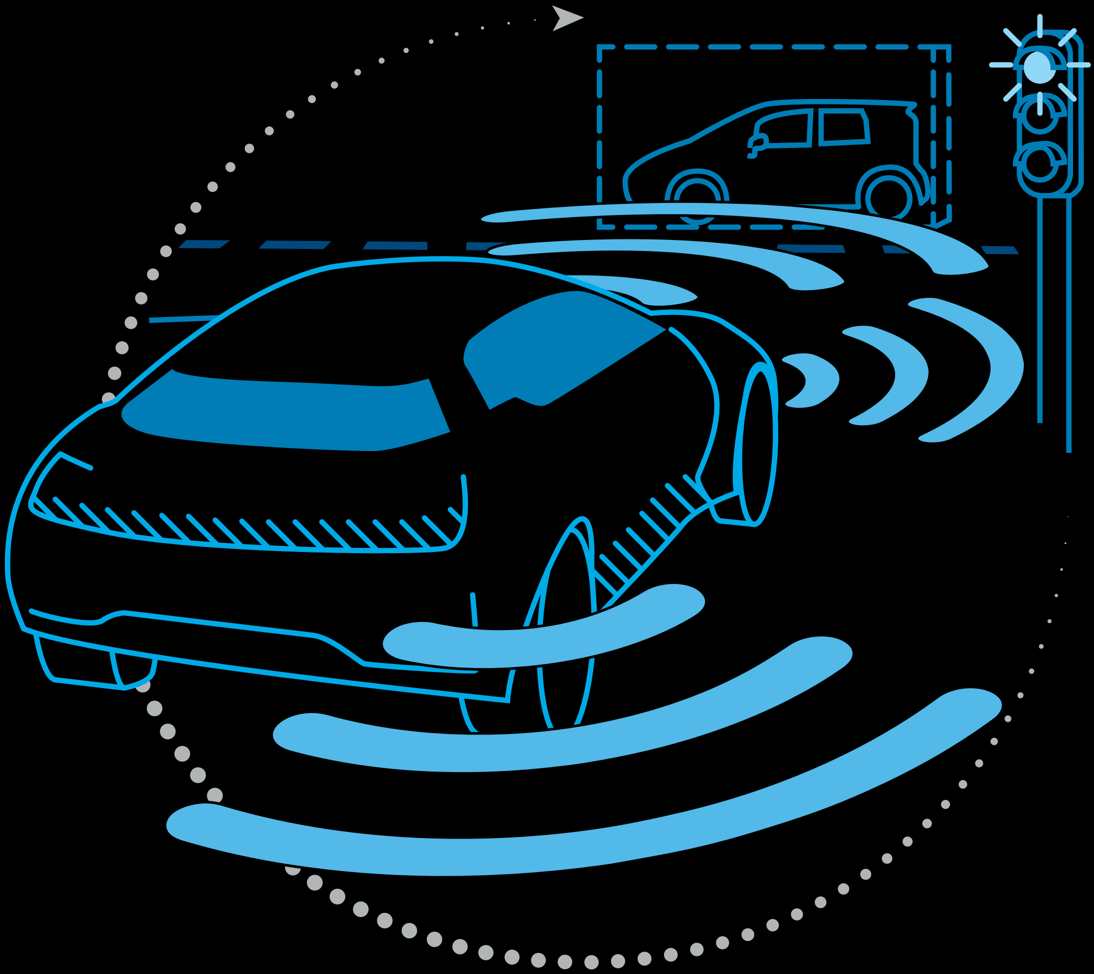
Deloitte.

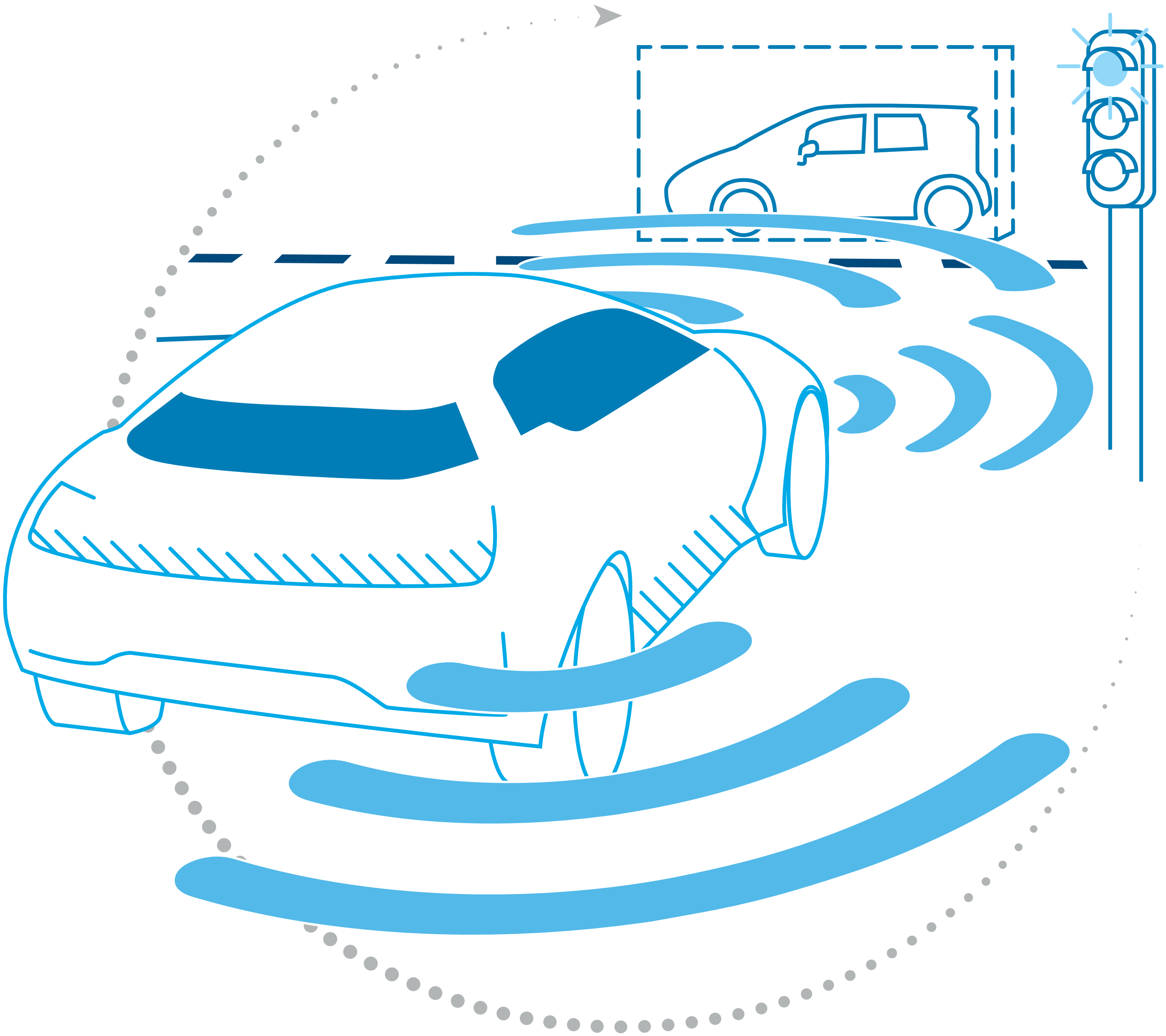


Autonomous Driving

Moonshot Project with Quantum Leap from Hardware to Software & AI Focus

Summary

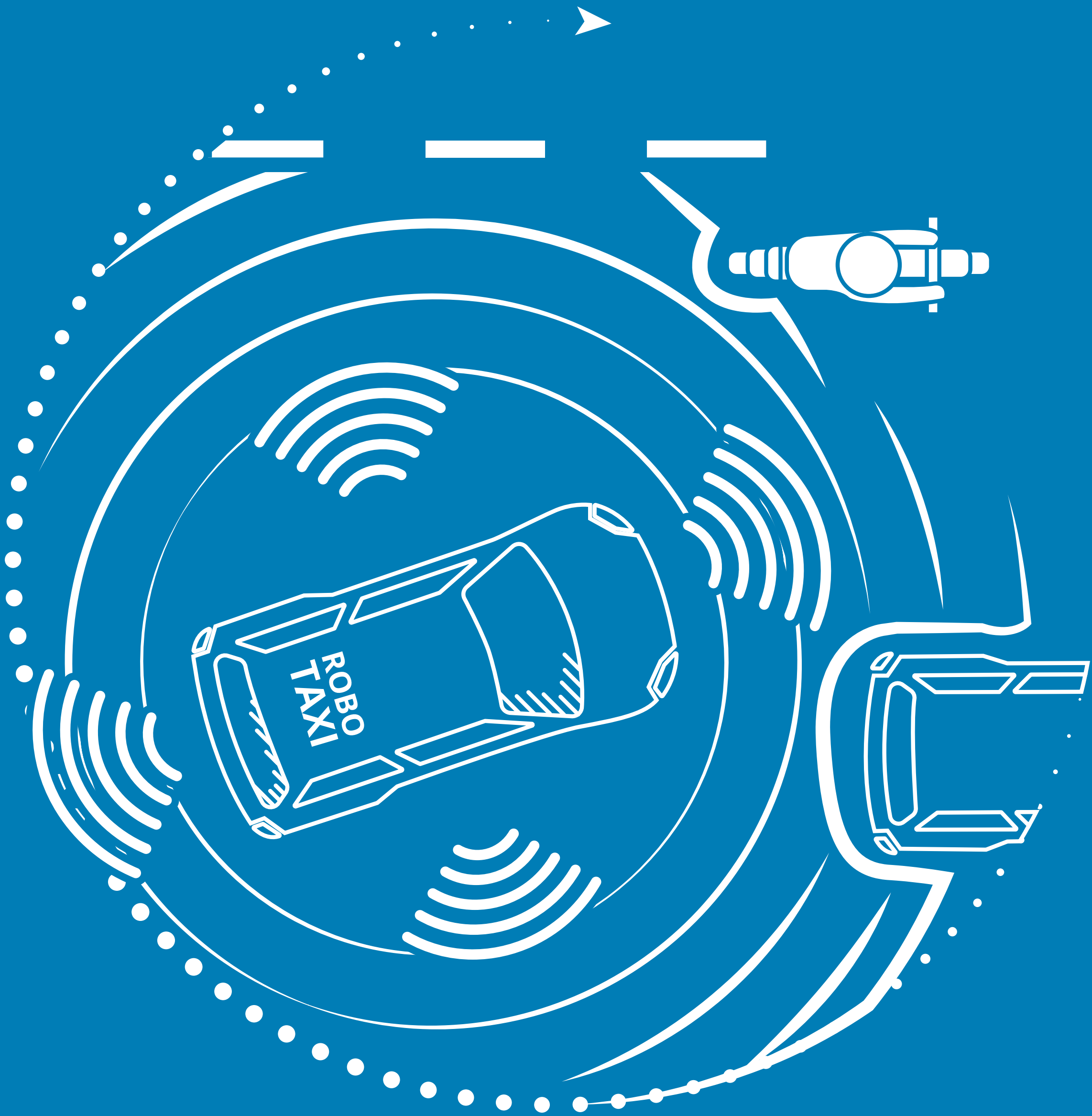
Future autonomous (electric) vehicles are primarily software-driven products compared to traditional cars. The upcoming transformation in the automotive industry from a “made of steel” business towards “software is eating the world” will be no doubt a game changer – for better or worse. Now that new players from the tech sector have entered the stage in the automotive industry, traditional manufacturers and suppliers try hard to continuously shorten development cycles and to catch up with the inevitable move into the new software era. Collaborative agile working models predominantly known from the software industry and more innovative cooperation management approaches are paving the way for tackling these challenges and turn them into opportunities.



Autonomous Driving: Hype or Reality?

In recent years, autonomous driving and so-called robo-taxis have become one of the hottest topics in the automotive industry - and beyond! Traditional car manufacturers and established suppliers are not the only ones who are trying hard to find the sweet spots in this new emerging mobility value chain.

Tech giants like Nvidia and Intel, leading software and internet players like Google (Waymo) and new mobility startups such as Aurora, Cruise and Uber are also on the verge of reaping the rewards of an entirely new future mobility era. Unlike the stakeholders of today's automotive industry, they do not have vested stakes to protect. However, on the other hand we are all aware of several technological hype cycles, ranging from the internet bubble at the turn of the millennium, the proclaimed significant increase in e-mobility, which the world is still waiting for, and lately blockchain and Bitcoin, which receive significant media attention. But where among all these trends and hypes can we place autonomous driving? The following paragraphs show some forecasts to frame the general market potential for autonomous driving solutions and provide a framework to align on common terms and wording when it comes to automated and 'real' autonomous driving.


ROBO
TAXI

Voices on Autonomous Driving

Autonomous driving is receiving significant media attention, not least because traditional car manufacturers and tech giants are investing heavily in new technologies and promising start-ups or forging new partnerships, but also because of significant technological advances. Overall, public perception is positive and surrounded by an optimistic enthusiasm. However, there has also been some bad press, mostly because of fatalities due to technological errors (see Figure 1). Some argue that these are individual cases and should not distort the fact that statistically speaking, autonomous driving is already safer than normal driving. At the same time, autonomous driving is under the scrutiny of the public eye due to its potential to massively change the way we live and the significance it has owing to the fact that we as humans give away control and thus put our lives in the hands of an algorithm. It will need time and positive reinforcement for the general public to ultimately accept and trust this new technology – and its inventors.

Figure 1 – Voices on autonomous driving

Where are we today?

