



Computer on Wheels: The Missing Market

How software commercialization will accelerate the advancement of software defined vehicles

SD[✓]VERSE

Roland
Berger



Management summary

Large, luxurious, with a 403-cubic-inch V8 engine, the Oldsmobile Toronado holds a special place in the hearts of car enthusiasts. But while many fans think of it as marking the end of an era, few people know that it was the beginning of another: the 1977 Toronado was the first production vehicle to incorporate embedded software.

The General Motors engineers who wrote those seven lines of code used to control the spark timing would be astonished to learn that today's typical vehicle leaves the factory with 100+ million lines of code under the hood—the equivalent of 1.8 billion pages of information. From the perspective of 2024, however, it is perhaps equally surprising that most of those lines are still being custom-written in-house by the original equipment manufacturers (OEMs) or Tier 1 suppliers. From Roland Berger automotive software market study, only 10 % of automobile software is sold separately from hardware, at a clear price, and with a license agreement.

If the system were cost-efficient, that wouldn't matter. However, since 2021, OEM in-vehicle software costs have risen 14 % per year, from USD 26 billion in 2021 to USD 38 billion today, according to Roland Berger projections. If current trends continue, the total could reach USD 59 billion by 2030, and at the same time, decelerate the fulfillment of the industry's next audacious goal, the software-defined vehicle (SDV). Fortunately, we know from a variety of other industries that there is a better way: the formation of an ecosystem of externally produced software products sold through a competitive marketplace. While today there is a variety of enterprise software solutions available to any company to meet their customer relationship management (CRM), fleet management or accounting needs, in the past it was commonplace to have such solutions custom-developed by corporations in-house or by software engineering service providers.

This paper will outline which trends in software development the automotive industry is now pursuing, where it lags and why it will not be able to reach its goals without a robust and dedicated software market.

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Fast Facts



OEM software spending could reach USD 59 bn in 2030, without transitioning to a software-defined approach

10%

of automotive software today is sourced as standalone software

68%

of industry participants believe lack of software commercialization is the key hurdle

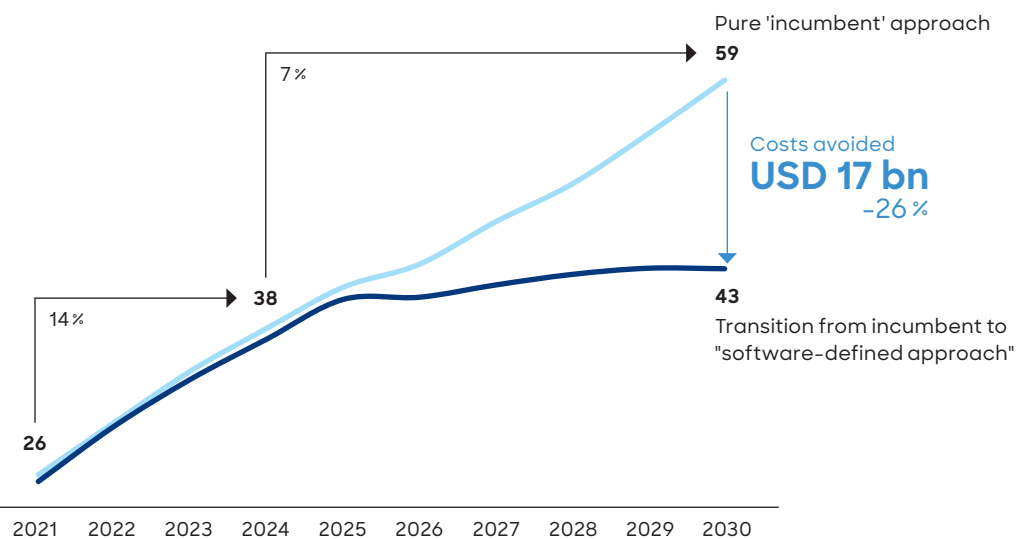
1

The challenge of delivering a Software-Defined Vehicle

Today's 100+ million lines of code are only the beginning for automobiles. Most industry experts believe the automotive industry is on the way to the production of what is being called the SDV, a vehicle in which many of its most important attributes—including safety, performance and maintenance features—are a function of software rather than hardware.

