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Software-defined vehicles: Engineering the mobility revolution

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SDVs on the fast track

For decades, vehicles have been governed by mechanical engineering concepts and powered by combustion engines. In the 1970s, electronic control units (ECUs) were introduced to manage different vehicle functions. Today, the global automotive industry is undergoing two unprecedented transitions: software-defined vehicles (SDVs) and decarbonization. While the ecosystem of zero-emission, electrified vehicles is growing rapidly, the software transformation journey is proving to be more challenging for traditional automakers than new entrants. In fact, there is a need for traditional players to move away from a hardware-centric approach to vehicle development. Today's vehicle engineering processes are not conducive for implementing digitally native products that require scalable hardware to enable ongoing value creation across the life of the vehicle. A software-led approach could also open the door to transformational efficiencies in manufacturing, increasing quality via real-time engineering feedback, and reduced exposure to costly warranty claims. To help meet the challenge that this transformation represents, companies should scale their software-based research and development (R&D) capabilities and restructure key supplier relationships to align with a rapidly emerging, software-centric automotive ecosystem.

The penetration of SDVs is poised for exponential growth, anticipated to surge from 2.4% in 2021 to 90% or more by 2029.[1] In addition, results from Deloitte's *2023 Global Automotive Consumer Study* reveal a strong correlation between electric vehicles (EVs) and the integration of connected, digital services.[2] Across consumer demographics, there is demand for a wide array of software-enabled experiences from in-cabin personalization and connected applications, to driver assistance and infotainment features.

However, while the automotive industry has evolved based on a "zero-fault" tolerance in manufactured vehicles, software is often inherently prone to errors and bugs. As the amount of software in vehicles increases rapidly, the ability to fix software bugs online becomes a critical requirement to help achieve maximum efficiency in the vehicle development process. Vehicle repairs have also traditionally been done offline (i.e., in a workshop), but fixing a software bug in a workshop seems anachronistic compared to a world in which many performance-related corrections can be made via "always-on," global over-the-air (OTA) software updates. This shift is also reflected in the expected growth of the global automotive OTA market, expected to rise from US$3.3 billion in 2022 to nearly US$14.0 billion by the end of the decade.[3]

To remain relevant in this new software-defined paradigm, incumbent original equipment manufacturers (OEMs) should deliver a compelling experience, offering upgradable vehicles with continuous onboard and off-board feature refreshes. This means moving from a hardware-centric vehicle design process to one that is centered on software and services. One emergent example is in-vehicle subscription models, where automakers can charge up to US$900 a year for services like enhanced vehicle acceleration.[4] Expanding the mobility experience beyond the vehicle itself relies on a larger software ecosystem in which third-party services are offered via a digital marketplace.

New "software-first" market entrants are causing traditional automakers to rethink their approach to software development in a software-driven ecosystem, recognizing the limitations of relying on in-house resources. Rather than competing with these new players, many OEMs have taken the opportunity to work with Tier 2 suppliers and tech vendors to improve the agility and scalability of software development. In addition, new technologies also create new requirements, including: (1) security and data protection, and (2) safety driven by approval processes and legal frameworks that are emerging in different regions. This represents a challenge for automakers, requiring the creation of processes to integrate these "type approvals" into the existing procedures.

What is an SDV?

An SDV has a different value proposition than that of a traditional vehicle. The passenger and driving experiences are no longer determined by mechanical or electrical systems because software capabilities continually improve during the vehicle life cycle. For example,

- A software update can be added to the vehicle to improve the accuracy of detecting pedestrians or roadside obstacles;
- Personalization features can be offered to provide location-dependent services using the vehicle's coordinates in combination with the driver's preferences;
- Software-enabled features can recognize when a specific driver enters a vehicle and automatically adjust the seat, mirrors, ambient lighting, temperature, and radio to established presets; and
- Augmented-reality features could be added to display higher-resolution images during poor weather conditions.

SDVs can also be defined in operational terms where software acts as the "brain" of the vehicle by (1) enabling enhanced features, and (2) containing critical information such as design parameters, failure-mode event analyses, quality fix procedures, and manufacturing processes. The combination of these data sets enables an SDV to self-diagnose and correct discrepancies as they emerge.

While most OEMs have outlined a desire to significantly expand their use of software solutions by 2030, current economic conditions are hampering their ability to execute these plans. There is also uncertainty among OEMs about how to align with the expectations of different customer segments when introducing new business models like one-time payments or monthly subscriptions for digitally enabled in-vehicle services. The introduction of new features also is often hampered by uncoordinated portfolio decisions, cumbersome corporate investment control processes, and lengthy business case analyses that can slow the process of business model innovation.

Although hardware will remain an integral part of future vehicle development, the primary driver of differentiation will be software features and an electric and electronics (E/E) architecture that is both less complex and more powerful. The main objective of this approach is to entrench a feature-first mindset so OEMs and suppliers can drive efficient product development and operations through intentional design choices, acknowledging the need for continuous innovation. The major difference of an SDV architecture is that while hardware requires minimal maintenance, software often requires ongoing updates and fixes. So, an upgraded E/E architecture will be the foundation of an SDV that enables digital management of the design and manufacturing process, provides continuous operational control, and allows for feature enhancements and a reduced hardware component count (e.g., from 60–150 ECUs[5] in a mid-tier car to less than five high-performance domain computers in an SDV).

When software runs almost everything in the vehicle, a huge amount of data is created that needs to be managed across the ecosystem. In 2022, the amount of connected vehicle data totaled 20 exabytes, and it is estimated to reach 117 exabytes by 2027.[6] The number

of software applications driving an enhanced mobility experience is also increasing at an accelerated rate. As a result, the rapidly expanding digital ecosystem is one reason for vehicle launch delays given the complexity involved in integrating software from a variety of stakeholders, including OEMs, suppliers, and technology collaborators. How do the various stakeholders make their software modules and interfaces work together? In fact, there is a need for common functional architecture to be revamped with central controls and simplified software to enable seamless communication. Software platforms enabled by cloud, artificial intelligence (AI), and agile development methodologies will affect the overall digital experience in vehicles going forward.

Enhanced levels of digitization are prevalent not only in the vehicle but also throughout the development process. The need for rapid releases of software updates from development throughout the vehicle's lifetime necessitates a shift in hardware development. Agile product development and rapid prototyping support iterative development, but its potential is constrained by physical limitations. As such, hardware virtualization and advanced simulation capabilities are emerging as game changers for SDVs, especially for early software testing and validation.

