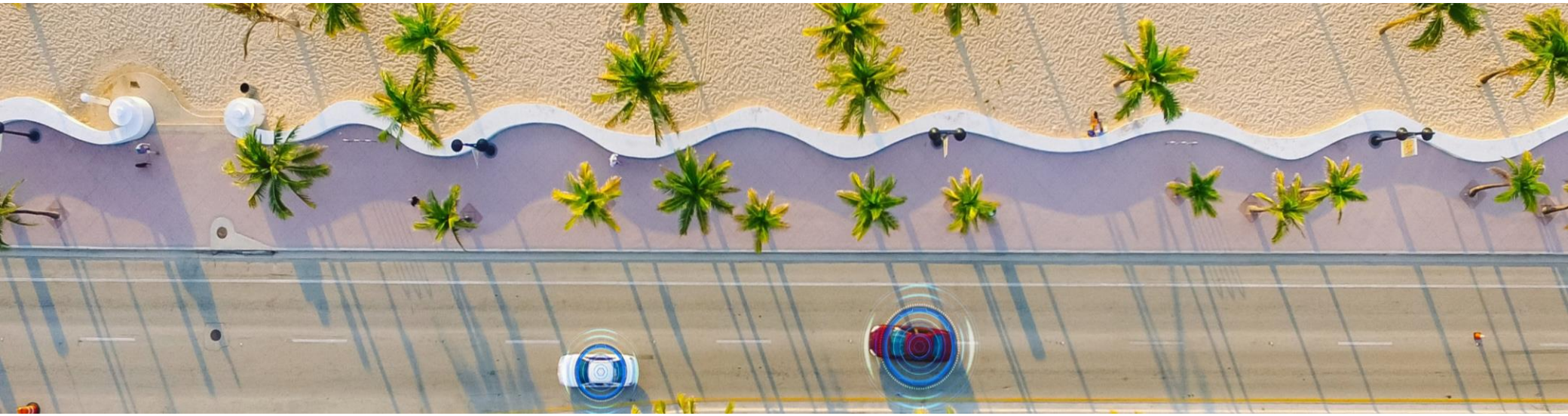

Autonomous Driving 2022

INVENSITY GmbH
Market Study
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Long product development time for autonomous technology as responsibility shifts to the OEM and regulations are not ready for autonomous driving

Business Model & Products

Hypothesis	Jump in comfort with L3 currently justify large investments, however technology needs time to mature

Progress 

Level of Confidence 

Assessment / Red-Flag 

Business Model

- Mercedes Benz currently the only OEM selling L3 system for at least € 5.950. Mercedes seems to pursue the strategy of selling continue to sell personal cars
- Waymo offers autonomous public traffic in Arizona USA
- OEMs and investors spend large sums in autonomous driving technology. (Investors invest in start-ups)

Product

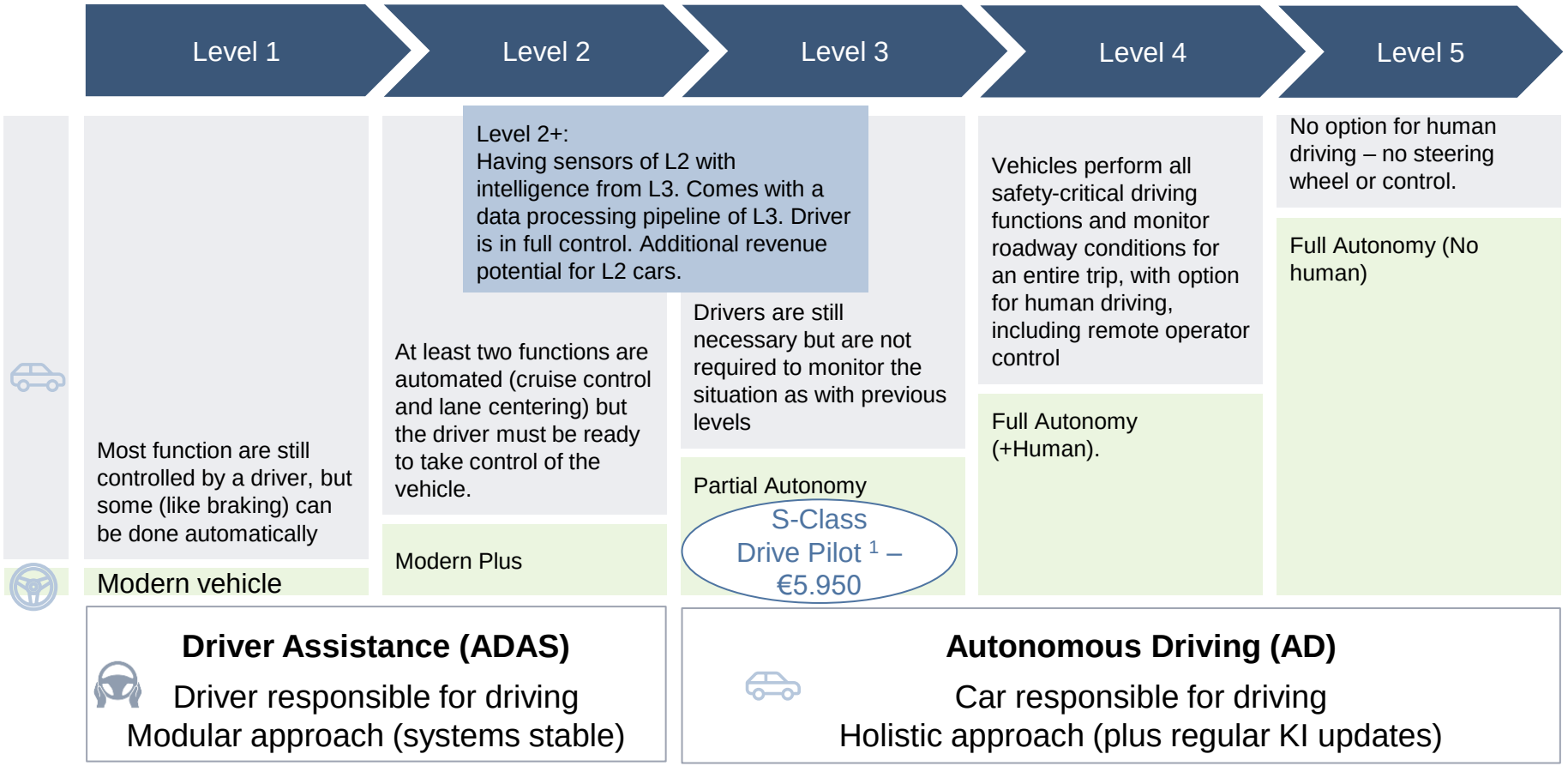
- Paradigm shift to computer with wheels instead of car with small control units
- Autonomous driving technology consume large computational power, which brings Nvidia and Qualcomm into a favorable position.
- Tesla and BMW hade made their platform open source
- Telcos expect impact from 5G which could not be verified by us