»Exclusive: BMW to introduce 'safe' fully autonomous driving by 2021 with iNext«
Digital Trends, 28 Sep. 2018

»Automated vehicles may bring a new breed of distracted drivers«
ABC News, 24 Sep. 2018

»Volvo and Baidu join forces to mass produce self-driving electric cars in China«
CNBC, 1 Nov. 2018

»Tencent builds autonomous driving team in Silicon Valley«
Financial Times, 7 Nov. 2018

»Have autonomous vehicles hit a roadblock?«
Forbes, 1 Nov. 2018

»Why People Keep Rear-Ending Self-Driving Cars«
Wired, 18 Oct. 2018

»Amazon Could Become the Next Big Player in Autonomous Driving«
The Street, 24 Sep. 2018

»Self-Driving Cars Can Handle Neither Rain nor Sleet nor Snow«
Bloomberg, 17 Sep. 2018

»Uber asks for permission to restart self-driving car tests in Pittsburgh eight months after its test vehicle killed an Arizona pedestrian«
Daily Mail, 2 Nov. 2018

»Waymo Shifts To 'Industrializing' Self-Driving Tech as Robotaxi Launch Nears«
Forbes, 6 Sep. 2018

The automotive industry is rapidly moving forward and undergoing massive change – automotive companies, tech giants, start-ups and others are working hard on solutions

Positive developments
Controversial developments

The Road Towards 'Real' Autonomous Driving

Based on Deloitte's Future of Mobility study, we envision four different personal mobility futures emerging from the intersection of two critical trends: Vehicle control (driver vs. autonomous) and vehicle ownership (private vs. shared), as depicted in Figure 2.

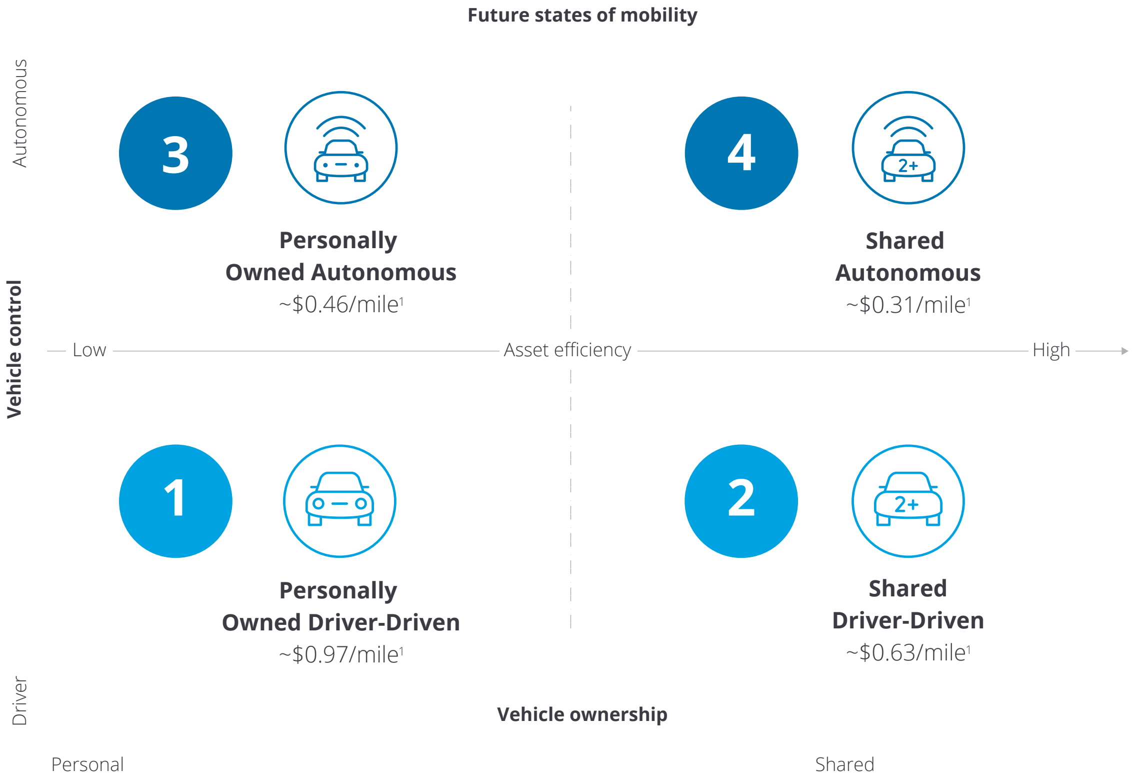
Our analysis concludes that change will happen unevenly around the world, with different types of customers requiring different modes of transportation. So all four future states of mobility may well exist simultaneously. Future state 1 describes the status quo in many markets, where traditional personal car ownership and driver-driven vehicles are the prevailing norm. While incorporating driver-assist technologies, this vision assumes that fully autonomous driving will not become widely available anytime soon.

Future state 2 anticipates continued growth of car and ride sharing. In this state, economic scale and increased competition drive the expansion of shared vehicle services into new geographic territories and more specialized customer segments. The costs per mile decrease and certain customer segments view car and ridesharing as more economical and sustainable for getting around, particularly for short point-to-point movements.

Future state 3 embraces the driverless revolution. Autonomous driving technology proves to be viable, safe, convenient and economical, yet private ownership continues to prevail.

Lastly, future state 4 envisions a new age of accessible autonomy. A convergence of both autonomous and vehicle-sharing trends will lead to new offerings of passenger experiences at differentiated price points. The earliest adopters seem likely to be urban commuters, using fleets of autonomous shared vehicles combined with smart infrastructures to reduce travel time and costs.

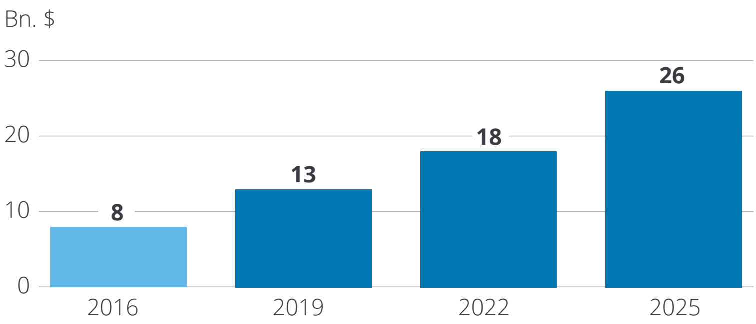
Figure 2 – Autonomous driving is the main driver of future mobility



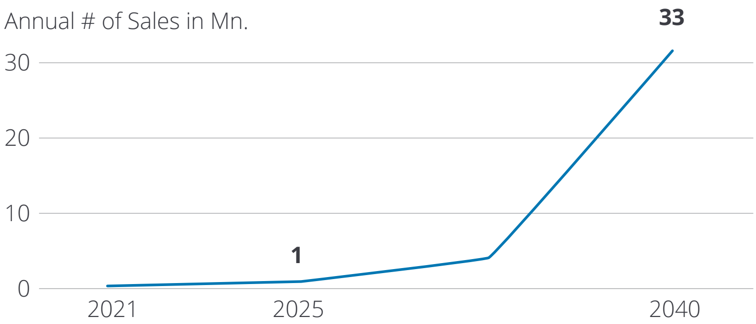
[1]~$X.XX cost estimate per mile based on US market example [2]ADAS: Advanced Driver Assistance Systems

Source: Deloitte FoM study 2018; Statista; IHS Automotive

ADAS[2] system



Autonomous Vehicle Sales

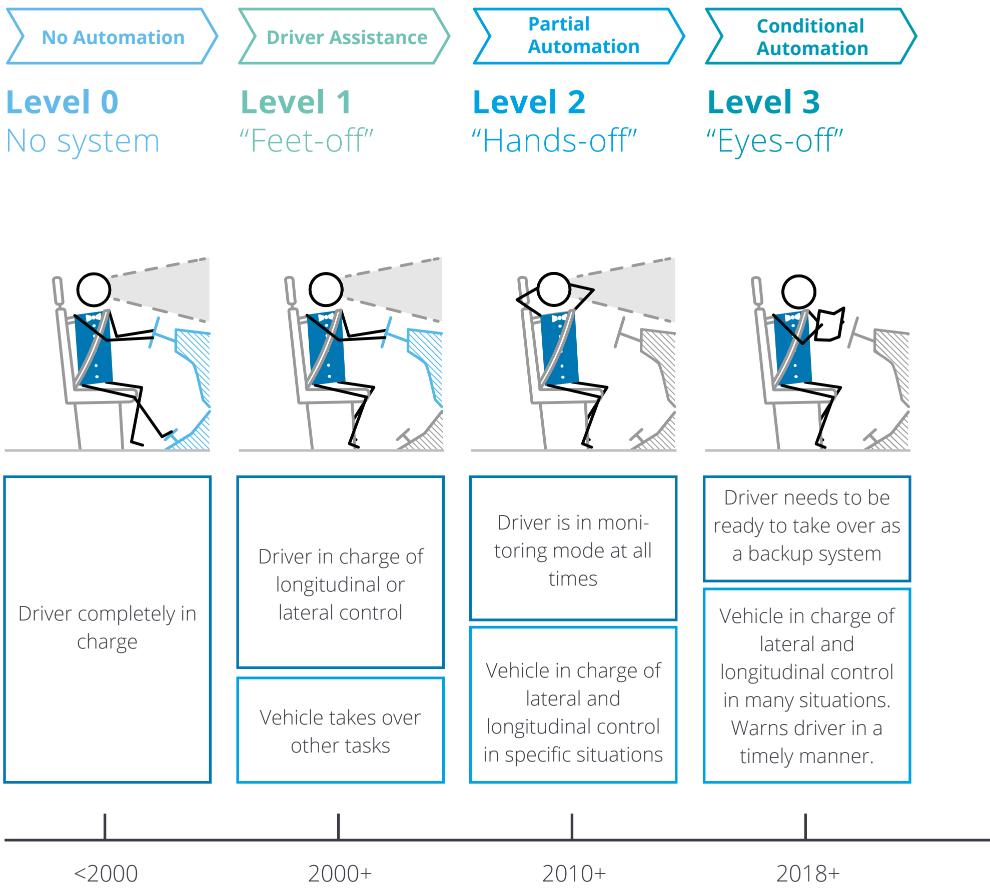


Currently, broad acceptance of autonomous vehicles seems much further away than a wide adoption of car and ridesharing. Sources of potential delay include the need to address existing technological limitations, such as proper functioning of sensors in all weather conditions and comprehensive availability of high definition maps, as well as concerns over cyber security and liability. On the other hand, ridesharing services in particular have a strong economic incentive to accelerate the adoption of autonomous vehicles, since it could significantly reduce one of the biggest operational cost in their system: the driver! This is one of the main reasons why tech players like Google do not rely on step-by-step driver-assist progression as most industry forecasts predict (Figure 2: e.g. tripling of advanced driver assist system (ADAS) revenues between 2016 and 2025), but instead try to jump immediately to fully autonomous driving. Rather than following the historical pattern of technological innovation, autonomous driving could constitute a step-change in development. However, the majority of industry experts expect the inflection point for widespread adoption of 'real' autonomous vehicles not before 2030. The following paragraph explains what we mean by 'real' autonomous driving.

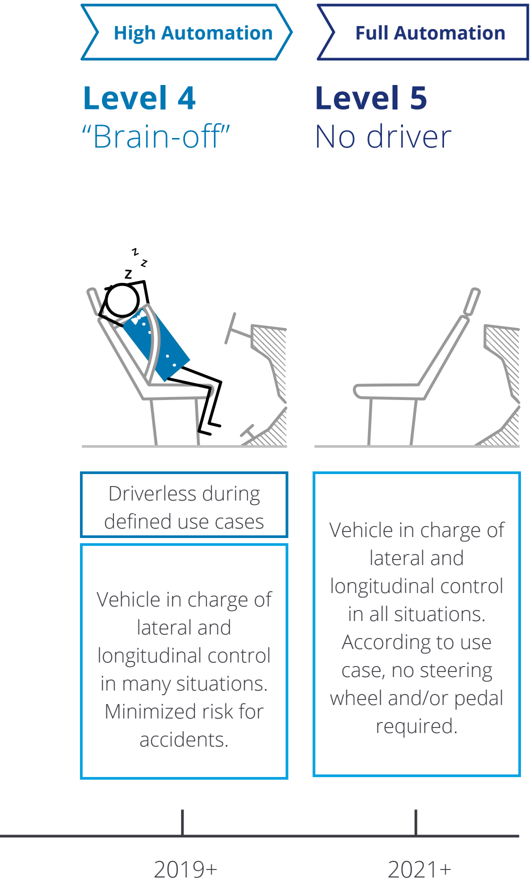
Classification of Autonomous Driving Levels

In terms of enabling technologies, automated driving is an evolution from the advanced driver assistance systems (ADAS) for active safety, which have been developed over recent decades and are still being continuously improved. A classification system based on six different levels, ranging from fully manual to fully automated systems, was published in 2014 by SAE International, an automotive standardization body (compare Figure 3). Level zero to level two requires a human driver to monitor the driving environment at all times. Level zero means no driver assistance at all, while level one provides simple support like speed control. Level two combines lateral and longitudinal control by the vehicle in specific situations. However, the driver needs to monitor the car and traffic at all times and be ready to take over vehicle control immediately.

