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CENTER OF AUTOMOTIVE MANAGEMENT

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The Software-Defined Future: Racing Toward the AI-Driven Vehicle – REPORT 2026

How Global Automotive OEMs Are Navigating the Paradigm Shift from Hardware to Software Centricity

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The Software-Defined Future: Racing Toward the AI-Driven Vehicle – REPORT 2026

How Global Automotive OEMs Are Navigating the Paradigm Shift from Hardware to Software Centricity

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Cover image: CAM/AI generated

Content (I)

Executive Summary (I)

- The world of automotive development is currently undergoing major changes. While just a few years ago the focus was primarily on hardware innovations driven by the paradigms of "stronger, faster, further," **software development,** with its diverse functionalities, is now taking center stage. Global automakers are responding to this **paradigm shift** in different strategies and, above all, at different speeds. While many new players are developing their vehicles from a software-centric perspective from the outset, many established OEMs are grappling with the high complexity of various hardware and software platforms and comparatively long development cycles. Differences in corporate culture also represent a significant factor in the development of new vehicles. The next step towards **AI-defined vehicles** is already visible, with some manufacturers emphasizing this direction. Initial AI applications at the product level – for example, personal assistants – are being examined.
- The aim of this study, conducted by the Center of Automotive Management (CAM) and Accenture, is to develop a **SDV Platform Framework** based on an analysis of ten automotive OEMs. Using this framework, the study provides a structured overview of the key SDV areas and outlines the steps required for the successful development of a Software-Defined Vehicle. The ten sample OEMs serve as examples of different implementations within the SDV framework. Progress in this area is currently very dynamic, as evidenced by the presentation of many innovations at events such as IAA Mobility 2025. In addition to desk research and the use of CAMs innovation database, an expert survey is being conducted to qualitatively determine the OEMs' status quo. A selection of leading industry experts has been consulted for this purpose.
- As a result, **three archetypes** can be identified, clustered along two dimensions. Firstly, the **development progress** regarding the software-defined vehicle varies considerably among the OEM. Development progress is determined based on seven criteria derived from **CAMs CoCoCO model** (Competencies, Cooperation, Culture & Organization): The OEM must master four decisive competencies like a unified software platform or a central computer strategy, OEMs need partnerships where necessary, and finally the OEMs company culture as well as the organization must support software development. All these criteria are necessary to successfully develop an SDV. Secondly, these archetypes differ in terms of the **technical manageability** of the hardware and software platform landscape of the OEMs. High manageability means less complexity: The fewer hardware and software platforms an OEM has to manage, the easier it is to introduce SDVs across the entire product range.
- **Archetype 1: The SDV Leaders**
  - Companies in this category are characterized by a high level of maturity in their Software-Defined Vehicles. These OEMs have developed their vehicles from the ground up, starting with the software, and have not had to consider older platforms. This "greenfield approach" creates decisive advantages over many established automakers in terms of platform and variant complexity. These OEMs are structurally better positioned to industrialize SDVs and to prepare for the next step toward AI-defined vehicles.
  - A unified software platform enables over-the-air (OTA) updates, with an update frequency of at least monthly, and sometimes weekly. Comprehensive AI integrations offer customer benefits in terms of vehicle operation and advanced functions such as autonomous driving. On the hardware side, a few, but powerful, central computers are easy to keep up-to-date, and data transmission takes place via a high-speed Ethernet bus. Such a hardware architecture results in lower weight and saves costs for the manufacturer.

Executive Summary (II)

- Cultural aspects also support SDVs: These companies are software-centric, with flat decision-making processes for new features and rapid development cycles ensuring continuous improvement, while always keeping the specific automotive requirements and their high safety standards in mind. In the case of less safety-critical functions, iterative processes provide a mechanism to handle uncertainty by allowing for the swift correction of faulty decisions, consistent with established software engineering practices. Regarding partnerships, companies in this category are particularly selective, focusing on maintaining their own customer touchpoints and data sovereignty. A significant portion of critical software development takes place in-house.

- **Archetype 2: The Fast Followers**
  - This archetype is characterized by the fact that OEMs have already reached a high level of maturity in some criteria, while progress is still possible and necessary in others. Some OEMs are still in the early stages of developing a unified software platform as well as a centralized hardware strategy. The first production models are available, but the SDV product portfolio is expected to grow to a double-digit number within the next two years. These OEMs have already successfully rolled out one technical advantage of SDVs: the ability to wirelessly deliver additional functions to the vehicles or fix errors via OTA updates.
  - Another important future topic is the integration of AI technology, where we are focusing on product-related applications. The "fastest competitors" are characterized by a comprehensive, personal voice assistant and a learning operating concept that continuously improves its understanding of the user and, ideally, proactively automates operating steps. These OEMs have internalized the fact that they can and must benefit from the technological expertise of the right partners. For example, they collaborate with competent partners such as Nvidia, Momenta, Amazon, Google, Spotify, WeChat, etc., on cloud solutions, chip technology, and, not least, content integration.
  - In addition to the technical factors described, the criteria of "culture and organization" represent a significant obstacle on the path to SDV development. Traditional automotive manufacturers are industrial companies that still need to learn how to develop software. While the focus used to be on the "start of production," i.e., the market launch of a finished, new vehicle model, the decisive goal today is that software is never truly finished. The goal is therefore continuous improvement, while still ensuring compliance with automotive safety requirements.
- **Archetype 3: The Catch-up Players**
  - Even more so than premium manufacturers, volume-oriented OEMs with their traditionally lower margins and high output, face significant challenges on the path to SDV (Software-Defined Vehicle). They must convert considerably more platforms, convince more employees, often deal with more partners, and adapt their often more cumbersome organizations. All OEMs of this archetype should recognize this and must develop unified software platforms, but their market launch, however, is still pending in some cases.

Executive Summary (III)

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- Over-the-air (OTA) updates are already possible in addition to simple infotainment updates at this OEMs. There are also significant differences in AI integration, where some manufacturers have already made considerable progress. Several catch-up players are already well-positioned in establishing suitable partnerships that take regional customer needs into account, for example, with partners like Waymo, Huawei, Microsoft, and Xiaomi. In terms of the factor "culture and organization", OEMs of this archetype still lag somewhat behind the best in the industry with lower software orientation and higher hierarchies.

- **Revenue potential through SDV**
  - Customers don't buy software directly. But it is the prerequisite, the "enabler," for the rapid and customer-oriented realization of innovations and added value from connected features and services. Software, data, and AI enable innovations in various technology and application areas: interfaces (immersion factors), connectivity/infotainment, autonomous driving, and more. These areas contain the **future revenue potential** and **profits of the automotive industry.** They are also increasingly shifting to the post-purchase phase and enabling regular after sales revenues – even for electric vehicles.
  - The resulting new value creation and **software & services revenue potential** from SDVs, for example in the areas of infotainment, e-commerce, charging, EV ecosystems, and autonomous driving, is estimated at around **€ 40 billion in 2030** and could increase to approximately **115 billion by 2035.** Potential **Average Revenues per Vehicle** (ARPV) can increase from the current € 75 to € 120 to approximately up to **€ 200 in 2030** and up to **€ 400 in 2035** through additional services and significantly larger fleets of suitable vehicles, including an increasing share of electric vehicles. At the latest then, the expenses that OEMs currently have to invest in the development of SDVs will be recouped through new revenues and profits.

1.

Objectives and methodology

1.1 Objectives and subject of the study

Objectives and subject of the study

SDV framework of 10 OEMs

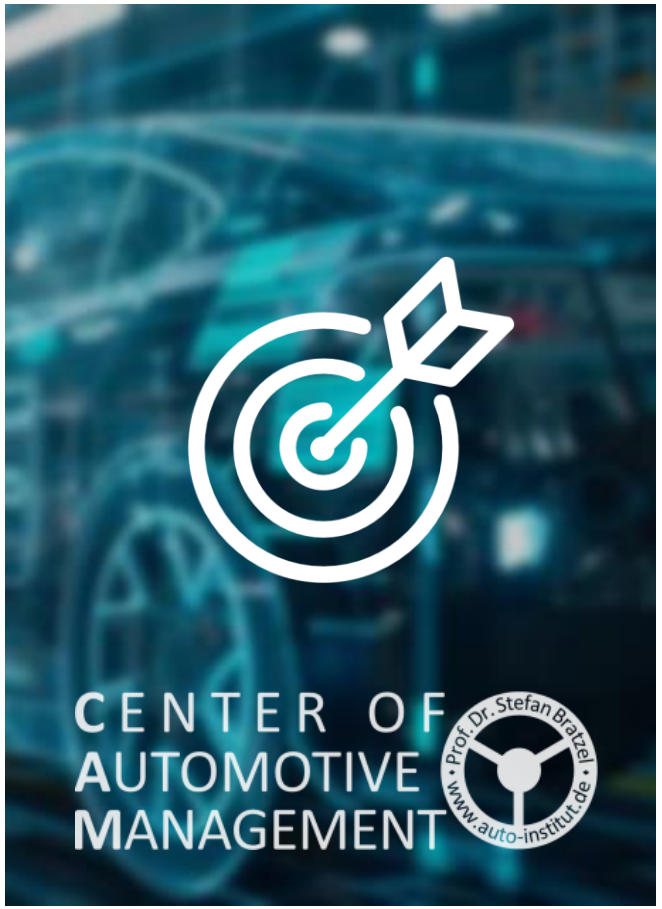
This study develops a SDV Platform Framework based on an analysis of ten automotive OEMs in order to provide a structured overview of the key SDV areas. As a result, three OEM archetypes are developed that show the different levels of SDV status quo.

- The Center of Automotive Management conducted in cooperation with Accenture a study on the "Platform Framework" of software defined vehicles with the help of a sample of ten global OEMs. The study aims to provide an overview based on a framework that is necessary for the successful development of an SDV.
- The ten sample OEMs serve as examples of different implementations within the SDV framework.
- As a method, the study utilizes desk research, including the CAM innovation database, and an expert survey to determine the OEMs status quo. This is supplemented by internal CAM/Accenture expert workshops.
- The individual chapters and contents of the study is presented based on theses clustered by topic (e.g., problem statement, solutions). Furthermore, the content will be illustrated with examples and in-depth analyses.
- The study examines in total ten OEMs from different countries with both new and legacy manufacturers and with premium and volume focus in order to provide a broad overview and to uncover differences in SDV status quo. These differences are clustered in three SDV archetypes.

VOLKSWAGEN GROUP Mercedes-Benz BMW GROUP	STELLANTIS	TOYOTA	TESLA	NIO BYD GEELY XPENG

Source: CAM.

Survey by CAM in cooperation with Accenture



Objectives and subject of the study
Success factors

The success factors of SDVs lead to faster development and shorter time-to-market. OEMs must strategically leverage the speed advantages of SDV development to remain competitive, especially against innovative startups and new players from China.

- The success of SDVs depend on several aspects. Forming effective partnerships is crucial, as companies need to participate in broader ecosystems, carefully select strategic partners, and proactively align with regulatory developments. The OEMs organizational framework must be adapted with a software-oriented culture and less “silo thinking”.
- Strong software competence becomes a key differentiator, meaning that product innovation should increasingly come from software rather than hardware, supported by reusable components. High data competence is essential, including the ability to integrate big data, leverage fleet data for continuous improvement, and use virtualization to accelerate development.
- But hardware expertise is also a basic requirement in the form of a central computer strategy with a zonal E/E-architecture. Comprehensive AI integration must span the entire value chain, including research and development, production processes, vehicle features, and related services.

Success factors of SDV leading to faster development speed

Comprehensive AI integration
- R&D
- Production
- Vehicle features
- Services

Framework: Organization
- Software-oriented organization
- Fast development (“China speed”)

Framework: Culture
- Continuous delivery
- Software evolution, defined release cycles
- Innovation culture

Hardware competence
- Central computer strategy
- Zonal E/E-architecture

Software competence
- Product differenciation via soft- not hardware
- Reusability
- Pooling resources on differentiating functions
- Open-source software on non-diff. functions

Partnerships
- Ecosystem play
- Partnership selection
- Proactive, regulatory alignment

OTA updates
- Connectivity
- Fleet data usage
- Product lifecycle

Source: CAM.

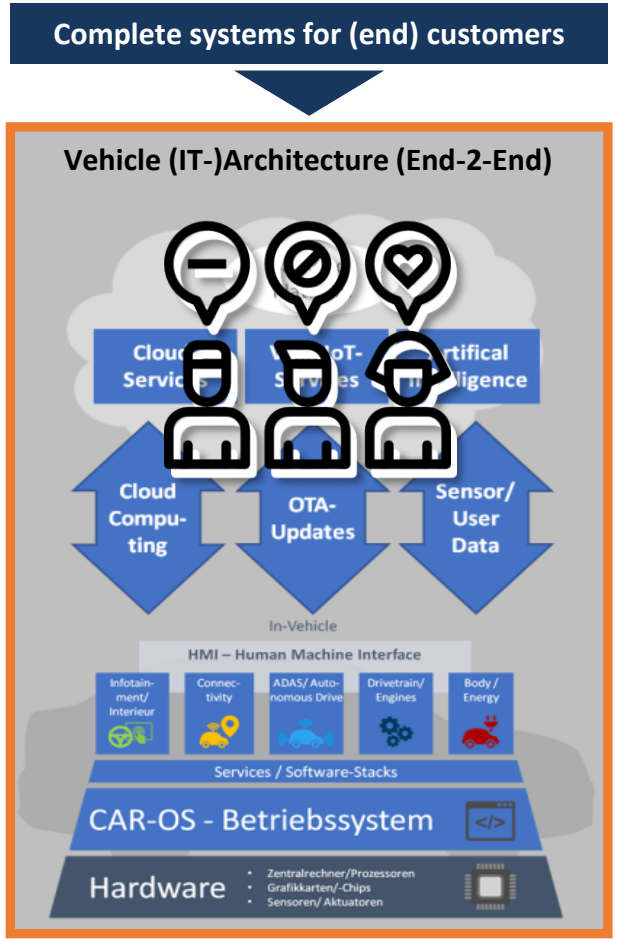
Objectives and subject of the study

Advantages of SDVs from a customer perspective

Win-win-situation for customers and OEMs: On the customer side, connectivity and connected services expand the functional horizon and therefore require a new software-defined vehicle architecture.

- "Connectivity & Connected Services" creates new customer benefits through infotainment offerings and at the same time is an enabler for other services such as driver assistance systems or autonomous driving, e-car charging services, e-commerce, etc. The prerequisite for this is an electrical/electronic vehicle architecture that enables comprehensive vehicle networking, including over-the-air updates and functions-on-demand. Central elements are a cloud connection, a uniform vehicle operating system (software basis, possibly domain-dependent) and a central computer architecture (hardware basis).
- The **advantages** of such an architecture from the **end customer's point of view** are in particular:
  - **Updates** without a visit to the workshop: The vehicles can be updated via over-the-air updates (OTA) and improved with additional functions.
  - **Improved user experience:** Drivers can customize and personalize their driving experience to meet their specific needs.
  - **Greater driving safety:** The software-first approach with the implementation and maintenance of ADAS systems or AI assistants can reduce accidents in road traffic.
  - **Efficiency and range:** Adjustments in the vehicle software, AI and machine learning can increase efficiency and increase the range of the vehicle (especially in conjunction with electric drive).
  - **Payment device:** The vehicle can serve as a payment device, e.g. for charging services, but also for numerous other services.
  - **Continuous optimization:** Regular updates and the use of artificial intelligence ensure the continuous improvement of the on-board assistants and avatars.
  - **Third-party integration:** An open ecosystem allows for the integration of third-party applications, expanding the possibilities for drivers and passengers almost indefinitely.
  - **Higher residual value:** When reselling, a higher residual value can be achieved compared to traditional vehicles, as the models can still keep up with newer generations even after a longer period of time.

SDV Advantages: Customers



Source: CAM.

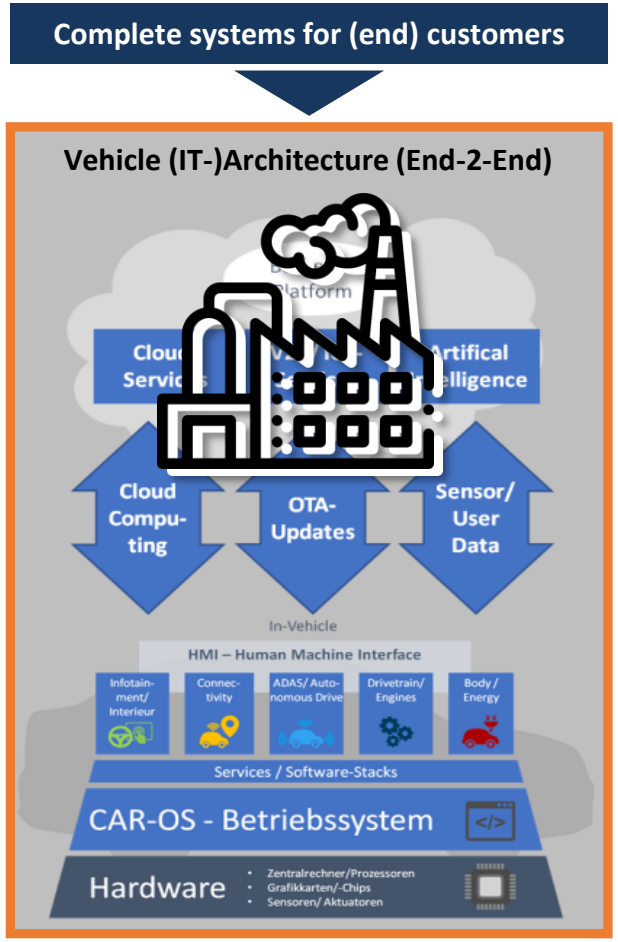
Objectives and subject of the study

Advantages of SDVs from a OEMs perspective

One the OEM side, SDVs are simultaneously a prerequisite for rapid product development and lower costs, as well as for future revenue potential with networked services and new functions.

- The **advantages** of such an architecture from the **OEMs point of view** are in particular:
  - **Lower development costs:** After platform development for SDVs, easier and more cost-effective differentiation of the group brands and models, resulting in higher revenue potential, open-source software for non-differentiating functions.
  - **Higher development speed:** Shorter development, faster time-to-market, esp. when reusing software, greater flexibility.
  - **Updates without a visit to the workshop:** The vehicles can be updated via over-the-air (OTA) updates and improved with additional functions, lower costs for OEMs
  - **Improved user experience:** Drivers can customize and personalize their driving experience to their specific needs, brand and model differentiation within one platform
  - **Efficiency and range:** Adjustments in the vehicle software, AI and machine learning can increase efficiency and increase the range of the vehicle (especially in conjunction with electric drive), lower CO2 emissions, avoidance of fines (EU)
  - **Continuous optimization:** Regular updates and the use of artificial intelligence ensure continuous improvement of on-board assistants and avatars, easier error elimination, function integration
  - **Third-party integration:** An open ecosystem enables the integration of third-party applications, expanding the possibilities for drivers and passengers almost indefinitely, creating new partnerships
  - **Customer loyalty:** By using customer data, loyalty can be increased thanks to personalized offers.
  - **New revenue potential:** OEMs hope to open up new revenue channels with software-defined vehicles. Software updates, on-demand functions and the monetization of data are expected to lead to increasing revenues.
  - **Improved customer orientation:** better adaptation to different markets and customer groups through pure software adaptations

SDV Advantages: Manufacturers



Source: CAM.

1.

Objectives and methodology

1.2 Methodical approach

Objectives and subject of the study

Platform readiness: CoCoCO model

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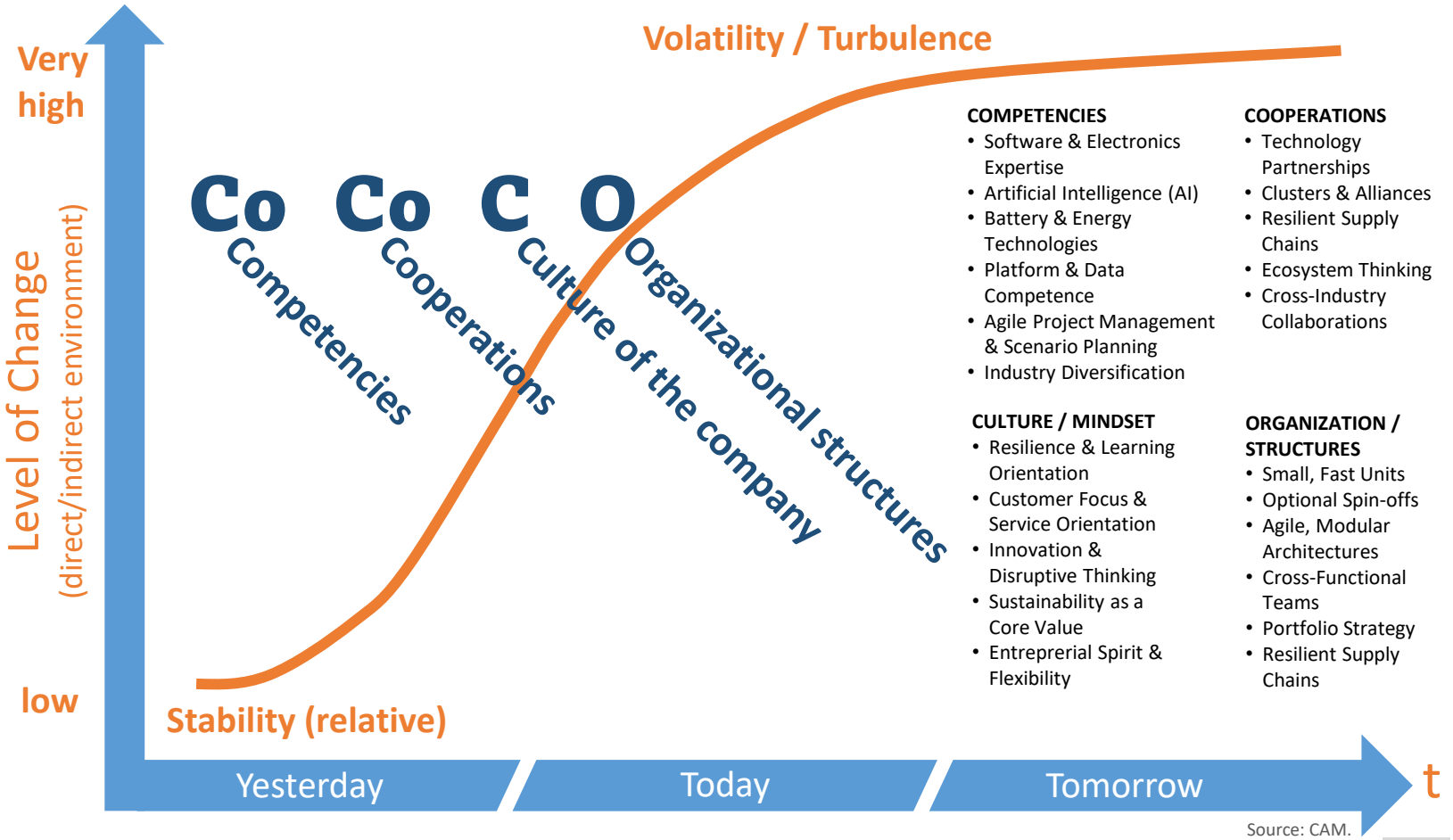
From an OEM perspective, the CoCoCO model captures the critical success factors for the effective introduction of software-defined vehicles and provides the foundation for deriving assessment criteria for OEM SDV readiness.

- In times of high market and technology volatility, competitive advantage is no longer driven by products alone but by an OEM's ability to adapt quickly. Based on the "CoCoCO" model competence, cooperation, culture, and organization are decisive factors.
- Within the model, there are **mutual dependencies** between the factors:
  - As competencies increase, fewer or different collaborations are needed. At the same time, both the mindset and the organizational structure must align with these competencies; adjustments may be necessary.

  - Conversely, the same applies: if one's own competencies are insufficient, increased cooperation is required as compensation, which in turn must be organizationally mapped and brought to life.

CAM's CoCoCO model



Source: CAM.

Objectives and subject of the study
CoCoCO model and SDV assessment factors

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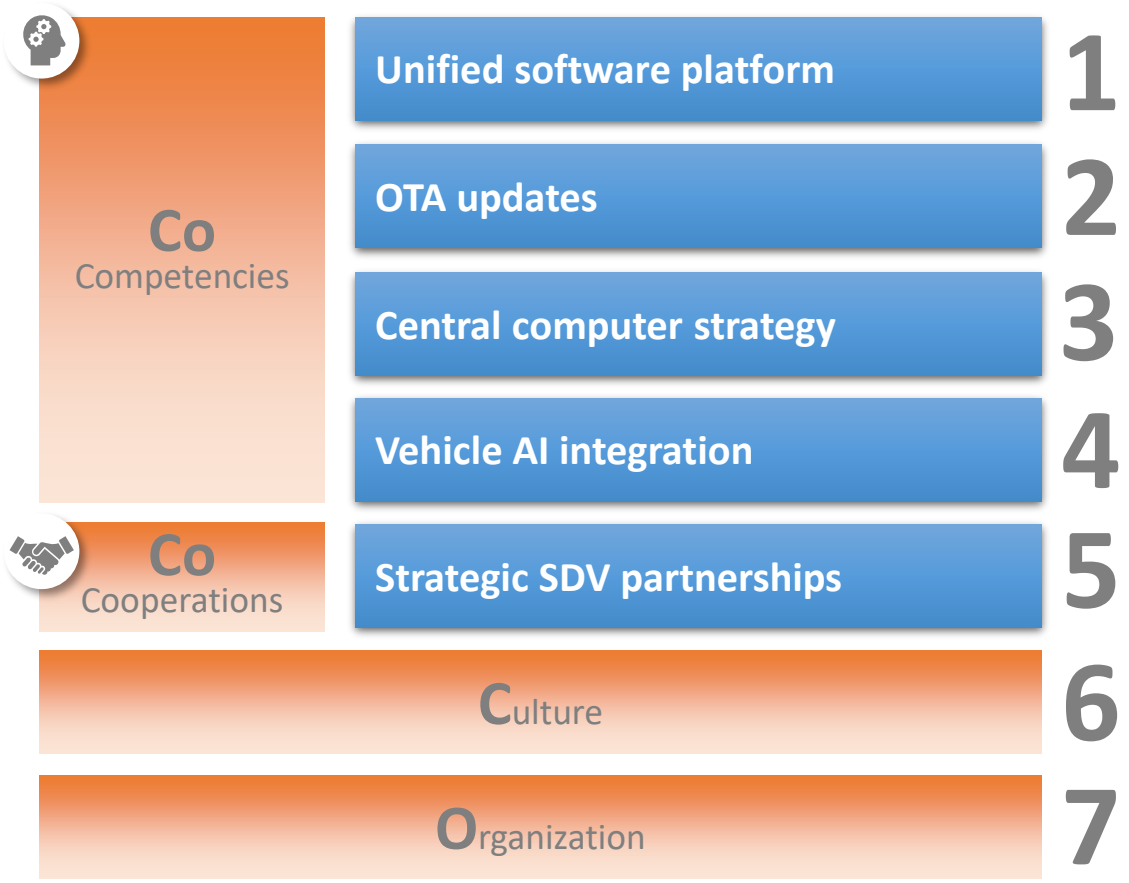
The individual evaluation criteria of a software-defined vehicle can be categorized according to the CoCoCO model.

