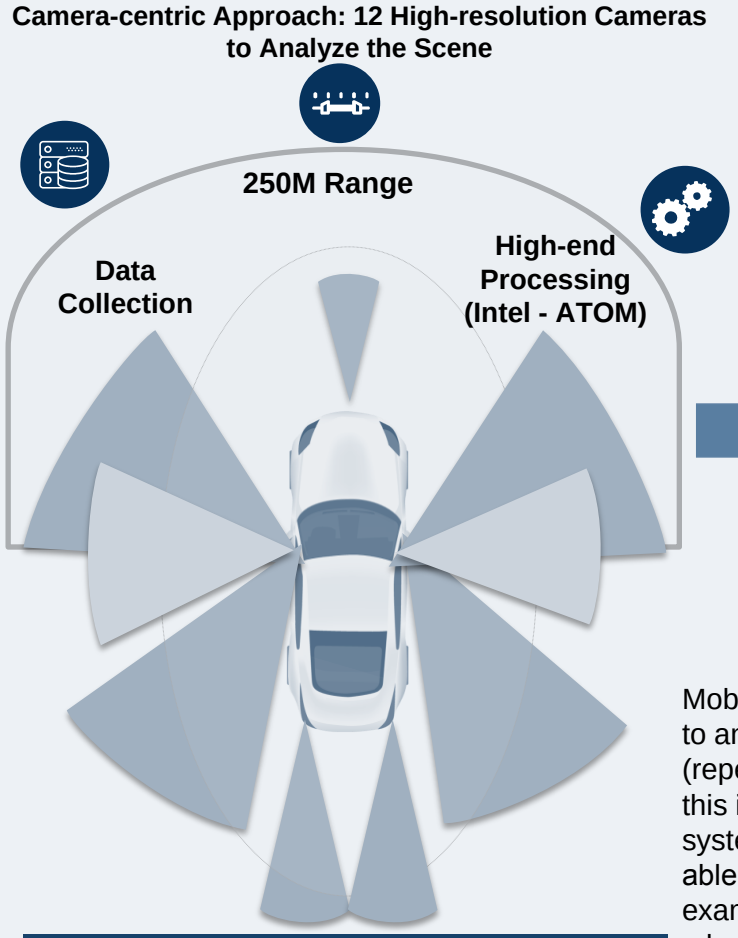
The information fed into the system will self-learn based on user preferences on several aspects such as infotainment system, mood lighting, and voice interactions.

Source: Frost & Sullivan

Case Study—Mobileye

Mobileye is working with BMW, FCA, Intel, and Delphi and is taking a similar approach as compared to Tesla in terms of a camera-centric solution and reinforcement machine learning techniques for software training.

AD Market Outlook: AI for AD, Mobileye, Global, 2017–2023



Self Driving Software exhibits intelligence in limited and well-defined domains

Use Case:

- Full Range Autonomous Driving (urban and night)
- Autonomous Bypassing
- Autonomous Headway Monitoring
- Autonomous Braking at Stop Signs and Pedestrian Detection

Deep Reinforcement Learning

Software trained to exhibit intelligence at par with humans across varied general fields in driving

Use Case: Fully Autonomous Vehicle and car acts as personal assistant

Mobileye is using deep Reinforcement Learning approach (algorithm learns to react to an environment) to tell the software if it has made the correct or the wrong decision (repetition of a process until positive outcome is yielded). Data required for achieving this is crowd sourced from existing vehicles equipped with the Mobileye vision system. With enough iterations, a reinforcement learning system will eventually be able to predict the correct outcomes and therefore make the 'right decision'. For example, AI will allow cars to determine in real-time how to navigate a four-way stop, a busy intersection, or other difficult situations encountered on city streets.

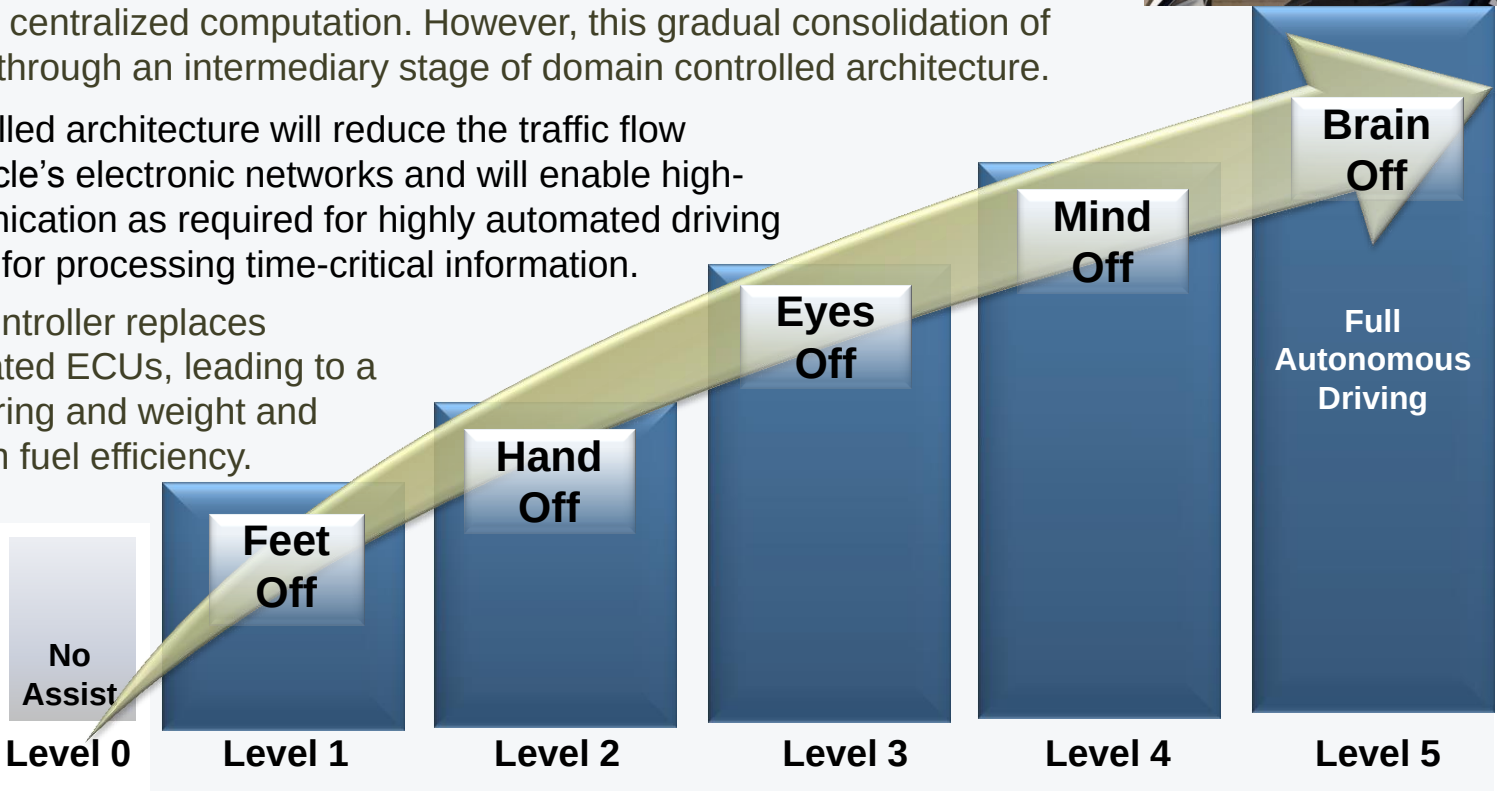
Source: Frost & Sullivan

2. Domain Controllers

The process of continually adding ECUs for each feature (driver assistance or autonomous driving) is no longer viable as it adds unnecessary cost in the vehicle's E/E architecture and also increases the complexity.

AD Market Outlook: Domain Controllers, Global, 2017–2023

- With advancements in autonomous driving, the traditional process of continually adding ECUs for new features is no longer viable. It increases the complexity as well as the cost of the architecture.
- This will result in transformation of the E/E architecture from decentralized computation to centralized computation. However, this gradual consolidation of ECU will pass through an intermediary stage of domain controlled architecture.
- Domain controlled architecture will reduce the traffic flow through a vehicle's electronic networks and will enable high-speed communication as required for highly automated driving (HAD) and AD for processing time-critical information.
- The domain controller replaces multiple dedicated ECUs, leading to a reduction in wiring and weight and improvement in fuel efficiency.



Source: Frost & Sullivan

Case Study—Audi zFAS (zentrale Fahrerassistenzsteuergerät)

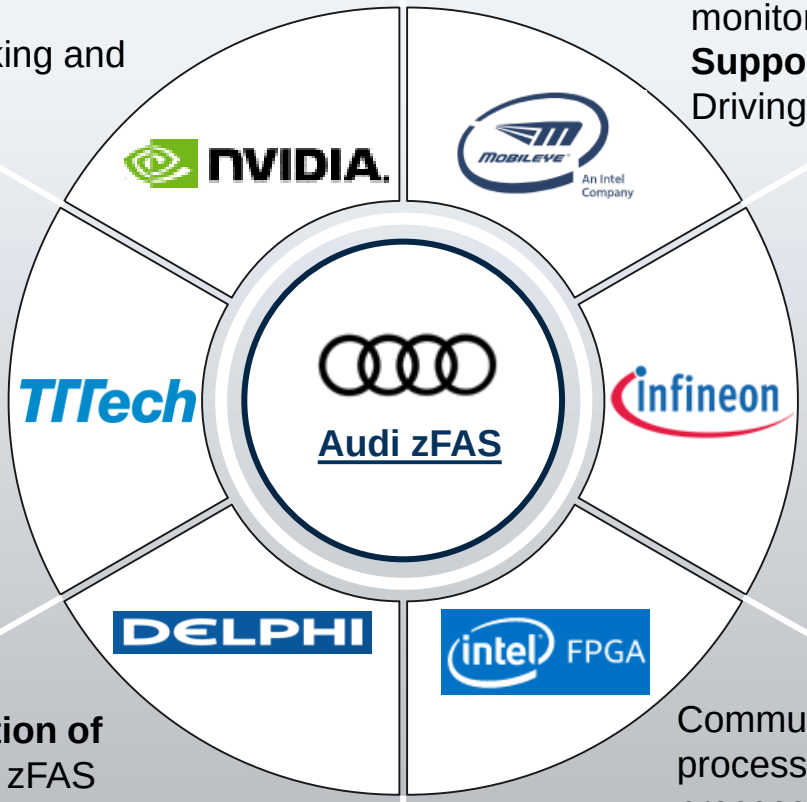
The zFAS processes data at a rate of 2.5 billion inputs per second and takes over the vehicle when engaged by the driver.