 High Level of Confidence  Low Level of Confidence  Positive Assessment  Partially Positive Assessment  Red-Flag

A. Brief introduction

Car is legally responsible with autonomy level L3

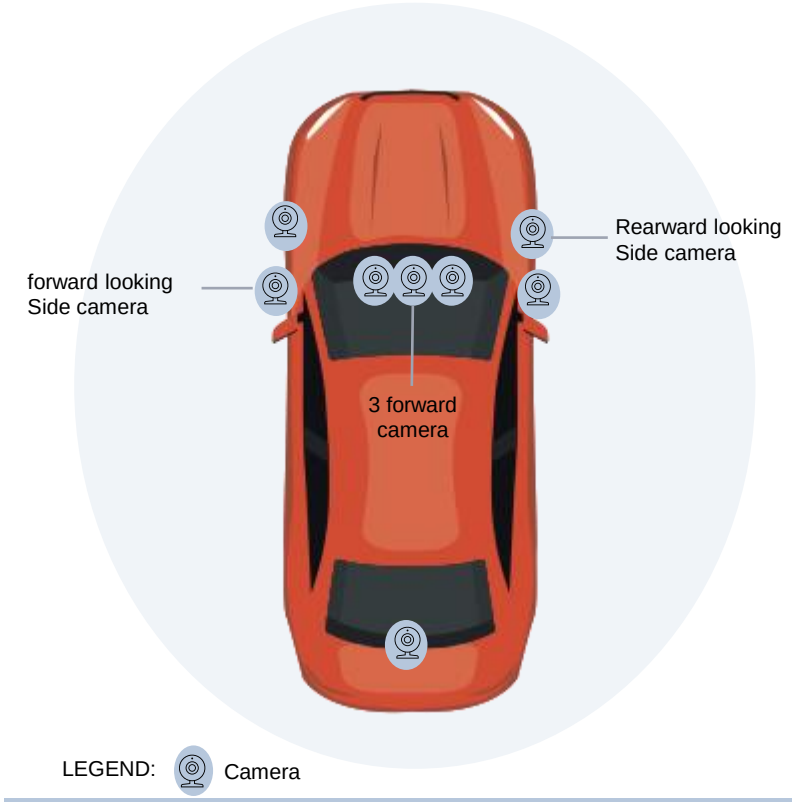
Levels of autonomy



Source: ceva-dsp.com; Auto Motor & Sport [1] Also available for EQS for €8.842

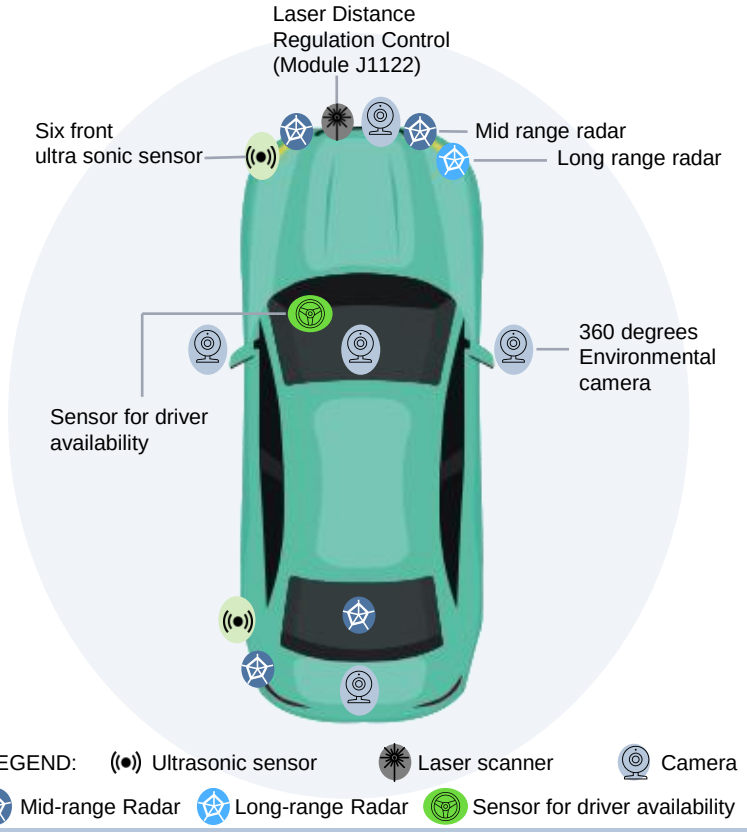
Tesla will be relying solely on vision while car maker Audi relies on a vider range of sensors and on a higher number