Figure 3 – Vehicle automation levels



Source: Deloitte research 2018, SAE International 2014



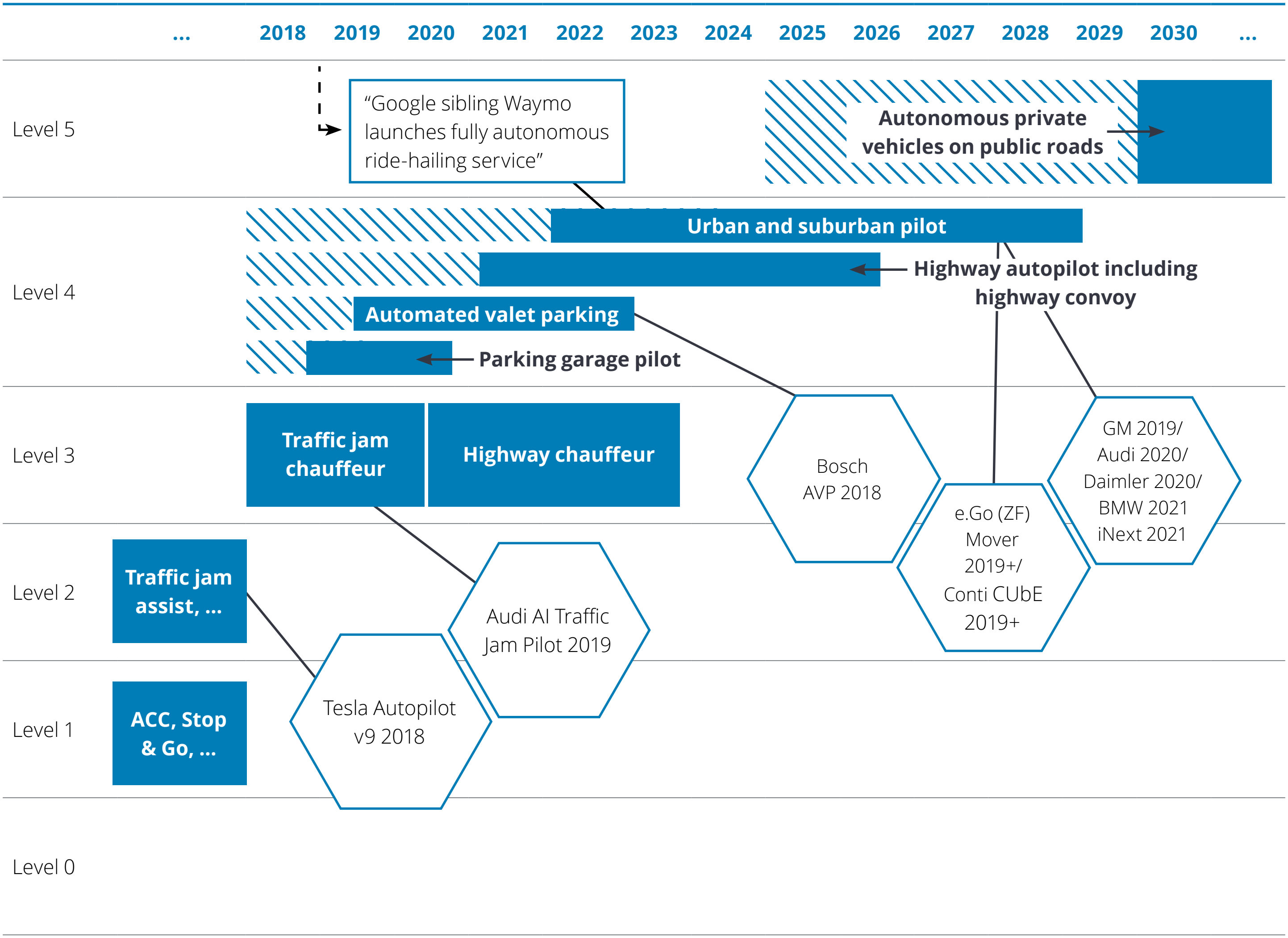
The focus of current developments by car manufacturers is in the range from level 2 to level 4. The most important transition is between partial automation (level 2) and conditional automation (level 3), since in the latter case the driver is allowed to be out of the loop. The main difference between level 4 (high automation) and level 5 (full automation) is the system's capability to handle specific restricted driving modes vs. all driving modes (eventually, these types of vehicles will not have a steering wheel at all).

Roadmap to 'real' Autonomous Driving

Automotive manufacturers are forging the path to high and full automation based on previous experience regarding driver assistance systems, where automation at level 2 has been realized successfully. However, the quantum leap in system reliability is between level 3 and level 4. At both levels, the system is already in charge of monitoring the driving environment, but at level 3 (conditional automation), a human driver still needs to be prepared to take control of the vehicle within a couple of seconds. At level 4, the system must be able to manage specified traffic conditions without any driver intervention and to reach a safety fallback state in the case of unexpected events.

Figure 4 shows a roadmap towards 'real' autonomous driving (level 5) for passenger cars, expected to hit the road with widespread adoption not before 2030. On the other hand, level 3 and level 4 market introduction are already underway, with level 3 being primarily focused on an automated highway pilot and level 4 on specified applications such as automated valet parking or first robo taxi fleets in selected cities (e.g. Phoenix, operated by Waymo).

Figure 4 – Roadmap towards 'real' autonomous driving



Source: ERTRAC 2017 "Automated Driving Roadmap", VDA 2018 "Automatisiertes Fahren", The Guardian 2017 "Google sibling Waymo launches fully autonomous ride-hailing service", Deloitte Research 2018

Testing and ramp-up phase
Series deployment

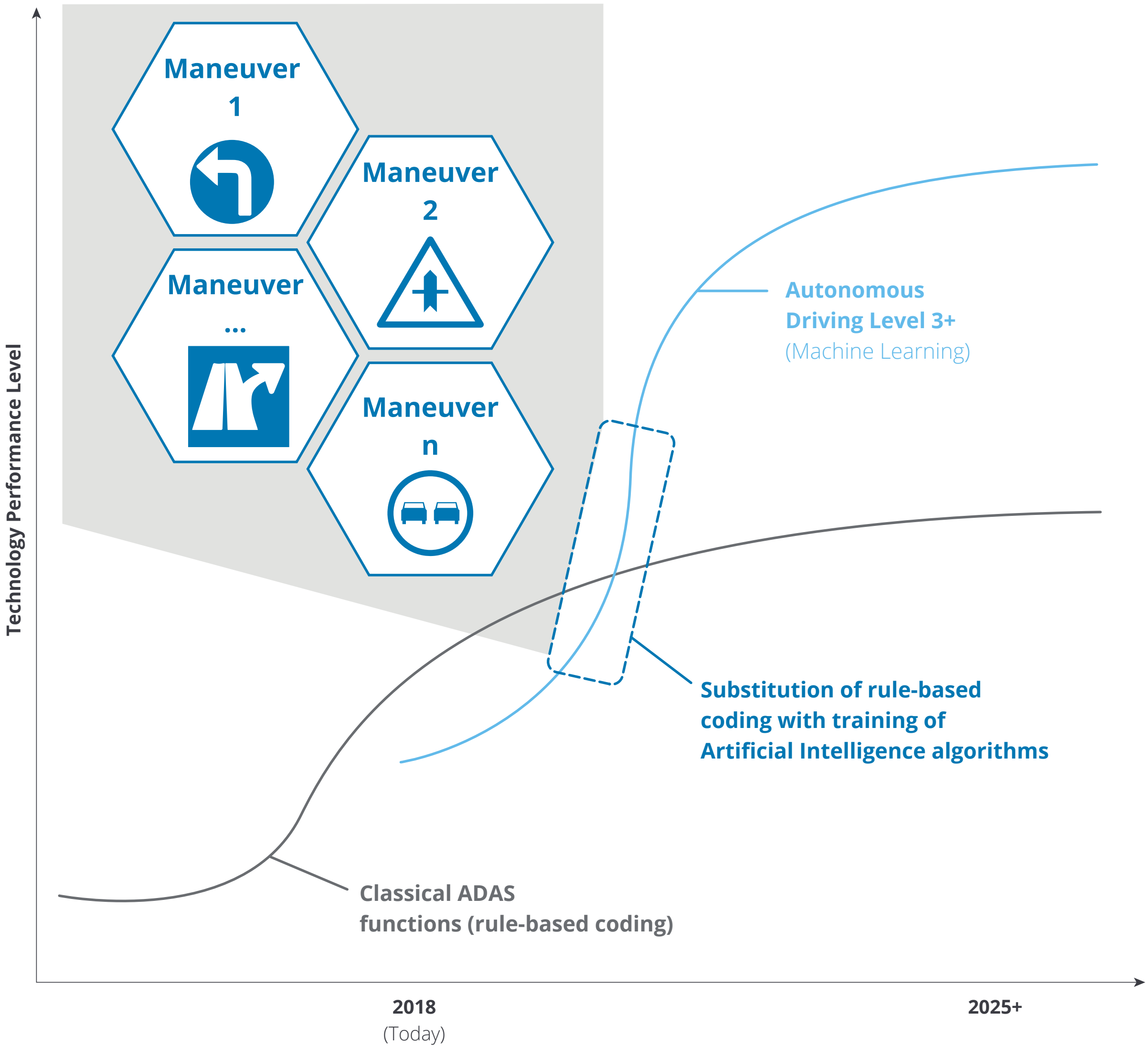
The market introduction and adoption rate of level 3 systems and above will differ by market and region, because not only do certain technological issues need an ultimate solution (e.g. how to cope with extreme weather conditions like snow, heavy rain or fog etc.), but regulatory and customer acceptance issues must also be addressed sufficiently upfront.

Key Challenges

The progression from level 3 to level 4 is not a steady one. Classic rule-based ADAS functions reach their limits with level 3 requirements. Linear "if then" conditions need to consider every possible use case or combination of use cases in any given traffic situation, which is virtually impossible in urban environments (level 4 and 5). Apart from confined spaces such as highways, traffic situations are highly dynamic and complex. For this reason, self-learning systems based on artificial intelligence (AI) that mimic human decision-making processes are critical for meeting the demand for complex scene interpretation, behavior prediction and trajectory planning. AI is becoming a key technology in all areas along the automotive value chain and is paramount for the success of level 4+ AD systems. Figure 5 illustrates the leap forward in technological progression from traditional software development to artificial intelligence.

However, AI talent is scarce and the market is highly competitive, resulting in skills shortages. This puts additional pressure on automotive companies still needing to build up expertise in those areas. But what exactly is AI in the first place? We are going to shed some light on this question in the next chapter.

Figure 5 – Quantum leap from classic rule-based coding to artificial intelligence



Source: Deloitte Research 2018

AI is crucial for AD level 3+, because classic coding is not sufficient to master and meet the necessary requirements

- Traffic situations are **highly dynamic and complex**
- Sensors collect tremendous amounts of data points, which need to be **interpreted in real time** (e.g. object detection, reduced visibility, natural behavior, map adjustments, …)
- The required processing speed for the amount of complex, new data input can only realistically be mastered with **self-learning systems**
- Deep learning systems can be trained to **mimic human decision-making processes,** which could ease human-machine interaction on the road
- Behavior **prediction** of other road users including vehicles, pedestrians, cyclists
- AI is becoming a **key technology** in all areas along the automotive value chain

»Artificial Intelligence is the new electricity.«

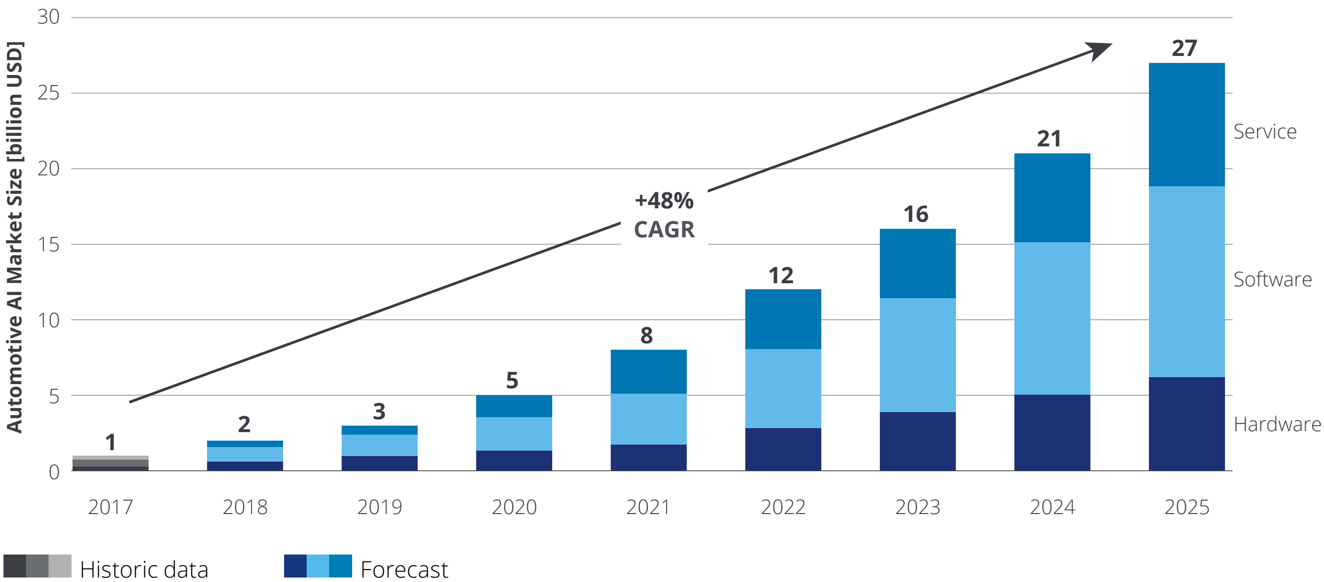
Andrew Ng (AI Entrepreneur, Adjunct Professor Stanford University)

Deep dive

Artificial Intelligence

Artificial intelligence is at the top of its hype curve. With potentially revolutionizing applications in almost every industry and domain, the market is experiencing explosive interest from established companies, research institutions and startups alike. The global automotive artificial intelligence market forecast shown in Figure 6 reflects this interest with a CAGR of 48% between 2017 and 2025, culminating in a total volume of around 27 billion U.S. Dollar in 2025.

Figure 6 – Global automotive AI market forecast



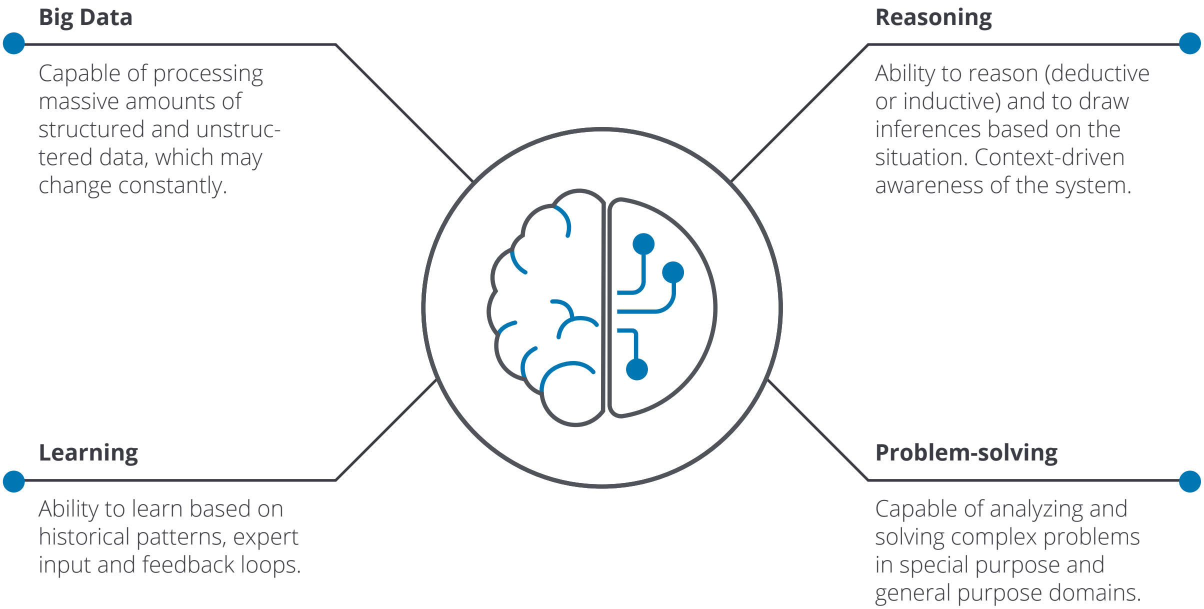
Source: Tractica 2018, Deloitte Research 2018

At the same time, there could not be a greater gap in experts' opinions on the technological short-term potential of artificial intelligence, which ranges from simple performance improvements in today's methods to artificial intelligence-powered robots conquering and enslaving the human race one day.