- A Software-defined vehicle (SDV) can be described as a fully digitalized car. All functionalities, including driving, entertainment, communication, safety, and comfort, are enabled, managed, controlled, and customized through software.
- SDVs are connected to the cloud and interact digitally with their environment. New functionalities are continuously deployed over-the-air (OTA) without requiring hardware changes.
- The survey identifies **seven success factors** for OEMs in order to develop an SDV:
  - Four decisive competencies like a unified software platform or a central computer strategy,
  - OEMs need partners where necessary,
  - OEMs company culture as well as the organization must support an SDV development.

CONCLUSION

As a result, a SDV ages more slowly because it can continuously adapt to the everyday lives of its users.

Assessment criteria of SDV progress



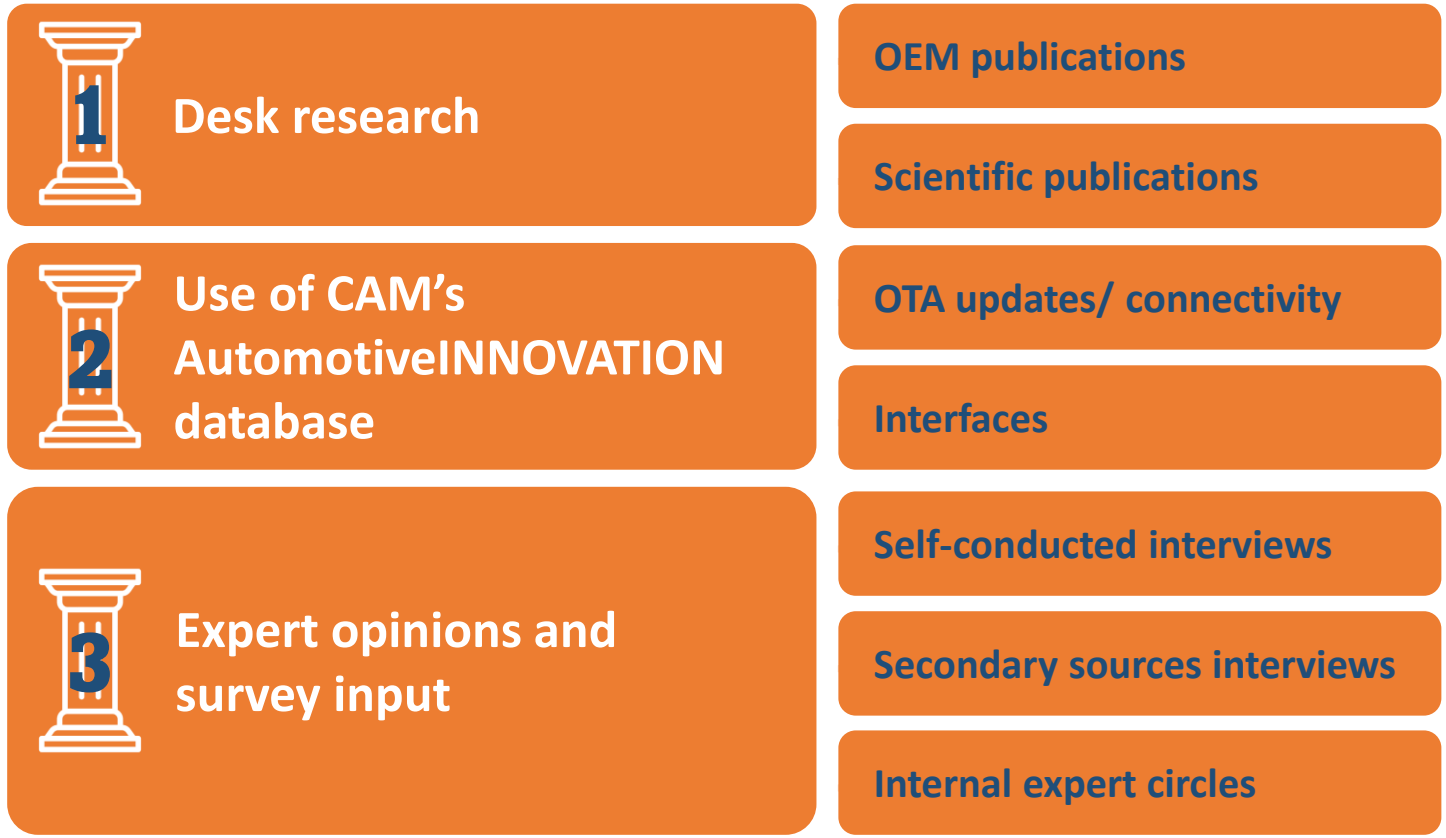
Source: CAM.

Methodical approach
Key elements

The methodology of this study is based on the three pillars of "desk research", "evaluations of AutomotiveINNOVATIONS database" and “expert interviews”, thus ensuring scientific approach.

- Desk research includes information gathered from OEMs press releases, official reports and other sources. Scientific sources include the German-language and international specialist press as well as news portals.
- The AutomotiveINNOVATIONS database includes the individually evaluated and categorized vehicle technology innovations, particularly in the CASE technology fields of connectivity, ADAS/AD, services and electric mobility. In this context, the database is used to analyze data related to vehicle software as well as OTA updates, connectivity and vehicle interfaces developments.
- To supplement and verify the information gathered, expert interviews were conducted. Some of these were carried out directly, while others involved relevant secondary sources.
- A key element of the study is the status quo analysis of selected OEMs. For this purpose, all collected information was presented to an internal evaluation committee.

Key pillars of method in this survey



Source: CAM.

Methodical approach
AutomotiveINNOVATIONS database

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The AutomotiveINNOVATIONS database delivers a systematic analysis of innovation trends and comparison of OEMs innovation performance.

- The Center of Automotive Management conducts an annual inventory of current innovations by 30 international automobile manufacturers and innovative startups with approx. 100 brands. It provides an accurate picture of upcoming automotive technology trends in the passenger car sector.
- After der verification of the innovation, each innovation of the OEM is categorized using more than 60 attributes, like technology field, innovation type, segment, maturity etc.
- In addition, innovations are systematically evaluated based on the M.O.B.IL approach. Each innovation gets a „score“ according to the maturity (series vs. concept), originality (world-first vs. company-first), benefit for the customer, and innovation level (low vs. high). This results in an index value for each innovation, which can be aggregated into totals for car groups, brands or models as well as whole countries or world regions.
- For this survey, the database delivers innovation input for the selected OEMs and supports the SDV assessments.

AutomotiveINNOVATIONS database

1 Research

Collection of technical vehicle-related innovations of global OEM

OEM Press News | Press Coverage | Motor Shows

2 Verification

Do the novelties meet the criteria of ou innovation definition?

3 Categorization

Categorization in technology fields, innovation types etc.

Source: CAM.

4 Evaluation

M	Maturity	(Reifegrad)
O	Originality	(Originalität)
B	Benefit	(Kundennutzen)
I L	Innovation Level	(Innovationsgrad)

Innovation strength
= Innovation level * Originality * Maturity * (1 + Σ Innovations benefit)

Series	1,0
Pre-Series	0,7
Concept car	0,25
World-first innovations	2,0
Company-first	0,7
Efficiency	0,30
Safety	0,25
Comfort	0,20
Environment	0,10
Versatility	0,10
Performance	0,05

'very high'	The automobile is decisively changed in terms of basic characteristics, highest customer potential	4	3,5*
'high'	The existing basic characteristics of the automobile are substantially improved, high customer potential	3	2,5
'medium'	An automotive sub-system is substantially improved, medium potential for certain customers	2	1,5
'low'	Certain customers receive a noticeable, desirable added value, can improve customer satisfaction	1	

DEFINITION: Innovations are understood as new developments that are of particular economic significance for the OEM or the passenger car market. To be accepted as an innovation, a technical novelty must meet three conditions:

1. Noticeable **additional benefit** to the customer, different to previous state
2. **Presentation** in an appropriate manner (e.g., press releases, trade fair etc.)
3. **Availability** in the form of (pre-)production-ready products or at least prototypes

Methodical approach
Expert opinions

The expert interviews verify the researched data and facts and supplement them with additional assessments, e.g. on the factors of culture and organization or platform strategies.

- The ten car manufacturers were selected to ensure a sample of typical cases of car manufacturers covering premium and volume OEMs as well as newcomers. Methodologically, the study carries out a preliminary assessment based on the researched data and facts using the seven assessment criteria.
- To verify these assessments, expert interviews were conducted with top management representatives (e.g. Chief Technology Officers) from selected OEMs and others. The conversations lasted approximately 30 minutes and have been conducted in parts during scientific conferences. In addition, thematically relevant interviews from secondary sources were evaluated.
- The content focused on five key themes, i.e. on how OEMs manage culture, software ownership, system complexity, vehicle architecture, and AI integration in the shift toward software-defined vehicles. It emphasizes understanding current capabilities, future plans, and organizational changes required for continuous delivery, centralized computing, and differentiated AI-based user features.
- The final assessment of SDV readiness was based on desk research and expert discussions during internal workshops by CAM and Accenture.

Expert opinions: Contents of the guided interviews

MAIN TOPICS FOR THE EXPERT SURVEY	Criteria*
Complexity: How many SW-platforms do OEMs currently maintain across their vehicle lines?	1 Software
Architecture: How is the OEMs leading E/E-architecture designed, e.g. in terms of centralized computing?	3 Hardware
AI integration: How do OEMs use artificial intelligence and ensure differentiating in-vehicle user features?	4 AI
SDV Culture: How can OEMs ensure a mindset shift in their development organization towards "continuous delivery"?	6 Culture
Software first: What level of in-house control do OEMs currently have over their software stack? What are their plans?	7 Organization

Source: CAM.

* Key criteria for the expert survey; other criteria are mainly obtained through desk research.

2.

OEM development of software-defined vehicles

2.1 Status quo

SDV: Status quo

Share of global innovation strength in the automotive industry by countries and regions

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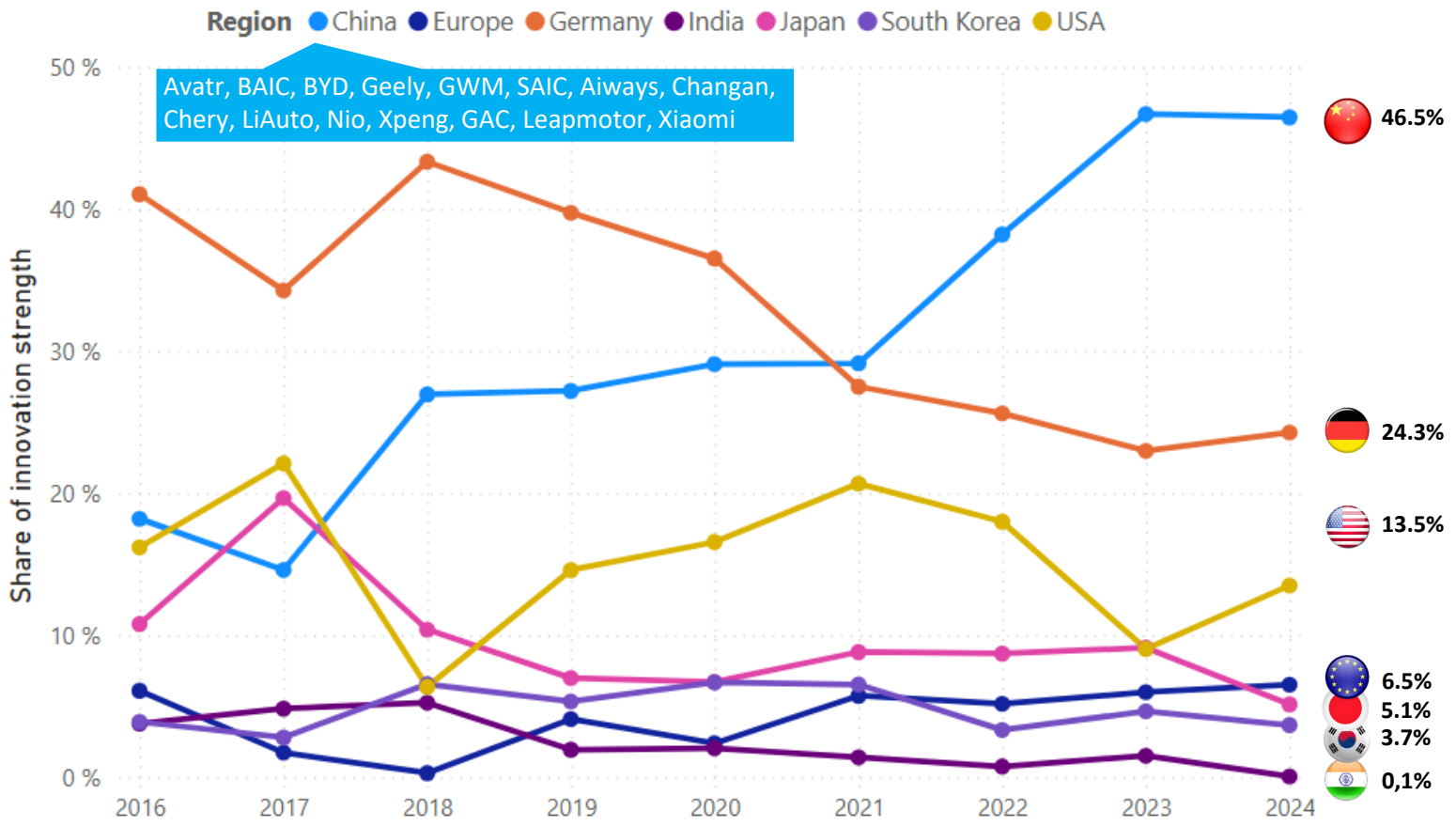
Chinese OEMs rapidly increased the innovation strength in the past five years and have overtaken their German counterparts. Based on the evaluation of 600 to 800 yearly rated series innovations the Chinese global share of innovation strength climbed to more than 46%.

- In 2024, China reached an innovation share of 46.5%, which can be attributed to intensive investments in digitalization and software, in addition to electric mobility. Germany, once a long-standing leader in automotive innovation, has experienced a decline in its share since 2019, then stabilized around 25 percent with a slight upturn in 2024. This reduction is likely due to several factors, including the challenges of transitioning from traditional vehicle platforms to new technologies like SDV and autonomous driving systems, areas where China is increasingly taking the lead.
- The U.S. OEMs have experienced a marked loss of share since 2022, falling to 9% in 2023, now rising to 13.5%. while Japan declines to the worst value of only 5%. This suggests that traditional automotive markets are increasingly being outpaced by the innovation capacity of emerging players like China.
- The European automotive share, excluding Germany, remains relatively stable with a share of 6.5% in 2024, though at a comparatively low level. Other countries, such as South Korea and India, continue to be marginal players in the global innovation landscape of the automotive sector, with shares of at most 3.7%.

Share of series innovation strength by countries/regions* 2016–2024 (in %)**



Source: CAM, Bratzel/Tellermann 2025. Grafik PBI-8 OEMReg.

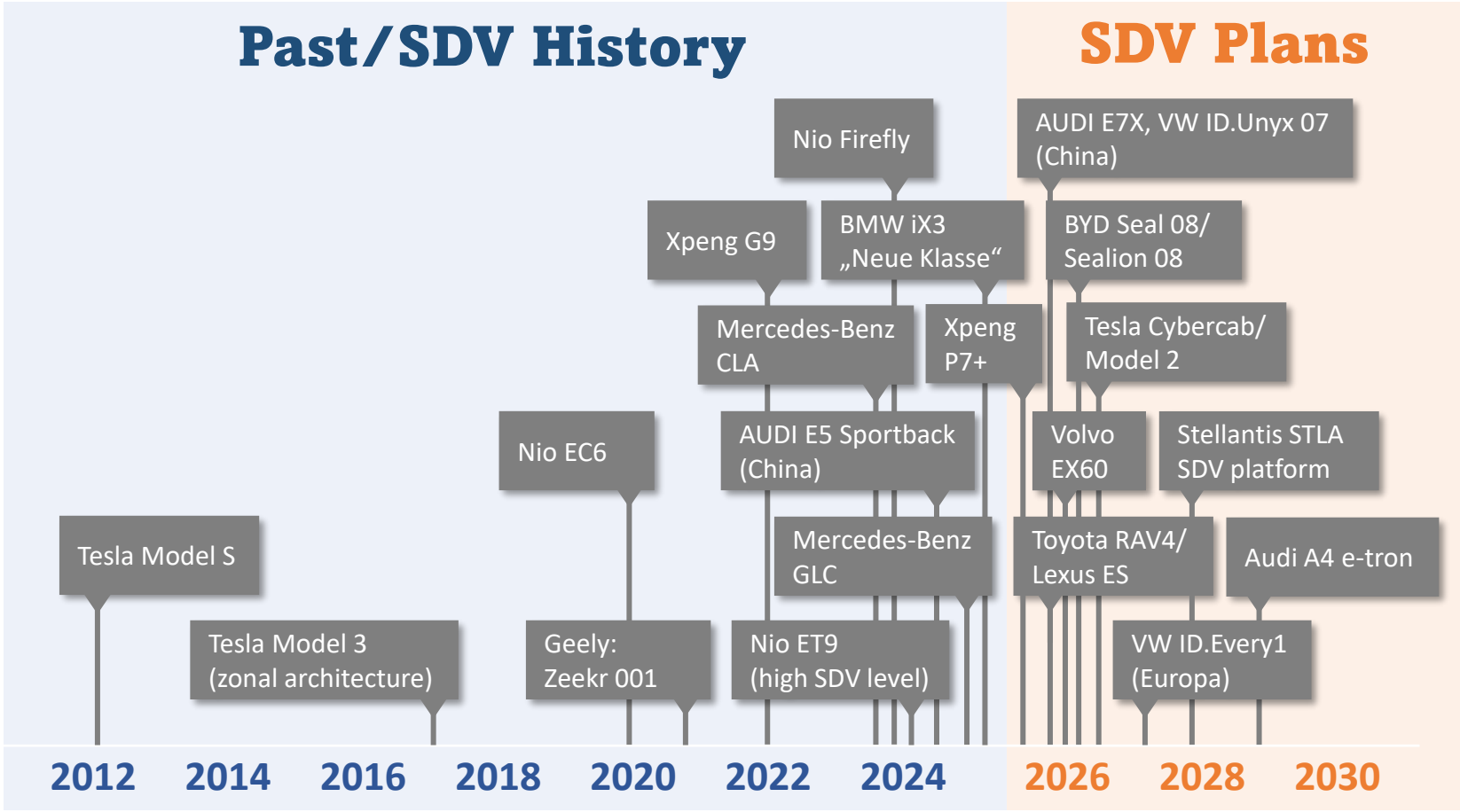
* Countries according to the headquarters of the OEMs. From 2020, methodological adjustments in innovation assessment, hence slightly limited comparability with previous years. ** All data in current year is unconsolidated and preliminary.

SDV: Status quo
Overview of SDVs on global markets

The progress of SDV development has accelerated significantly since 2024 and will continue rapidly in the near future.

- Tesla Model S (2012) is considered one of the first true software-defined vehicles (SDVs) on the market. It pioneered OTA updates and an early form of centralized vehicle software. Tesla Model 3 (from 2016, with zonal architecture) represents an important step toward a modern, modular E/E-architecture that later became an industry reference point
- From 2018–2022, more SDV-oriented models appear across manufacturers — including Nio (EC6, ET9), Lucid Air, Rivian R1T/R1S, as well as Mercedes-Benz CLA/GLC and AUDI E5 Sportback for the Chinese market.
- The launch of the BMW iX3 "Neue Klasse" (2025) symbolizes the strategic shift of major OEMs toward software-centric platforms intended to underpin multiple future vehicle lines.
- The period 2024–2030 shows a clear acceleration in SDV roadmaps: many manufacturers are planning vehicles with even higher software content, centralized high-performance computing, and extended OTA capabilities, e.g., Rivian R2/R3, Tesla Model 2.
- The planned models from 2026 onward illustrate how SDVs are moving from premium vehicles into high-volume segments, e.g., Toyota RAV4, VW ID.Every1.

Past and planned market launch of SDVs of selected OEMs*



Source: CAM.

* Model examples of OEMs selected for this survey with different levels of SDV development.

SDV: Status quo
Assessment criteria

The survey identifies seven success factors for OEMs to develop an SDV: Besides own core competencies OEMs need the right partners, an SDV oriented culture as well as organizational requirements.

- To reliably measure the SDV platform readiness of OEMs, the seven criteria – derived from the CoCoCO model – were operationalized using various parameters. While some of the parameters are easily measurable (e.g., SDV status in the model portfolio), others require an estimation of the current situation (e.g., corporate culture). The methodology addresses this by incorporating extensive desk research and expert opinions.
- The seven criteria outline the importance of technical enablers such as OTA update capabilities, centralized computing architectures, and AI-driven vehicle functions. Strategic dimensions like partnerships, company culture, and the shift toward a software-oriented organization are highlighted as essential for SDV success.
- For each criterion, the method provides concrete measurement factors — such as market experience, OTA update frequency, AI functions, and vehicle development speed — that illustrate how the status quo is operationalized.
- The following slides in this chapter present each of the seven criteria individually in four steps: Introduction of the criterion, meaningful example, status quo of the 10 OEMs, and conclusion.

Overview: Seven criteria to assess the SDV readiness of OEMs and examples of operationalization

1	Unified software platform	• Market experience with SDVs • Number of SDV models in global markets • Number oft software platforms
2	OTA updates	• Vehicle domains addressable with OTA updates • Fleet Size capable for OTA updates • OTA update frequency
3	Central computer strategy	• Hardware architecture • Bus system • High performance CPUs
4	Vehicle AI integration	• AI-based personal (voice) assistant • AI-based operating concept • further AI-based application areas
5	Strategic SDV partnerships	• Selection of partners, complementary competence • Quality of partnerships (regionality, scope), esp. content partners, e.g. for infotainment
6	SDV company culture	• Hardware vs. software-centric culture • Focus on SoP vs. continuous improvements
7	SDV oriented organization	• Industry comp. vs. software comp. organization • High vs. flat hierarchy • Vehicle development speed

Presentation Criterion → OEM Example → 10 OEMs Status quo → Conclusion

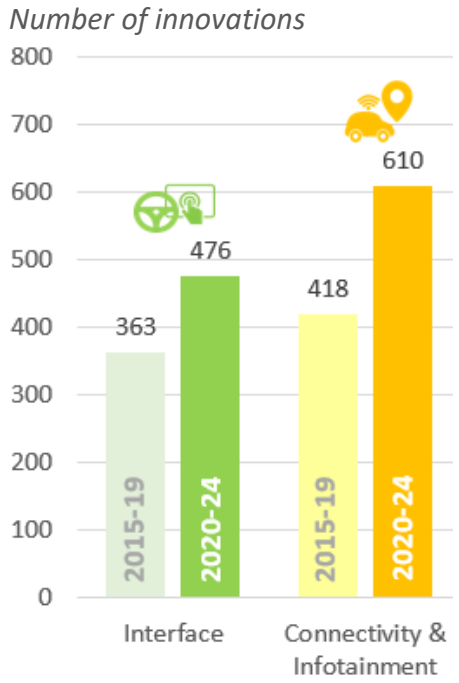
Source: CAM.

SDV: Status quo

Software platform: From hardware to software orientation

Software must become the primary driver of product strategy, business value, and differentiation - not hardware.

- In hardly any other area is the paradigm shift from hardware-driven to software-driven innovations as evident as in the cross-cutting theme of "Infotainment & Cockpit."
- This is also reflected in the increased number of innovations in recent years (see below)



Source: CAM, Bratzel/Tellermann 2025.

Crit. 1 Software platform

Future trends of Software-Defined Vehicles

	2010 – 2020th	2025/2030	
User Interface	**Hardware focus** Customers buy vehicles and special equipments/ accessories	**Software/ services focus** Customers use software/ services, hardware becomes commodity	• **Augmented Reality:** Projection of enhanced, dynamic content onto the windshield, e.g., navigation, warnings, highlighting of hazards, e-commerce (e.g., fuel prices) • **Interactive voice control:** User engages in dialogue with AI • Freely configurable control surfaces ("virtual buttons") with finger recognition ("minimalism") • **Holographic operation** simplifies and complements gesture control • **Anticipation:** Vehicle anticipates driver wishes • **Facial expression recognition** of occupants, considering voice control, driver monitoring as a component of assistance systems ("takeover request")
Connectivity **Connected Services**			• **Enhanced OTA updates:** continuous data and function updates, on-demand feature activation, and on-demand use. • **On-demand apps:** context-, event-, and customer profile-oriented, enhanced entertainment apps in autonomous vehicles. • **E-commerce:** tailored offers for the driver and/or passengers based on location, time of day, etc. • **Car-to-Car, Car-to-Infrastructure (C2x):** complete networking of the vehicle with its environment, other road users, and infrastructure, including situation-dependent features such as preventative traffic jam avoidance and automatic right-of-way control.

SDV: Status quo

Software platform: Eclipse foundation as an example for Open-Source Software initiative

CENTER OF AUTOMOTIVE MANAGEMENT

Open-source base layers are the industry's answer to eliminating wasteful duplication and enabling focus on true differentiation.

The **Eclipse Foundation** is a tral, non-profit organization that provides a platform for open-source software development and collaboration. The SDV Working Group focuses on developing open-source code and standards for software-defined vehicles. Its goal is to provide the automotive industry with a common, scalable software platform to accelerate innovation.

Open Technology Platform

- Open-sourced, modular software components and frameworks that are fully integrated into the developer experience with a high degree of automation and virtualization.

Automotive-Grade

- High performance computers as well as legacy ECUs. High standards for quality management, security, and safety across all vehicle domains.

Open Standards

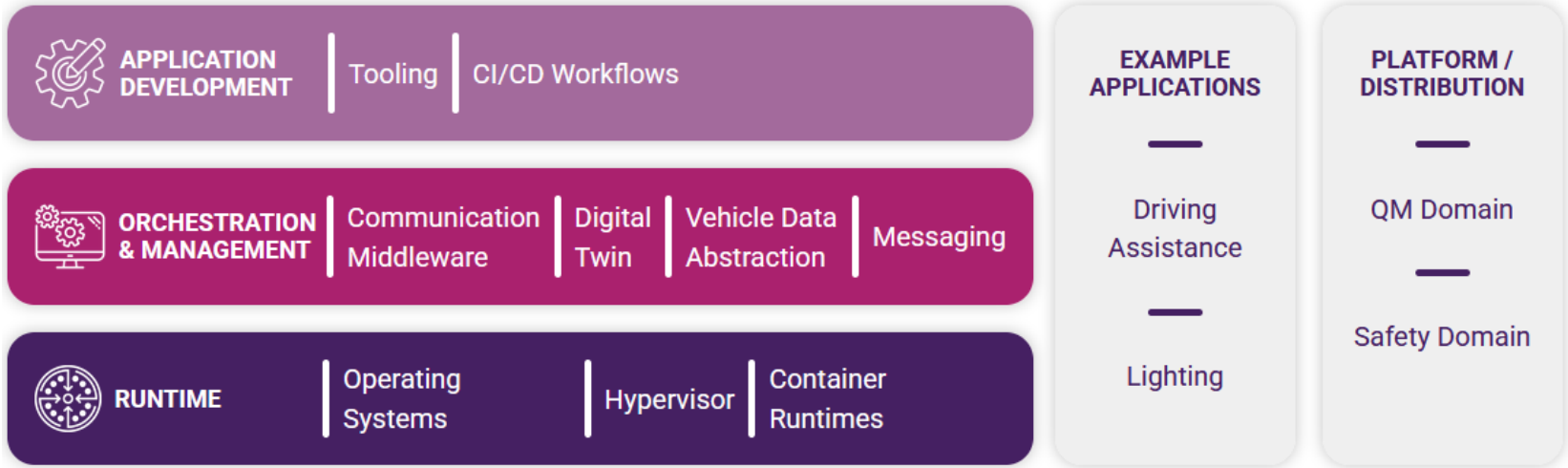
- Eclipse solutions don't aim to "reinvent the wheel" but uses open standards to leverage the power of open collaboration.