Level 2: Tesla Autopilot



Tesla focus solely on vision, phasing out radar and ultrasonic in 2022/23

Level 3: Audi A8 system (sold as L2 system)



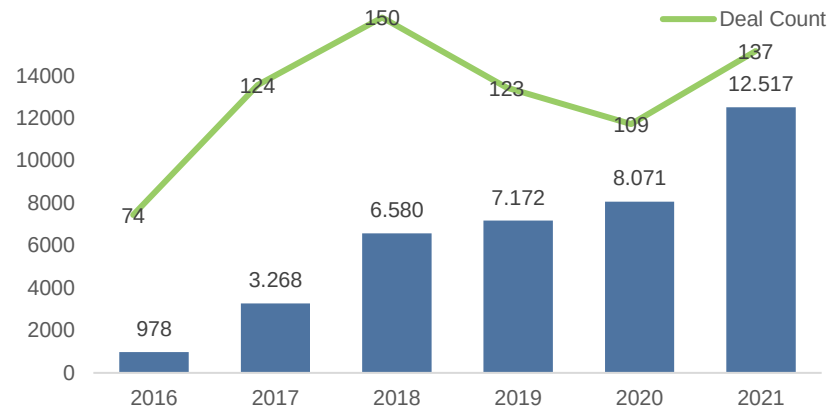
Audi uses five sensor types to achieve L3 functionallity

Source: Tesla (1)(2), MOTOR AUTHORITY, NHTSA

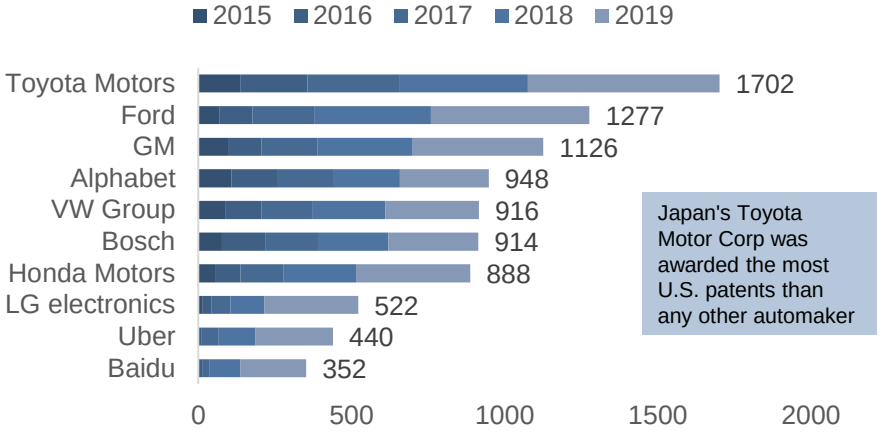
B. Market

Incumbent car companies lead in patents and there is growing investment in autonmous driving start-up companies

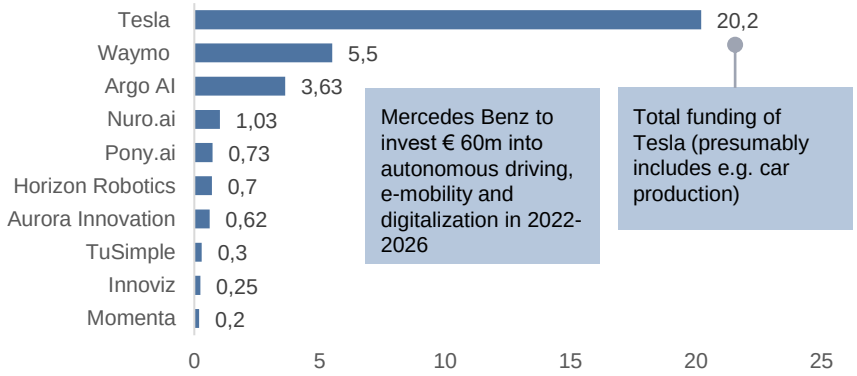
Autonomous Driving disclosed deals & funding, ($ m) 2016-21



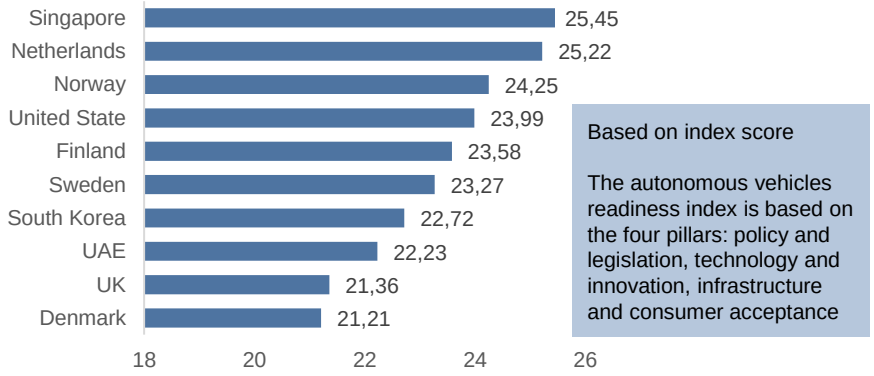
ADAS & Autonomous Driving Patents, by active patent families