OEMs budget in software development have risen nearly 50 % since 2021. Unless their production model evolves quickly, this number is on track to reach USD 59 billion by 2030. Beyond that? Expect a doubling of costs every one or two vehicle generations, roughly every 6–8 years, as well as ever-fiercer fights for a limited talent pool. ▶ A

A OEMs in-vehicle software budget 2021-2030 [USD bn]



Source: Roland Berger

What's at stake? A new kind of automotive offering, one that will be able to keep delivering new experiences long after the car has rolled off the lot. "The automakers leading the shift to software-defined vehicles will have unique, superior customer experiences that can be updated regularly," explains Kristin Toth, Executive Director, Electrical Systems and Software at General Motors.

To bring that day closer, most automotive industry software leaders are currently pushing six major initiatives:

Embrace cloud-native software development

Cloud-native approaches to software development are among the first levers that OEMs and suppliers are pursuing. This includes introducing modern centralized E/E (electrical and electronics) and associated microservices software architectures with containerized software modules, integrate modular software development processes, adopt DevOps approach to software lifecycle management and introduce a wide variety of new tools.



// Commercial software products are needed to close this gap."

Konstantin Shirokinskiy, Partner, Roland Berger

The challenge ahead: While the industry has witnessed the emergence of consortia, alliances, and conferences dedicated to addressing the technical challenges of efficient, cloud-native software development, operational challenges lag far behind the aspiration.

2 Adopt industry-wide standards

Industry standards such as AUTOSAR (Automotive Open System Architecture), will play a crucial role in accelerating the development, integration and validation of software components in SDVs. While 83% of industry executives agree¹ that a common standard would be highly beneficial, broad adoption is not yet in sight.

The challenge ahead: Creating a unified approach to software development that fosters cooperation among stakeholders to create and adopt common industry-wide standards for SDVs, facilitating interoperability and efficient development processes.

3 Build with open-source software

There is a growing recognition among industry participants (in a recent Roland Berger survey, 66% agreed) that open-source software (OSS) holds the potential to enhance the development speed and quality of vehicle features. While OSS can offer viable solutions for middleware and non-differentiating applications, concerns regarding security and safety impede its widespread deployment across the entire software stack, particularly for safety-critical applications. OEMs and suppliers also aim to differentiate their offerings based on key features, a goal that is fundamentally misaligned with the collaborative nature of OSS.

The challenge ahead: Despite the potential benefits, the lack of defined commercial models poses challenges for the sustainable development of OSS in the automotive industry.

4 Insource differentiating features ...

OEMs and Tier 1 suppliers often insource the development of key applications that align with their core business DNA (e.g., engine management software for a powertrain manufacturer). While such targeted insourcing often makes sense, many OEMs tend to want to build everything at home, which is inefficient and costly: it hinders resource allocation and slows down progress towards full implementation of SDVs.

The challenge ahead: To optimize resource allocation and accelerate SDV development, industry players must carefully evaluate which parts of the software stack truly differentiate their offerings.

5 ... but outsource non-differentiating code

By outsourcing non-differentiating software, OEMs and Tier 1 suppliers can save resources and focus their internal efforts on developing truly differentiating applications. The demand for skilled software engineers in the automotive industry exceeds the available talent pool.

1 Industry survey of 30 participants from 10 automotive players globally, including OEMs, Tier 1 suppliers, engineering services providers, software vendors

Outsourcing non-differentiating code is one way of mitigating the shortage of in-house engineers with the relevant expertise.

The challenge ahead: Building the discipline to outsource non-differentiating parts of the software stack.

