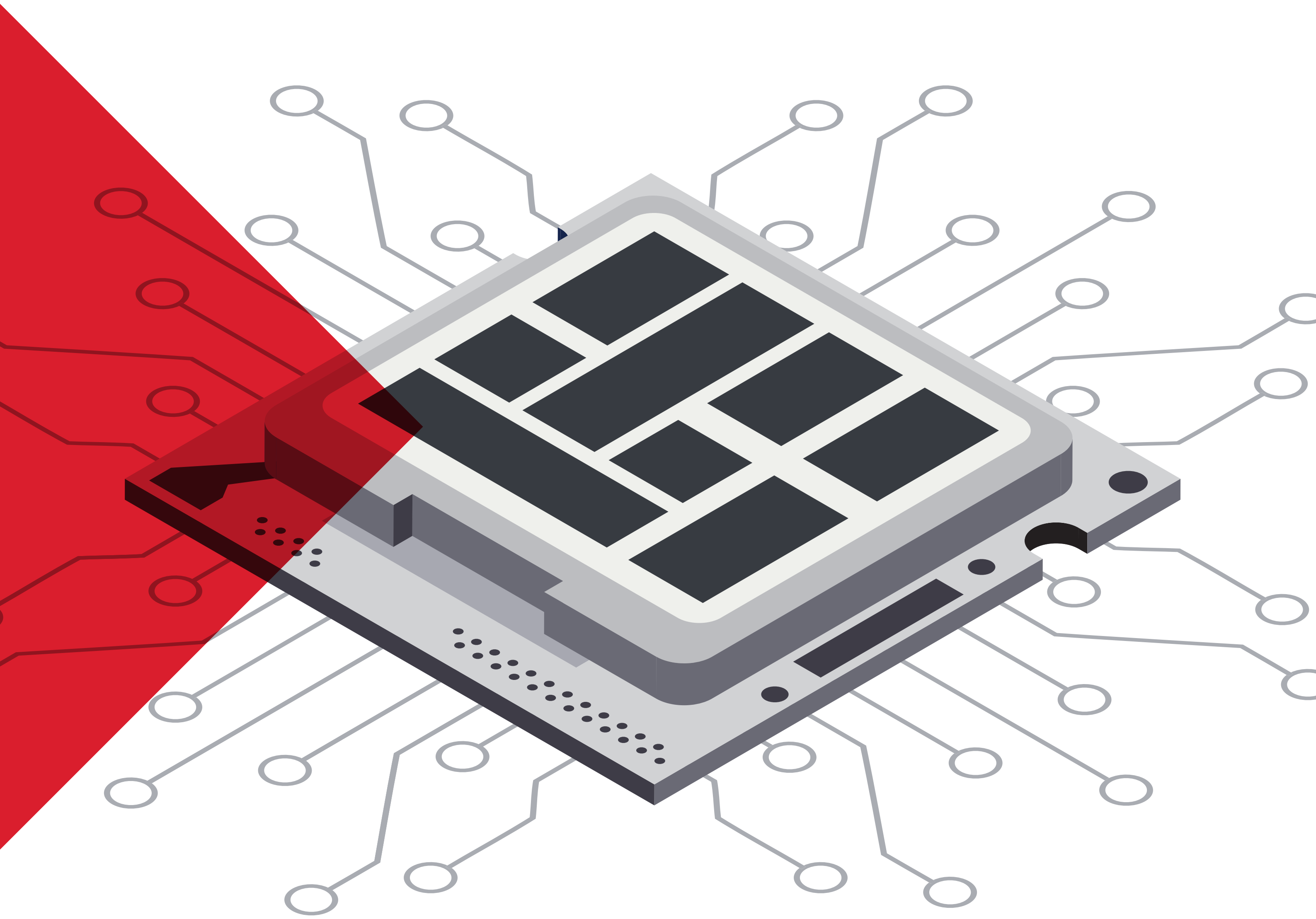
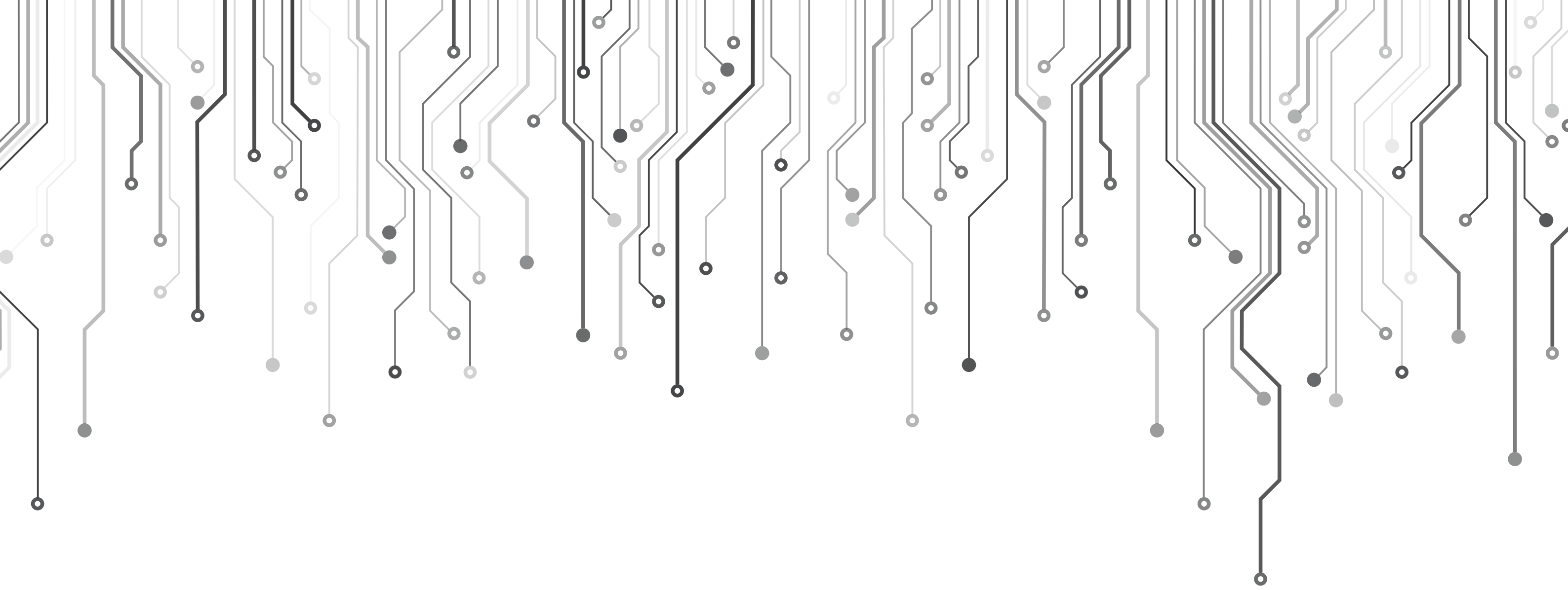
Technology Strategy



Strategic Semiconductor Management

From shortage to competitive advantage

Porsche Consulting
Strategic Vision. Smart Implementation.



Management summary

This strategy paper stresses the paradigm shift that industries such as automotive, industrial goods, or consumer electronics need to consider based on the semiconductor supply chain disruptions they recently faced. In the past, OEMs and suppliers had not focused sufficiently on semiconductors. This perception changed with the beginning of the COVID-19 crisis and the resulting lockdowns. All industries were affected, however the automotive sector was hit particularly hard. During the 2021 lockdowns, automotive OEMs canceled supply orders based on decreasing demand for mobility. In parallel, the consumer electronic sector experienced a particularly high demand. When the situation recovered, semiconductor manufacturers were already fully booked. As a result, rising demand of the automotive industry could not be served.