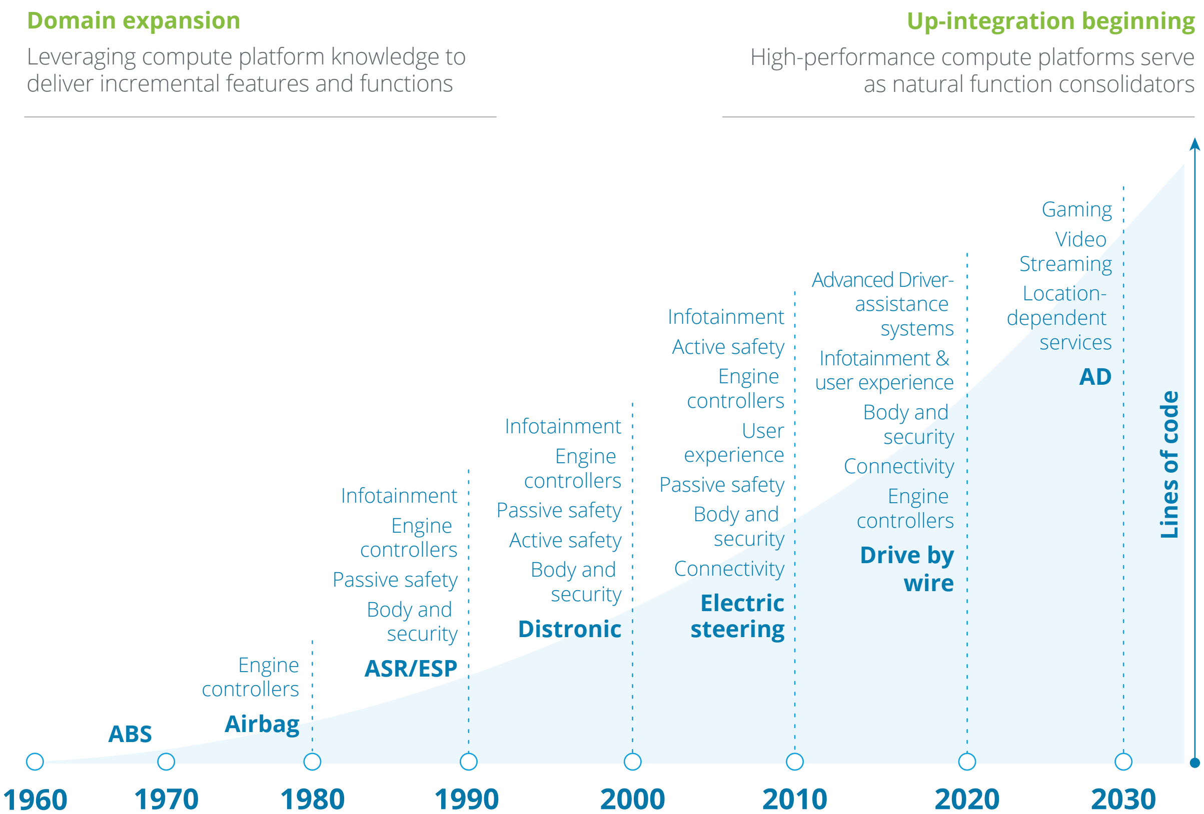
An approach to automotive software development that emphasizes testing activities as early as possible in the development cycle (i.e., "shift-left" testing) is quickly being adopted. Hardware virtualization and advanced simulation facilitate shift-left testing by enabling developers to create virtual environments that accurately mimic target hardware and vehicle configurations including their physical properties. This allows for early, cost-effective software testing in a controlled environment and fosters rapid development iterations before hardware prototypes are built. Identifying functional or integration concerns as early as possible can reduce the risk of potentially critical bugs or safety hazards in the final product and makes automotive software development safer and more economical. Eventually, fully virtualized vehicle models will likely enable complete high-fidelity testing and validation, supporting the development of safer, seamlessly integrated mobility solutions.

SDVs support a focus on customer-centricity by facilitating personalization, autonomous driving, and security to enhance the digital experience for consumers. The future in-vehicle experience relies on a myriad of evolving technologies and connectivity with numerous services. Many active safety systems such as vehicle-to-vehicle communication, driver mood sensing, object detection, and remote monitoring are rapidly evolving in cloud-enabled connected ecosystems.

SDVs can also add new value by enabling customized settings and individual customer profiles that increase user comfort and flexibility when operating shared vehicles. As a result, digital offerings and personalization opportunities may also encourage a growing demand for shared mobility. Results from Deloitte Global's *Future of Automotive Mobility to 2035* study suggest that nearly half of people aged 18–34 in the EUROPE5 region, which comprises France, Germany, Italy, Spain, and the United Kingdom, question whether they need to own a vehicle because of their experiences with shared transportation (compared to 38% in the United States).[7] As shared mobility develops in these markets, it will likely be critical for automakers to establish the right technology stack with core characteristics including agility, flexibility, and scalability. In parallel, companies need to adopt a less "Tayloristic"[8] approach to management across the organization.

To help maximize the opportunity that SDVs represent, vehicle manufacturers can establish an open software ecosystem designed to tap into third-party app developers similar to the way smartphone app stores operate. In fact, just like a smartphone that receives updates to its operating system (OS), vehicles are being transformed into "digital experience engines." Once an SDV architecture is supported by configurable sensors, touch-sensitive displays, high-performance computing power, and adequate memory, new features including autonomous driving, enhanced security, gaming, and new content services with personalized apps can be delivered via OTA updates at any point during the vehicle's life cycle. SDVs can also encourage the development of creative features that may require more certification processes to ensure compliance with applicable laws and regulations.

Figure 1. Increasing software share in automotive components



Source: Deloitte Global analysis.

A glance in the rearview mirror

Software is by no means a new phenomenon in the automotive industry. In fact, software has been an integral part of automotive innovation since the early 1970s. Its first applications were focused on safety features like anti-lock braking systems (ABS) and airbags, later followed by cruise control and active safety systems. In parallel, software also enabled performance improvements with automated engine controllers. As new software-controlled features were added, the need for cybersecurity systems came into focus. Over time, frameworks, standards, and regulations have been introduced to help ensure the safe deployment of automotive software applications (figure 1). However, there is a fundamental difference between vehicle **features** that were *enabled by* software and *vehicles* that are *defined by* software. In the past, features were managed by control units with embedded software dedicated to a single purpose. In most cases, the software was designed to never be touched again throughout the vehicle's life.

Today, software is typically no longer synonymous with embedded system software in ECUs. Software has become the centerpiece (i.e., the brain) of the vehicle and an engine for growth and innovation. Software and cloud-enabled connectivity provides the foundation for a thriving mobility ecosystem that connects customers with OEMs and third-party contributors. It mimics the same pattern we have observed in modern cloud-based smart-device development and is further fueled by AI advancements, affecting each aspect of the new automotive value chain.

Transformation hurdles

Software and digital innovation often lie at the heart of the emerging profit pools that may define the next era of global automotive mobility. To help stay competitive, automakers may need to progress on multiple fronts simultaneously. For incumbent players, adapting to new technology may be a relatively minor hurdle. The larger challenge will likely be breaking away from "Tayloristic" organizational structures to enable more flexibility and innovation.