Examples of AD companies' funding, ($ bn) till 2020



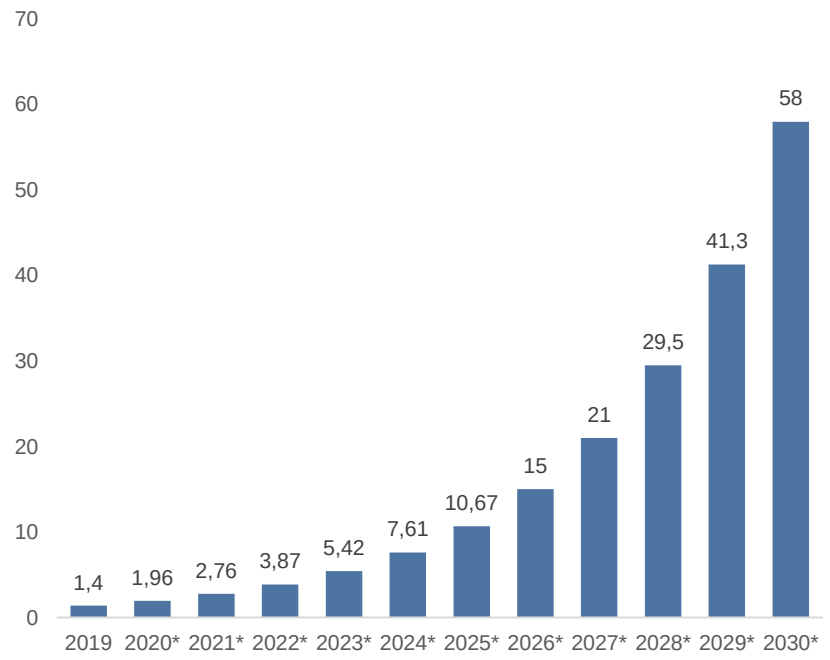
Preparedness for autonomous vehicle – by country; 2020



Source: Statista (1)(2)(3), Crunchbase (1)(2), Toyota, Cbinsight, Continental (1), bw24.de

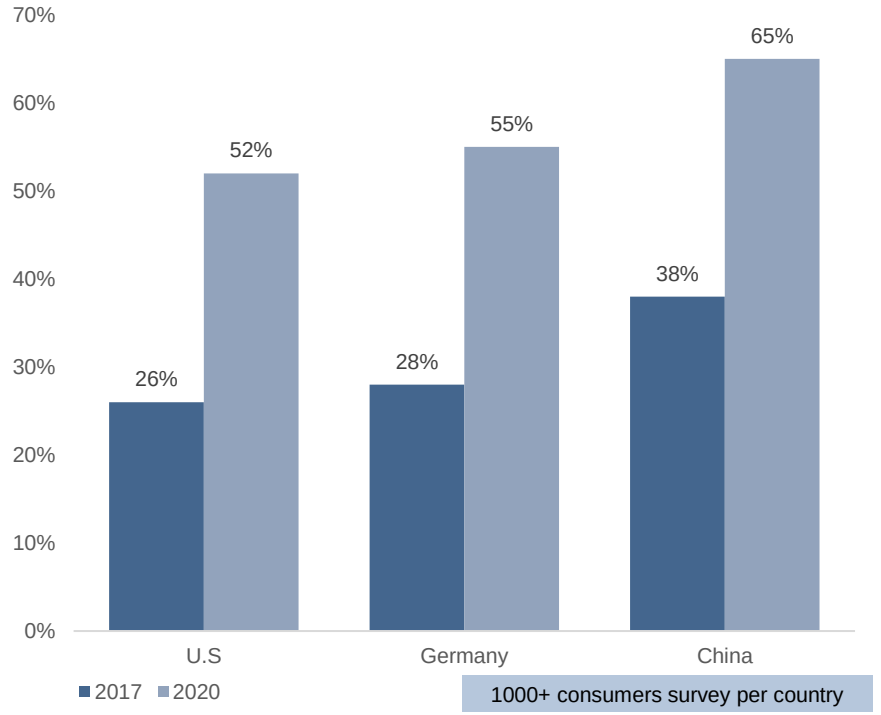
People grow confident in autonomous cars

Projected sales of at least L3 AD vehicles,(m units) 2019 - 30



Percentage of consumers who think self-driving vehicle will be safe – by country

A Deloitte survey found that global consumer acceptance of autonomous vehicles has rapidly increased in the past year. In the U.S., 52 percent of consumers surveyed think autonomous cars will be safe, up significantly from previously recorded 26 percent. Interestingly, consumers in China are some of the most positive about self-driving vehicles, with the percentage of those who think autonomous cars will be safe rising from 38 percent in 2017 to 65 percent in 2020.