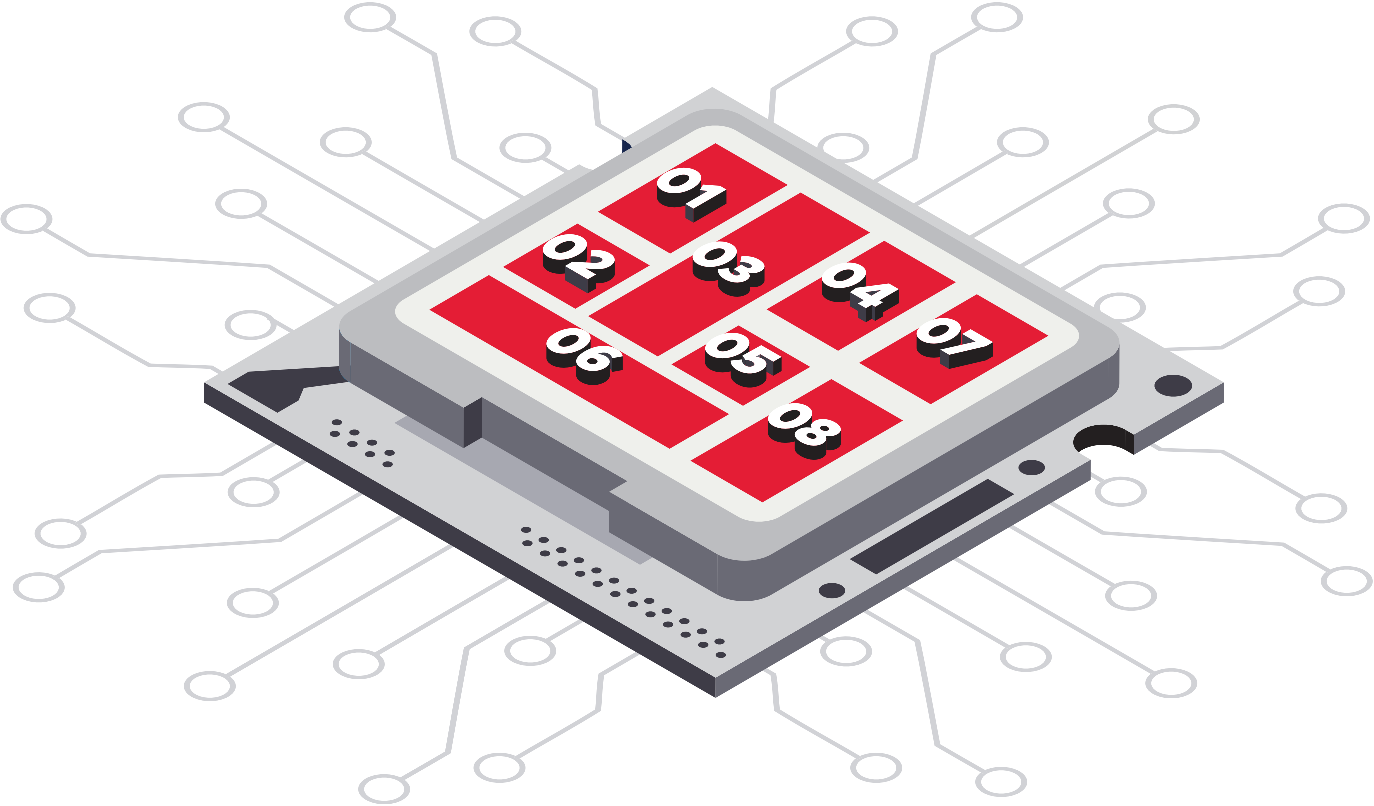
Looking ahead, it can be forecast that particularly for semiconductors of mature technology nodes, the shortage will last beyond 2025. This situation highlights the necessity for leading companies of all industries to reconsider their semiconductor activities and to establish a strategic semiconductor management. For this purpose, Porsche Consulting conceptualized a framework consisting of eight fields of action, as described in the following.

Transparency and risk management are essential for strategic semiconductor management. Therefore, a semiconductor database must be developed and implemented, including all applied semiconductors and long-term demand as well as technical specifications and supply chain information. Based on that information, a data-driven risk management assessment can be continuously carried out, also deriving effective mitigation measures. To forecast potentially arising future disruptions, global demand and capacity analysis are necessary. With the transparency about technology nodes used in the company, a comparison of the market development with the company demand can be conducted.

The transparency obtained can then be further capitalized to secure long-term supply, increase profitability, and gain a competitive advantage for the future. To achieve these three objectives, complexity management is the approach to reduce variants and bundle volumes, as a fundamental enabler for new business models and technical advantages. In cooperation with the technology strategy, considering future product road maps and innovations, a strategic semiconductor portfolio can be derived. Another key to succeed in the semiconductor ecosystem is direct collaboration with suppliers, including continuous communication of demand forecasts, securing supply and the exchange of technology and product road maps. Collaboration management, jointly with a semiconductor portfolio and bundled volumes also enables new sourcing strategies, such as direct purchasing of chips by the OEM. All these measures ultimately lead to guidelines for purchasing and product development, resulting in sustainable and strategic semiconductor management along the entire product development process as well as the product life cycle - on the road, in the air, on water or in the customer's pocket.

Purpose of
SEMICONDUCTOR MANAGEMENT

- Secure your semiconductor supply
- Become a reliable stakeholder along the entire semiconductor value chain
- Shape your products semiconductor road maps in coordination with suppliers
- Anchor semiconductor management in the product development process
- Increase your profit and generate competitive advantages



01 Semiconductor database and risk management

02 Complexity management

03 Technology strategy

04 Sourcing strategy

05 Collaboration management

06 Demand and capacity analysis

07 Technical alternatives

08 Guidelines for development and sourcing departments

INSIGHTS

//01

Supply chain transparency and profound risk management become minimum standards

//02

Complexity management for volume bundling is essential for the semiconductor industry

//03

Building a collaborative ecosystem around the organization is decisive to ensure security of supply

//04

Direct sourcing is a key enabler for resilience and profit creation

//05

Companies must step forward from securing supply to generating competitive advantages by semiconductor design

Introduction

Challenges and ways to succeed in the semiconductor ecosystem

Semiconductor devices, also called integrated circuits (IC) or microchips, in the following just "semiconductors," are the foundation for any electronic device. A wide range of complex tasks can be performed in a minimum available space by combining several semiconductor devices on a PCB, e.g., detection of the heart rate and blood oxygen by a smart watch. Over the past 70 years semiconductors have made electronic devices smaller, faster, and more efficient.

Rising semiconductor complexity

The importance of semiconductors for the power of innovations can be observed in the automotive sector. The first application of an electric control unit (ECU) in a Porsche 911 G Series in 1978 had approximately eight semiconductors[1,2] per vehicle. The task of the ECU was to control injection times in the combustion engine. Current models have 50–90 electric control units, containing respectively up to 5,000–7,000 semiconductors[1], as shown in Figure 1. The functionalities of these ECUs vary from, for example, adjustment of the seat position to highly automated driving.

Semiconductor | Semiconductors are solids that, in terms of their electrical conductivity, are located between conductors and non-conductors. Their electrical conductivity is strongly temperature-dependent. In the near absolute zero, semiconductors are insulators. Semiconductor elements have one great advantage: by introducing foreign atoms, it is possible to change their electrical properties in one direction or the other. By doing this—for example, by applying an electrical voltage— they can conduct electricity or block it completely. Examples of this material are silicon and germanium.

Transistor | The best known example of a semiconductor is probably the electronic switch (transistor). It serves as a basic part for complex components such as microcontrollers and processors, which can consist of many thousands of transistors. They are common in cell phones or laptops.

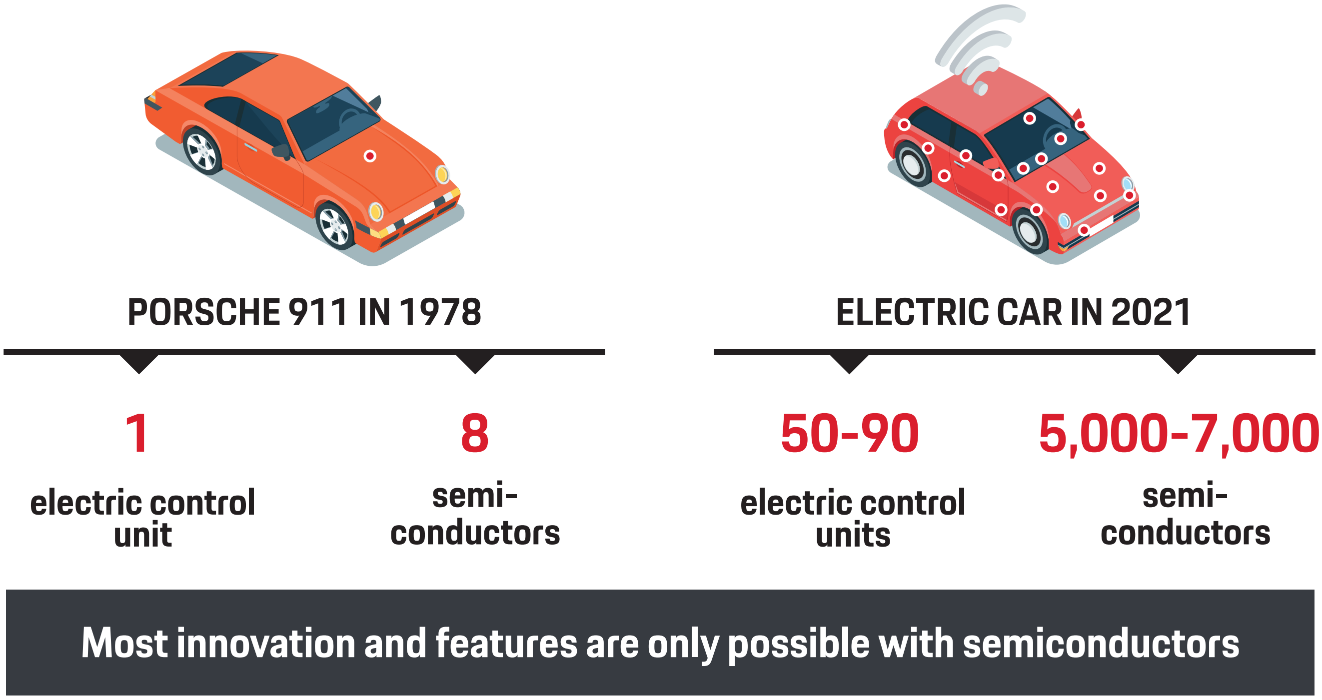


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Fig. 1. Semiconductors are innovation-driver in the automotive industry.