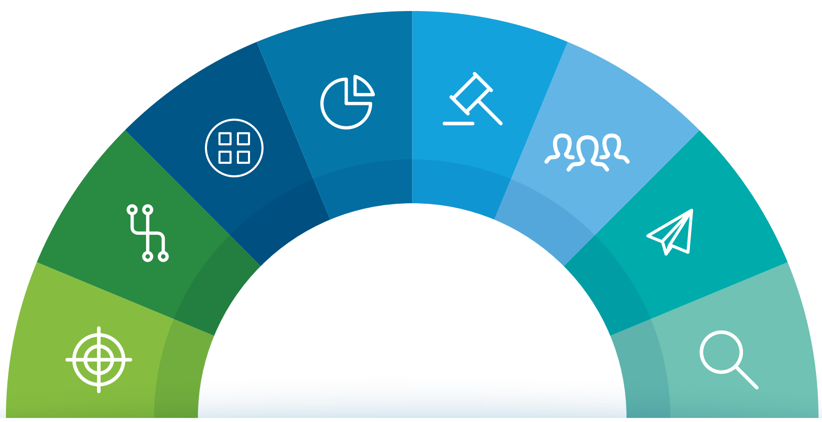
Agility and flexibility are fast becoming the guiding principles in product development for OEMs and suppliers. Brand value and reputation are being heavily influenced by the efficacy of software solutions, in terms of their performance, and compliance with safety standards. The ability to deliver robust, reliable software has almost become synonymous with brand reputation.

"Every automotive player is adapting to a new software frontier. However, incumbents have to move away from rigid, "Tayloristic" organizational structures to unlock the full potential of creativity, empowerment, and responsiveness in the software development process."

–Elmar Pritsch
Partner, Deloitte Consulting GmbH

DevOps[9] is also transforming the approach automakers are taking toward vehicle life cycle management. For example, vehicle recalls can be a costly burden for OEMs, sometimes resulting in fines exceeding US$300 million for failure to comply with update and notification requirements.[10] Additionally, software-related recalls affected nearly 10 million vehicles in 2022 versus approximately 600,000 vehicles in 2012.[11] Despite this challenge, the application of proper risk management frameworks can allow automotive companies to fully embrace the opportunities that SDVs represent. However, automakers will likely have to dramatically change their approach to software architecture in order to overcome a range of emerging challenges (figure 2).

Figure 2. SDV transformation hurdles



Distributed software architecture
The current architecture (e.g., onboard software development) **is not ready for the transition to off-board software** development with the increased current complexity: Only by transforming the focus and partnerships in this area will the shift to SDV succeed.

Decentral accountabilities
To successfully transform, it is necessary to have a dedicated team and executive to oversee the transformation and to drive progress **along all value chain segments**.

Traditional business focus
New business models are required in order to maintain competitiveness. Dedicated adapted hardware, sufficient usage of driver data, and adaptable software to the buyers' needs harbor a lot of potential with the **right partners and drafting of new business models**.

Ramp-up investments required
Smart **investments to transition** engineering processes as well as software-related functions (e.g., AI or OTA) cause ramp-up challenges.

Unaligned regulatory support
Markets in the EU, US, and China offer **different conditions regarding over-the-air updates, cybersecurity and autonomous driving**. Understanding the impacts of the new homologation processes is hard.

Geographical customer preferences
Consumers willingness to absorb the costs of new off-board updates and to get familiar with the new rising technologies varies regionally and could limit automotive players' motivation to shift their product portfolio. Additionally concerns around the cybersecurity can arise and stop the transformation.

Dynamic partnership landscape
Partnerships are required to share efforts and scale fast, but the landscape of software companies targeting the automotive sector is highly dynamic making selection of the right partners difficult and therefore the **definition of new standards with community partners still challenging.**

Uncertain paths for scaling
Companies **struggle to understand drivers** and have **limited visibility in tracking the progress**. Nevertheless speed is essential when setting the course for software-defined vehicles.

Source: Deloitte Global analysis.

Distributed software architecture
Manufacturers should focus on developing a common, streamlined software architecture characterized by efficient coding techniques. Without this approach, there is a risk that companies could be exposed to an overload of requirements, resulting in potential contradictions created by different models and brands. Software architectures should be designed with an eye to minimize complexity, enabling shorter iteration cycles with higher productivity. Without a common platform, OEMs may not be able to meet operational requirements or maintain a clear picture of the overall system. OEMs also often fail to establish a sufficient, future-oriented resource structure focused solely on the next generation of software architecture, making it important to keep software design teams unencumbered by day-to-day operational matters.

Ultimately, it may be challenging to scale the next-generation SDV architecture while serving legacy platforms. A successful strategy could involve outsourcing legacy software architectures prior to winding them down, leaving internal developers to focus on a simple, common architecture that will drive the development of new features in the shortest possible time.

Decentralized accountabilities
Traditionally, car manufacturers outsource large portions of a vehicle's development process to various suppliers. The introduction of new technologies and inherent complexity of an SDV may mean that this disconnected approach is no longer possible as companies rarely possess the skill set and capabilities to develop solutions without external contributors. High-tech companies are often well positioned to achieve a shorter time-to-market leveraging an agile approach, while OEMs and more traditional suppliers are often more specialized in manufacturing at scale. Moving to SDVs requires an approach to development that spans the vehicle's life cycle. As such, the pursuit of strong relationships and organizational structures that support decentralized accountabilities is often crucial for success. In short, OEMs should evolve from a top-down, "supplier steering view" to more of a "collaboration on par" perspective.

Traditional business focus
Despite having a reputation for progress and innovation, the automotive sector has maintained traditional business models for many decades. The trajectory of R&D has been largely dependent on hardware, and many players have resisted attempts to disrupt the formulas that led to their successes. However, as with smartphones, consumer products and services are becoming increasingly customized. The convenience offered by OTA updates, customer-specific infotainment systems, and autonomous driving (AD) features are becoming too valuable for automakers to ignore, often forcing them to embrace change.

Automotive manufacturers should build a software business within hardware-centric organizations, while reconciling infrastructure, processes, and culture. Traditional players may also have to overcome skill gaps and a lack of advanced software engineering. As a result, auto companies are starting to compete with high-tech players for top software and AI resources, requiring them to develop entirely new talent acquisition and retention techniques.[12] In effect, organizations should embrace a holistic talent management transformation mindset that ensures new employees are provided with the right tools and environment in which to thrive. This may require companies to reassess many long-standing norms, including their organizational hierarchies, compensation models, and incentive programs.

The SDV business case requires smart investments
Competition among automotive manufacturers for the development and deployment of SDV technology is intense. At the same time, companies should find a way to maintain profitability while managing organizational and product transformation. Today's complex architectures, traditional development processes, and small-scale structures consume large amounts of development effort and are highly inefficient. As a result, the SDV business case requires company-wide consideration to allow for smart investments to successfully manage the complex landscape of SDV transformation. For example, it can cost up to US$2.7 billion[13] per year to build up an in-house software unit.[14] Indeed, the level of investment can rise even further, as additional acquisition costs are not uncommon.[15] Ambitions for AD without real

business cases are generating further costs (i.e., it can cost approximately US$2 billion per year for a unit or subsidiary dedicated to AD).[16]

It is also important to consider ramp-up investments in the fields of R&D and data acquisition and management, alongside the costs associated with regulatory compliance, organizational structure, resources, and manufacturing infrastructure development. In short, companies should find creative ways to finance these costs, preferably by surfacing efficiencies that may be buried in traditional, hardware-driven R&D architecture and methodologies. Companies can also focus on software development productivity gains that come with an SDV architecture, employing web-based development tools with higher reusability, shorter iteration cycles, and open-source libraries. Another way to finance these costs is through subsidies, governmental agencies, venture capital, and other channels. They also need to decide what strategic investments should be developed in-house and what activities should be outsourced.