AD Market Outlook: Autonomous Domain Controller: Audi- zFAS, Global, 2017–2023

Tegra K1
Sensors: Surround cameras, Radars, LiDARs and ultrasonic sensors
Supported Features: Parking and Piloted Driving

EyeQ3
Sensors: Stereo camera and driver monitoring camera
Supported Features: Piloted Driving

Developed the **deterministic Ethernet bus** used within the zFAS board and the **middleware layer**, enabling the platform to run multiple virtual machines in a safe and secure manner.



Aurix Microcontroller to monitor the safety of the system by matching the results of same computational tasks obtained from two identical cores of the microcontroller.

Responsible for **integration of the components** on the zFAS board and providing it to Audi.

Communication between the host processor and the application processor runs through **Cyclone 5 FPGA** provided by Altera.

Logo Source: Mobileye, Intel, Infineon, Altera, Delphi, TTTech, Audi

Source: Frost & Sullivan

3. Driver Monitoring System

DMS is important in evaluating the driver's condition before taking over and handing back control of the system in the case of a Level 3 and 4 autonomous vehicle.

AD Market Outlook: Driver Monitoring System, Global, 2017–2023

UNECE REGULATION NO. 79

Automatically commanded steering function (ACFS) mandates a driver availability recognition system that detects if the driver is present and is able to take over the steering. A driver camera is mandatory for HAD systems over Level 3.

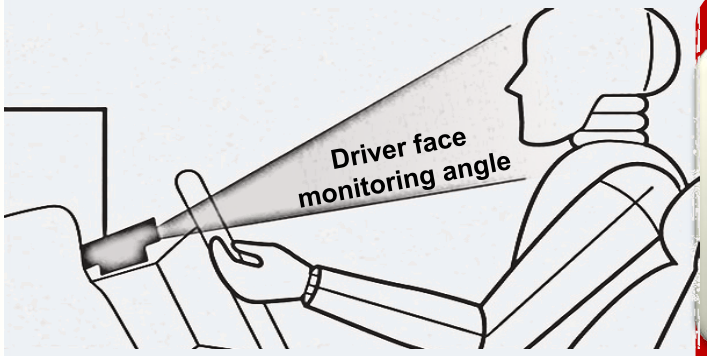
CAMERA-BASED	DMS	BIOLOGICAL SENSOR-BASED
• Driver authorization • Gaze detection • Eye tracking and texting detection • Occupant monitoring	MONITORING PARAMETERS	• Heart beat and blood pressure monitoring • Skin temperature and respiration rate • Hyperthermia, dehydration monitoring • Brain waves
• Stereo camera • Mono camera • 3D camera • IR camera	TYPES	• Pressure transducer • Capacitive sensor • Piezoelectric sensor • IR sensor
• Ability to work in all lighting conditions • Camera placement to suit different drivers • Detect drivers' eyes when wearing sun glasses	CHALLENGES	• Placement of sensors on the steering wheel, seat belt, and driver seat is a challenge • Costly solution if the sensors have to be installed on the entire steering wheel or seat belt
NA: Featured in the Cadillac CT6 as part of the SuperCruise in 2017- commercialization expected by GM and Tesla (hardware present but activation pending) by 2018 **EU:** Commercialisation by Mercedes, Audi and BMW expected by 2018	MARKET	**NA:** Ford is experimenting on these technologies **EU:** Commercialization by Mercedes, BMW by 2020 **Germany's rule to install a black box that could record the events in autopilot mode will also act as a catalyst for the penetration of vision-based DMS.**

Source: Frost & Sullivan

Case Study—General Motors' Driver Attention System

GM's system is the first in the market to incorporate an inward facing camera for detection of driver attention for safely reassigning vehicle control back to the driver in Level 3 systems.

AD Market Outlook: GM Driver Monitoring System, Global, 2017—2023



Head position, facial expression, blinking rate, eyeball rotation

Driver Monitoring Camera by Seeing Machines—FOVIO

Monitoring Parameters

Output Medium

Steering vibration | Audio alerts | Seat vibration | Visual displays

Super Cruise
(Hands Free Highway Driving)

One of the pre-requisites for activation of Super Cruise is If the Driver Attention assist is active

Why Driver Attention Monitoring?

- Stepping stone to Level 3 and 4 autonomous driving
- Helps to decrease accidents by reducing distracted driving
- Supports autonomous handoffs
- Brand differentiation (GM - Only Mass Market OEM in the world to offer camera-based DMS currently)

- The DMS technology portfolio developed by Seeing Machines is being sourced to support autonomous driving features and reduce the potential for accidents caused by distracted driving in the Cadillac CT6 currently.
- The system has the ability to track the driver's eyes even if he/she is wearing sunglasses; it also alerts the driver when he/she is distracted.
- For higher levels of automation, GM and Seeing Machines plan to use machine learning techniques to better sense and predict the in-vehicle environment, creating a powerful set of signals that improve automated driving systems and ADAS functionality.

Source: Frost & Sullivan

Automated Vehicle—Timeline and Major OEM and Supplier Activities

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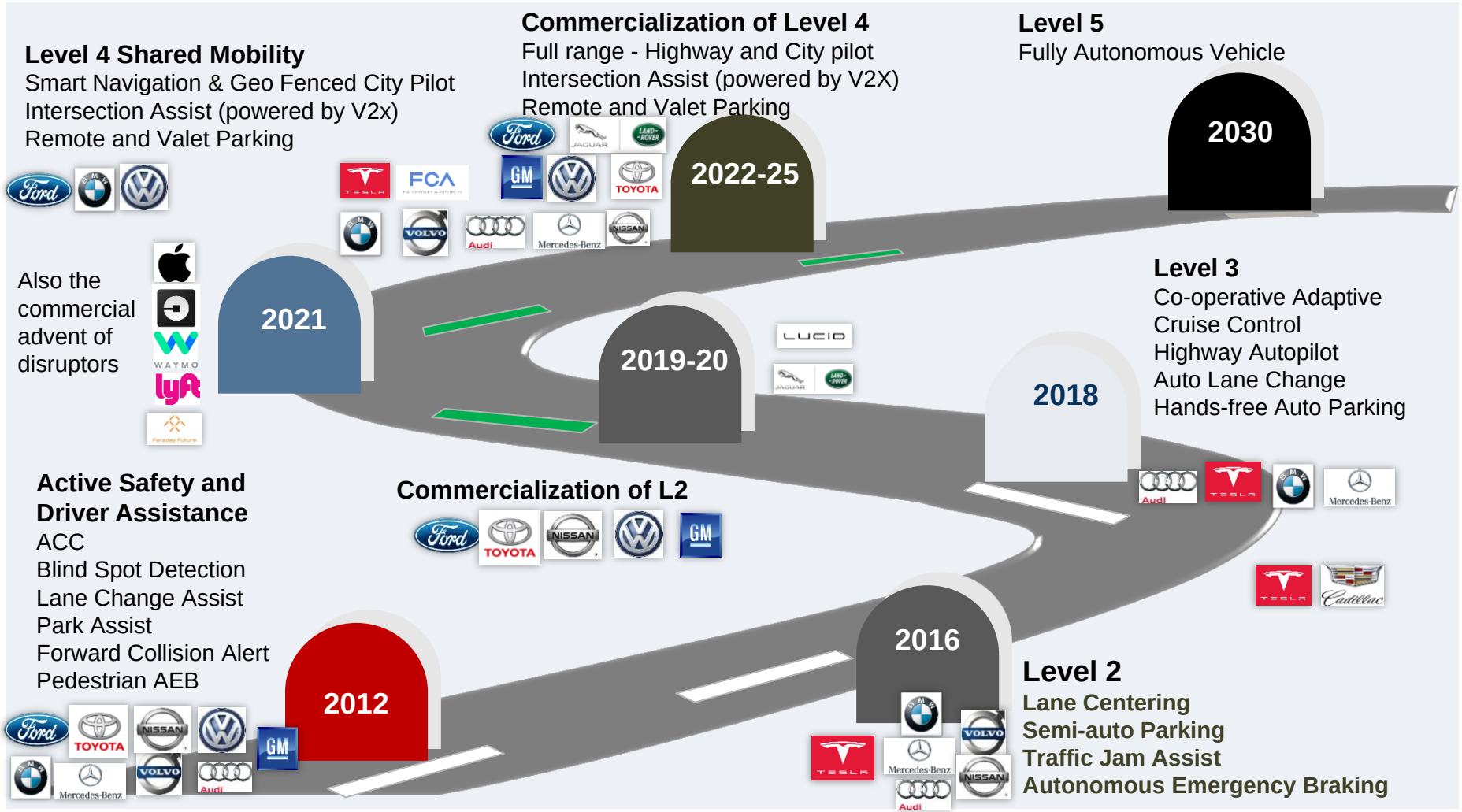
Feature Roadmap—Autonomous Driving

At least four OEMs are expected to skip introducing Level 3 Autonomous Driving, while full Level 5 capability is not expected to be available before 2025.

AD Market Outlook: Feature Roadmap, Global, 2017–2030



Source: Frost & Sullivan

Major OEM Outlook—1: Global

Several OEMs are looking at “Self-driving cars as a service” and expect it to be a major revenue generator, besides sale of legacy vehicles, over the coming years.

AD Market Outlook: Competition Landscape, Global, 2017–2023

Audi	BMW	Mercedes-Benz	Volvo	Tesla	Ford	Toyota	GM	FCA
Present	L2	L2	L2	L2	Between L2 & L3	Driver Assistance	Driver Assistance	Driver Assistance & L2	Active Safety
Future-Targeted Applications	Highway Pilot, City Pilot, Automated Parking	Focused primarily on L3, L4 for fleet by 2021	L4 automation on cars by 2020	No L3. L4 by 2020	Mind off highway autopilot by 2018-19, L4 by 2021	No L3. Shared Mobility Fleet (L4) by 2021	Level 4 Highway teammate post 2020	SuperCruise L3 with lane change. Shared mobility by 2019	L4 by 2020 with Waymo
Expected Sensor Fusion Strategy	1x LiDAR + 5x radars + 5x cameras including forward-facing stereo camera + Ultrasonic sensors + GPS	6 radar sensors + 8 cameras + 5 LiDAR	1x LiDAR + Stereo camera + Radars + GPS + FLIR	1 Stereo/ trifocal camera + 1 LiDAR + 7 Radars + 4 Cameras + 12 ultrasonic sensors + HAD Maps	1 Radar + 8 Cameras + 12 ultrasonic sensors + HAD Maps	Stereo / trifocal camera + 2 LiDARs (for L4 only) + Radars + Camera + HAD Maps	4 long range LiDARs + Radars + Camera + HAD Maps	2/4 x LiDAR sensors + 14 cameras + 8 static long-range radar units + 10 ultra-short-range radar sensors	5x LiDARs+ Radars + Cameras + Ultrasonic Sensors + GPS
Key Partnerships	Valeo, Mobileye, Conti,Bosch Nvidia	Mobileye, Intel, Bosch, Conti	Nvidia, Conti, Autoliv, Bosch	Nvidia,Autoliv,Delphi, Valeo	Nvidia, Conti, Delphi	Magna, Conti, Delphi, Valeo, Velodyne	Denso, Conti, Nvidia	Conti, Takata, Denso, Autoliv, ZF, Gentex	Waymo, Mobileye, BMW, Intel

Source: Frost & Sullivan

Major OEM Outlook—2: Global

Several mass-market OEMs prefer improving and increasing the penetration of active safety and driver assistance features over introducing any form of autonomous driving features on their legacy vehicle portfolio.

