Software-Defined Vehicles: Adoption and Impact

Auto Industry's Shift to AI and a Software-first Future

Signals Report – Automotive Spotlight

March 2025

Why read this paper?

This paper explores how SDV is becoming the top strategic priority for the industry driven preeminently by the need for OEMs to shorten development cycles, reduce costs, and design, build, and deliver new vehicle models to the market in less time across ICE, Hybrid, and EV platforms. The paper also highlights how OEMs and Tier-1 suppliers are responding to growing customer demands for enhanced connectivity, automation, and personalization, creating new revenue-generating and customer experience enhancing features.

As a key principle of SDV, the paper also draws attention to the rise of zonal architecture and how manufacturers are adopting it to streamline vehicle electronics to keep up with the evolving market landscape. Finally, the paper outlines how manufacturers can navigate challenges associated with these transformations, with a detailed analysis of how OEMs and suppliers are increasingly turning to cloud and AI solutions to improve planning and requiments, development, testing, and data management processes in a software-centric zonal architecture environment.

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Key findings

1. **SDV is the top strategic priority for both OEMs and suppliers and supports key vehicle capabilities.**
   - A majority of OEMs (45%) and suppliers (45%) regard SDV as their top priority, followed by autonomous driving/advanced driver-assistance systems (AD/ADAS; 25% OEMs, 24% suppliers) and EVs (14% OEMs, 12% suppliers).
   - Over-the-air (OTA) software updates are the most widely rolled-out SDV capability today (64% of vehicles sold in 2024 are enabled with OTA capability).

2. **Zonal architecture has become the standard for SDV development.**
   - 80% of OEMs have already transitioned from traditional domain, distributed, and federated architectures to zonal architecture for thier SDVs, and 81% of suppliers are already making components for zonal architecture in SDVs.
   - Spending on Vehicle Architecture and Design is 18% of OEM's overall expenditure across V-Model phases of SDVs, closely behind software (21%) and electrical/electronic E/E (19%).

3. **The costs of transitioning from legacy systems and skill gaps are major barriers to SDV adoption.**
   - 30% of OEMs and 26% of suppliers emphasize cost challenges associated with retrofitting hardware and re-engineering software as major barriers.
   - OEMs identify a lack of internal skills and expertise (18%) as the primary hindrance in transitioning to zonal architecture.

4. **Cloud plays a critical role in addressing these challenges and in optimizing design and testing processes in SDVs.**
   - 73% of OEMs and 71% of suppliers consider the cloud to be a critical technology in enabling OTA updates.
   - While hybrid/public cloud is preferred for optimizing design, testing, and data processing activities, workloads specific to zonal architecture are handled in private clouds and on-premises environments.

5. **AI technology is expected to further improve design, testing, and in-vehicle functionalities in SDVs.**
   - AI is recognized as a valuable technology, especially in software development and validation (89% of OEMs and 79% of suppliers regard it as valuable) and in E/E system design and testing (77% OEMs and 76% suppliers).
   - Generative AI (GenAI) is coming up with notable use cases in systems engineering, including translating vehicle requirements into executable tests and generating technical specifications.

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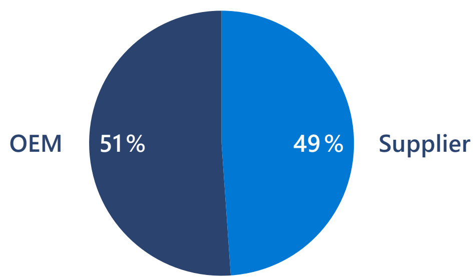
Scope of this report

Automotive OEMs and tier-1 suppliers: This report offers insights into digital engineering, including the design and development processes for automotive OEMs and tier-1 suppliers, particularly those involved with both passenger and commercial vehicles, rather than focusing on manufacturing operations only.

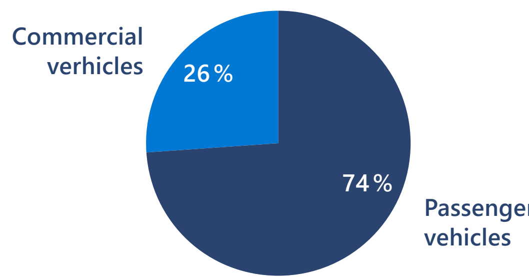
About the data: Survey of 86 executives in the automotive industry

Overview of N=86 participants

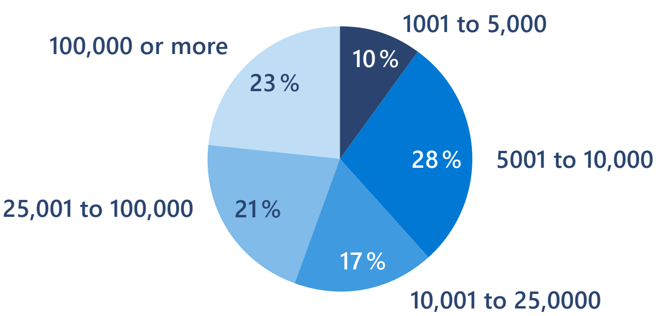
Respondent type distribution



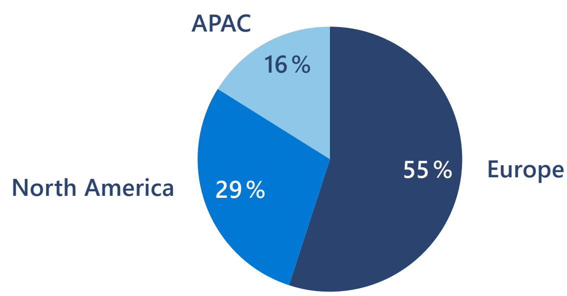
Vehicle type that respondents answered the survey for



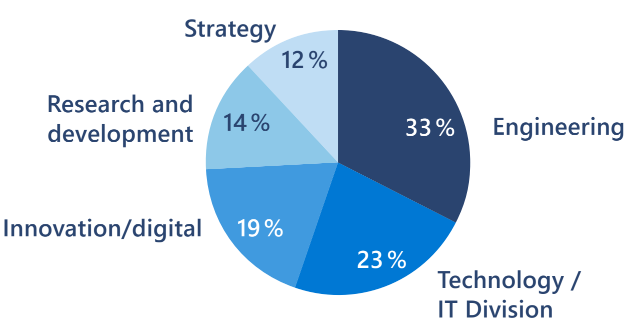
Number of employees



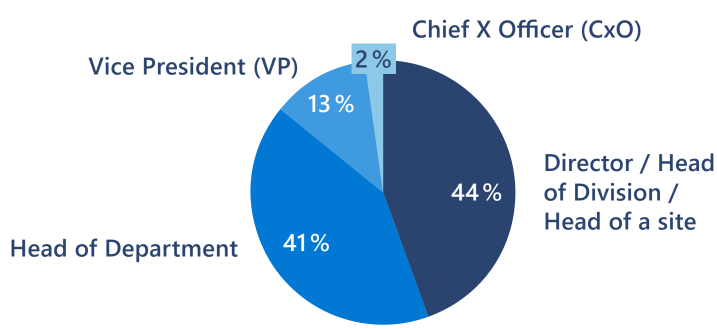
Region



Department



Seniority



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Methodology

Microsoft developed this document in close collaboration with IoT Analytics, a boutique market research company focusing on IoT, AI, the cloud, edge technology, and Industry 4.0.

The centerpiece of this research is a survey conducted between January and February 2025, with a total of 86 respondents working in automotive industries worldwide. The respondents are key stakeholders in organizational strategy, spanning roles in engineering, R&D, and technology/digital initiatives. The survey respondents represent a diverse cross-section of automotive manufacturers, covering OEMs and tier-1 suppliers of both passenger and commercial vehicles. They come from key organizational functions, including IT and innovation, with a majority holding senior leadership roles. Geographically, the respondents are primarily from Europe, North America, and Asia-Pacific, and they work for companies ranging from mid-sized enterprises to large multinationals, including those with over 100,000 employees.

1 Current state of SDV adoption

The automotive industry is prioritizing SDVs, with both OEMs and suppliers focusing on software to enhance vehicle functionality.

- **Regional differences in strategy.** European and APAC OEMs are leading the SDV transition, while North American companies focus more on AD/ADAS technologies.
- **Critical role of OTA updates.** OTA updates enable new features and unlock monetization opportunities.
- **Key challenges in adoption.** Data privacy, regulations, and profit-sharing remain significant hurdles.
- **Managing the transition effectively.** While SDVs streamline development and create new revenue streams, they require careful management of technology and customer trust.

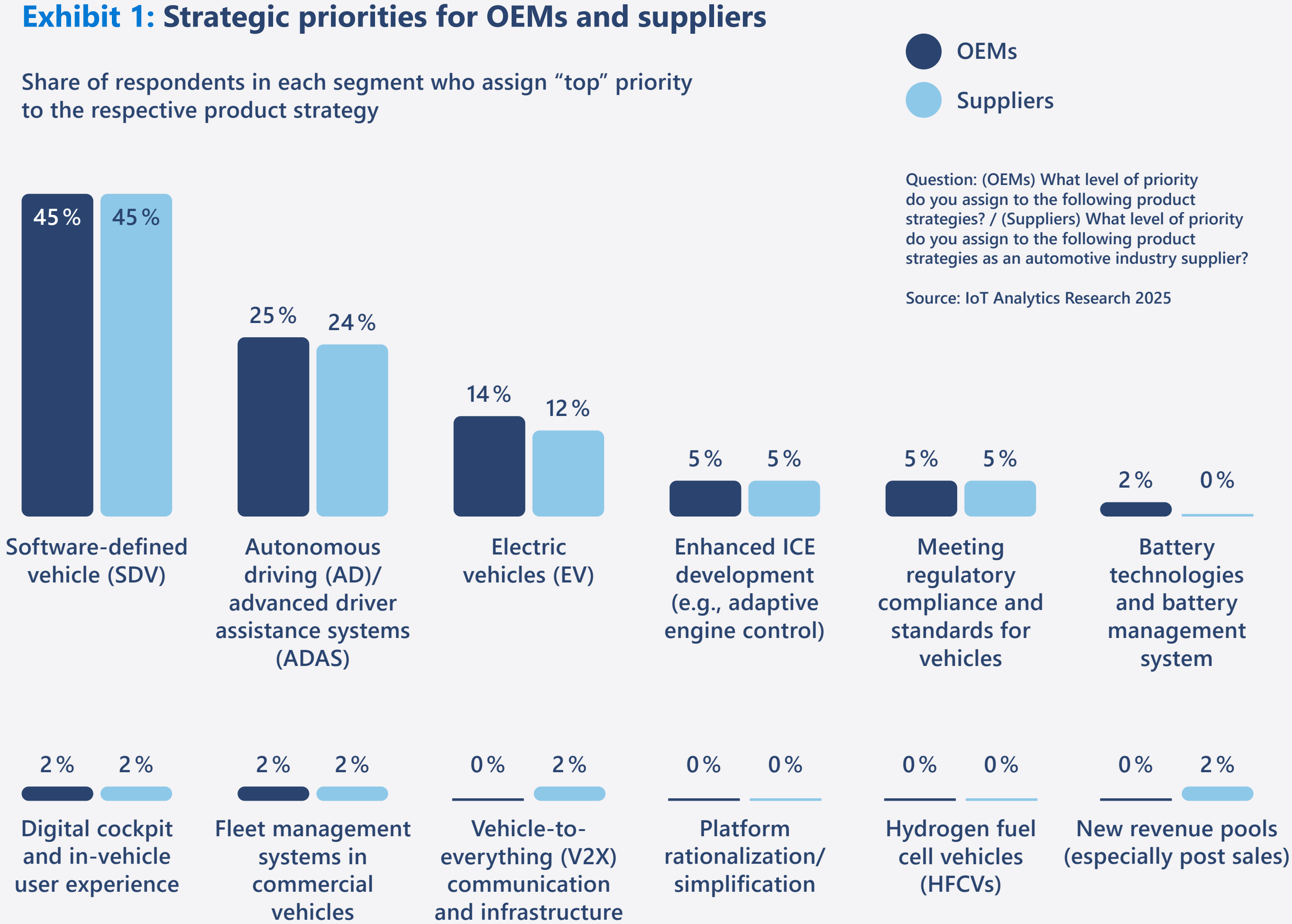
SDV's role in the future of automotive strategy

SDV is the top strategic priority for OEMs and suppliers, ahead of AD/ADAS and EV.

The auto industry is undergoing significant product transformation with three key changes: EVs, autonomous vehicles, and SDVs. Software-defined is the number one priority (45% of OEMs and suppliers), followed by AD/ADAS (25% OEMs and 24% suppliers) and EVs (14% OEMs and 12% suppliers). Regionally, European and APAC OEMs are at the forefront of this shift, while in North America, AD/ADAS retains prominence. Within vehicle segments, SDVs are prioritized in passenger vehicles, whereas commercial vehicle OEMs, facing distinct challenges, adopt a more measured approach to this transition.

Exhibit 1: Strategic priorities for OEMs and suppliers

Share of respondents in each segment who assign "top" priority to the respective product strategy



Question: (OEMs) What level of priority do you assign to the following product strategies? / (Suppliers) What level of priority do you assign to the following product strategies as an automotive industry supplier?