Unaligned regulatory support

Although some OEMs are hesitating to accept the reality that frequent updates and security patches to fix software bugs are necessary, it is fast becoming the norm for SDVs.[17] One of the main reasons for their hesitation stems from the fact that new, and still widely unknown, approvals must be implemented across the development process. New regulations for SDVs are complex and rapidly evolving, with different rules emerging in each region around the world. This can create uncertainty for automotive manufacturers that must comply with multiple sets of regulations while still developing competitive SDV solutions.

Many manufacturers are still afraid to do OTA updates on vehicle safety features given the complexity of adhering to new standards. For this reason, different certificates for the vehicle life cycle may need to be introduced so manufacturers can make necessary updates seamlessly. A new homologation process requires different regulatory frameworks, which are currently being established. The challenge for OEMs may be to adopt future-proof processes for type approval in the production development process.

Limited customer buy-in

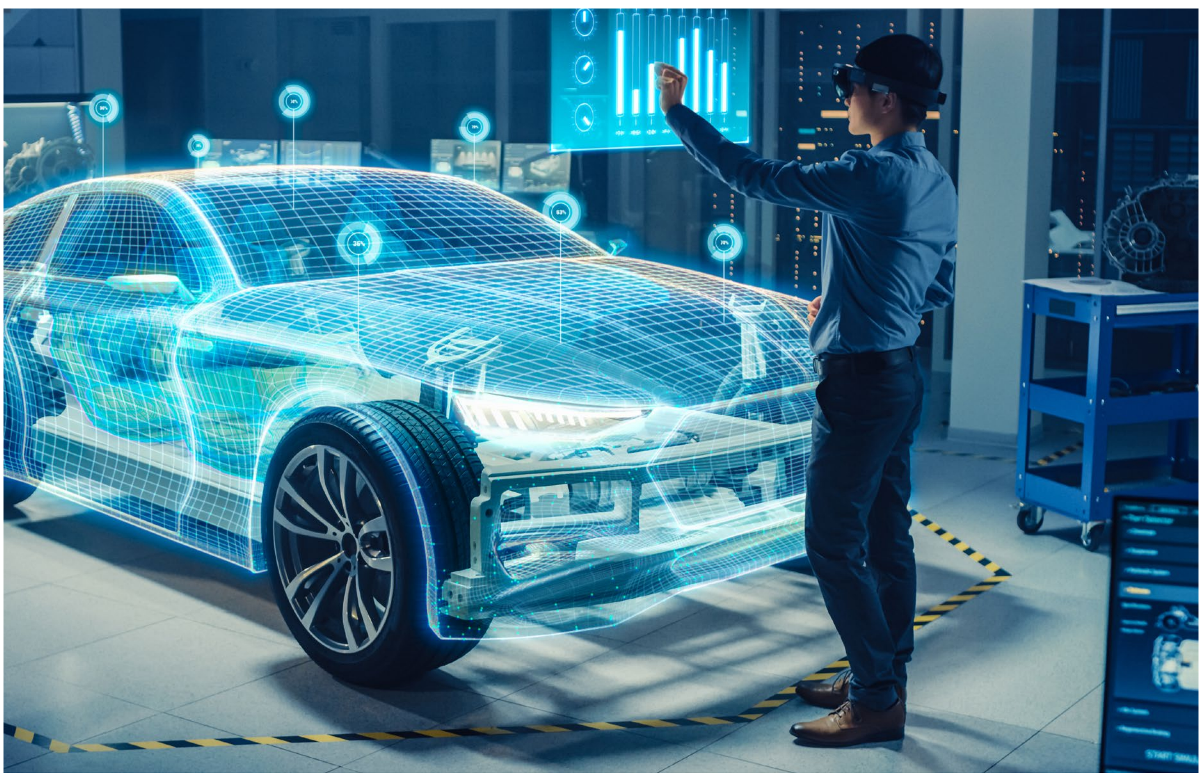
Consumer concerns regarding new technologies can slow the pace of development for automakers. Safety concerns fueled by negative media headlines can have a considerable influence on customers. Strategies should be developed to work in a customer-centric manner, establishing measures that can have a considerable influence on consumer behavior. An example of this phenomenon can be found with EVs. Deloitte's *2023 Global Automotive Consumer Study* found that a shift in consumer preferences toward EVs is taking place at different speeds around the world. In most markets, consumers would prefer a hybrid engine in their next vehicle. However, consumers in China would prefer a full battery electric vehicle.[18] It is important to identify the concerns that lead to customer reservations (e.g., range anxiety) and develop effective strategies to address them. In this case, a solution could include the development of stakeholder relationships designed to raise the investment necessary to build an EV charging network that facilitates broad consumer access. At the same time, measures can also be taken to protect the privacy of consumers in a way that allows technological transformation to flourish.

Dynamic relationship landscape

OEMs need to navigate a complex and rapidly changing landscape to remain competitive as tech startups continue to target the automotive industry. Indecision can result in missed opportunities or lost market share. One of the main challenges is deciding which SDV technology platforms to invest in. There are many different approaches to developing SDV technology, and organizations must decide which technologies to pursue and which business cases offer the greatest upside potential. Another big hurdle that needs to be overcome is the overreliance on the supply network. Long contractual commitment prohibits transparency and control of the software stack and can lead to "black box" development. This results in complex supplier orchestration, contract management with long lead times, and the inability to change code in-house.

Uncertain paths of scaling

Scaling SDVs is only possible if manufacturers are open to the broader software ecosystem. Trying to maintain complete value chain control may severely limit the possibilities for any software-defined platform. In fact, it is crucial to embrace the broader software ecosystem to achieve scale and avoid being limited to a smaller market share and/or developer pool. Overall, there are two different approaches to achieve scale in software development. The first approach involves having full control over the value chain, which is cost intensive. The second approach involves connecting with community stakeholders to establish standards that promote integration, opening the door to scaling opportunities. By investing in R&D, collaborating with other industry stakeholders, establishing a clear transformation plan, evaluating the different business models with an appropriate framework, and closely monitoring the evolving regulatory landscape, OEMs can overcome this challenge and position themselves for greater growth.



Wayfinding in the SDV solution space

SDV transformation efforts can be classified into six broad categories (figure 3).

Figure 3. Deloitte's perspective on SDVs: Solution space

Autonomous driving

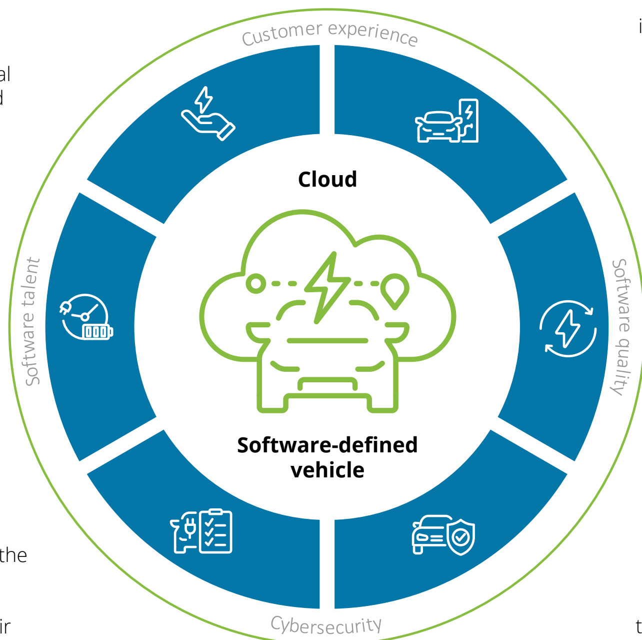
ADAS, as the most demanding application, will increase vehicle and road safety, supporting the path to autonomous driving based on deep business, regulatory, and technology expertise. Alliances are beneficial to share development costs and gain speed.