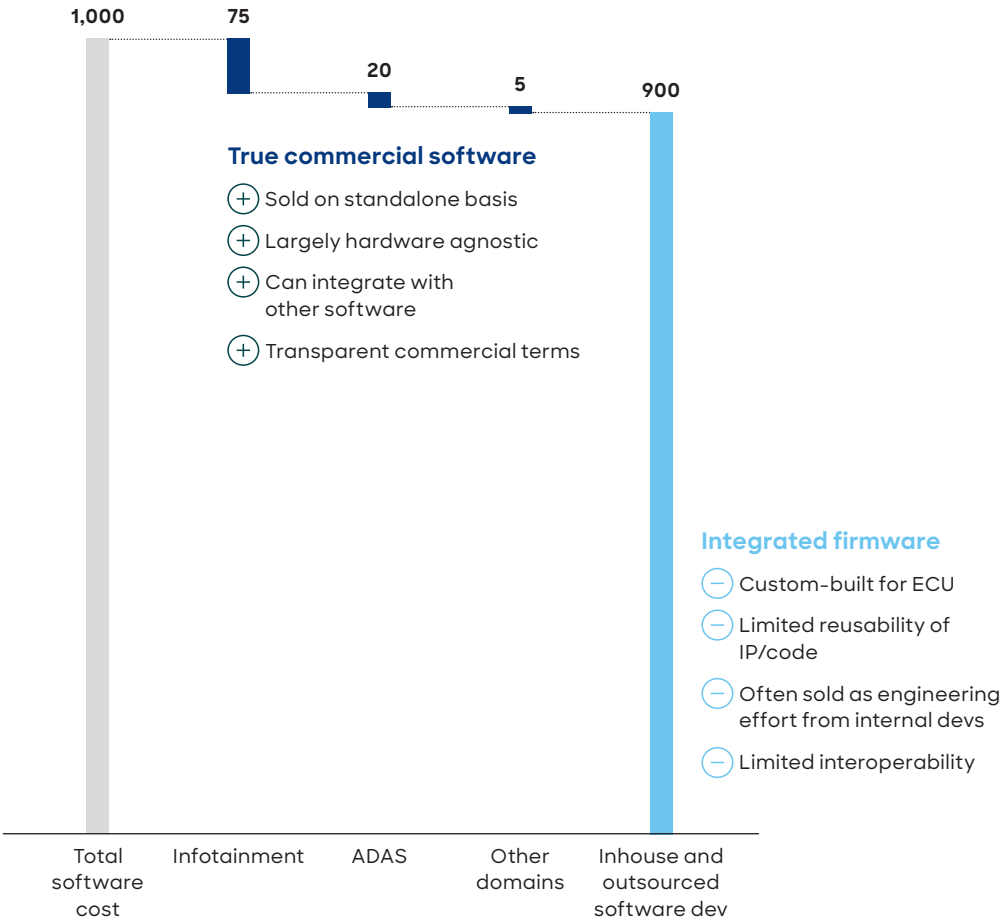
Use more commercial software

When developed and commercialized effectively, commercial software offers numerous benefits, including enhanced reusability of intellectual property, seamless integration, and flexibility to operate across different hardware and middleware platforms. Despite these advantages, only a small fraction—approximately 10 %²—of vehicle software is currently supplied by commercial vendors as a standalone product. ▶ **B**

The challenge ahead: The immaturity of the supply base creates a mismatch between supply and demand that has led to over-insourcing. However, there are simply not enough engineers and dollars in the budget for every OEM to insource all its software development, leaving the pace of production slower than necessary. "Commercial software products are needed to close this gap," says Konstantin Shirokinskiy, Partner at Roland Berger.

2 From Roland Berger automotive software market study (2023)

B OEM software spend breakdown by commercial vs in-house or outsourced efforts per well-equipped vehicle [USD]



Source: Roland Berger

2

Building the missing software market

Each of these six steps will bring the industry a little closer to the era of the SDV, but slowly and at a high cost—unless something changes. Our analysis suggests that one structural change could accelerate these first six steps and turbocharge automotive software development: the creation of a third-party software market that most major industries have had for decades. Until now, however, a variety of structural factors have throttled development of a healthy, competitive software market for the automotive sector. Tara Akhavan, PhD, Software Solutions and Ecosystems Vice President at FORVIA agrees that with the advancement of software only product in the automotive industry, comes the complications in software standards and specifications, ability for buyers and sellers to maintain and update the software and have the right business models for software sales and marketing. "FORVIA is committed to working with the ecosystem partners in creating the first comprehensive software marketplace in the automotive industry."

HURDLES FOR SOFTWARE VENDORS

Traditionally, software vendors who serve OEMs have been engaged primarily for projects that demand custom implementations based on the OEM's specific requirements. Often, the software is built without adherence to universal standards, with poorly documented APIs, and no containerized code. This practice can lead to the development of bespoke programs that can't be reused without significant integration effort. The layering of multiple such projects also adds complexity over time, raising the cost of updates throughout the vehicle's lifecycle.