Source: IoT Analytics Research 2025

This focus on SDVs is driven by the need to shorten development cycles, reduce cost and complexity, deliver products to market faster and as needed, and introduce new revenue-generating and customer experience-enhancing capabilities and features.

> “Today, BMW can deliver over-the-air updates to more than nine million SDVs worldwide. And we can update the entire vehicle software in this way. It allows us to keep improving our vehicles without the need for a workshop visit. It provides our customers greater comfort and safety and offers them new features and functional improvements from time to time. The fact that nine million Remote Software Upgrades have now been carried out underlines how popular this form of innovation is with our customers.”
>
> **—Christoph Grote, senior vice president for electronics and software at BMW Group**
> **(Source: BMW Group Press Release))**

SDV adoption across different vehicle platforms

OEMs prioritize SDVs across both EV and modified ICE vehicle platforms.

SDVs stand out as the foremost priority for OEMs, but their development transcends platform type. Although dedicated EV platforms slightly lead, they are closely followed by modified ICE and hybrid vehicle platforms, demonstrating a strategic, balanced approach to integrating SDV capabilities across both traditional and electrified architectures. In contrast, EV-first platforms are witnessing comparatively lower adoption.

Exhibit 2: Vehicle platforms for integrating SDV capabilities

Share of respondents in each segment who mentioned their organization is considering the respective platform strategy for integrating SDV capabilities

		Region			Vehicle type	
EV ↕ ICE	Overall	Europe	North America	APAC	Passenger vehicles	Commercial vehicles
Electric vehicle platforms	77.3 %	82.6 %	61.5 %	87.5 %	79.3 %	73.3 %
EV-first platforms (primarily designed for electric vehicles, but adaptable for ICE vehicles)	31.8 %	21.7 %	53.8 %	25.0 %	24.1 %	46.7 %
Hybrid vehicle platforms	68.2 %	87.0 %	53.8 %	37.5 %	69.0 %	66.7 %
Modified ICE vehicle platforms	75.0 %	73.9 %	69.2 %	87.5 %	69.0 %	86.7 %

Question: For your organization's vehicles, what platform strategy are you considering for integrating SDV capabilities?
Source: IoT Analytics Research 2025

"The shift towards integrating SDV capabilities by ICE OEMs is not to match feature to feature with EV/Tech-native OEMs but to enhance the overall customer experience through a software-defined vehicle approach. Traditional OEMs are placing greater emphasis on technology and software, striving to make vehicles more connected to consumers' everyday lives, like how smartphones have become integral."

—Senior program manager for connected vehicle services at a major European car OEM

North American OEMs balance SDV integration across multiple platforms.

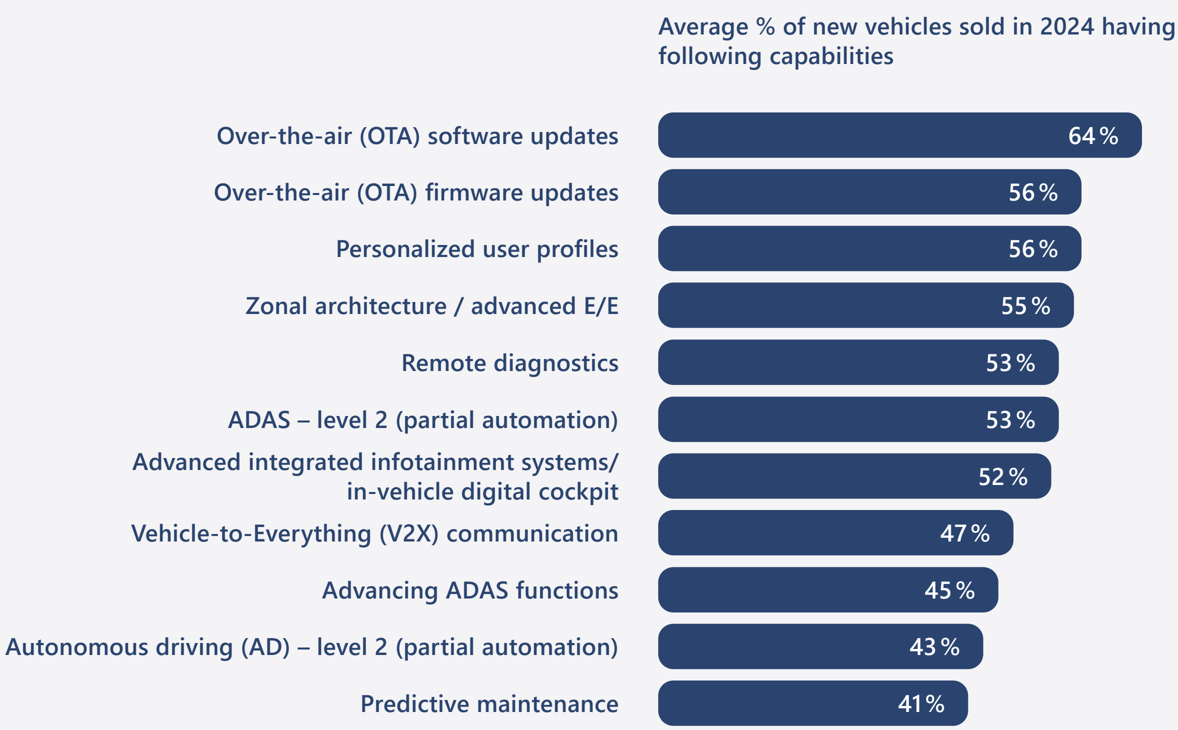
Compared to their European and Asian counterparts, North American OEMs are more open to integrating SDV capabilities into vehicles built across various platforms, including EV-first platforms (designed for EVs but adaptable for ICE). This may stem from North American OEMs' focus on balancing innovation with existing infrastructure, deploying a more pragmatic, profit-driven approach. Another trend to note here is the rationalization of vehicle platforms, with OEMs aiming to reduce the number of platforms they build. In contrast, European OEMs prefer dedicated architectures due to stricter emissions and sustainability regulations, while Chinese OEMs invest in purpose-built EV platforms and, at the other end of the spectrum, in modified ICE platforms to remain competitive in both markets. Additionally, the entry of tech-native mobility players is influencing the landscape, as these players leverage the latest technologies with fewer constraints than traditional OEMs.

Key SDV capabilities and business models

OTA is the cornerstone of unlocking SDV's full potential.

OTA software updates are the most common SDV capability rolled out in 2024. This capability is rapidly becoming a cornerstone of SDV development, as it is an enabler for integrating many other capabilities throughout the vehicle's lifecycle.

Exhibit 3: The most-rolled out SDV capabilities in 2024



Question: For your organization's vehicles, please estimate what % of new vehicles sold in 2024 have the following SDV capabilities.
Source: IoT Analytics Research 2025

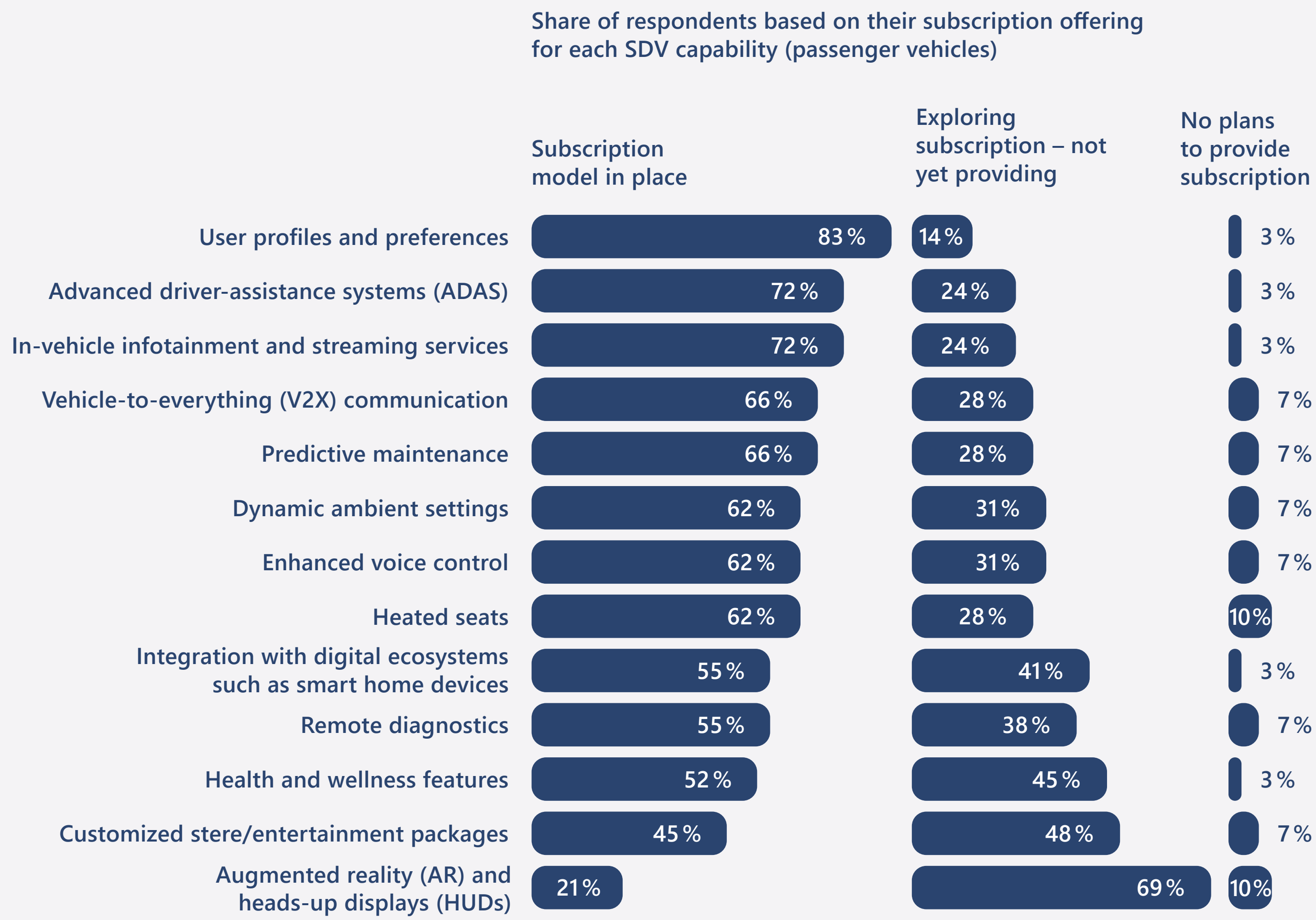
Another crucial benefit of OTA adoption is the reduction in software version variability across different vehicles. With fewer versions to manage, OEMs can lower operational complexity and streamline maintenance. On-board diagnostics also plays a pivotal role, enabling proactive issue detection and remote fixes. This capability, combined with predictive maintenance tools, helps OEMs not only maintain vehicle performance but also enhance customer satisfaction by minimizing unplanned downtime.

> "The primary motivation behind the adoption of OTA updates is the significant cost avoidance they offer. By remotely deploying software updates, especially for repairs and recalls, OEMs can bypass costly trips to the dealership, saving millions annually."
>
> **—Senior program manager for connected vehicle services at a major European car OEM**

OTA is also enabling a variety of potential new business models and monetization opportunities for SDV features.

In terms of monetizing SDV capabilities, OTA is enabling OEMs to provide subscription plans across many different SDV features. In passenger vehicles, some subscriptions have been widely rolled out, such as user profiles and preferences, ADAS, or in-car infotainment, while others are still in the exploration phase, such as augmented reality (AR) and heads-up displays (HUDs). Commercial vehicles are still far behind passenger vehicles in terms of adopting subscription-based SDV capabilities. However, user profiles, preferences, and predictive maintenance, which have been widely adopted in the passenger vehicle segment, offer strong growth potential.