AD Market Outlook: Competition Landscape, Global, 2017–2023

	Volkswagen	Mazda	Hyundai	Nissan	Renault	Porsche	PSA Groupe
Present	Active Safety and Driver Assistance	Active Safety and Driver Assistance	Active Safety and Driver Assistance	Active Safety and Driver Assistance, Infiniti - Level 2	Driver Assistance	Driver Assistance	Driver Assistance
Future-Targeted Applications	L2 vehicles by 2019	Autonomous driving technology on Mazda vehicles by 2025	L4 autonomous vehicles by 2021-22	L2 autonomous by 2019	L4 Vehicles by 2022	Optional autonomous drive mode operational on driver's demand	First L2 vehicle by 2018
Expected Sensor Fusion Strategy	5x radars + 5x cameras including forward-facing stereo camera + GPS	2 LiDARs + 4 Radars + 3 Cameras	2 LiDARs + 4 Radars + 3 Cameras + ultrasonic sensors + GPS	6 LiDAR + 9 Radars + 12 camera + 12 ultrasonic sensors + HAD Maps	Ultrasonic sensors + Vehicular antennas + Radar + LiDAR+ cameras + HAD Maps	Stereo/trifocal camera + LiDAR (for L4 only) + radars + camera + HAD Maps	Up to 7 Radars + 5 Cameras + HAD Maps
Key Partnerships	Aurora, Intel, NVIDIA	Mobileye, Intel, Bosch, Conti	Aurora, Hyundai Mobis, LG	Microsoft, NASA, Intel	Embotech, Tom Tom, LG, Ubisoft, IAV, Sanef	Magna, Conti, Delphi, Valeo	nuTonomy, Almotive

Source: Frost & Sullivan

Autonomous Shared Mobility—Competition Landscape

OEMs such as BMW, Ford, Toyota, and VW are seriously exploring development and launch opportunities with robo-taxi service as part of a new mobility brand.

AD Market Outlook: Autonomous Shared Mobility Solutions, Competition Landscape, Global, 2017–2023

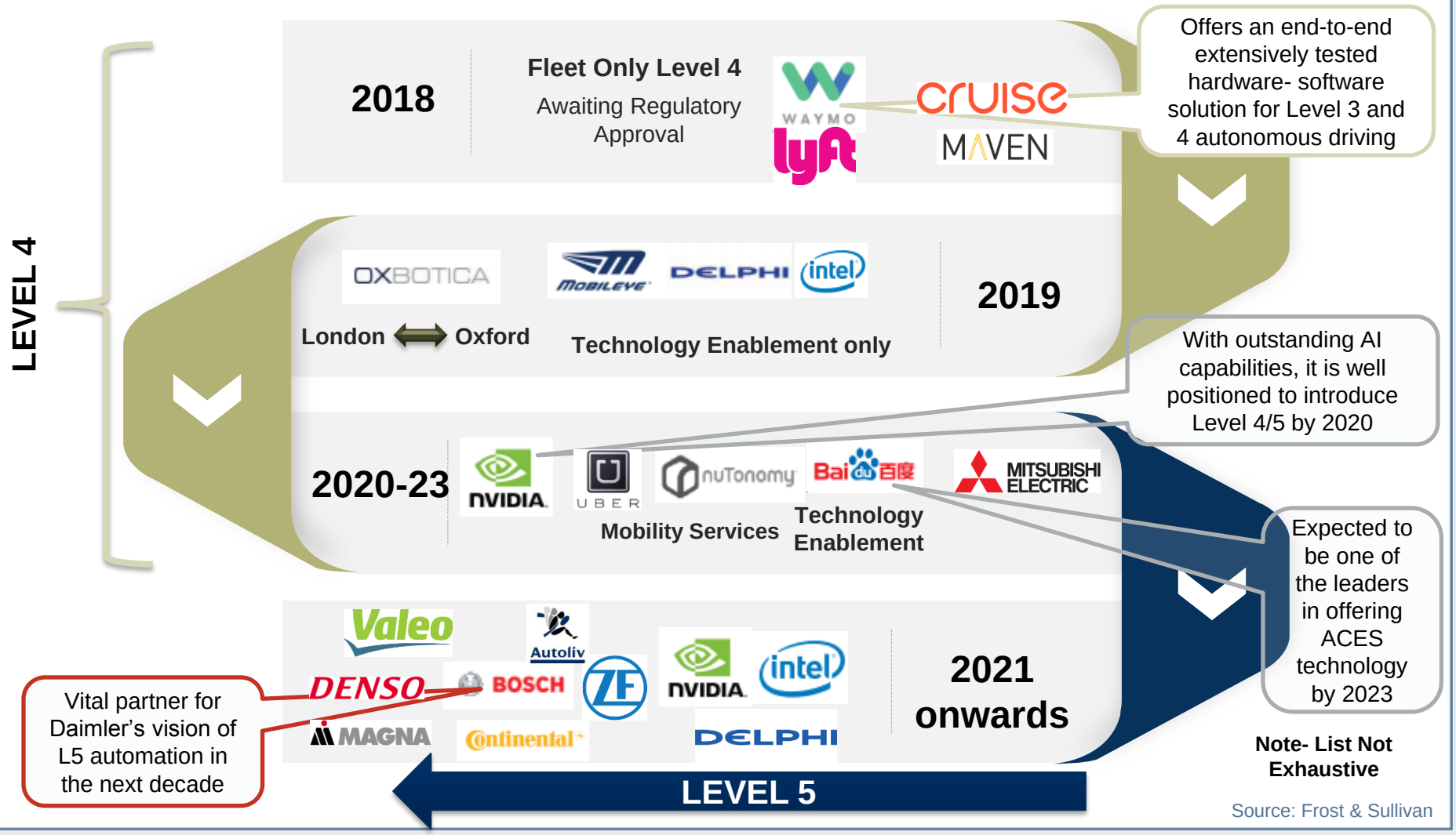
	OEM/ DISRUPTOR	Apple	BMW	Daimler	Ford	GM	Tesla	Uber	VW	Volvo	Waymo
MOBILITY	H/W	N/A	Mobileye, Nvidia, Intel	Qualcomm, Mobileye	Velodyne Nvidia	Mobileye, Delphi	Nvidia In-house	Velodyne	Mobileye, Nvidia, LG	Velodyne	In-house, FCA, Lyft
	S/W	In house	IBM Watson	In-house	In-house	Cruise Automation	In-house	In-house	In-house	In-house	In-house
	NEW MOBILITY SERVICES	Didi Chuxing	JustPark, ParkNow	Car2Go, Blacklane	Zoomcar, Getaround	Lyft, Maven	N/A	UBER	GETT	Fleet	Waze Carpool
	OTHER MOBILITY SERVICES	-	Moovit	Moovel, Ridescout	N/A	N/A	Hyperloop	Otto, Drone Taxi	N/A	Smile	Otto Fighter, Drone
SERVICES	PARKING APPS	Parkopedia		Gottapark, ParkTag, Park2gether	N/A	N/A	N/A	N/A	N/A	N/A	Waze
	MAPPING	Apple Maps	HERE Maps	HERE Maps	Civil Maps	On-Star	In-House	Bing	HERE Maps	HERE Maps	Google Maps
	CONNECTED SERVICES	Home Kit, CarPlay	N/A	N/A	Sync / Alexa	N/A	Superchargers	N/A	N/A	N/A	NEST, Android Auto

Source: Frost & Sullivan

Technology Enablers and Major Suppliers

The most aggressive predictions come from Waymo, Mobileye (Intel), Delphi and Oxbotica, who see Level 4 technology a reality by as early as 2018 or 2019.

AD Market Outlook: Technology Enablers, Timeline, Global, 2018–2023



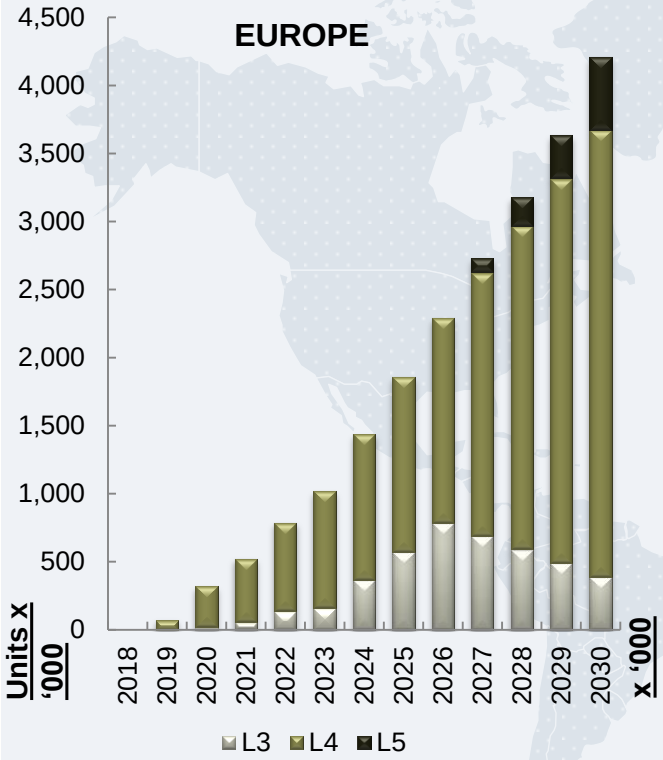
Source: Frost & Sullivan

Region-wise Estimation of AD Unit Shipments—Market Leaders

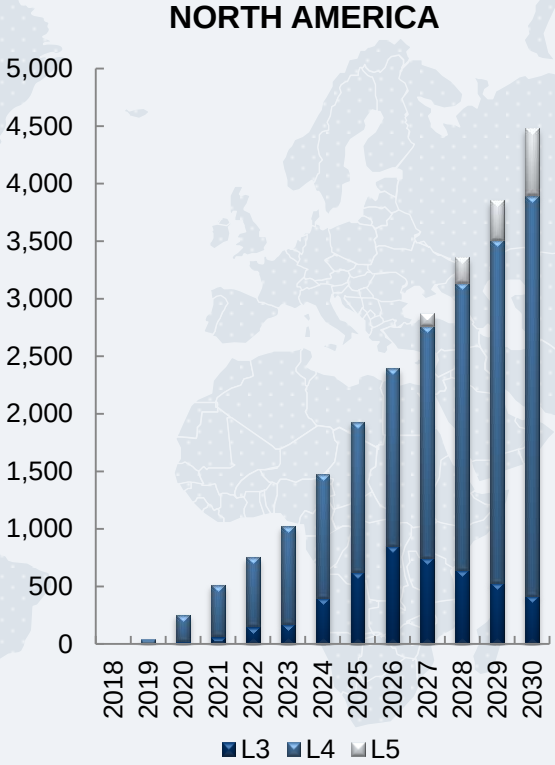
By 2025, China is expected to lead North America and Europe by the number of automated vehicles sold, whereas technology penetration wise, Europe is expected to lead the market for autonomous driving globally.