While there are promising advances across the entire spectrum, we see an inflation of technologies branded as artificial intelligence. For example, a demand prediction model based on machine learning, which has been around for years and would usually classify as data mining, is now rebranded as 'AI'. Companies follow such strategies to tap into the hyped sales potential. One of the prevailing reasons is that the term artificial intelligence is ill-defined. There is no single, agreed-upon definition that removes all doubt; rather all definitions leave room for interpretation and therefore room for deceptive product specifications. This should by no means diminish the impressive advances and speed of development in the artificial intelligence realm. As Elon Musk put it: "The pace of progress in artificial intelligence (I'm not referring to narrow AI) is incredibly fast. Unless you have direct exposure to groups like Deepmind, you have no idea how fast - it is growing at a pace close to exponential. The risk of something seriously dangerous happening is in the five-year timeframe. 10 years at most."

In order to separate hype from reality, we will classify artificial intelligence in the broader context of science, which includes but is not limited to computer science, psychology, linguistics and philosophy. Figure 7 shows the key characteristics of an AI system. The common understanding of artificial intelligence is that it is used to get computers to do tasks that normally require human intelligence. Common to most definitions is that "intelligence" refers to the ability to sense and build a perception of knowledge, to plan, reason and learn and to communicate in natural language. In this context, it also comprises the ability to process massive amounts of data, either as a means of training AI algorithms or to make sense of hidden information.

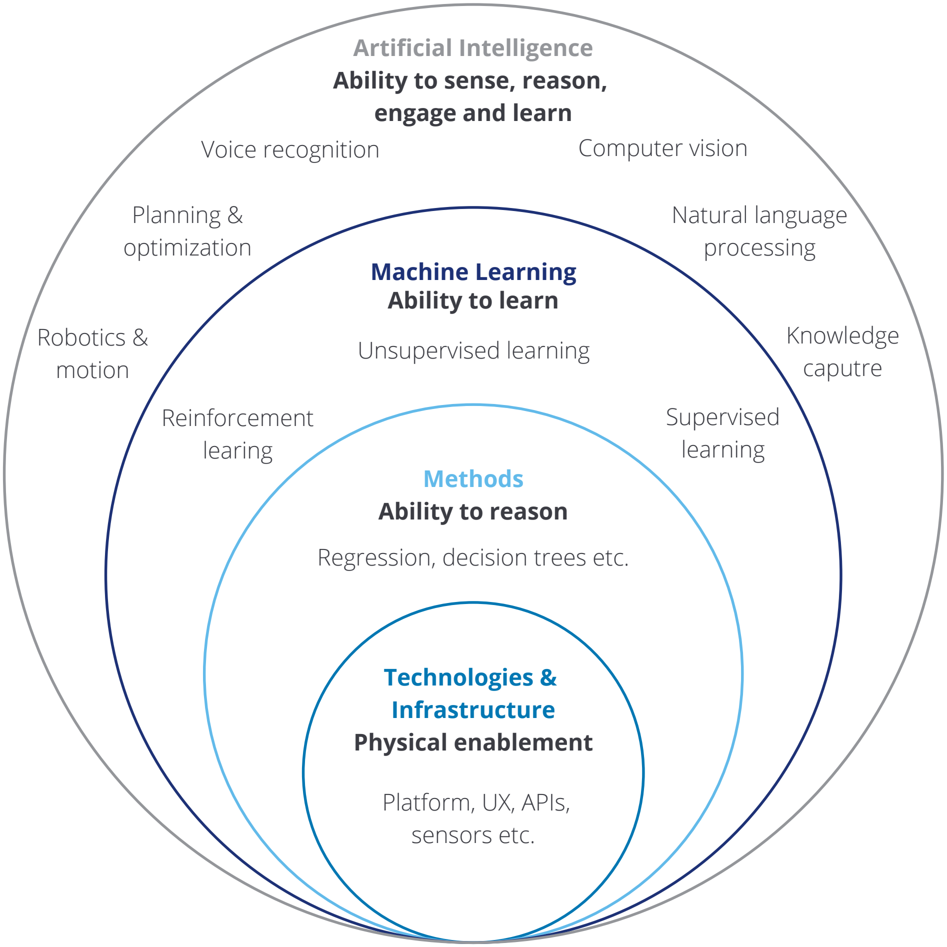
Figure 7 – Key characteristics of an AI system



Source: Deloitte 2018 “Artificial Intelligence”

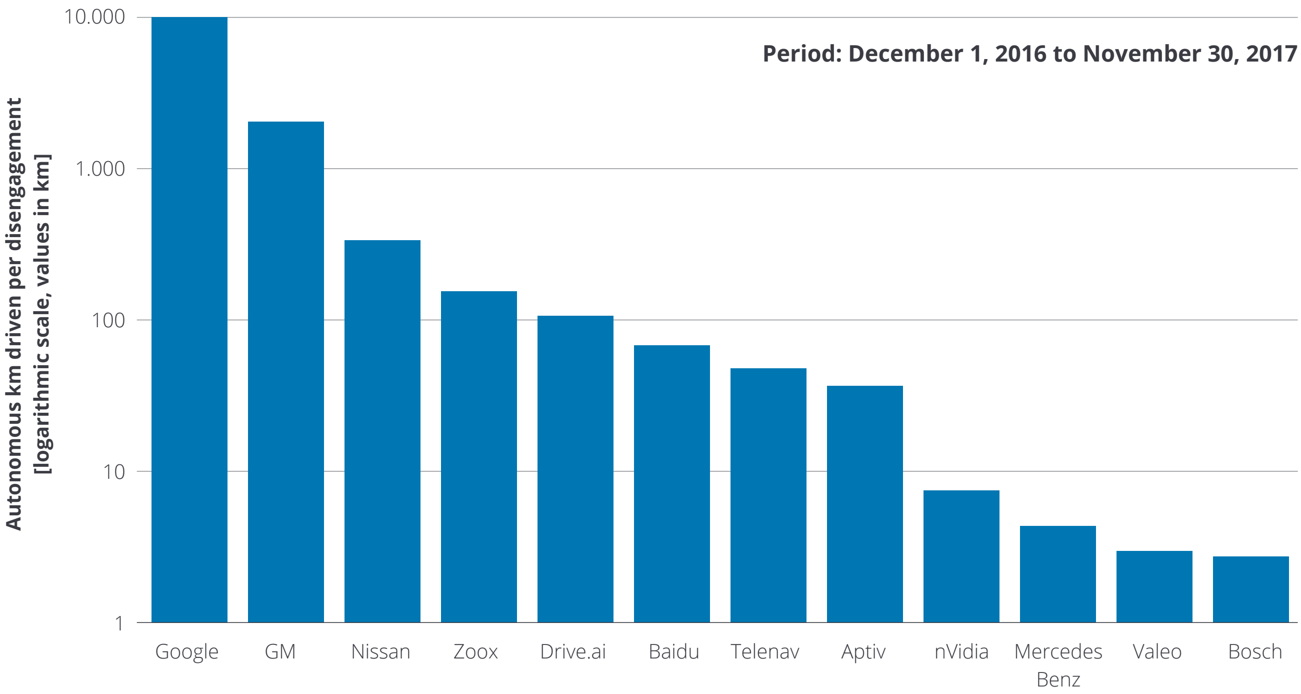
We differentiate between narrow and general artificial intelligence. Today's artificial intelligence solutions are almost exclusively narrow. In this context, narrow means that an AI algorithm only works in the specific context it was designed for, e.g. computer vision-based object detection algorithms in autonomous driving systems. Such algorithms have the potential to exceed human performance by orders of magnitude. General AI, on the other hand, refers to the more human interpretation of intelligence in the sense that such AI solutions are able to understand, interpret, reason, act and learn from any given problem set. An AI system typically combines machine learning and other types of data analytics methods to achieve AI capabilities (Figure 8).

Figure 8 – 'Machine learning', 'Methods' and 'Technologies & Infrastructure' in the context of AI



Source: Deloitte Research 2018

Figure 9 – Autonomous vehicle disengagement report statistics[1]



Source: "Autonomous Vehicle Disengagement Reports 2017", DMV, CA

[1] Please note, that this figure is only indicative, given that it only shows the state of California. Some firms, including German OEMs, do not test their vehicles in California and therefore do not appear in the data

- Based on the 2017 “Autonomous Vehicle Disengagement Reports” published by the DMV, California, Waymo leads the race for autonomous driving leadership by far

- GM’s investments in Cruise Automation helped them propel to second place in terms of autonomous kilometers driven per disengagement

- Nissan following in third place with a wider gap

- Noticeable advancements especially from startups and tech companies

- Audi, BMW, Volkswagen, Tesla not considered in this chart due to a lack of test data tracked by the DMV

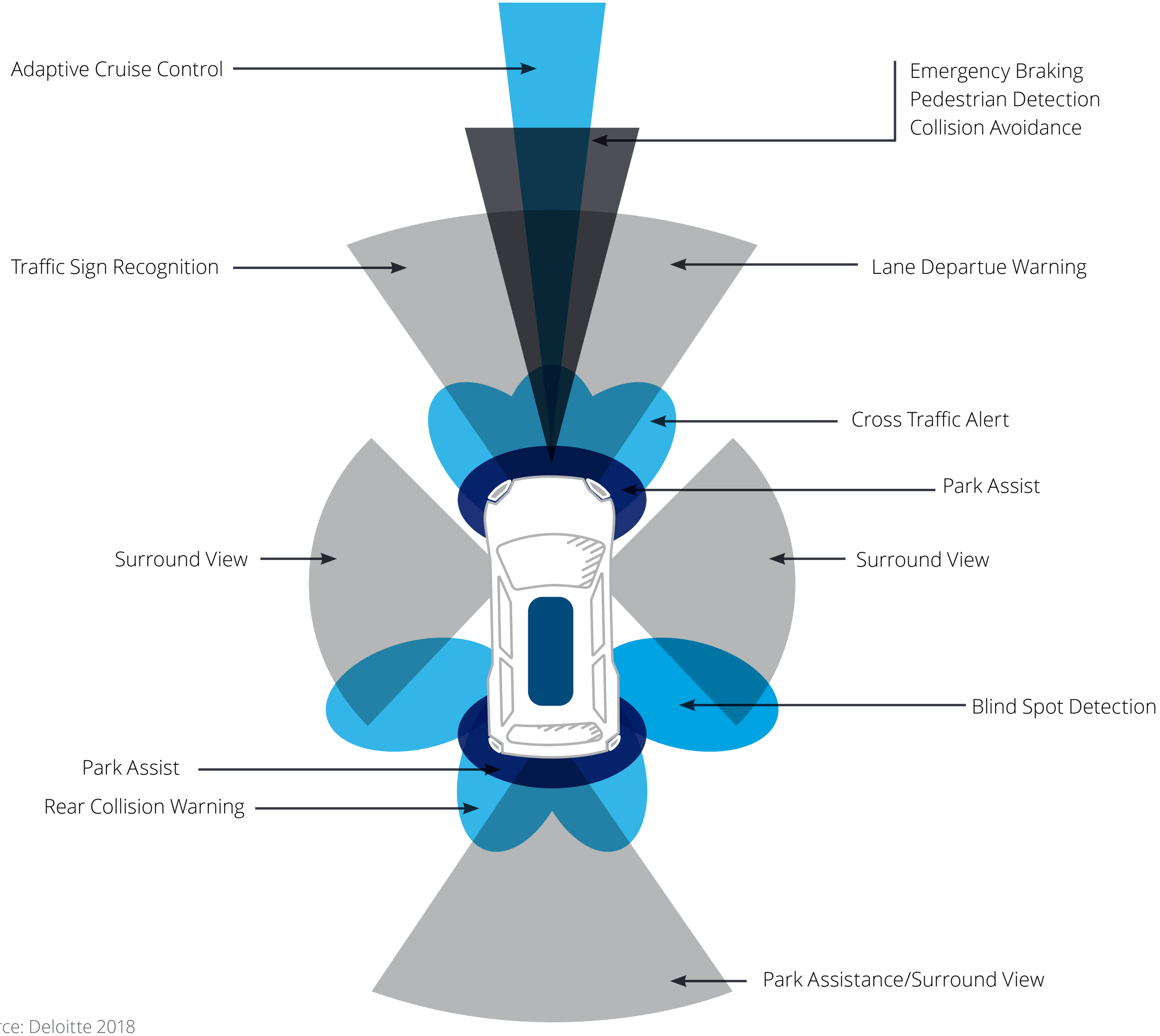
Artificial intelligence is one of the crucial elements for level 4 and 5 autonomy. Recent autonomous vehicle disengagement reports issued by the Department of Motor Vehicles, California, illustrate the autonomous miles driven before disengagement becomes necessary, in critical or non-critical situations (Figure 9). While many factors come into play here, it is undeniable that the firms known to be strong in AI are leading the statistics. Please note that the DMV only registers firms that perform test drives in the state of California. The graph therefore does not represent the full picture, but rather serves illustrative purposes. Based on our experience, the relation between top performers and mid to low performers is accurate though.