Exhibit 4: Subscriptions enabled by OTA in passenger vehicles



Question: Which of the following SDV capabilities currently have or are being considered for a subscription model?
Source: IoT Analytics Research 2025

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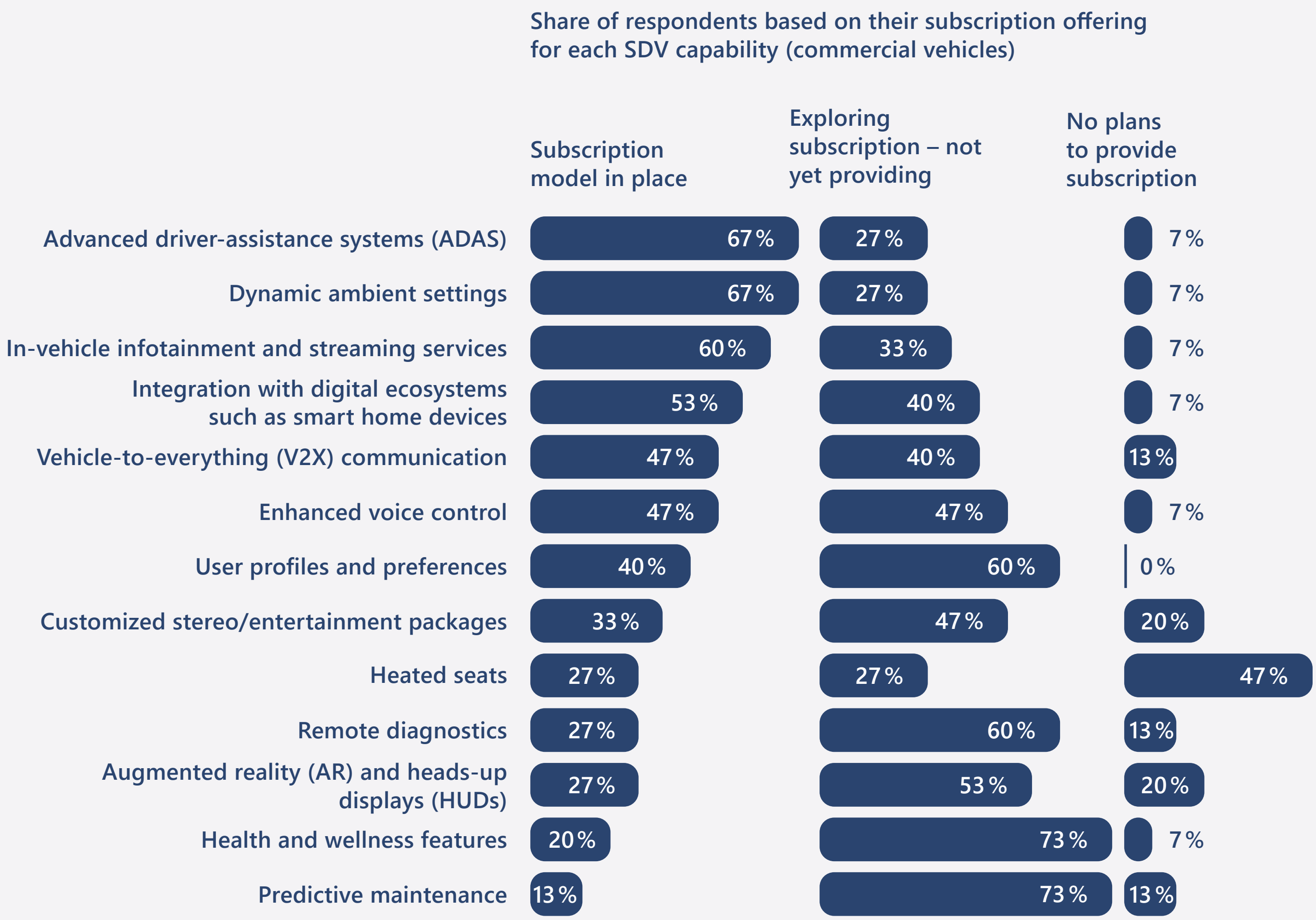
Exhibit 5: Subscriptions enabled by OTA in commercial vehicles



Question: Which of the following SDV capabilities currently have or are being considered for a subscription model?
Source: IoT Analytics Research 2025

Beyond subscription models, there are several emerging data monetization approaches. One is usage-based insurance, where driving data can be shared with insurance companies to adjust rates. Another is data monetization, where data on driver habits and location can be leveraged for the following reasons:

- Create more targeted and personalized marketing
- Enhancing smart city infrastructure
- Partnering with service providers to monetize insights like traffic patterns or vehicle usage
- Offering predictive maintenance and after-sales services to customers

Additionally, there is potential for other innovative offerings like Feature on Demand (FOD). For example, on-demand horsepower upgrades, changes in suspension settings, etc. However, three key challenges persist:

1. Consumer backlash regarding data privacy
2. Regulatory concerns related to data sharing with OEMs
3. Issues surrounding data access and sharing between OEMs and suppliers, compounded by the lack of profit-sharing frameworks between the two.

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2 Zonal architecture: Enabler for SDVs

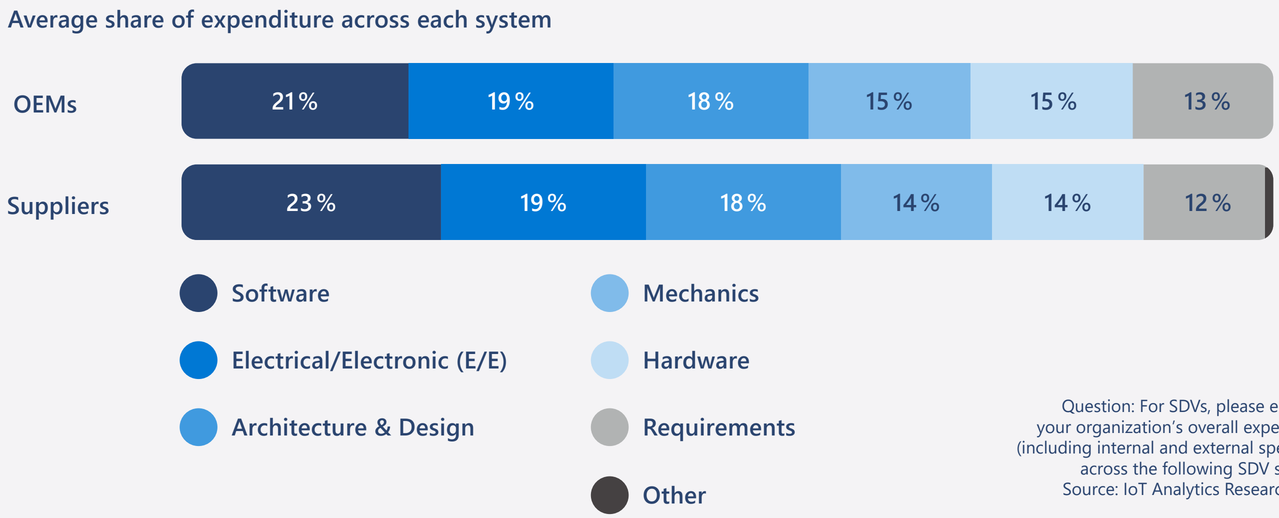
- **Investment in software and modern architectures.** OEMs and suppliers are prioritizing software development and adopting modern architectures to manage the growing complexity of SDVs.
- **Central role of zonal architecture.** Zonal architecture is key to streamlining vehicle electronics, improving scalability, efficiency, and reliability.
- **Benefits of zonal architecture.** Zonal architecture simplifies key systems like monitoring, diagnostics, and safety features while reducing wiring, weight, and manufacturing costs.
- **Challenges for traditional OEMs.** While tech-native companies have led the transition, traditional OEMs face greater challenges balancing in-house efforts with outsourcing.

How software-defined features are transforming vehicle architectures

OEMs are investing in both software development and the transition to modern architectures.

As the integration of SDV features grows, so does the complexity of vehicle design and development. While software leads in SDV spending priorities, OEMs and suppliers place significant emphasis on other SDV systems, including architecture and design.

Exhibit 6: Expenditure across SDV systems



Question: For SDVs, please estimate your organization's overall expenditure (including internal and external spending) across the following SDV systems
Source: IoT Analytics Research 2025

This balanced approach supports the growth of software alongside essential architectural frameworks, ensuring successful SDV deployment. However, the issue of scale remains a significant challenge for OEMs, particularly when it comes to competing with tech-centric companies like Tesla, which appears to have more flexible and scalable systems through verticalization. These OEMs face friction with suppliers, balancing in-house efforts with outsourcing to manage costs. Some OEMs partner from the start, while others choose a mixed strategy, adjusting based on their needs and competitive priorities.

> "A shift towards a more centralized architecture such as zonal is evident, as companies recognize the need to streamline systems while addressing key concerns such as safety and functionality. Within this context, OEMs like Mercedes and BMW lead the way with significant in-house capabilities, while others, such as Stellantis, are engaging in strategic partnerships with suppliers to bolster their SDV development."
>
> **—Head of corporate strategy development at a top 10 automotive tier-1 supplier**

Zonal architecture’s role in accelerating SDV adoption

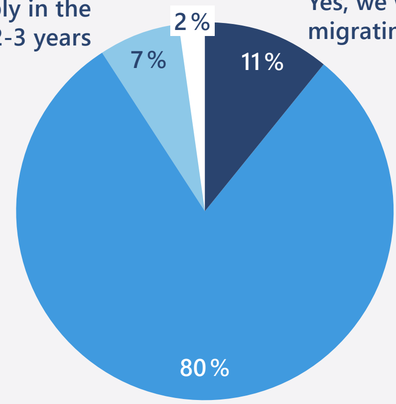
Both OEMs and suppliers recognize that zonal architecture is simplifying vehicle electronics to support growing SDV complexity.

The shift to zonal architecture is accelerating, with 80% of OEMs and 81% of suppliers already adopting it and 11% of OEMs and 10% of suppliers planning to follow suit. Zonal architecture is emerging as the foundation for efficient, scalable, and future-proof vehicle design as the industry increasingly moves away from the traditional domain, distributed, and federated models.

Exhibit 7: Migrating to zonal architecture for SDV adoption

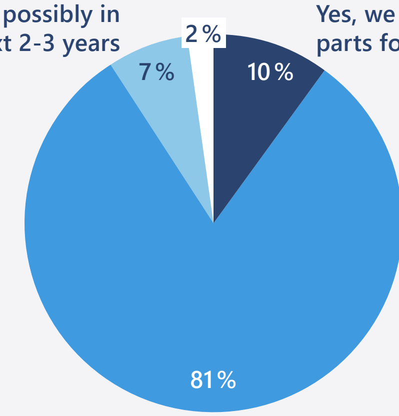
OEMs

Share of respondents based on their migration (plans) to zonal architecture for SDVs



Suppliers

Share of respondents based on whether they are expecting their customers to migrate to zonal architecture for SDVs



Question: (OEMs) Do you agree with the following statement: In the future we are migrating (or have already started to do so) to zonal architecture?
(Suppliers) Do you agree with the following statement: In the future our customers are migrating (or have already started to do so) to zonal architecture in SDVs?
Source: IoT Analytics Research 2025

Zonal architecture offers several significant advantages, including:

a. **Reduced wiring harnesses –** Consolidates ECUs into zones, cutting down on complex wiring

b. **Weight reduction –** Less wiring lowers vehicle weight, improving efficiency and range.

c. **Cost savings –** Fewer wires and connectors, reducing material and manufacturing costs

d. **Manufacturing efficiency –** Streamlines assembly with fewer components and simpler processes

e. **Scalability and flexibility –** Support easy integration of new features and software updates

f. **Improved reliability –** Fewer connections reduce the risk of electrical faults and failures

g. **Enhanced performance –** Better signal integrity and reduced electromagnetic interference

h. **Simplified maintenance –** Faster diagnosis and reduced time to first fix due to fewer wires and organized systems

i. **Platform consolidation & time to market –** Reduces development time and helps meet long-term regulatory (ISO/SAE 21434, UNECE WP.29) requirements

Survey question: Why are you migrating to zonal architecture?

Key answers:

- "Zonal architecture fits perfectly with our automation goals, helping us streamline processes and reduce manual work"
- "Better balance of data optimization. Workload sharing"
- "With zonal architecture, maintenance becomes easier as the technicians can focus on specific zones instead of navigating through a complex web of wiring"
- "Helps with modulation"
- "Because of the increasing features and faster control, primarily due to major success in China"
- "Centralization of compute is an important enabler for new features required by the market, e.g., SOTA, ADAS"
- "To reduce cost and increase re-use and flexibility"

Challenges are more significant for traditional players compared to digital-native manufacturers

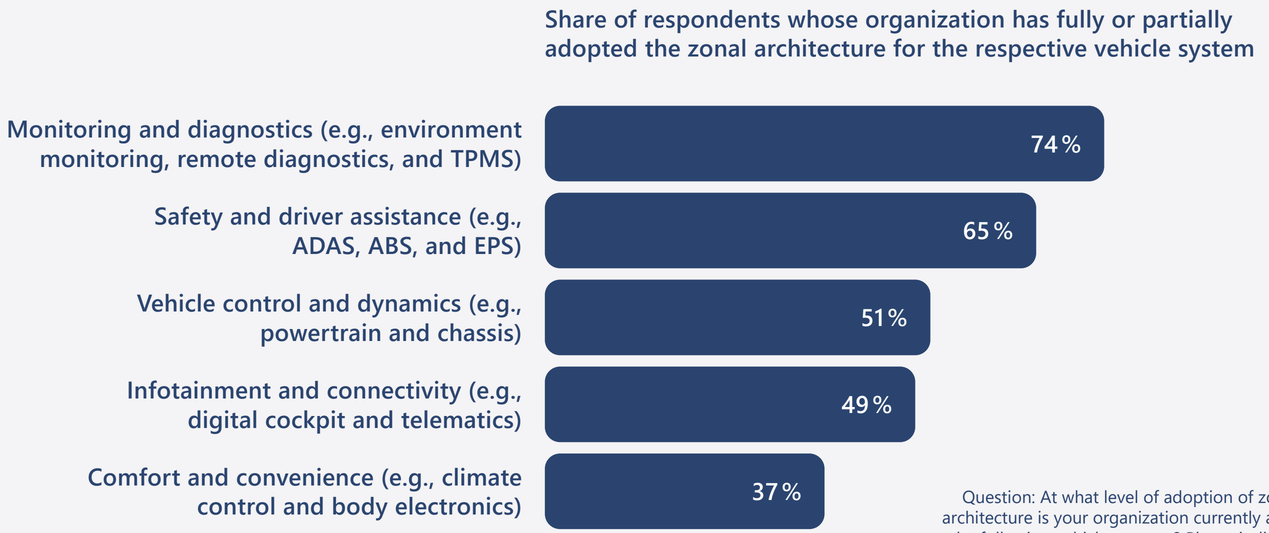
While EV-native companies like Tesla and Rivian adopted zonal architecture for different reasons, such as streamlining hardware and minimizing complexity, traditional OEMs are embracing this approach to simplify their architecture and reduce the complexity of OTA updates.