Community

- It is the aim to build value together and welcome new members. Joining forces on the non-differentiating parts decreases time-to-market and enables sharing of best practices.

Open-Source Software: Eclipse Foundation SDV Projects Landscape

Crit. 1 Software platform



KEY MEMBERS

BMW GROUP, CARIAD, CodeThink, HARMAN, Mercedes-Benz Tech Innovation, Microsoft, BOSCH Invented for life, VECTOR, ZF GROUP, accenture

Source: CAM, Eclipse Foundation 2025.

S-CORE INITIAVE since 2024

- **Safe Open Vehicle Core:** open-source project focused on developping an open software core for SDV
- middleware platform situated between OS and application layers
- goals: standardize the development of complex vehicle software, facilitate collaboration between automotive manufacturers and suppliers, accelerate innovations

SDV: Status quo
Software platform

CENTER OF AUTOMOTIVE MANAGEMENT

A standardized, modular SW platform and API structure is the foundation for reuse, scale, and ecosystem integration.

- Platform complexity varies considerably among OEMs, ranging from more than five different software platforms (e.g., within the VW Group) to just one platform used by new, software-driven brands like Tesla, Nio or Xpeng.
- Hardware-based vehicle platforms also contribute to complexity. For example, the multi-brand Stellantis Group has to manage around 16 different platforms on which vehicles are currently offered worldwide. The goal, however, is to reduce this number, with STLA Brain playing a central role in the future.
- The communication between individual components via defined interfaces (APIs), both within the vehicle and externally, is one of the key advantages of SDVs. Here, complexity increases with the number of platforms. External interfaces, in particular, offer the advantage from a customer perspective that additional functions can be integrated via third parties. Tesla, for instance, only has to manage one API toolkit and has made this available to third-party software since 2023 (see TeslaMag 2023).

Current software and vehicle platforms of selected OEMs in comparison

Crit. 1 Software platform

	VOLKSWAGEN GROUP	TOYOTA	STELLANTIS	BMW GROUP	Mercedes-Benz	BYD	GEELY	TESLA
Software platforms	E^3 1.1 E^3 1.2 CEA (mit Xpeng) SSP Additional legacy platforms like MIB etc. based on **~12 vehicle platforms** like PQx, MQB, MEB etc.	Arene Aditional legacy platforms like Automotive Grade Linux (Infotainment), Toyota CONNECT, Toyota T-Connect etc. based on **6 vehicle platforms** (TNGA-x)	STLA ABC Additional legacy platforms based on **~19 vehicle platforms** like Chrysler/ RAM/ Jeep, Fiat, PSA, STLA Small/ Medium/ Large etc.	Superbrains NK/ OS X* OS 9 Additional legacy platforms based on **5 vehicle platforms** like UKL, FAAR, CLAR, AOL etc.	MB.OS MBUX Additional legacy platforms based on **6 vehicle platforms** like MRA2, MMA, EVA2, MB.EA etc. and future platforms VAN.EA, AMG.EA	e-Platform 3.0 + DiLink Additional legacy platforms based on **4 vehicle platforms** DM-platform for hybrid vehicles and e-platforms	SEA GEA 3.0 Additional legacy platforms based on **11 vehicle platforms** like SPA, SPA2, CMA, PPA, SEA-Z, EPA, M.A.P. etc.	Tesla unified software platform for all models** NIO Nio SkyOS for all current models XPENG X-EEA 3.0 + Xmart OS / SEPA 2.0, CEA (mit VW)
Number of software platforms	>5	>2	>2	>3	>3	>2	>2	1-2 (each)
Number of vehicle platforms	~12	6	~16	5	6	4	11	1-2 (each)

SDV: Status quo
Software platform: Conclusion

CENTER OF AUTOMOTIVE MANAGEMENT

The "Unified software platform" criterion describes the OEM's ability to develop a vehicle software – ideally for its entire product portfolio – that can be flexibly supplemented and improved with new functions across all domains.

Summary: Success criteria for "Software platform"

Crit. 1 Software platform

Aspects	Description 1
Market	**Years of market experience with SDVs:** Long-term experience with software-defined vehicles, like at Tesla, means greater progress on the learning curve and faster developments in the future.
SDV-Models	**Number of current and planned SDV models in OEMs lip:** In addition to many years of experience, numerous model introductions of SDVs (e.g. Xpeng, NIO) also speak in favor of a sufficient software platform.
Platforms	**Number of current software platforms:** A low number of Software platforms indicate the unified approach. Ideally, one mature platform like Tesla would be best. Additionally, a high number of hardware platforms within the group (e.g. Stellantis) increases the complexity.

Software platform: BMW (exemplary)

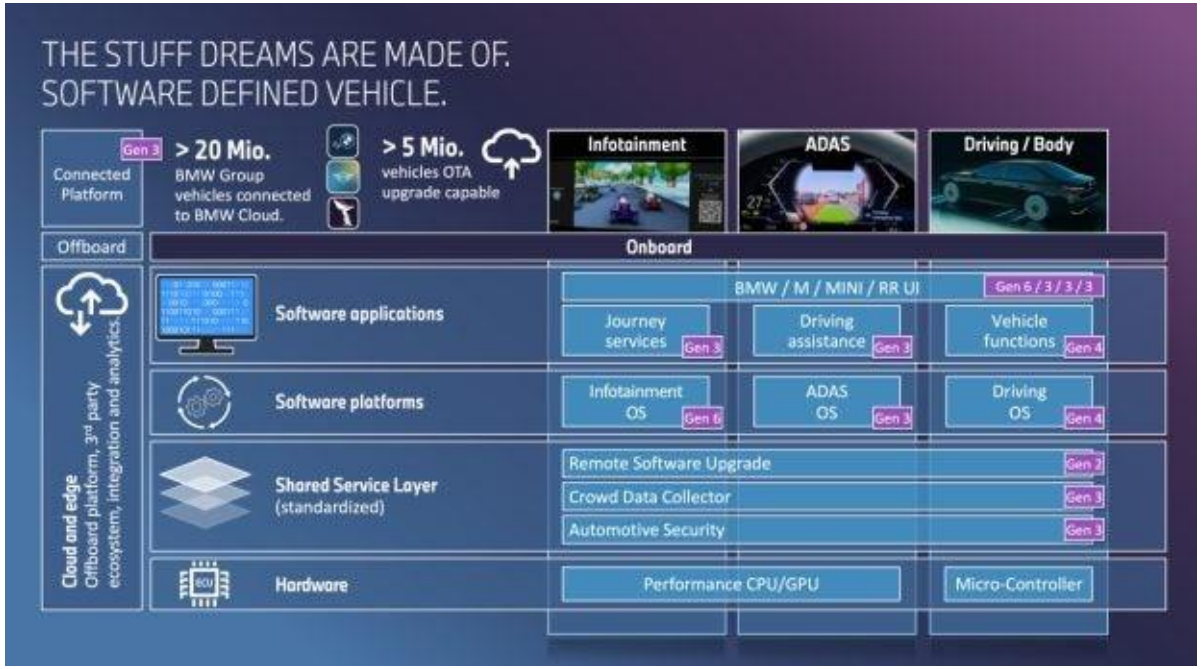


Image source: BMW

CONCLUSION

A "Unified Software Platform" is optimally implemented when it is already mature and rolled out across many of the OEM's brands and models. For low complexity, the company should ideally have as few software (and hardware) platforms as possible.

SDV: Status quo

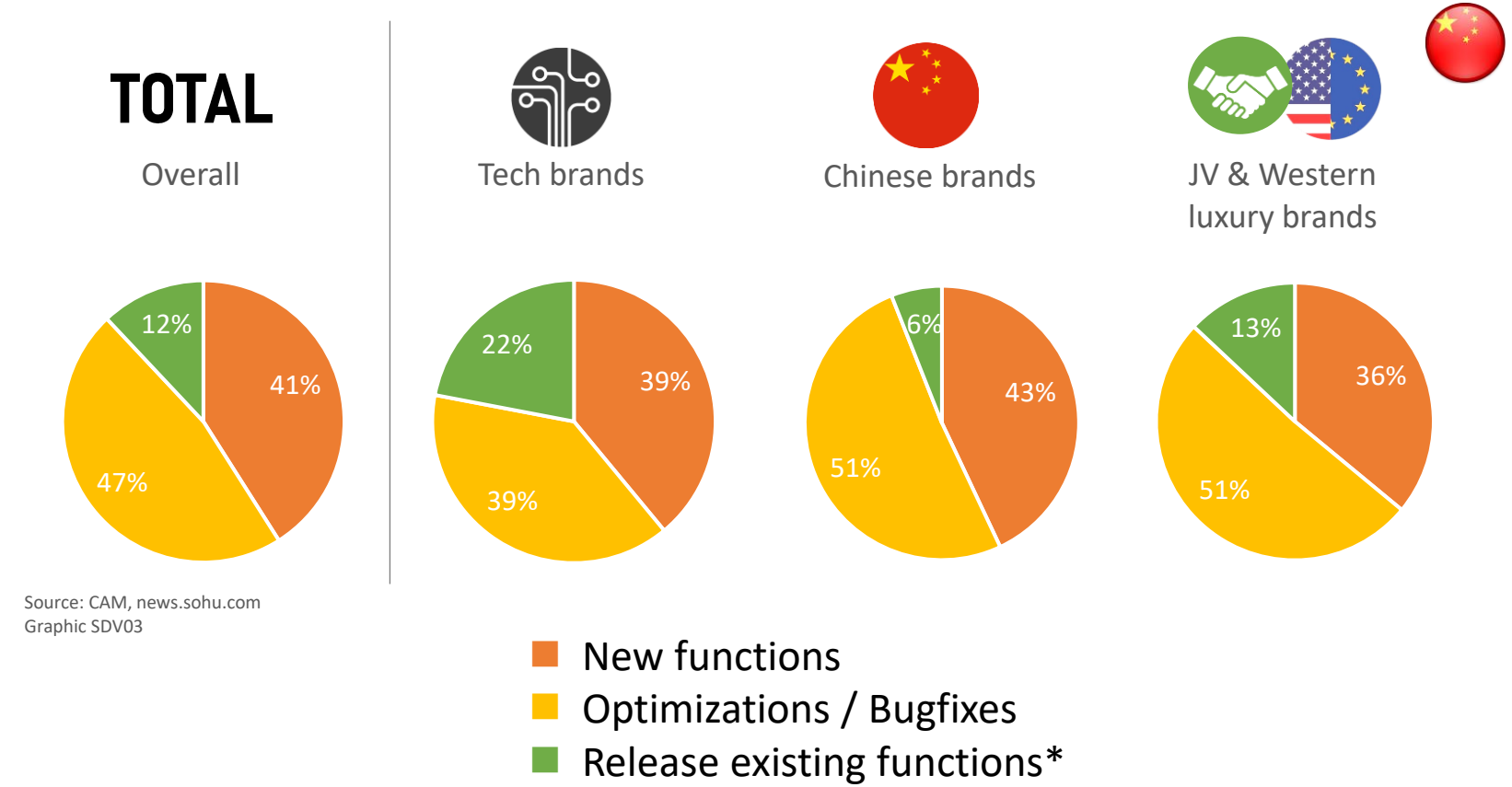
OTA-Updates: Example Chinese market

When it comes to OTA updates it is not all about quantity but quality: Beside mere bugfixes Chinese customers expect added value in the form of new functions and additional features.

- One of the key advantages of SDVs is the possibility to keep the vehicles in fleet up-to-date. Therefore, no visit in a repair shop is necessary, but updates come “over-the-air” (OTA).
- In our example market China, nearly half of OTA updates consist of optimizations or bug fixes, while new functions make up about 41% and the release of existing functions accounts for the smallest share.
- Tech brands provide a relatively balanced mix of new functions and optimizations, but they deliver a notably higher share of releases of existing functions compared to other brand groups.
- Chinese brands and JV/Western luxury brands focus more heavily on optimizations or bug fixes, while new functions remain the second-largest category and releases of existing functions represent only a small portion of their OTA updates.
- In terms of technology the voice assistant gets most updates by far within the example period (84), followed by navigation or map updates (52). Already in third place is a safety-relevant category: A total of 43 updates to driver assistance systems were released.

Share of OTA updates in China by update quality (Example: June 2025)

Crit. 2 OTA updates



Source: CAM, news.sohu.com
Graphic SDV03

Source: CAM, news.sohu.com | June 2025 * Function is already provided on the hardware side (e.g. an assistance system) and is released via an update or software activation, e.g. after a purchase, subscription or trial period.

SDV: Status quo
OTA-Updates: Tesla

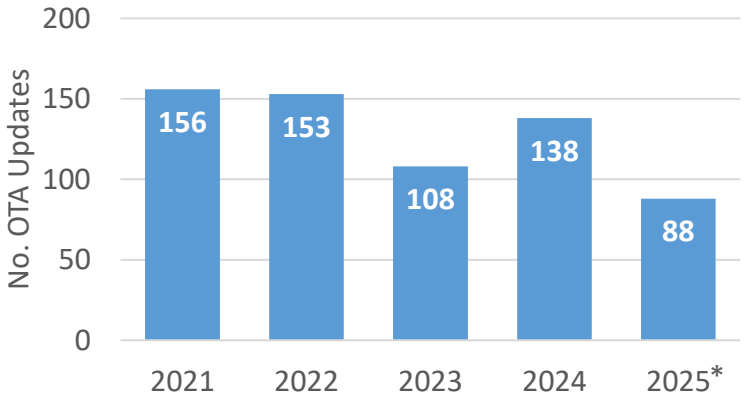
Over-the-air (OTA) updates are part of Tesla's brand DNA and are offered across all platforms for all production vehicles, starting from their first model years.

- One of the pioneers with OTA updates is Tesla. Since 2012 these updates are possible in Model S and during the last years the OTA frequency throughout the whole model range is continuously high with over 100 updates per year in 2021–2024), underscoring the strong software and lifecycle focus of its vehicles. At Tesla, right from beginning vehicle development doesn't end with the start of production, just delivery changes.
- Approximately 70% of OTA updates address bugs, while about 20% introduce new features—an indicator of stable software maintenance combined with ongoing functional development.
- Extensive functional enhancements via OTA: The timeline for the second half of 2024 shows that Tesla rolls out infotainment, ADAS, comfort, safety and service features via OTA (e.g. Autopark, Vision features, media apps, holiday updates), not just small software patches.

Number of OTA updates: example Tesla

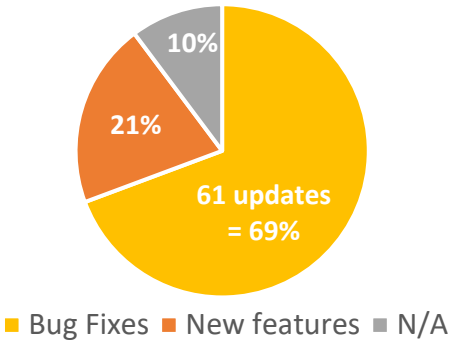
Crit. 2 OTA updates

Tesla Number of OTA updates (total)



Source: CAM/ TeslaScope 2025. Graphic SDV05 *Until end of Oct.

Tesla Number of OTA updates by type 2025*



Source: CAM/ Teslascope 2025. Graphic SDV6 *Until end of Oct. 2025.

Tesla OTA feature updates (expl. 2nd half 2024)

Source: CAM, TeslaScope 2025, Notateslaapp 20252. As of October 2025

SDV: Status quo

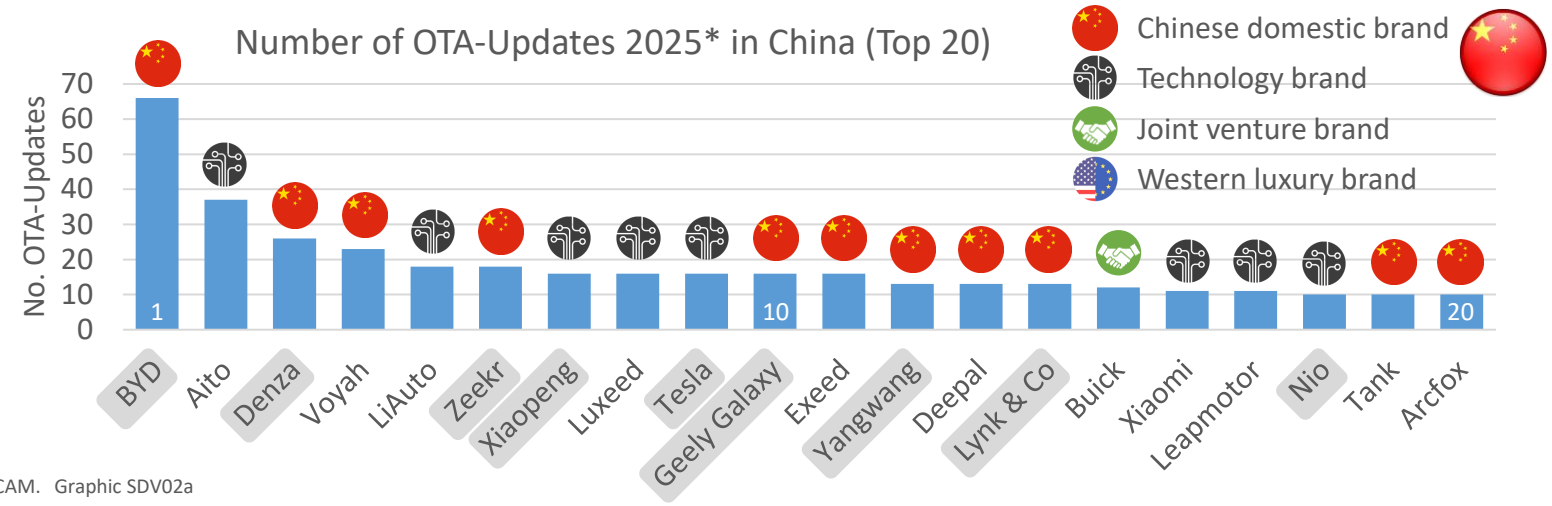
OTA-Updates: OEMs in comparison (Chinese market)

Winning OEMs shift from Start-of-Production (SOP)-driven cycles to a continuous delivery mindset, treating the car as a platform that evolves over its lifetime.

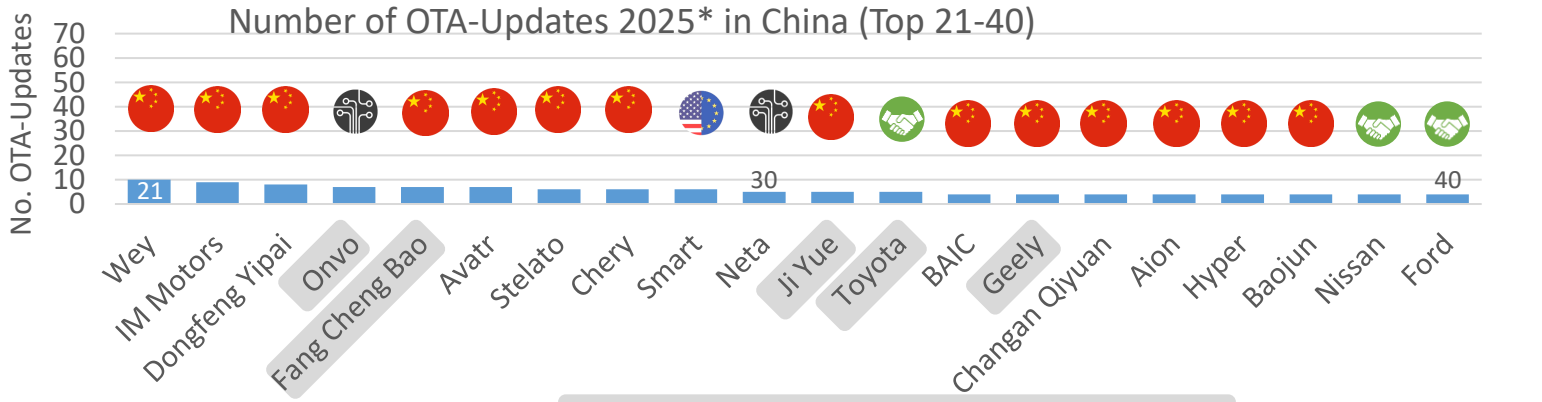
- The software-defined vehicle with a corresponding E/E-architecture (one or a few central computers) is what makes comprehensive OTA updates possible in the first place, or at least significantly facilitates them.
- The ability to keep a vehicle up-to-date throughout its entire life cycle and even to equip it with completely new functions is one of the most important advantages of an SDV from a customer perspective.
- The number of registered OTA updates in Chinese market in twelve month between July 2024 and June 2025 shows, that Chinese domestic brands as well as technology brands (which are mostly Chinese, too) are clearly in front. Western or even joint venture brands are far behind e.g. BYD, Aito, LiAuto, Zeekr (Geely group) or Xiaopeng. German Automobile manufacturers like VW, BMW, Mercedes or Audi are not even present in the top 40 list and are ranked from place 52 downwards. Unlike many Chinese OEMs, the German manufacturers did not yet have an SDV on the market during the period under review.

Number of OTA updates for selected automotive brands in China 2024/25*

Crit. 2 OTA updates



Source: CAM. Graphic SDV02a



Source: CAM. Graphic SDV02b

KEY: Brands of OEMs considered as examples in this study.

Source: CAM, news.sohu.com 2025. As of October 2025. * Month:7/2024 - 6/2025.

SDV: Status quo

OTA-Updates: OEMs in comparison (Chinese market)

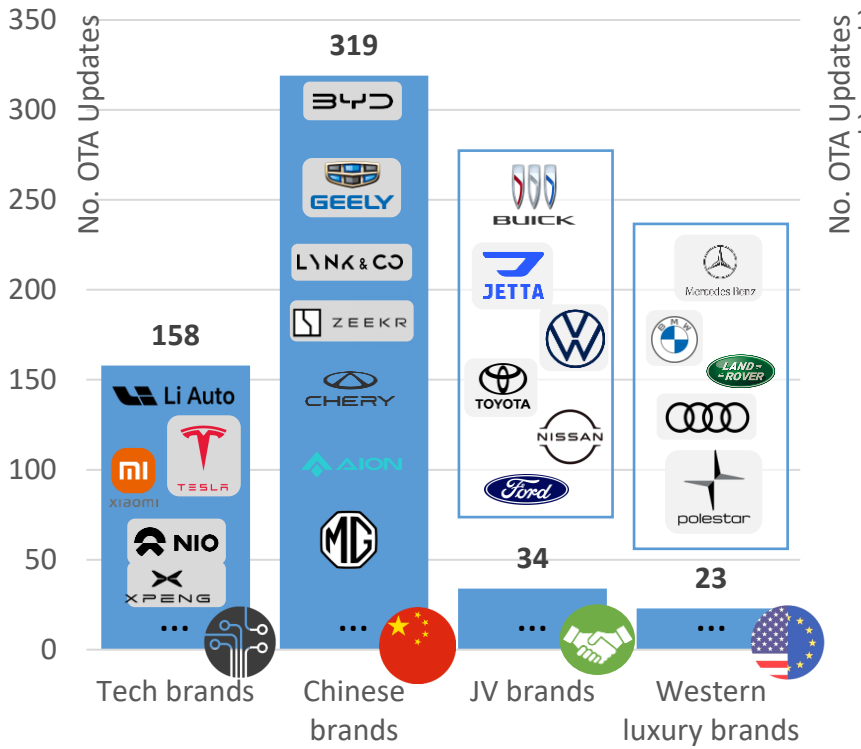
Technology brands, as well as some traditional Chinese manufacturers, were able to develop SDVs directly without an existing platform and in most cases took advantage of this opportunity.

- Brands with a strong focus on new technology like Tesla or Nio as well as more traditional Chinese brands like Zeekr (Geely) or BYD took advantage of the “greenfield approach”. They were able to develop a new software platform for new cars with build-in opportunity of profound OTA updates, not only for infotainment or navigation maps but also for safety-related functions like ADAS or drivetrain.
- Most OTA updates in the period of twelve month up to June 2025 cam from Chinese domestic brands with 319 updates, followed by tech brands with 158. Joint venture and western brands follow at a considerable distance with only 34 and 23 updates, respectively.
- If you look at the number of OTA updates not as an absolute figure but related to the number of brands in each category, the dominance of technology brands becomes obvious. These manufacturers are able to release updates almost monthly (11,3 in 12 month), while brands like VW or Ford only get 3,8 OTA updates. It is striking that premium brands like Mercedes-Benz or Audi are even lower, with around 2 updates. It will be interesting to see of upcoming SDVs like Mercedes’ CLA can increase this value.

Number of OTA updates in China by brand category 2024/25

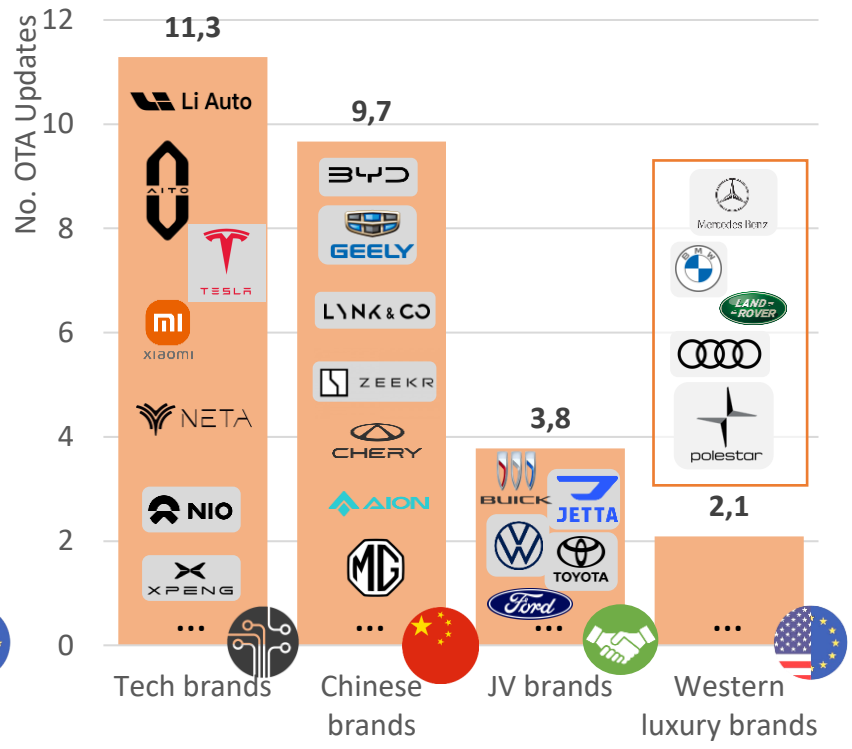
Crit. 2 OTA updates

No. of OTA Updates by Brand Category 2025*



Source: CAM. Graphic SDV02c

No. of OTA Updates per Brand 2025*



Source: CAM. Graphic SDV02d

KEY: Brands of OEMs considered as examples in this study.