AD Market Outlook: Region-wise Estimation of AD Introduction, Market Leaders, Global, 2018–2030

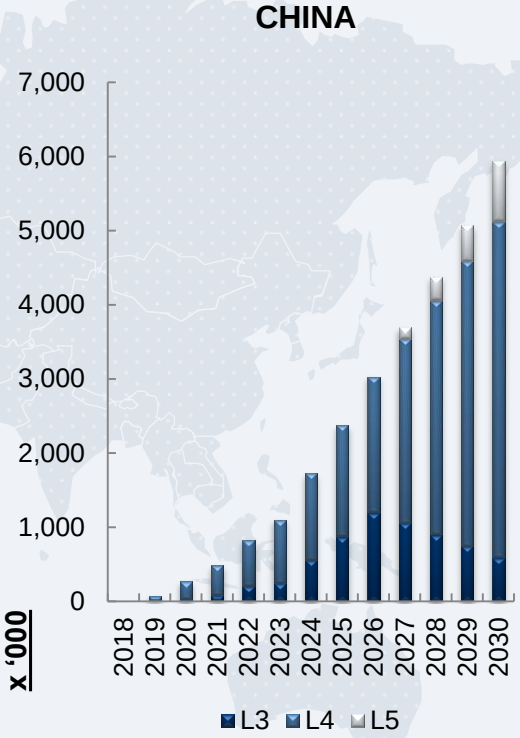
Leading Markets—Ownership Based



The region is expected to have the highest penetration (about 4.3%) of L3 and L4 autonomous vehicles combined by 2023



About 3.9% of vehicles by 2023 is likely to have fully automated features. Level 3 automated vehicles are expected to witness stunted growth by comparison



With L4 vehicles counting approximately 2.8% of the total vehicle population, China would not be far behind in terms of Level 4 vehicles by 2023, owing to the high rate of technology development and testing

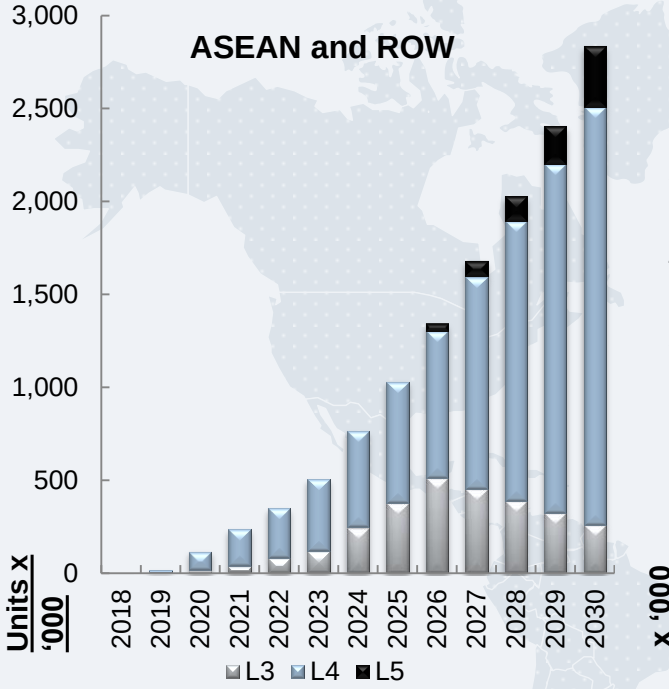
Source: Frost & Sullivan

Region-wise Estimation of AD Unit Shipments—Market Followers

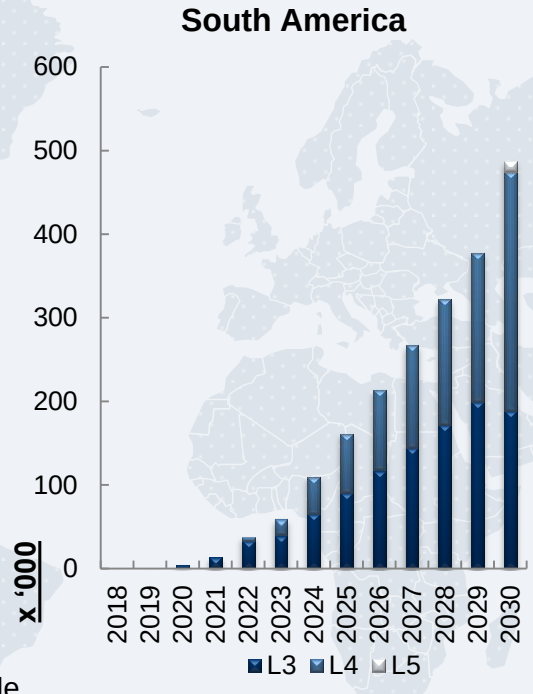
Despite regulatory uncertainties, technological and infrastructure challenges, the market for autonomous driving in emerging markets is expected to pick up toward 2023, primarily in Asia followed by South America.

AD Market Outlook: Region-wise Estimation of AD Introduction, Market Followers, Global, 2018–2030

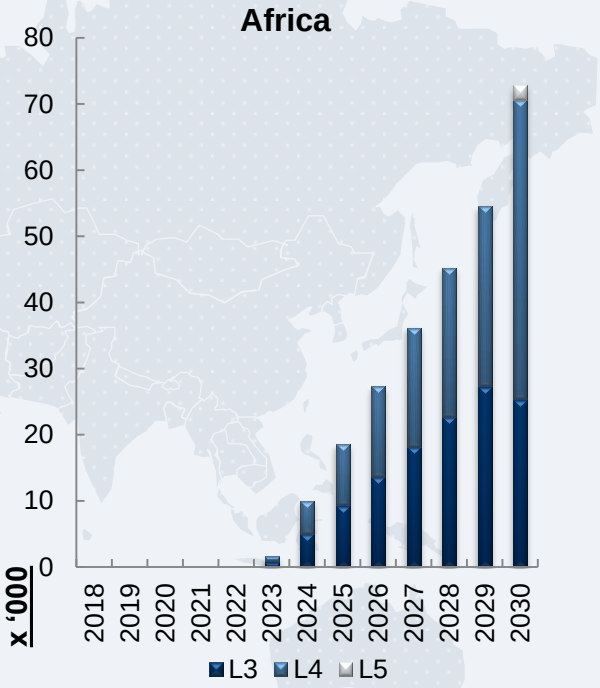
Follower Markets—ownership Based



AD to be introduced first in Japan due to possible legal and regulatory frameworks. More likely to have an equal penetration of Level 3 vehicles, with them accounting for 0.6% of the total vehicles sales by 2025. Australia, South Korea, and Singapore are expected to be the other countries with 3.9% penetration of autonomous vehicles by 2023.



One of the fastest developing markets for autonomous driving, with approximately 0.4% of the total vehicles sold in 2023 expected to have Level 4 features



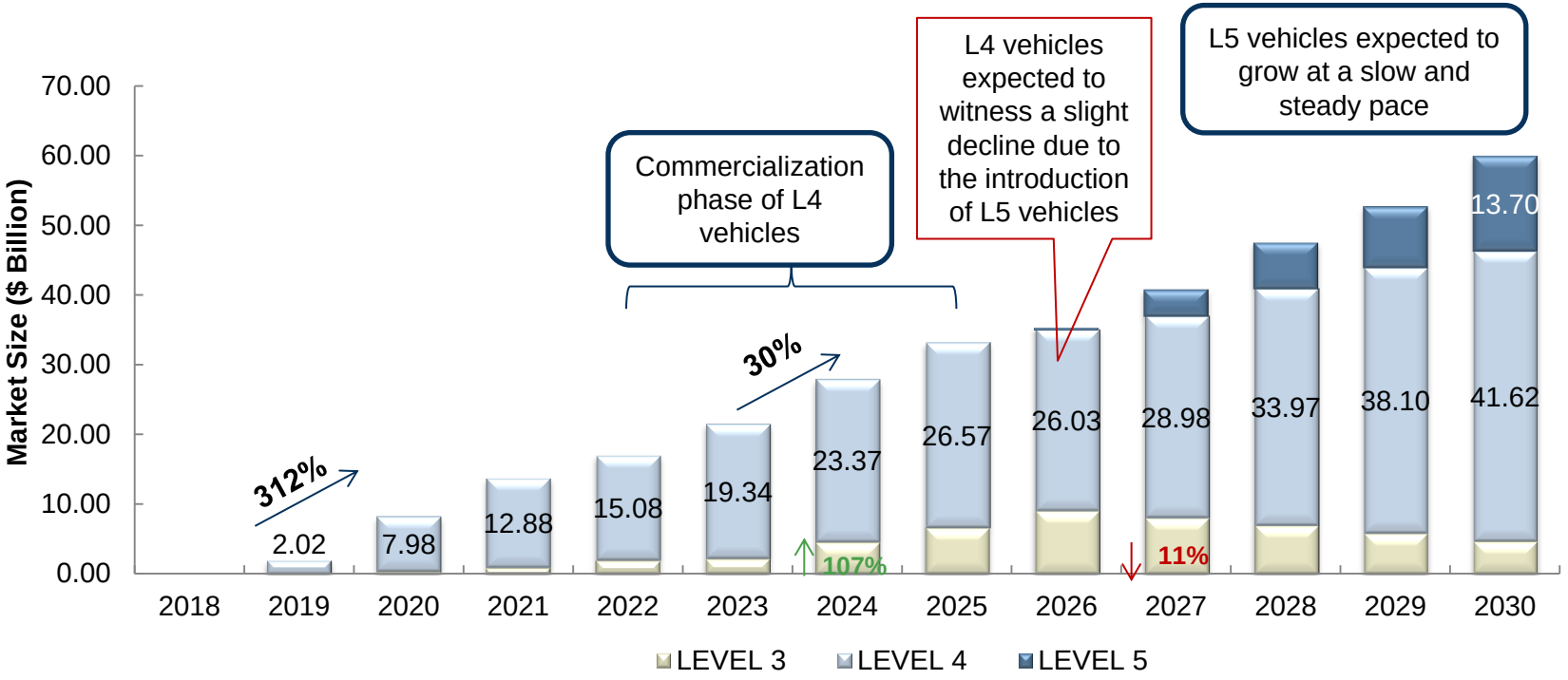
A developing market, with 0.1% vehicles by 2023 expected to have autonomous driving features

Source: Frost & Sullivan

Total Market Size Autonomous Vehicles (Ownership)

By 2023, L3 and L4 automated functions are expected to account for approximately 0.8% and 2.3% respectively of the total vehicles sold globally.