Power train and vehicle motion

ADAS as the most demanding application will increase vehicle and road safety supporting the path to autonomous driving based on deep business, regulatory and technology expertise. Alliances are beneficial to share development costs and gain speed.

User-centric experience

As control is shifting away from the manufacturer, giving the consumer a greater say in what, when, and how they receive their services, infotainment and interior solutions become the key points of contact with services ranging from location-based to remote feature unlock and upgrade requiring frequent software updates over the air.



Architecture core blueprint

Facing increased complexity, well-designed concepts of the new SDV architecture at the logical and physical level and implementing their elements and interfaces are key to successful scaling operations.

Software-based R&D and operations

Designing and developing cars has long passed the hardware era. New structures, powerful software platforms, more efficient methodology, continuous operating models, and governance of R&D are required to keep pace with the shortened time-to-market.

Data-driven and connected services

Automotive players increasingly value sources of data direct from the consumers as a way of gaining competitive advantage. The shift to data-driven business models enables the monetization of data in the future mobility ecosystem around the connected vehicle as the central hardware pillar.

ADAS: advanced driver-assistance systems

Source: Deloitte Global analysis.

Systems architecture core blueprint

The new software-defined era could significantly increase the value of the vehicle, but there is also a risk that it could come at the cost of increased complexity. Therefore, a well-designed concept involving the implementation of a new physical and logical architecture is key to successfully scaling operations. It can be critical to ensure software compatibility across development departments and subsequent architecture generations. It may also be necessary to pick the right ecosystem stakeholders to lay the foundation for a profitable path going forward.

In the world of smartphones, app stores invite third parties, including startups, to develop content to maximize the number of creative solutions available to consumers through their devices. As such, consumers decide what apps are successful, which is a largely new paradigm for automotive OEMs that are used to having their engineering departments decide what is best for the customer. Strong alliances are often needed to provide a diverse platform to generate a broad user base. The power of cloud-based development tools cannot be ignored nor should open-source communities be rejected. Open-source techniques should also be considered for internal development teams.

However, companies can still stand out from the competition and offer added value despite an open-source approach. For example, the SDV OS plays a crucial role in data management and security. OEMs that have control over the OS can protect vehicle-generated data, ensuring its security and alignment with data privacy policies. This control over data ownership and security is particularly important as data becomes an increasingly valuable asset in the automotive industry. On the other hand, developing an independent OS requires significant investment, knowledge, and ongoing maintenance. OEMs must carefully consider factors such as cost, time-to-market, strategic relationships, and the trade-off between customization and leveraging an existing OS platform, which is becoming commonplace for many players. OEMs can also differentiate the customer experience with a purchased OS. They can achieve this by implementing a customization layer, integrating their own services, and prioritizing differentiated hardware and design, while delivering exceptional customer support.

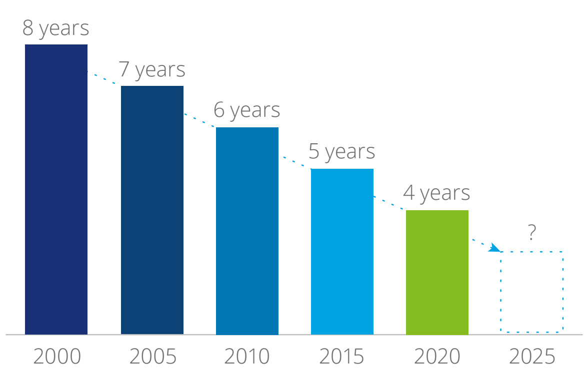
Software-based R&D and operations

Today, the vast majority of vehicles are not capable of delivering updates outside the infotainment and telematics systems. While most players are adept at developing static, onboard vehicle software, OEMs need to rethink their approach to off-board software development. They also need a modern approach to both onboard and off-board development streams, moving away from old siloed practices, in favor of strong alliances in a new regulatory landscape.

Designing and developing cars is no longer simply a hardware issue. The chip shortage exposed the enormous difficulty involved in managing the increasing complexity of software. It also highlights the importance of introducing hardware flexibility to mitigate risk. In addition, product cycle times have been cut in half since the year 2000, forcing companies to adapt their approach to R&D and operations.[19] New structures, powerful software platforms, and more efficient methodologies are quickly becoming necessities.

In fact, change is inevitable on both an organizational and work structure level. Classic waterfall structures are being enhanced or fully replaced with agile approaches over the whole product life cycle. Short development cycles, flat hierarchies, and rapid adaptation are typically needed to break the traditional, hierarchical, command-and-control management style.

Figure 4. Average automotive product development cycle time (2000–2020)



Source: Dr. Harald Proff, Thomas Pottebaum, and Philipp Wolf, *Autonomous driving: Hype or reality? Moonshot project with quantum leap from hardware to software & AI focus*, Deloitte, 2019.

Data-driven and connected services

Upgrading your car in a workshop may soon be a relic of the past. Items such as vehicle performance corrections, the addition of driver assistance systems, security feature updates, and the introduction of personalized apps will be released and updated via over-the-air updates.

The shift to data-driven business models also enables the monetization of data from connected vehicles. Further, collecting and managing data to advance machine learning models for state-of-the-art advanced driver-assistance systems (ADAS) and AV features is growing exponentially. Doing so in a cost-effective and timely manner can provide game-changing competitive advantages in the rapidly evolving mobility landscape.

User-centric experience

As the automotive industry shifts toward giving consumers more control over their mobility experience, infotainment and interior solutions have become the main point of contact for a range of services. These include location-based features and remote unlocking/upgrading of features that require frequent OTA software updates. Digital cockpits and larger, heads-up displays have already changed the look and feel of the vehicle's interior design, and gaming engines—along with streaming entertainment media—will likely intensify this trend.

With the help of connected technologies, valuable product-usage data can be captured and leveraged to develop closer customer relationships and higher brand loyalty. Increasingly tech-savvy consumers are also becoming more sensitive to privacy and security risks surrounding the collection of customer data. Several solutions can be implemented to address this challenge. Data processing can be aligned between the cloud and the vehicle with the help of computing platforms. AI can also be used as a key enabler for enhanced user services, providing personalized recommendations and multimodal solutions such as functions on demand, AI-driven ADAS, infotainment systems, and OTA updates to improve the user experience.

By implementing new AI-driven and connected solutions, several value-added outcomes can be realized. Strong alliances can provide diverse platforms and generate a broad user base, enabling scale. Opening the ecosystem to third parties and leveraging cloud solutions will also provide further benefits. Moving the majority of automotive product development activities to the cloud will likely help accelerate the introduction of intelligent vehicle solutions. An effective cloud strategy for vehicle software should incorporate a multi-cloud and multi-system-on-chip approach. This strategy stems from the idea that developers focused on crafting a superior driving experience should not be concerned with the underlying hardware.

