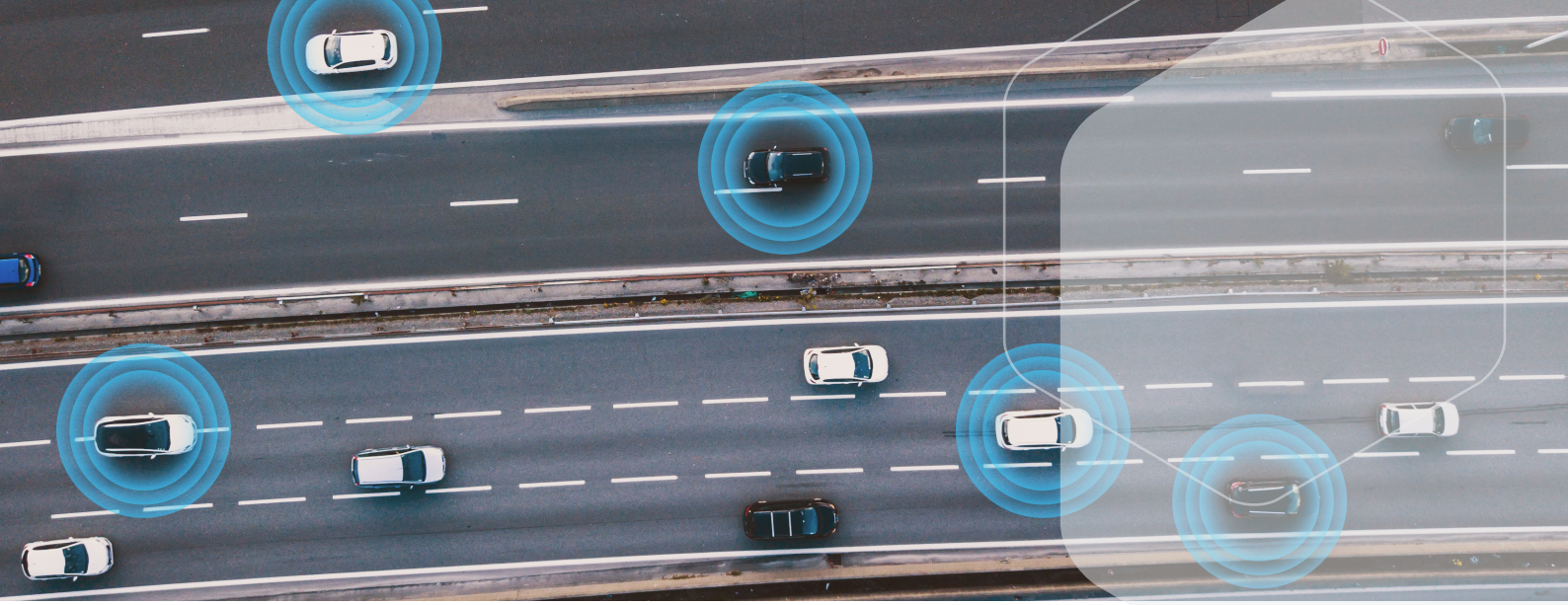
BERYLLS STRATEGY ADVISORS

MARKET EXPECTATIONS AND PROSPECTS FOR SOFTWARE-DEFINED VEHICLES



AGENDA

Cars are evolving rapidly from pure hardware to software-on-wheels. Established manufacturers will have to put their foot down to avoid losing the race to Tesla and tech giants such as Google.

1 INTRODUCTION

The automotive industry is on the verge of the most significant transformation in its history, as the world shifts to electric-powered and increasingly autonomous cars. In meeting this challenge, a key issue will be software. Volkswagen's chairman Herbert Diess has described software as the biggest test of the coming change, forecasting that it will eventually account for 60-70% of vehicle product differentiation[1]. The reason lies in the nature of the product: the electric car of the future will always be connected, updatable and mostly self-driving, and be part of an ever-expanding, integrated mobility services ecosystem.

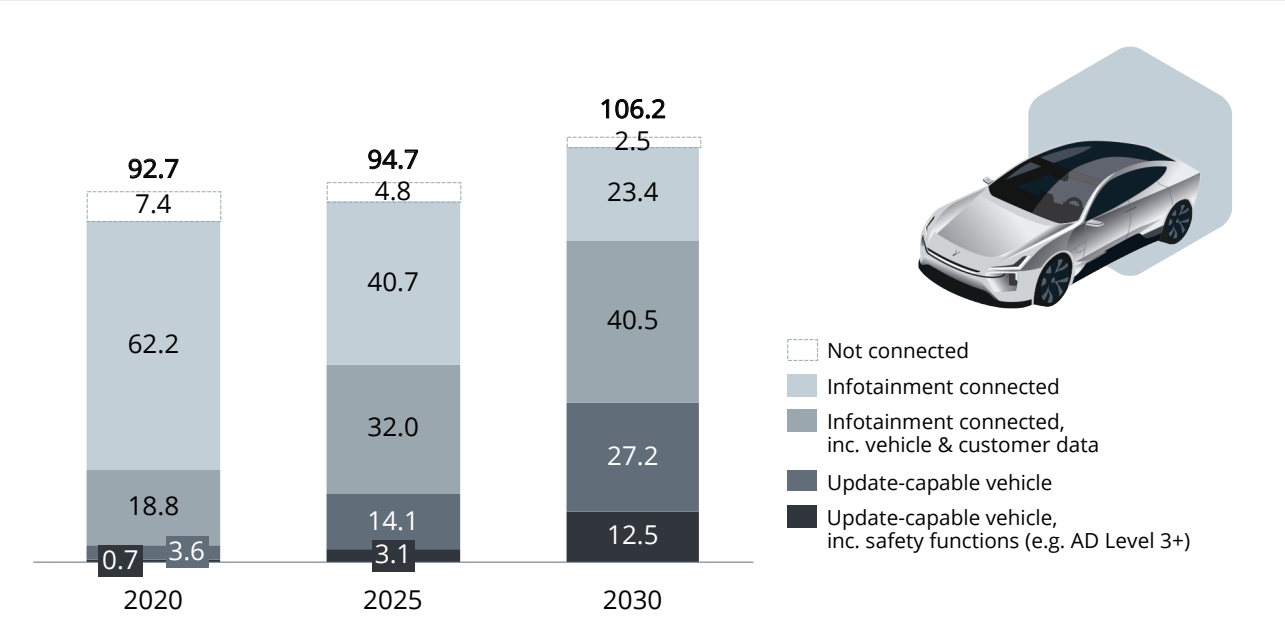
Berylls Strategy Advisors expects that by 2030 the proportion of vehicles worldwide that are connected, upgradable beyond just infotainment, and may even support autonomous driving[2], will sharply increase from less than 5% to 37%. Meanwhile, connectivity will progressively expand beyond online services for "connected" cars to software updates for the entire vehicle system, including critical safety functions such as driver assistance (see Figure 1).