The number of control units in vehicles increased due to decentralized electronic architecture combined with a high number of sensors and actuators. Additionally, the automotive industry is confronted with highly individual car configurations, which increase the variability of the applied electric control units and semiconductors.

Comparing a smartphone with a passenger car illustrates the difference in complexity. Smartphones are highly integrated computers. It takes roughly 60 semiconductors per phone, compared to 5,000–7,000 semiconductors per vehicle[3].

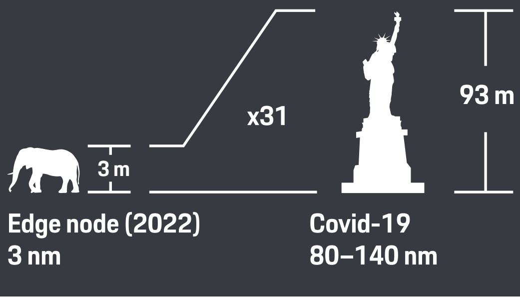
Moreover, the applied semiconductors differ significantly in each sector, e.g., smartphones have a high integration level, high energy efficiency, and a low voltage level. Therefore, semiconductors with technology nodes below 45 nanometer are applied. In case of the automotive and industry sector, which handle high voltages up to 900 V, power electronics from mature technology nodes of >45 nm often up to ≥250 nm are applied. In comparison, a Covid-19 virion has a diameter of 80–140 nm[4].

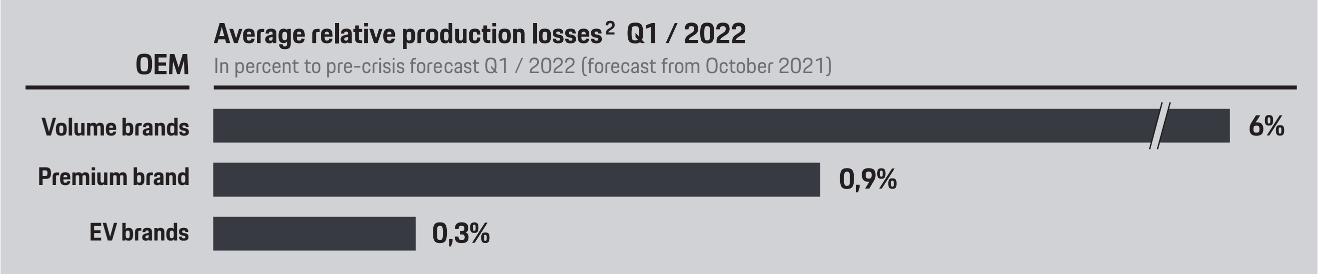
Current market situation and forecast

The Covid-19 lockdowns and the resulting demand volatility among others caused a semiconductor supply shortage.

Conducting further analysis of the first quarter of 2022 for automotive production losses arising from semiconductor shortage shows a heterogeneous distribution, see Figure 2. High-volume brands such as Toyota or Stellantis are significantly stronger affected by the shortage than premium brands (e.g., BMW) and EV brands (e.g., Tesla)[5].

Technology node | The technology node (also known as a process node, process technology, or simply node) refers to a semiconductor manufacturing process and its design rules. Different nodes imply various circuit generations and architectures. In general, the smaller the technology node, the smaller the feature size on the silicon die, resulting in smaller transistors that are faster and more power-efficient.





Nodes	Products in automotive	2022	2025	Trend	Invest volume 2025[1]
> 90 nm	CAN interface, voltage regulators, power switches, LED drivers	🔴	🔴	↘	No further invest
≤ 45–90 nm	Communication, transponder, microcontroller	🔴	🔴	↗	High
≤ 28–45 nm	Microprocessor, microcontroller, audio DSP	🔴	🟡	↗	Medium
≤ 16–28 nm	Microprocessor, microcontroller	🟢	🟢	↗	Low
≤ 10–16 nm	Microprocessor, microcontroller	🟢	🟢	↗	Medium
< 10 nm	Microprocessor for ADAS	🟢	🟢	→	High

1) Based on VLSI Research forecast for CAPEX allocation in 2025 – excluding U.S. Chips Act 2) Database from IHS Markit, Bloomberg and Porsche Consulting analysis
Source: Porsche Consulting, omdia Q1/2022, World market overview enriched by specific semiconductor market expert interviews

🟢 Coverage 🟡 Demand ~ Supply 🔴 Shortage | Size of circles scaled with extent of coverage/shortage

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Fig. 2. Data-based forecast of automotive specific capacities and demands show shortage until 2025.

Due to a higher number of product models and a low electronic carryover rate, the specific exposure for shortage rises. Moreover, higher cost pressure in the volume segment promotes the application of mature technology nodes.

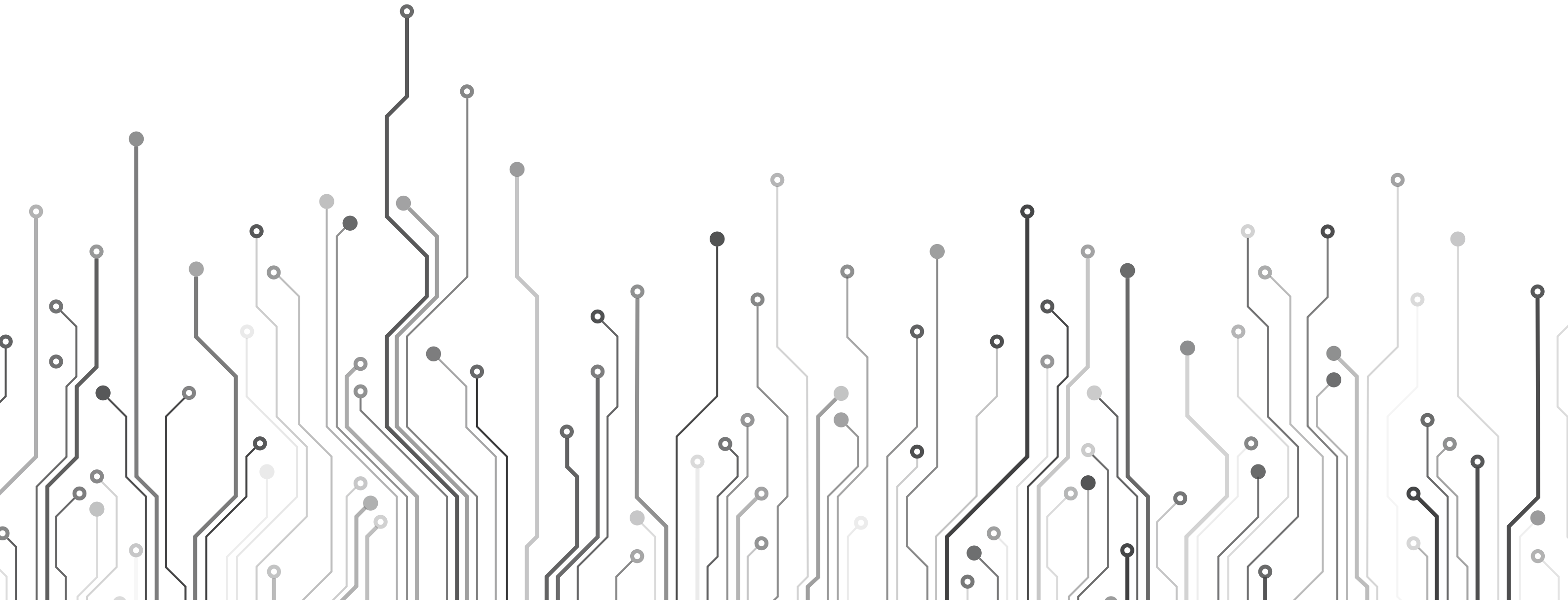
EV manufacturers use a centralized electronic architecture with a lower total semiconductor variability. They further benefit from a manageable number of models and with it a high carryover rate of ECUs.

The apparent market situation can be confirmed and forecast using a data-based methodology for global production capabilities and global semiconductor demand[6]. In the case of the automotive sector, the current state of supply shortage depending on technology node and application is shown in Figure 2.

It demonstrates a structural shortage in technology nodes >28 nm until 2025. These technology nodes are mostly applied to voltage regulators, power switches, communication, LED drivers, and mature microprocessors. Investments for production capacity ramp-up are only committed for nodes <90 nm[7]. Consequently, nodes >90 nm will potentially suffer supply shortages or demand increases, based on the rising number of electric vehicles. This is confirmed by the global semiconductor market growth. While the overall market is growing at an 8.2 percent compound annual growth rate (CAGR), the automotive sector within the semiconductor market is experiencing above average growth, at 16.3 percent CAGR from 2020 until 2025[8].