AD Market Outlook: Total Autonomous Vehicle Market Size (ownership), Global, 2018–2030



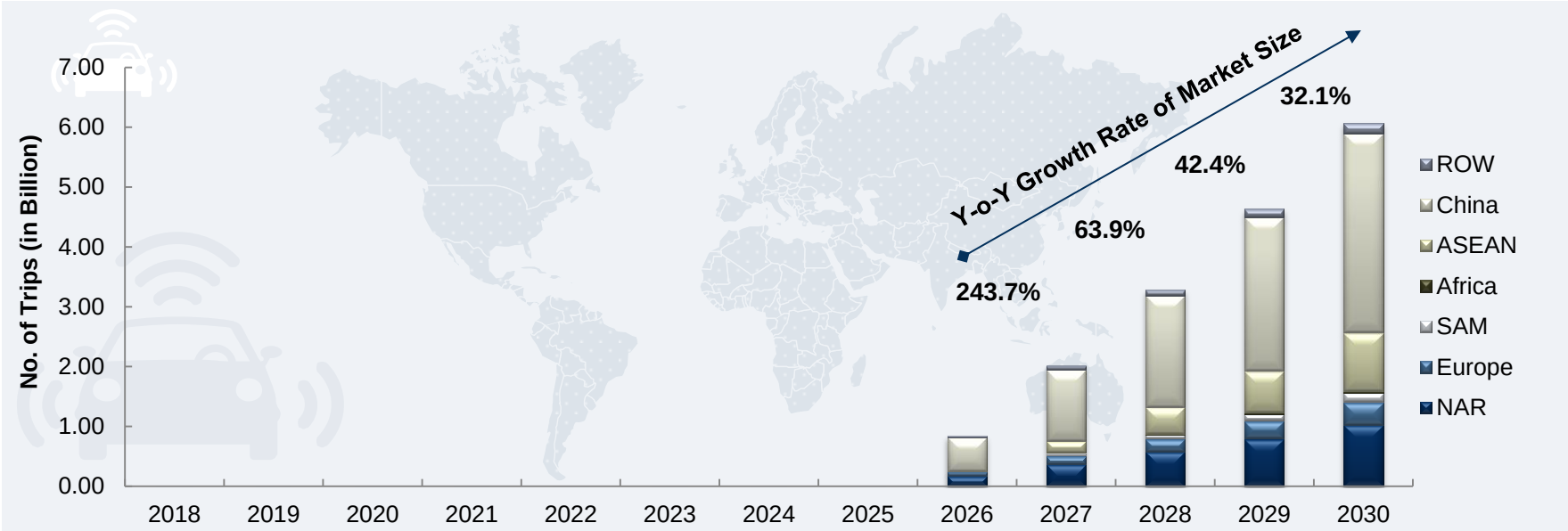
- Total market for privately owned autonomous vehicles is expected to be $60.01 Billion by 2030.
- The total market size is estimated based on the approximate price of autonomous driving kits for the subordinating year.
- 2018 is expected to be the year of introduction of L3 vehicles, but 100% of them would be in the premium segment, and subsequently a low-volume market.
- L4 vehicles are expected to surpass L3 and L5 vehicles in terms of market penetration from 2020 onwards.

Source: Frost & Sullivan

Automated Driving—Shared Mobility: Taxi, By Rides

The global market size of the autonomous shared taxi segment is expected to reach $38.61B by 2030, with China and North America being the major markets.

AD Market Outlook: Expected YoY Adoption Rate Of Autonomous Taxis by Number of Rides, Global, 2018–2030



Markets include developed regions like Australia, Japan, and Singapore where autonomous taxis are likely to grow faster. The average cost per trip by 2030 is expected to be around $3.64, with 30-40% of the total estimated to be driver costs.

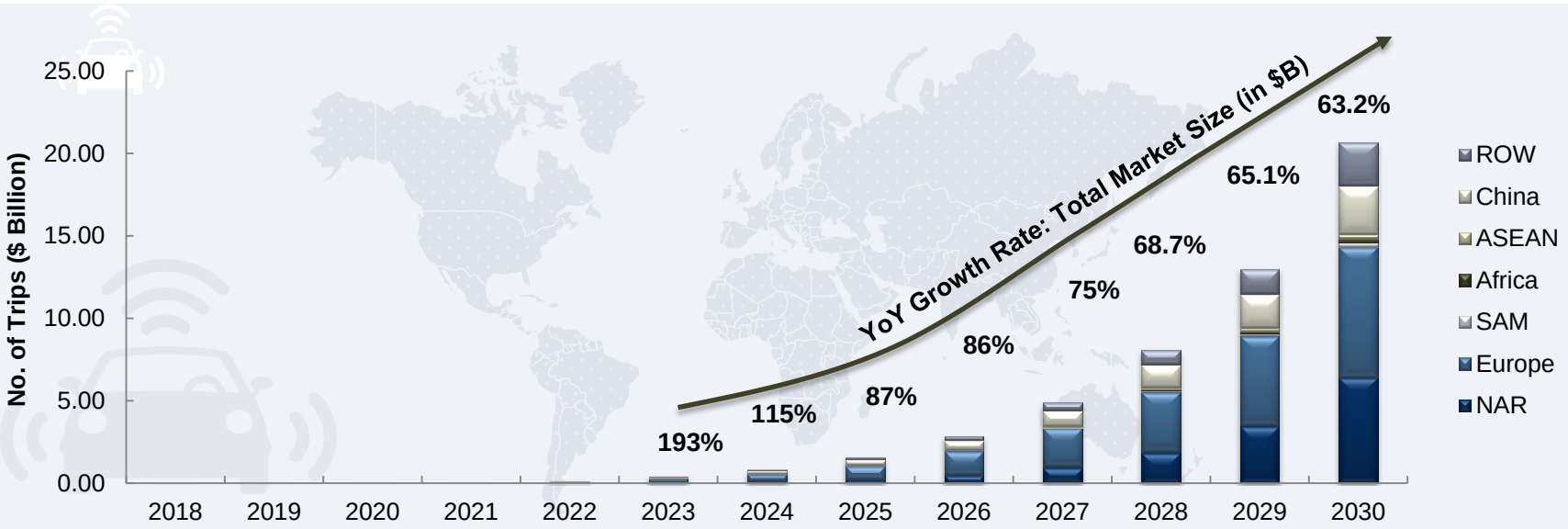
	2018	2025	2026	2027	2028	2029	2030
Total Estimated Number of Trips (in Billion)	0	0	0.85	2.02	3.28	4.64	6.08
Global Average Fare per ride (in US$)	NA	0	4.3	6.2	6.3	6.3	6.4
Autonomous Trips Penetration	0	0	0.6%	1.4%	2.1%	2.9%	3.7%
Market Size ($ Billion)	0	0	3.64	12.52	20.53	29.24	38.61

Source: Frost & Sullivan

Automated Driving—Shared Mobility: Shuttles, By Rides

The total market size of the autonomous shuttles is estimated to reach $74.42 B by 2030 based on a weighted average of the fares ($3.6 per autonomous trip) globally.

AD Market Outlook: Expected YoY Penetration Rate Of Autonomous Shuttles by Number of Rides, Global, 2018–2030



Today, the fare per ride is estimated at $3.9. This figure breaks down as follows: Operator Profit (@15%) = $0.6 30%; Labor Cost =$1.2 35%; Operation Cost (Insurance, parking) = $1.4 20%; Maintenance Cost (Service, Fuel) = $0.8

	2018	2023	2025	2027	2028	2029	2030
Total Estimated Number of Trips (in Billion)	0	0.41	1.59	4.92	8.09	13.02	20.7
Global Average Fare per ride for a certain length (in US$)	NA	3.13	3.16	3.32	3.41	3.5	3.9
Autonomous Rides Penetration	0	5.7%	11.4%	19%	22.9%	26.8%	30.7%
Market Size ($ Billion)	0	1.25	5.04	16.38	27.63	45.61	74.5

Source: Frost & Sullivan

Key Start-ups and their Capabilities

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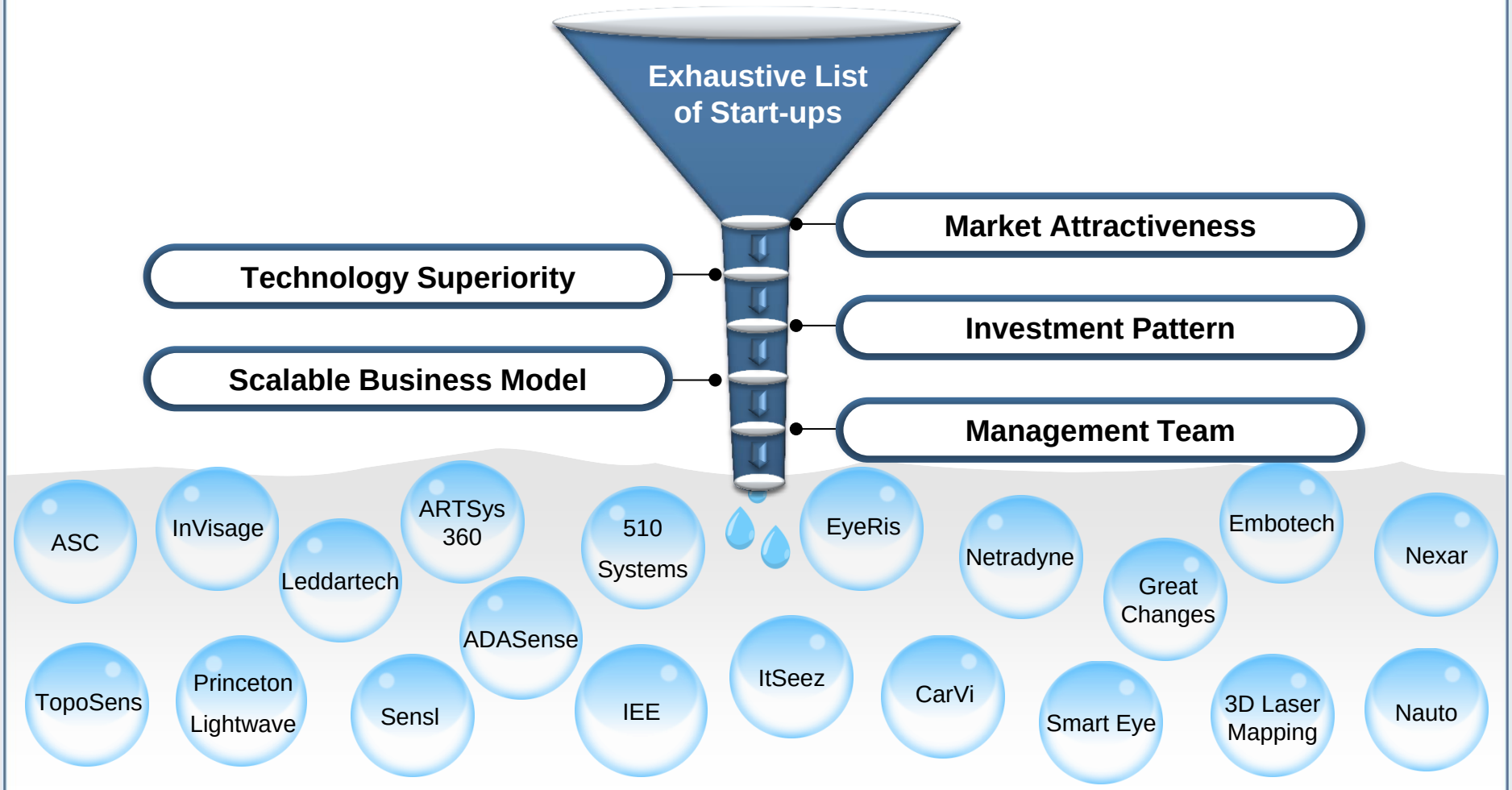
Frost & Sullivan's Key Criteria to Shortlist Companies

From devising hardware and software for computer vision required for autonomous driving and mapping, to low-cost driver assistance systems, these start-ups are racing to the far edges of reshaping road transportation.