Greater connectivity will enable continuous innovation, even after the vehicle has been sold, as customers' purchasing decisions continue to shift away from traditional selling points such as engine power and torque to software functionality and over-the-air (OTA) update capability.

Tesla is an example of how public perception of electric cars is now being significantly influenced by the innovative potential of software. Founded in 2003, the California-based company's status as the leading pioneer of software-defined vehicles has propelled its meteoric rise to a market value of around $689bn in August 2021. Tesla is now the most valuable car manufacturer of all time, worth more than Toyota and Volkswagen combined, even though the latter companies respectively delivered 14.7 times and 12.7 times as many vehicles as Tesla in the first quarter of 2021[3].

FIGURE 1:

EVOLUTION OF VEHICLE CONNECTIVITY (2020-2030)



Source: Berylls

[1] Source: Handelsblatt
[2] ADAS or HAD Level 3-5
[3] Source: Quarterly reports

Both Toyota and Volkswagen recognize that they can only become more attractive to investors by pushing forward with e-mobility and vehicle connectivity. These automotive titans are increasingly having to move beyond their core strengths and trusted network of suppliers into new partnerships with companies from other sectors.

Alongside new manufacturers like Tesla, major technology players are making substantial inroads into the global automotive market, led by Google, Apple, Amazon and Microsoft, whose core competencies lie in software and cloud services.

Their activities range from strategic partnerships, such as Microsoft and Volkswagen's collaboration to build VW's Automotive Cloud, to internal projects such as Android Auto. Apple in particular has repeatedly made headlines for poaching top executives from automotive OEMs.

Amid the disruption, this report launches our latest Berylls Insights series, "Software-defined vehicles: Inside a game-changing transformation," which analyzes the opportunities, risks and potential strategies for market participants, and forecasts how the market is likely to develop.

2 TRENDS AND DRIVERS

Berylls has identified six major trends and drivers of change in the automotive software market, among a multitude of interconnected developments:

1. Growing consumer expectations regarding connected services
2. Increasing relevance of vehicle lifecycle management and "over-the-air" (OTA) updates
3. Shifting functionality from hardware to software
4. Increasing regulation
5. Rising cost and efficiency pressures
6. Increasing use of data analytics to unlock efficiencies and new services

2.1 Growing consumer expectations regarding connected services

What 10 years ago was still a controversial topic has now become commonplace: today, connected services and digital features are decisive purchase criteria for prospective car buyers. This is particularly true of younger customers, who have grown up as digital natives with smartphones and tablets. Consumer expectations have risen accordingly that services will be updatable, usable, upgradable and with real-time data capabilities, as well as being portable – that is to say transferrable from one machine or system to another.

This trend is particularly relevant as vehicle sales shift increasingly to market segments with high contribution margins such as China, with its vast base of young, digitally-savvy consumers. Higher customer expectations are also reflected in a reduced willingness to pay extra for additional software features: in Germany, three-quarters of customers consider that digital services should be included in the purchase price of the car; in China, the figure is about 50%[4].

Against this background, it is crucial for car manufacturers to offer products that can be integrated into their own digital ecosystems, whether delivered by Apple, Google, Amazon, or Microsoft. Otherwise, manufacturers risk losing touch with the world of digital experience and by extension with their customers.

2.2 Increasing relevance of vehicle lifecycle management and OTA updates

Despite the growing collaboration between car manufacturers and Big Tech, the former have an interest in continuing to dominate the customer interface inside the vehicle, thereby creating additional revenue streams via pay-per-use, membership, or subscription models.

This is why OTA updates and upgrades are now among the most important features in new vehicles, especially in China, where three-quarters of customers expect them. Tesla is an impressive example of how this offer, alongside a continuously improving service, can maintain vehicle value years after the sale. Residual values of the Tesla Model 3 – 80% after one year, and 54% after three years – are in some cases distinctly higher than those of other premium battery electric vehicle (BEV) brands that do not currently offer OTA improvements. For example, the Audi e-tron's equivalent residual values after one and three years are 77% and 48%, while those of the BMW i3 are 67% and 41%[5].

Continuous lifecycle management has significantly expanded the existing OEM business model because new solutions need to be developed which then require operation and maintenance.

Manufacturers must take charge of all digital product management worldwide, including version control, security, customer relations, transaction capabilities, and documentation. As a result, OEMs are shifting from being primarily manufacturers and distributors to service providers.

2.3 Shifting functionality from hardware to software

Technical developments inside the vehicle are driving change as decisively – if not more – as the impact of evolving customer expectations on the business model. Increasingly complex functions can now be performed by software, such as X-by-wire or battery electronics control for e-vehicles. The goal is no longer merely to optimize space and weight; it is also about developing the new business model over the vehicle lifecycle and reducing product variations with additional hardware. In this context, Apple's replacement of the classic keyboard and control functions on a mobile phone with a single touchscreen is a prime example of how the flexibility of software facilitates the creation of product variations.

[4] Source: Deloitte 2021 Global Automotive Consumer Study

2.4 Increasing regulation

There are inevitably increasing regulatory requirements that OEMs have to fulfill, given the rise of electrification, automation, and even fully autonomous driving. Most importantly, these requirements cover safety certification for the operating software, particularly for AD/ADAS, such as ISO 26262 and SOTIF for functional safety, and the quality of software development processes such as automotive SPICE as part of ISO 15504. This means a significant increase in compliance processes and documentation for the automotive industry.

