The headache of *Software-Defined Vehicles* today: Will it continue?

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Abstract

Incumbent automotive players have been embarking on ambitious software transformation journeys for about 5 years, investing heavily in launching Software-Defined Vehicles (SDV)initiatives, hiring large numbers of software engineers and creating substantial software entities. These strategic investments aimed to revolutionise the automotive industry by integrating advanced software features into vehicles, providing innovative services, generating new revenue streams, and enhancing the customer experience.

The gold rush euphoria of the first years is now gone. After 5 years of transformation, it is now possible to qualify and quantify the impact on OEMs' and Tier-1 suppliers' businesses.

Start of Production (SOP) is being delayed by 3 to 5 years, with budgets being exceeded, placing managers and organisations under extreme pressure. The transformation will probably take more than 5 years to come to a new normal with high risks to OEMs' reputation and the entire ecosystem of suppliers and solution providers.

In 2025, the incredible pressure on the automotive industry (a result of unstable economy and politics, reduction of sales, unrealized promise of electrification, and new competitors) puts even more pressure on SDV programs which could finally save or damage the traditional OEMs.

The main challenge is now to deliver SDV programs on time and quality whatever the budget and come back to a deterministic path which was common to automotive players for decades.

Based on Capgemini's experience in product/programme development and transformation programs, this paper will first detail the challenges to a transformation by looking at organization, product methods and software practices. The timeline for these multiple transformations is more likely to be 6 to 8 years, not 3 to 4 years as initially expected.
The automotive sector is reaching the first half of this transformation journey. Despite the difficulties, the various stakeholders embarked in this journey have reached the point of no return and must keep fighting. Through Capgemini's experience, we provide recommendations and decisions to stabilize the situations of both OEMs and Tier-1 suppliers.

Keywords: Software Defined Vehicle, Software Transformation, Passenger Cars, Commercial Vehicles

Introduction: The promise of a new world, the gold rush of software

For the last five years, traditional automotive OEMs have started ambitious software transformation journeys, investing heavily in launching SDV initiatives. These investments aimed to revolutionize the automotive industry by integrating advanced software functions into vehicles, using more connectivity, and providing new services.

Furthermore, all players in the automotive industry targeted a boost in their services-related revenues by setting ambitious business goals. The initial, and attractive, software promise covers:

- Creating seamless digital experience
- Enabling complex cross-domain functions (such as highway assist, traffic jam pilot)
- Reaching new software-based revenues (from new business and subscription models for OEMs)
- Supported by Over-the-Air features (OTA) enabling continuous vehicle improvement and maintaining customer satisfaction.

Significant investments were then made in a short period of time ($1 to 4 billion per year) to create software entities within existing organizations and/or new software-dedicated companies. These companies hired large volumes of software engineers and created software academies to support upskilling and management transition.

New technologies for automotive - SOA (Service-Oriented Architecture), hypervisor, HPC (High Performance Computing) - promised to transform vehicles into sophisticated, software-driven machines capable of continuous improvement and enhanced user experiences.

Back to reality: The disillusionment

Despite the large investments made and high software-based revenue projections, the complexity of integrating these technologies and the high costs associated with their development have not led to the expected financial returns.

Currently, there is extreme pressure on all organizations in the automotive ecosystem:

- All initial budgets have been exceeded
- Most of the SDV programs have been delayed, from months to several years
- The expected value for end customers was not reached
- Strategic restructurings had to be launched

When building complex multi-layer software, the whole product development process is disrupted, impacting the organizations. As OEMs integrate software activities that are historically managed by Tier-1 suppliers, the whole automotive ecosystem is impacted.

For OEMs, the difficulties were amplified as they needed to hire and manage new organizations expected to master emerging technologies still under development.

Delivery of high quality, high integrity software in safety critical applications is extremely difficult, with poor-quality impacting the company's reputation and disappointing customers.

Despite these challenges, the potential value of SDVs remains significant in the automotive industry to tackle the exponential increase of technical crossdomain features, to ensure end-customer value creation and to realize the business potential.

OEMs and Tier-1 suppliers have reached the point of no return, having invested billions in SDV, they now have the obligation to deliver SDV programs.