Technological Hurdles

On-board & Off-board

Technological hurdles for level 3 automation and above are still manifold. We differentiate between on-board and off-board challenges, as shown in Figure 10. As far as on-board issues are concerned, the key challenges revolve around sensors, computing hardware, basic software and autonomous driving core software. In order to ensure the safety requirements imposed by industry and government, sensor quality still needs to be improved to cater for e.g. accuracy for speeds up to 130 km/h and in some cases, especially with lidar, the price point is still too high to be economically feasible. With new central processing units and operating systems come new challenges regarding the vehicle's overall safety concept. ECUs need to process large amounts of input data, but also compute complex algorithms based on artificial intelligence techniques, such as convolutional neural networks (CNN) for object detection, in real time. Considering the industry-wide trend towards electric drivetrains, the ECU's requirement for computing power is counteracted by the demand for low energy consumption. In terms of software development, the challenge lies in creating, training and securing (validation and verification) safe algorithms.

Figure 10 – On-board and off-board challenges in autonomous driving



Source: Deloitte 2018

On-board hardware

Camera/Optics
Collect optical images to be interpreted by advanced AI & analytics

System on a Chip (SOC)
High performance energy-efficient computer hardware

Radar
Determines speed and distance of objects using electromagnetic waves

V2V/V2I
Communication with vehicles & infrastructure over short range

LiDAR
High resolution sensor using light beams to estimate distance from obstacles

Actuators
Translation of electronic signals into mechanical actions

Ultrasonic sensors
Short distance object recognition (e.g. parking)

GPS
Localization of vehicle using satellite triangulation

Odometry Sensors
Measure wheel speed to predict vehicle travel and complement localization

Off-board hardware / software

Data Center
Storage and processing of hot and cold vehicle data

AV Cloud Operation
Learning, adopting and updating HD maps & algorithms

On-board software components

High Definition On-Board Maps
Precise localization information about roads, infrastructure and environment

Localization & Mapping
Data fusion for vehicle localization and environment analysis

Perception & Object Analysis Algorithms Detection and classification of objects and obstacles

Prediction Foresight of movements and actions by vehicles, pedestrians and other moving objects

Decision-Making
Planning of vehicle route, maneuvers, acceleration, steering and braking

Vehicle Operating Systems
Operating system running algorithms in real time

Supervision platform
Analytics to monitor the AV system operation, detecting & correcting faults

While some companies see level 3 functionalities as an evolution of classic ADAS functions, which can be mastered with rule-based coding, level 4 and 5 autonomy require artificial intelligence to cope with the complexity of traffic situations. The latter typically demand large data sets (e.g. raw sensor data) for training, testing and validation of (deep learning) algorithms. In order to store and process these data, companies make use of data centers or cloud solutions. The data are labelled, clustered and ultimately used to optimize and update algorithms. It remains an open challenge today to efficiently validate artificial intelligence algorithms such as CNNs. AI algorithms operate like a black box in the sense that it is not trivial to determine what triggers certain decisions. Validating correct functionality is cumbersome and today only feasible statistically via numerous test cases.

Besides, data centers constitute the basis for simulation purposes. Theoretical estimates show that in order for level 3+ autonomous vehicles to achieve approval for commercial use, the system needs to undergo billions of kilometers of testing. It is neither economical nor does it prove to be a swift approach to achieve this amount of mileage in real world testing. Simulations effectively contribute to this requirement, covering more than 95% of the mileage demand. However, it remains a challenge to set up the proper test concept and collect or create sufficient data for validation.

Overall, the challenges for companies working on autonomous driving technology are significant and vastly affect the dynamics of the automotive industry. The following paragraph discusses our view on some of the key implications confronting the automotive industry.

»We're entering a new world in which data may be more important than software.«

Tim O’Reilly (Founder O'Reilly Media)

Impact on Today's Automotive Industry

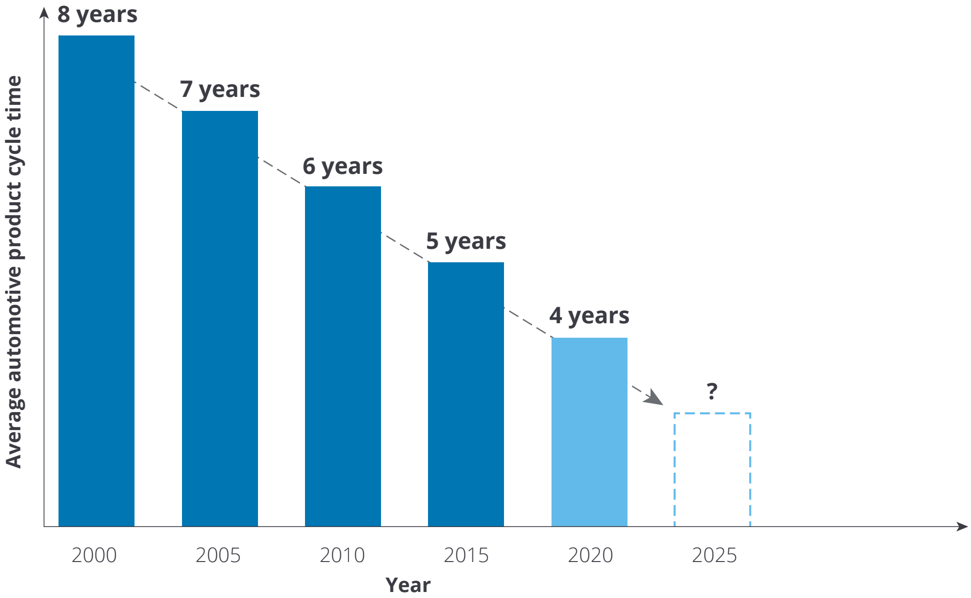
Cars are no longer merely the means of getting from point A to point B, nor are they simply status symbols; instead, they have become functional assets. Particularly in recent years, car manufacturers have discovered growing customer demand for digital infotainment solutions and other in-car services. In the telecommunications industry, smartphones replaced the traditional mobile phone, with telephony being just one of many features and oftentimes not even the most important one.

Car manufacturers face a similar trend nowadays, namely that the car is turning into a platform to serve a variety of functions. As Nitesh Bansal, Senior Vice President and Head of Manufacturing Practice Americas and Europe at Infosys, put it: "The modern car is a supercomputer on wheels, and its sensors and cameras generate a wealth of data that someday might be worth more than the automobile itself" – in that, for car manufacturers, the car is becoming a rich source of data they can use to improve products and business operations.

The same goes for development: 50 years ago, the distribution of a car's added value between hardware and electrics, electronics (E/E) and software was approximately 95% compared to 5% respectively. In an average car today, the distribution is closer to 50% hardware and 50% E/E and software. Along with the technological progression of the semiconductor industry, development of E/E as well as software has increased exponentially over the past two decades. At the same time, the average product cycle time has halved over the same period (see Figure 11).

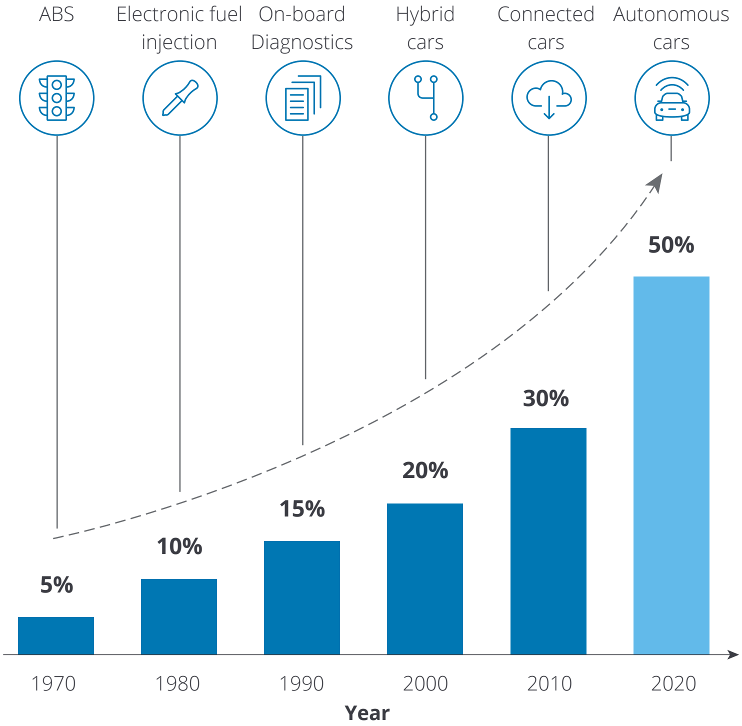
Figure 11 – From hardware to software focus

Average automotive product cycle time



Source: Diez (2015), Deloitte Research 2018

E/E & SW share of total value add in automotive



Source: Statista 2018, GTAI 2016, Brandt 2016, freescale semiconductor 2010, Wallentowitz et al. 2009, Deloitte Research 2018

That said, OEMs increasingly deviate from a "One Product, One Function" strategy and instead approach a "One Product, Many Functions" philosophy, similar to what we have seen in the telecommunications industry with the introduction of smartphones. While an average car today still features around 60 control units to manage the multitude of functionalities in the vehicle, the trend is going clearly towards a central processing unit that controls all functions of the vehicle in unison. One of the crucial challenges associated with a central processing unit lies in managing the criticality of control signals and the bandwidth of bus connections. Car manufacturers have started to accept the challenge and subject themselves to - in some cases drastic - transformation programs, which we will dive into in the following paragraph.

Paradigm Shift in OEM Product Development Organizations

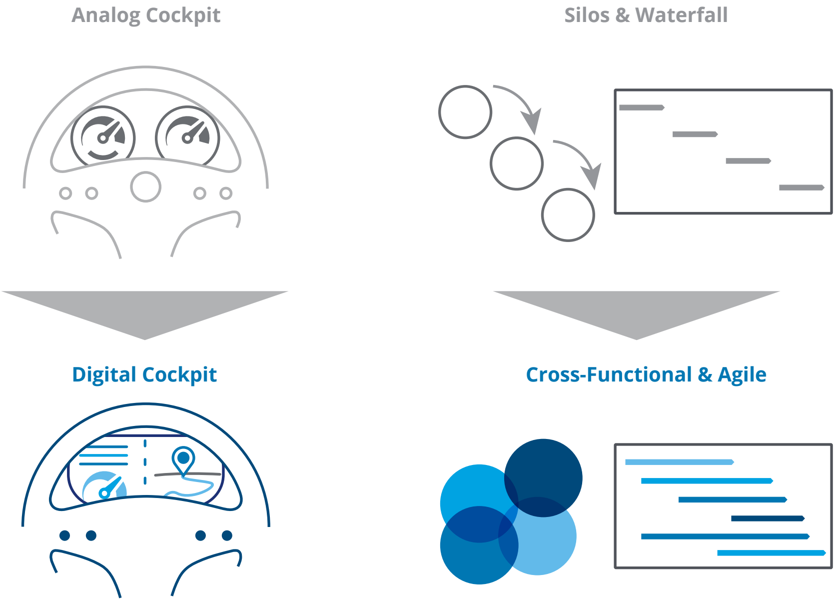
Historically, car manufacturers have established a very strong top-down chain of command. This made sense when labor division between "thinkers" and "doers" was strict. The engineer defines how the mechanic needs to assemble the car, the senior engineer instructs the junior engineer, etc. In today's VUCA world (volatile, uncertain, complex, ambiguous) these rules do not apply anymore. The environment has changed, new competitors have entered the market and are constantly challenging and changing the rules and dynamics of the game. Core competencies, skills and know-how that have been perfected for decades to build great quality cars fade into the background, while the focus is placed on innovation, agility and software, including but not limited to autonomous driving, artificial intelligence, agile working, electric vehicles and new business models.

Based on our experience, Deloitte sees four major areas of change that will ultimately change the dynamics of the automotive industry for good (Figure 12).

Figure 12 – Four major areas of organizational change

1 Product Structure: Hardware vs. Software Share

2 Work Structure follows Product Structure: Agile Development Organization Processes



- Value add of software in the vehicle continues to increase
- Trend is supported by surging importance of artificial intelligence (AI)
- Shift away from “one function, one device” philosophy towards a “many functions, one software platform” approach

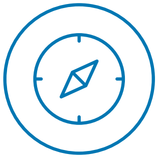
- Better consideration of 'real' customer needs & requirements by applying minimal viable product (MVP) approach
- Reduced development time, shorter time-to-market and lower development cost
- Ability to cope with uncertainty and complexity

Source: Deloitte 2018

3 New Steering Models:
KPI vs. Progress Indicator

KPI

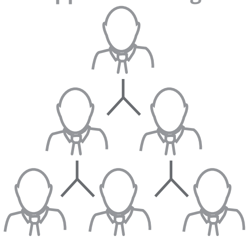
Progress Indicator



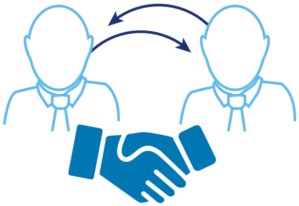
- The nature of agile working environments requires new steering models
- Progress indicators, such as OKRs (Objectives and Key Results), should be used more as a compass to ensure movement in the right direction rather than a numerical control on detail level

4 Mastering New Technologies:
Cooperation vs. Supplier Relationship

Supplier Steering



Partnership



- Autonomous driving brings a new level of development complexity that can no longer be managed by individual players alone
- Both technology companies and car manufacturers benefit from complementing each others' skill sets and sharing development efforts

Area 1 refers to the product structure. The share of value added to the vehicle between hardware versus E/E and software is shifting in favor of the second. Consequently, car manufacturers undergo major transformations to refocus their core competencies and build up expertise in those areas.

Area 2 describes the change that is necessary on an organizational and work structure level. Structures and processes that have proven successful for the development of products with low shares of E/E and software are no longer ideal for the development of autonomous vehicles. Companies are increasingly replacing classical waterfall structures with agile approaches. The goal is to move away from long development cycles, inflexibility and hierarchical command-and-control style management practices and replace them with shorter development cycles, adaptivity, flat hierarchies and team empowerment.

New work structures and development processes require new steering models, which is the focus of Area 3. Key performance indicators (KPIs) are an effective tool to evaluate an organization's success at reaching targets. This applies mostly to situations that are predictable and linear. Environments that are complex and unpredictable in nature, such as the development of autonomous vehicles, require different approaches to success evaluation. Where the technology is new, the outcome uncertain and the timeline unpredictable, classical KPIs often do not provide sufficient benefit in measuring and steering the progress of development. Instead, agile steering models should focus on continuously measuring holistic progress and direction as compared to performance at specific milestone dates. After all, agile development practices support the ambition to cope with uncertainty by providing a new level of adaptivity. Upfront top-down planning, including meticulous project timelines, run counter to the philosophy of agile development. However, a smart alignment between major top-down project milestones (e.g. on a quarterly basis) and bottom-up progress indicators, which show operational work advancements (e.g. on a bi-weekly basis), provide good orientation regarding the overall project status and direction.