2.5 Rising cost and efficiency pressures

Increased customer requirements, new and more sophisticated software functions, and greater regulatory oversight are rapidly accelerating interconnectivity between processor units, sensors and actuators inside the vehicle. This trend is in turn increasing the complexity and cost of development, testing and safeguarding, as can clearly be seen in the investments made by OEMs and suppliers in e-mobility and autonomous driving.

The need to continue bringing competitive, affordable products to market is also driving up costs, and not just at the development stage. Typically, operating costs at major manufacturers for cloud-based functions and OTA updates can easily reach more than €100m per year, which can add costs of several hundred euros per vehicle over the lifecycle. Yet too often, OEM business cases fail to take this expenditure into account.

2.6 Increasing use of data analytics to unlock efficiencies and new services

OEMs are relying more and more on vehicle data analytics to offset these increased cost pressures. On the one hand, analytics can reveal potential efficiencies that can be achieved by refining and optimizing functions and components in line with their actual usage. On the other hand, the development of predictive and personalized services in areas such as maintenance, finance and insurance can generate additional revenue.

Effective data usage depends on a matching cloud infrastructure that can receive and process vehicle data, using machine learning. Almost every major car manufacturer has incorporated the development of cloud infrastructure into its digitization roadmap. However, our research and engagement with clients suggests that the potential of data analytics is rarely explored, evaluated and scaled up systematically, meaning the results often fall short of expectations.

COMPLEXITY IS GROWING, WIDENING THE PERFORMANCE GAPS

These six drivers and trends have resulted in an explosion in complexity and product diversity, which current management and technical structures are ill-equipped to tackle.

Traditional electronic/electrical (EE) architecture is neither connected nor flexible, incorporating 80 to 120 individual computer units and software functions which are interlinked with the vehicle platform. For cost reasons, the architecture is usually already close to maximum output when the product launches. Moreover, the trend toward complex, interconnected software functions demands the harmonization of all conceivable interfaces between the individual components, amounting to several thousand per platform.

That is not all. Performance and functionality of vehicle services already lag behind state-of-the-art digital products at the time of going to market, because the software specification is coupled to the hardware's design freeze and therefore "locked in" before production begins. By necessity, manufacturers attempt to mitigate this problem through last-minute software releases shortly before delivery, which can create difficulties during the ramp-up of new vehicle projects and sometimes lead to industry recalls. Projects can come under severe pressure in terms of time, quality and costs, even with high-volume model series from established manufacturers.

So how is the industry responding?

TECHNOLOGY TRENDS: CENTRALIZATION, PLATFORM-BUILDING AND CONVERGENCE

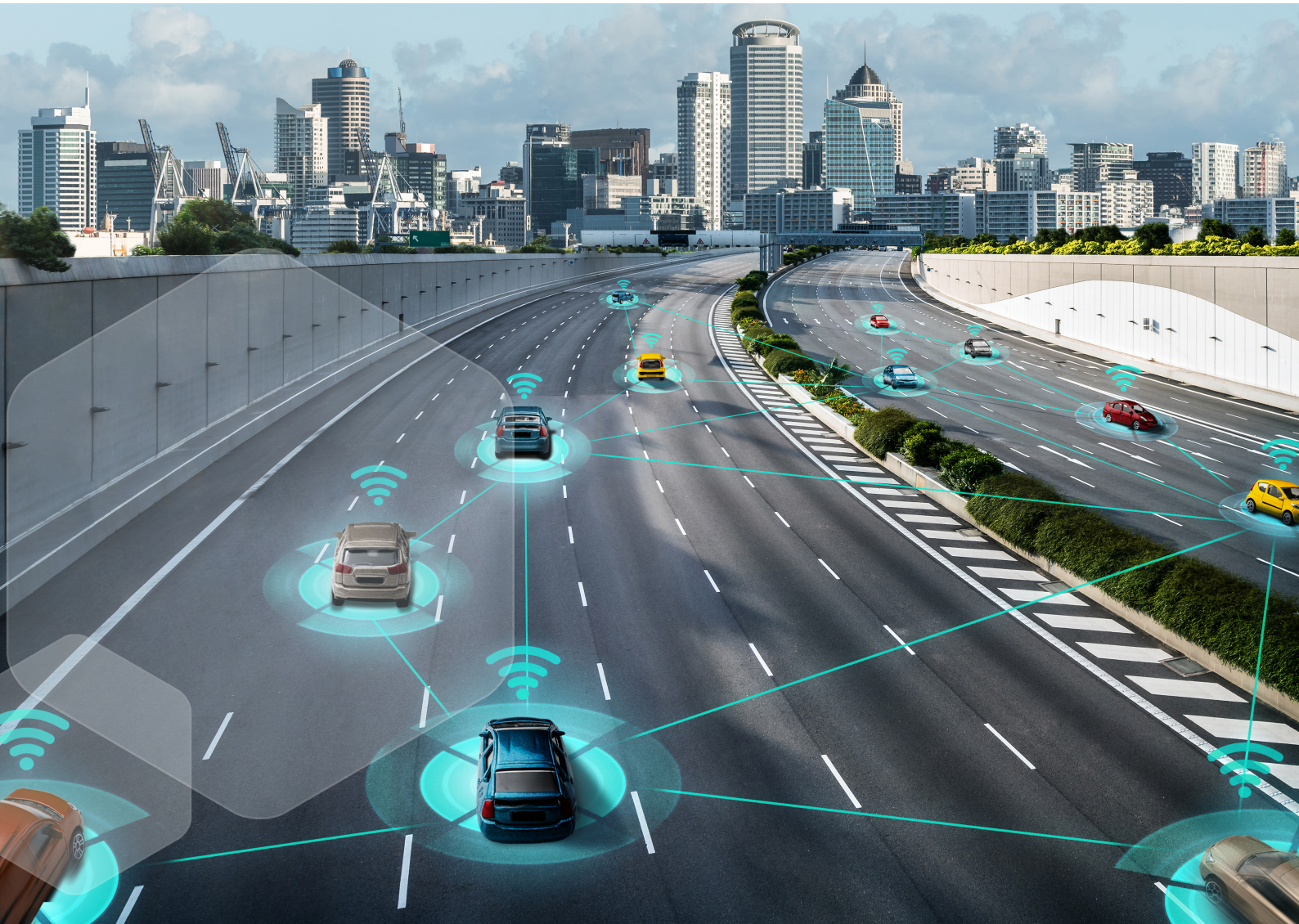
OEMs have realized that the potential for dealing with these glaring problems using the same tried-and-tested approaches has now been exhausted. Consequently, they have set in motion a series of fundamental changes to their technological and organizational models.