The key question now is how to approach the adoption of zonal architecture: should it be implemented all at once or system by system? This is particularly relevant for safety-critical systems, as zonal architecture consolidates resources, while these systems often require dedicated, isolated control units to maintain reliability.

Safety systems: A high-priority in zonal architecture

Among OEMs, the adoption of zonal architecture is progressing across key vehicle systems. They focus on monitoring and diagnostics (75%), followed by safety and driver assistance (66%), highlighting its importance for operational efficiency and safety.

Exhibit 8: Adoption of zonal architecture by vehicle system by OEMs



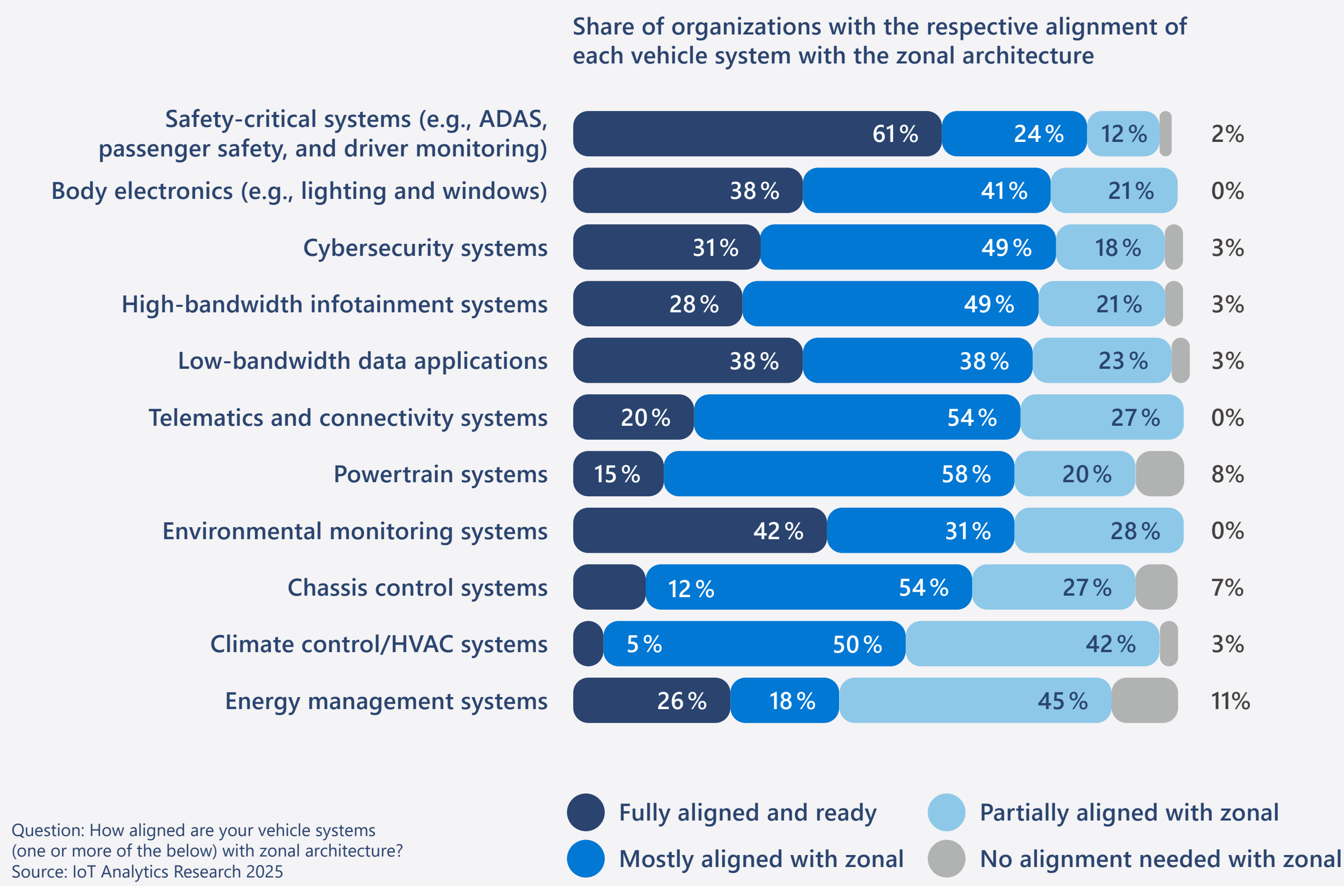
Question: At what level of adoption of zonal architecture is your organization currently at in the following vehicle systems? Please indicate your current level of adoption.
Source: IoT Analytics Research 2025

While OEMs may not say safety systems as their top priority, they are still investing heavily in them by isolating critical systems within zonal architecture based on their criticality, ensuring that breaches cannot easily impact vital functions. Additionally, the implementation of safety measures can vary depending on regional safety and compliance regulations, which further influence how safety-critical systems are designed and managed within zonal architecture.

> "Any OEM that tells you safety is not their number one priority is likely not being truthful. Without a doubt, as vehicles become more connected, the potential for cybersecurity breaches grows however, they are investing heavily in isolating critical systems within zonal architecture. Some safety systems within zonal are tightly locked down to prevent external access, using separate communication buses, particularly with varying speeds, adding an extra layer of protection against denial-of-service attacks."
>
> **—Senior program manager for connected vehicle services at a major European car OEM**

On the other hand, suppliers prioritize safety-critical systems (85%) the most, followed by body electronics (79%) and high-bandwidth infotainment (77%).

Exhibit 9: Alignment of vehicle systems with zonal architecture for suppliers



Question: How aligned are your vehicle systems (one or more of the below) with zonal architecture?
Source: IoT Analytics Research 2025

> "There are differing views on which vehicle system should go to zonal first, with some suggesting starting with comfort elements and introducing ADAS later. However, I don't see any significant roadblocks to fully implementing zonal architecture from the start, including ADAS. Running a parallel system alongside zonal architecture would limit its full potential, especially in terms of weight reduction, wiring harness simplification, and having a unified OS or software system for the entire vehicle. From my perspective, the trend is to implement everything in zonal architecture from the outset."
>
> **—Executive program director of advanced safety and user experience at a major automotive technology provider**

However, this transition comes with its own set of technical challenges. For example, when hardware components from multiple suppliers are integrated into a single zone controller, the OEM must handle software integration and validation, which adds complexity and responsibility. Additionally, although centralizing computing in zonal architecture reduces the number of components, it does not necessarily eliminate risks like single points of failure. Proper design and safety mechanisms are essential to ensure the system's reliability and mitigate risks of system-wide failure.

3 Barriers to transitioning to SDVs

- **Cost of transitioning legacy systems.** OEMs and suppliers cite expenses related to retrofitting hardware, re-engineering software, and integrating AI technologies as key barriers to SDV adoption.
- **Manageable challenges.** Skill gaps and high upfront costs are recognized but are seen as manageable rather than major obstacles.
- **Importance of collaboration.** Effective collaboration between OEMs and suppliers is crucial, with real-time design, simulation, and validation being key to SDV success.
- **Cybersecurity concerns.** Cybersecurity remains a priority, with most OEMs handling some aspects internally while relying on specialized teams and external expertise to manage evolving risks.

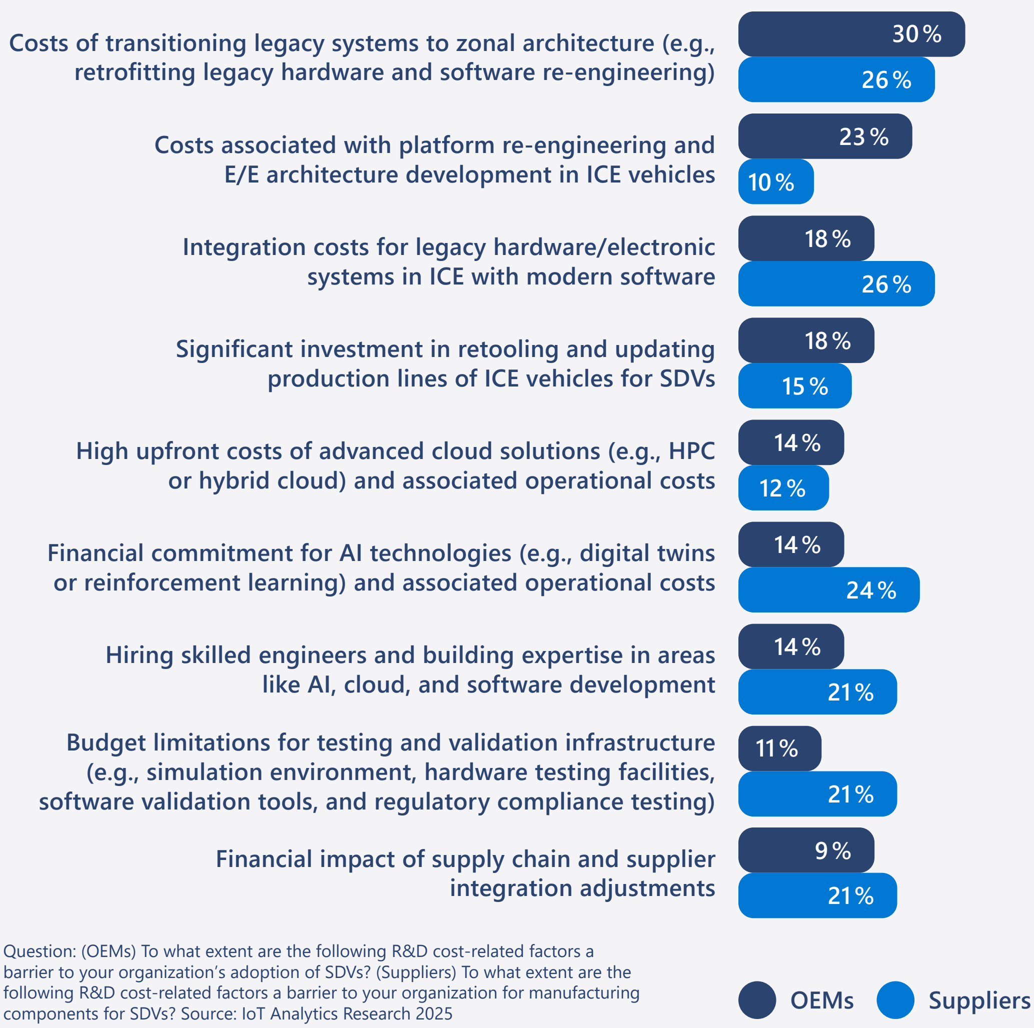
Major cost barriers in SDV engineering

The costs of transitioning legacy systems remain a significant barrier to SDV adoption.

OEMs (30%) and suppliers (26%) emphasize the cost of transitioning legacy systems, generally associated with retrofitting hardware and re-engineering software, as the biggest cost barrier for SDV adoption. Additional cost pressures include integration costs for legacy hardware in ICE vehicles with modern software (18% OEMs, 26% suppliers), financial commitments for AI technologies like digital twins (14% OEMs, 24% suppliers), and costs of platform re-engineering for ICE vehicles (23% OEMs, 10% suppliers) underscoring the financial complexity of this transformation.

Exhibit 10: Cost barriers for SDV adoption

Share of respondents in each segment who mention that the respective cost-related factor is a "significant" barrier for adoption of SDVs



Question: (OEMs) To what extent are the following R&D cost-related factors a barrier to your organization's adoption of SDVs? (Suppliers) To what extent are the following R&D cost-related factors a barrier to your organization for manufacturing components for SDVs? Source: IoT Analytics Research 2025

Primary challenges in transitioning to zonal architecture

There are no major obvious challenges, but skill gaps for OEMs and high upfront costs for suppliers are hindering the transition to zonal architecture.

Although there are challenges, none appear to be major obstacles, with the top challenge, insufficient internal skills and expertise, identified by only 18% of OEMs. Other challenges, such as legacy system compatibility (16%), resistance to change from stakeholders (16%), and supplier collaboration and integration (16%) persist and add to the complexity of navigating this transformation.