Finally, Area 4 addresses new forms of working with suppliers and partners. Traditionally, car manufacturers have outsourced large shares of development work to suppliers in classic contract relationships. This is a viable option when confronted with known technologies that can be partitioned with clear interfaces. In the case of autonomous driving, there are many unknowns for what constitutes the optimum technical solution. Additionally, no single player in the industry possesses all the skills necessary to develop the perfect solution. Google and Apple hold great expertise and talent in software development and artificial intelligence, but lack the automotive know-how to build cars themselves. Car manufacturers possess the necessary automotive expertise and infrastructure, but lag behind with software capabilities. For this reason, companies are joining forces in development partnerships and increasingly via mergers and acquisitions.

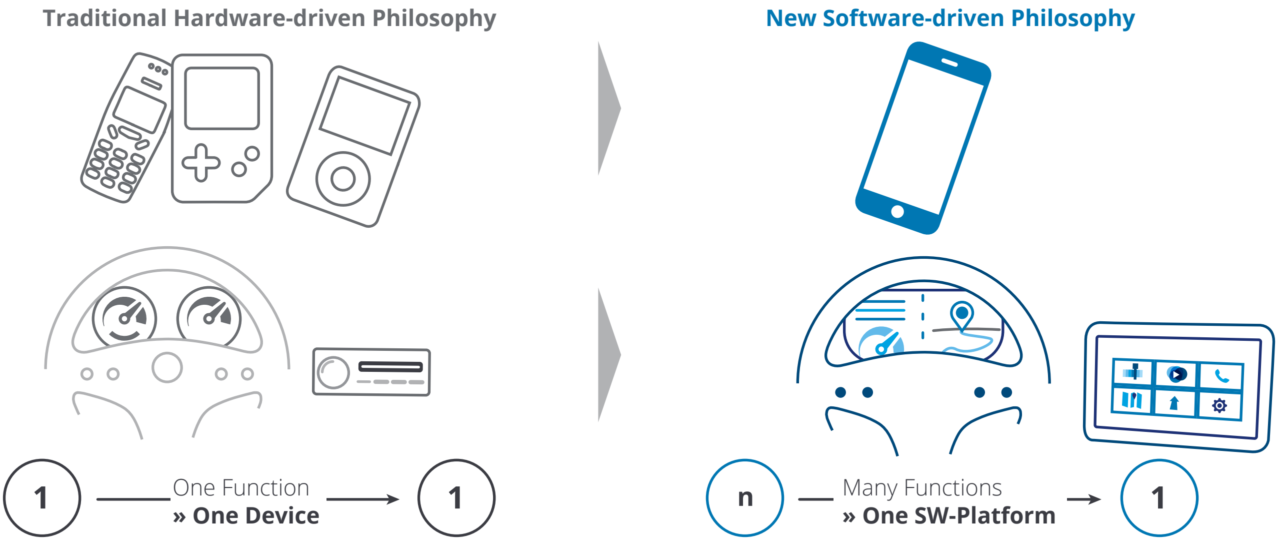
1

Product Structure: From Hardware to Software Focus

For decades, traditional car manufacturers have perfected their craft to build great quality cars. Over the last 30 years, automotive E/E as well as software applications have gained great traction, along with the rise of enabling technologies including computer chips, the internet, etc. Initially, speed of innovation was slow in this domain compared to modern standards. This is why it made sense that a single control unit had the sole purpose of powering a single function (of course, this is a simplified explanation because several E/E functions are commonly executed across several ECUs. However, the E/E architectural philosophy often still allocates specific functions to dedicated controller units). Simply put, this remains the industry standard today: One device, one function. To the same degree, it still holds true that traditional car manufacturers are cost optimizers more than innovative game changers. The current business model is to make money by selling cars. New entrants follow a more radical strategy. Technology companies have identified the value of data for their business and leverage business models that support this notion, such as Waymo's robo-taxi pilot program in Phoenix, Arizona.

Traditional car manufacturers have identified their need for change and are drastically investing in becoming more agile, more software oriented "automotive technology companies" with shorter release cycles for software applications. The underlying change in product structure goes away from the "one function, one device" philosophy, towards a "many functions, one software platform" approach, as shown in Figure 13. The computing power required to process the huge amounts of sensor data, primarily from cameras, radars and lidars in autonomous vehicles, makes those cars supercomputers on wheels, as stated earlier. Thus, it makes sense to take advantage of this technology potential and use it as a central source for data processing.

Figure 13 – Shift from hardware to software focus

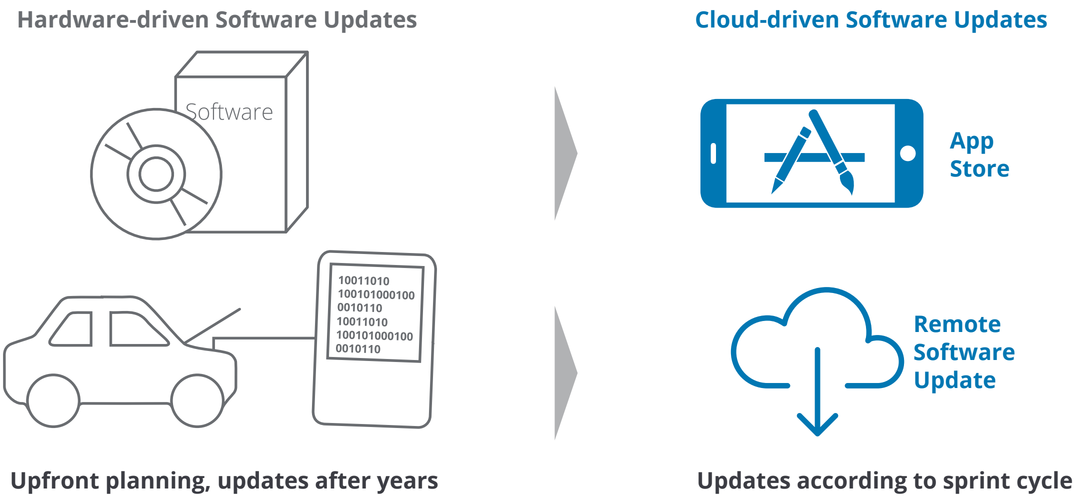


Source: Deloitte 2018

The aforementioned changes do not only apply to hardware, but also to the way software is applied (Figure 14). Up until recently, there was no demand for regular software updates. Control units were flashed during production and in most cases never saw an update until the end of the car's product lifecycle. Software was designed under the premise of avoiding errors at all costs, and therefore required substantial lead and development times.

In agile software development, software quality is of paramount importance as well, oftentimes even more so than in waterfall approaches. The main difference lies in the software development sequence: While waterfall follows a sequential path from conception to deployment, agile has an iterative approach where potentially shippable software increments are developed according to a minimum viable product approach. This is relatable to the way smartphone apps are created today. The updates regularly released to app stores are product increments resulting from a sprint (in Scrum, a time-box of 4 weeks or less during which a potentially shippable product increment is developed). Remote software updates (RSU) in automotive gain in importance as vehicles continue to become more connected and autonomous. The most prominent example of a company that is already using RSUs successfully is Tesla, which regularly releases updates to its fleet to improve the autopilot function, battery range, or others. Other prominent players, including traditional car manufacturers such as BMW and Daimler, have gained substantial experience with RSUs, not least because of their car-sharing fleets.

Figure 14 – Shift from hardware-driven to cloud-driven software updates



Source: Deloitte 2018

»For whatever reason somebody can be convinced to buy a PC, it opens up a whole new market for all of us in the software business.«

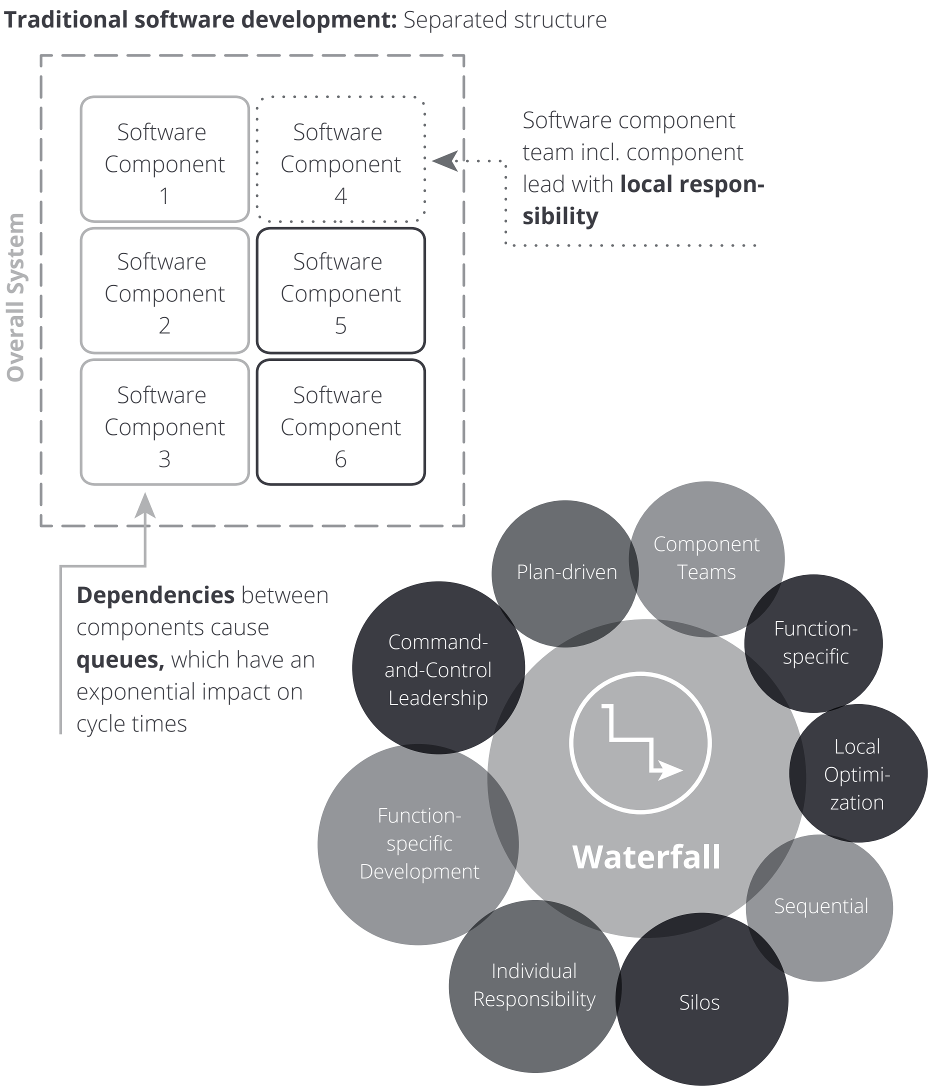
Kevin O'Leary (Co-founder SoftKey)

2

Work Structure follows Product Structure

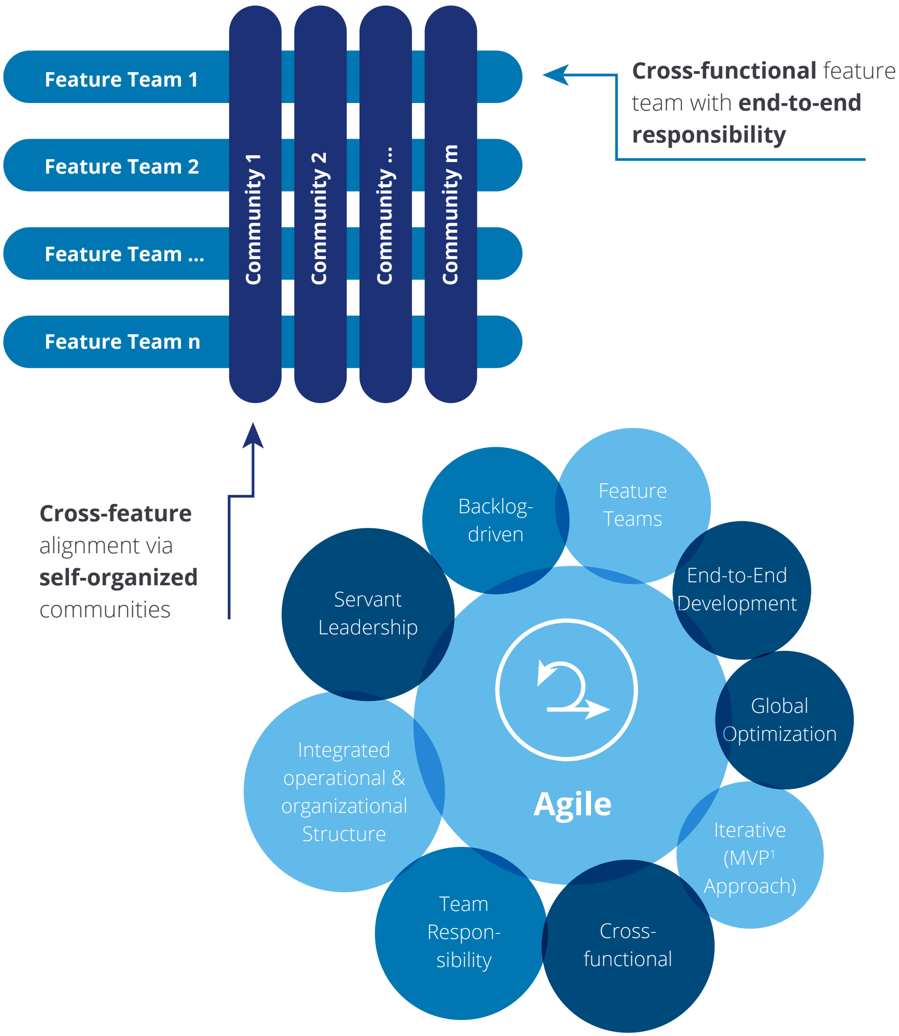
As mentioned, traditional software development follows individual development stages sequentially. From an architectural standpoint, building blocks are divided into software components, which are taken care of by component teams (compare Figure 15). Since development times can be extensive for certain software components, this approach requires meticulous upfront planning: First, to enable teams to work in parallel with clearly defined interfaces, tasks and responsibilities; second, to reduce dependencies to a minimum, as queues have an exponential impact on cycle times. In complex systems, dependencies cannot be avoided every time, which increases coordination efforts and complicates system integration. Owing to this structure, waterfall development is characterized by local optimization of single software components due to silo development. Operational and organizational structures are detached and require coordination teams. Management follows a command-and-control style leadership, because technical decisions are made top-down.