AD Market Outlook: Disruptive Start-ups—Criteria for Shortlisting, Global, 2017



Note: This is the first issue of the featured start-ups; subsequent issues to feature new set of companies.

Source: Frost & Sullivan

Capabilities of Shortlisted Start-ups—ADAS Sensors

AD Market Outlook: Shortlisted Start-ups, ADAS Sensors, Global, 2017–2023

Company	Product	Description	Investors
ASC	LiDAR	Advanced Scientific Concepts focuses on 3D Flash LIDAR technologies and cameras	NA
AEye	LiDAR	Develops advanced vision hardware (solid state LiDAR), software and algorithms that act as the eyes and visual cortex of autonomous vehicles.	Intel Capital. Kleiner Perkins Caufield & Byers
InVisage	LiDAR	InVisage operates as a fabless semiconductor company that develops Quantum Film based infrared image sensors for automotive LiDAR	Horizon Tech, Arsenal Venture partners, etc.
Princeton Lightwave	LiDAR	Princeton Lightwave designs and manufactures high-performance Single-Photon Avalanche Photodiodes (SPADs), the core of Geiger-mode cameras, which are used in LIDARs enabling high-speed and resolution 3D imaging.	Morgenthaler, First Analysis Group
Sensl	LiDAR	SensL offers a range of Silicon Photomultipliers and SPAD Arrays for LiDAR	NA
ARTSys 360	Radar	ARTSys develops compact 360-degree (horizontal) and 45-degree (vertical) radars with no moving parts	NA
CarVi	Camera	The company uses an in-vehicle outward camera to monitor road and provide real-time hazard data. It also captures driving data. Synced to smartphone.	KT Corp, POSCO, Samsung VI
Netradyne	Camera	The product Driveri is a 4-camera driver assistance and monitoring system aimed at commercial fleet applications	Reliance Industries

Source: Frost & Sullivan

Capabilities of Shortlisted Start-ups—Computer Vision Software

AD Market Outlook: Shortlisted Start-ups, Computer Vision Software, Global, 2017–2023

Company	Description	Investors
ItSeez	ADAS platform performing Traffic Signal Recognition, Lane Departure Warning, Collision Detection, Pedestrian Detection, and facial recognition functions built on machine learning algorithms.	INTEL (owners)
EyeRis	Deep Learning-based emotion recognition software that reads facial micro-expressions.	NA
ADASense	Provides software services (machine vision, embedded software solutions for a camera-based automotive ADAS system) for automotive OEMs in camera-based drive assist systems along with IP licensing.	Fico Mirrors and Denso - JV
510 Systems	Provides complete product development, including the computing platform sensors and software for 3D mapping, surveying, and autonomous driving.	Google – full ownership
Chronocam	Develops machine vision sensor technology inspired by biological eye. Claims to significantly outperform current vision systems.	Robert Bosch Venture Capital, Ibionext, CEA Investissement
Nexar	Provides an AI dashcam app for smartphone. It records the road ahead and the dangerous events during driving and sends it to a cloud.	True Ventures, Maniv Mobility, Aleph Venture Capital, Slow Ventures, Mosaic Ventures
Great Changes	Develops a software for the detection of drowsy driving and fatigue. Snooze control contains ADAS features developed using conversational artificial intelligence.	NA

Source: Frost & Sullivan

Capabilities of Shortlisted Start-ups—Other Systems

AD Market Outlook: Shortlisted Start-ups, AD Software, Mapping and Inward Camera, Global, 2017–2023

Company	Capability	Description	Investors
Nauto	Inward camera	A smart car network and technology company that offers a device, network, and app for collecting visual driver data and processing in the cloud.	Draper Nexus Ventures, Index Ventures, Playground Global
IEE	Inward cameras	Driver sensing and passenger detection systems.	Aerospace Hi-Tech Holding Group
Embotech	AD Software	Develops autonomous driving and parking, and mapping software without using artificial intelligence.	NA
3D Laser Mapping	Mapping	3D Laser Mapping is a world-leading provider of mobile mapping and monitoring solutions. Designed to capture the world in 3D and deliver information for making decisions.	NA
TopoSens	Mapping	TopoSens uses ultrasound and radar to build 3D sensors for localizing 3D positions to precisely detect objects in real time. It is one of the few companies that provides features such as non-optical vision to autonomous vehicles and navigation systems for gesture recognition, 3D scanning, etc.	Techfounders

Source: Frost & Sullivan

Regional Market Trends and Analysis—2018

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European Automated Market—Overview

Germany and the UK are playing active roles in bringing automated driving to European roads.

AD Market Outlook: Automated Market Overview, Europe, 2017–2023

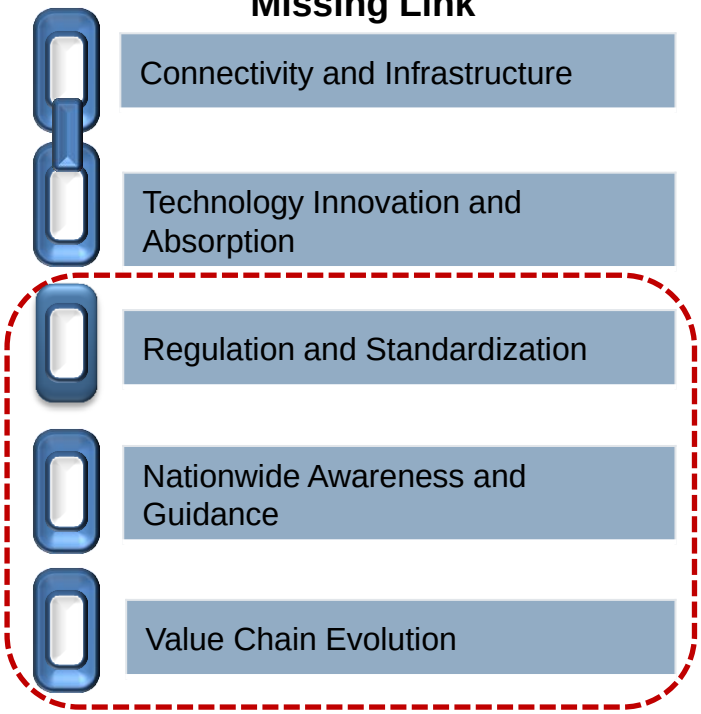
Salient Highlights of the Regulations by UNECE

Five Categories of Automatically Commanded Steering Functions (ACSF) defined

- Automated parking up to 12km/h
- Automated steering initiated by the driver
- System performs lane changing when initiated by the driver
- Systems would consist of a function that can indicate and execute it only after the driver's confirmation
- Functions are initiated or activated by the driver and can continuously determine maneuvers (e.g., lane change) and complete them for extended periods without additional intervention from the driver.

Key OEMs/Disruptors	Volvo, Audi, BMW, Mercedes Benz, Uber, Oxbotica
Key Vendors	Bosch, Continental, Here, TomTom

Missing Link



Market Trends

- The proposals for the first set of amendments to R79 pertaining to lane keep assist systems, lane departure, remote control parking systems are expected to be in force by 2018.
- Germany allowed automated driving as long as a driver is behind the wheel to assume control of the vehicle when necessary. The country's regulation also mandates the presence of a "black box" to record whether the vehicle was being controlled by the driver or by the system.
- The automated driving domain will be dominated by suppliers that have exceptional capabilities in chassis-ADAS-safety integration.

Source: Frost & Sullivan

North American Automated Market—Overview

American legislators want the US to stay on the forefront of self-driving technology. They are working towards passing a law which paves way for the use of self-driving cars without human controls.

AD Market Outlook: Automated Market Overview, North America, 2017–2023

Salient Highlights of the new SELF DRIVE Bill

- States could set rules on registration, licensing, liability, insurance and safety inspections, but not performance standards.
- Initially allows sales of up to 15,000 self-driving vehicles per manufacturer in the first year and up to 80,000 after three years.
- The bill grants the National Highway Traffic Safety Administration (NHTSA) authority to exempt vehicles from federal safety requirements and the agency would have to make a determination within six months of getting a request.
- OEMs would need to disclose what information self-driving cars are collecting about individuals and how it is used.

Key OEMs/Disruptors	Tesla, Audi, Ford, Google, Cadillac, Mercedes Benz, Waymo, Uber, Apple
Key Vendors	Delphi, NVIDIA, Cisco Systems, Mobileye, Intel, IBM

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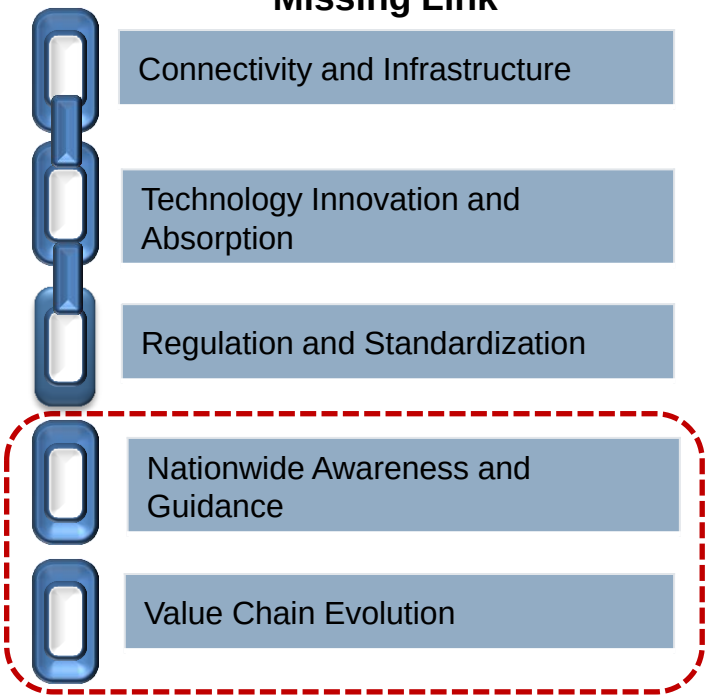


Market Trends

- Tier- I supplier Delphi, partnering with Mobileye, is working briskly to provide off-the-shelf automated driving systems by 2020.
- Autonomous technologies will push the market from being product centric to one that is service driven. A strong need to look beyond traditional sales models to strong leasing and shared mobility offerings are vital for the initial market break-in. Ford is expected to be the first L4 automated mobility service provider in North America.
- OTA upgrades are likely to be adopted by all OEMs before 2025, even for conventional cars. Besides Tesla, GM is also working on this for implementation in V2V and V2I, along with infotainment systems.