The planned capacity increase for the nodes between 28 to 90 nm will be compensated by increasing demands of the automotive sector. A relaxation in supply of nodes <28 nm can be expected. At this point it is important to mention that a shift from mature nodes to leading edge nodes by die shrinking is mostly connected to a new chip development. New development and industrialization can take three to five years and may not be a sufficient solution. Especially for device types handling high voltages, die shrinking is usually not possible due to physical restrictions.

Funding programs for ramping up semiconductor capacity, such as the U.S. CHIPS Act, will help the industry get back on its feet in the long term. However, a new plant typically takes three years to construct and there are currently also bottlenecks among machine manufacturers with lead times up to 24 months[9]. Furthermore, these funding programs will prioritize local shortages only. Accordingly, the problems will not be solved in the mid-term and the whole industry must secure their supply not just in an operative manner but develop a deep understanding of their own electronic products and take control to guide their companies through the coming years.



Strategic ways out of the crisis

Fundamental fields of action as an excerpt of the entire framework can be highlighted and are described in detail in this paper.

//01 Supply chain transparency and profound risk management become minimum standards
It is mandatory to create transparency about the semiconductors applied in products. Order codes, technical specifications, long-term demand as well as supply chain information of the respective semiconductor must be stored in a central database. Transparency of data is a requirement for all strategic levers.

//02 Complexity management for volume bundling is the key to the semiconductor industry
With a better understanding of the built-in semiconductors and technical specifications, complexity management reduces variants and bundles volumes into a strategic semiconductor portfolio. Large volume orders are the key to controlling the own supply chain, thus enabling new business models and competitive advantages.

//03 Build a collaborative ecosystem around the organization to outperform peers
Based on the semiconductor portfolio, different ways of collaboration are sought depending on the volume, the strategic importance of the components as well as the criticality of the shortage situation. While for smaller volumes procurement via brokers or distributors is a sensible approach, larger volumes of strategically important components must be secured directly from the semiconductor manufacturer.

//04 Direct sourcing as a key enabler for resilience and profit creation
Leading companies source their strategic semiconductor portfolio directly from the semiconductor manufacturer to achieve long-term supply security and realize cost advantages.

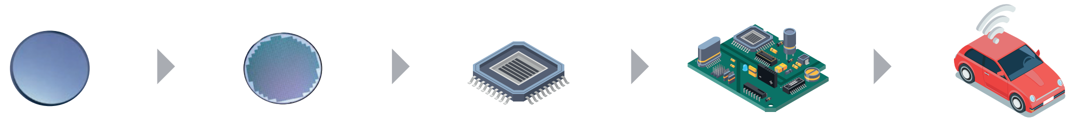
//05 Step forward from securing supply to generating competitive advantages
Subsequent co-development of new semiconductor products is represented as a future means of generating a competitive advantage in the semiconductor ecosystem.

A detailed description of these fundamental fields of action, including illustrative examples from leading consumer electronics and automotive companies, will be presented within the following pages. The results of all approaches provided lead to the organizational anchoring of strategic semiconductor management in the product development process, across various industries.

01

Supply chain transparency and risk management

The past few years have mercilessly exposed many industries' current deficiencies with regard to semiconductors and their supply chain transparency as well as risk management approaches. These deficiencies have been particularly felt by some industries, such as the automotive. Various factors in particular have magnified the impact on the automotive industry.



	01 Wafer fab	02 Front-end fab	03 Back-end fab	04 Component manufacturer	05 Vehicle OEM
Product	Raw wafer	Fabricated wafer	Semiconductor	ECU	Vehicle
Location	Japan	Italy	Malaysia	Romania	Germany
Today	❌	❌	❌	✅	✅
Future	☑	✅	✅	✅	✅

❌ **No supply chain transparency** ☑ **Limited supply chain transparency** ✅ **Full supply chain transparency**

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Fig. 3. Simplified production process and supply chain of an automotive semiconductor.

The majority of OEMs prefer to buy large functional scopes (like complete control units) directly from their component manufacturers. As a result, most component manufacturers control semiconductor selection and installation as well as semiconductor transparency within the bill of material (BOM), but do not share information with the OEM. Moreover, the manufacture of a chip is extremely time-consuming, involving up to 1,000 process steps and various companies and facilities from the fabrication of the raw wafer to the testing of the semiconductor. It is therefore more challenging to maintain supply chain visibility across all organizations that are directly or indirectly involved in industrial operations. Lastly, the fragility of the semiconductor supply chain has been underlined as a result of rising supply chain interruptions (e.g., natural disasters, political conflicts, etc.) and have exposed companies' missing approaches to proactive risk management.

Figure 3 shows an example of a condensed semiconductor manufacturing process for a power management integrated circuit (PMIC) from the viewpoint of an automotive OEM. A monocrystalline silicon blank is initially cast using just pure silicon. (01) At the wafer fabrication plant in Japan, the wafers are cut into tiny slices (raw wafers) and then polished. (02) The raw wafers are then sent to the Italian front-end fab, where integrated circuits are applied on the polished raw wafers by repeating a series of procedures (oxidation, coating, lithography, etching, etc.). (03) The finished wafer is delivered to the Malaysian back-end fab for dicing, assembly, packaging, and testing. (04) At the Romanian component manufacturer, the semiconductor is integrated into the ECU. (05) The ECU is then delivered to the OEM's manufacturing facility to be integrated into the car. Currently, OEM transparency is limited to the preliminary stage of its value chain.

OEMs need to know their built-in semiconductors and supply chain

Because of today's limited visibility across the semiconductor supply chain, OEMs are unable to identify and mitigate supply chain disruptions in a timely manner. This is critical, however, because supply chain disruptions have already grown 88 percent in 2021 compared to 2020 and have resulted in significant economic losses and long-term productivity deficits for various industries[10]. In order to increase transparency as well as identify and mitigate risks across the semiconductor supply chain, OEMs and component manufacturers are proposing to set up four necessary action streams.

//01 Semiconductor transparency

The first stream of action is to identify the built-in semiconductors in the purchased products. OEMs can generate transparency by disassembling ECUs. However, this cannot guarantee complete transparency of all semiconductors, because information such as labels or order codes may not be printed on the chip package. The goal must thus be to generate component transparency in direct collaboration with the component and semiconductor manufacturer. In addition to the transparency of which semiconductors are utilized, further critical parameters such as total volume per semiconductor and the semiconductor's technical specifications are also required. The understanding and transparency of the total volume per semiconductor are the essential foundation for complexity management. The semiconductor's technical specifications allow for the comparison of semiconductors in order to analyze and assess technical alternatives for use in the event of unanticipated risks.

//02 Supply chain transparency

Collecting the necessary information on suppliers and their subsuppliers involved in the process is required for the second stream to increase transparency. OEMs and suppliers must comprehend the semiconductor industry's production processes, including what is produced where and by whom. Only in this way can earlystage supply chain disruptions be identified and prevented by respective measures. Indirect actors in the supply chain, such as those that provide specialized equipment or materials to support production operations, should also be considered, as disruptions in the supply chain might influence them.

//03 Semiconductor database

Because of the enormous amount of semiconductor data (e.g., 5,000–7,000 semiconductors per vehicle), leading companies should use a centralized database for semiconductor data storage and administration. To ensure the availability and quality, OEMs must introduce a governance process for sustainable data collection. In summary, providing data across multiple levels of the supply chain increases transparency and should be therefore prioritized in the cooperation between all stakeholders.