Figure 15 – Traditional waterfall vs. agile software development



Source: Deloitte 2018

Agile software development: Integrated structure



[1] Minimum Viable Product Approach

This is in stark contrast to the characteristics embodied by agile software development, which in its core embraces self-organization on team level, pushes decision-making down to the lowest possible hierarchy level and fosters servant leadership. Teams are cross-functional and assume end-to-end responsibility for a product feature (i.e. minimum viable product increment). In analogy to the most common agile framework, Scrum, teams are by definition feature teams; development is consequently oriented toward the highest customer value and prioritized via a backlog of development items. Consequently, the organization continuously strives to achieve a global optimum. A perfect feature team is able to do all the work necessary to complete a feature (backlog item) end-to-end. Cross-feature alignment is self-organized and all feature teams work on a common software repository. Operational and organizational structures are integrated and streamlined to focus on value-adding activities while eliminating overhead.

Many companies view agile as the holy grail for securing innovation leadership, which leads to massive transformation programs, sometimes without taking the necessary time to analyze and evaluate the full spectrum of implications. Agile (software) development brings many benefits, but it has to suit the purpose and environment. The dynamics and challenges in pure software development environments such as banks, insurance companies or in app development are fundamentally different from the ones in the automotive industry. The car industry is highly sophisticated and consists of an advanced network of manufacturer, supplier and partner relationships. OEMs outsource large portions of development work to suppliers, which creates dependencies and the need to define and manage clear interfaces. In addition, we are talking about embedded software development with significant hardware shares. These circumstances pose new challenges to agile working models, which have their origins in pure software development. In order to cope with such high levels of dependency and hardware shares, companies have to be willing to continuously challenge the status quo and adapt where necessary. When considering introducing an agile working model, you should ensure that not only is it compatible with your overarching product development process, but also meets the demands posed by supplier relationships, hardware development and computing power constraints. Bill Gates famously coined the phrase: "Intellectual property has the shelf life of a banana." If you want to create the future, you have to innovate as fast as your competition, at the very least. Becoming agile and adaptive can help achieve that goal, but you need to be smart about it. Agile transformations in complex environments such as the automotive industry constitute a fine line between significant performance improvements and the complete inability to act.

»Today, companies have to radically revolutionize themselves every few years just to stay relevant. That's because technology and the Internet have transformed the business landscape forever. The fast-paced digital age has accelerated the need for companies to become agile.«

Nolan Bushnell (Co-founder Atari, Inc.)

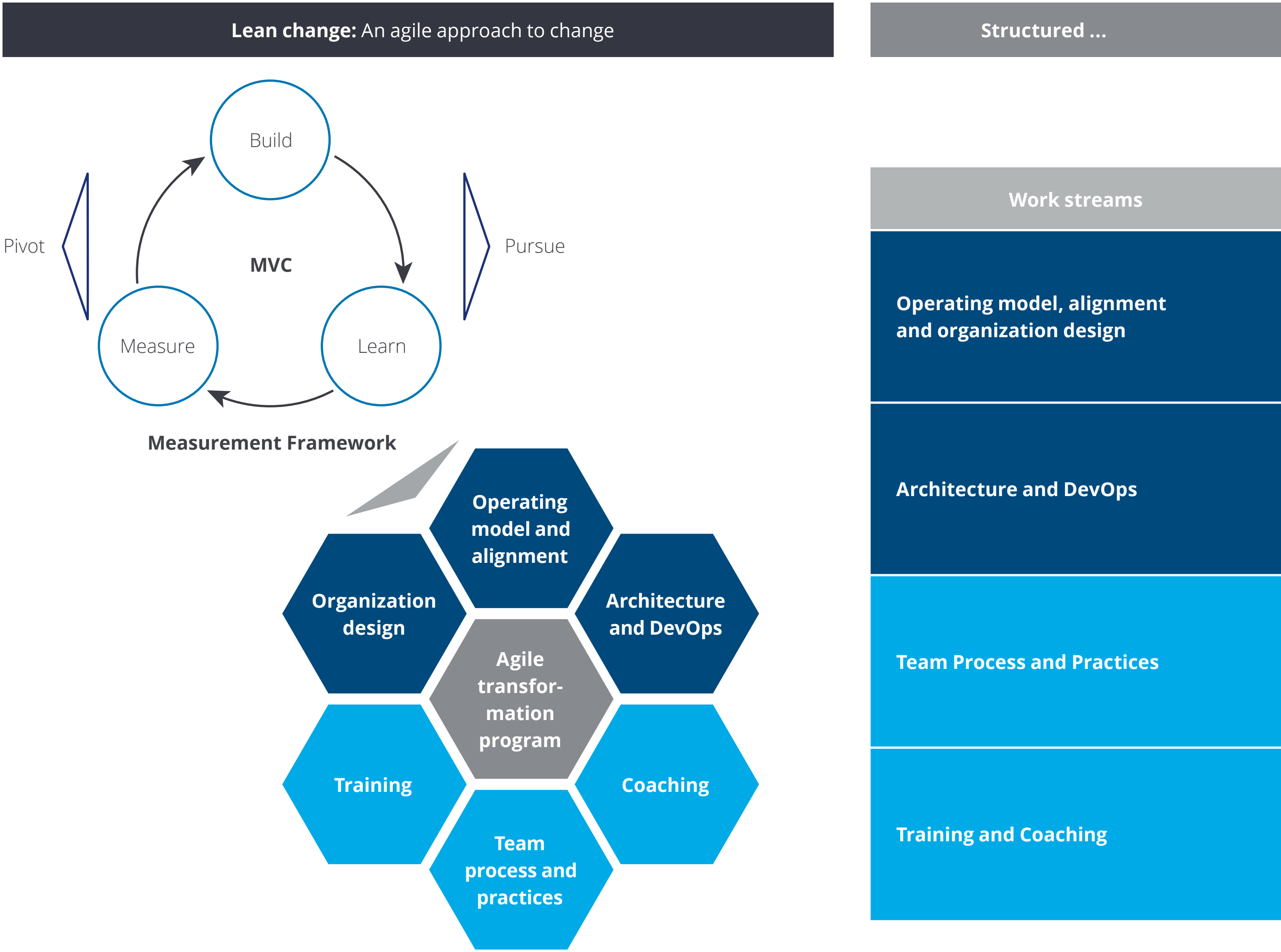
You also need to use the right scaling strategy. Autonomous driving development divisions typically employ several hundred employees for the software content alone. It is a tremendous challenge for any organization to change everything from the ground up. A real agile transformation not only changes the way developers work with one another; it fundamentally changes how the organization operates, from the organization structure, via the operating model, product architecture, verification and validation procedures, to the culture, to name but a few. For example, hierarchical barriers are broken down, technical experts become technical leaders empowered to make technical decisions without the alignment obligation with their superiors, silos are eliminated and replaced with strong cross-functional team setups - in short, interaction mechanisms, processes, structures and skill requirements change and need to be re-trained. For traditional car manufacturers, this is a particular challenge owing to long-established and perfected processes, legacy systems and complex dependencies across departments, cooperation partners and suppliers.

Our experience with hundreds of agile transformation programs across the globe has shown that large enterprises are successful when they follow a structured agile transformation playbook. Most often, a "big bang" implementation, where the entire organization is flipped at once, culminates in a "big failure", simply because the organization is not able to change everything quickly enough and therefore cannot sustain the momentum, support and positive energy required to drive the undertaking towards success. Top management as well as employees will soon lose trust in the change if it does not yield positive results. Therefore, we recommend starting with a pilot, a small agile nucleus, where a group of highly motivated people come together to function as spark for the change and drive its initiation phase. Word about the pilot's first successes will soon spread into other groups or departments, who will then be eager to "go agile". Figure 16 shows an example of a structured agile transformation roadmap, including some of the most crucial steps to consider in an agile transformation (Deloitte's structured enterprise agile transformation playbook).

»Agile is more a 'direction', than an 'end'. Transforming to Agile culture means the business knows the direction they want to go on.«

Pearl Zhu (Author of "Digital Master" book series)

Figure 16 – Deloitte's structured enterprise agile transformation playbook



Source: Deloitte 2018

... enterprise agile transformation playbook

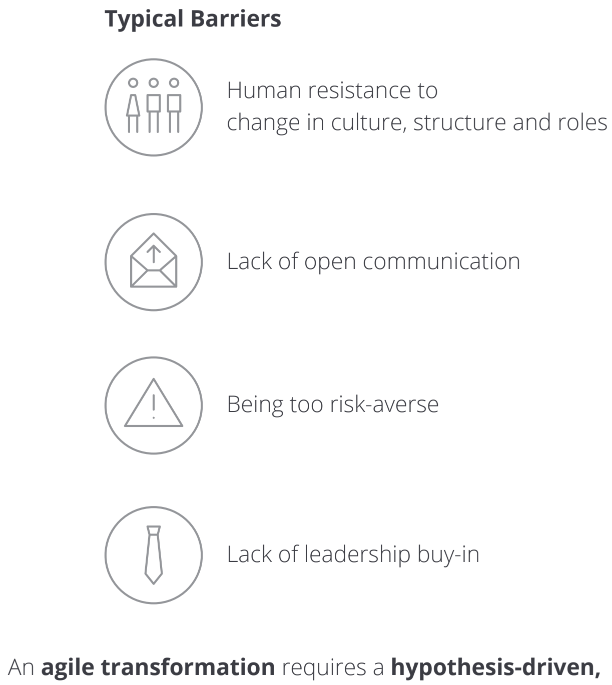
Pilot	Refine	Adopt	Scale
Establish agile vision and success criteria	Define agile change and ops team	Stand-up agile change and ops team	Establish enterprise wide agile COE[4]
Define base operating model and road map	Refine and extend	Stand-up organization and team structure	Integrate and extend across the enterprise
Assess architecture and DevOps capability	Componentization and DevOps strategy	Refactor architecture and stand-up DevOps	Mature architecture and DevOps
Define core agile SDLC[1] method for pilots	Refine SDLC method	Apply and refine agile SDLC method	
Define agile tooling stack	Setup agile tooling	Stand-up tooling enablement team	Stand-up tooling enablement team
Train pilot groups	Define training and coachinng program	Execute training Program (executive, management, PO[2], scrum master, RTE[3], team)	
Coach pilot groups		Transition portfolio, programs, and teams by waves	

[1] SDLC: System Development Life Cycle
[2] PO: Product Owner
[3] RTE: Release Train Engineer
[4] COE: Center of Excellence

Typically, you need to overcome a number of barriers during the agile transformation (see Figure 17). First, humans have the tendency to resist any kind of change in culture, structure and roles within a company. You can counteract this resistance by creating a mutual understanding of the change, adding new competences and trying it out in a pilot. Next, there is a lack of open communication. Instead of forcing a form of communication onto employees, create transparency, e.g. through sharing information, avoiding information access restrictions or working in pairs. Especially large, established corporations are often too risk-averse. In order to become agile, you need to adopt a fail fast, learn fast mentality, because "failure is success if we learn from it" - Malcolm Forbes. Another crucial aspect is the often seen lack of leadership buy-in. If there are no senior leaders backing the agile transformation, it is doomed to fail. You have to provide a solid mandate to managers and strong leadership support if you want the transformation to be sustainable.

Naturally, agile working models do not respond to the same steering mechanisms as waterfall approaches. The following paragraph discusses the differences in more detail.

Figure 17 – Barriers and solutions in the agile transformation



Source: Deloitte 2018 “Agile 101: Discover the agile ways of working”

Solutions

Create a mutual understanding of the change, add new competences and try it out in a pilot

Create transparency through sharing information and working in pairs

Fail fast, learn fast.
„Failure is success if we learn from it." – Malcolm Forbes

Provide a solid mandate to managers and strong leadership

feedback-oriented focus and implementation

3

New Steering Model

Classical KPI-driven reporting systems often follow an underlying traffic light logic. Holistic top-down defined project plans with detailed milestones and deliverables for each single work package (or even on the task level) are still considered to be the holy grail. On the other hand, a few months after implementing a steering model, the milestone-related progress tracking with classic KPIs usually indicates a (negative) deviation from the originally projected timeline and consequently leads to red traffic lights at aggregated project tracking overviews. Of course, the underlying reasons range from bad planning accuracy and over-optimistic assumptions to execution problems. The real problem here comes into play because of natural human behavior: Every single red traffic light seems to indicate a need for action. As a consequence, countermeasures are often initiated to fight red traffic lights individually without keeping an eye on the big picture, see Figure 18.