The troubles rarely come alone

In addition to the challenges encountered when conducting an SDV transformation, the automotive industry companies must deliver results as they are facing several other difficulties in the same period, such as:

- Recovering performance from the Covid-19 pandemic crisis (sales, supply chain…)
- Operating in a politically unstable environment of regulation and protectionism
- Dealing with consumers that are more and more cautious with vehicle price and performance - especially EVs
- Facing the new competition from Asian that compels other OEMs to reduce vehicle development time from 3 to 2 years.
- Facing the unrealized growth targets of electric vehicles where sales are stagnating, at least in Europe and USA

In that context, there is an obligation for traditional OEMs and Tier-1 suppliers to restructure, reduce costs, including R&D, and focus on profitable segments.

As a conclusion, the headache of SDV emanates from the fact this is a bold transformation as it can:

- Either be an opportunity to set new strategic foundations (set software a core technology,optimized/improved operations & teams' efficiency, market recognition)
- Or be a risky path that will seriously affect their competitiveness.

A challenging transformation journey to Software-Defined Vehicle

As a global leader in transformation, engineering, and technology, Capgemini has been involved in this industry shift and is now able to share insights based on projects conducted with automotive players.

Firstly, the transformation of automotive companies into software companies will likely take closer to 6–8 years rather than the 4 years initially targeted by industry players.

Building a 1000+ engineers software practice and software delivery organisation requires time to reach full efficiency, while talent management remains a huge challenge.

- To **scale-up** Software development and penetrate the SDV market, automotive players have grown as fast as possible by **recruiting thousands of software engineers,** software architects, quality engineers, Cybersecurity experts, … In addition, the workforce was sourced both internally (in organizations) and externally, on the market or through partnerships with engineering companies.
- This massive ramp-up is characterized by a significant **variety of backgrounds:** developers with a systems engineering mindset and those from the digital and tech ecosystem. **New organizational structures** and leadership approaches have emerged.
- New software delivery methods and tools based on Dev/Sec/Ops and SAFe have been promoted and implemented to enable software development. However, resistance to change from engineering profiles was often underestimated, leading to discrepancies in adopting these new ways of working.
- For these new software practices, achieving efficiency while managing a rapid ramp-up and a diverse mix of cultural backgrounds requires a **3- to 5-year journey,** guided by **top leadership to oversee new organizational practices.**

Developing cross-domain vehicle features is highly R&D-intensive and providing the necessary effort and an appropriate organizational approach may not have been considered a critical step in delivering software.

Complex new functions such as ADAS Level 2+ and 3, as well as infotainment with new digital experiences, have been added to highperformance vehicle electrification as a top priority in client desirability rankings.

- The delivery of such complex functions has increased the level of collaboration required across different engineering domains. ADAS Level 2+ and 3 require cross-domain collaboration between OEMs and Tier-1 suppliers.
- Systems engineering culture, with strict MBE/MBSE methods, has been pushed into the background as agile software development methods gained prominence. Moreover, most OEMs and Tier-1 suppliers did not collaborate sufficiently to address increasingly complex product development challenges.

The implementation of new E/E architecture, hardware, and software programs has gone through **too short of a predevelopment phase before transitioning to development.**

- HPC was under development to host SOA software for next SOP, meaning that predevelopment phase was not possible to conduct. This was mainly driven by time-tomarket issues.
- Usually, a 2 to 3 years predevelopment should have been a prerequisite, prior to 3 -5 years of development.

Delivering bug-free, safe, and compliant software is essential to achieving final vehicle quality; however, the **processes, methods, and tools approach was underestimated.**

- Software quality on complex functions involving thousands of engineers has required a minimum of 3 years of intensive practice. For example, a Tier-1 company needed 3+ years to stabilize the software delivery on complex multicore ECU like infotainment involving 1000+ engineers.
- Ultimately, a software organization should be prepared to successfully undergo external audits, with evidence of compliance with industry norms (ISO26262, ISO21434, ASpice, …)
- Quality and PMT (Process, Methods, Tools) management should not be considered as "overhead" but as mandatory productive functions in the organization. In addition, project management is key to enabling delivery performance and setting standards for development teams.

Engineering software at scale requires a broad set of dedicated technological infrastructures, guided by corporate strategy.

- Most software organizations have managed to grow in "start-up mode" successfully. However, we may have observed internal competition between embedded software engineering driven by R&D and offboard application developments implemented by IS/IT organizations. Considering onboard and offboard as one common development is critical, but frequently missed during early-stage development.
- Cloud-based developments, virtualization, and massive data storage are key to scale and foster AI-based software development and too often implemented late while not being fully aligned with corporate policies.