3.1 Centralization of E/E computer architecture

To reduce complexity and costs, OEMs are looking to replace their current, widely diffused and decentralized processor units with a centralized computer architecture that usually requires between three and five powerful central computers carrying out domain-specific tasks such as the chassis, powertrain, and passenger comfort. Tesla has gone further, reducing the architecture to a single SoC (System on Chip), while also installing redundant copies of the SoC as a safeguard against possible failure.

3.2 Integration and convergence of onboard and offboard instances

In future, software functions will be designed, developed and operated beyond the vehicle, including cloud integration. This will lead to an increasingly strong convergence between onboard and offboard instances, where the vehicle ultimately becomes an "edge device" within the cloud. As well as helping to reduce production, development and operational costs, this convergence will also ensure the vehicle upgrades and updates capabilities over its lifecycle. Inevitably, this process will involve significantly increased demand for security and data compression technologies.



3.3 Hardware/software decoupling and development of vehicle operating systems (OS)

To address escalating complexity, computers and smartphones now require their own layered open systems interconnection (OSI) model. Vehicle IT is also pursuing the same exit route, by effectively "decoupling" software, E/E and vehicle platforms.

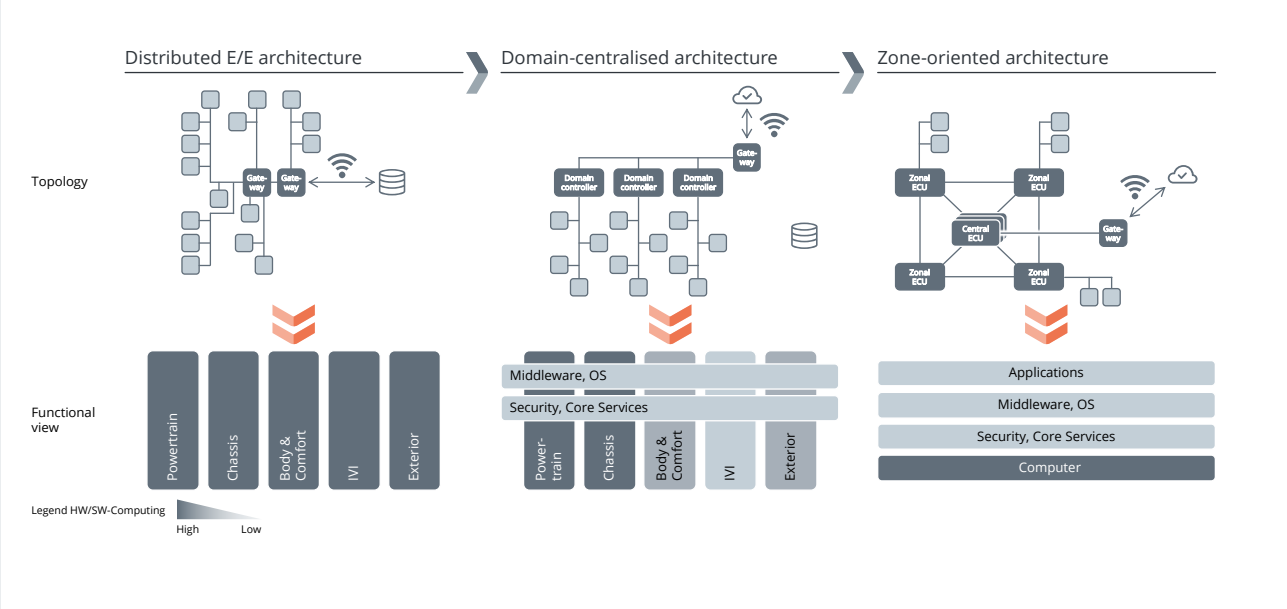
Increasingly, E/E platforms will be rolled out across all products, rather than developed for a single vehicle range and integrated with the vehicle platform via standard interfaces. The resulting reusability and scalability will significantly reduce adjustment costs. Volkswagen has already discovered this benefit and plans to run only a single E/E platform across all vehicles, compared with the current worldwide total of at least seven variants.

More and more manufacturers, such as Volkswagen and Daimler, are implementing standard functionalities and basic technical services using a vehicle operating system (OS) to improve the quality and "reusability" of the software code, while still reducing costs. OS functions are developed centrally on a one-time basis and made available via standard interfaces to applications across various areas, such as drive, in-vehicle infotainment (IVI), advanced driver-assistance systems (ADAS), and passenger comfort.

The development of OS structures inside the car, and the convergence of cloud and vehicle, ultimately appears inevitable. This outcome will chiefly benefit IT giants and "hyperscalers," with tech giants such as Google, Amazon Web Services (AWS) and Microsoft gaining locked-in access to the vehicle. Google in particular is making significant inroads into the vehicle infotainment sector with Android Automotive, supplying complete software stacks for various applications. Google's partnership with Volvo is the most striking evidence so far of the company's IVI ambitions.

FIGURE 2:

DEVELOPMENT OF E/E AND SOFTWARE ARCHITECTURES.



Source: Berylls

3.4 Developing the vehicle's transaction capabilities

In order to dominate the customer interface, OEMs must build up their e-commerce capabilities across the board in B2C, B2B and B2B2C, including associated customer services. As well as connecting their own vehicle and mobility services, they must make their interfaces available to third-party providers looking to engage commercially with or on the vehicle platform. Accordingly, OEMs are changing from SOP-driven manufacturers to service providers that must continuously respond to client wishes. This recalibration of their business model has far-reaching implications and presents a major technical and organizational restructuring challenge.