Source: CAM, news.sohu.com 2025. As of October 2025. * Month:7/2024 - 6/2025. Top-10 brands each category, if applicable.

SDV: Status quo

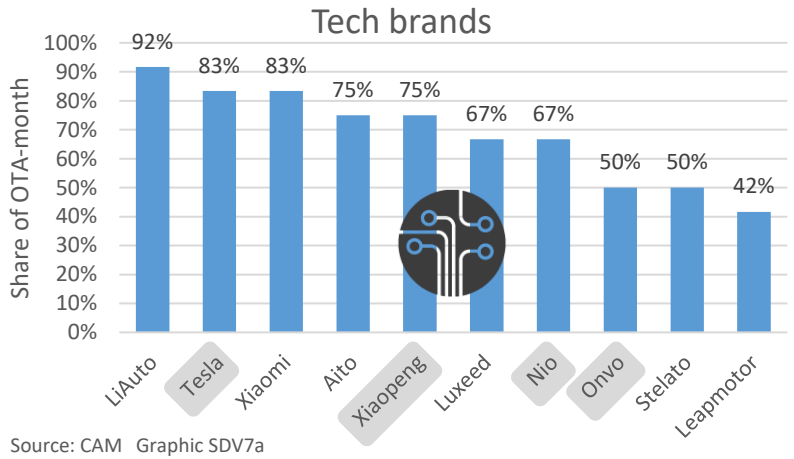
OTA-Updates: OEMs in comparison (update frequency)

More of a hygiene factor than a sales argument: Chinese customers expect OTA updates. Besides the sheer number, the frequency also plays an important role in the Chinese market.

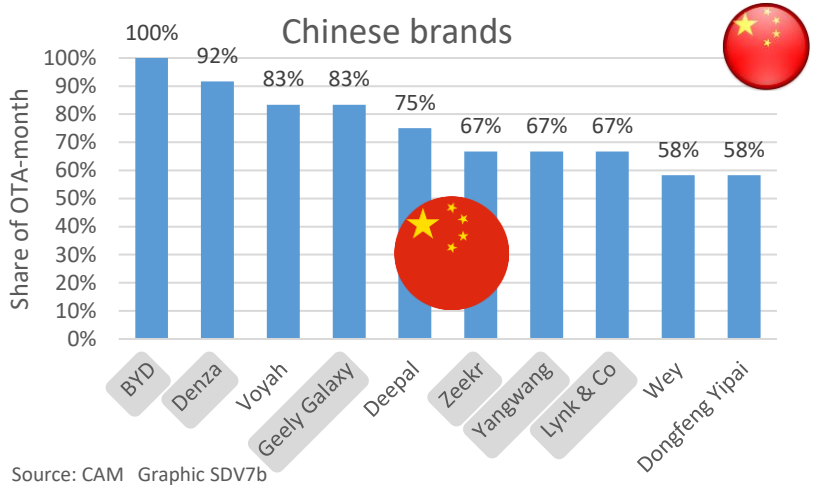
- In China, monthly updates are almost standard, and some brands like BYD have a significantly higher frequency. In many months of the observation period, BYD released between four and nine updates, suggesting an almost weekly frequency.
- Similar to previous analyses, the technology and Chinese brands are leading in update frequency. The top 10 brands among these released at least one OTA update in ca. 75 percent of all months in the period up to June 2025. Among Western and premium brands, this figure is only around 20 percent.
- Surveys show that 69% of Chinese consumers value over-the-air (OTA) functionality, and 62% would even be willing to pay for it. This demonstrates high expectations for OTA capabilities in vehicles.**.
- Studies on consumer expectations suggest that in China, digital vehicle functions, and therefore over-the-air (OTA) software updates, are now considered crucial factors for vehicle sales.*** This means that OTA updates are not just a "nice-to-have," but are perceived by many Chinese customers as a standard feature of a modern vehicle.

Update frequency: Share of month with at least 1 OTA update (Top-10)*

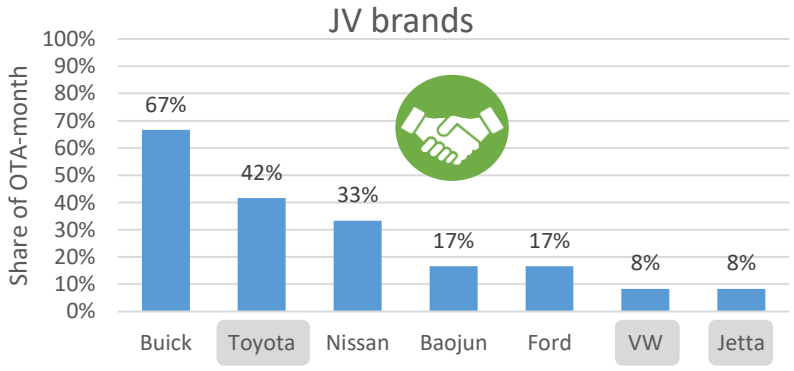
Crit. 2 OTA updates



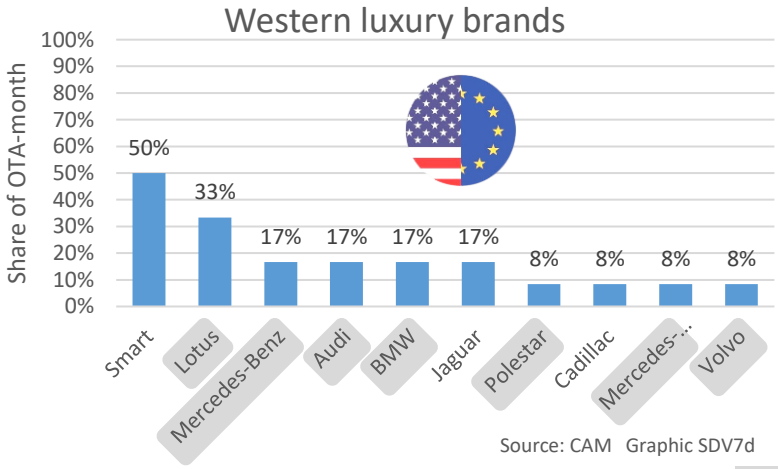
Source: CAM Graphic SDV7a



Source: CAM Graphic SDV7b



Source: CAM Graphic SDV7c



Source: CAM Graphic SDV7d

KEY: Brands of OEMs considered as examples in this study.

Source: CAM, news.sohu.com 2025. As of October 2025. * Month:7/2024 - 6/2025. Top-10 brands each category, if applicable. ** Source: KPMG/Business Insider 2021: Impact of Chinese OEMs in Europe (Part II). *** MHP 2023: The Software Race.

SDV: Status quo
OTA-Updates: Conclusion

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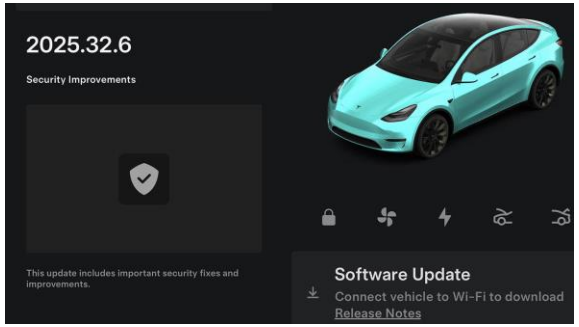
The “OTA Updates" criterion describes the OEM's ability to take use of one of the most important SDV advantages: To improve the product after it has left the factory.

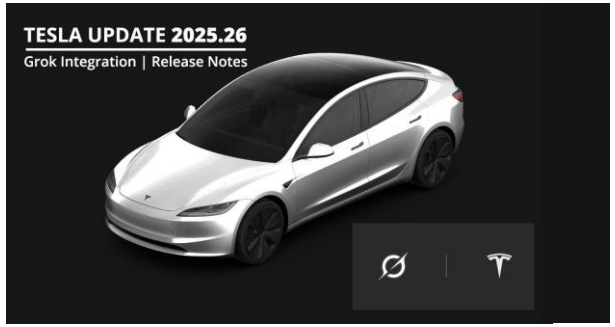
Summary: Success criteria for “OTA Updates”

Crit. 2 OTA updates

Aspects	Description 2
Domains	**Number of updatable domains:** The domains differentiated are infotainment, comfort/body, powertrain, and ADAS/AD. The more numerous and complex these domains are capable of OTA updates, the more advanced the OEM is rated.
Frequency	**Frequency of OTA updates:** Not many updates, but the ability to roll out updates with high frequency, if necessary, is an important criterion.
Fleet size	**Number of vehicles with OTA-update capability:** A large fleet of vehicles capable of receiving OTA updates is a testament to the OEM's extensive experience and an important step in transforming vehicles from purely hardware-based products into connected, constantly improving platforms.

OTA-Updates: Tesla (exemplary)





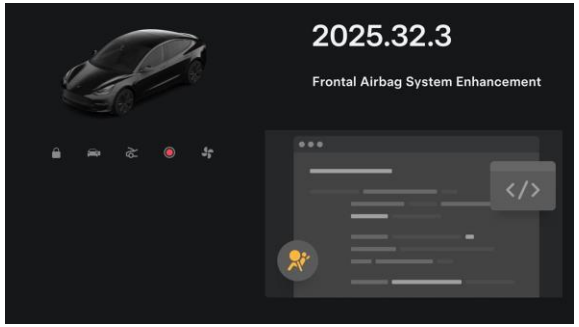


Image source:: Tesla

CONCLUSION

A large fleet of OTA-enabled vehicles is crucial for car manufacturers because it enables continuous improvements, reduces workshop costs (by avoiding physical recalls), strengthens customer loyalty and opens up new business models with paid functions.

SDV: Status quo
Central Computer Strategy

CENTER OF AUTOMOTIVE MANAGEMENT

Decoupling software from hardware cycles unlocks parallel innovation, faster time-to-market, and greater flexibility.

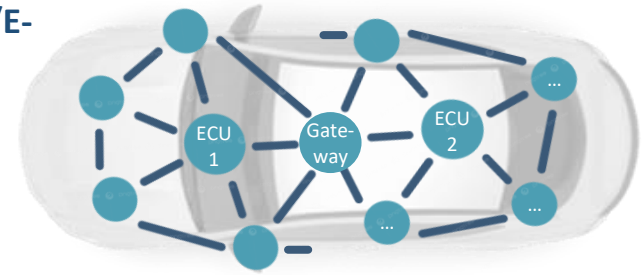
- Vehicle electrical and electronic (E/E) architectures have evolved through three main stages — distributed, domain, and zonal — each offering different balances of complexity, cost, and efficiency.
  - **Distributed E/E-architecture:** Traditionally, vehicles use many small ECUs, each handling a specific function (e.g., braking, lighting). These are networked via CAN buses, resulting in heavy wiring and high system cost. Advantages include modularity and redundancy, but scalability and bandwidth are limited.
  - **Domain E/E-architecture:** Groups ECUs by function (domains such as powertrain, chassis, or infotainment), each managed by a domain controller. This reduces ECU count and wiring slightly while improving organization and communication efficiency.
  - **Zonal E/E-architecture:** Divides the car into physical zones (front left, rear right, etc.), with one controller per zone handling all functions locally and serving as a communication hub. It minimizes wiring, enables easier software updates, reduces cost and weight, but introduces challenges with latency and cybersecurity.

Types of E/E-architectures with main application period and advantages of SDVs

Crit. 3 CPU strategy

Distributed E/E-Architecture

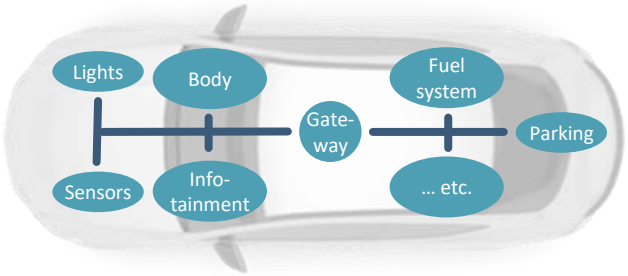
1990 - 2015



- Each ECU is dedicated to one function
- Modern vehicles with more than 100 ECUs
- Heavy and complex wiring,
- CAN bus network
- Software coupled to hardware

Domain E/E-Architecture

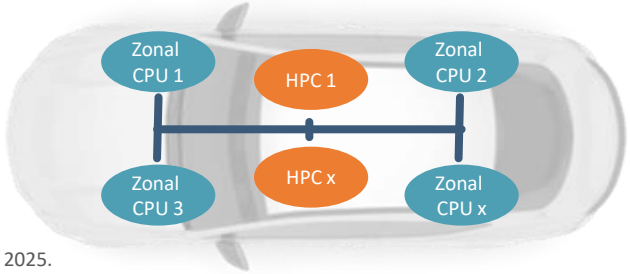
2010 - 2025



- Domain-specific CPUs with functional division
- CPUs controlling sub-ordinate ECUs and sensors/ actuators
- Limited OTA update functionality

Zonal E/E-Architecture

2025+



- One or two central high power CPUs
- Few zonal CPUs controlling sensors/ actuators
- Complete decoupling of hardware, software and car models/ SOPs

Source: CAM/ LeddarTech 2025.

SDV Advantages (Example BMW)

BMW GROUP

4 central performance computers (Superbrains)

Co-location for efficiency

< 400W
E/E system energy consumption

Physical headroom
for hardware upgrades

30% less weight

factor **3.000** less variants

Automated production
of sub-harnesses

Source: Grote (2025)

SDV: Status quo
Central Computer Strategy: E/E-Architecture

From domain based to zonal architecture: OEMs like BMW, Volkswagen and Toyota communicate their plans for future E/E architectures, while "new" players like Tesla, Nio or Xpeng have already largely implemented them.

- Centralized approach as the foundation for SDV: Major OEMs like BMW Group, Volkswagen Group or Toyota are transitioning from distributed control units to centralized or zonal computing architectures to enable software-defined vehicles.
- Separation of hardware and software: All examples demonstrate a clear layering of hardware, middleware, and software platforms (e.g., BMW "Superbrains", Toyota "Arena", VW CEA) to support over-the-air updates, data management, and AI functions.
- From domains to vehicle regional zones and centralization: The transition is evident from domain-based integration (e.g., ADAS, cockpit, body) to zonally networked architectures with a central computer. Future vehicle architectures are software-centric, updatable and integrated across functions.
- Pioneer Tesla has been relying on these core elements since 2012: a Full Self-Driving (FSD) computer and a SoC-based central infotainment computer, additionally, there is a battery/ powertrain controller and a high-speed network connection for data-intensive functions.

Central computer strategy – examples

Crit. 3 CPU strategy

BMW GROUP

"Neue Klasse" Software Stack with „Superbrains foundation"

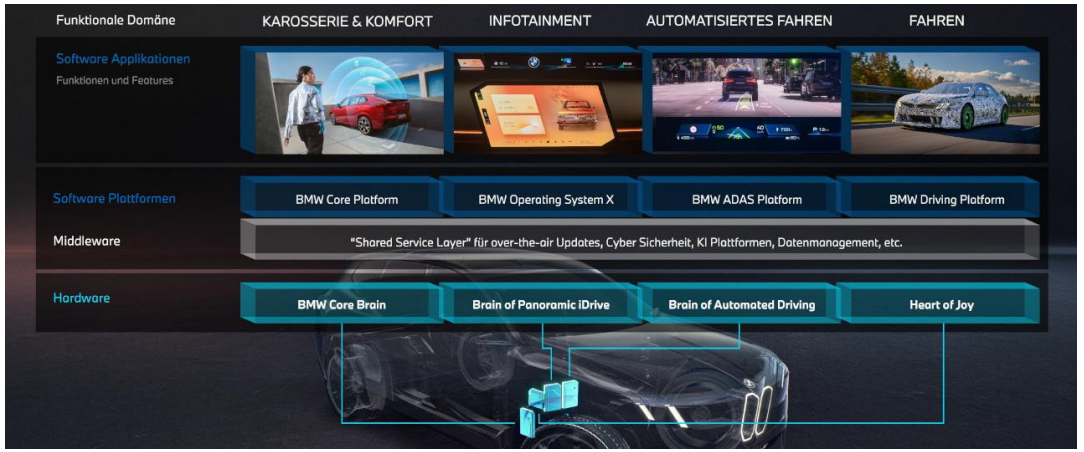


Image source:: BMW

VOLKSWAGEN GROUP

New China Electrical Architecture (CEA)

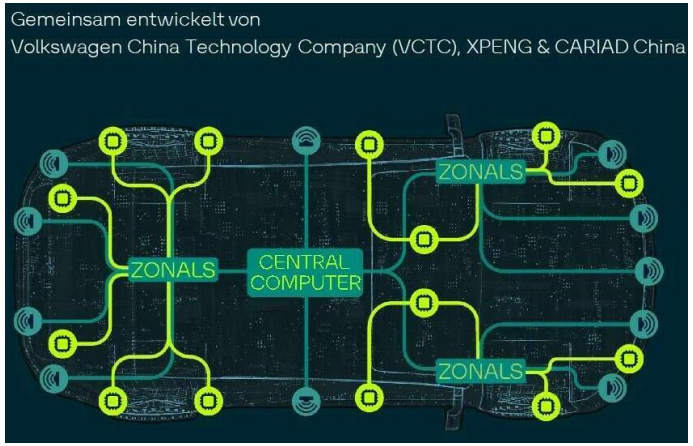


Image source:: Volkswagen

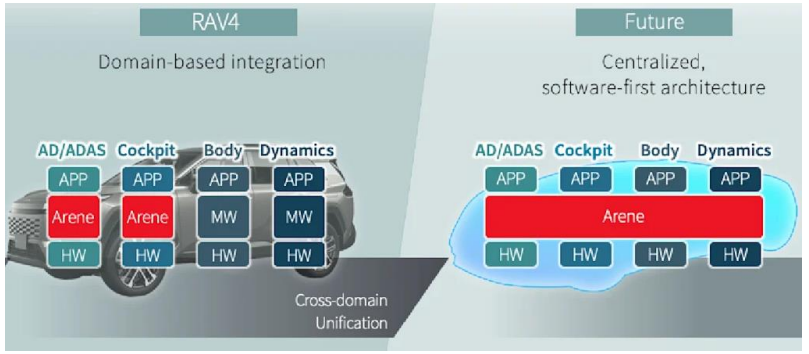


Image source:: Toyota

TOYOTA **Arene Architecture 2026 (RAV4) and future**

Source: CAM | As of October 2025. * Next generation technology platforms, exact number of CPUs not published, ECUs reduced by 50% on ~60 units.

SDV: Status quo

Central Computer Strategy: OEMs in comparison

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All OEMs are striving for a centralized hardware platform with a few high-performance computers, while some OEMs have already implemented this new industry standard.

- OEMs have different plans concerning their hardware layout of software-defined vehicles. That affects the software platform as well the number of central computers – an important factor of complexity and integrity.
- At Volkswagen Group, at least three software platforms are planned: The already introduced E³ 1.2, which is used by Audi and Porsche already, additionally the China-platform CEA, and for western markets the platform developed by the Rivian joint venture.
- Toyota and Stellantis have plans for the (near) future to implement their central computer strategy. Among the sample group, these are the only OEMs who have not yet implemented their strategy.

Central computer strategy – selected OEMs in comparison

Crit. 3 CPU strategy

OEM	PLATFORM	NO. OF CPUs*	DESCRIPTION
VOLKSWAGEN GROUP	E³ 1.2	5 ✓	Expl. Audi with 5 High Performance Computers: HCP 1: Drivetrain and chassis. HPC 2: ADAS, HPC 3: Infotainment,. HPC 4: Comfort/body HCP 5: connectivity.
	CEA	3 ✓	3 high performance central computers, reducing quantitiy of ECUs by 30%, cross-zonal OTA updates.
	Rivian JV	7	Rivian with 7 central computers on current Rivian platform for: infotainment, autonomy, motor drive units, battery management and others.
TOYOTA	Arene	4	Arene-platform, first introduction with RAV4. 4 central computers for: AD/ADAS, Cockpit, Body, Dynamics.
STELLANTIS	STLA ABC	3**	STLA Brain, STLA SmartCockpit, STLA AutoDrive, partly still in development.
BMW GROUP	Neue Klasse	4 ✓	"Neue Klasse"-platform with 4 "superbrains": Infotainment, automated driving, driving dynamics and basic functions. Each with own software platform
Mercedes-Benz	MB.OS	2 ✓	2 high performance computers: Infotainment, ADAS/AD. Additionally 2 control units: driving/ charging, body. 1 connectivity module.
TESLA	Tesla	2 ✓	Architecture in Model 3/Y: FSD (full self driving) for ADAS, MCU (media control unit) for infotainment applications.
NIO	Sky OS	4 ✓	2 Shenji NX9301 chips, 2 Qualcomm Snapdragon 8295 chips. Sky OS schedules tasks on multi-core system.
BYD	e-Platf. 3.0	4 ✓	≥3 Domain-Controller + 1 ADAS-Compute (Orin; High-End teils 2× Orin-X)
GEELY	SEA/ GEA	2 ✓	2 Core Computer (additionally 2 Zonal Controller)
XPENG	X-EEA	2 ✓	1 zentrale Supercomputing-Plattform + ADAS-ECU (z. B. 2× NVIDIA Drive Orin SoCs / 508 TOPS)

Source: CAM | As of October 2025. *✓ = implemented. ** Next generation technology platforms, exact number of CPUs not published, ECUs reduced by 50% on ~60 units.

SDV: Status quo

Central Computer Strategy: Conclusion

CENTER OF AUTOMOTIVE MANAGEMENT

The hardware side: In order to enable OTA updates with acceptable complexity, the fragmented electronic control unit architecture must transform into a centralized architecture with a few high-performance computers.

Summary: Success criteria for "CPU strategy"

Crit. 3 CPU strategy

Aspects	Description 3
Architecture	**Type of hardware architecture:** The hardware architecture has developed from distributed to domain-based ECUs. The next step and crucial for SDVs is the zonal architecture for minimized wiring, easier software updates and reduced cost and weight.
Bus system	**Type of bus system:** Few, fast computers need a fast connectivity with automotive ethernet instead of CAN bus or flexray. Ethernet delivers sufficient bandwidth, centralization and cloud integration.
Computers	**High Performance CPUs:** Instead of the old principle "one function – one ECU" modern SDVs need only few (most OEMs use a maximum of 4) but very fast computers for e.g. autonomous driving with sensor fusion and AI models.

CPU strategy: Mercedes-Benz (exemplary)

Image source:: Mercedes-Benz

CONCLUSION

Without a Central Computer Strategy, there is no true Software-Defined Vehicle. It is the technical and organizational key to becoming OTA-enabled, AI-enabled, scalable, update- and service-oriented.

SDV: Status quo
Vehicle AI integration

CENTER OF AUTOMOTIVE MANAGEMENT

AI-driven engineering is the key lever to free capacity, eliminate inefficiencies, and dramatically accelerate development speed.
Within the vehicle, AI is – besides autonomous driving – the key lever to improve a more complex interface for the driver and passengers.

AI Integration in products (focus) and organization

Crit. 4 Vehicle AI integration

Impact of artificial intelligence on SDV

Product-related impacts
(focus in this survey)

Infotainment

Intelligent Voice Assistants
- Control various vehicle functions by voice
- Optimize routes based on the user's preferences

Interface Assistant
- Automated operations
- Learning interfaces

ADAS/AD

More effective driver assistance systems
- Anticipation of hazards and automatic interventions
- Fast detection of other road users by image recognition and computer vision
- Behavior adaption to traffic conditions and the environment by machine learning

Services

Anomaly detection
- Plan maintenance proactively
- Reducing the risk of breakdowns
- Extending vehicle life

OEM Organization

Vehicle development
- Simulation/ testing
- …

Vehicle production
- Quality control and testing
- Manufacturing

Supply chain optimization
- …

Benefits

Product Quality
- Increased safety and comfort for end customers
- Improved test coverage
- Automated consistency and traceability reports

OEM Speed
- Faster prototyping
- Increased time-to-release through test automation
- Faster change management
- Automated historical data analysis

OEM costs
- Reduction of manual tasks
- Reduced efforts in supplier management through automated requirements management
- Analysis to prevent component defects

Challenges

Cyber security
- Automated software vulnerability checks
- Automated error detection and management

Personal data protection
- Danger of customer data leaks
- OEM data protection management

Source: CAM, Valeo 2025, Bezerra 2025, PTC 2025.

SDV: Status quo

Vehicle AI integration: Example BMW

BMW is a good example of comprehensive use of artificial intelligence during the whole vehicle development and production cycle, as well as for customer benefits.

AI Integration: Example BMW

Crit. 4 Vehicle AI integration

Product-related impacts (focus in this survey)

Vehicle Development	• Investing in tools to improve engineering processes, such as a tool for analyzing requirements documentation and technical standards and regulations, to increase efficiency and precision in development. • Using AI in product development for comprehensive simulations, e.g., in the areas of crash simulation, aerodynamics, and autonomous driving. This reduces the dependence on physical prototypes and enables faster development cycles.
Vehicle Production	• Goal: The fully digital BMW iFACTORY. BMW AI Quality Platform (AIQX) enables continuous monitoring of production lines, real-time analysis of sensor and image data for rapid error detection and correction. • Research into the use of humanoid robots for complex assembly tasks, intelligent transport systems, and autonomous driving of new cars as a logistics application on BMW factory premises.
Product Integration	• The BMW Intelligent Personal Assistant uses artificial intelligence to learn the user's personal habits from your voice commands. • Goal: Better information tailored to personal needs. Start market: Germany, others planned.
Customer Services	• Use of an AI-based assistant for customer questions around the clock, providing verified information from a knowledge database on BMW products and services. • Proactive Care: Tools that allow the vehicle to automatically detect existing and foreseeable service or repair needs, often acting proactively and proactively offering the customer solutions.
Others	• Artificial intelligence in purchasing: Tender Assistant, Offer Analyst, multi-agent system AIconi.
Conclusion	**Comprehensive and advanced use of AI, not only in vehicle**

Image source:: BMW

Source: CAM, BMW Group 2025 | As of October 2025

SDV: Status quo

Vehicle AI integration: OEMs in comparison

CENTER OF AUTOMOTIVE MANAGEMENT

In automotive product environment, AI support plays a key role especially in the areas of operating concepts and personal assistants (besides autonomous driving) .

- Regarding the integration of artificial intelligence, the focus here is on **product-related applications for car interfaces.** Two application areas with particularly large AI impacts are considered:
  - **AI Operating Concept:** The system recognizes frequently recurring patterns (e.g., the daily commute to work) or certain preferences of the driver and can make suggestions or even perform certain actions based on this.
  - **AI Personal Assistant:** The voice control and information is based on generative AI with Large Language Models and enables comprehensive interaction with the driver, e.g., regarding the vehicle, traffic, POIs, knowledge content, etc.
- Further AI integration, e.g. in vehicle production, development or after-sales, provides additional insights and innovation potentials for OEMs.