In the last few years, the automotive industry has gone through a large transformation and software is now the cornerstone of this change as automakers and suppliers see its potential: it is flexible, adaptable, and easily connected with existing systems. Software opens the door to new challenges and opportunities. But, despite all the efforts, we still have not fully shifted into high gear. Today, we are at a critical moment and the automotive sector is facing the **three following main challenges to implementing SDV:**

First, the market is still on its path to maturity. As aresult, when talking about business expectations, return on investment is not there yet for incumbent players/automakers.

- New revenues brought by software in cars, (driving assistance, connected services...), have not yet been reached as the technologies are still maturing.
- Regarding SDV costs & investments, designing a new electrical/electronic (E/E) architecture requires the development of a new and dedicated Platform software which is long, tedious, and costly. This platform SW development may not be affordable for all automotive players who aim to launch their SDV solution. Moreover, internal software R&D capabilities costs are significant enough to prevent a full internal software transformation.

Second, for automotive OEMs, **integrating software capabilities is a challenge.**

- Previously, software activities were largely delegated to Tier-1 suppliers. They were developing complex subsystems such as ADAS, IVI & connectivity. The OEMs were mostly system integrators. As software is at the heart of each vehicle, automakers now want to manage software themselves, to guarantee their sovereignty on this critical technology. But it is far from easy as it disrupts the roles & value chain of the entire automotive ecosystem. With software, operational and organizational complexity is increasing significantly for car manufacturers.
- Developing software takes time; it is a new discipline to embrace in addition to the mechanical & electrical ones. Moreover, as the historical roles between carmakers, partners and suppliers have changed, it has added other challenges in the design and delivery chain.

Third, at the company level, the transition to a software-driven journey has likely been underestimated.

- Good software needs skilled people. Unfortunately, as teams require exciting projects, but **daily production often takes priority over innovation,** attracting and retaining the best software talent and creating a new software culture in automotive is challenging.
- Understanding, enabling and on-boarding software within traditional mechanical companies is hard. **Merging software culture within an existing organization,** requires a huge commitment and investment to ensure the transition.
- Managing legacy (from business & assets) is a challenge for incumbent players, adding another dimension in an SDV journey that newcomers don't have. The difficulties arising when dealing with all these challenges at the same time create a perfect storm.

While operating under high market pressure and embracing significant changes to the company, while trying to build the next-generation vehicle enabled by software, it is hard to define the root causes of the challenges and drive changes in a consistent way.

By putting too much emphasis on becoming "Techcompanies", automakers have often experienced difficulties and lost focus on delivering high value for customers, which is the driver of business value.

The way forward: A simple headache or more? The pivotal moment to regain control of the story

We demonstrated that the software transformation is likely to be completed in 6 to 8 years due to the accumulation of complexity and dimensions.

The OEMs and Tier-1 companies are now entering the stormy phase. **How will they sustain over the next 2 to 3 years?** Are there new targets or shall the companies continue to stick to the initial settings? While the pressure increases for all managers, it is time for them and the experts to react and regain control of the challenges.

Based on Capgemini's feedback on projects with OEMs and Tier-1 suppliers across various industrial sectors, including automotive, we provide recommendations to overcome the challenges in vehicle projects in the short and mid-term, aimed at SDV managers and experts who need to keep pushing forward.

We consider it mandatory to react in the short and mid-term, focusing on the following three dimensions and acting on fundamental practices: Management/Steering, Program/ Project Execution, and Engineering/IT.

SDV developments are still following the same new paradigm: coding, validation, tools, and products are still at a high rate of innovation and uncertainty, with maturity expected to improve over the next 2-3 years.

We recommend the following:

1. The **management responsibilities** are more important than ever. Top managers must admit that the transformation is not finished yet but that they are in the first half of the journey. Therefore, continuous focus on organization and operating models, while delivering, is necessary to react.

   Managers must assess their perimeter with a 360° view, for their organizations and for their customers' satisfactions, even internal to their company such as vehicle brands/programs. Under high pressure, **top management requests transparency** about .organizations, operations, programs, achievements and root cause analysis of troubles. A one-shot assessment will not be enough; we recommend a periodic evaluation every 6 months to closely monitor and react.

   At company level and especially in software entities, we consider that it is strategic **to set new governance roles to secure the performance.** The **Software Engineering Fairness Officer** would have the role of ensuring transparency within the organization regarding development maturity, time schedule maturity, and compliance with development frameworks, in addition to the traditional role of quality managers.
   In addition, we noticed too much decoupling of software entities with other engineering functions. We consider installing a role of **overarching Chief System & Software Engineering Officer** to bridge the software entity with other vehicle engineering functions.