While this principle may not always hold, particularly for safety-related features, centralizing test-and-build systems have been recognized as an efficient way to enhance developer productivity and feature development speed. For example, setting up a desktop with the necessary local tools, including compilers for target processors and microcontrollers, and real-time operating systems can take weeks.

Moreover, a multi-cloud strategy represents a risk-reduced way for OEMs to explore different provider capabilities and scaling scenarios for future vehicle environments. For example, requesting additional in-vehicle computational resources without understanding their potential impact can affect the size and reliability of regular software updates. Cloud-based simulations enable quality teams to test on vehicle models, reducing the likelihood of error states. In addition, scaling in the cloud is typically a smooth process, allowing OEMs to understand the effects of OTA retries and rollbacks. However, implementing an auto cloud strategy must account for a required shift among developers that may not yet be comfortable with coding in a virtual model.

Powertrain and vehicle motion

When it comes to powertrains, OEMs must develop effective strategies covering a variety of key technologies. These range from electric drivetrains with new cloud-based communication and AI-based battery health prediction models, to the underlying energy and charging infrastructure network. The latter is crucial to synchronize the life expectancy of a vehicle with the life span of EV batteries. While the average life span of a vehicle is on the rise and currently exceeds 12 years,[20] current EV batteries have an estimated life span of 10 years for a mobility application.[21] Due to strong reactivity between the electrolyte and electrode, capacity loss in batteries is inevitable. To help counteract this eventuality, predictive battery health recommendations can help extend the life of EV batteries.

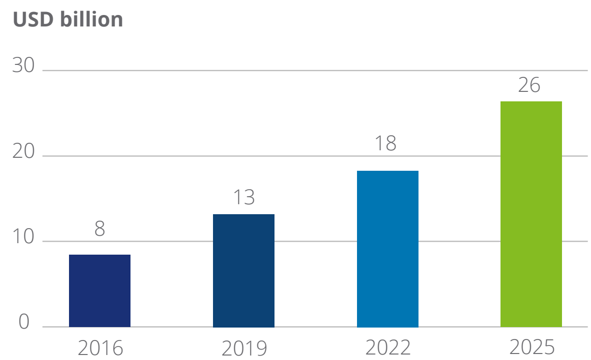
Autonomous driving

ADAS continues to have a dramatic impact on increasing vehicle and road safety. They also put the industry on a path to full AD with the penetration of these systems expected to grow significantly by 2025.

However, there is a quantum leap between traditional, rule-based coding and ADAS based on AI. Traditional ADAS allows for rule-based coding ranging from a human driver monitoring the driving environment (Level 0 automation) to the vehicle overseeing lateral and longitudinal control in many situations with minimized risk for accidents (Level 4). Apart from confined corridors such as highways, which traditional ADAS can manage, traffic environments can be extremely complex and dynamic. Traditional ADAS are already reaching their limit in urban environments, and it is virtually impossible to program these systems for every potential use case. Self-learning systems (Levels 4 and 5) are critical to interpret different complex scenarios and mimic human decision-making processes.[22]

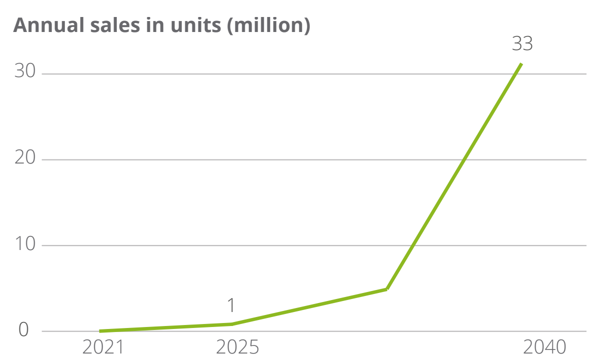
At this point, AI is a key enabling technology, but it can require large data sets (e.g., raw sensor data), proper training, testing, paths to move massive quantities of data, and deep learning algorithms. Companies may have to use data centers or cloud solutions and adapt to a new regulatory landscape. However, fully automated passenger cars are expected to start hitting the road en masse after 2030. To profit from this growth opportunity, stakeholders can seek out AI alliances to share development costs and gain speed to market.

Figure 5. Global ADAS revenue in USD (2016–2025)



Source: Proff et al., *Autonomous driving: Hype or reality? Moonshot project with quantum leap from hardware to software & AI focus.*

Figure 6. Autonomous vehicle sales in millions of units



Source: *Autonomous driving: Hype or reality? Moonshot project with quantum leap from hardware to software & AI focus.*

The value of alliances and ecosystems

As the SDV market is rapidly evolving and growing, it may require extensive collaboration among various stakeholders to drive innovation and create value. Alliances and ecosystems are critical to enable different market players to pool resources, share expertise, and deliver value to their customers. Through alliances, ecosystems can gain access to a wide range of resources, which is necessary to deliver truly differentiated customer services and solutions.

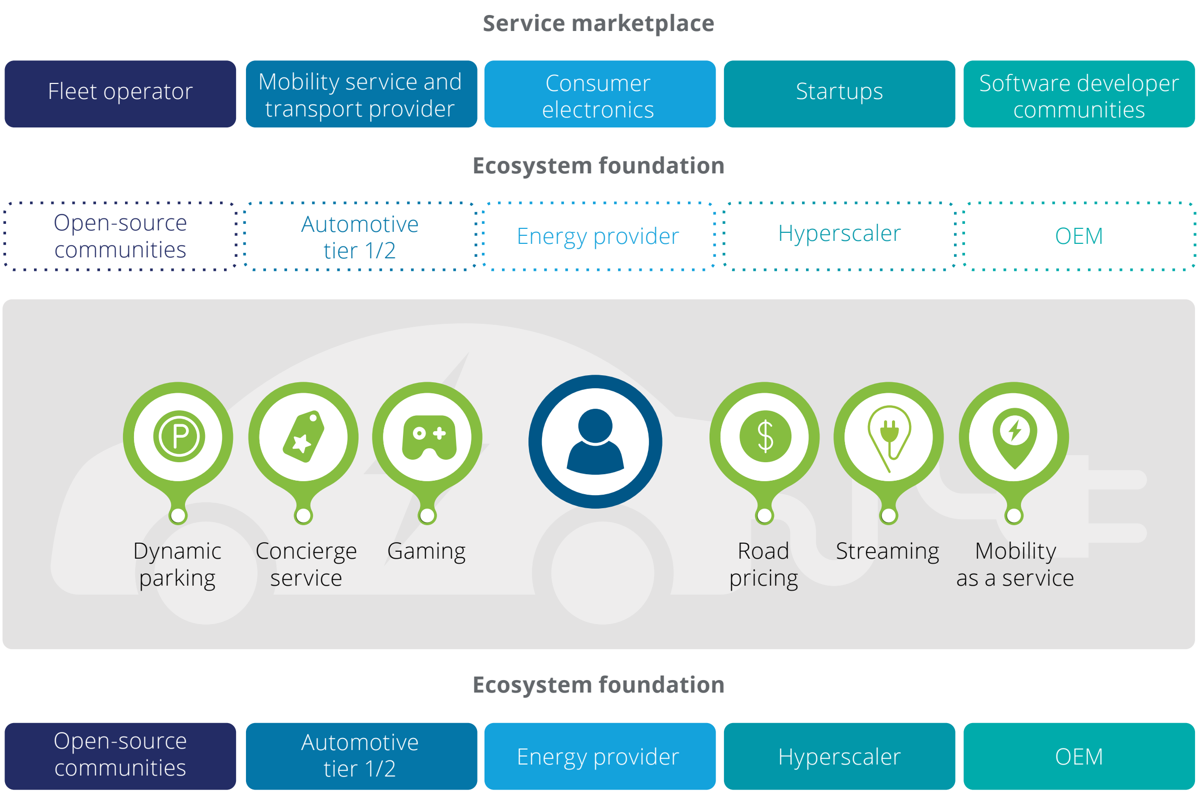
The Deloitte Global Automotive Mobility Market Simulation tool forecasts a compound annual growth rate of 5% in the automotive mobility market between 2022 and 2035 (in the EUROPE5 countries as well as the United States).[23] Due to the potential benefits of new SDV technologies, automakers can also expect to raise sticker prices by approximately US$3,000 per vehicle. Overall, global automotive industry profit is projected to increase from US$315 billion in 2020 to US$405 billion by 2030.[24]