CONCLUSION

Among the OEMs considered here, nearly all make use of AI in the vehicle context at least for one application (e.g. Geely for interfaces/ personal voice assistants).

Vehicle AI Integration by selected OEMs

Crit. 4 Vehicle AI integration

OEM	AI OPERATING CONCEPT	AI PERSONAL ASSISTANT
VOLKSWAGEN GROUP	• Audi Assistant: Learning from user routines, proactive suggestions and actions • Audi A6 / Q6 e-tron, Porsche (2024)	• ChatGPT integration • VW Golf, VW ID.3 etc. (2024)
TOYOTA	• Not implemented yet, only air condition that measures passengers' temperature for automatic control	• In Arene platform planned from 2026 on • Own GenAI LLM as prototype
STELLANTIS	• Still in development, together with Mistral AI	• ChatGPT integration • Peugeot 208, 308, etc. (since 2024)
BMW GROUP	• BMW Intelligent Personal Assistant, learning from drivers' habits	• Development of KI assistant together with Amazon (Alexa) • Planned for Neue-Klasse-Modelle
Mercedes-Benz	• Pioneer with MBUX prediction features • CLA with virtual assistant for routines	• First OEM with ChatGPT • Addressing >3 million customers
TESLA	• Vehicle learning operating concept for preconditioning (A/C only)	• Since 2025 version 4 of Tesla owned Grok assistant is in Tesla vehicles available
NIO	• In combination with NIO learning operation and suggestions, but not fully automated	• Since 2024 NioGPT for assistant NOMI, partner Microsoft Azure Open AI
BYD	• Passive assistant with suggestions	• Personal voice assistant
GEELY	• AI interface in Full-Domain AI 2.0 and G-ASD	• Personal voice assistant
XPENG	• X-Combo system • Partly implemented, based on defined rules	• Personal voice assistant

Source: CAM | As of October 2025.

SDV: Status quo
Vehicle AI integration: Conclusion

CENTER OF AUTOMOTIVE MANAGEMENT

The integration of AI into the vehicle is a customer-relevant application made possible by the software-defined vehicle. It particularly simplifies the increasingly complex operation of the vehicle for the customer.

Summary: Success criteria for "Vehicle AI integration"

Crit. 4 Vehicle AI integration

Aspects	Description 4
Assistant	**AI-based voice assistant:** Voice control and knowledge retrieval using artificial intelligence as a thematically comprehensive language model with regard to vehicle operation, traffic, POIs, knowledge content, etc.
Interface	**AI-based operating concept:** A learning vehicle interface that recognizes frequently recurring patterns (e.g., the daily commute to work) or certain preferences of the user and can perform actions independently based on this.
AI & OEM (supplementary aspect)	**Further AI application areas:** AI integration in the whole value chain from research and vehicle development, production and after sales services.

Vehicle AI integration: BMW (exemplary)

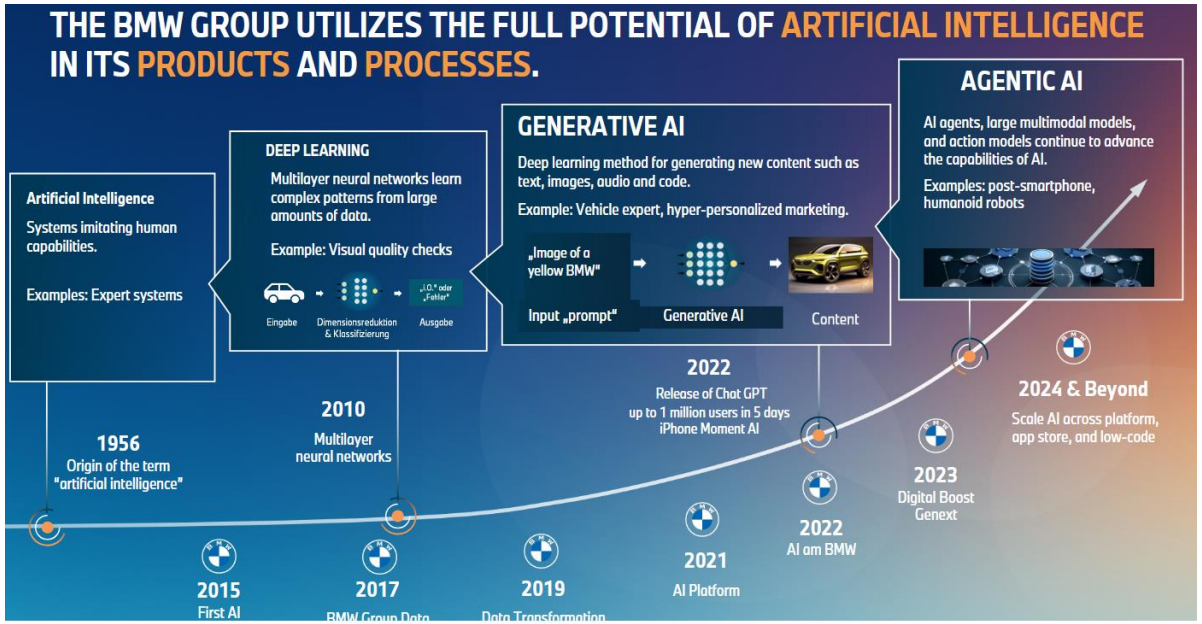


Image source: BMW

CONCLUSION

SDV answers the question: How is software brought into the vehicle? AI goes a step further and answers the question: What can this software intelligently do?

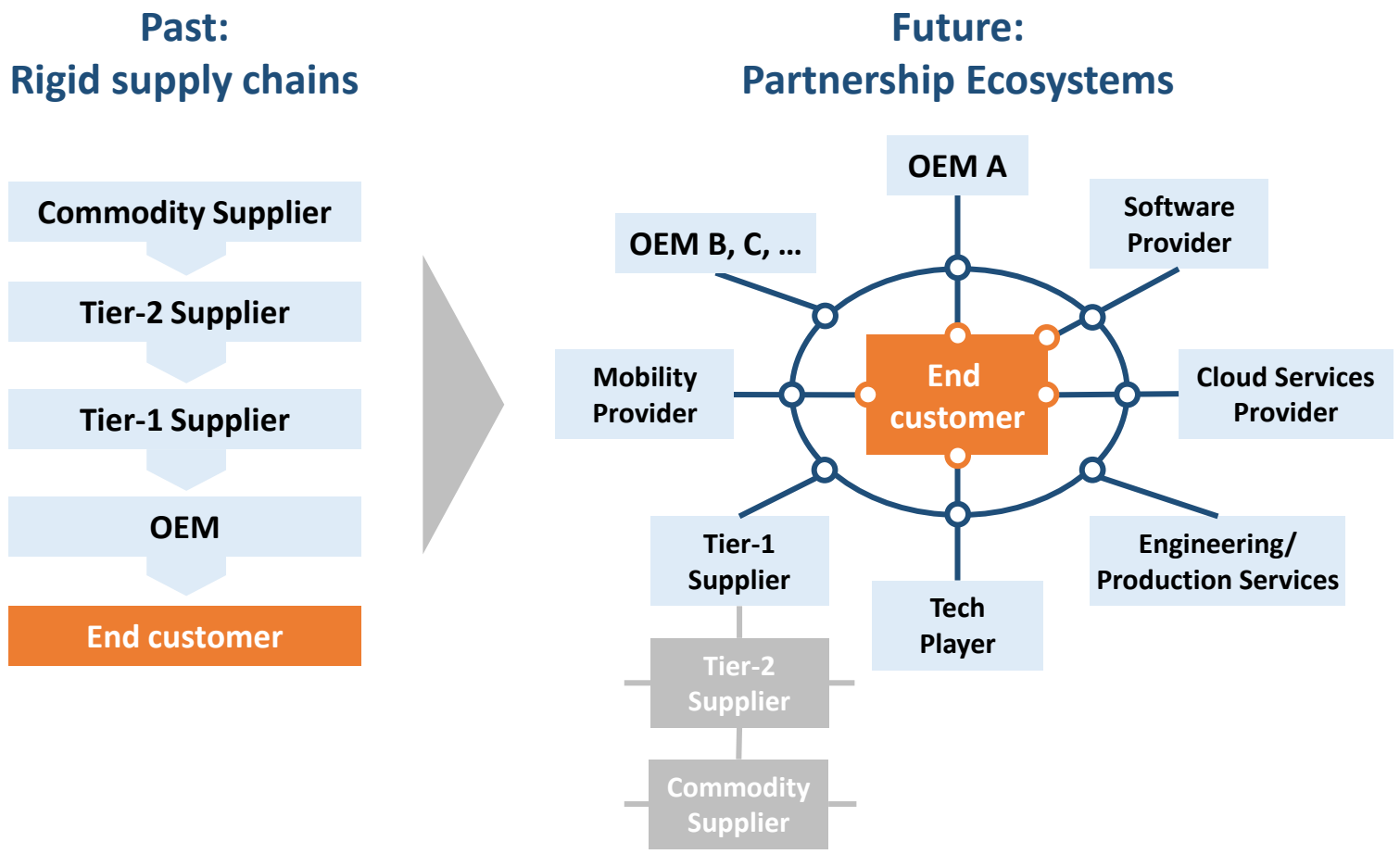
SDV: Status quo
Cooperations (Partnerships)

Co-created platforms with partners and suppliers are essential to escape lock-in and build a resilient, scalable ecosystem.

- SDV requires a shift away from a rigid supply chain toward a partnership ecosystem in which all actors are interconnected, including various OEMs.
- Some of these actors can also maintain direct relationships with the end customer, not just the OEM as in the past. This includes software providers such as Google or mobility providers such as Uber.
- Examples:
  - **Software Provider:** Alphabet, Baidu, Nvidia
  - **Cloud Services Provider:** Amazon, Microsoft
  - **Engineering/ Production Services:** Magna, Bertrandt
  - **Tech Player:** Xiaomi, Apple, Samsung
  - **Tier 1 Supplier:** Bosch, Denso, CATL
  - **Mobility Provider:** Uber, Didi Chuxing, Bolt, Free2move
- **Quality over quantity:** An important factor in the selection of partners lies in the company's own competencies: OEMs with a high level of vertical integration and extensive software capabilities need different and possibly fewer partners than manufacturers with catching up to do.

Partnerships of Automotive OEMs: Change in supplier chains

Crit. 5 Partner-ships



Source: CAM

SDV: Status quo

Cooperations (Partnerships): Strategic product-related SDV partnerships of selected OEMs

SDV partnerships are crucial for OEMs because no single automotive manufacturer can develop SDV components in all domains quickly, scaleably, and competitively on its own. OEMs differ in the type and number of partnerships they pursue.

- One of the most obvious differences between legacy OEMs like Volkswagen or Toyota and technology driven pioneer manufacturers like Tesla, Xpeng or NIO is the number of strategic partners in decisive domains like drivetrain/ energy, ADAS/ AD/ Safety, infotainment/ comfort, and connectivity (see following page).

- New OEMs tend to high value creation within the company. Both Tesla and NIO develop decisive parts of SDVs inhouse, including software and chip design. Tesla as an US-company is adapting its software to the Chinese market with the help of domestic partners like Deepseek or ByteDance. NIO, on the other hand, is using Here-data for European mapping, location-data and ADAS.
- Content partnerships (see table on the right) are important areas, e.g. for infotainment content, as the data and services are highly relevant to customers and can hardly be covered by OEMs themselves. Up-to-date content provides tangible added value for customers.
- Electric mobility has accelerated the customer demand of infotainment content, especially on long journeys, to bridge charging breaks. It is striking that premium manufacturers like BMW and Mercedes are actively promoting a large number of content partners like Spotify, Netflix, AirConsole globally, as well as TikTok, Tencent video and others for the Chinese market.

SDV important content partners

Crit. 5 Partner-ships

OEM	Content Global	Content China
VOLKSWAGEN GROUP	Spotify, AirConsole, Youtube, Dazn, WhatsApp	WeChat, Tencent Music
TOYOTA	iHeartRadio, Pandora, Yelp, Apple Music, Amazon Music	Huawei Harmony
STELLANTIS	Amazon FireTV	-
BMW GROUP	Alexa, AirConsole, Disney, Youtube, Xperi, Tivo, FireTV, Mediatheken	Huawei, Alibaba TMall Genie, Tencent, DeepSeek, Gaode (Baidu)
Mercedes-Benz	Spotify, MS Teams, Zoom, Boosteroid (Gaming), AntStream, Sony Ridevu, Dazn, Amazon Music, Lieferando, Youtube, Booking	Amap, TikTok, Bilibili, iQIYI, NetEas, QQ Music, Tencent Video, Yun Ting Music, Need For Speed
TESLA	Spotify, Netflix, Arcade, Tiktok, Amazon Music, Apple Music, Apple Podcasts, Audible, LiveOne, Tidal, TuneIn, YouTube Music	Vohico, Baidu Maps
NIO	Disney+, Apple TV, Apple Music, Instagram, Youtube, SoundCloud	iQIYI, Bilibili (China Video)
BYD	Spotify, Stingray Karaoke	Tencent Video, iQiyi, Stingray Karaoke, Singing Machine
GEELY	Spotify, Google built-in App-Ökosystem (Polestar/Volvo)	QQ Music, iQiyi, NetEase Cloud Music, Karaoke Apps, Flyme Auto
XPENG	KaraFun, ACCESS Twine4Car	iQIYI (Ankündigung)

Source: CAM | As of: October 2025.

SDV: Status quo

Cooperations (Partnerships): OEMs in comparison

CENTER OF AUTOMOTIVE MANAGEMENT

Automobile manufacturers maintain partnerships with the world's most important technology companies: Google (including subsidiaries like Waymo), Nvidia, Qualcomm, Amazon, Microsoft etc.

Cooperations: Selected strategic SDV partnerships by domains

Crit. 5 Partner-ships

DOMAIN	VOLKSWAGEN GROUP	TOYOTA	STELLANTIS	BMW GROUP	Mercedes-Benz	TESLA	NIO	BYD	GEELY	XPENG
Drivetrain/ Energy	QuantumScape *inhouse**	BYD SUMITOMO METAL MINING *inhouse**	LEAPMOTOR Factorial	e-on RIMAC *inhouse**	GEELY Factorial *inhouse**	Panasonic CATL *inhouse**	ZF *inhouse**	TOYOTA *inhouse**	CATL	CALB BYD
ADAS/AD, Safety	mobileye BOSCH Horizon Robotics	WAYMO NTT momenta	WAYMO pony.ai	Qualcomm momenta	NVIDIA Qualcomm momenta	Baidu 百度 *inhouse**	NVIDIA	HUAWEI NVIDIA Horizon Robotics	NVIDIA WAYMO Baidu 百度 mobileye	NVIDIA *inhouse**
Infotainment/ Comfort	ThunderSoft RIVIAN	HUAWEI Unity Google	Applied Intuition MISTRAL AI_	Alibaba Group GARMIN *inhouse**	Google 高德地图 amap.com *inhouse**	Content only, e.g. Spotify *inhouse**	NVIDIA *inhouse**	Alibaba Group HUAWEI Qualcomm	Google MEIZU	Qualcomm
Connectivity	Microsoft RIVIAN 4screen	xiaomi Google	aws 4screen	aws	Microsoft Google ByteDance	- *inhouse**	NVIDIA	Alibaba Group Google	aws Google	Alibaba Group
Others	*China SDV:* XPENG SAIC	*Vehicle engineering:* Microsoft Google aws	*Vehicle engineering:* dSPACE MISTRAL AI_	*SDV software:* TATA TATA TECHNOLOGIES	*SDV hardware:* NVIDIA Qualcomm	*AI in China:* deepseek ByteDance	*AI platform/ maps:* NVIDIA here	-	-	*SDV/ engineering:* VOLKSWAGEN GROUP MAGNA
CONCLUSION	Region-specific part-nerships with solid expertise especially in China	Similar to VW region-specific partnerships, several cloud partners for veh. development	Innovative partners, promising partnership with Amazon on SmartCockpit ends	Regional partnerships at ADAS/AD, but also relevant in-house developments	MB.OS as architect of purpose-built MB.OS, relevant global part-ners, China specific	Many in-house deve-lopments, hardly any strategic partnerships except for content.	ZF and Nvidia as strategic partners, SDV is mainly developed inhouse.	Many competent partners across SDV-relevant areas, regional ecosystems.	Very broad, crossbrand partner ecosystem with globally leading SDV players	Selected highly repute-ble SDV partners, stra-tegic E/E-architecture collaboration with VW, in-house expertise.

Source: CAM | As of: October 2025. * Decisive development work is carried out in-house (additionally).

SDV: Status quo
Cooperations (Partnerships): Conclusion

CENTER OF AUTOMOTIVE MANAGEMENT

Partnerships can meaningfully complement OEMs own SDV hardware and software expertise and are essential, especially to provide regionally adapted content that offers monetizable added value for customers.

Summary: Success criteria for "SDV partnerships"

Crit. 5 Partner-ships

Aspects	Description 5
Selection	**SDV partner selection:** Selection of partners in terms of complementary competence to the OEM, quality of partnerships in terms of regionality and scope.
Content ecosystem	**Scope of content partnerships:** Since OEMs usually do not provide content like infotainment (navigation, streaming, garming etc.) the selection of content partners is of particular importance regarding the scope and quality of the offering, as well as regionality.
Competence (supplementary aspect)	**Inhouse competence:** Partnerships are not an end in themselves but serve to compensate for OEMs shortcomings. Where the own skills are sufficient, partnerships play a subordinate role.

SDV partnerships: Mercedes-Benz (exemplary)

Image source : Mercedes-Benz

CONCLUSION

In the SDV era, it is not the OEM with the largest production capacity that wins, but the one with the best ecosystem, consisting of software, hardware, cloud, data and services – delivered as "best-of-breed" components by partner networks.

SDV: Status quo
SDV Culture

CENTER OF AUTOMOTIVE MANAGEMENT

Successful OEMs shift from Start-of-Production (SoP)-driven cycles to a continuous delivery mindset, treating the car as a platform that evolves over its lifetime.

The transition to an SDV culture presents challenges for established manufacturers, including:

- **Lack of In-house Software Expertise:** Traditional OEMs often need to build significant software talent and skills.
- **Organizational Change:** Shifting from rigid organizational structures to more flexible, software-oriented teams can be difficult.
- **Cybersecurity Focus:** Increased connectivity and remote updates necessitate a strong, proactive cybersecurity culture to protect critical vehicle systems from remote threats.
- Essentially, the SDV culture is about **transforming the entire automotive industry,** from engineering and manufacturing to business strategies and the customer relationship, placing software at the core of future mobility.
- **SDV paradigm shift:** Most SDV problems OEMs might have aren't technical but lie in the cultural structure.

Challenges in adopting the SDV-culture

Crit. 6 Culture

	Traditional Vehicle Development	SDV Vehicle Development
Starting point	New vehicle, partly even new platform, new specifications	Existing platform, existing software base, evolution
Development focus	Milestones leading to start-of-production (SoP)	SoP as one milestone among others, development continues during lifecycle
Knowledge and Collaboration	Distributed across several teams, often lost after handover	Consolidated in architecture and software, end-to-end feature ownership, no silos
Innovation Culture	Team members fear rapid error sanctioning, no ideal environment for creativity	Team members feel safe to experiment, fail, and learn for innovation goals. Executives drive the new way of working.
Agility and adaptability	Deep hierarchy, long decision-making processes, low agility	Flexible culture to adapt to technological leaps and changing customer requirements
Delivery model	One time delivery	Ongoing release cycles and product updates (OTA)
Software use	Specifications from scratch	Systematic reuse of software modules
Architecture	Hardware-centric design, built for hardware integration	Software-centric design, built for software integration
Value creation	Peaks at SoP	Accelerates after SoP

Source: CAM, SDV Guide 2025 | As of October 2025.

SDV: Status quo

SDV Culture: Tesla as an example

CENTER OF AUTOMOTIVE MANAGEMENT

Tesla has been an early example of an OEMs with a continuous delivery mindset, treating the car as a platform that evolves over its lifetime.

- Tesla has an **innovative problem-solving** organizational culture. This type of corporate culture motivates employees to develop profitable solutions to current and emerging problems in the target market, also by thinking beyond this market (e.g. automotive vs. electric energy markets).
- For example, the company employs its organizational culture in developing advanced electric vehicles as a solution to environmental issues surrounding automobiles and internal combustion engines. The company's ability to keep introducing advanced electric vehicles reflects the benefits of its work culture.
- The company's progress and growth are based on technological innovation. Tesla's organizational culture has remained focused on such innovation since the founding of the business. However, it is expected that the company will gradually change its business culture to accommodate new needs as the business expands and diversifies its product offerings.

Tesla's six culture principles (exemplary)

Crit. 6 Culture

1 Move fast!

- Tesla's culture prioritizes speed and **quick adaptation to market trends.** Employees are expected to respond rapidly to global industry changes for highly competitive products
- Fast responsiveness strengthens Tesla's **resilience** in the automotive market

2 Do the impossible!

- Tesla encourages employees to **think beyond conventional ideas** to support cutting-edge innovation.
- **Training** pushes workers past traditional limits of **creativity and productivity,** enabling new energy and transportation solutions.
- Tesla distinguishes between **successful failures and unsuccessful failures.** The latter are tolerated, the first endured and are part of the knowledge management database.

3 Constantly innovate!

- Tesla's culture centers on **continuous innovation,** driving ongoing research and development. This constant innovation enables the creation of cutting-edge products and helps the company stay ahead in a highly competitive industry.
- Empowered employees are allowed **to think outside the box,** provide innovative ideas, and **enthusiastically challenge the status quo.**

4 Identify root causes!

- Tesla's culture encourages "first principles" thinking—solving problems by **identifying and addressing root causes.**
- Employees are **trained** to apply first-principles reasoning through **HR-led programs.**
- This mindset strengthens Tesla's ability to **tackle real-world technical challenges.**

5 Take (calculated) risks!

- Tesla's innovation culture reflects personal characteristics of **Elon Musk like intolerance for inefficiency and incompetence** and emphasis on intellectual courage, high risk-taking under strict supervision and new ideas.
- The company uses **rigorous hiring and HR management practices,** enforcing strict performance standards in a flexible, innovation-driven work environment. This

6 Create synergies!

- Tesla's culture **promotes teamwork that minimizes conflict** and creates synergy among employees.
- This synergy **maximizes the value of employees' skills** and strengthens the company's competitiveness.
- A **unified team culture** supports effective management and smooth strategy implementation across the organization.

Source: CAM, Meyer 2024, Ganesh 2025, Sayyadi/Provitera 2025 | As of October 2025.

SDV: Status quo
Culture: OEMs in comparison

Significant differences in software mindset: Tesla, NIO, XPENG, and to some extent BMW are clearly software-first, while VW, Toyota, and Stellantis are still heavily influenced by traditional industry and SoP thinking.

- **Lifecycle rather than SoP as a differentiating factor:** Software first companies focus on continuous improvement via OTA (Over-the-Air) updates, while laggards continue to primarily think of software up to the start of production.
- **Cultural change as a key challenge:** Legacy OEMs are still adapting their culture to a software first culture, while new EV OEMs have built their culture around software from the outset.
- **Agility and user-centricity are crucial:** High SDV maturity goes hand in hand with agile development, high release frequency, and systematic user feedback.
- **China as a pacesetter for SDV culture:** Chinese OEMs demonstrate particularly strongly that a focus on software and UX, as well as OTA-driven product maintenance, are becoming the cultural standard.

Crit. 6 Culture

SDV culture progress of selected OEMs

OEM	Software mindset	Life cycle focus
VOLKSWAGEN GROUP	• Fragmented software development standards • R&D of domains are split up among the brands with CARIAD as integration partner	• Mainly new vehicles based on legacy platforms with SoP focus, but already first SDV platforms in series production (China), RoW planned
TOYOTA	• Traditional organization of an industrial company, switch to software organization not present • Woven: Partially implemented for upcoming vehicles	• Current focus on SoP, SDV platforms in planning • Traditional Kaizen process: with continuous (process) improvement
STELLANTIS	• Separation of hardware and software development	• Still focus on SoP, new platforms with delay (e.g. STLA Brain)
BMW GROUP	• Benchmarking the operations of major digital players Tracking state-of-the-art software industry methodologies	• From “Neue Klasse”-platform with a focus on continuous improvement • Agile SW engineering with 200k builds/day
Mercedes-Benz	• Still industrial, but fostering a culture that puts software first, blending cutting-edge software with a legacy of quality, safety, and sustainability	• Goal: A tech stack that enables continuous innovation without ever demanding the spotlight
TESLA	• Built up from the beginning as a software or tech company, 6 culture principles like “do the impossible”	• Life cycle focus built up from the beginning with continuous OTA updates
NIO	• Similar to Tesla software-first approach	• Iterative Development & User Feedback with KPIs like “user benefit assessment"
BYD	• Strong software/tech focus in the cockpit (DiLink, Android-based; Cloud/Remote Features).	• OTA as part of the product lifecycle, updates are rolled out in waves/batches
GEELY	• Strong focus on "user experience" and digital cockpits across brands (e.g. Zeekr)	• Continuous improvement via Connected Services/OTA; structured integration of user feedback
XPENG	• Explicitly user-centered, software-driven approach • User experience in focus; "intelligent innovation“ motto	• Strong lifecycle focus: frequent major OTA releases with feature and personalization updates.

Source: CAM | As of October 2025.

SDV: Status quo
Culture: Conclusion

CENTER OF AUTOMOTIVE MANAGEMENT

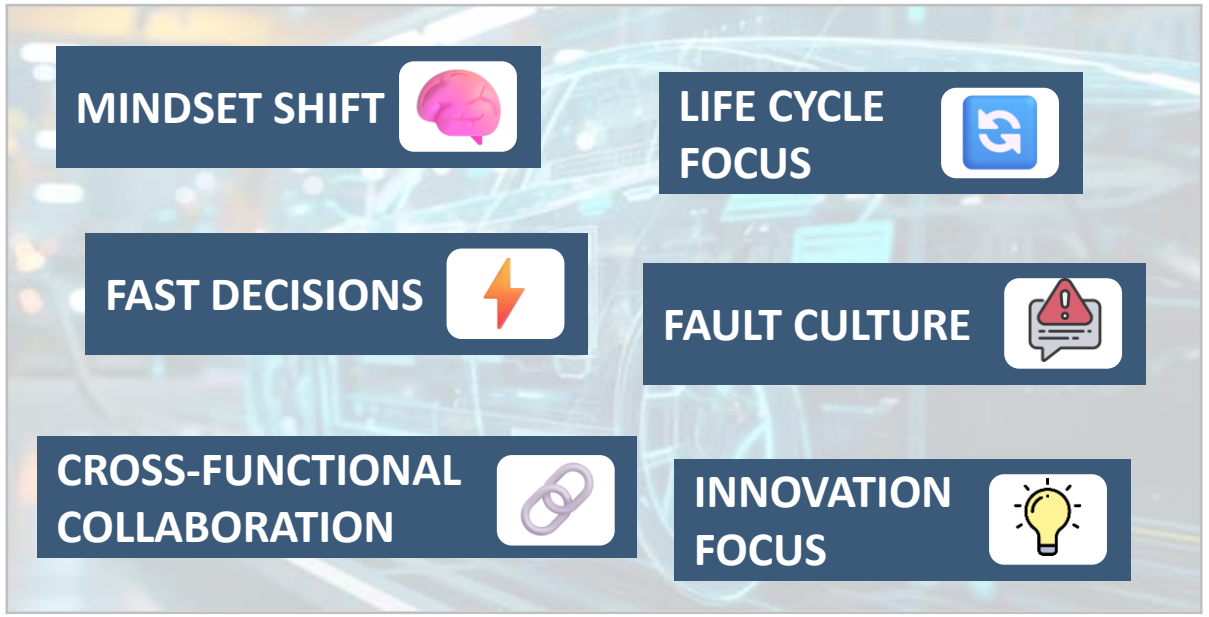
SDVs are changing the way cars are developed: How can innovation be accelerated? How fault-tolerant is a company? How focused is the OEM on continuous improvement even after the SoP?