Despite the obvious disadvantages of custom software, the software teams who create it are typically not in a good position to convert to being a producer of standalone products. They lack a robust commercial strategy and the necessary capabilities to support such a product. In fact, many of these teams lack an independent identity even within their own company. They are often embedded within physical product groups and primarily serve internal customers. With respect to the vehicle, their sales model is mostly through service contracts, not licensing or sale of distinct products. Such contracts can preclude the development of a software product because the vendor teams with the deepest domain software expertise may not actually hold the rights to the OEM's software, although they may have built it themselves. ▶ C

Additionally, years of buyers becoming accustomed to working with vendors on purchasing bundled hardware/software packages has compounded challenges in transitioning towards buying and selling software as a standalone product.

To overcome these barriers, software vendors will need to adopt new commercial strategies that emphasize the unique benefits of standalone software, establish clearer pricing models and restructure internally to support the development and commercialization of software as a product.

Joerg Grotendorst, Senior Vice President, Corporate R&D for Magna International, agrees: "In order to thrive in the rapidly evolving automotive industry, Tier 1 suppliers must proactively embrace transformative changes and shift towards software-focused business models. By fostering collaboration, innovation and strategic software partnerships with trusted industry players, we can optimize our organizational structures, define revenue models and unlock the full potential of our systems. Together, we can

C Type of barriers preventing vendor from selling standalone software solutions

Industry survey of 30 participants from 10 automotive players globally, including OEMs, Tier 1 suppliers, engineering services providers, software vendors

Technical

e.g., software not designed to be sold standalone

Operational

e.g., organizations are not structured to support software product sales

Commercial

e.g., lack of commercial strategy, access to buyers



15.6%

16.7%

67.8%

Source: Roland Berger



deliver cutting-edge solutions to customers at an affordable price, while staying ahead of the competition."

HURDLES FOR SOFTWARE BUYERS

Long accustomed to purchasing integrated hardware/software bundles, many OEMs find themselves grappling with a lack of in-house capabilities to manage hardware/software integration effectively. In response, several OEMs have formed in-house development teams tasked with building entire software stacks for specific vehicle domains. However, this approach often proves inefficient, as it involves the internal creation of many non-differentiating software components that could be more effectively and economically sourced as commercial-grade products from external vendors.

Further complicating these challenges is the hardware-centric legacy of the automotive industry, which continues to operate with procurement processes and supply chains that are primarily designed for physical components. Domain-focused procurement teams, adept at evaluating the technical and financial aspects of hardware-based RFP responses, often struggle with the nuances of procuring standalone software.

OEM teams typically acquire software through service contracts but often lack the necessary expertise to navigate true software contractual structures or to conduct thorough software costing analysis. Even with adequate software procurement expertise, these teams frequently face difficulties in gaining clear visibility into the market offerings that align with their specific requirements.

This lack of clarity and expertise hampers the ability of OEMs to make informed decisions about purchasing commercial-grade software, thereby further slowing the pace of SDV adoption and integration.

"Engineering service providers will have an important role to play in facilitating seamless and continuous integration," predicts Dr. Swarup Mandal, Global Head Automotive for Wipro Engineering Edge. "A well-defined integration and software modernization framework will allow off-the-shelf, components to be integrated with next generation software platforms," he says, adding that benchmarking will likely prove to be another important aspect of successful commercialization.

"The SDVerse marketplace fosters software integration by offering software solutions and connected engineering services as a package. We now proudly offer our software IP and engineering services on the SDVerse platform to turn engineering IP into customized software solutions," says Thomas Hülshorst, Group Vice President of Intelligent Mobility & Software at FEV.