4

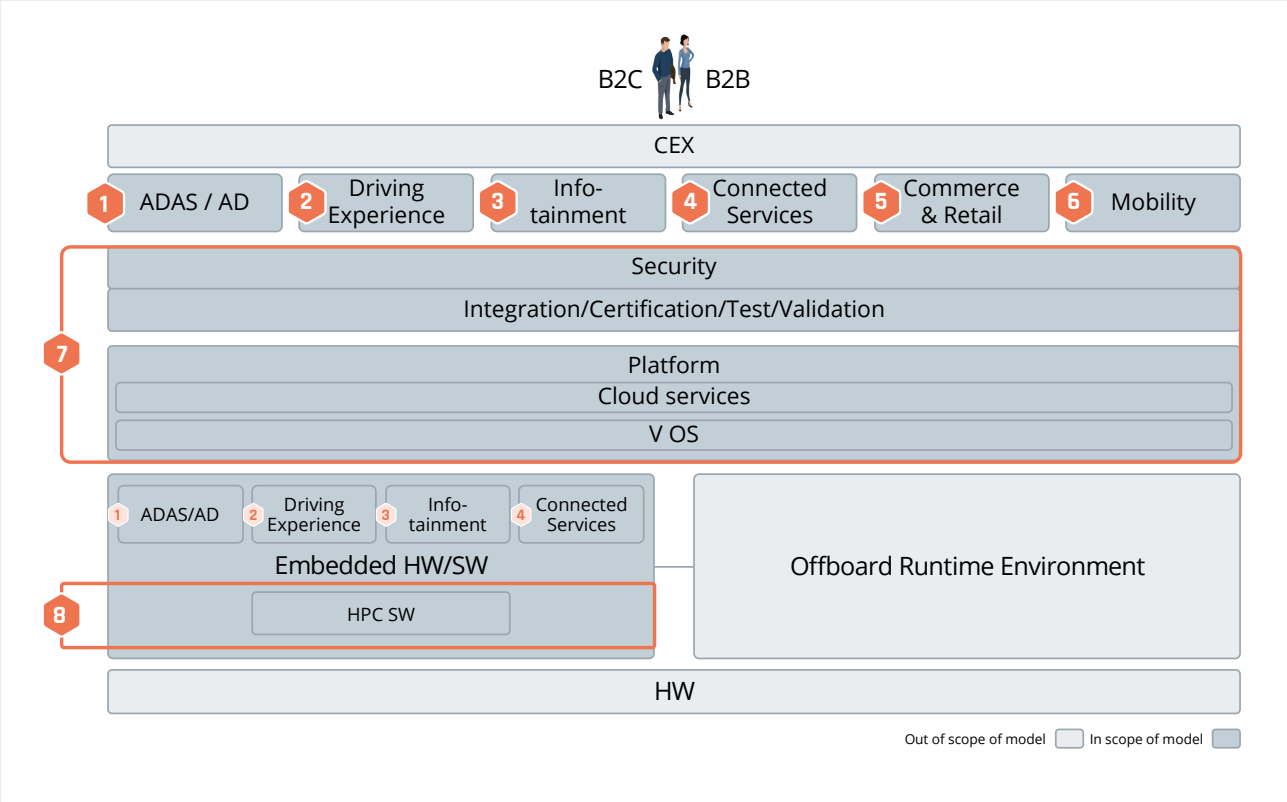
AUTOMOTIVE SOFTWARE: MARKET TRENDS FROM 2025 TO 2030

Based on the trends we have identified, Berylls anticipates that the automotive software market will approximately treble in size over the next 10 years, at an average annual growth rate of 13%. Between 2020 and 2030, we also expect to see the total worldwide annual value of automotive development services increase from €76bn to €252bn.

This forecast only includes the value added from automotive software development in the strictest sense, such as application stacks for ADAS/AD, the driving experience and the vehicle OS (see Figure 3 for a full list). The costs for embedded hardware, customer experience (CX), and cloud infrastructure are not included.

FIGURE 3:

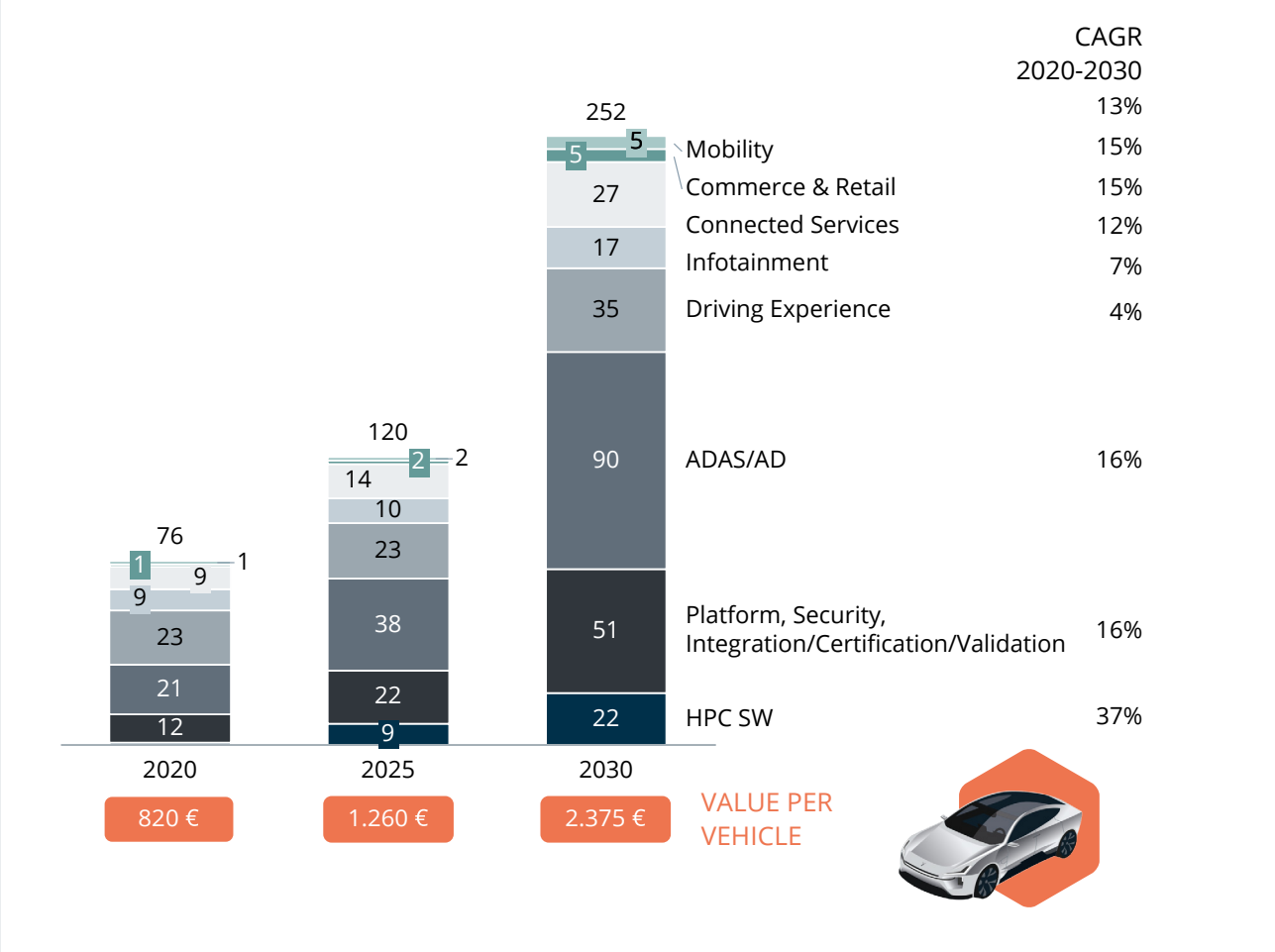
BASIC STRUCTURE OF THE AUTOMOTIVE SOFTWARE STACK