Summary: Success criteria for "SDV culture"

Crit. 6 Culture

Aspects	Description 6
Software mindset	**Hardware vs. software-centric mindset:** It's the way from a hardware-centric approach, where perfection must be achieved by SoP and changes are expensive and undesirable, to an SDV culture, where developments are faster and innovations more frequent. Possible errors can be corrected via OTA updates. SDV requires acceptance of iteration instead of perfection.
Lifecycle focus	**Focus on continous improvements:** Traditionally, most development ends with the start of production (SoP). In the reality of software-defined product development (SDV), a significant portion of the value creation only occurs after SoP. Functionality, quality, and revenue grow throughout the product lifecycle via software.

SDV Culture: Key elements



Source: CAM

CONCLUSION

Ultimately, SDV does not primarily represent a technological change, but a cultural change. Because software development differs fundamentally from traditional automotive engineering: Release fast, improve continuously, while maintaining automotive safety.

SDV: Status quo

Organization: Rapid product development by Chinese car manufacturers

CENTER OF AUTOMOTIVE MANAGEMENT

Speed in SDV development requires organizational simplification, breaking silos and empowering end-to-end accountable teams.

Crit. 7 Organi-zation

Organizational Factors for successful SDV development (Example: China)

1. Platform strategies & modularity
- Use of **flexible vehicle platforms,** e.g., dedicated EV platforms like BYD e-Platform or Geely SEA.
- High **standardization of components** (batteries, powertrains, control units) enables rapid derivatives.
- **Over-the-air updates** reduce development effort for hardware changes, as many functions are added via software.

2. Speed through digital development
- **Virtual Development & Simulation:** Use of digital twins, VR/AR, and AI-supported design.
- **Software-first approach:** Vehicles are primarily modeled digitally, faster prototype development.
- **Big Data utilization:** Customer feedback and driving data are incorporated into further development in real time.

3. Industrial ecosystem & supplier integration
- **Dense clusters** (e.g., in Shenzhen, Shanghai): battery companies, electronics, software suppliers.
- **Vertical integration:** BYD manufactures batteries, chips, and many components itself → less dependence on suppliers.
- **Cooperations & joint ventures:** Start-ups (NIO, XPeng) work closely with established suppliers and tech companies.

4. Agile organization & corporate culture
- **Flat hierarchies** and fast decision-making processes compared to Western OEMs.
- **Start-up mentality:** Focus on a minimum viable product (fast to market, then iteration).
- **High risk tolerance:** More pilot projects, shorter test cycles, faster market launch.

5. Market orientation & customer proximity
- Very short **model cycles** (sometimes only 2–3 years)
- **Customer feedback** is directly incorporated into updates and facelifts.
- Focus on **software features and infotainment** that are key to purchasing decisions in China.

6. Governmental framework
- **Relaxed regulatory framework** in China → Vehicle approval is often faster than in Europe.
- **Massive subsidies and funding programs** for EVs and batteries.
- **Political support** for the development of charging infrastructure.

CONCLUSION

Chinese manufacturers combine **digital development processes, modular platforms, vertical integration, and government support** with an **agile corporate culture.** This allows them to achieve **development cycles of often 24–36 months**, while Western OEMs traditionally have cycles of **48–60 months.**

Source: CAM | As of October 2025.

SDV: Status quo

Organization: Rapid product development: Examples in China and first improvements in Europe

CENTER OF AUTOMOTIVE MANAGEMENT

Empirical data shows: R&D Organization and “build-to-purpose” lead to an imensive speed advantage of Chinese brands.

Crit. 7 Organi-zation

Product development at BYD, Chery and Geely-brand Zeekr (exemplary)

- Taking advantage of China’s lower labor costs, BYD deploys about 900,000 employees, **102.000 R&D employees**! At its headquarters, BYD promotes a work-focused life through company-subsidized housing, transportation and schools.
- Unlike most automakers, **BYD makes most of its own parts** rather than relying on suppliers, another factor that speeds development and lowers costs.
  - The Seal electric sedan, for instance, contains **75% in-house parts**, compared with 46% for Tesla’s Model 3 and 35% for VW’s electric ID.3 (AlixPartners analysis).

EUROPEAN EXAMPLE: RENAULT

- New development process called "Leap-100" with Chinese partners. Support from development center in China with approx. 100 engineers.
- Reduction of development time by 41% to 100 weeks and of development costs by 50%
- Fewer variants: only 2 trim levels and 4 colors

Image source : Renault

- Chinese automakers’ employees often work **six 12-hour days a week**, said Peter Matkin, Chery’s chief international-brands engineer.*
  - BYD has built an immense workforce in part by paying **modest salaries** and recruiting from second-tier colleges.
  - The vehicles’ journey from idea to assembly is accelerated by **round-the-clock engineering**. “Zeekr engineers in Shanghai and Hangzhou pass work at the end of each day to colleagues at its design center in Gothenburg, Sweden, enabling up to 20 uninterrupted hours of development” (Zeekr Vice President Yun Xu, project manager for several models).
  - Legacy automakers tend to work in a linear fashion, with departments waiting their turn to work on parts or systems. Chinese automakers **deploy teams in parallel**. Zeekr’s Xu estimated that using “old processes” would “double or triple” Zeekr’s development time.
  - Christian Hering, Zeekr’s chief platform architect for Europe: VW’s real-world testing protocols were rigid, he said: Even slight software tweaks were treated like physical-component changes – each requiring 25,000 kilometers (15,534 miles) of road-testing.
  - Zeekr uses **artificial intelligence to mine a digital library containing** 20 years of Geely designs and **tell engineers which existing parts will work best and cost least**.
- Chinese automakers release good-enough vehicles quickly, with **far fewer prototypes** and a fail-fast philosophy mirroring Silicon Valley tech startups, industry executives and experts said. They lean more on **simulations and artificial intelligence** than real-world testing for safety and durability.
- Chinese automakers also save time and money by using **standardized vehicle platforms** and components across model lines to a greater degree than many global automakers.
- They treat **model launches more like the start** than the end of development, adding frequent upgrades based on **consumer feedback**.
  - Engineers at BYD and other Chinese automakers are willing to change designs and components **later in the model-development process** than foreign competitors, which employ strict timelines and vetting milestones.

Source: * Carey/Shirouzu (Reuters) 2025, Knauer 2025.

SDV: Status quo
Organization: OEMs in comparison

CENTER OF AUTOMOTIVE MANAGEMENT

Platform and software focus as a key difference: Chinese OEMs like Nio or Xpeng rely heavily on modular platforms and standardized software components, while Western OEMs (e.g. VW, Stellantis) have historically been more hardware- and prototype-driven.

- **Digital development approaches vs. traditional processes:** SDV pioneers use simulation, big data, and continuous updates as integral parts of development; traditional OEMs still often work with longer, sequential development cycles.
- **Deep supplier integration:** Chinese OEMs pursue vertical integration and close collaboration with suppliers, while Western OEMs are more characterized by complex supply chains and external dependencies.
- **Agility and organizational culture:** An agile organization with rapid decision-making and a start-up mentality fosters SDV progress; Western OEMs often struggle with bureaucracy and complex processes and classic industrial hierarchy. But OEMs like BMW and Mercedes-Benz have recognized these problems and are beginning to position themselves more towards software companies.
- **Framework conditions as accelerators or brakes:** Government support and lower regulatory hurdles act as SDV accelerators in China, while regulation and certification requirements in Western markets slow down the transformation.

SDV organizational progress of selected OEMs

Crit. 7 Organi-zation

OEM	SDV software organization	Company hierarchy structure
VOLKSWAGEN GROUP	• CARIAD is a member of the Eclipse-Foundation, but other development areas still strongly proprietary • Separation of hardware and software at the beginning • China SDV competence center, AI Lab since 2024	• Rather classic industrial organization • Deep hierarchy • Traditional industrial structure, layered approval, slower software cycles
TOYOTA	• Toyota software academy: 100 courses covering topics such as artificial intelligence, cybersecurity etc. • GAIA program (global AI accelerator): Program for Toyota's internal AI development, competence building	• Rather classic industrial organization • Rather deep hierarchy legacy structure, slow software decision processes
STELLANTIS	• n.a.	• Deep hierarchy, • Many brands, complex global structure
BMW GROUP	• Software development in "software continuity" mode, reuse and scalability of software • Member of the Eclipse-Foundation	• Cross-organizational project teams for SW development • Still structured, but more agile than Toyota/VW
Mercedes-Benz	• Electric software hub Sindelfingen, Shanghai tech center • In total more than 10.000 software developers • Member of Eclipse-Foundation	• Teams apply DevOps principles, collaborate across departments, modern programming languages. • More centralized compared to Toyota, less hierarchical
TESLA	• Tesla has fully embraced SDVs, integrating software control across diverse vehicle functions	• Extremely fast decision-making, minimal hierarchy
NIO	• Regional adaptations and developments, e.g. at the Nio Innovation Center in Berlin	• Agile & Low-Hierarchy Structure: less hierarchical team environment where ideas are shared openly
BYD	• Very large engineering/R&D capacities; Establishment of large software teams (including intelligent driving)	• Centrally managed, highly vertically integrated technology group (R&D bundled in many institutes).
GEELY	• Consolidate/scale digital cockpit development across brands; in addition, external tech arms in the group	• Organization under restructuring: merging teams (Geely, Lynk&Co, ZEEKR) into one unit
XPENG	• Strong internal software/OS development (XOS)	• Flat, tech-company-like organization

Source: CAM | As of October 2025.

SDV: Status quo
Organization: Conclusion

CENTER OF AUTOMOTIVE MANAGEMENT

The company's organizational structure forms the foundation for SDV development. This is where the course for success is set.

Summary: Success criteria for "SDV organization"

Crit. 7 Organi-zation

Aspects	Description 7
Structure	**Industry company vs. software company organization:** Product and platform teams instead of component departments, no silo thinking, and end-to-end responsibility from concept to operation. Open-source software for non-differentiating functions and In-house developments for differentiating functions.
Hierachy	**High vs. flat hierarchy:** Flat hierarchies, clear product ownership, decisions where the knowledge resides, management sets goals and priorities, not detailed decisions.
Agility (supplementary aspect)	**Vehicle development speed:** Agile vehicle development, shorter software cylces instead of product cyles, SoP is starting point for further revenues

SDV organization: Chery (exemplary)

	Chinese OEMs	Western OEMs
	Platform strategies & modularity Flexible platforms, standardization of components	Long-standing in-house development – manufacturing & R&D outsourced
	Digital development Simulation, big data, over-the-air updates	Traditionally hardware- and prototype-centric
	Industry ecosystem & supplier integration Vertical integration, close collaboration with suppliers	Strong dependence on suppliers
	Agile organization & corporate culture Fast decision-making, start-up mentality	Complex processes, high level of bureaucracy
	Government support Auto industry seen as core global technology and supported	Regulation, higher certification hurdles

Source: CAM

CONCLUSION

SDV development requires an organization that operates like a tech company – not like a classic industrial group, with flat hierarchies and clear ownership, cross-functional teams, and management acting as enablers, not gatekeepers.

2.

OEM development of software-defined vehicles

2.2 OEMs SDV fact sheets

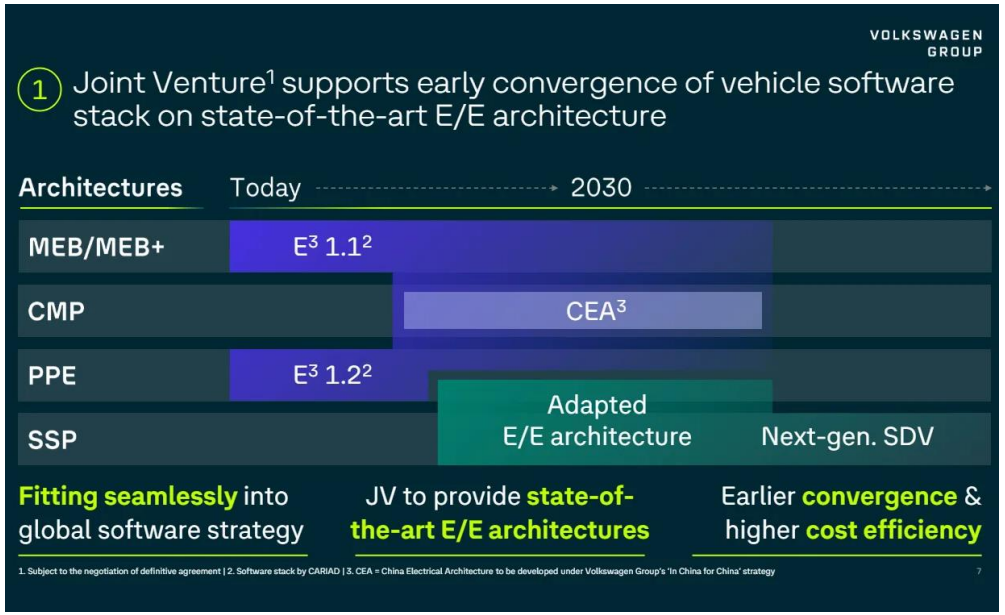
SDV fact sheets
Volkswagen Group

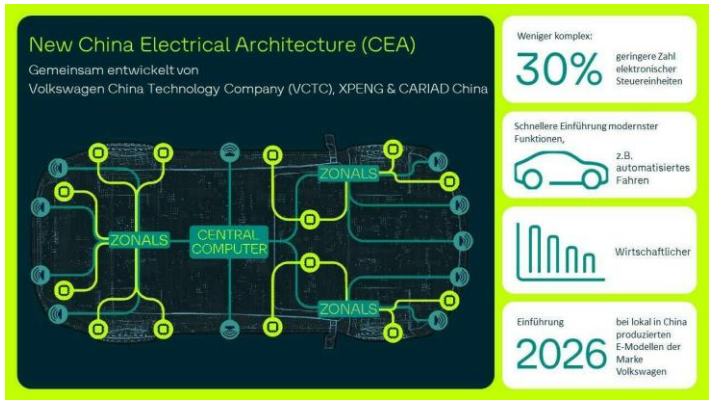
CENTER OF AUTOMOTIVE MANAGEMENT

Factsheet: Volkswagen SDV Activities*

VOLKSWAGEN GROUP

Software platform	CARIAD/ VW Software Stack
Market launch	East: fall 2025, West: fall 2027
First models	East: AUDI E5 SB (SAIC), t.b.d (Xpeng) West: VW ID.Every1 (Lupo?) (Rivian)
Status quo OTA-Updates/ FoD	☒ Infotainment ☒ Convenience functions/ Body ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☒ Transition ☐ Zonal **No. of CPUs:** 3 (CEA), 5 (PPE E3 1.2), 7: Rivian **Plans:** • China: 2025 CEA platform with Xpeng for zonal architecture, from 2027 also for ICE • Europe: 2027 with Rivian
Autonomous driving	• **Current:** L2 • **Plans:** 2026: L2+ (China)
Strategic SDV partnerships	• **West:** Intel/ Mobileye, Rivian • **East:** SAIC (Audi), Xpeng (VW) • **„Driver“:** Bosch, Horizon Robotics
SDV culture & organization	• 30% shorter development time • China SDV competence center • AI Lab since 2024
AI product integration	☒ Personal AI voice assistant ☒ AI-based, learning operating concept





Source: CAM

Images source: Volkswagen

* Status quo as of October 2025

SDV fact sheets
Toyota Group

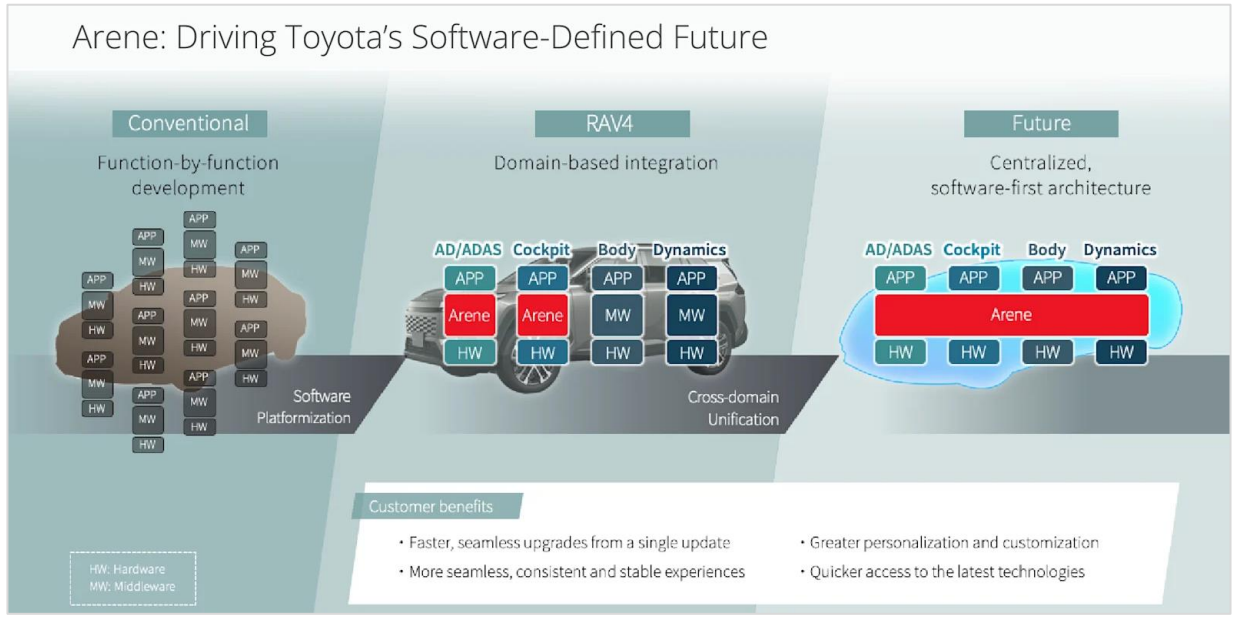
CENTER OF AUTOMOTIVE MANAGEMENT

TOYOTA

Factsheet: Toyota SDV Activities*

Software platform	Arene (by Woven)
Market launch	2026
First models	Toyota RAV 4, Lexus ES
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Convenience functions/ Body ☒ ADAS/ AD/ Safety functions ☐ Drivetrain
E/E-architecture	☒ Domain ☐ Transition ☐ Zonal **No. of CPUs:** 4 (Arene, RAV4) **Plans:** 2026 zonal architecture and central computer in the next generation of BEV vehicles
Autonomous driving	• **Current:** L2 (Highway, z.B. Lexus LS) • **Plans:** L4 in 2027
Strategic SDV partnerships	• **Waymo:** Autonomous Driving L4 • **Uber:** Toyota-Investment • **BYD:** JV since 2020 • **Huawei:** HarmonyOS 5.0 in bZ7 • **Xiaomi:** Seamless smartphone integration in bZ7
SDV Culture & organization	• Toyota software academy • GAIA program (global AI accelerator)
AI product integration	☐ Personal AI voice assistant (planned for Arene platform) ☐ AI-based, learning operating concept

Source: CAM



Images source: Toyota

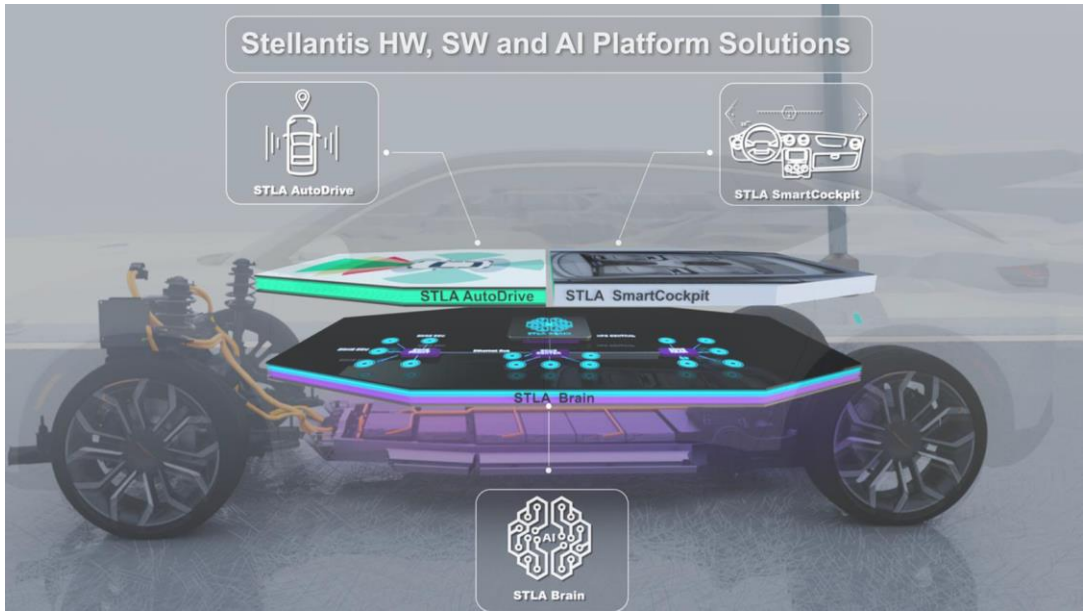
* Status quo as of October 2025

SDV fact sheets
Stellantis

Factsheet: Stellantis SDV Activities*

Software platform	STLA ABC platform
Market launch	t.b.d.
First models	t.b.d.
Status quo OTA-Updates/ FoD*	☒ Infotainment ☐ Body/ Comfort functions ☐ ADAS/ AD/ Safety ☐ Drivetrain
E/E-architecture	☒ Domain ☐ Transition ☐ Zonal **No. of CPUs:** 3 **Plans:** 2025/26 introduction of STLA Brain planned, including zonal architecture and central computer
Autonomous driving	• **Current:** L2+ Highway • **Plans:** 2025 L3 cancelled
Strategic SDV partnerships	• **Mistral AI:** vehicle engineering and manufacturing, fleet data analysis, internal car sales • **Amazon:** AWS for cloud applications, Alexa integration
SDV Culture & organization	• Separation of hardware and software development • Multinational corporation (especially USA, Europe) with very diverse platforms, few synergies
AI product integration	☒ Personal AI voice assistant ☐ AI-based, learning operating concept

Source: CAM



Images source: Stellantis

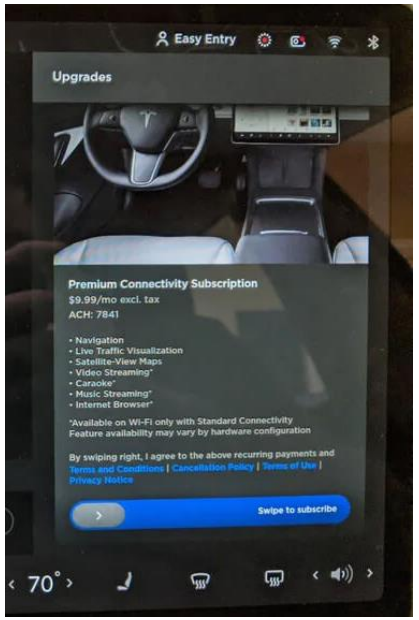
* Status quo as of October 2025

SDV fact sheets
Tesla

Factsheet: Tesla SDV Activities*

Software platform	Tesla proprietary
Market launch	2012
First models	Model S, 2017: Model 3 with zonal architecture
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☐ Transition ☒ Zonal • **No. of CPUs:** 2 (Tesla Model 3/Y) • **Plans:** all current models SDV, since 2017 with zonal architecture
Autonomous driving	• **Current:** L2+ Urban • **Plans:** 2026 L4 („before 2027“), robotaxi activities
Strategic SDV partnerships	• Mainly in-house developments • For content regional partnerships
SDV Culture & organization	• **Six main features of organization-nal culture:** 1. Move Fast, 2. Do the Impossible, 3. Constantly Innovate, 4. Reason from “First Principles”, 5. Think Like Owners, 6. We are “all in”
AI product integration	☒ Personal AI voice assistant ☒ AI-based, learning operating concept (Partially, applies to preconditioning of air conditioning/ heating, since 2015)

Source: CAM



Images source: Tesla/AI

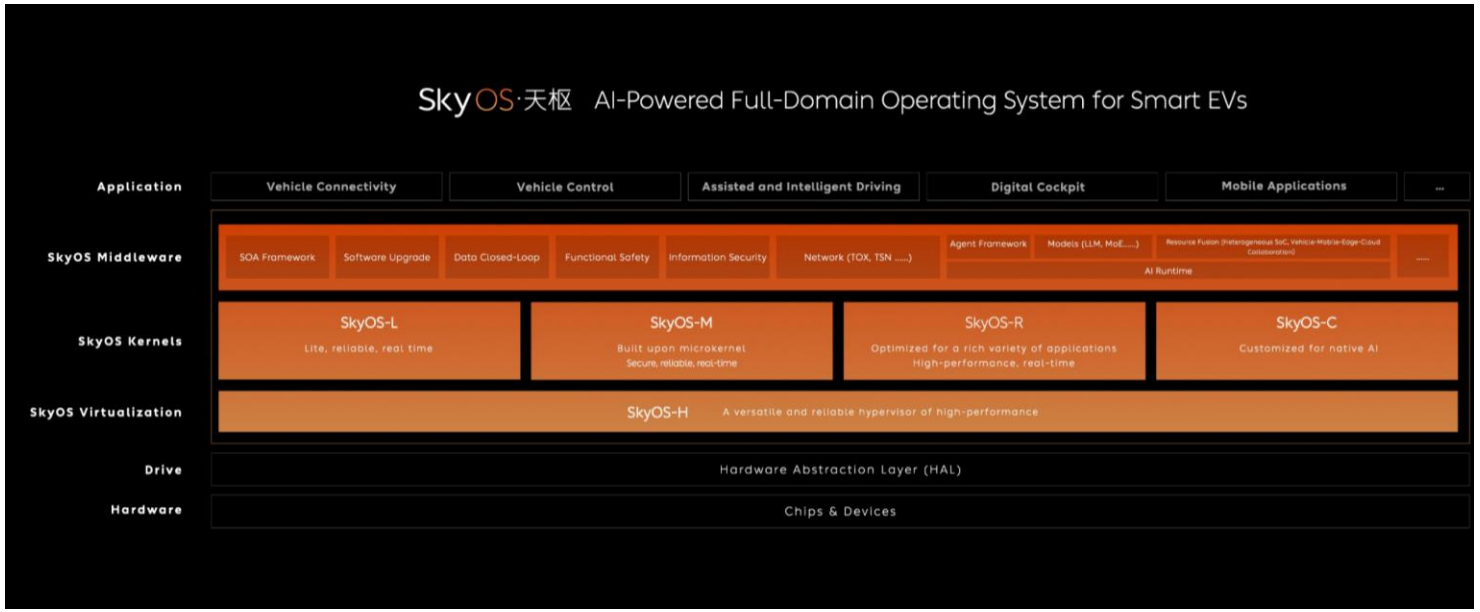
* Status quo as of October 2025

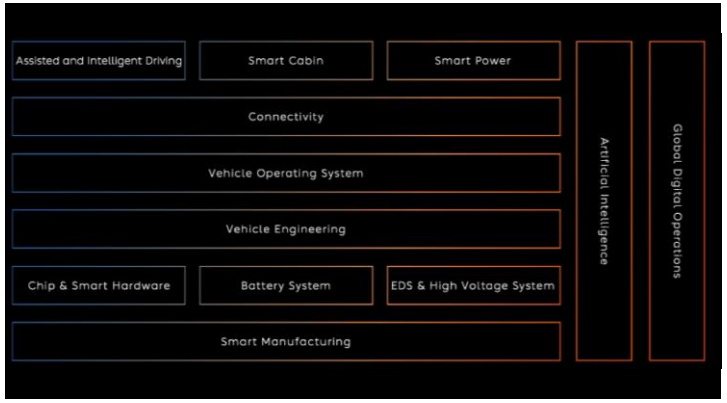
SDV fact sheets
NIO

Factsheet: NIO SDV Activities*

Software platform	Sky OS
Market launch	2020
First models	Nio EC6. Since 2024 ET9 as SDV milestone
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☐ Transition ☒ Zonal **No. of CPUs:** 4 (Nio ET9) • **Plans:** ET9 with latest stage of the Nio E/E architecture with central computer platform, zonal controllers
Autonomous driving	• **Current:** L2+ Urban • **Plans:** Regulatory approval to test Level 3 and Level 4 technologies in China, L3 not yet integrated in series
Strategic SDV partnerships	• **Nvidia:** ADAS, Infotainment • **ZF:** Drivetrain • + In-house developments, e.g. 5 nm Shenji chips for the first time in ET9
SDV Culture & organization	• Regional adoptions globally • Iterative integration of user feedb. • Agile & Low-Hierarchy Structure
AI product integration	☒ Personal AI voice assistant ☐ AI-based, learning operating concept