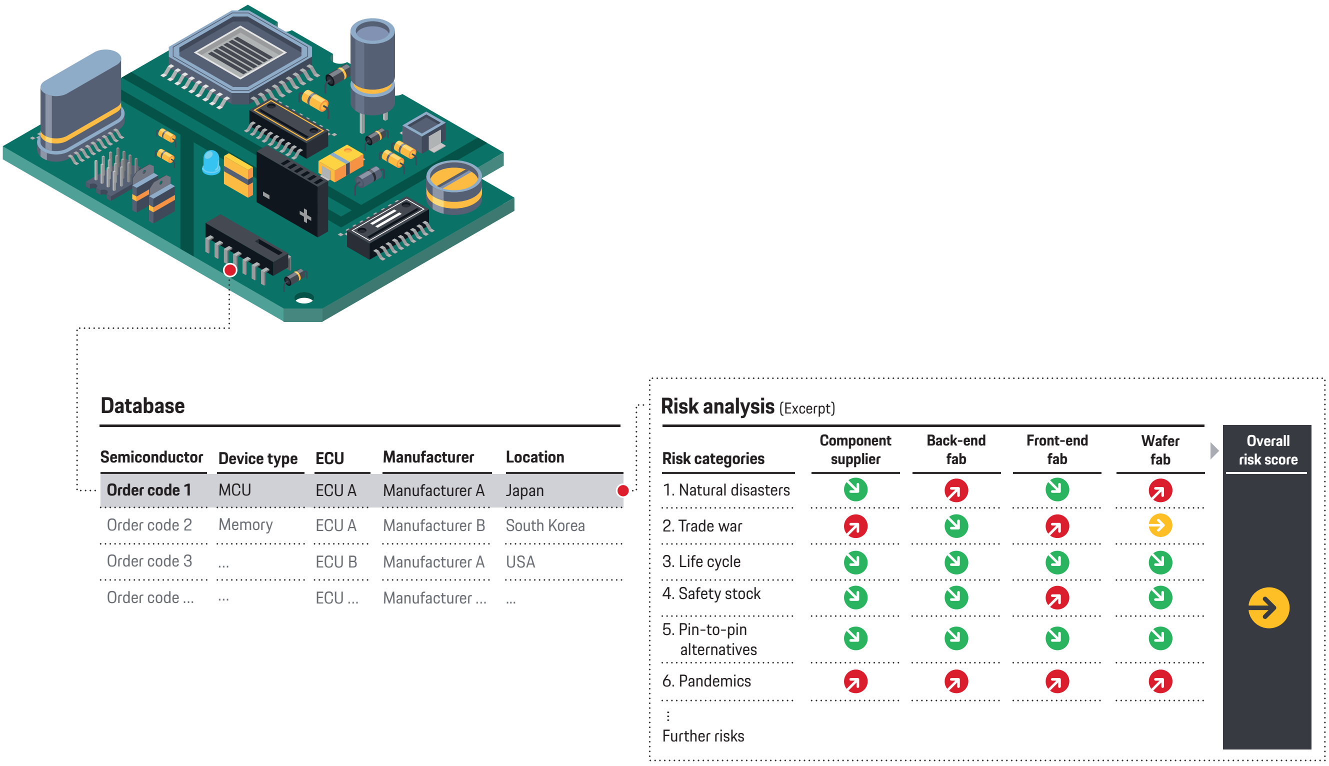
In conclusion, the first three streams allow for the development of increased data openness on semiconductor devices. However, due to the rising volatility of the semiconductor supply chain in recent years, OEMs and suppliers must also proactively identify and manage the risks and adverse effects.

//04 Data-driven risk management

The fourth and final action stream is the setup of a comprehensive risk management tool, as seen schematically in Figure 4. The risk management should be composed of different evaluation dimensions. The first dimension must differentiate several risk aspects, such as natural disasters, trade wars, product life cycle, safety stocks, pin-to-pin alternatives or pandemic risks. Further risk dimensions have to be included as well. All dimensions must then be linked to the data in the database. For the likelihood that not all necessary data is stored in the database, it is advised to include further external data sources such as safety stocks at suppliers, or information on political and geographical risks. The datasets should be used to construct a data model. The model's purpose is to calculate a risk score that will serve as the foundation for the following prioritization of mitigation measures. After building, evaluating, and testing the model, OEMs have taken the first step towards a data-driven approach to semiconductor risk management. The ability to effectively monitor, assess, and mitigate supply chain risks increases and needs to be anchored into the product development process. Therefore, early-stage effects of risks on the organization can be reduced while also decreasing the possibility that they will occur. Furthermore, information gaps across the entire supply chain can be overcome between OEMs, component manufacturers, and their suppliers.

Organizations must raise their level of understanding regarding semiconductor data transparency and risk management, as it serves the minimum standard and cornerstone for developing a long-term semiconductor strategy.

Data transparency is the enabler for data-driven risk management



Database

Semiconductor	Device type	ECU	Manufacturer	Location
Order code 1	MCU	ECU A	Manufacturer A	Japan
Order code 2	Memory	ECU A	Manufacturer B	South Korea
Order code 3	...	ECU B	Manufacturer A	USA
Order code ...	...	ECU ...	Manufacturer ...	...

Risk analysis (Excerpt)

Risk categories	Component supplier	Back-end fab	Front-end fab	Wafer fab	Overall risk score
1. Natural disasters	↘	↗	↘	↗	→
2. Trade war	↗	↘	↗	→	
3. Life cycle	↘	↘	↘	↘	
4. Safety stock	↘	↘	↗	↘	
5. Pin-to-pin alternatives	↘	↘	↘	↘	
6. Pandemics	↗	↗	↗	↗	
⋮ Further risks					

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Fig. 4. Transparency of all build-in semiconductors and data aggrigation of technical and suply chain information are the key for data-driven risk management.

02

Managing complexity responsibly

There are various ways to define the complexity of semiconductors. The density and variety of integrated circuits in semiconductors are two factors to describe semiconductor complexity.

In contrast, complexity can be described as the diversity of all different semiconductors and their variants utilized in a certain product or organization. In the following, only product diversity is examined in the context of complexity management.

Because of the high degree of integration and function density, as well as the projected continual improvement in performance and energy efficiency in future products such as vehicles, the number of different semiconductors has gradually expanded over the last decade and will continue to do so in the future. For the automotive industry, this involves expanding the focus from the complexity management of vehicle components such as seats, wheels, or lights onto the underlying hardware and software with a focus on semiconductors.

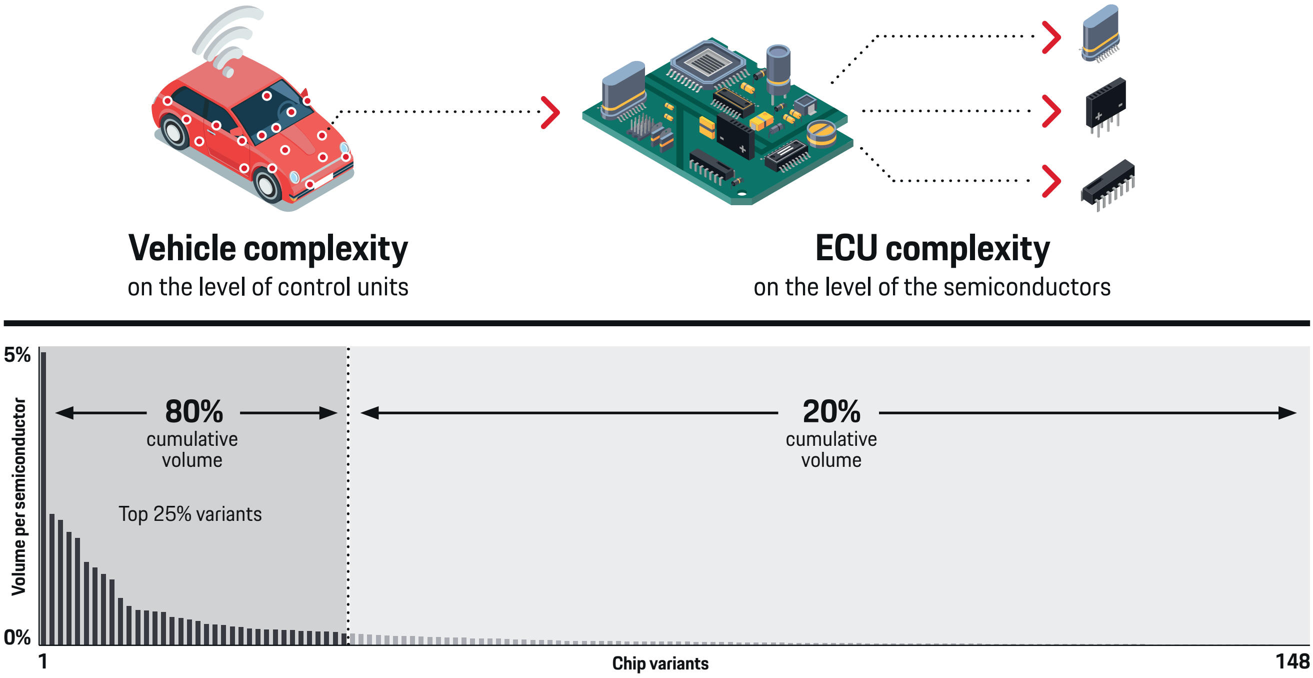
To be able to establish complexity management at the semiconductor level, leading companies must examine their products from new, partially unknown perspectives. These are briefly detailed in Figure 5 using a vehicle as an example from the viewpoint of an automotive OEM.

// Vehicle perspective

Today, automotive OEMs look at their vehicle's product portfolio, consisting of different model series, including their vehicles and their derivatives. Following that, each vehicle employs an electrical/electronic architecture (E/E architecture), which essentially connects all of the vehicle's important electrical control units, of Figure 5. The goal is to make sure that ECUs can be used across several vehicles.

// ECU perspective

One level down, the component manufacturers keep track of their ECUs as well as the quantity and variety of semiconductors and are consequently in charge of today's complexity management. The vehicles' ECUs (50–90 per vehicle) are distributed across several component manufacturers. OEM' semiconductors are therefore not stored in a centralized location. Each of these ECUs contains different active and passive electronic components, e.g., microcontrollers, memories and more, which result in a total amount of semiconductors for every ECU.



Top 25% of microcontroller variants make up to 80% of cumulative volume

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Fig. 5. The number of semiconductor variants in an average mid-sized automotive OEM without complexity management can be tremendous.