Exhibit 11: Barriers in adopting zonal architecture for OEMs

Question: How much do you expect the following barriers to slow you down in the adoption of zonal architecture?
Source: IoT Analytics Research 2025

> "Traditional OEMs face challenges in transitioning, especially with older engineers who are accustomed to older methodologies. Shifting to a more modern, systems-thinking approach in tools like JIRA can be difficult for these experienced engineers."
>
> —Digital transformation officer at a leading American car OEM

For suppliers, high upfront costs and investments (29%) is the most significant barrier. Additional challenges include a lack of standardized frameworks and industry guidelines (19%) and sub-supplier collaboration and integration issues (19%).

Exhibit 12: Barriers in supplying zonal architecture components for suppliers

Question: In designing and testing of your components for zonal architecture, what is your current level of adoption of AI technologies, including generative AI?
Source: IoT Analytics Research 2025

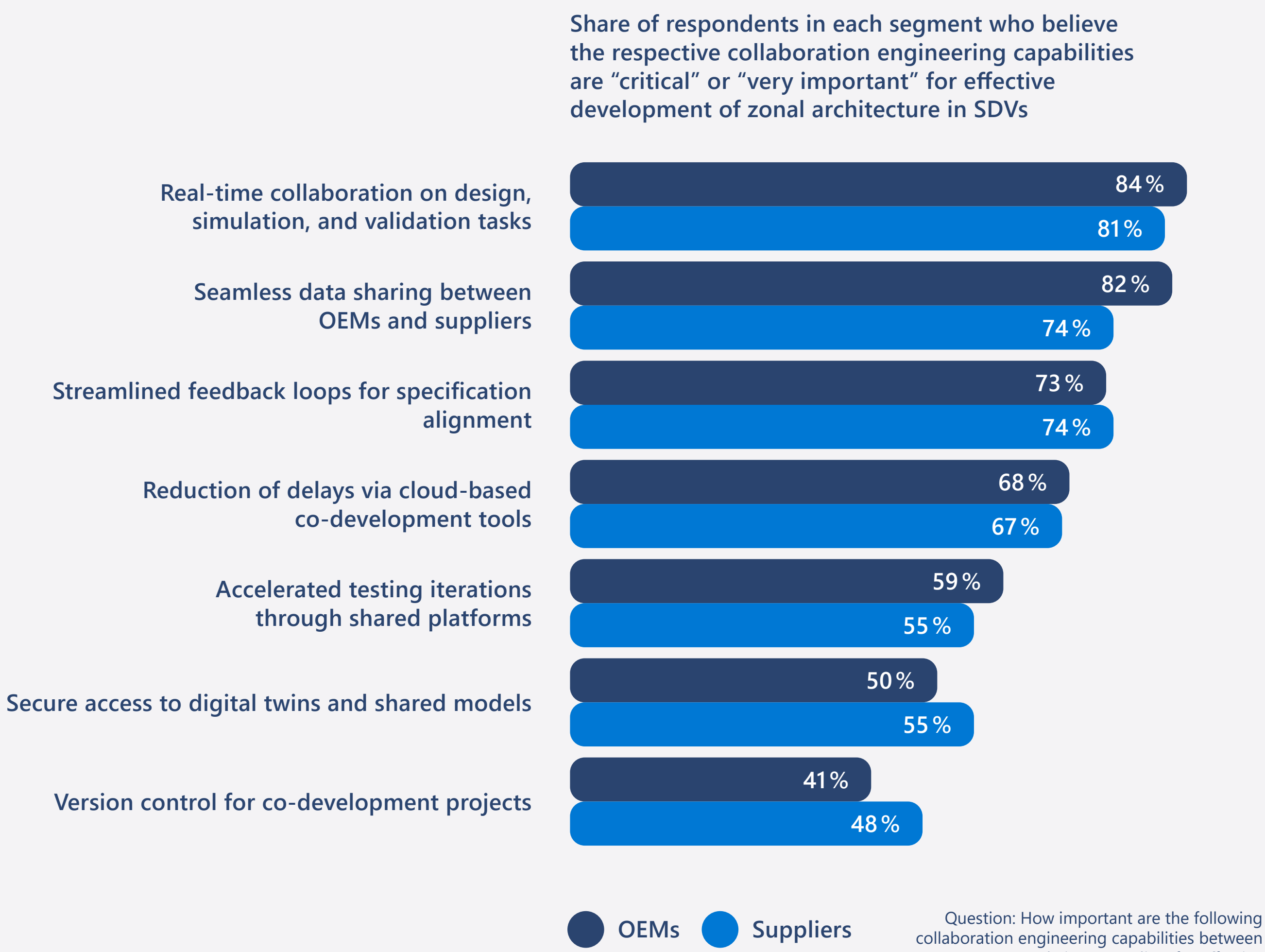
> "Generally, OEMs do not fund suppliers for development activities. In few cases OEMs, amortize the cost piece to cover the risk associated with the volume - if they face losses due to not being able to sell at expected levels."
>
> **—Executive program director of advanced safety & user experience at a major automotive technology provider**

> "We are not commited to zonal architecture. Implementing zonal architecture can require substantial upfront investment in new hardware and software systems, which we are uncertain about the ROI"
>
> **—Head of Engineering at large auto OEM in India**

Collaboration engineering capabilities offer a part of the solution.

Collaboration engineering capabilities between OEMs and suppliers are vital for the effective development of zonal architecture in SDVs, with real-time collaboration on design, simulation, and validation tasks as the most critical factor, highlighted by 84% of OEMs and 81% of suppliers. Seamless data sharing between OEMs and suppliers (82% OEMs, 74% suppliers), streamlined feedback loops (73% OEMs, 74% suppliers), and reducing delays through cloud-based co-development tools (68% OEMs, 67% suppliers), further underscore the need for aligned and efficient partnerships in navigating this transition.

Exhibit 13: Collaboration engineering capabilities



Question: How important are the following collaboration engineering capabilities between OEMs and Tier-1 suppliers for effective development of zonal architecture in SDVs?

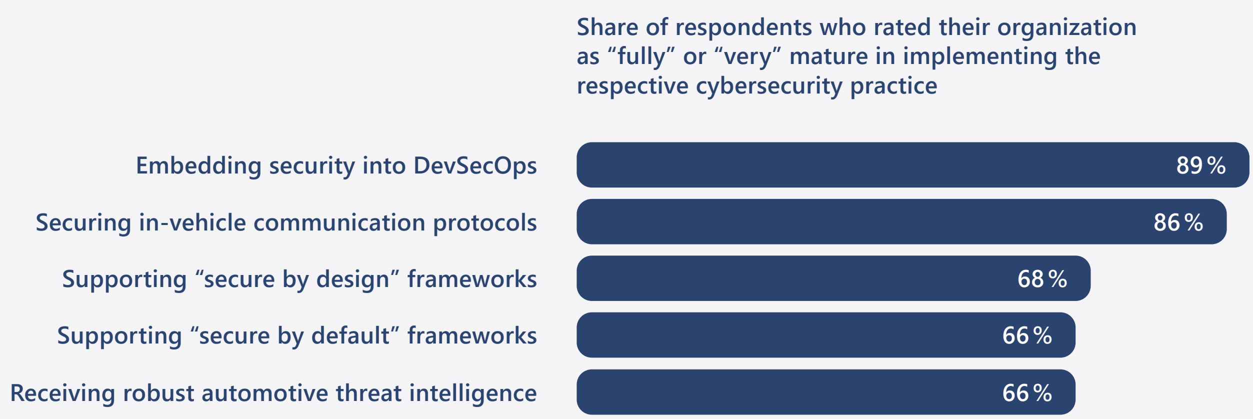
Cybersecurity challenges and its management in SDVs

Cybersecurity is a critical component of SDVs, but no OEM handles all aspects in-house. While they manage some elements internally, most OEMs outsource parts of their cybersecurity strategy due to the high level of expertise required and limited resources. Outsourcing allows them to tap into specialized knowledge while maintaining control over key areas, such as design and prioritization.

> "Larger companies work with partners while ensuring they retain oversight, particularly over proprietary systems. The major concern is liability and safety, with OEMs needing to ensure their practices meet high standards for security. Despite outsourcing some functions, OEMs will continue to oversee cybersecurity to ensure the best mitigation strategies are in place."
>
> **—Senior program manager, connected vehicle services at a leading European car OEM**

OEMs are making strides in adopting robust practices, with 89% of OEMs internally embedding security into DevSecOps workflows. Securing in-vehicle communication protocols (86%) and supporting "secure by design" frameworks (68%) further reflect the growing maturity and readiness of the industry to address evolving cyber threats in the transition to SDVs.

Exhibit 14: Maturity in implementing cybersecurity practices



Question: How would you rate your organization's maturity in implementing the following cybersecurity practices?
Source: IoT Analytics Research 2025

The responsibility for managing cybersecurity in SDVs is clearly delineated among specialized cybersecurity teams within OEMs, with dedicated automotive security teams overseeing the vehicle cybersecurity lifecycle (75%) and threat intelligence (43%). In-vehicle security teams focus on securing communication and data exchange (61%), while DevSecOps teams ensure the integration of security practices during design and testing (66%), highlighting a structured approach to addressing multifaceted cyber risks in SDVs.

Exhibit 15: Cybersecurity responsibilities

Share of respondents who point to the respective team as being primarily responsible for managing each cybersecurity aspect

	Organizational team				
Cybersecurity aspect	IT security team	In-vehicle security team	DevSecOps team	Dedicated automotive security team	Other
Vehicle cybersecurity lifecycle management after deployment	15.9 %	2.3 %	6.8 %	75.0 %	0.0 %
Securing in-vehicle communication and data exchange	13.6 %	61.4 %	0.0 %	25.0 %	0.0 %
Integration of in-vehicle security practices in design/testing processes	15.9 %	2.3 %	65.9 %	15.9 %	0.0 %
Threat intelligence for the automotive industry	34.1 %	20.5 %	2.3 %	43.2 %	0.0 %

Question: Who is primarily responsible for managing the following aspects of cybersecurity?
Source: IoT Analytics Research 2025

4 Cloud: A key solution to overcome barriers

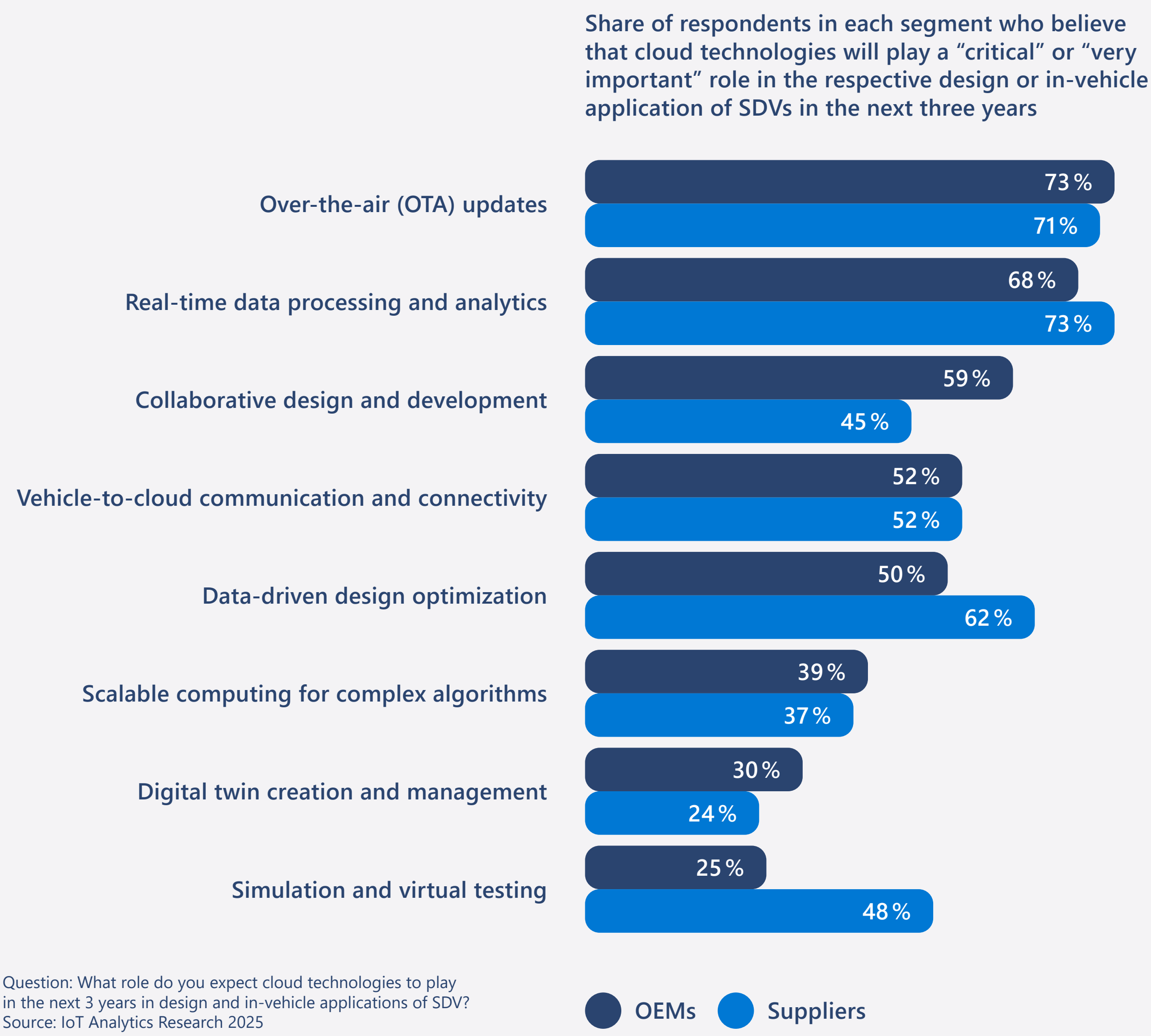
- **Cloud technologies for SDV capabilities.** The cloud is increasingly essential for enabling OTA updates, real-time data processing, and inter-departmental collaboration.
- **Hybrid cloud models.** Due to security concerns and high costs, OEMs prefer hybrid models that combine the scalability of the public cloud with the stability of on-premises solutions.
- **Limited public cloud adoption for zonal architecture.** Specific tasks associated with zonal architecture, such as container orchestration, are hindered by organizational resistance and the cost of transitioning from legacy systems.
- **Improved collaboration.** Despite challenges, cloud solutions play a critical role in enhancing internal collaboration and streamlining SDV design processes.