Key: NHTSA—National Highway Traffic Safety Administration; DoT—Department of Transport; HAV—Highly Automated Vehicles;

Source: Frost & Sullivan

APAC (China and Japan) Automated Market—Overview

Japan is looking to promote the development of autonomous car technology in the run-up to the 2020 Tokyo Olympics and Paralympics amid a global race to develop autonomous vehicles.

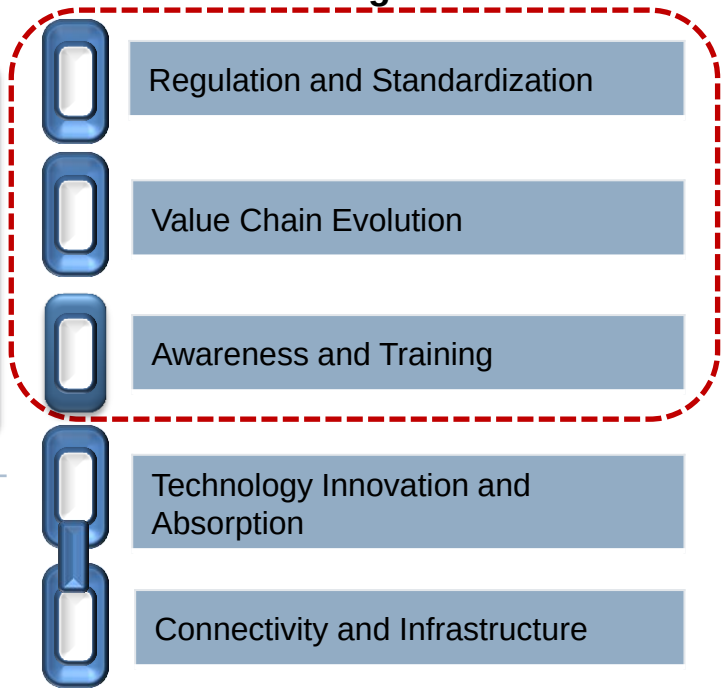
AD Market Outlook: Automated Market Overview, China and Japan, 2017–2023

Salient Highlights of the New Proposed Standards by the National Police Agency (NPA) - Japan

- Testing of an autonomous vehicle cannot take place on public roads without the presence of a driver with a valid driver's license.
- Mandatory systems that stop vehicles automatically in case of emergency.
- Testing of autonomous vehicle technologies would require mandatory police permission, following which the police will test the functionality prior.
- Testing would not be permitted on crowded roads and can be carried out only on roads with constant availability of radio communication.

Key OEMs/Disruptors	Honda, Mazda, Nissan, Toyota, Baidu, Didi Chuxing
Key Vendors	Aisin, Clarion, Denso, Fujitsu, Panasonic, Pioneer, NTT

Missing Link



Market Trends

- The Japanese NPA is putting together a set of norms to discuss the policy of liabilities and driver licenses, and also confirming security in relation to cyber attacks for the amendment of current laws.
- China on the other hand has set itself a steep target of putting fully autonomous vehicles on roads by 2025, although as of now there are no regulations in place for the testing and deployment of autonomous vehicles.
- In Japan, numerous partnerships have been established among OEMs and tier-I suppliers and between tier-I and tier-II suppliers in order to establish the de-facto norm in the connected car space.

Source: Frost & Sullivan

Opportunity Analysis

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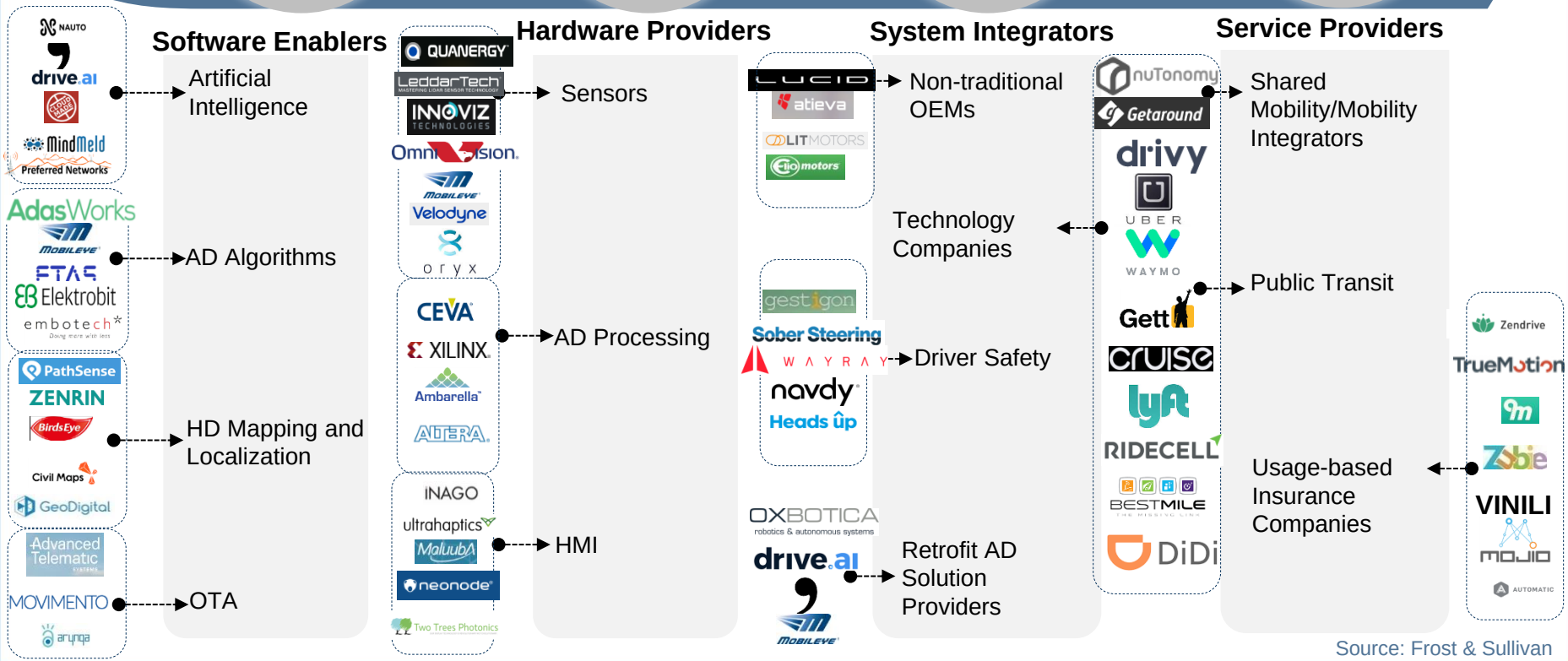
Transformation in Autonomous Driving Ecosystem—2018

Start-ups majorly disrupting the system integration and software development spaces is enough to convince OEMs and major technology providers to partner, acquire, or collaborate with them to build a strong portfolio.

AD Market Outlook: Transformation in Autonomous Driving Ecosystem—Global, 2018



Source: Frost & Sullivan

Growth Opportunity—Investments and Partnerships From OEMs/TSPs

AD Market Outlook: Growth Opportunities, Global, 2018

- Mega Trends Impact
- Disruptive Technology
- Business Models
- Regulation impact
- Business diversification
- Acquisition/Investment/ M&A
- Portfolio Expansion
- Value-add Services
- Partnerships
- Geographic Expansion

Applicable Segments	Shared Mobility	Software/Processing	Hardware
Applicable Regions	North America	Europe	APAC

Context and Opportunity

- When moving on to higher levels of automation, one centralized ECU for every domain is going to be a must.
- New entrants in the market and several Tier-1 players expected to introduce mass-production worthy LiDARs in 2018. Inward cameras to monitor driver behavior to gain traction for L3 systems.
- OEMs, suppliers, and technology providers will rely more on artificial intelligence for development, testing and simulation of autonomous driving hardware and software.

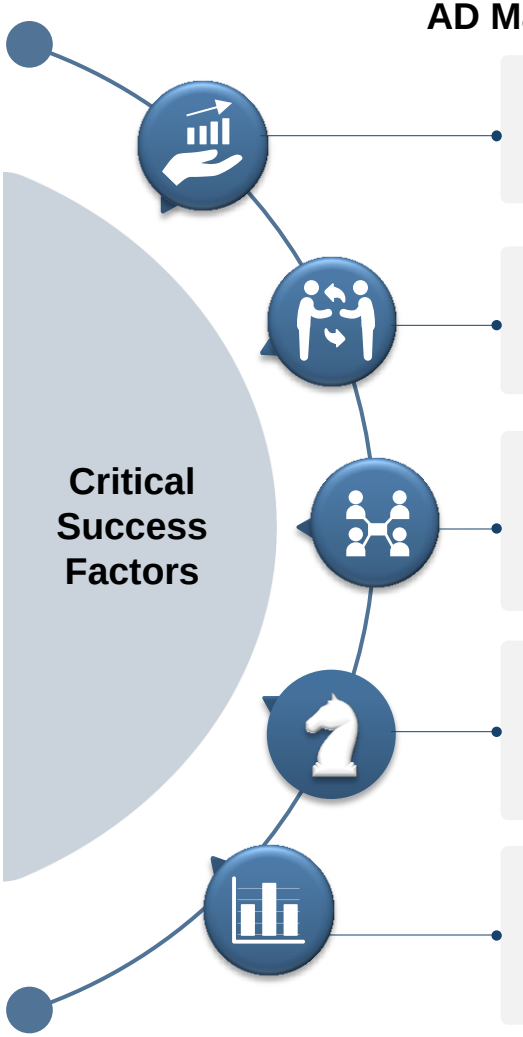
Call to Action

- The advent of advanced assisted drive functions and autonomous vehicles will require a transformation in the architecture of automobile control systems.
- The industry cannot only rely on the development and improvement in LiDARs as in every case it is going to be secondary sensor. The driver monitoring systems market is expected to boom starting 2019, and will be present in every automated vehicle up to L4.
- Tier I names and OEMs should collaborate and acquire TSPs to leverage their AI industry know-how for the AD market.