OEMs need a structured approach for the complexity management on semiconductor level

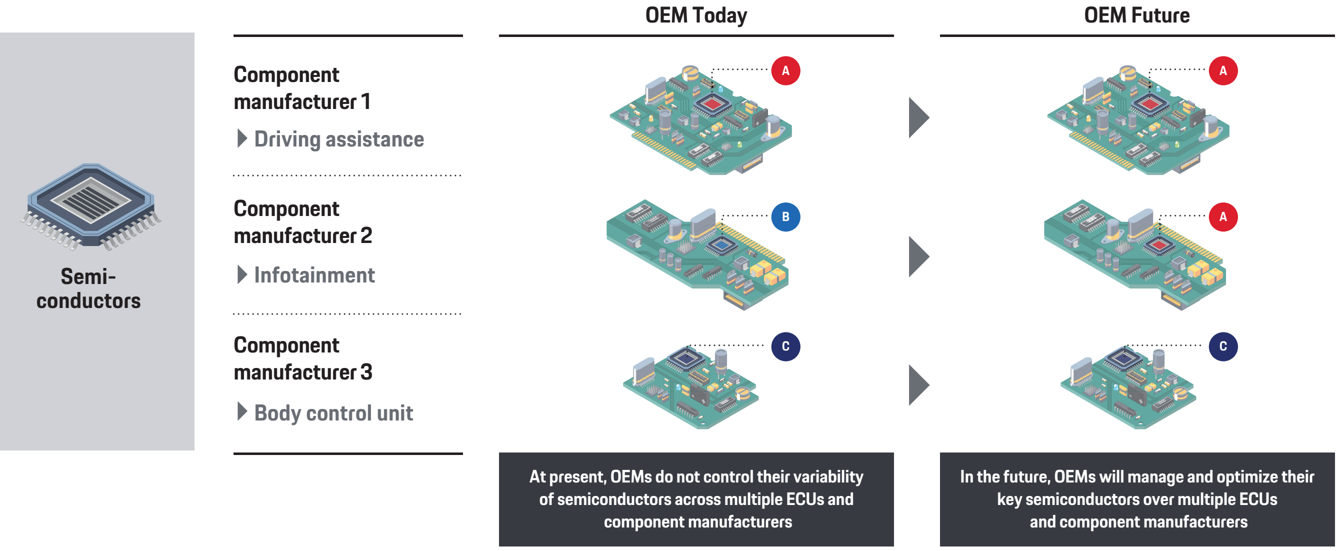
Following the ECU perspective, component manufacturers are also responsible for the semiconductors in all of their ECUs.

To estimate the semiconductors (here: microcontrollers) utilized by a mid-sized automotive OEM (~120 models), multiple data analyses and teardowns[11] were performed. The total amount results in 148 microcontrollers across the OEMs' vehicle portfolio with a total volume of ~151 million units are used. 25 percent of microcontroller variants account for 80 percent of total microcontroller volume across all vehicles. As a result, 75 percent of microcontroller variants are used for 20 percent of total volume. According to the findings, OEMs should inspect the variance (75 percent) for less volumes (20 percent), since otherwise substantial complexity costs can occur in the company over time (e.g., due to necessary R & D, production effort, and procurement effort) per semiconductor variant.

// OEM conclusions

Transparency all the way down to the semiconductor level provides opportunities for variant reduction of semiconductors as well as volume bundling, particularly for strategically important semiconductors. OEMs should also keep in mind that volume bundling can also be accomplished with a high BOM coverage per semiconductor manufacturer. Therefore, price reductions per semiconductor can be achieved in direct discussions with semiconductor manufacturers due to higher direct volume orders. Without high volume, OEMs have no opportunity to work directly with semiconductor manufacturers. As illustrated in Figure 6, today's semiconductor product range in the automotive sector is marked by substantial diversity and variability (chip A, B, and C across 3 ECUs), which increases effort to manage the number of semiconductors in total.

Additionally, it contributes to increasing the overall complexity of the vehicle. Consequently, automotive OEMs are not able to use bundling effects for critical semiconductors shared by multiple ECUs.



At present, OEMs do not control their variability of semiconductors across multiple ECUs and component manufacturers

In the future, OEMs will manage and optimize their key semiconductors over multiple ECUs and component manufacturers

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Fig. 6. Strategic placement of semiconductors in multiple control units enables high volumes.

Future approach to complexity management

In order to provide the foundation for effective complexity management in the future, OEMs must first conduct deep-dive analysis (e.g., ABC analysis, cost breakdowns) for important ECUs and the semiconductors across multiple component manufacturers. The amount and significance of various semiconductors and their producers can then be categorized and prioritized by OEMs.

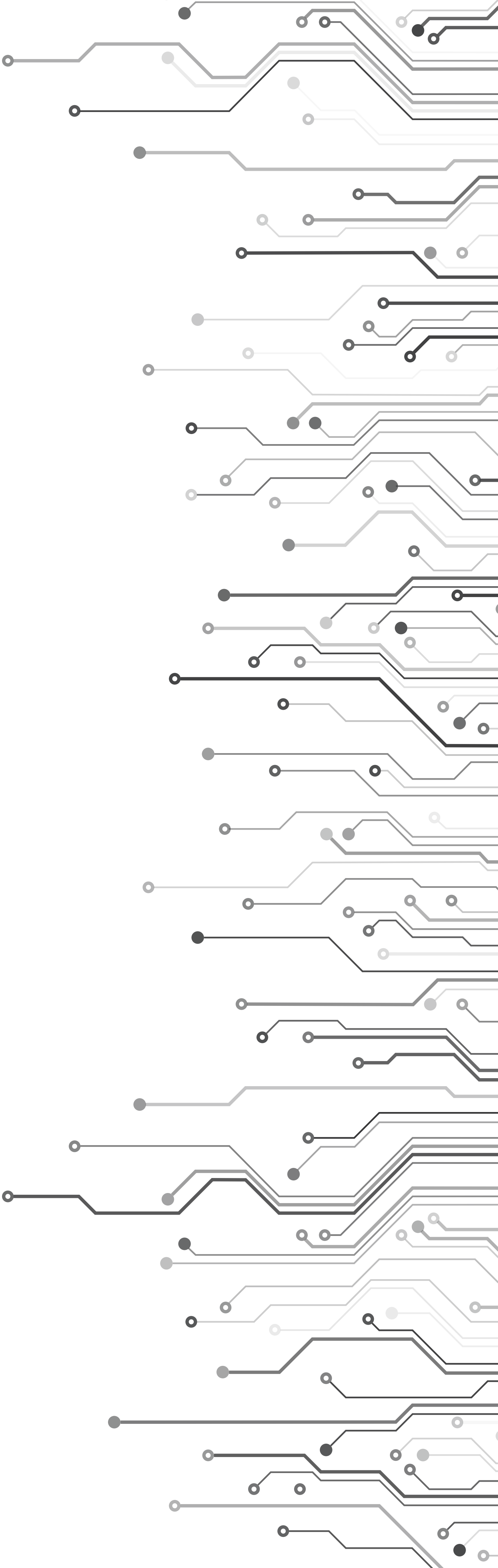
Lastly, OEMs must choose important chips and distribute them over several ECUs, creating the potential for significant volume effects (Chip A across 2 ECUs). OEMs and component manufacturers with high-volume sales are given priority in the semiconductor industry in particular. Without that, direct customer interactions and opportunities such as direct purchasing or co-development activities with semiconductor manufacturers are not possible. With the future approach, OEMs have created a new perspective on complexity management for the most strategically important semiconductors. It becomes clear that OEMs must rapidly adapt their views of complexity management for semiconductors and actively start managing it if they want to keep up their level of competitiveness and exert more control over the current supply chain.

> **Complexity management with the aim of a semiconductor portfolio and volume bundling is mandatory for more control with respect to technology and purchasing**

03

Semiconductor ecosystem

Leading companies establish a semiconductor ecosystem around their organizations to enable collaboration, direct access to stakeholders, and proper decisions.



Semiconductor ecosystem

In the last decade, the semiconductor landscape developed a lot and became more complex. The boundaries between business models are increasingly blurred. Wafer producers perform fabrication processes to manufacture raw wafers and provide them to semiconductor suppliers for further value creation. Further, chip designers, also referred to as fab-less companies, develop and hold intellectual property (IP) while outsourcing the fabrication of their hardware. A foundry performs many microfabrication processes, such as ion implantation, etching, thin-film deposition of various materials, and photolithographic patterning. Integrated circuits are built under the brand of the company that hires them. Integrated device manufacturers (IDM) combine most production steps and design, manufacture, and sell integrated circuits autonomously. Distributors act as an interface between the OEM, component supplier, and semiconductor manufacturer. They bundle volume and provide semiconductor related logistics services to the OEM. Chip brokers act as partners for short-term demand and offer chips from various manufacturers.

Basic interaction models

Basically, leading companies focus on three collaboration dimensions. By establishing cross-industrial innovation boards across the value chain of chips, knowledge exchange is fostered and transparency created. Further partnering and co-development enable highly individualized solutions to accomplish competitive advantage. Finally, contractual agreements or incentives enable new business opportunities and potential profit increase.