Source: Berylls

FIGURE 4:

VEHICLE SOFTWARE MARKET SIZE 2020-30 (ONBOARD/OFFBOARD)



Source: Berylls

Berylls anticipates that the ADAS/AD domain will account for the largest share of growth in the automotive services market between 2020 and 2030, amounting to around €70bn in value added. This growth will be primarily driven by a projected 20-fold increase by 2030 in the global market share of vehicles that are at least AD L2 capable to around 13 million units.

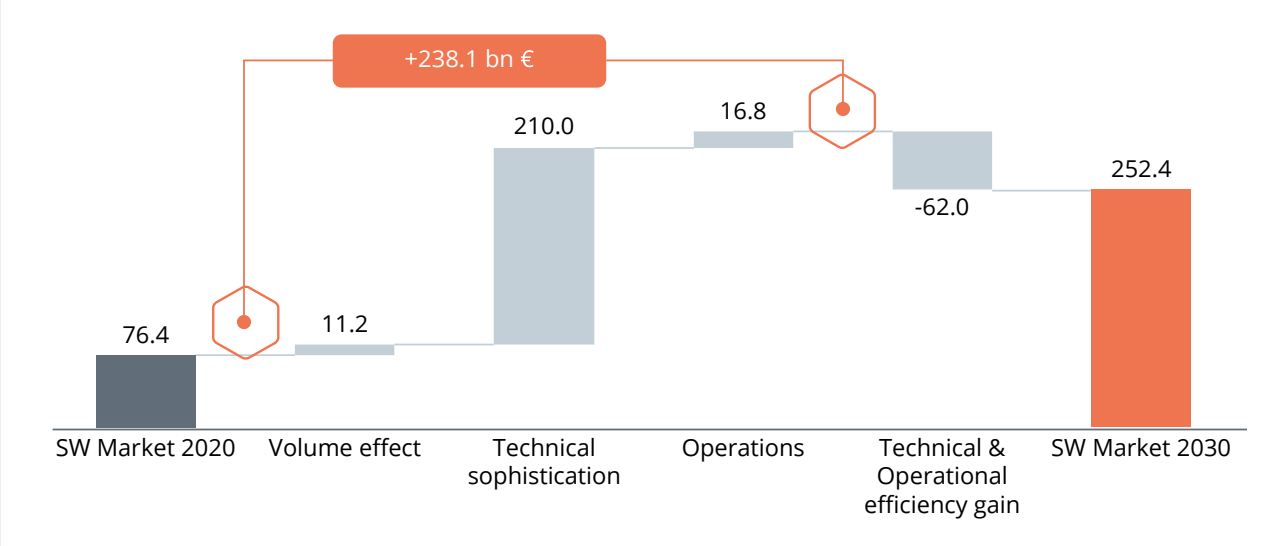
The highest compound annual growth rate (CAGR) is expected from HPC software alone, at 37%. This increase is mainly because technology nodes and semiconductor device fabrication are moving from 7 to 5 nanometer (nm) production, which will progressively be incorporated into the corresponding vehicle computer architecture.

We also believe that the growing operational and technical complexity of functions and their connectivity will add costs of €210bn by 2030. The volume effect of vehicle production seems relatively low in comparison, with approximately €11bn in additional expenditure, and additional costs for the backend operation of around €16bn.

Thus, without technical and organizational countermeasures, the automotive software market would reach a total global value of €314bn by the end of the decade, compared with €76.4bn today. However, consistent implementation of platform solutions and adaptation of working methods would allow for realistic efficiency gains of around 20%, or approximately €62bn, thereby reducing the market's total value to about €252bn.

FIGURE 5:

BREAKDOWN OF VEHICLE SOFTWARE MARKET DRIVERS



Source: Berylls

5

ORGANIZATIONAL IMPLICATIONS

Today, meeting these challenges and mastering this increasingly complex landscape is already straining traditional management models. Technical problems inevitably arise due to sequential, deterministic planning solutions in long decision-making cycles, and lead-in times which are tied to the vehicle development process. Furthermore, these issues are usually only recognized when production is about to start or at the vehicle approval stage. They are already being felt all along the automotive value chain by OEMs, their suppliers and the latter's own suppliers.

In development and critical start-up projects with suppliers and OEMs, we have identified a range of agile working models and delivery organizational levers to address these problems.

They include toolchain integration, systematic partner management, a realignment of financial management fundamentals, and modern leadership and culture tools.

5.1 Agile approaches and toolchain integration

The fact that task forces brought in to "rescue" software projects have now become the rule rather than the exception is a strong sign that the time has come for a fundamental rethink of traditional approaches.