Cloud's role in optimizing design process and operations of in-vehicle applications

OTA on the cloud is a very popular desired state across OEMs and suppliers.

Cloud technologies are emerging as a cornerstone for providing SDV capabilities, with 73% of OEMs and 71% of suppliers emphasizing their critical role in enabling OTA updates over the next three years. Beyond OTA, key applications such as real-time data processing, collaborative design, and seamless vehicle-to-cloud connectivity highlight the cloud's centrality in driving efficiency across SDV development.

Exhibit 16: Cloud in design, testing, in-vehicle applications



Question: What role do you expect cloud technologies to play in the next 3 years in design and in-vehicle applications of SDV?
Source: IoT Analytics Research 2025

Microsoft

> "The big dream around the OTA is that at a certain point of time, with the right connectivity, put everything into right cloud solutions."
>
> **—Executive program director of advanced safety & user experience at a major automotive technology provider**

> "There is a strong desire to shift OTA updates to the public cloud. While security concerns remain high, the cost advantages of the cloud are driving the industry toward finding a way to make it work, although it will take time."
>
> **—Senior program manager, connected vehicle services at a leading European car OEM**

Hybrid cloud models – A clear priority for software engineering.

In the context of software development and system engineering for SDVs, cloud infrastructure plays a key role in shortening development and testing cycles. Public cloud models, in particular, offer scalability and cutting-edge technology, enabling rapid expansion without the need for the OEM to manage its own data centers.

However, the initial high cost of public cloud services, especially for computationally intensive tasks, makes hybrid cloud models increasingly popular. These models combine the flexibility of the public cloud for global scaling and on-demand computing with the stability and cost-effectiveness of on-premises solutions for specific tasks.

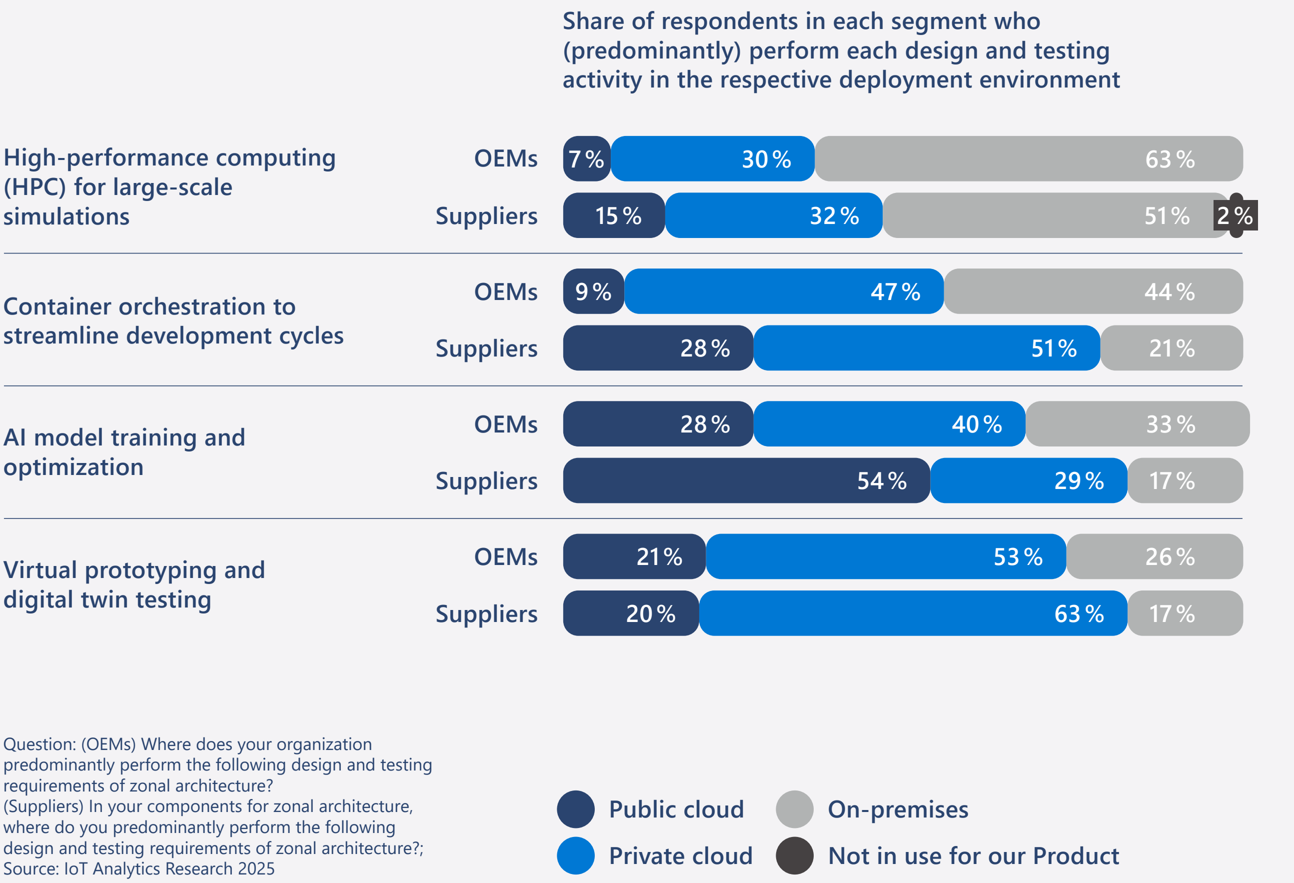
> "Cloud-based systems centralize the accessibility of software engineering tools such as source code management, requirements management, and test case tracking, fostering collaboration among engineering teams."
>
> **— Executive chief architect at a leading American car OEM**

Cloud's added value in zonal architecture design and testing

Overarching preference for private and on-premises models for critical workloads in zonal architecture design and testing.

Although cloud adoption is growing, public cloud adoption remains limited for workloads like container orchestration, digital twin modeling, and virtual prototyping, with private cloud and on-premises solutions being favored in these areas. However, AI model training and optimization showcases the growing reliance on public cloud infrastructure, particularly among suppliers (54%), who lead in adoption compared to OEMs (28%).

Exhibit 17: Deployment environment for key zonal architecture design/testing activities



Question: (OEMs) Where does your organization predominantly perform the following design and testing requirements of zonal architecture?
(Suppliers) In your components for zonal architecture, where do you predominantly perform the following design and testing requirements of zonal architecture?;
Source: IoT Analytics Research 2025

The major challenge in adopting a public cloud for these specialized automotive workloads stems from organizational mindsets and internal barriers. Many large organizations have significant investments in private data centers and cloud infrastructures. These internal systems create resistance, as moving to the public cloud can be seen as a threat to established teams and investments. Additionally, the migration process is costly and time-consuming, creating further obstacles. While public cloud providers offer potential benefits, such as scalability and flexibility, the transition is often more complex and less seamless than expected, making it a bumpy and expensive road for companies with legacy infrastructures. The challenge lies in balancing security, control, and cost, with OEMs needing to assess the stage of their product development cycle and decide on the best approach for cloud infrastructure.

"During development, OEMs typically maintain complete control over the product lifecycle, including software and hardware testing. The challenge arises when collaborating with suppliers, especially when data needs to be securely exchanged for the development of vehicle components. This requires defining clear communication standards and security protocols, particularly when public cloud services are involved, which may raise security concerns for larger OEMs who prefer maintaining control over their infrastructure."

—Digital transformation officer at a leading American car OEM

"On the cloud front, there is a clear preference for private cloud solutions, particularly for sensitive design and testing workloads, due to security and safety concerns."

—Head of corporate strategy development at a top 10 automotive tier-1 supplier

"I don't know really what is driving their decision on using private cloud. My view is that OEMs just want to go step by step by public cloud. Before going to a cheaper solution, they want to master the full system, ensuring they are mastering cybersecurity and controlling information flow especially because they don't want to have bad experiences like cars being hacked due to not understanding all aspects of the cloud."

—Executive program director of advanced safety and user experience at a major automotive technology provider

Survey question: Why do you prefer private cloud?

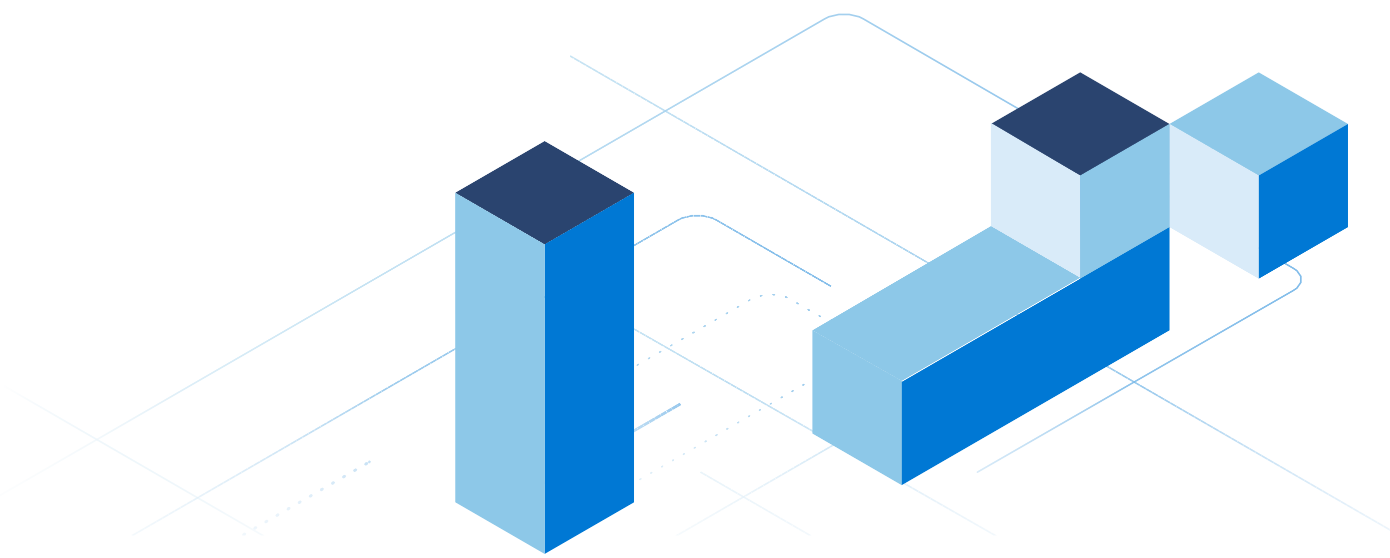
Key answers:

- "With specific configurations and custom applications, we find private clouds more adaptable to our unique requirements compared to the more standardized offerings of public clouds."

Survey question: Why do you prefer public cloud?