Source: Frost & Sullivan

Strategic Imperatives for Success and Growth

AD Market Outlook: Strategic Imperatives—Global, 2018



- Growth of AI and its enablers will be the key drivers for the growth of the autonomous driving market in 2018 and beyond.
- All major OEMs are targeting partnerships or acquisitions within the ride hailing or sharing space to bolster their mobility service platform by 2019-20.
- The three biggest entry opportunities for non-automotive tech companies into the autonomous driving value chain will be in the areas of in-vehicle infotainment systems, cloud services, and open OS development.
- First use cases highlighting the convergence of electrification / hybridization, connectivity and autonomous driving should be made possible by traditional OEMs in 2018.
- Most major OEMs would be looking to modify existing services as to make an application of it, which in turn can be used in a larger application enabling a one-time hardware sale and OTA-based service deliveries.

Source: Frost & Sullivan

Key Conclusions and Big Predictions for 2017

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The Last Word—Three Big Predictions

AD Market Outlook: Last Word and Conclusion—Global, 2018

1	All major OEMs and TSPs are shifting their focus toward the development of artificial intelligence and off-the-shelf AD solutions for software and hardware testing and mapping, enabling tremendous growth and partnership opportunities for start-ups in 2018.
2	Key OEMs such as Daimler, Volvo, Toyota, BMW, VW, Ford, and GM are expected to begin building a product portfolio apart from their legacy vehicles, converging electric, autonomous, shared, and connected driving.
3	One-time hardware sale and functions on demand is expected to be the future – a feature currently offered in the connectivity space will extend to the autonomous driving and mobility domains as well. Customized cars for different journey types, connected services with on-the-go insurance, and HMI for different driving scenarios are also expected.

Key: TSP—Technology Service providers

Source: Frost & Sullivan

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The Frost & Sullivan Story
The Journey to Visionary Innovation

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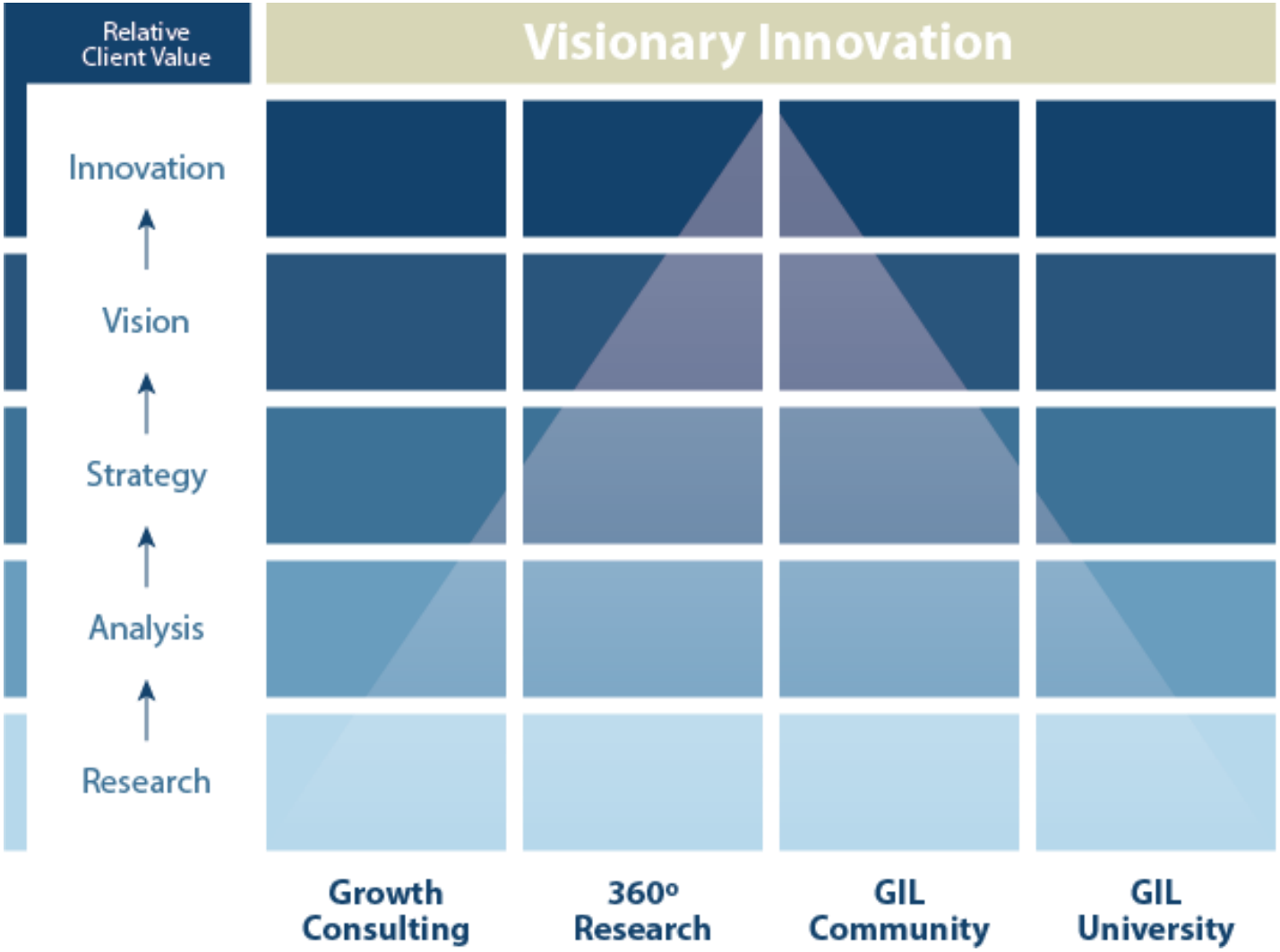
The Frost & Sullivan Story

Value Proposition—Future of Your Company & Career

Our 4 Services Drive Each Level of Relative Client Value



Global Perspective

40+ Offices Monitoring for Opportunities and Challenges

Industry Convergence

Comprehensive Industry Coverage Sparks Innovation Opportunities

Aerospace & Defense

Measurement & Instrumentation

Consumer Technologies

Information & Communication Technologies

Automotive Transportation & Logistics

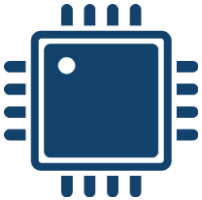
Energy & Power Systems

Environment & Building Technologies

Healthcare

Minerals & Mining

Chemicals, Materials & Food



Electronics & Security

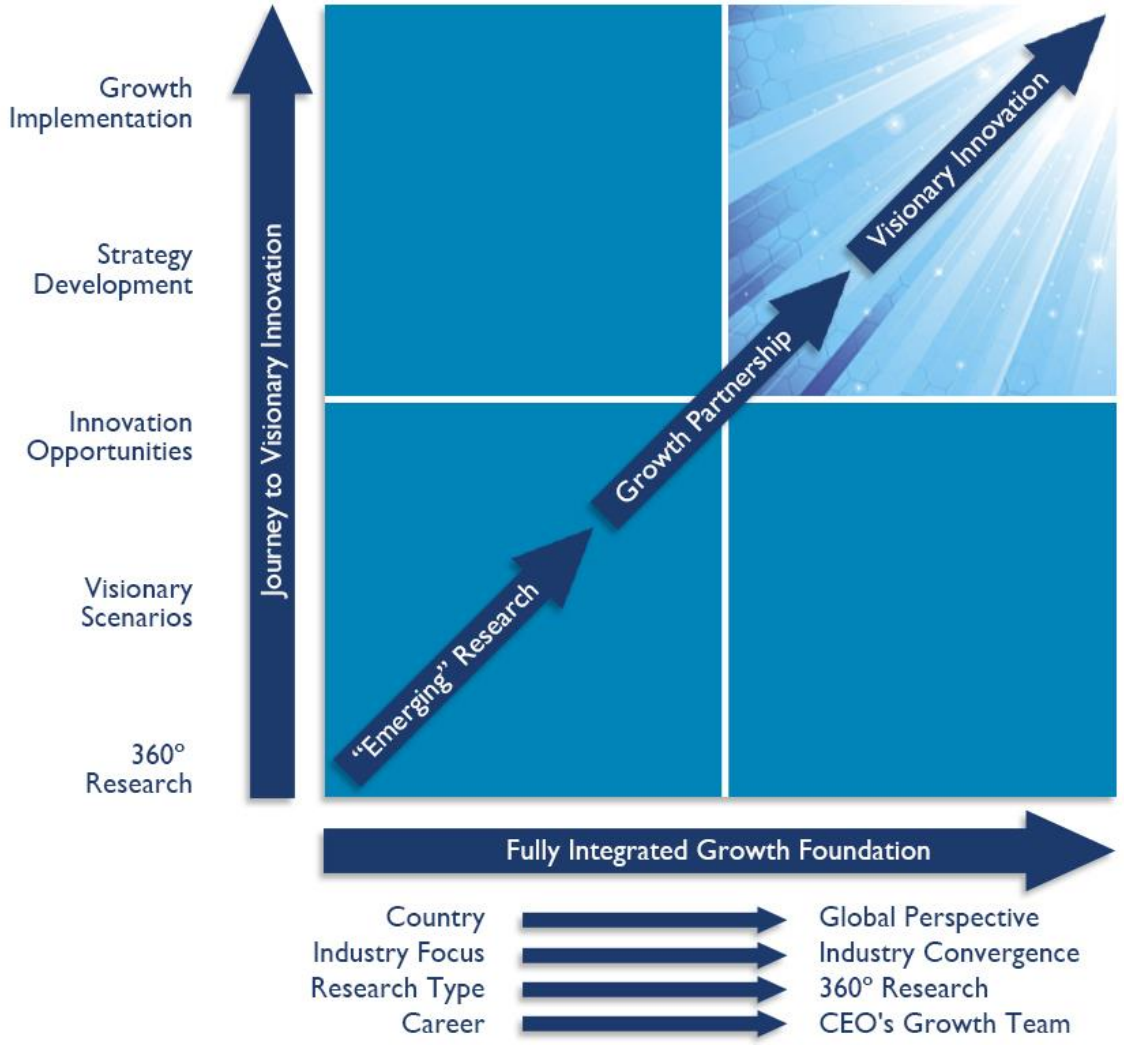
Industrial Automation & Process Control

360º Research Perspective

Integration of 7 Research Methodologies Provides Visionary Perspective

Implementation Excellence

Leveraging Career Best Practices to Maximize Impact

Our Blue Ocean Strategy

Collaboration, Research and Vision Sparks Innovation