Figure 18 – From KPIs to progress Indicator

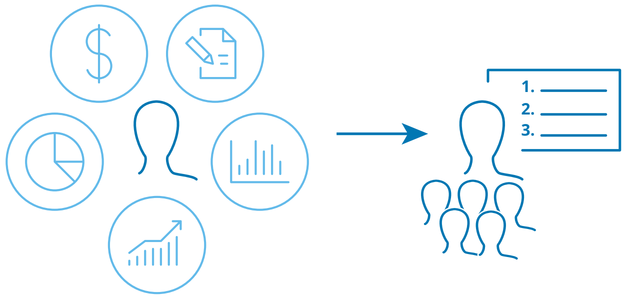
Traditional KPI-driven steering model

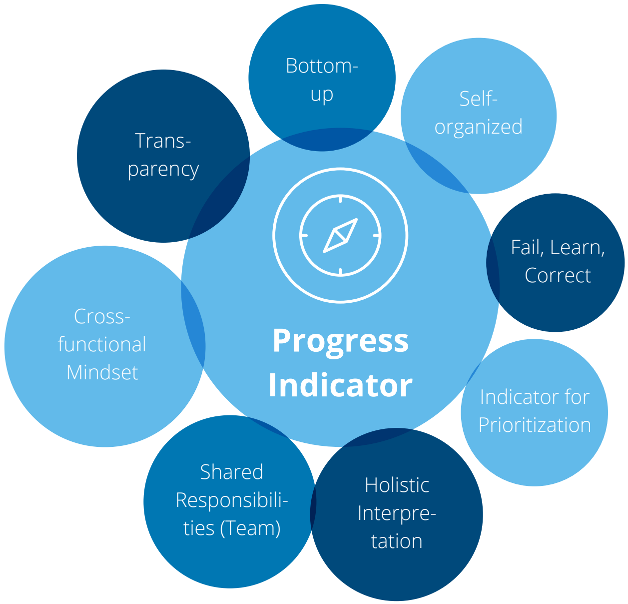
If KPI shows a red traffic light, specific counter-measure has to be defined and triggered

If KPI target value is achieved, no counter measure is needed

Steering in an agile working model

Product Owner (PO) prioritizes the product backlog based on a comprehensive picture enabled by a holistic set of progress indicators and feedbacks





Source: Deloitte 2018

Agile working environments require progress indicators more as a compass to ensure movement in the right direction rather than a numerical control on detail level. The old mantra of "the more, the merrier" in terms of numbers of KPIs does not hold true anymore - and in fact it never really did. Likewise, agile working principles should not be used as an excuse to avoid any type of top-down milestone planning. At the end of the day, project success in agile environments is similar to sailing: If you do not plan any course or direction before you set sail, you will not know where you end up. Even Silicon Valley tech players from Intel to Google use so-called OKRs (objectives and key results) which combine top-down planning (approx. 30%) with bottom-up defined OKRs (approx. 70%). It is more important to spend some time defining the right OKRs rather than having too many, and they should follow some simple rules: Define SMART goals (specific, measurable, actionable, relevant and timely). Furthermore, make sure that there is one responsible individual for each OKR or progress indicator. The tricky part is being smart in aligning the big picture milestone plan with short- and midterm agile progress indicators and deriving reasonable holistic countermeasures in case of major deviations.

»Measuring programming progress by lines of code is like measuring aircraft building progress by weight.«

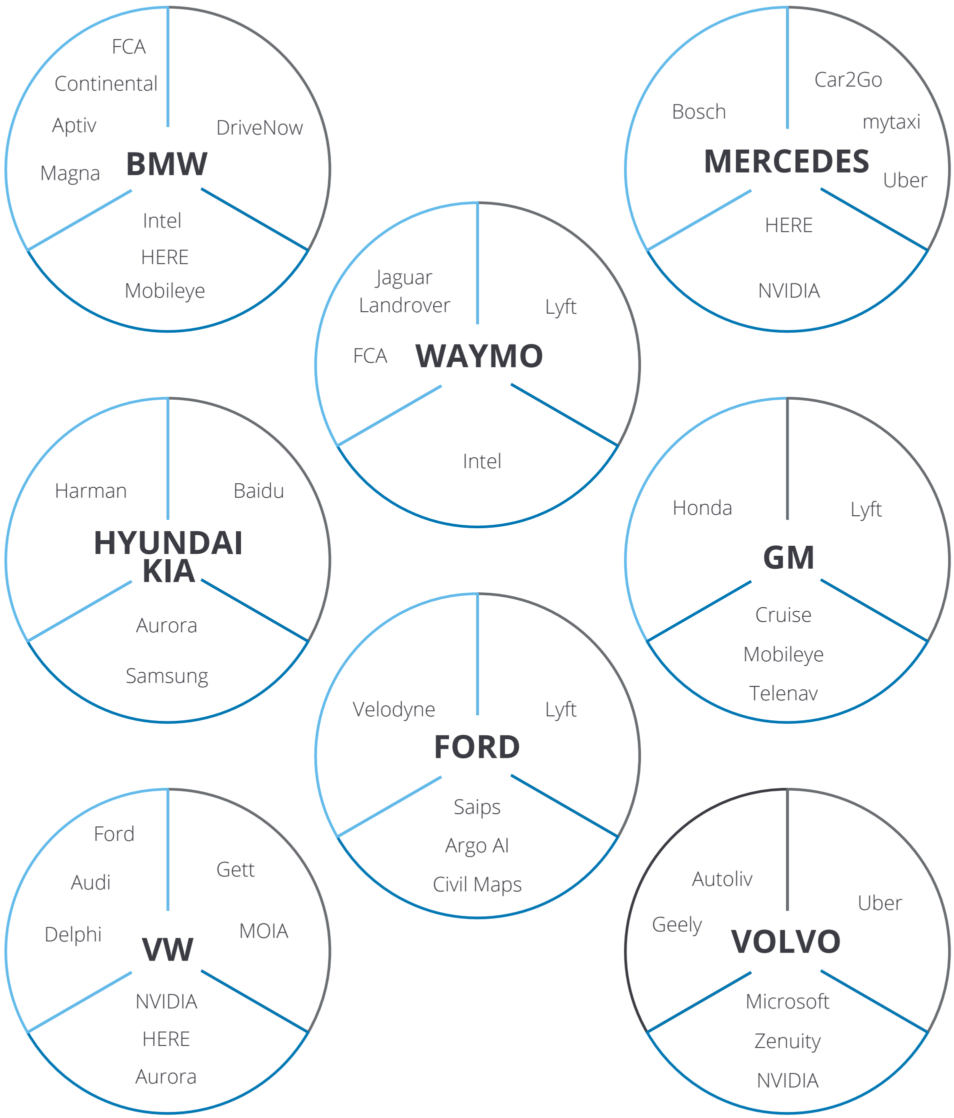
Bill Gates (Founder Microsoft)

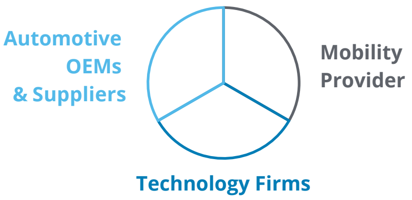
2.1.4 Mastering New Technologies

As mentioned above, autonomous driving is one of the most complex development challenges in the automotive industry. The broad range of required skills and capabilities barely exists in-house at any traditional OEM, supplier or tech player. The latter are well positioned when it comes to software development and agile working principles to achieve shorter development cycles and time to market, but often lack the experience with industrialization and scaling a real hardware business like building cars. On the other side, OEMs and traditional automotive suppliers often struggle with the transformation towards a new agile product and software development system with significantly shorter cycle times for E/E and software-related functions.

Cross-industry partnerships are an inevitable prerequisite to mitigate these complex challenges and to close own technology blind spots. All major stakeholders engaged in the development of autonomous driving solutions have established or joined specific cooperations or partnerships (Figure 19). In addition to the lack of technological or process expertise, there are several other reasons to join forces. Reduced development costs and risk sharing between partners are further important drivers for the emergence of those cooperations. Lastly, from a topline perspective, a larger addressable customer base and associated revenue potentials have to be mentioned.

Figure 19 – Cooperations and partnerships





Why Partnerships?

Gain access to necessary capabilities

Partner up with others to combine complementary capabilities in order to create a superior product or service and cover own capability blind spots and/ or resource bottlenecks

Foster sales & market penetration

Gain access to foreign markets and customers by collaborating with local partners in unexploited geographic regions and leverage regional know-how and relationships

Share risks

Share commercial (investment, deployment) and technical risks (feasibility, operability) among several partners as well as potential risks resulting from liability and warranty claims

Reduce costs

Reduce own investment costs (manpower, equipment, R&D) and create further synergies through joint activities, e.g. industrialization

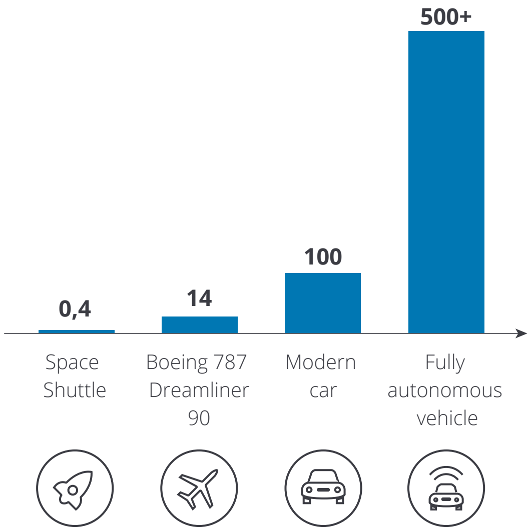
Specific collaboration setups range from classic development contracts to joint ventures and mergers and acquisitions. While European automotive OEMs tend to prefer contractual development agreements to coordinate collaboration efforts, especially US companies are more open to buying stakes in startups, like General Motors did for example with Lyft and Cruise Automation. Either way, the key success factor for all types of cooperations is to align and streamline the interests of all stakeholders towards a common goal. This sounds trivial, but has often been a major obstacle for sustainable results and success in former cooperation initiatives.

The Way Forward

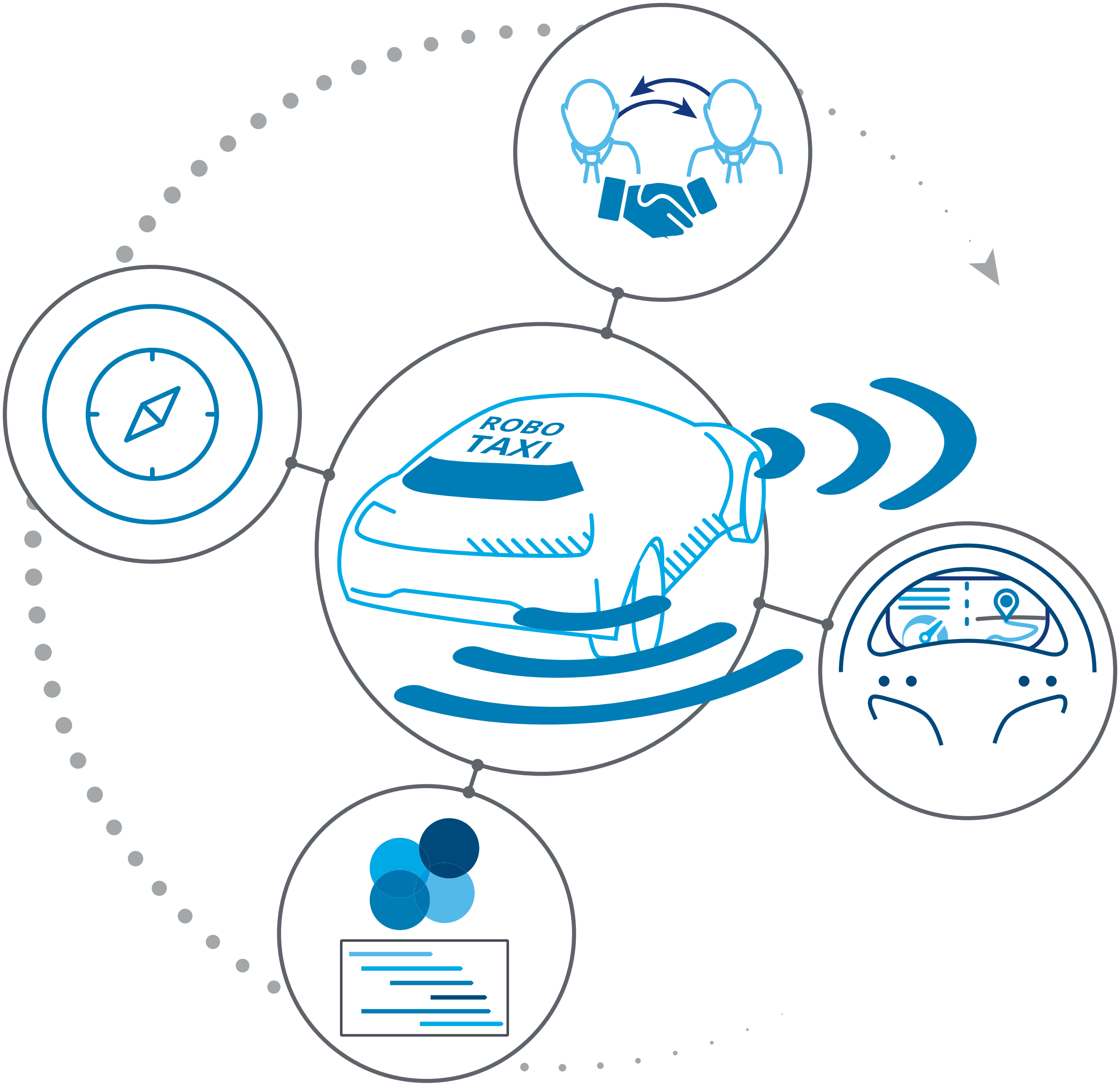
The trend towards a continued substantial increase in the importance of software development and the application of artificial intelligence and machine learning techniques in the automotive industry is irreversible, or in the words of Marc Andreessen: "Software is eating the [automotive] world".

OEMs and suppliers are already aware of the situation, but sometimes still struggle to embrace these inevitable changes. The trend from hardware to software in the automotive industry requires new thinking, starting with innovative product architectures (i.e. onboard vs. off-board service architecture) up to new target costing approaches and entire vehicle business cases. Independent from the vehicle ownership question, future revenues and especially profits will gradually shift towards the aftersales phase. Frequent remote software updates and the provision of new (software-enabled) functions over the entire vehicle lifecycle will change the existing profit generation pattern in the automotive industry. It is not clear right now who the leaders of tomorrow's mobility world will be, but if OEMs consistently work on their ability to quickly adapt to these changes and become digitally fluent, they are in a strong position to capture a significant share of the future automotive and mobility value chain.

Figure 20 – Lines of code in millions



Source: Deloitte research 2018, FEV 2018, Wired 2018, NXP 2017, MIT 2016


ROBO
TAXI

Authors

Dr. Harald Proff
Lead Partner
Operations Germany
Tel: +49 (0)151 5800 2696
hproff@deloitte.de

Thomas Pottebaum
Director Monitor Deloitte Strategy
Automotive
Tel: +49 (0)151 5800 4516
tpottebaum@deloitte.de

Philipp Wolf
Senior Consultant
Strategy & Operations
Tel: +49 (0)151 5807 0480
phwolf@deloitte.de

Deloitte.

Issue 01/2019