Source: CAM





Images source: NIO

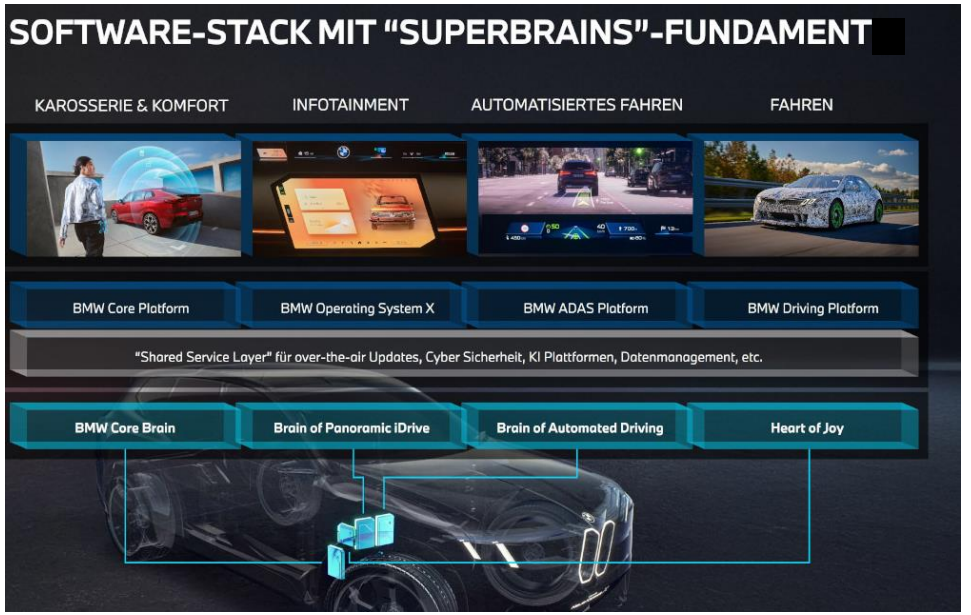
* Status quo as of October 2025

SDV fact sheets
BMW Group

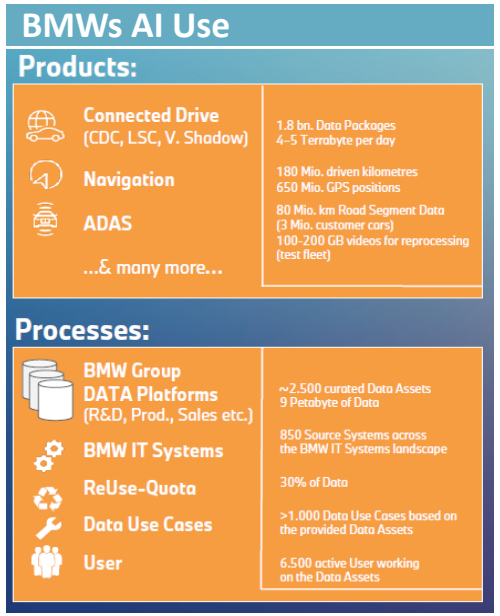
Factsheet: BMW SDV Activities*

Software platform	Neue Klasse Software Stack
Market launch	2025
First models	BMW iX3 (Neue Klasse), 2026: BMW 3er/i3 Plans: 40 models during the next 2 years
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture**	☒ Domain ☐ Transition ☒ Zonal **No. of CPUs:** 4 • **Architecture:** 4 Superbrains: Infotainment, automated driving, driving dynamics, basic functions each with its own SW platform (e.g. OS X)
Autonomous driving	• **Current:** L2+ / L3 • **Plans:** L3 can be used in darkness, L4 already in BMW factory premises, Level 4 parking planned from 2026 on
Strategic SDV partnerships	• **Regional partnerships** for ADAS/AD • Some **technology partnerships** with innovative players, but also **in-house** developments
SDV Culture & organization	• Software continuity principle • Following state-of-the-art SW industry method • Member of OSS Eclipse Foundation
AI product integration	☒ Personal AI voice assistant (in preparation) ☒ AI-based, learning operating concept

Source: CAM



Images source: BMW



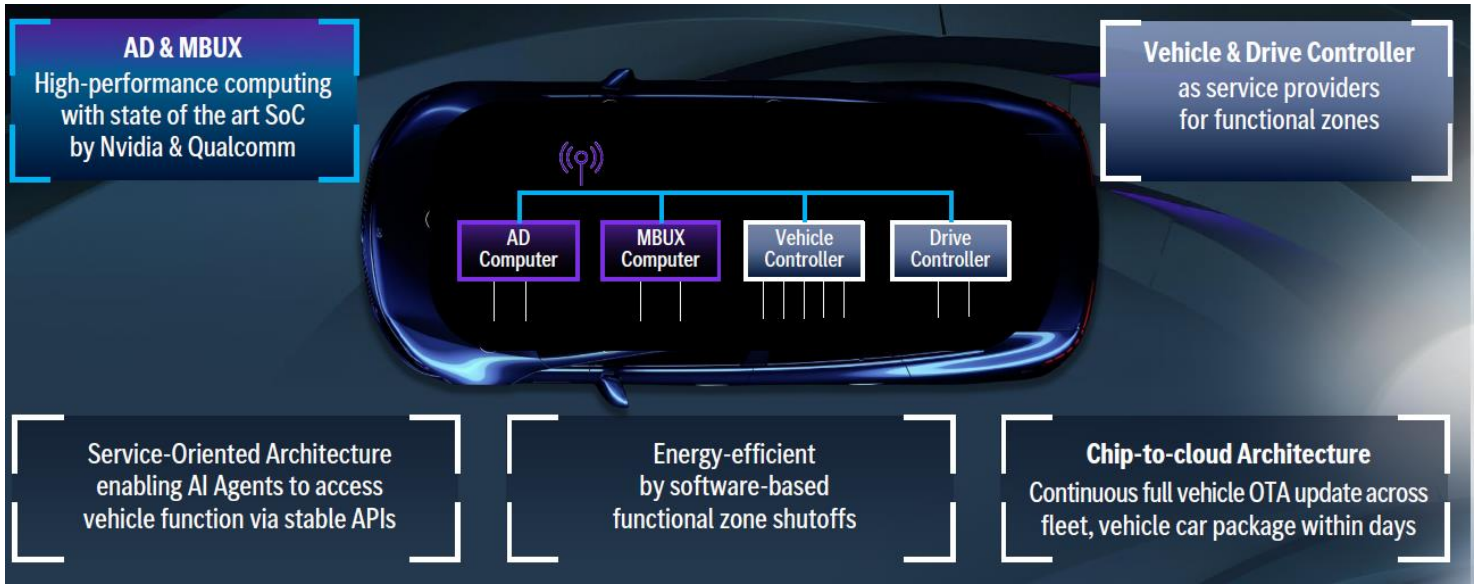
* Status quo as of October 2025. ** Combined domain-based and zonal approach.

SDV fact sheets
Mercedes-Benz Group

Factsheet: Mercedes-Benz SDV Activities*

Software platform	MB.OS
Market launch	2025
First models	Mercedes-Benz CLA, 2026: GLC Plans: 15 E-models up to 2027
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☐ Transition ☒ Zonal **No. of CPUs:** 2 • **Architecture:** 2 HPC: Infotainment, ADAS/AD. Additionally 2 control units: driving/charging, body. 1 connectivity module.
Autonomous driving	• **Current:** L3 (temporarily suspended 2026), L4 parking together with Bosch • **Plans:** L2++ (*door-to-door") is planned for market launch of the CLA in China and the USA, Europe will follow by appropriate legislation
Strategic SDV partnerships	• **Geely, Factorial:** Drivetrain • **Nvidia, Momenta:** ADAS/AD • Many regional content partnerships
SDV Culture & organization	• Fostering a culture that puts software first • MB still industrial company, change started • Member of OSS Eclipse Foundation
AI product integration	☒ Personal AI voice assistant ☒ AI-based, learning operating concept

Source: CAM



Images source: Mercedes-Benz

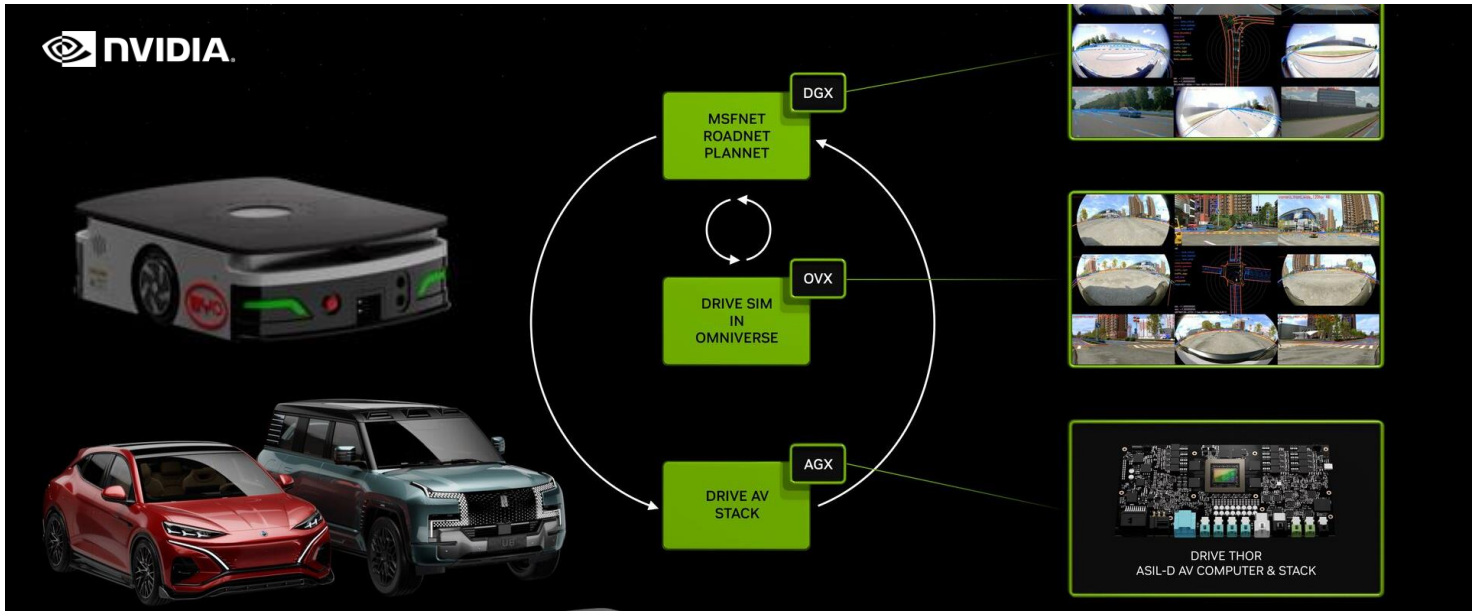
* Status quo as of October 2025

SDV fact sheets
BYD Group

Factsheet: BYD SDV Activities*

Software platform	e-Platform 3.0
Market launch	2021
First models	BYD Dolphin, Atto 3 (Yuan Plus), Seal (examples) Plans: More models of Ocean series
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☐ Transition ☒ Zonal **No. of CPUs:** 4 • **Architecture:** Domain architecture with Powertrain Domain Controller (Drive Train DC), Cockpit Domain Controller, and Body Domain Controller (in series production since 2021).
Autonomous driving	• **Current:** L2+ with broad availability in the model portfolio • **Plans:** L3 testing permit in China
Strategic SDV partnerships	• **Nvidia:** important SDV partner • Additionally, regional ecosystem partnerships (China smartphone integration) • global content partnerships.
SDV Culture & organization	• Very large engineering/R&D capacities; building large software teams, including AD
AI product integration	☒ Personal AI voice assistant ☒ AI-based, learning operating concept (passive system with suggestions)

Source: CAM



Images source: BYD

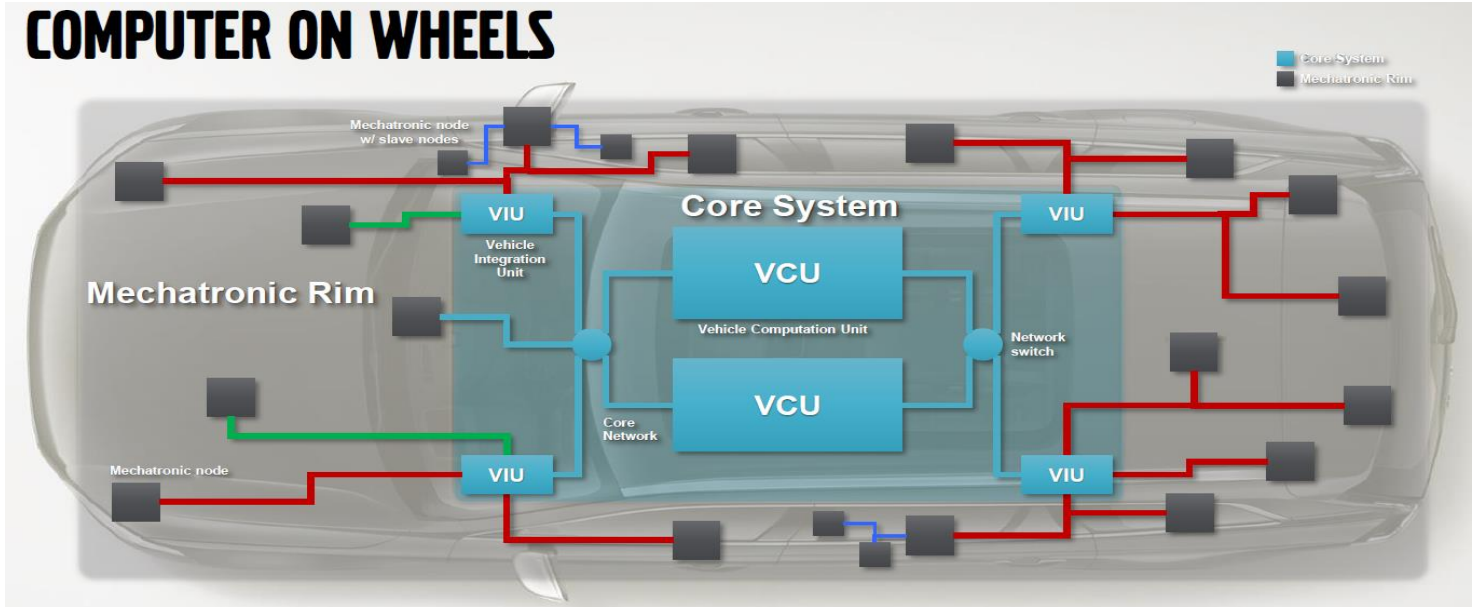
* Status quo as of October 2025

SDV fact sheets
Geely Group

Factsheet: Geely SDV Activities*

Software platform	SEA / SEA2 + GEA (with GEEA 3.0 E/E-architecture)
Market launch	2021
First models	Zeekr 001, Smart #1, Volvo EX30, Polestar 4 Plans: further models on SEA/GEA platform in A-D segment, e.g. 2026 Volvo EX60
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☐ Transition ☒ Zonal **No. of CPUs:** 2 • **Architecture:** Number of CPUs: 2 Core Computers + 2 Zonal Controllers (Volvo SPA3); Zeekr ADAS partly 2× Orin SoCs
Autonomous driving	• **Current:** L2+ with broad availability in the model and brand portfolio (Volvo, Zeekr etc.) • **Plans:** L3 on Zeekr 9X
Strategic SDV partnerships	• A very broad, cross-brand partner ecosystem with globally leading SDV players (Google, NVIDIA, Mobileye, AWS, Waymo) • China-specific cockpit/ecosystem partnerships (Meizu/ECARX, Baidu Apollo).
SDV Culture & organization	• Continuous improvement via OTA • Structured integration of user feedback
AI product integration	☒ Personal AI voice assistant ☒ AI-based, learning operating concept

Source: CAM



Images source: Geely/ Volvo

* Status quo as of October 2025

SDV fact sheets
Xpeng (Xiaopeng)

Factsheet: Xpeng SDV Activities*

Software platform	X-EEA 3.0 + Xmart OS / SEPA 2.0, CEA (mit VW)
Market launch	2022
First models	Xpeng G9 (X-EEA 3.0), G6 (SEPA 2.0). Plans: X9 (MPV) and further models
Status quo OTA-Updates/ FoD*	☒ Infotainment ☒ Body/ Comfort functions ☒ ADAS/ AD/ Safety ☒ Drivetrain
E/E-architecture	☐ Domain ☐ Transition ☒ Zonal **No. of CPUs:** 2 • **Architecture:** X-EEA 3.0: centralized supercomputing platform and local control modules; layered software, Gigabit Ethernet
Autonomous driving	• **Current:** L2+ with broad availability • **Plans:** Xpeng secures L3 road test license in Guangzhou
Strategic SDV partnerships	• Selected, highly reputable SDV partners (Nvidia, Qualcomm, Alibaba Cloud) plus strategic E/E-architecture cooperation with VW
SDV Culture & organization	• Extensive in-house software/OS development (XOS) with global OTA rollouts • flat hierarchy, tech-company organization
AI product integration	☒ Personal AI voice assistant ☒ AI-based, learning operating concept (“X-Combo”: restricted, based on defined rules)

Source: CAM

Images source: Xpeng

* Status quo as of October 2025

SDV fact sheets

Overview: Status quo of 10 selected OEMs regarding 7 criteria

CENTER OF AUTOMOTIVE MANAGEMENT

OEM \ CRITERIA	1 Unified software platform	2 OTA updates	3 Central computer strategy	4 AI integration (in vehicle)	5 Strategic SDV partnerships	6 SDV culture	7 SDV organization
VOLKSWAGEN GROUP	• regional platforms planned • >5 software platforms • 1 SDV model, ≥3 planned	• all domains addressable • medium update frequency • OTA updates since a few years possible, medium fleet	• from 3 (CEA) to 7 (Rivian) number of CPUs (platform) • starting 2026	• ChatGPT since 2024 (VW Golf, ID.3 etc.) • predictive maintenance • Audi proactive assistant	• region-specific partner-ships in China with Xpeng, • use of Rivian expertise still questionable	• beginning to establish software company standards	• classic organization of industrial company • SDV competence center in China, AI Lab since 2024
TOYOTA	• Arene software platform in 2026 expected • ≥2 SDV models planned	• some domains addressable, esp. infotainment content • medium update frequency	• Arene platform with 4 CPUs • launches in 2026 with initially only 2 models • currently no zonal CPUs	• predictive maintenance in development • Chat GPT for Arene planned • own GenAI as prototype	• region-specific partnerships, in China with Xiaomi, Huawei • Waymo important partner for ADAS/AD	• SDV platforms planned • traditional Kaizen process with continuous (process) improvements	• Toyota software academy with courses for SDV etc. • GAIA program for AI • industrial company organization
STELLANTIS	• SDV planned • many platforms • high complexity	• infotainment domain with OTA updates • low update frequency	• 3 zonal CPUs for STLA Brain platform planned	• ChatGPT since 2024 in all Peugeot models	• relatively few partnerships • Mistral AI for infotainment	• separation of hard- and software development is the claim • focus on SoP	• US and European departments with few synergies • many brands, complex global structure
BMW GROUP	• modern „Neue Klasse“- software stack • only few software platforms • 1 SDV model, ~40 planned	• OTA updates up to operating system possible • large OTA-fleet on streets already with 10+ mill. cars	• 4 “superbrains“ at “Neue Klasse” platform • starting 2025 with iX3, until 2027: 40 e-Klasse models	• BMW Intelligent Personal Assistant for user routines • LLM AI assistant improved since “Neue Klasse” (iX3)	• ADAS/AD with regional partne-rships, innovative technology partners (e.g. Momenta) • in-house developments	• software continuity principle • Following state-of-the-art methods in the software industry	• software continuity principle • Cross-organizational SDV teams • OSS: member of Eclipse-Foundation
Mercedes-Benz	• own MB.OS platform • only few software platforms • 1 SDV model, ~15 planned	• high update frequency with MB.OS: weekly updates possible in the future • large OTA-fleet ca. 11 Mio.	• 2 high performance computers, 2 control units • starting 2025 with CLA, growing	• ChatGPT integration • addressing >3 mio. customers • MBUX prediction features	• globally relevant partners • regional content partners • also in-house developments, e.g., operating concept	• blending cutting-edge software with a legacy of quality, safety, and sustainability	• OSS: member of Eclipse-Foundation • in total more than 10.000 SW developers
TESLA	• single vertical SW stack across all models • own operating system • low complexity, all cars SDVs	• complete operating systems of all domains addressable • high update frequency since several years, complete fleet	• central CPU strategy since Model S in 2012, extensive experience • all models on SDV platform	• Tesla Grok AI assistant since 2025 in vehicles available • Vehicle learning for preconditioning (A/C only)	• inhouse competence • early integration of many content partners, e.g. Spotify, gaming etc.	• build up as software company • 6 principles like „move fast“, „do the impossible“ etc.	• organization similar to software company • integrating software control across diverse vehicle functions
NIO	• single vertical SW stack across all models • short software cycles, NT 3.0 platform since 2025	• complete operating systems of all domains addressable • high update frequency since several years, complete fleet	• 4 CPUs since NT3.0 (2025) • bigger model portfolio than Tesla, all models on SDV platform	• assistant NOMI with Microsoft Azure Open AI since 2024	• technology partnerships with ZF, Nvidia • many inhouse developments, e.g. first own SoC in ET9	• software first approach • user experience company with KPIs like "User Benefit Assessment"	• low-hierarchy structure • regional adaptations and developments, e.g. at the Nio Innovation Center in Berlin
BYD	• broad SDV base, rapid scaling across many models	• complete operating systems of all domains addressable • very high update frequency esp. in China	• central computing platforms (Orin) are being scaled	• Product related AI integration in terms of personal assistant and automated interfaces	• Numerous competent partners across SDV-relevant areas • regional ecosystem partnerships, global content partners	• connected Services as a software platform • lifecycle view: quality improvements by OTA updates	• large, dedicated R&D/software capacities and rapid iteration • software-centric development organization
GEELY	• broad platform base (SEA/GEA) across many brands and segments • focus on modern E/E-architecture	• operating systems of all domains addressable • high update frequency for several years, many current models	• advanced E/E approaches • high heterogeneity across brands/ platforms	• AI used for personal assistants • AI automated interface partly in Full-Domain AI 2.0 und G-ASD	• broad, cross-brand partner eco-system with globally leading SDV players • China-specific cockpit/ecosystem	• ZEEKR with user-centric tech/software culture • supports it through user participation programs.	• high investments in software organization • Volvo with own software testing center
XPENG	• SDV focus with its own centralized E/E-architecture • platforms are consistently rolled out across a few model lines	• complete operating systems of all domains addressable • high update frequency for several years, many current models	• centralized supercomputing platform with an Ethernet backbone and cross-domain FOTA are in series production	• AI used for personal assistants • automated interfaces in the form of rules, not completely AI-based	• Several highly reputable SDV partners • Content/experience partnerships • high in-house expertise	• emphasizes continuous improve-ments based on user feedback	• transparent release cadence (OTA)

Source: CAM | As of: October 2025.

3.

Revenue potential of OEMs through SDV

Revenue potential of OEMs through SDV
Market potential

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Four use case packages cover a large part of future revenues that OEMs can realize with at least connected, but preferably with software-defined vehicles.

- To estimate potential revenues that SDVs may generate, four use cases were developed, covering a broad range of applications from the customer's perspective like autonomous driving, infotainment or electricity use cases.
- The revenue estimates are based mainly **on two factors:**
  - The global **fleet size** for each use case, meaning the vehicles already on the street must meet the necessary technical requirements. For autonomous driving, this includes sensor sets and AD software; for e-commerce and infotainment, sufficient and fast connectivity; and for the electricity use case, at least a PHEV battery storage system, and potentially vehicle-to-grid capability.
  - The second factor is the **average revenue per vehicle (ARPV)**. It is defined as the price for the service, based on prices in major global markets like USA, Europe, China, multiplied by the percentage of customers who book this service ("take rate").
- In total, this results in a revenue volume projected for the years 2030 and 2035 based on current revenue figures (2025).

Global market potential for SDV: 4 use cases

Use Case 1: **ADAS/ Autonomous Driving (min. L2+, Highway & City)** 	• Highway Pilot: L2+ and L3, i.e. combination of ACC, lane assist, automatic lane change, intersection assist • revenues based on leasing rates for optional equipment, current subscription fees • City Pilot (L4): from 2030 on expected, door-to-door AD in urban areas • Revenues based on number of urban trips, price per booking period, e.g. € 6 per day
Use Case 2: **In-Car E-Commerce** 	• Mobility e-commerce: e.g., electric charging** ("plug & charge"), automated payment of parking and toll fees • Non-mobility e-commerce: e.g. restaurants booking, leisure, shopping • Revenues based on OEM commissions
Use Case 3: **In-Car Entertainment** 	• Audio and video streaming, in-car entertainment like gaming, social media connectivity • Revenues based on OEM offerings (e.g. VW WE.connect plus, Tesla Premium Connectivity) or OEM commissions
Use Case 4: **Vehicle-to-Grid / Home Energy** 	• OEM as virtual fleet operator with fleet battery capacity, usable for electricity grid operators (e.g. Renault with Mobility House) • OEM as electricity provider (e.g. Elli by VW group) • Revenues based OEM commissions

Source:: CAM. Note: * Based on current prices (inflation), all values are rounded. Only revenue from digital, connected services after vehicle purchase is included, excluding one-off purchases such as optional extras when ordering a new car. **Only electricity revenue in the mobility sector, i.e., charging the electric car while traveling/on the go.