Until now, manufacturers have specified software services and functions far in advance of market launch. There is an increasingly urgent need to shift to more agile procedures, where the integration of development partners and suppliers does not involve burdensome specifications. Instead, the specification focuses on individual roles such as product owners or program managers, using agile development frameworks such as SAFe, LeSS and Holacracy.

It is not only development, but also purchasing and procurement that need to change, with processes and governance rules adapting to new working and delivery models. The integration of toolchains between OEMs and suppliers offers significant optimization potential via automated check-in and check-out, code integration and testing, version control and permissions management, all in the same software development environment.

Furthermore, wrong decisions in automotive hardware are usually irreversible and associated with high sunk costs, meaning there are different economic considerations for hardware development than for software. In terms of future viability, synchronizing and ultimately reintegrating development processes for both software and hardware is the "holy grail" for manufacturers and suppliers alike.

5.2 Managing partners

Major tech players such as Microsoft, Amazon, Apple and Google share the same ambitions in the automotive market: to establish themselves as indispensable partners, particularly in the cloud domain, and gradually incorporate increasingly large automotive-specific software applications into their portfolios. In addition, there are countless smaller tech companies entering the market with specific expertise in cloud computing, connectivity, autonomous driving, compression processes, security and customer relationship management.

OEMs need to assess carefully which areas offer potential for strategic partnerships with tech companies and identify the most attractive partners. They must also get used to forming such partnerships on an equal footing. This represents a fundamental shift in thinking for manufacturers, which by extension will have implications in terms of contract drafting, including liability regulations.

In the race for the software-defined vehicle, strategic and systematic partner management will become an absolute core skill, culturally, commercially and legally.

5.3 Changing commercial logic

Commercial governance in the automotive industry is at odds with the iterative control logic of the software industry, constituting one of the biggest obstacles to more agile processes and ways of working. OEMs and suppliers must therefore initiate a comprehensive transformation:

» From lengthy planning rounds and design freezes long before market launch to integrated software development

» From amortization of product-related investments by the "first user" to strategic investments such as "blind" hardware installation that can generate additional revenue over time with new services

» From vehicle project-related budgets and profitability considerations to business cases with lifetime revenues that facilitate agile maintenance of digital content.

Successful use cases have shown the value of introducing a new commercial logic. For example, Tesla's blind series hardware installation of its autopilot, at a price of around $1,800, without charging the customer, would probably never have happened at a traditional OEM. Today, Tesla can update the software OTA across its entire fleet, analyze the data, and train its autonomous driving system (ADS) using a "Big Loop" process.

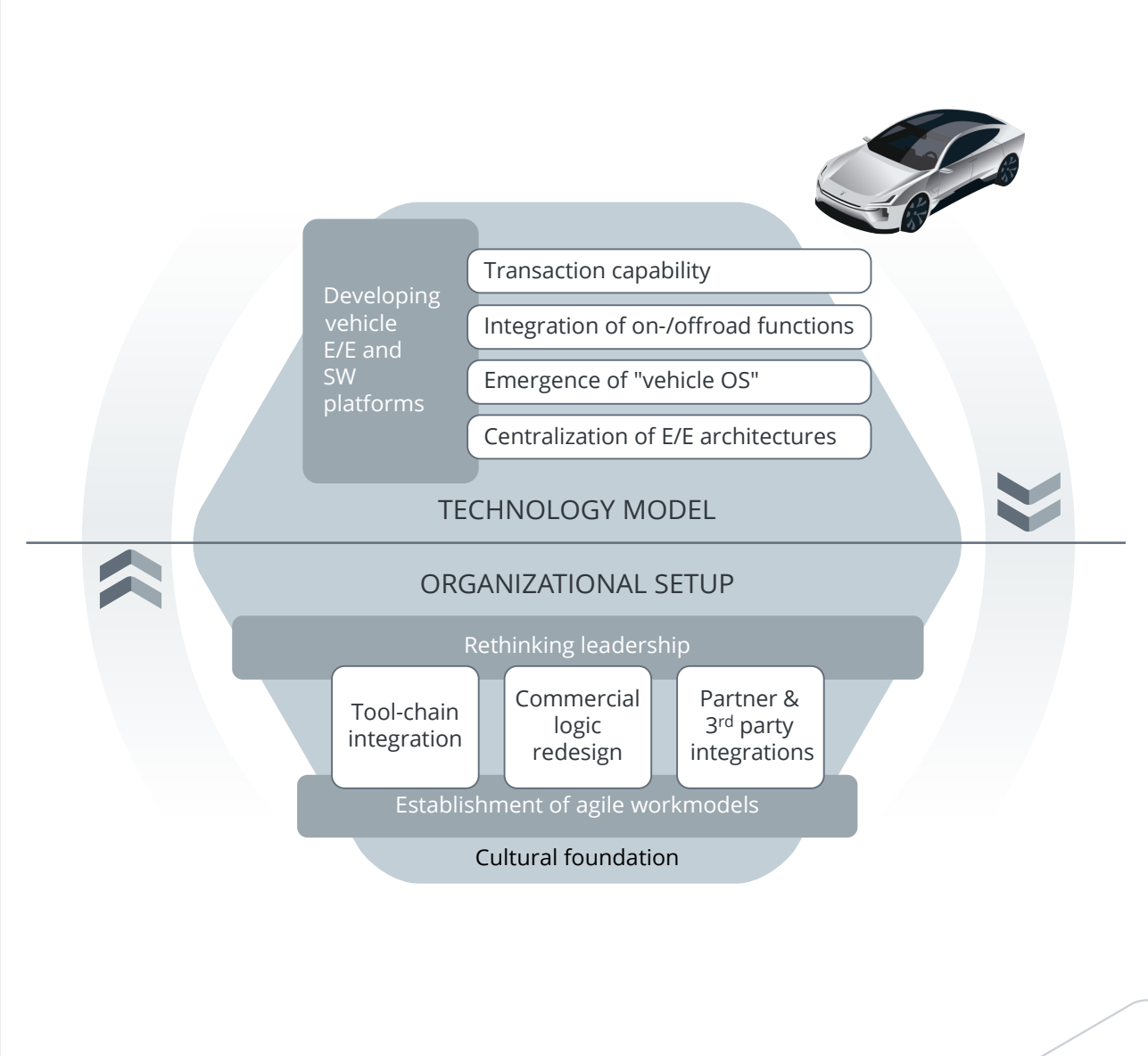
5.4 Changing leadership and culture

Leadership in agile environments demands a different philosophy to the automotive industry's current model, which until now has been strongly defined by centralization, hierarchy and committees. The distinguishing features of agile software environments, such as decentralized decision-making, consistent delegation, continuous deployment (CD) through automated processes and trial and error, are fundamentally at odds with the prevailing automotive philosophy.