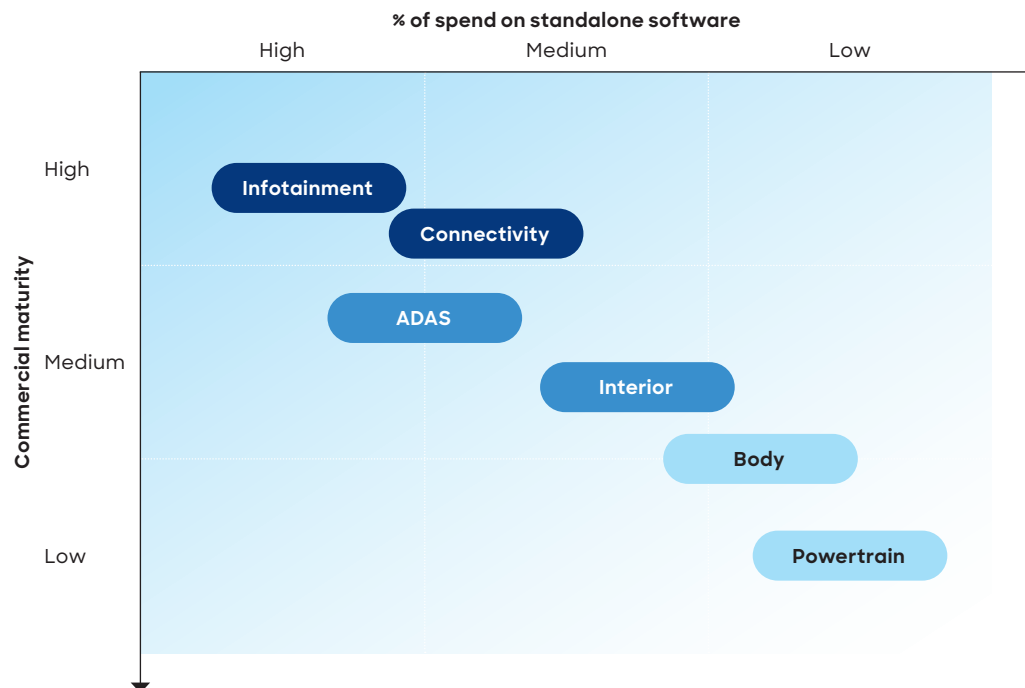
2.1/ Commercial readiness of software by vehicle domain

The challenges described above are not uniform across different vehicle domains. This variance reflects the uneven progress in the adoption and integration of standalone software solutions within the sector. Infotainment, for example, is the most mature area, while powertrain has attracted the lowest spending for software development. ▶ D

Meanwhile, in the domains of advanced driver-assistance systems (ADAS) and connectivity, a growing number of both emerging startups and existing vendors are actively developing standalone embedded software solutions or cloud-based applications. These



D Commercial maturity and share of total spend on standalone software by vehicle domain [% of spend on standalone software]



Source: Roland Berger

developments indicate a positive trend towards greater software independence and innovation, suggesting that these domains are on their way to achieving a similar level of commercial readiness as infotainment.

Conversely, vehicle domains such as powertrain, chassis and body controls face distinct challenges, most of which are the result of a scarcity of standalone software options. In these domains, buyers are often constrained to purchase integrated software/electronic control unit (SW/ECU) solutions. The highly specialized requirements and safety-critical nature of these domains has traditionally favored tightly integrated solutions to meet stringent performance and reliability standards. This lack of flexibility hinders the adoption of more modular and scalable software solutions, making it a critical area for the industry to focus its developmental efforts.

2.2/ Building a mature software ecosystem

In an ideal scenario, an efficient market is characterized by transparent product information, which facilitates maximum value creation at the system level. However, the automotive industry struggles with a lack of visibility into the comprehensive universe of available products, their features, functionality, pricing, integrations and the standards to which they adhere. This opacity makes it exceedingly difficult for buyers to locate and procure software solutions that precisely meet their needs.



"Our industry is refining how best to process transactions for software products and services, which needs to be different from the traditional approach we use for automotive hardware. We find that more upfront collaboration is needed to establish software as a product in automotive," says Jeffrey Shay, North American President of Valeo.

Compounding this issue is another pervasive industry-wide dynamic: the reluctance or inability of market players to engage across different levels of the value chain. For instance, OEMs that possess substantial in-house capabilities and valuable intellectual property might explore avenues to monetize these assets further. This could involve licensing their software or offering it as a standalone product to other industry players. So far, however, they have been reluctant to pursue such opportunities.

Similarly, Tier 1 suppliers, who traditionally view themselves primarily as software vendors, should consider opportunities to outsource the development of non-differentiated software components. This strategic shift would not only reduce development costs but also allow them to focus their in-house resources on creating more specialized, higher-value software solutions.