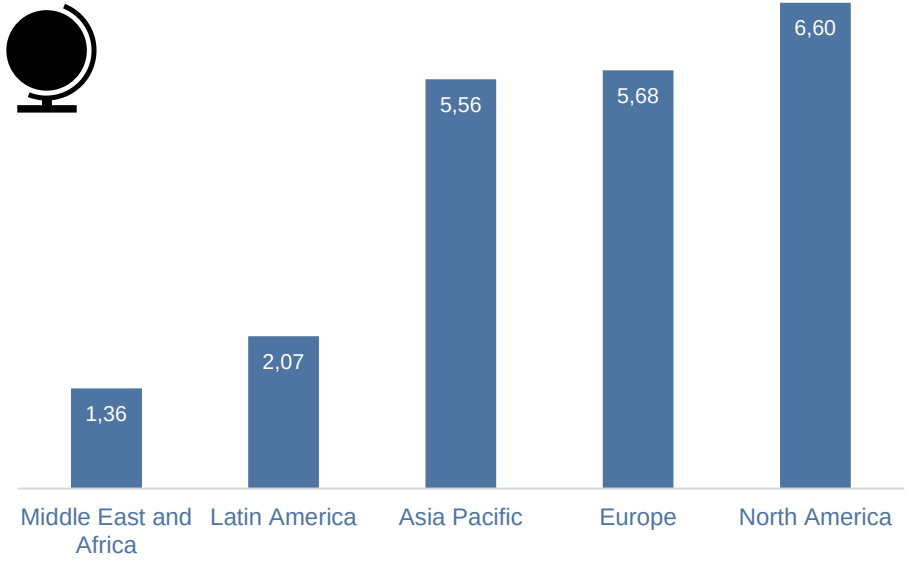


Source: Statista (1), la-francaise

Global ADAS market projected to expand over the upcoming years

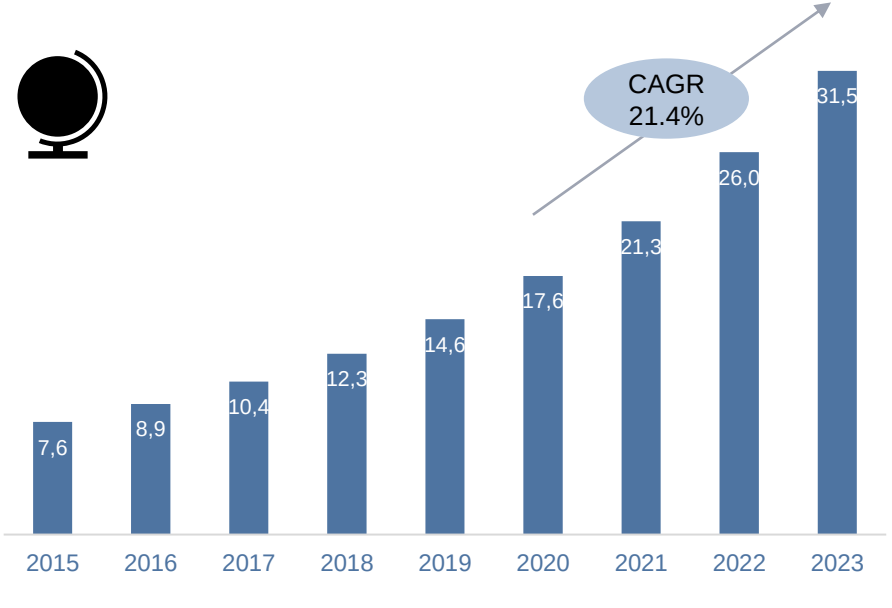
Global ADAS market size – by region, ($ bn) 2021

The advanced drive assistance systems (ADAS) industry is projected to generate around 6.6 billion U.S dollar in North America during 2021. Although electronic system have been improving vehicle performance for decades, the market is growing rapidly.



Projected global ADAS market size, ($ bn) 2015 - 23

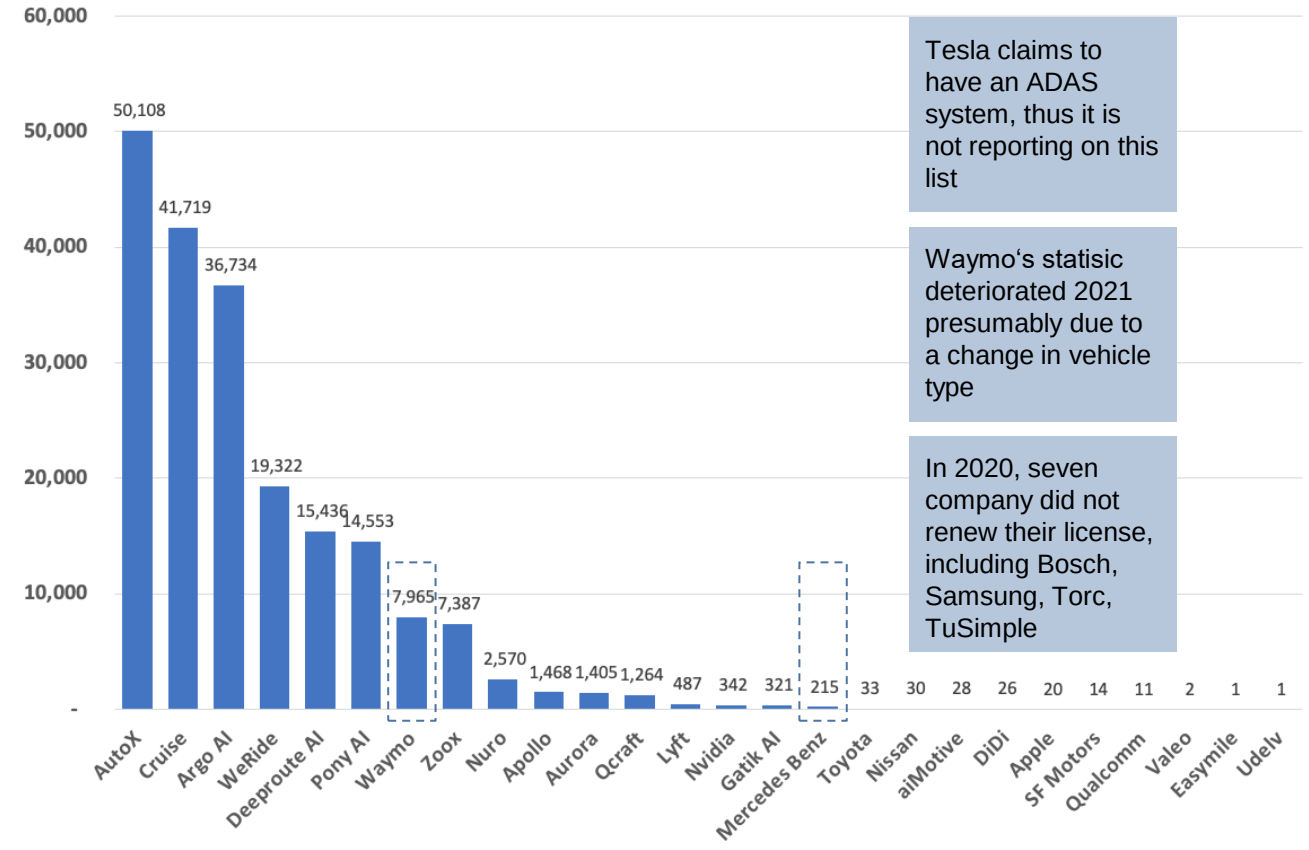
In 2020, the advanced drive assistance systems (ADAS) industry generated around 17.6 billion U.S dollar globally. Between 2015 and 2020, the global market doubled in every five years. The global ADAS market continues to grow and reach nearly 32 billion U.S dollars by 2023. Some example for advanced driver assistance systems includes automated emergency brake, lane keep assist, automatic parking and adaptive cruise.