Key answers:

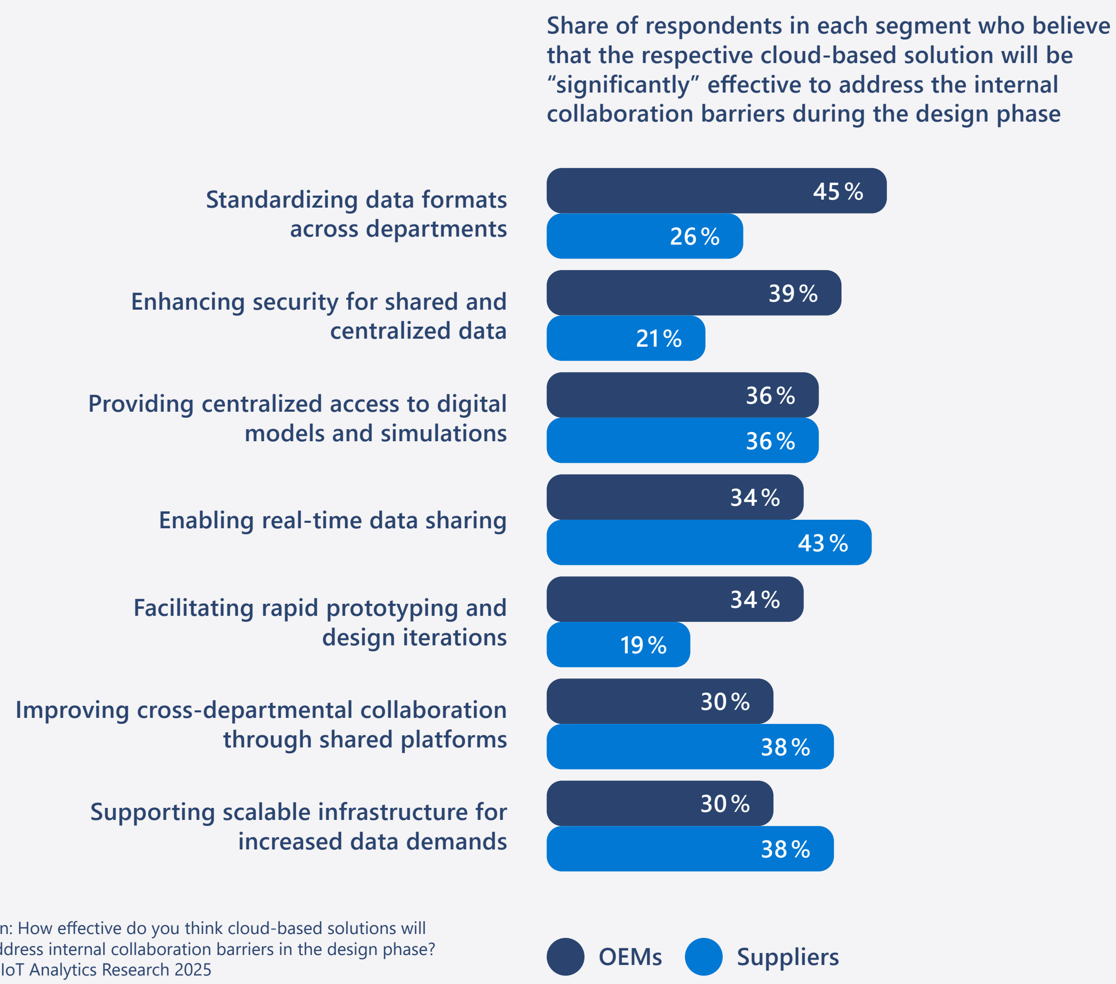
- "Public cloud offers seamless integration with AI and machine learning services, which are crucial for our workloads."



Cloud for overcoming internal collaboration barriers during SDV design

Cloud-based solutions are pivotal in overcoming internal collaboration barriers during SDV design, with OEMs prioritizing the standardization of data formats to streamline workflows across departments. Enhancing data security, providing centralized access to digital models and simulations, and enabling real-time data sharing further highlight the cloud's role in fostering seamless communication and improving cross-departmental collaboration for both OEMs and suppliers.

Exhibit 18: Cloud solutions to overcome collaboration barriers



Question: How effective do you think cloud-based solutions will be to address internal collaboration barriers in the design phase?
Source: IoT Analytics Research 2025

5 AI: Driving innovation in SDVs

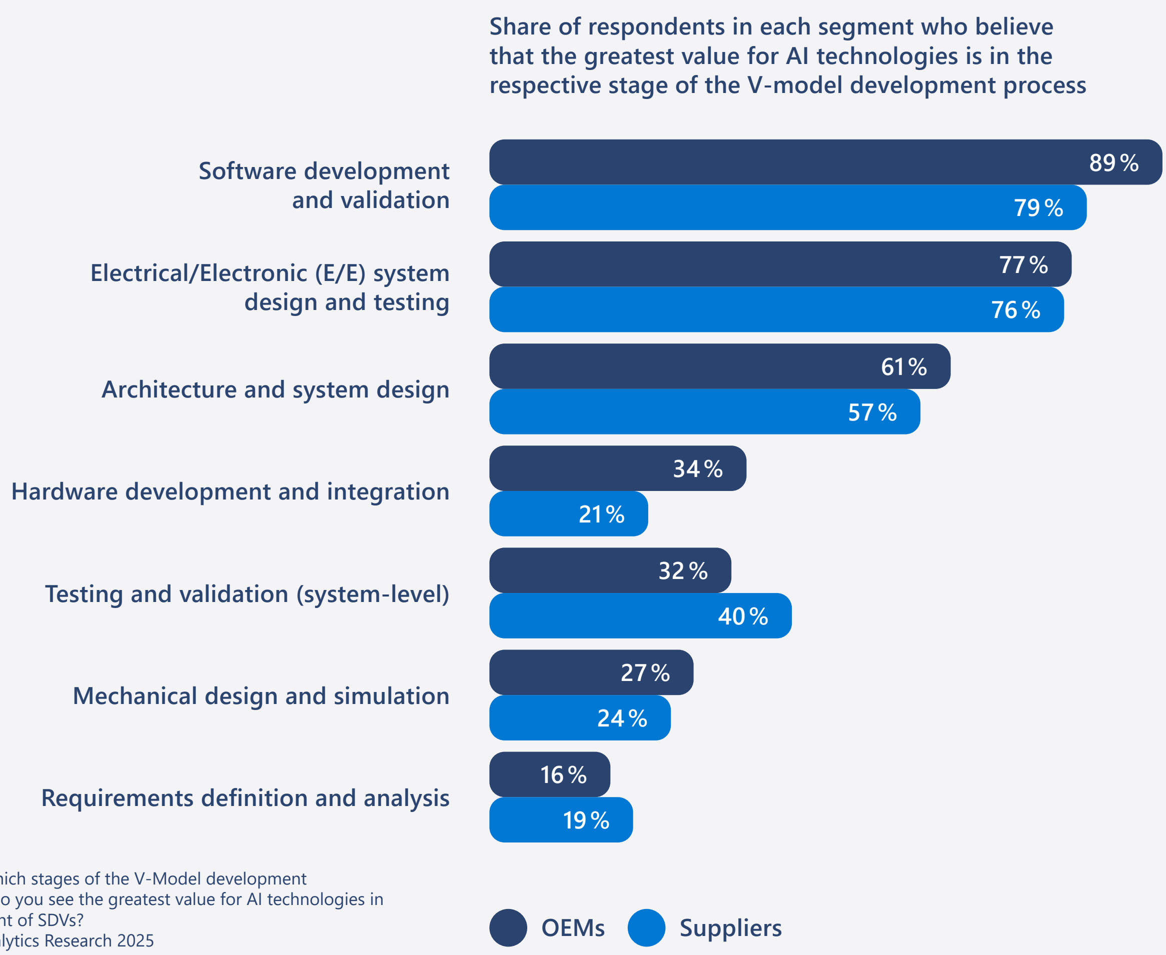
- **Growing AI adoption.** AI is increasingly recognized for its value in software development, validation, and E/E system design in SDVs.
- **User-experience enhancements.** AI is being explored to improve personalization and data management in SDVs.
- **AI in zonal architecture design.** Real-time simulation, predictive modeling, and anomaly detection are key AI applications optimizing zonal architecture design and testing processes.
- **Emerging role of GenAI.** GenAI is gaining traction for requirement gathering, automated design, and code generation, though full integration is still in progress.

Role of AI across various stages in SDV development

AI adoption in SDVs is steadily progressing across OEMs and suppliers, especially in software development and validation.

AI is recognized as a significant value provider across all the key V-model phases of software development and systems engineering, with three key activities expected to benefit the most. AI's highest perceived value is in software development and validation, recognized by 89% of OEMs and 79% of suppliers. Its role in E/E system design and testing is also quite impactful, with 77% OEMs and 76% suppliers highlighting its importance. Followed by architecture and systems design (61% OEMs and 57% suppliers).

Exhibit 19: Value of AI in the development of SDVs



Question: At which stages of the V-Model development methodology do you see the greatest value for AI technologies in the development of SDVs?
Source: IoT Analytics Research 2025

AI is also playing a crucial role in user experience and data management.

On the user experience front, AI is being explored to improve how customers interact with their vehicles, enhancing personalization and providing value-added services like tailored recommendations and advertisements. And from a technical perspective, AI offers substantial advantages in managing the vast amounts of data flowing through SDV's vehicle systems.

Survey question: What functions do you see being powered by AI?

Key answers:

- "AI will integrate multiple safety features, such as lane-keeping assistance and collision avoidance systems, into a cohesive safety framework."
- "Advanced voice recognition powered by AI will allow drivers to control vehicle functions hands-free, enhancing safety and convenience."
- "I see AI making navigation smarter by providing real-time traffic updates and recommending the best routes."
- "AI will improve adaptive cruise control systems, enabling them to adjust speed based on real-time traffic conditions more effectively."

"As AI tools continue to evolve, their role in in-vehicle applications is also expected to grow dramatically, leading to significant improvements in vehicle performance and first line runs. With vehicles transmitting up to 25 to 30 signals per second, AI can help make sense of this data, identifying key patterns and improving decision-making in areas like predictive maintenance and remote diagnostics."

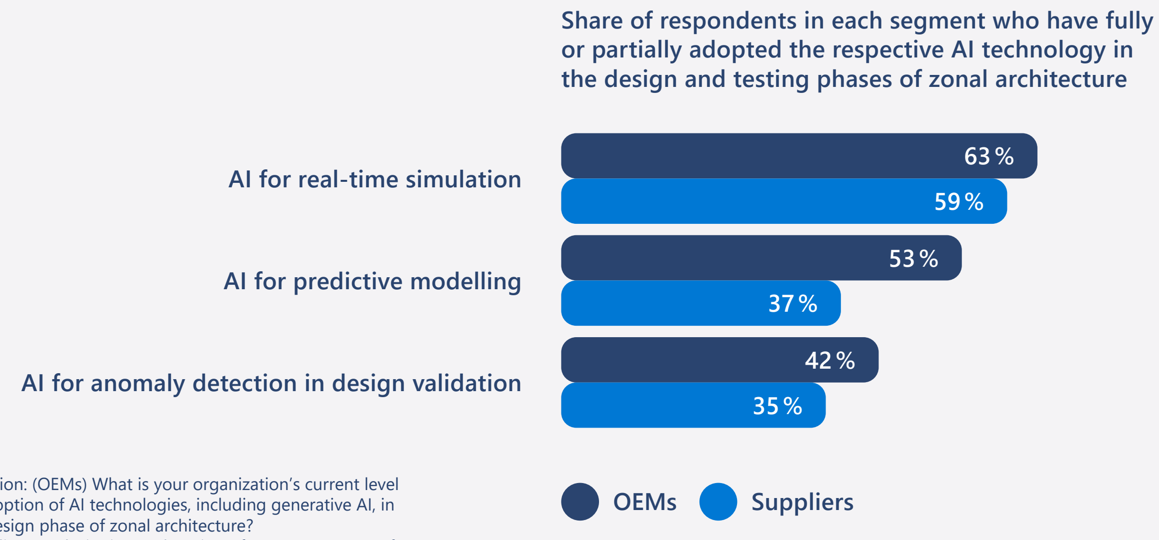
—Senior program manager, connected vehicle services at a leading European car OEM

AI for zonal architecture design and testing

AI seen as highly valuable in real-time simulation and predictive modeling in zonal architecture.

In zonal architecture design and testing, real-time simulation emerges as the leading AI application, enabling OEMs and suppliers to optimize performance and streamline development processes. Predictive modeling and anomaly detection further complement these efforts, showcasing AI's growing role in refining design and validation workflows.