Encouraging movement across different segments of the value chain could unlock significant potential, benefiting individual players and enhancing the overall automotive ecosystem. To overcome these challenges, however, will require a concerted effort to increase transparency and flexibility within the market. This includes improving the availability of information about software products and encouraging a culture of collaboration and openness to diversifying roles within the value chain.

3

Call to action for industry players

Cars are changing. Wheels and steel still matter, but what matters more is the intelligence within. The Toronado will always have its fans, but these days, car buyers are looking for brains as well as brawn.

As cars change, so must production methods. When software was a minor part of production, an in-house coding factory may have made sense. But now it has become an expensive luxury.

To accommodate this shift, the automotive industry needs a robust software marketplace. OEMs, Tier 1 suppliers and technology providers must adopt advanced software development methodologies to enhance development speed, security and interoperability. Clear commercialization strategies with transparent pricing and deep customer engagement will be crucial to align products with market needs.

Operationally, streamlining procurement processes and leveraging advanced deployment tools will support rapid software integration. Collaboration through marketplaces, alliances and consortia will be vital for product visibility, standardizing practices and fostering innovation. But to get there, the whole automotive community will need to make a number of changes in how it makes, buys and services software:

TECHNICAL ADAPTATIONS

To successfully develop and integrate commercial grade automotive software, OEMs and Tier 1 suppliers need to consider several technical adaptations. First, they will need to





package their software stack, document APIs and align with industry standards. By standardizing and clearly defining the software products, OEMs and Tier 1 suppliers can ensure compatibility across different platforms and systems. Secondly, they will need to refine their integration requirements. This is essential for standalone developers and for ensuring maximum compatibility and interoperability.

OEMs should convey their integration needs to software vendors, enabling them to develop products that align with the OEMs' requirements and integrate seamlessly with their platforms. Furthermore, leveraging reference designs, virtualization and cloud-based software development can be extremely helpful in identifying interoperability issues quickly and understanding how different software components can be assimilated. These innovations allow software buyers and vendors to test out multiple configurations of software components on varying microcontrollers and processors, ensuring compatibility and reducing hardware dependency for software development.

One semi-conductor executive is already thinking about what this might mean for his industry. "Semiconductor vendors can offer commercial software optimized to unlock the full potential of their microcontrollers and processors and provide valued services and applications to accelerate the path to SDV production," says Sebastien Clamagirand, Senior Vice President, Automotive Embedded Systems & Marketing, NXP Semiconductors.

COMMERCIAL STRATEGY

For effective commercialization, both software buyers and vendors must embrace strategic changes in their sales and marketing efforts. Software vendors need to develop clear revenue models, pricing structures and commercial terms. Robust go-to-market capabilities and sales channels will be crucial to reach the market and ensure the successful commercialization of software products.

As they provide more transparency and predictability in their offerings, vendors will establish trust and confidence among potential buyers. Additionally, increasing customer intimacy through close collaboration and feedback loops will enable vendors to better

// We have a vision of a centralized marketplace that fosters innovation, accelerates development and ensures that solutions meet market needs, driving industry growth and improving the consumer experience."

Prashant Gulati, CEO, SDVerse



understand OEM needs and design more informed product roadmaps. This customer-centric approach will drive the development of commercial grade software that aligns with the specific requirements of the automotive industry and the end-consumers.

On the buyer side, defining optimized make vs. buy strategies is essential. Buyers need to carefully evaluate which software components are core to their differentiation and should be developed in-house, and which components can be efficiently procured from external sources. Establishing robust, software-centric procurement capabilities will enable buyers to identify and select the most suitable commercial grade software solutions. This includes developing effective processes for evaluating software vendors, negotiating contracts and managing ongoing relationships to ensure successful integration and long-term support.

If they adopt these measures, buyers could enhance their software procurement processes, reduce inefficiencies in software development and accelerate the integration and commercialization of advanced software components in their vehicle platforms.

However, even as automotive software becomes a scalable product, executives say it will remain a high-touch business. Marc Lang, Senior Vice President, Business Development & Sales, TTTech Auto, notes that the growth of his software-only business model highlights the fact that "success in the software-only business is not just about creating exceptional software, but about building relationships and delivering value at every touchpoint."