Chip portfolio and component coverage as key drivers

Based on the chip portfolio, organizations must elaborate individually which collaboration approach best fits their needs, see Figure 7. Leading companies put direct buy sourcing into practice and provide high-volume and long-term forecasts to semiconductor manufacturers. Companies with a long-term demand but small to medium volume should collaborate with a distributor to secure supply and realize first efficiencies. Enterprises with a short-term demand but high volume can collaborate with a distributor but include quotations of brokers in their approach. Organizations with a short-term demand and small to medium sized volume need to use the service offering of a semiconductor broker. For leading companies, it is crucial to bundle volume to achieve best positioning for sourcing. Furthermore, within direct sourcing approaches, it is beneficial from a technical and commercial perspective to discuss the coverage from a system's point of view with the semiconductor supplier. The focus is on jointly identifying technical improvements and enhancing the component coverage to incentivize and generate commercial potential.

OEMs generate commercial and supply benefits by enhancing ECU coverage of chip suppliers

In the following, two concrete collaboration activities of top organizations are presented. Insights from a direct sourcing approach are shared and a deep dive into partnering activities is provided by guiding through a co-development.

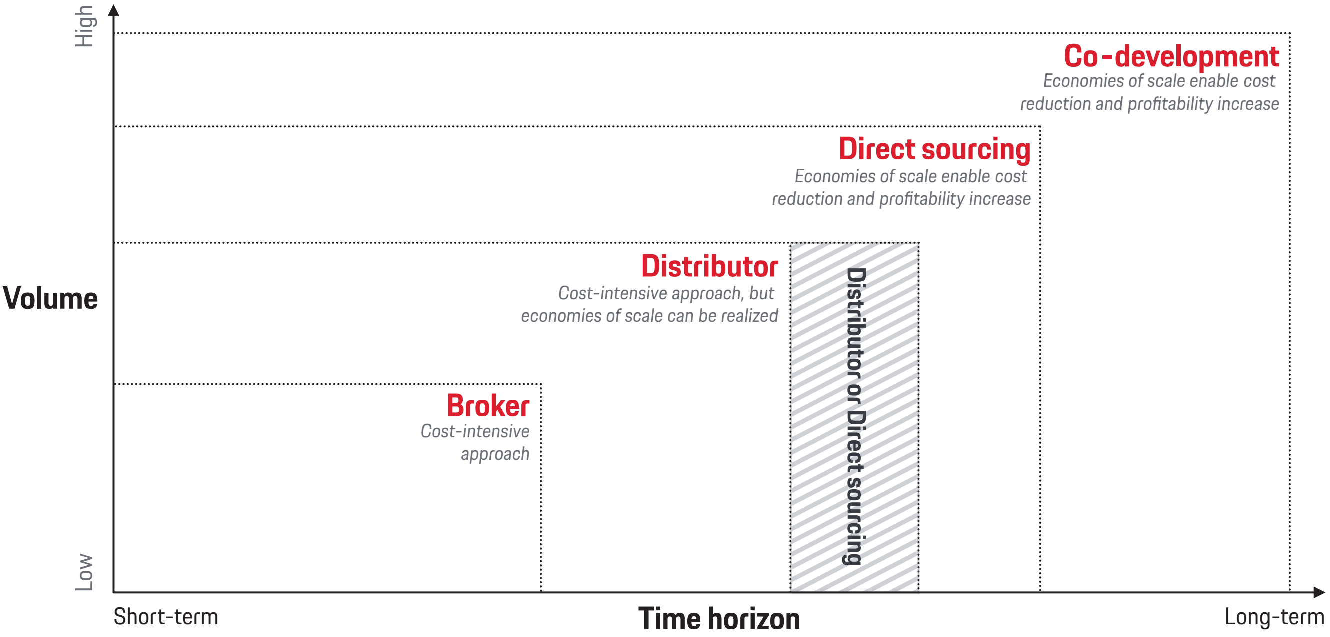


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Fig. 7. Decision guide for collaboration targets and sourcing approaches.

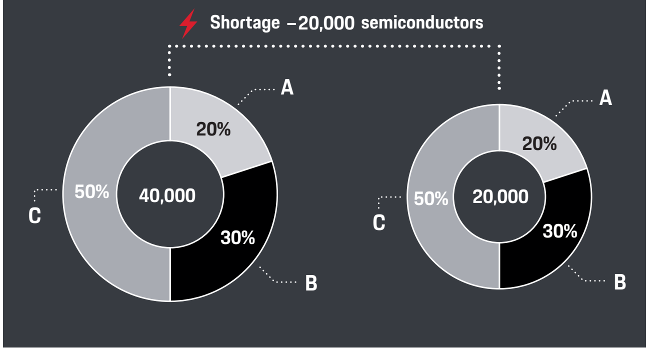
04

Sourcing strategies for semiconductors

High chip volumes enable direct sourcing approaches and thus long-term supply security

The global demand exceeds the supply significantly. In addition, the Covid-19 crisis and natural hazards disrupted semiconductor supply chains. Especially the automotive sector was confronted with shortages along the supply chain. Available inventories had to be allocated by a fair-share approach at every value chain step. The automotive industry has a long supply chain with many parties and respective allocation stages. In addition, the high variance of built-in semiconductors hindered automotive OEMs to purchase chips directly. Moreover, the share of the automotive market on the global semiconductor market is <13 percent[12]. All points have aggravated the situation for automotive manufacturers.

Fair-Share Allocation | Given a shortage, semiconductor supplier must follow a fair share allocation to be in line with competition law. This allocation approach says, that each customer (A, B, C) is given its fair share ('quota') in the total cumulative volume of all orders. No customer is treated differently compared to the others.



Bundled volumes provide new sourcing strategies

Industry leaders perform complexity management to bundle significant volumes and to simplify technical architecture. This consolidated chip portfolio enables new purchasing opportunities due to the considerably decreased number of suppliers to talk to and in parallel a significant volume can be sourced via a very limited number of suppliers. To establish direct sourcing options, it is crucial for semiconductor manufacturers to have high volume commitments as production capacities are blocked by direct sourcing. Leading companies source their strategic semiconductor portfolio directly from the manufacturer to achieve long-term supply security.

Align sourcing strategy with operating model

Purchasing semiconductors directly is a meaningful building block towards an active role in the semiconductor supply chain. To put the direct relation with the semiconductor manufacturer into practice, OEMs must decide in a first step which sourcing strategy needs to be implemented .

Therefore, OEMs must evaluate internally what resources and competencies are required to conduct and maintain sourcing activities. As with direct sourcing the OEM will assume more responsibility, it is crucial to create a clear picture on the target operating model. Further, it is important to align with suppliers along the whole value chain on roles and responsibilities based on renewed procedure. A distinction is made here between direct buy and directed buy.

Direct Buy | The OEM buys the chips directly from the semiconductor manufacturer and provides them to the component manufacturer. The supplier installs the semiconductors on the PCB and delivers the component to the OEM.

Directed Buy | The OEM specifies to the component supplier from which subsuppliers the semiconductor must be sourced. Nevertheless, a regular contractual relationship exists between the component supplier and the semiconductor supplier. A payment for the component is issued by the OEM.

By putting a direct buy strategy in practice, organizations create a powerful positioning, see Figure 8. The starting point for the OEM is to negotiate binding long-term volume orders and prices for the semiconductor. In parallel they need to establish a contractual framework in which the ECU manufacturer commits to build in the company-specific chips into the OEM components. The semiconductor manufacturer is paid directly. The chip manufacturer sells the electronic part to the OEM and a title transfer takes place. The chip is then provided to the component manufacturer. Based on the agreement, the semiconductor is obstructed in the component and shipped. Afterwards, the OEM pays the ECU manufacturer per part reduced by the expenses and overhead for the chips. Five central advantages are thereby created:

//01 Chips are the property of the OEM and not affected by fair-share allocation
//02 Material flow can be steered by the OEM
//03 A three- to six-month safety stock can be built up
//04 Overhead costs can be reduced and profitability increased due to economies of scale
//05 Active positioning of the organization in the semiconductor value chain is established

Internal and external success factors to be considered

For a successful long-term implementation of the new sourcing strategy, crucial internal success factors need to be considered. Firstly, it is essential to consciously create internal capacities to map administrative activities on the one hand and to control the additional procurement flows on the other. Secondly, the need for an internal distribution of tasks and roles within the framework of the new supplier relationship is crucial.

For the material handling, existing logistics processes must be checked inbound and outbound for the new tasks as well as technical requirements regarding the handling of goods.

In addition, external success factors apply as well, such as a common understanding of the sourcing model to be established with suppliers. A jointly agreed governance is of particular importance here. Key content to be considered includes supply process and standards, data-driven KPI management and C-level reporting as well as communication streams. Reported KPIs need to reflect all essential customer supplier metrics that create transparency on the (long-term) status of demand and supply per semiconductor. The implementation of a common supply chain cockpit is recommended. Within this dashboard all participants along the value chain have the best overview of the delivery status and capacities. OEMs should take these success factors into account when operationalizing their future purchasing strategy. Direct sourcing reduces overhead costs and enables flexible part allocation. Becoming an active partner of the semiconductor ecosystem is a game changer for the OEM horizon as it has been defined in the past. On the one hand, the OEMs must strongly deepen knowledge of an electronic sector that has already existed for several decades. On the other hand, the semiconductor supplier must become familiar with the strict requirements and challenges faced by the OEM. Establishing understanding for each other and starting joint development activities will enhance the learning curve for both sides.