Automaker profit-and-loss statements are currently driven by physical vehicle platforms and programs. Automotive CEOs may be hesitant to adopt a software-as-a-platform approach given the current lack of SDV-driven business cases. However, there are several ways to capture the enormous potential of the growing SDV market:

- Various entertainment and service options can be offered and personalized with SDVs. This can include relationships with content providers, e-commerce platforms, health monitoring, and service providers to offer streaming media, mobile shopping, and concierge services.
- Monetization of data such as vehicle performance, user preferences, and traffic patterns that can be collected and anonymized. This data can be made available to a variety of downstream third parties, including urban planners, insurance providers, advertisers, or logistic providers, who can then leverage the data to develop insights for decision-making and targeted marketing. For example, the allocation and utilization of SDV fleets can be optimized with better resource allocation. This could involve route planning, demand prediction, and resource management algorithms to help maximize operational efficiency and reduce costs for fleet owners.
- Through collaboration with cities and municipalities SDVs can be integrated with smart infrastructure systems. This could involve implementing vehicle-to-infrastructure communication technology, enabling SDVs to interact with traffic signals, parking systems, and road infrastructure for improved traffic flow and efficiency. Infrastructure could also be developed by city planners based on the data generated from SDVs. For example, as cars become more automated, driverless transportation is coming into focus. Robo-taxis or buses can have a significant impact on the transportation of the future. With the increasing level of car sharing, these possibilities are also gaining significance and represent a potentially lucrative business model.
- In the area of safety, automatic emergency calls can be sent in case of accidents or breakdowns. Collected data can also help to prevent breakdowns, using predictive maintenance algorithms to prompt adjustments before a failure occurs.

With the development of new software and growing connectivity, OTA updates, and mining of personal data, the question of privacy and cybersecurity is also quickly coming into focus. Regulatory policies addressing these concerns will have to be developed and introduced into the vehicle product life cycle. Automakers can help to establish these policy frameworks by collaborating with a variety of industry stakeholders and regulators.

Figure 7. SDV ecosystem



Source: Deloitte Global analysis.

Pushing forward with SDVs

Traditional suppliers have often played a pivotal role in the automotive industry by enabling the development of innovative products such as ADAS and flexible production processes. These advancements enable the production of multiple vehicle models on the same line as well as the establishment of efficient just-in-time supply chains with minimal inventory. However, the automotive landscape has undergone significant transformation, brought on by the emergence of new technologies. This has introduced new challenges and opportunities for both OEMs and suppliers. In this new context, tech companies have emerged as increasingly significant players in the industry.

Over recent years, many businesses have made substantial investments in automotive technology. This investment heavily relies on the expertise brought by new market entrants, particularly in areas such as software development, AI, and connectivity. This marks a significant shift in the industry, blending traditional automotive knowledge with leading-edge technological capabilities to shape the future of automotive production and design. According to recent study results, 75% of automotive CIOs indicated their largest technology investments were around cyber/information security. Cloud platforms, business intelligence, enterprise resource planning, and application modernization also played leading roles in technology investments,[25] which are prerequisites for developing ADAS and connected car services.

The relationships between OEMs, traditional suppliers, and tech companies can offer significant benefits. By working together, these companies can leverage their respective strengths and resources to develop and deploy new technologies more quickly and efficiently. By working with tech companies, OEMs and traditional suppliers can develop new business models and services that capitalize on these opportunities.

However, there are also challenges associated with these relationships, including conflicts over intellectual property, source code transparency, and data ownership. Tech companies may want to retain control over the software and data they develop, while OEMs and traditional suppliers may want to integrate these technologies into their vehicles and control the generated data. Another challenge is the potential for cultural differences between players. Tech companies may have a more agile and entrepreneurial culture, while OEMs and traditional suppliers may have more risk-averse cultures. Bridging these differences can be a significant challenge, but it is essential for the success of these relationships.

Figure 8. Guiding questions for SDV transformation

Software-defined vehicle players

OEM	Supplier	Tech player
What will the SDV architecture look like?	How does this impact my organizational setup & governance?	How can I increase (train & grow) developer base for my platform?
How can I increase my SDV fleet?	Which impact has the defined OEM architecture on my product portfolio?	How to build up automotive industry know-how?
How can I control my globally dispersed vehicle fleet in the field 24/7?	How does the collaboration with the OEM change with SDV?	How do we generate traffic on our platform?
How do use cases for commercial and passenger cars differentiate?	Which is the most promising future proof position for suppliers in the SDV value chain?	How do we increase usage?
What is my key differentiator in positioning in the SDV market?	Which are my profit pools within SDV? Do I need to rearrange my product portfolio?	What national markets do we want to play in?
Which regional regulatory requirements do I need to comply with?	Which capabilities do I need to build up?	Which dedicated operate services need to be developed for automotive specifically?
How will the aftermarket be impacted?	What is the growth strategy moving forward	
What is the impact on current ADAS?	Which are the right technology platforms to build upon?	
	What are there any regulatory aspects that impact me? (IT security, Carbon Footprint)	
	How to increase service delivery compared to product delivery?	

Source: Deloitte Global analysis.

In the race to position themselves for success in a software-defined future, companies across the automotive value chain are recognizing the need to focus on four priorities: (1) adopting a software-led mindset to product development, (2) simplifying software platforms, (3) maintaining quality as a guide to the ongoing transformation, and (4) using cloud-based environments to connect all aspects of the ecosystem.

Figure 9. Four priorities for SDV success

01 **Software-led product development mindset**
Software is at the core of the product and likewise must become the core of automotive product development.

02 **Platform simplification and evolution to software**
Shifting toward a platform-centric approach for software-feature proliferation while reducing hardware complexity.

03 **Quality needs to guide the ongoing transformation**
Quality is a customer requirement and is increasingly needed to meet ADAS/AD* safety standards.

04 **Controlled pivot to cloud-based and virtual environments**
The cloud is the binding element between vehicle, customer, OEM, suppliers, and others enabling continuous updates.