An agile leadership culture encourages faster decisions and correspondingly faster learning cycles. It also encourages employees to identify more strongly with the product and the company, due to the trust which agile working methods places in them. This in turn translates into higher quality work and increased worker commitment.

FIGURE 6:

TRANSFORMATION TOWARDS THE SW DEFINED VEHICLE



Source: Berylls

SUMMARY AND OUTLOOK

The extent of the upheaval currently underway in the automotive software sector is immense. Established manufacturers face ever-growing cost and efficiency pressures resulting from customer, market and regulatory requirements, which they are trying to offset with technological and organizational overhauls.

At the same time, leading global tech companies are seeking to position themselves as strategic partners in the automotive software market. Vehicles are increasingly becoming devices-on-wheels, with the decoupling and synchronization of hardware and software representing key skills in the development process. In parallel, the manufacturers' business model is shifting from pure production to operating digital business models, where the vehicle constitutes a transaction channel and platform.

The software-defined vehicle lies at the heart of this transformation, which will overturn and replace traditional measures of success. As in the mobile phone sector, this change will be managed well by some established manufacturers, bring down others, and enable new, innovative smaller companies to enter the market.

In subsequent reports, Berylls will explore the implications for value-chain structures, forms of collaboration, and the business models of manufacturers, suppliers and technology companies.

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The **Berylls Group's** services are fully dedicated to the automotive industry. From offices in Germany, China, the UK, South Korea, North America and Switzerland Berylls experts cover all current and future topics within the automotive ecosystem. Their expertise is combined in four specialized units – the Berylls Quartet.

Berylls Strategy Advisors – The expertise of our top management consultants extends across the complete value chain of automobility – from long-term strategic planning to operational performance improvements. Based on our automobility thought leadership Berylls Strategy Advisors stand out with their broad experience, their profound industry knowledge, their innovative problem-solving competence and, last but not least, their entrepreneurial thinking.

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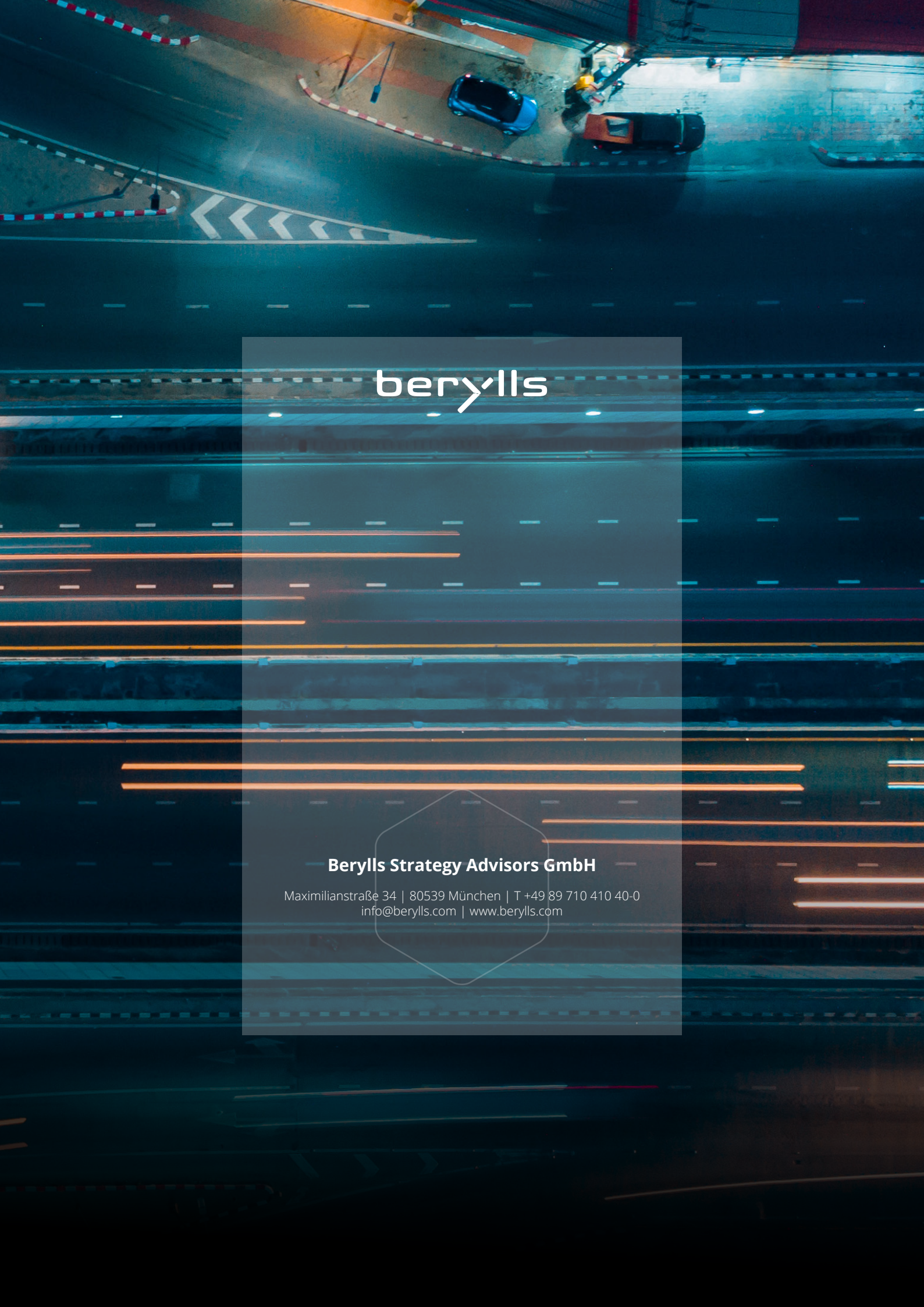

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