   Organizations and programs are increasingly **entering a task force mode.** The role of management is to communicate about it and convey its purpose to all involved employees.

   One priority will be to secure strategic talented people for the completion of targets in the coming 6 to 12 months. Companies are still fighting to acquire the best experts, and this is not the right time to lose experts to competitors or suppliers, especially given that recruiting competent people can take more than 6 months.

2. **Programs and projects will request the update of their targets and priorities.** The euphoria is replaced by a prioritization of key features with a priority on high customer value features and system foundations. The priority developments will likely be the core platform, which will serve as the foundation for further carline features, whether upgrades or downgrades.

   For instance, we noticed that many organizations decided to start their SDV journey by clustering on and off board development especially for connected services. We encourage a **convergence of both on/off board streams under single responsibility** and as single value stream to guarantee the final delivery to customers. This will create additional operating models independent of the established organizational structure, but it will ensure that execution is transparent and visible to the company.

   Organizations must first secure and deliver software platforms with essential core enablers, such as OTA, as the foundation for deploying additional applications and services to vehicles after SOP.

3. The engineering and IT departments are handling the delivery. As for program management, the **culture of transparency** is mandatory to bring back the cooperation mindset. The ramp-up of software capabilities at OEMs has generated a shift of software activities from Tier-1 suppliers to OEMs with new contracting models. It is likely time to adapt the models and bring the most experienced suppliers on board to leverage their years of experience in software delivery and quality. Contracting models must be revised to foster partnerships with delegated responsibilities, shifting from 'at cost' to 'at value' or 'at risk.

   The experience of multiple transformation programs in industries shows that **process, methods and tools are often underestimated** or follow the business processes. It is still **time to invest in process and tools** to support the developments and validations with automation, virtualization, and (re)simulations. By performing many assessments in industrial organizations, we notice that the potential for further productivity and quality is significant. The software development lifecycle can be boosted by the recent GenAI methods only if the adoption is made possible by training and demonstrations.

   This marks the emergence of a new discipline: Global Software Industrialization, including PMT & Quality, Engineering, and IT/ Infrastructure, which should be considered as important as development, and no longer as overhead.

   For instance, we noticed that large software driven companies did not adopt and rollout the benefits of GenAI to their full potential. The technologies can be highly beneficial for engineers, but they require a comprehensive transformation program to ensure successful adoption and ROI.

   Another example concerns the **full traceability of developments** from top requirements to final validations. We see that the software entities struggle to create an efficient expertise stream to guarantee the final quality of the deliverables. It is time to follow what Tier-1 suppliers did in the previous decade and apply it at vehicle level, with automatic system/software code and documentations, documentation with access back to code etc…

   Engineering and IT teams will finally need to anticipate post-SOP maintenance and optimize processes for software bug fixes.

Final thoughts

SDV has now become the new normal for the automotive industry as the state of the art of the technology is progressing and the competition intensifies with new digital native players. In that context, automotive players have fully entered the software world, transforming and reinventing themselves in a very short time. A huge step has already been achieved, demonstrating the dynamism of the industry and the ambition around SDV.

However, four years after the start of the SDV journey, the automotive players are on the brink of collapse after having invested billions for their transformation without reaching its expected ROI.

The magnitude of the SDV transformation across all its components (business, organization, technical, and skills) was underestimated, and today's forecasts indicate that automotive players will not realize tangible benefits before at least 2028. Current assessments show that most automotive players are about halfway on their global transformation.

The initial SDV promise (to reduce costs, accelerate time-to-market, create an evolving customer experience, handle complex new features, and generate new revenues) is nevertheless still valid. But the industry must react to navigate the next 3-4 years. A pivotal moment has now been reached.

An urgent deep dive on the 3 dimensions (executive management and steering, programs and projects, engineering and IT) is necessary to rebuild the foundations of the software delivery model while protecting upcoming short term vehicle SOPs.

The SDV journey is still long, and the challenges are numerous. The technology must now be realigned to serve the business and deliver its full initial promise. However, there is a path to alleviate the challenges and transform them into a real opportunity.

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Glossary

ADAS: Advanced Driver Assistance Systems

AI: Artificial Intelligence

CV: Commercial Vehicles

E/E: Electrical / Electronic

IVI: In-Vehicle Infotainment

KPI: Key Performance Indicators

OTA: Over-the-Air

PC: Passenger Cars

ROI: Return on Investments

SDV: Software-Defined Vehicle

SOP: Start of Production

SDLC: Software Development Lifecycle

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