Source: Statista (1)(2)

Long way for autonomous driving

Disengagement report, California, 2021; miles per disengagement



Tesla claims to have an ADAS system, thus it is not reporting on this list

Waymo‘s statisic deteriorated 2021 presumably due to a change in vehicle type

In 2020, seven company did not renew their license, including Bosch, Samsung, Torc, TuSimple

Source: TheLastDriverLicenseHolder (2021)(2020)

C. Shift in paradigm

Autonomous driving is further accelerating a trend towards unified control architecture, increasing reuse of SW, reducing cost and power consumption

Illustrative evolution of number of ECU over time

First monolithic ECUs in 1970

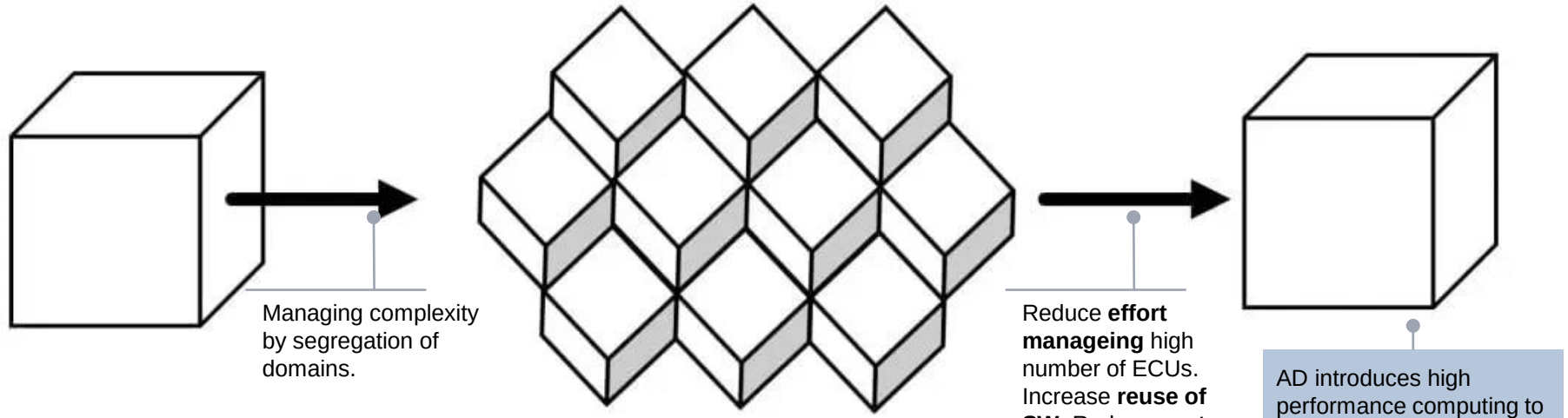
At first an ECU (engine-control-unit) controlled the state of the engine.

Control unit landscape last two decades

Last to decade saw the grow in number of ECUs. Modern luxury cars can have as much as 150 ECUs (2017 BMW 7series).

Trend to monolithic architecture in

Autonmous driving is accelerating a trend towards more unified control architectures.



Revenue of supplier with ECU will decrease as electric development is reduced to pure HW controller SW on the device. Value add is happening in SW on a centralized control unit

Source: INVENSITY (1), EENewsAutomotive, shmj.or.jp, semiengineering.com

Quotes

Selected quotes on market and industry

"TOPS (power of the CPU) is the new horsepower. The performance of a car is no longer defined by its engine, but by its computer"