Exhibit 20: Adoption of AI for zonal architecture

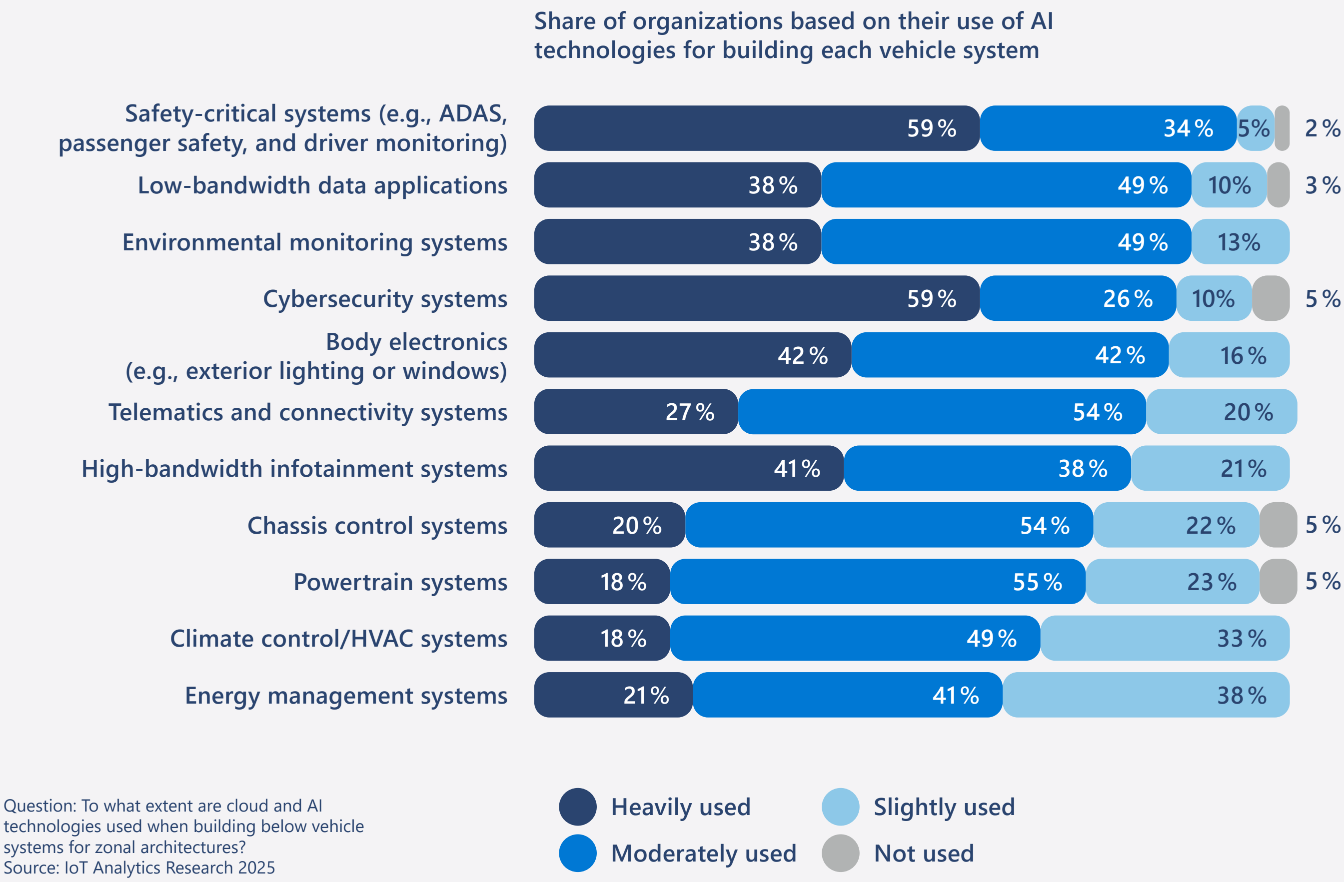


Question: (OEMs) What is your organization's current level of adoption of AI technologies, including generative AI, in the design phase of zonal architecture?
(Suppliers) In designing and testing of your components for zonal architecture, what is your current level of adoption of AI technologies?
Source: IoT Analytics Research 2025

Safety components manufacturing suppliers extensively leverage AI.

For suppliers, in addition to designing and testing the compatibility of their components with OEMs' zonal architecture, they are utilizing AI to develop their own vehicle systems. The top three areas of focus include safety (93%), low-bandwidth data applications (87%), and environmental monitoring systems (87%).

Exhibit 21: Use of AI technologies by suppliers for building vehicle systems



Question: To what extent are cloud and AI technologies used when building below vehicle systems for zonal architectures?
Source: IoT Analytics Research 2025

GenAI enabling a wide range of new and unique use cases

GenAI's usage in systems engineering is gaining traction.

In systems engineering, during the design and testing phases of SDV, the potential for GenAI to play a pervasive role in requirement gathering and analysis is immense.

"GenAI can be very useful in optimizing the design and testing phases of SDVs, particularly by addressing conflicting requirements and improving the functional sequencing of tests. By identifying conflicts in requirements early, GenAI helps prevent issues that could arise during system integration. Additionally, GenAI assists in the functional sequencing of testing, such as in ECU software testing, ensuring that the design and testing processes are aligned with technical requirements."

—Senior program manager, connected vehicle services at a leading European car OEM

"The first and most prevalent use case is assisting software engineers, particularly in code generation and assisting with the creation of tests from requirements. Translating requirements into executable tests and generating formal test cases from technical specifications are also significant use cases for GenAI.

In addition, GenAI can help in generating reports, extracting relevant information from large databases, and debugging systems by making smart queries into patterns."

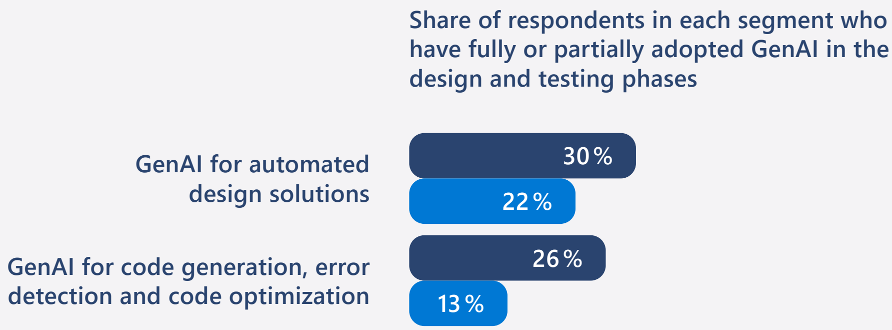
—Executive chief architect at a leading American car OEM

"System engineering involves understanding the requirements and deciding how to develop each requirement or function, whether it's with hardware, software, or a combination of both. Understanding conflicting requirements, which are common among different OEMs is crucial. This process can be time-consuming due to the complexity involved. GenAI provides a significant advantage in comprehending various requirements and ensuring their alignment. One more use case GenAI is enabling in systems engineering is designing the skeleton of the system. For example, when you develop an ECU, system requirements that are written on it which needs to be translated to technical requirements therefore helpful in overall design of the system."

—Executive program director of advanced safety and user experience at a major automotive technology provider

GenAI is also helping OEMs and suppliers in automated design solutions and code generation.

Exhibit 22: GenAI in design and testing



Question: (OEMs) What is your organization's current level of adoption of GenAI, in the design and testing phase? (Suppliers) In designing and testing of your components, what is your current level of adoption of GenAI?
Source: IoT Analytics Research 2025

However, full GenAI integration is still in its early stages, with companies gradually expanding its use in various areas such as knowledge management and overall design and testing optimization.

6 How OEMs are transitioning to SDVs: 3 case studies

Case Study 1: BMW

Accelerating automotive development with cloud and AI

Overview: Transforming vehicle development with MDR and cloud technology.

BMW sought a solution to streamline the process of capturing and analyzing operational data from its fleet of 3,500 development cars. The goal was to accelerate innovation and reduce the time-to-market for new vehicle features. This led to the creation of the Mobile Data Recorder (MDR) system, powered by Microsoft Azure, which transformed BMW's vehicle development process.

1 Challenges: Manual processes and scalability limitations slowed innovation

- **Inefficient data transfer.** Engineers manually moved data from on-board hard drives to on-premises servers, delaying vehicle design and prototyping.
- **Growing data management complexity.** Increasing vehicle sophistication made handling large data volumes difficult.
- **Limited scalability.** Traditional systems could not support the required expansion of data infrastructure.

2 Solutions: MDR system leveraged IoT, cloud, and AI for efficiency

- **Advanced IoT integration.** MDR collected over 10,000 signals per second, transmitting data to a centralized cloud backend.
- **Cloud scalability with Microsoft Azure.** Integration enabled real-time data analysis and efficient troubleshooting.
- **AI-powered MDR Copilot.** Azure AI and GPT-4 allowed engineers to generate KQL queries using natural language, streamlining data analysis.

> “BMW has always blended luxury and performance with cutting-edge technologies. With Microsoft’s cloud and AI leadership, we could capture the potential of our MDR system to accelerate development of our innovative cars.”
>
> **—Christof Gebhart, MDR co-creator, BMW Group**

3 Results/benefits: Faster insights, lower costs, and accelerated development

- **10x faster data processing.** Insights that previously took days were now available in hours or minutes.
- **Lower costs and faster feedback loops.** Reduced lead times decreased costs per outcome, allowing rapid configuration adjustments and testing.
- **Scalability and impact.** Initially deployed in 50 vehicles, MDR expanded to thousands, improving vehicle development efficiency and accelerating time-to-market.

> “The Azure AI works smoothly, significantly lowers the entry barrier, and will open up a much wider range of applications.”
>
> **—Christof Gebhart, MDR co-creator, BMW Group**

Case Study 2: Volkswagen

Volkswagen Group's transformation to SDVs with CARIAD and Microsoft Azure

Overview: Building a scalable cloud infrastructure for continuous innovation.

CARIAD, the in-house software development subsidiary of Volkswagen Group, sought a robust cloud infrastructure to enable software-driven vehicle evolution. The aim was to enhance safety, comfort, sustainability, and connectivity. By partnering with Microsoft Azure, the CARIAD Service Platform successfully supported Volkswagen's vision for continuous innovation, allowing rapid deployment of new services and applications

1 Challenges: Unified cloud platform required for scalability and consistency

- **Fleet management needs.** Volkswagen Group required a scalable, unified platform to manage 14 million connected vehicles, ensuring backend consistency.
- **Security and scalability issues.** The platform needed to support security, scalability, and responsiveness during peak demand.

2 Solutions: The CARIAD platform built for scalability and security

- **CARIAD Service Platform.** Containerized applications were deployable across the Volkswagen Group.
- **Azure Kubernetes Service (AKS).** Container orchestration ensured high availability, security, and automatic backups.
- **Scalability with Azure.** The cloud enabled CARIAD to scale resources up and down based on demand, ensuring cost efficiency.

> "Moving forward, on top of mechanical construction, choice will be defined by digital capabilities, features, and connectivity."
>
> **—Dr. Patrick Bauer, head of cloud platform at CARIAD**

3 Results/benefits: Streamlined development and robust service reliability

- **Faster deployment.** 800 developers could rapidly deploy and refine applications for over 200 products.
- **Continuous service.** AKS ensured that if one container failed, another would take over, guaranteeing consistent service to vehicles and passengers.
- **Agile development.** The CARIAD Service Platform accelerates the development and deployment cycles for new vehicle software and features, including predictive maintenance, autonomous operations, and entertainment systems.

> "We are innovating software-defined vehicles by providing the CARIAD Service Platform—helping our developers create and deploy innovations faster and better."
>
> **—Dr. Patrick Bauer, head of cloud platform at CARIAD**

Microsoft

Case Study 3: General Motors

GM's accelerating development processes with cloud-based solutions

Overview: Enhancing productivity and security with cloud-based tools.

GM sought to modernize its development processes to improve productivity, security, and agility within engineering teams. This goal was achieved by integrating Microsoft's cloud-based developer tools, including Microsoft Dev Box, Azure Deployment Environments, GitHub Copilot, and GitHub Advanced Security.

1 Challenges: Inefficiencies and security concerns in development processes

- **Manual environment setup.** Development environments were set up manually, causing delays and inefficiencies.
- **Access management.** Managing secure access for developers working on multiple projects proved challenging.
- **Lack of real-time assistance.** The absence of AI-driven support and real-time security checks hindered agility.
- **High administrative overhead.** Security risks and administrative burdens were higher for both internal and external collaborators.

2 Solutions: Modern cloud engineering platform to streamline development

- **Microsoft Dev Box.** Developers became able to quickly access preconfigured development environments, speeding up setup times.
- **Azure Deployment Environments.** Developers could quickly spin up and test app services, boosting code-to-cloud automation.
- **GitHub Copilot.** AI-powered tools provided real-time code suggestions, improving developer efficiency and reducing errors.
- **GitHub Advanced Security.** AI-enhanced security tools delivered real-time security analysis, identifying vulnerabilities as code was written.

> "Our customers expect to have the products and services that they need when they need them. Working with Microsoft and the developer cloud platform gives us that 24-by-7 capability, as well as the operational reliability and stability that we need, and the scale to burst up whenever we have a change in demand."
>
> **—Michael Anderson, director of enterprise technology services at GM Information and Digital Technology**

3 Results/benefits: Faster development, enhanced security, and improved productivity

- **Reduced development time.** Instant access to fully provisioned environments sped up project initiation.
- **Stronger security.** Zero-trust security was implemented through Dev Box and Azure, ensuring safe access control for developers.
- **Increased developer efficiency.** Tools like GitHub Copilot and GitHub Advanced Security improved productivity by automating code generation and offering real-time security feedback.
- **Streamlined collaboration.** GM's development teams can now seamlessly collaborate across projects without the risk of compromising security or losing data.

> "Nothing is on the laptop. So, it makes it secure. We can manage compliance, just because their box is within Intune."
>
> **—Lakshmi Jagan, director of enterprise technology services inventory automation and development at GM Information and Digital Technology**

Microsoft

How Microsoft can support your next actions

The automotive industry is facing a paradigm shift in mobility, transforming how vehicles are designed, built, maintained, and experienced by end-users.
This shift creates the need for automotive OEMs to become as capable in software development as in manufacturing and assembly. Tomorrow's vehicle platforms will be increasingly powered by more complex software defined systems that are less hardware dependent. Developing these vehicles and systems provides opportunities for advanced design and engineering techniques leveraging open-source software, cloud, and AI across the value chain.

Microsoft provides the platform for innovation in automotive enabling OEMs and the extended ecosystem to engineer and deliver higher quality products to the market in less time. Follow the links below to learn more:

Microsoft in Automotive

Revolutionizing mobility: Solutions for an AI-powered future

Advancing the future of automotive and mobility

Microsoft mobility reference architectures

Contact Sales

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