Revenue potential of OEMs through SDV

Market potential

CENTER OF AUTOMOTIVE MANAGEMENT

For the four assumed use cases, the OEM can currently generate revenues of approximately €100 per vehicle. These figures could increase to €150 per vehicle by 2030, and to €350 per vehicle by 2035.

- The **four major SDV use cases** can generate a strong overall growth in software-based revenues over time as SDV capabilities ("fleet size") and customer adoption ("take rate") increase.
- **ADAS and autonomous driving** clearly represent the largest revenue driver, with ARPV growing from **€60–80 in 2025** to **€220–280 by 2035**, reflecting rising demand for advanced safety and automation features. **In-car e-commerce** and **in-car entertainment** show steady but smaller growth, supported by expanding digital ecosystems and user engagement inside the vehicle.
- **Vehicle-to-grid and home energy services** start with limited revenue potential but become more relevant toward 2030 and 2035. In total, average SDV-related ARPV is expected to increase from **around €100 per vehicle in 2025** to **€350 by 2035**, underlining the growing importance of software and services as long-term revenue streams for OEMs.
- The range for Average Revenue per Vehicle (ARPV) depends on brand and market: Lower range = volume brand, Chinese market. Higher range = premium brand, European/ German market.

Global market potential for SDV use cases: Average Revenue per Vehicle (ARPV) range*

	2025	2030	2035
Use Case 1: **ADAS/Autonomous Driving (from L2+ on, HWY+City)** 	**60 - 80 €**	**80 - 120 €**	**220 - 280 €**
Use Case 2: **In-Car E-Commerce** 	**5 - 20 €**	**20 - 30 €**	**40 - 60 €**
Use Case 3: **In-Car Entertainment** 	**10 - 15 €**	**15 - 25 €**	**20 - 40 €**
Use Case 4: **Vehicle-to-Grid/ Home Energy** 	**0 - 5 €**	**10 - 20 €**	**20 - 40 €**
TOTAL AVERAGE (Range)	**~ 100 €** (75 – 120 €)	**~ 150 €** (125 – 195 €)	**~ 350 €** (300 – 420 €)

Source: CAM. * All values are rounded.

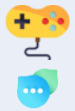
Revenue potential of OEMs through SDV

Market potential

The total market revenue for automotive OEMs stands at approx. €7 billion and could rise to €40 billion by 2030. A nearly tripling of this figure is expected by 2035 to an amount of approx. €115 billion globally.

- Assuming an average revenue per use case and vehicle, as well as a specific number of vehicles suitable for each use case, a total market revenue can be estimated. It highlights how software-based vehicle functions are expected to become a major revenue pillar for the automotive industry over the next decade.
- The values represent:
  - **ARPV** = Average revenue per vehicle of the global fleet size of capable cars.
  - **Revenue** = possible market size for each use case for automotive OEMs
  - **Total revenue** = possible market size for global OEM automotive market.
- In the future, the highest revenues are expected for In-Car e-commerce services, followed by infotainment. Here, OEMs primarily generate revenue through commissions, for example, via integrated advertising, while autonomous driving services enable additional direct sales.
- Overall, total SDV-related revenues across all use cases are expected to increase from around **€7 bn in 2025** to **~€40 bn in 2030** and approximately **€115 bn by 2035**, underlining the long-term monetization potential of SDV ecosystems.

Global market potential for SDV use cases: Market size*

Use Cases		2025	2030	2035
Use Case 1: Autonomous Driving (min. L2+, Highway & City) 	ARPV (€)	70	100	250
	Revenue (€)	1.4 bn	10.0 bn	21.0 bn
Use Case 2: In-Car E-Commerce 	ARPV (€)	10	25	50
	Revenue (€)	2.5 bn	15.0 bn	48.0 bn
Use Case 3: In-Car Entertainment 	ARPV (€)	10	20	30
	Revenue (€)	2.5 bn	12.0 bn	28.8 bn
Use Case 4: V2G/ Home Energy 	ARPV (€)	5	15	30
	Revenue (€)	0.4 bn	3.7 bn	16.4 bn
TOTAL	**Revenue**	**~ 7 bn**	**~ 40 bn**	**~ 115 bn**

Source: CAM. * All values are rounded.

4.

SDV archetypes & way forward

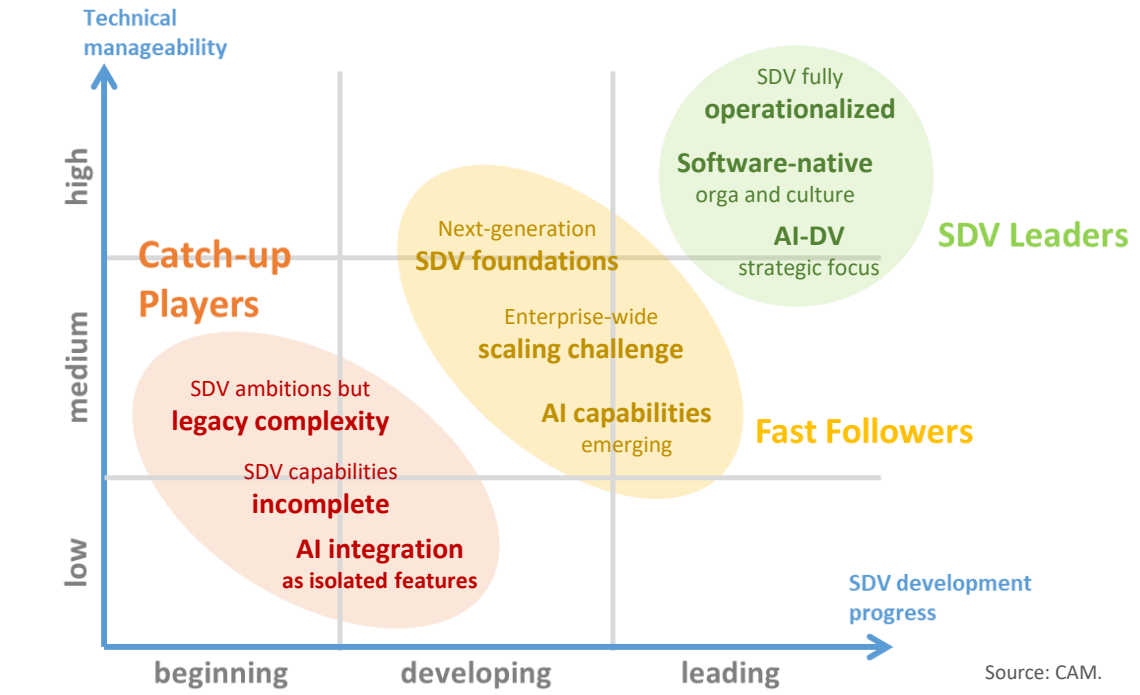
SDV archetypes & way forward

SDV assessment matrix & SDV archetypes

Currently, there is a high OEM risk for being "stuck in the middle" – being caught between technical manageability and the development progress of software defined vehicles.

- The chart illustrates the SDV assessment matrix and resulting SDV archetypes: SDV **development progress** as the combined outcome of seven interrelated criteria, covering technology, organization, and ecosystem dimensions on the one hand, and **technical manageability** as "simplicity" on the other hand.
- On the horizontal axis, **SDV development progress** reflects how far an OEM has advanced from early SDV concepts toward broad, series-wide deployment of SDV platforms. In leading cases, this is characterized by high-frequency, multi-domain OTA updates, a clear central or zonal compute strategy with only a few high-performance computers, and comprehensive AI integration, particularly in vehicle operation and personal assistants. SDV leaders also combine strong in-house software competence with best-in-class technology and content partners, enabling fast innovation without excessive dependency. Crucially, these capabilities are embedded in a software-first culture and agile organization, resulting in significantly shorter development cycles.
- The vertical axis represents **technical manageability**, which serves as a proxy for architectural simplicity. High technical manageability means that an OEM operates with a limited number of vehicle platforms and ideally one unified software platform across the portfolio. Such simplicity reduces integration effort, accelerates OTA rollouts, and allows SDV features to scale efficiently across multiple models. OEMs positioned in the upper-right quadrant typically have years of SDV experience, have already rolled out their SDV platforms across large parts of their model range, and have many—or all—future vehicles developed as SDVs from the start.

SDV Assessment matrix



Source: CAM.

- Conversely, low technical manageability is associated with high architectural complexity, often reflected in more than ten vehicle platforms and multiple parallel software stacks. OEMs in this situation face significant challenges in coordinating updates, integrating AI consistently, and scaling SDV features across brands and regions. As the chart shows, this complexity acts as a structural constraint on SDV development progress. Accordingly, technical manageability emerges as a key explanatory factor: OEMs with simpler, more unified architectures systematically achieve higher SDV maturity, while those managing fragmented platform landscapes tend to remain in catch-up or transitional positions despite significant individual investments.

Source: CAM | As of: October 2025.

SDV archetypes & way forward
Summary

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Catch-Up Players

- **SDV ambition is evident, but execution remains constrained by legacy complexity**, with fragmented software stacks, high variant diversity, and misaligned organizational structures preventing the establishment of a unified, scalable platform across brands and regions.
- **Industrialization of core SDV capabilities is incomplete**, as OTA, centralized compute, and cross-domain integration are not consistently deployed beyond selected use cases, limiting both speed of innovation and lifecycle value capture.
- AI-DV readiness is structurally limited, with **AI largely applied in isolated features rather than as an integrated decision layer**, due to missing data foundations, insufficient compute abstraction, and lack of end-to-end platform ownership.

Fast Followers

- **Next-generation SDV foundations are largely in place**, including modern software stacks, centralized compute architectures, and OTA-enabled fleets, but remain concentrated in new vehicle lines and are not yet scaled consistently across the full portfolio.
- **The primary challenge lies in enterprise-wide scaling and governance**, requiring stronger platform discipline, clearer decision rights, and reduction of architectural heterogeneity to translate technical capability into sustained delivery speed.
- **AI capabilities are emerging but not yet system-defining**, with a transition underway from assistant-level features toward cross-domain intelligence, while missing a fully integrated AI platform spanning data, models, and vehicle-cloud orchestration.

SDV Leaders

- **SDV is fully operationalized through unified software platforms and centralized compute**, enabling rapid iteration, high-frequency OTA updates, and consistent deployment across the entire vehicle fleet as a standard operating model.
- **Organizational setup and culture are deeply software-native**, allowing tight integration of development, data, and operations, and enabling continuous improvement loops at fleet scale.
- **The strategic focus has shifted toward AI-DV as the next differentiation layer, where AI becomes the core decision-making system of the vehicle**, powered by integrated data pipelines, scalable compute, and continuous learning across the fleet.

SDV to AI-DV

Core Differentiating Factors Of Archetypes and AI-DV

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SDV

Catch-Up Players

- Ambition visible to unify vehicle portfolio
- Fragmented software platforms
- SDV implementation differs across domain and region

Fast Followers

- SDV light house cars launched with a central computer strategy and advanced software platform
- Investments in software talent and cross-org. SDV programs

SDV Leaders

- Unified software stack across broad vehicle platform
- Centralized compute architecture implemented
- Software mindset embedded also in their organizational setup and culture

AI-DV

- AI as the central decision-layer
- Goal-driven interaction instead of feature control
- AI-orchestrated system behavior across vehicle and cloud
- Fleet-level intelligence and continuous improvement
- Adaptive, probabilistic, and emergent vehicle behavior

Source: Accenture.

Archetype 1 — Catch-up Players

Reach SDV industrialization baseline and reduce complexity drag.

Theme: High ambition, constrained by legacy complexity

Catch-Up Players

- Ambition visible to unify vehicle portfolio
- Fragmented software platforms
- SDV implementation differs across domain and region

Where They Stand

SDV progress exists, but execution is slowed by:

- fragmented legacy stacks
- too many vehicle/platform variants
- limited OTA reach beyond infotainment
- early-stage AI integration

Core issue: **technical and organizational manageability is still low**

CTO Agenda (Next 24 Months)

Unify software platforms: enforce one group-wide baseline, retire legacy diversity

Move to zonal + central compute: consolidate ECUs into fewer high-performance nodes

Introduce AI with functional ROI: measurable benefits, not chatbot experiments

Expand OTA across all domains: infotainment → powertrain → safety → full vehicle

Break silos: vertical feature teams with end-to-end accountability

Shift culture from SOP to continuous delivery: software lifecycle becomes the operating model

Source: Accenture.

Archetype 2 — Fast Followers

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Industrialize SDV at enterprise scale and close the gap to leaders.

Theme: Strong foundations, now scaling is the challenge

Fast Followers

- SDV light house cars launched with a central computer strategy and advanced software platform
- Investments in software talent and cross-org. SDV programs

Where They Stand

Core SDV building blocks are largely in place:

- next-gen software stacks
- meaningful OTA fleets
- central compute rollouts starting
- assistant-level AI integration

Core issue: **scaling consistently across brands and vehicle lines**

CTO Agenda (Scale Phase)

Scale SDV baselines across the full portfolio: not just flagship launches

Consolidate domains onto fewer SoCs: reduce architecture heterogeneity

Move beyond IVI AI toward contextual vehicle intelligence: cross-domain orchestration

Shift OTA from bugfix to value delivery: feature velocity becomes competitive weapon

Strengthen governance and decision rights: central software authority is critical

Partner strategically: outsource infrastructure, keep differentiation in-house

Source: Accenture.

Archetype 3 — SDV Leaders

Own the vehicle's intelligence layer as the ultimate differentiator.

Theme: Software-native OEMs defining the next frontier

SDV Leaders

- Unified software stack across broad vehicle platform
- Centralized compute architecture implemented
- Software mindset embedded also in their organizational setup and culture

Where They Stand

These OEMs operate with SDV maturity as default:

- unified platforms
- high-frequency OTA across fleets
- centralized compute architectures
- rapid software iteration culture

Core issue: **the next frontier is AI-governed vehicle behavior**

CTO Agenda (Next Frontier)

Extend unified software into unified AI model platforms

Design AI-first compute architectures: AI becomes the decision layer, not an add-on

Build AI governance at fleet scale: safety, compliance, lifecycle control

Deploy OTA for AI evolution: parameters, models, behavioral tuning

Create dedicated AI platform organizations: not feature teams, but system ownership

Evolve culture from software-first to AI-governed decision-making

Source: Accenture.

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Appendix

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A.

Appendix

2. About Center of Automotive Management

About Center of Automotive Management

Research priorities: AutomotiveINNOVATIONS Ecosystem

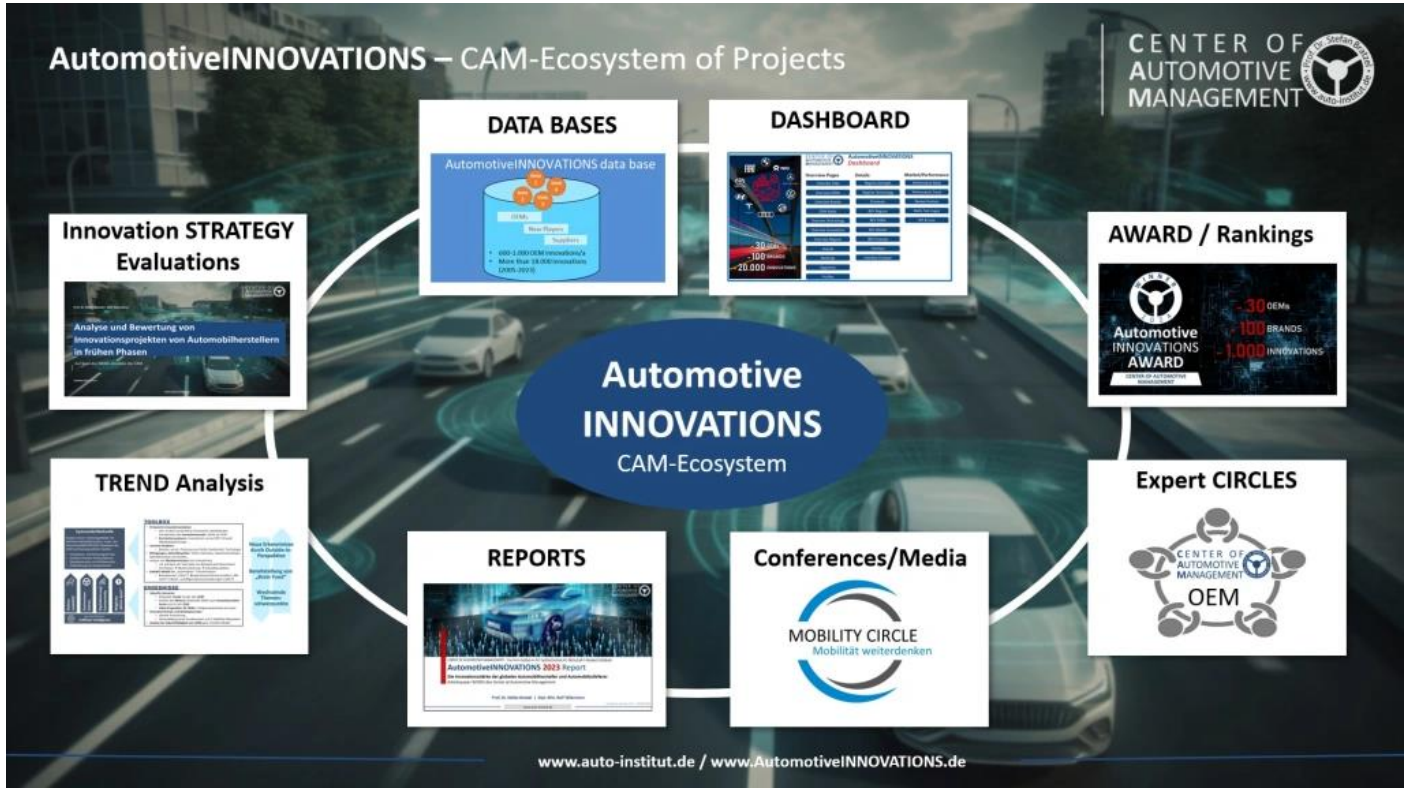
The **Center of Automotive Management (CAM)** is an **independent, scientific institute** for **empirical automotive and mobility research** as well as for **strategic consulting** at the University of Applied Sciences for Economics (FHDW) in Bergisch Gladbach near Cologne, Germany.

The CAM focuses its research on **innovation trends** and success factors in the future fields of **electromobility, software-defined vehicles, autonomous driving** and **mobility services.** Based on in-depth industry know-how and extensive databases – particularly on vehicle technology innovations in the global automotive industry and mobility services – CAM develops **individual market research concepts** and helpful solutions for its customers from the **automotive and mobility industries.**

The director of the Center of Automotive Management (CAM) is **Prof. Dr. Stefan Bratzel,** who founded the institute in 2004.

Please find further information on CAMs website www.auto-institut.de or feel free to contact us.

AutomotiveINNOVATIONS – CAM-Ecosystem of Projects



About Center of Automotive Management

AutomotiveINNOVATIONS Dashboard based on Microsoft Power BI

The **CAM AutomotiveINNOVATIONS database** is filled on a regular basis. Every quarter a new update is released. The databases contains more than 18.000 single innovations at present. Each innovation is tracked and analysed using more than 50 attributes.

Free trial version:

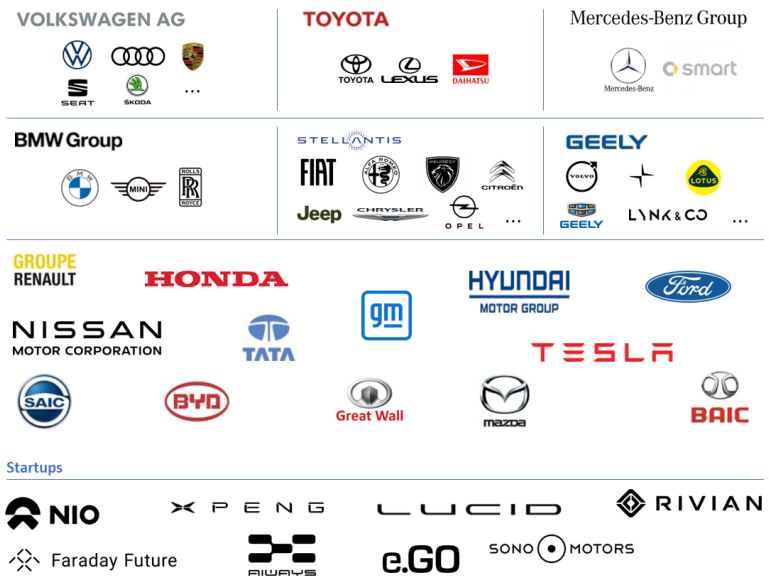
https://automotiveinnovations.de/

About Center of Automotive Management

CAM Innovations- and Mobility Services Databases

CAM research is fundamentally based on **several databases on innovations and services** which are continuously updated, enlarged and improved since 2005

CAM AutomotiveINNOVATIONS OEM database: 28 global car groups and newcomers with 80 automotive brands



CAM AutomotiveINNOVATIONS Supplier database: Top 100 global automotive suppliers and innovative digital players

CAM MobilitySERVICES database: Automotive global car groups and non-automotive mobility players

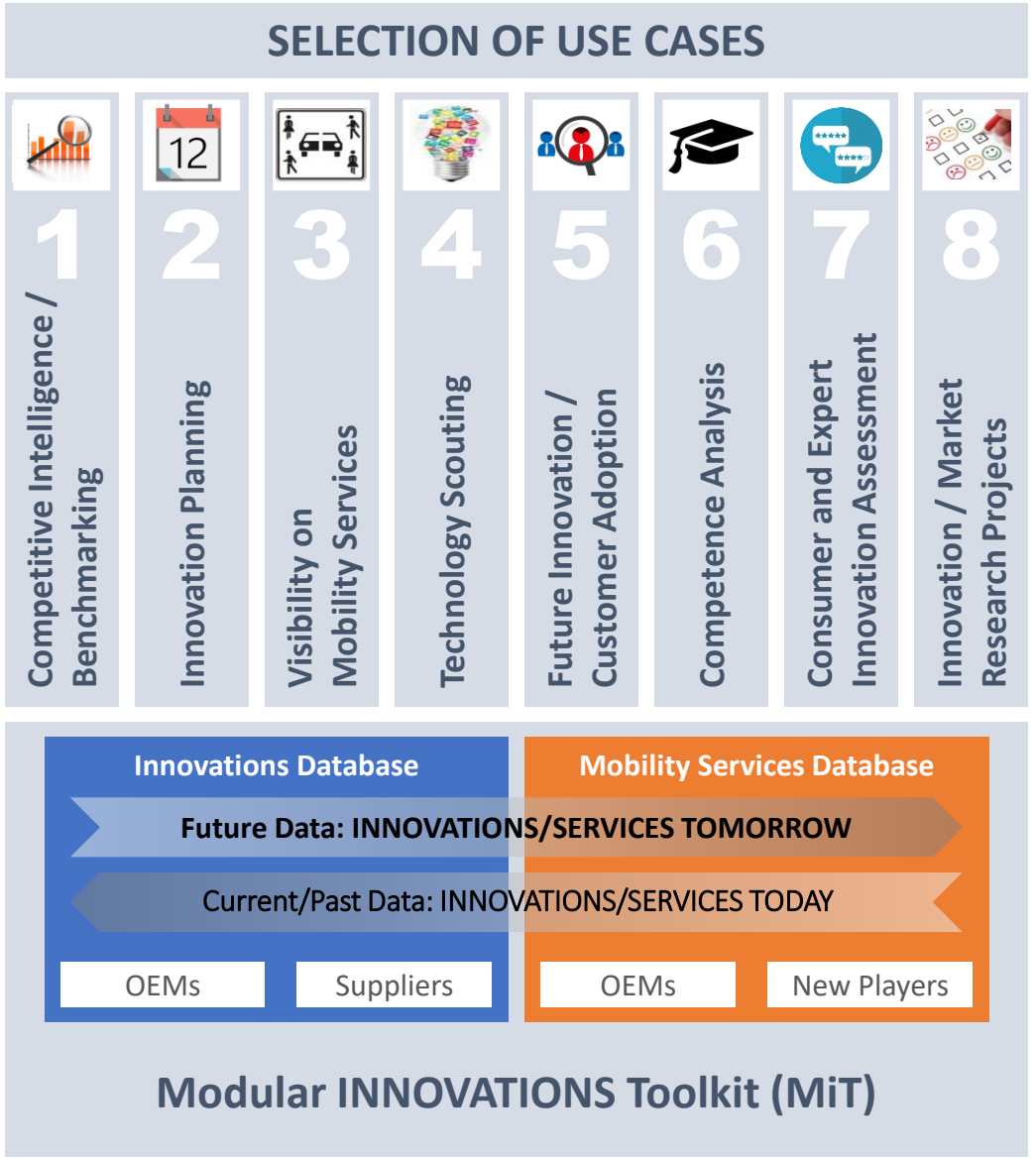
About Center of Automotive Management

CAM Modular INNOVATIONS Toolkit

The **Modular INNOVATIONS Toolkit (MiT)** is developed by CAM as an unique strategy and planning tool designed to evaluate current and future trends of the automotive industry and the mobility system.

MiT is based on …

- an **AutomotiveINNOVATIONS data base** surveying approx. 100 car manufacturers in key technology areas like powertrain, connected car, safety and autonomous driving, interieur. Customer centric novelties are continually updated and analysed using about 50 defining attributes like innovations type, originality, maturity etc.
- a **Mobility Services data base** consists of more 400 platform services like ride hailing, car sharing, intermodality that are offered by automotive manufacturers as well as mobility providers or digital players and start-ups. Mobility Services are periodically updated and analysed.
- **CAM Research reports** providing market data, analytic insights and forecasts on key technology fields like E-Mobility, Connectivity and Autonomous Driving.



About Center of Automotive Management
CAM premium partnershift

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- Annual CAM studies from the AutomotiveINNOVATIONS series as Power Point, including specials e.g. on connected cars, e-mobility, mobility services
- Annual CAM studies from the AutomotivePERFORMANCE series as PowerPoint, including market forecasts, competitive comparisons, car recalls
- Incl. all updates and extensions to the study series during the year
- Option to extend over several years
- Special conditions for lectures by Prof. Dr. Stefan Bratzel
- Cooperation with the CAM on commissioned studies
- Opportunity to cooperate with the University of Applied Sciences for Business (FHDW) for internships for automotive students
- Several newsletters per year with current research results from the CAM
- Attractive fixed price per year

A.

Appendix

3. Contact/ Imprint/ Copyright

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The director of the **Center of Automotive Management** is Professor Dr. **Stefan Bratzel**, who founded the institute in 2004.

At the same time, Prof. Bratzel is the **director** of the **business administration** major Automotive Management at the private **University of Applied Sciences (FHDW)** in Bergisch Gladbach. Stefan Bratzel (born 1967) has worked for several years in product marketing at the former Daimler subsidiary smart and as sales manager at an automotive supplier.

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