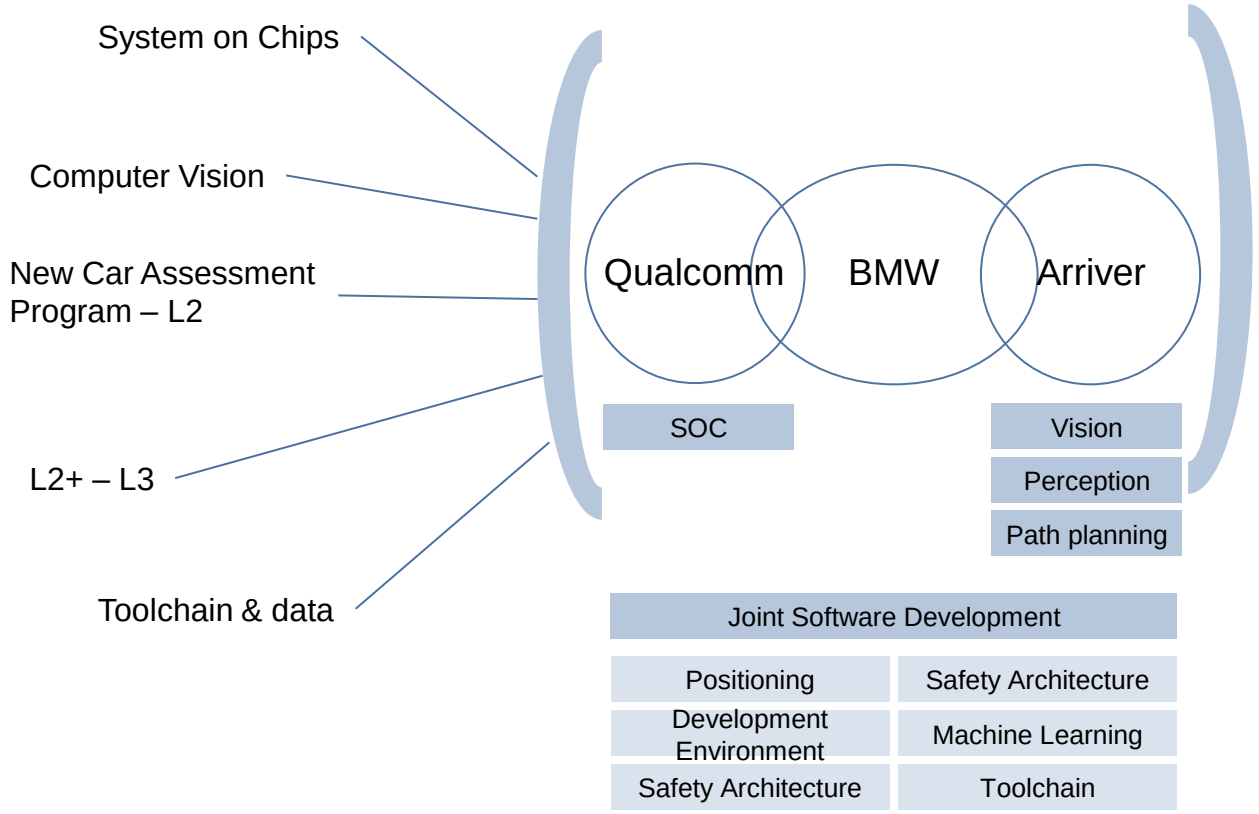
Jason Huang – CEO Nvidia

"Software is going to define the car"
"It was a car with software in it, now it will be a computer with wheels attached to it"

Various quotations

Source: Handelsblatt (1)

BWM onboards Qualcomm / Arrive as partner for Level 3 driving functions for its “new class” platform launching in 2025, and abandon Intel/Mobileye



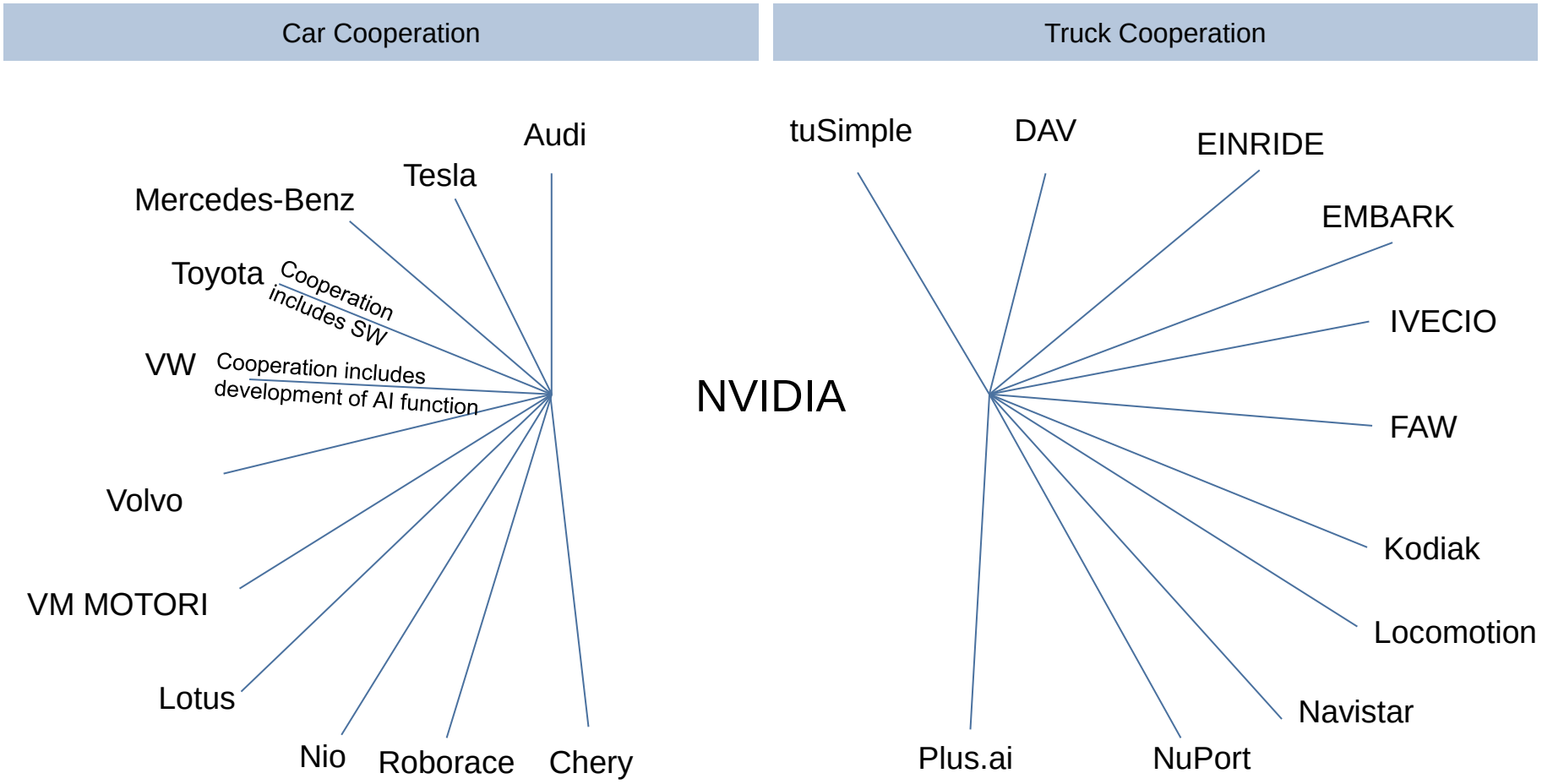
BMW started a new cooperation with Qualcom and Arriver for L3 driving functions of its „new class“ platform launching in 2025, covering all cars.