Source: Walid Negm et al., “The future of the automotive industry is software-led,” Deloitte, May 18, 2023.

Leading considerations for industry stakeholders:

1. **Start with an SDV maturity self-assessment and define a vision for the future**
   Finding a differentiating value proposition in the software-led evolution of mobility is the first step in positioning the company for future success. Assessing the company's maturity level, including the current state of technology and core architecture, along with identifying key transformation challenges, should be a priority for setting realistic targets.

2. **Develop an SDV architecture blueprint**
   Modularity, scalability, and flexibility need to be considered to accommodate future advancements and enable seamless integration of new features and updates in the shortest possible time. Traditional OEMs that need to transition away from legacy software platforms can focus on the development of a core architecture blueprint to provide a more efficient framework to scale vehicle software updates.

3. **Identify the right SDV alliance collaborators**
   Traditionally, many OEMs have struggled with the concept of collaboration in an ecosystem environment. However, establishing mutually beneficial strategic alliances and relationships will likely be essential for success in an SDV future. In fact, these ecosystems can capitalize on the complementary strengths and resources of individual participants to help accelerate the development of SDVs. Strong alliances can also generate a broad user base to achieve scale, while the inclusion of diverse stakeholders, such as legal entities and research facilities, can enable SDV ecosystems to navigate a complex and rapidly evolving regulatory landscape.

4. **Design a company-wide masterplan with a clear focus on execution**
   Building on the development of an architecture core blueprint, companies should design a comprehensive change management plan to align cross-functional transformations throughout the organization. High-performance teams should also be set up with a focus on dedicating resource capacity to innovative future topics.

5. **Embrace the journey toward a software-driven organization**
   To help with succeeding in the SDV market, it may be crucial to transition into a software-led organization that emphasizes data-driven decision-making in an environment grounded in cross-functional collaboration and knowledge sharing. Companies can shift their organizational focus toward software development by investing in software engineering talent, training, and tools. Companies should also adopt agile development methodologies to enable rapid iterations and continuous integration of software over the vehicle life cycle. Lastly, software security and safety measures need to be taken to ensure reliable and compliant operations.

6. **Realize efficiency gains**
   Breaking down traditional "Tayloristic" structures will result in simpler, faster development cycles, reducing complexity while increasing the potential for reusability. The implementation of new core architectures, AI, agile transformation, strategic relationships, and process restructuring can also help to realize significant efficiency gains. Moreover, portfolio decisions need to be streamlined to focus on business cases that help to secure future viability.

7. **Capitalize on new SDV revenue streams**
   New SDV-enabled revenue streams are emerging as large amounts of data are generated from increasing vehicle and fleet connectivity. These involve one-time purchases or recurring subscriptions for entertainment or personalization services, security, mobility as a service, and smart infrastructure solutions.

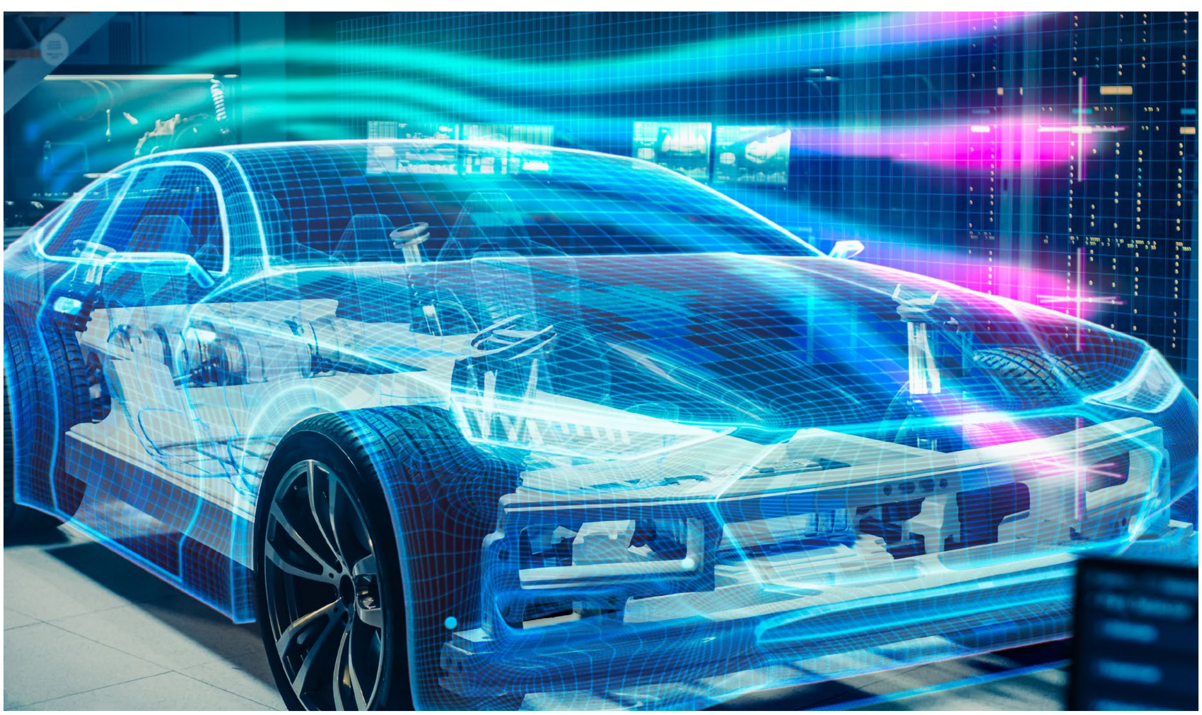
Conclusion

Key market players must adapt swiftly to SDV technology, reimagining their roles and business models. Those who embrace change can seize new opportunities for growth and innovation, while those who resist may find themselves left behind in a rapidly evolving landscape. OEMs will likely have to establish differentiating services, finding ways to integrate new software architectures into their growing SDV fleets. Suppliers may have to rethink their products, while tech players will likely have to compete for the talent needed to develop advanced solutions for the new automotive industry.

At the same time, strategic relationships should emerge around gaining regulatory approval to help drive technology forward while maintaining the automotive industry's demanding standards for safety and reliability. Support structures with participation from a variety of stakeholders will likely be imperative while new regulatory laws and test procedures to address security risks will likely have to be introduced. Amid these challenges, fostering an open ecosystem is crucial. Open collaboration among stakeholders is essential to facilitate knowledge sharing and promote collective problem-solving to develop safe, efficient, and exciting vehicles.

Furthermore, the rising importance of shared mobility for new generations cannot be overstated. SDVs have the potential to reshape the way we move, enabling convenient and efficient transportation solutions. Shared autonomous fleets can significantly reduce traffic congestion, lower emissions, and enhance accessibility for underserved communities. By enabling individual, cloud-based profiles and settings that can be accessed from any vehicle, the driving experience gets more personalized, contributing to the growing trend of flexible mobility.

In summary, SDVs offer a glimpse into a future where transportation is safer and more efficient and provides a wealth of new user experiences. By embracing new digital trends via an open ecosystem, the full potential of SDVs can be unlocked. Together, there is an opportunity to help shape a future where roads are not just driven on, but driven by innovation, sustainability, and the power of human potential.



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