OPERATIONAL EXCELLENCE

For OEMs and Tier 1 suppliers, optimizing resource utilization will be the key to driving efficiency and innovation. High-value software development should be prioritized in-house to maintain competitive advantage and control over core technologies. Simultaneously, procuring non-differentiating software components from external sources will streamline operations and reduce costs. This strategic division will enable OEMs and Tier 1 suppliers to focus their internal resources on breakthrough innovations while leveraging the broader software ecosystem for standardized solutions.

The formation of specialized teams dedicated to different stages of the software development lifecycle will also be critical to further enhancing operational efficiency. Establishing independent software development teams, integration teams and testing teams will help to focus expertise where it is most needed yet encourage collaboration to ensure seamless development and deployment of software products. This structured approach will not only accelerate the development process but also enhance the integration and testing phases to ensure that the developed software meets technical specifications, user expectations, and safety standards.

Beyond internal operations, embracing a culture of innovation and agility within the organization will be paramount. This will require fostering an environment that supports rapid learning and cross-functional collaboration. Investing in advanced technologies and infrastructure, such as cloud computing and data analytics tools will also support these endeavors, enabling sophisticated software development and data-driven decision-making. Additionally, revising supply chain strategies to include software vendors as key partners and staying compliant with evolving industry regulations will be essential.

COLLABORATIVE SUCCESS

Individual effort has its place. The seven lines added by the Toronado's unknown coder would probably have been more difficult to outsource than just write in-house. But today,





automotive software development needs to go the way automotive development has always gone—toward a global scale, supported by an extended, sophisticated supply chain.

Collaboration will be essential in the development of this market. OEMs and Tier 1 suppliers often lack the scale to independently make transformative investments. However, by pooling resources, expertise and technology through partnerships, companies can distribute financial burdens and accelerate technological advancements. This collaboration will not only facilitate the sharing of best practices but encourage standardization within the industry, streamlining the development of SDV systems.

Yunsoo Jin, Software R&D Fellow at HL Mando, says it's important that a global software ecosystem develops to prevent redundant investment, extend the global market and facilitate alliances that will strengthen the automotive software market and improve SDV adoption.

Finally, to bridge the gap between software buyers and vendors, establishing transparent and well-structured marketplaces will be critical. These marketplaces should provide clear information about product features, compatibilities, standards and commercial terms, fostering an environment of trust and informed decision-making.

Transparency regarding these elements will ensure that all market participants have a comprehensive understanding of their investments, which is vital for building confidence in the products and standards promoted through the marketplace. Improving market visibility of all available automotive software products will be key to ensuring that buyers can identify and leverage the best software solutions available while vendors can maximize IP reusability and access new customers.

Creating a successful automotive software market will require a collective effort in which stakeholders actively contribute to a shared ecosystem. Establishing transparent marketplaces and promoting collaborative networks will be crucial. Such a unified approach will not only drive the future of automotive software but also ensure the industry's transition to software-defined vehicles proves sustainable.

"With over USD 100 billion invested in automotive software over the past three years, it's crucial for automakers to optimize resource utilization, balancing in-house development with the procurement of non-differentiating software components," says Prashant Gulati, Chief Executive Officer of SDVerse.

BUILDING THE NETWORK

Markets are mysterious. As with any ecosystem, the conditions have to be just right to be successful. Not enough sellers and you can't attract buyers, but without enough buyers, you cannot attract sellers.

Prashant Gulati believes that SDVerse has hit on the right combination. His marketplace gives buyers the transparency they need to evaluate an offering and vendors the opportunity to showcase their offerings. "We have a vision of a centralized marketplace that fosters innovation, accelerates development and ensures that solutions meet market needs, driving industry growth and improving the consumer experience," he says.

Prashant Gulati points to dramatic advantages. "On the SDVerse marketplace, buyers and sellers can save up to 80% of the time spent on product discovery and RFQ generation, leading to significant cost-savings and more efficient resource use," he says.



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SDVERSE is a first-of-its-kind B2B marketplace for buying and selling automotive software. Backed by founding members General Motors (GM), Magna and Wipro, SDVerse is accelerating the future of software-defined vehicles by providing a matchmaking marketplace for buyers and sellers that benefits the entire automotive ecosystem. Its standard-agnostic marketplace is available to all OEMs, suppliers and any other company with relevant software offerings and tools. Learn more at www.sdverse.auto

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