BWM uses Qualcoms Snapdragon Ride platform together withs arrivers S

Thus, BMW is ending exiting cooperation with Intel/Mobileye in 2025. Till then, Intel/Mobileye is the partner für ADAS systems and L3 functions in eg. The BWM 7-series

Source: t3n, Prnewswire

Most cooperation center around Nvidias calculation power for AI and machine learning through Nvidia's system-on-a-chip computers



Source: Nvidia Partner Network (1)

D. 5G connection

5G particulary enables V2X emergency breaking and streaming of high resolution 3D maps for autonomous driving

Overview technical advantages of 5G compared to LTE based V2X or WiFi 802.11p DSRC

Category	Picture	Rational	Impact
Ad-hoc networks possible		Ad-hoc network enables cars to communicate directly with other cars or devices (V2X).	Enable the use case of direct and low latency V2X communication. Use case are automated emergency braking for following cars, looking ahead into crossings or detect 5G smartwatch
Ultra low latency		1ms at up to 500 km/h speed	Together with ad-hoc networks, allow emergency braking scenarios
High peak data		20 Gpbs at up to 500 km/h	Allow download of high resolution 3D-maps that could improve autonomous driving. Highly useful data would be always available
Extreme device density		Up to 1m connected cars and devices	Allow installation of 5G moduls in all infrastructure devices (traffic lights, lamps, streets, parking lots)

Source: INVENSITY analysis, Keysight, Note: V2X – vehicle to device communication

Most 5G use-cases revolve around emergency functions

Overview of V2X communication

	Category	Picture	Rational	Impact
V2V	Vehicle-to-vehicle		Very low latency in ad-hoc networks enables emergency braking for following cars. Cars would send warning signals over 5G ad-hoc network	Potentially saving lifes and preventing material damage. Thus also reducing load on healthcare and insurance system.
V2N	Vehicle-to-Network		Calling SOS functions and streaming of high resolution 3D maps for autonomous driving. Availability important	Potentially saving lifes. First responders are allerted more early and receive more precise location information. Unclear Availability of network is critical
V2I	Vehicle-to-Infrastructure		Infrastructure can share their condition and additional data. Eg. A traffic light could perceive approaching traffic or pedestrians	Potentially saving lifes and preventing material damage. Low latency is critical
V2P	Vehicle-to-Pedestrian		5G mobile devices or wearables could warn about location of pedestrians nearby	Potentially saving lifes. Widespread adoption might need consent of people and either appropriate standardized HW features or a capable app
V2G	Vehicle-to-Grid		Vehicles communicate with the powergrid. The vehicle battery turns to a energy storage for the grid during parking	Condition data can be exchanged directly between grid and vehicle. However, payment might still be run over a centralized cloud with user account.

None of the use-cases is directly related to comfort features. Thus public regulations might accelerate adoption.

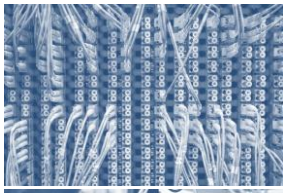
The real-time stream of 3D maps improves autonomous driving, though the driver does not necessarily feel the improvement. Plus the underlying approach would deteriorate autonmous driving in remote places

Vehicle to grid would turn the car into an energy service, potentially earning some money to the owner. Produces of renewable energy would profit as well by being able to sell excess energy and preventing the price to drop. Cost of storage and energy transfer must be low to effectively stabilize energy markets

Source: INVENSITY analysis, Keysight, Note: V2X – vehicle to device communication

Value of 5G for autonomous driving currently marginal, though it could enable a number of use-cases

5G advantages over LTE

Advantage	Picture	Rational	Comment
Increase in maximum number of devices connected to a cell		In an IoT scenario, not only the cars are connected, but also the infrastructure could provide data. This would allow to connect each traffic light and parking lot	We think transforming the infrastructure takes time as infrastructure technology tends to long life-cycle periods. The use-case of traffic information is already covered by applications as GoogleMaps, whose access to user generated traffic data is virtually free.
Separate networks of devices within a cell		Infrastructure devices could be garantueed a quality of service in case other parts of the network become congested	This is an advantage over the current 4G network. Availability of infrastructure IoT devices can
Shorter latency		In remote-operator scenarios, latency is important. As time critical decision about driving have to arrive	Remote operator scenario are likey to be fall back solutions: Get a car out of trouble at low speeds
Higher bandwidth		Video based control system could be used at scale. Either video streams to the car or every remote operator scenario	Stream Netflix to a cell-phone is already possible today. Maybe this incentivices more people to upgrade to more expansive plans.

The value of 5G for autonomous driving is currently marginal. And the advantage can be also captured with conventional cars. As each driver could use these kind of information. It centeres around getting information from parking-lots and traffic lights, which both have long life-cycle times which makes it unattractive to leverage the value soon.

Source: INVENSITY analysis

E. Resume

Automotive supplier industry could further fragment as the software, hardware and actuator could be supplied by different companies

Trends

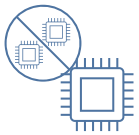
ADAS Level 3 functions gain traction as L4 is not available. OEMs cooperate with suppliers and sell features as add-on to conventional cars.

Software defined vehicle. Thus, introduction of car operating systems.

Deeper integration of cars into cloud computing application to enhance autonomous driving.

Cooperations among technology companies as barely no one alone can commercialize the technology.

Centralization of computing, introduction of high-performance computing.



Reduction of number of ECUs

Through the adoption of more centralized computing, the supplier industry could further fragment, as sensors, SW and actuator could each come from a different supplier.

Feel free to get in touch in case of questions or feedback

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