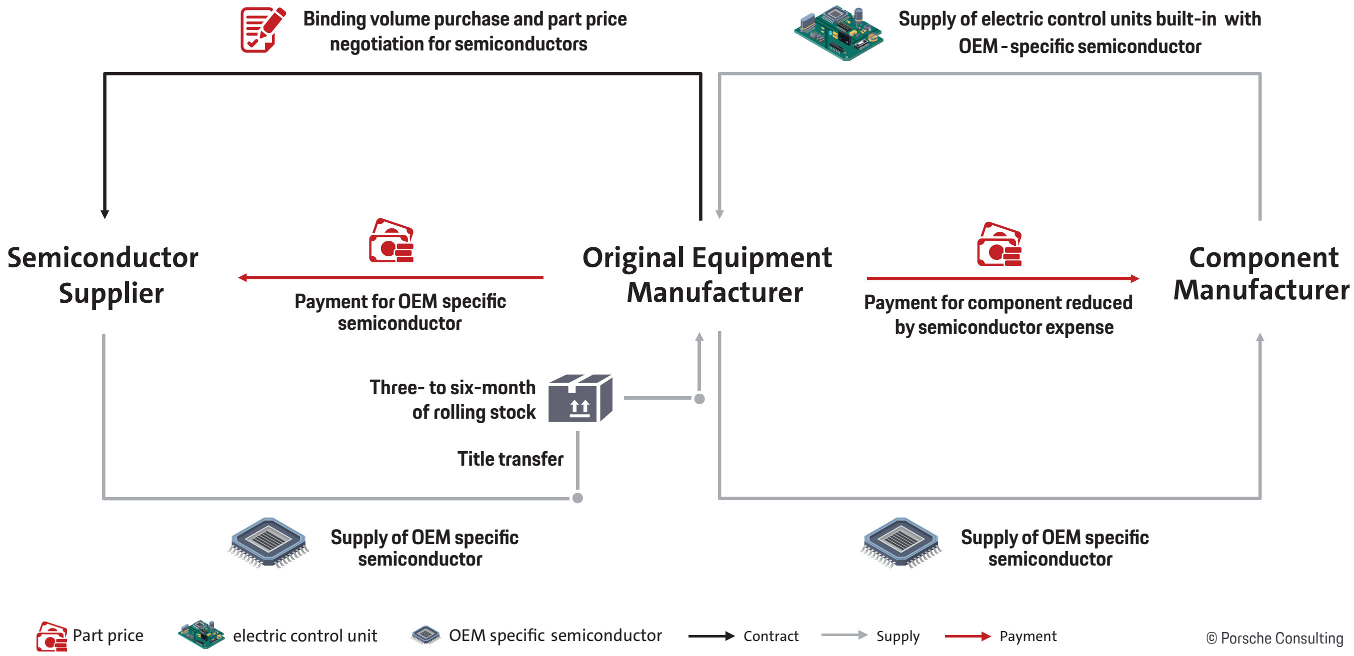


Fig. 8. Schematic of direct buy sourcing of semiconductors from the semiconductor supplier.

05

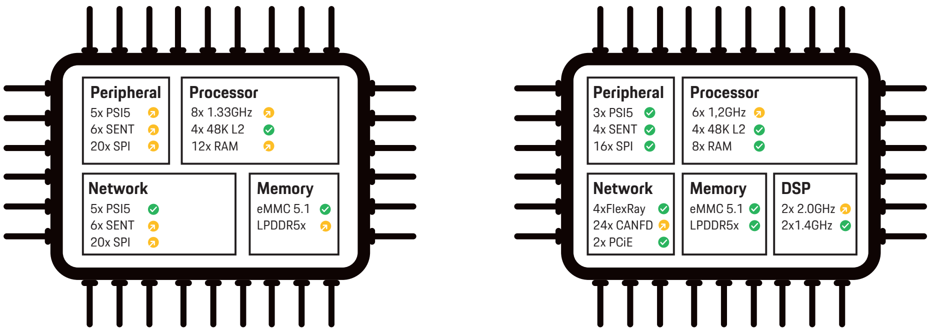
Development strategies for competitive advantages

In addition to procurement strategies, there are further competitively attractive options for securing and actively shaping future semiconductor supply. Leading companies boost their product differentiation and performance by establishing co-development agreements with semiconductor manufacturers and designers, resulting in higher outperformance of their competition.

Requirements and performance gap

In the automotive market, several co-development activities (e.g., multichip modules, power electronics) have been prioritized between leading automotive companies and semiconductor manufacturers in recent years. Automotive OEMs noticed that the traditional product catalogue of semiconductor manufacturers could not meet their expanding technical requirements due to new vehicle functions as well as the increasing system complexity in a vehicle. Figure 9 illustrates the difference in the requirements and subsequent performance between a standard and co-developed semiconductor (Example: SoC, system-on-a-chip).

OEMs' next-level capabilities must include the customization of their own semiconductors



Requirements gap	Standard semiconductor	Co-developed semiconductor
Performance & energy efficiency	✓	✓
OEMs application scalability	✗	✓
Compatibility to OEMs development standards	✗	✓
Compatibility to OEMs safety standards	✓	✓
Cost & headroom optimization	✗	✓

Co-development enables OEMs to match the semiconductors' specifications to their unique technical requirements

✓ requirement fullfilled ↗ overperformance of requirement ✗ requirements not fullfilled

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Fig. 9. Gap of technical requirements between standard and OEM specific System-on-a-chip (SoC).

Both SoCs consist of several building blocks that are mapped together in a block diagram and form the schematic layout of the semiconductor. In order to process digital signals, a digital signal processor (DSP) extends the co-developed SoC in comparison to the standard product. When the technical specifications of both chips are compared, it is quite evident that the standard semiconductor's performance surpasses that of the co-developed one. For the OEM, this means that a significant portion of the available performance cannot be utilized, and as a result, the standard product is overpriced for the OEM's performance needs. Furthermore, specifications that fail to meet the technical requirements are also possible. In this case, OEMs must accept functional compromises if they want to use a standard product. In comparison to a standard semiconductor, a co-developed semiconductor ensures that the technical requirements match the technical specifications. In the case of particularly critical technical specifications, a conscious overperformance of the building elements can be built in so that the potential overhead is already calculated, and future functions can be expanded accordingly. As a result, OEMs can enable new features (e.g., via over-the-air updates) as needed without having to modify the existing hardware. The reason for the trend towards overperformance in standard semiconductors lies within the fulfillment of a wide range of different product requirements and specifications. A conventional SoC, for example, can be integrated into a vehicle's ECU and, with minor software modifications, it can also be integrated into a standard computer.

This demonstrates that standard products are designed to fit practically anywhere, regardless of product-specific requirements. Co-developed semiconductors are designed to fit specific use cases and therefore remove expenditures for unused performance. Yet the initial costs for developing an OEM-specific chip are obviously considerably higher than the purchase of standard products from semiconductor manufacturers. To enter into such partnership agreements on co-development companies should focus on three essential factors:

//01 Strategic relevance

Prioritize semiconductors that are part of the strategic semiconductor portfolio, as they are the most valuable for the company.

//02 Economic feasibility

Support each co-development activity with a strong business case in order to avoid wasting company resources, as it is a long-term commitment and investment.

//03 Technical scalability

Assure the semiconductor's technical scalability, e.g., across many products (car central control units) or taking into account sufficient headroom for the creation of additional functions.

Opportunities and challenges of co-development

At the same time, companies are advised to analyze the opportunities and challenges, as described in Figure 10. In the long term, the benefits of a co-development cooperation outweigh the potential consequences. That is because many challenges already have solutions, as described in this paper. Challenges one and two can be prevented through direct discussions with semiconductor manufacturers. For the third challenge, OEMs can hold or implement a rolling stock of three to six months in order to secure their semiconductors.

Opportunities

- **Trade-off between performance and energy efficiency**
  OEM criteria can be addressed perfectly through co-development, resulting in the best performance vs. energy consumption.
- **Transparency & security of supply**
  Supply is assured as a result of exclusive OEM development and production.
- **Cost effectiveness and scalability**
  Standardization of semiconductors results in higher volumes and greater leveraging synergies across OEM products.
- **Synchronicity between hardware and software**
  Matching hardware and software requirements allows higher performance and efficiency.

Challenges

- **Long-term commitment for OEMs**
  Co-development implies long-term technological and commercial commitments between both partners.
- **Technology dependency**
  The future technology orientation is solely focused on one corporation. If this falls behind, it impacts the OEM negatively.
- **Supply dependency**
  Customized semiconductors have less technical alternatives compared to standard products.
- **Concept responsibility**
  The OEM takes concept responsibility down the semiconductor level, clarifing liability and warranty with the component manufacturer.

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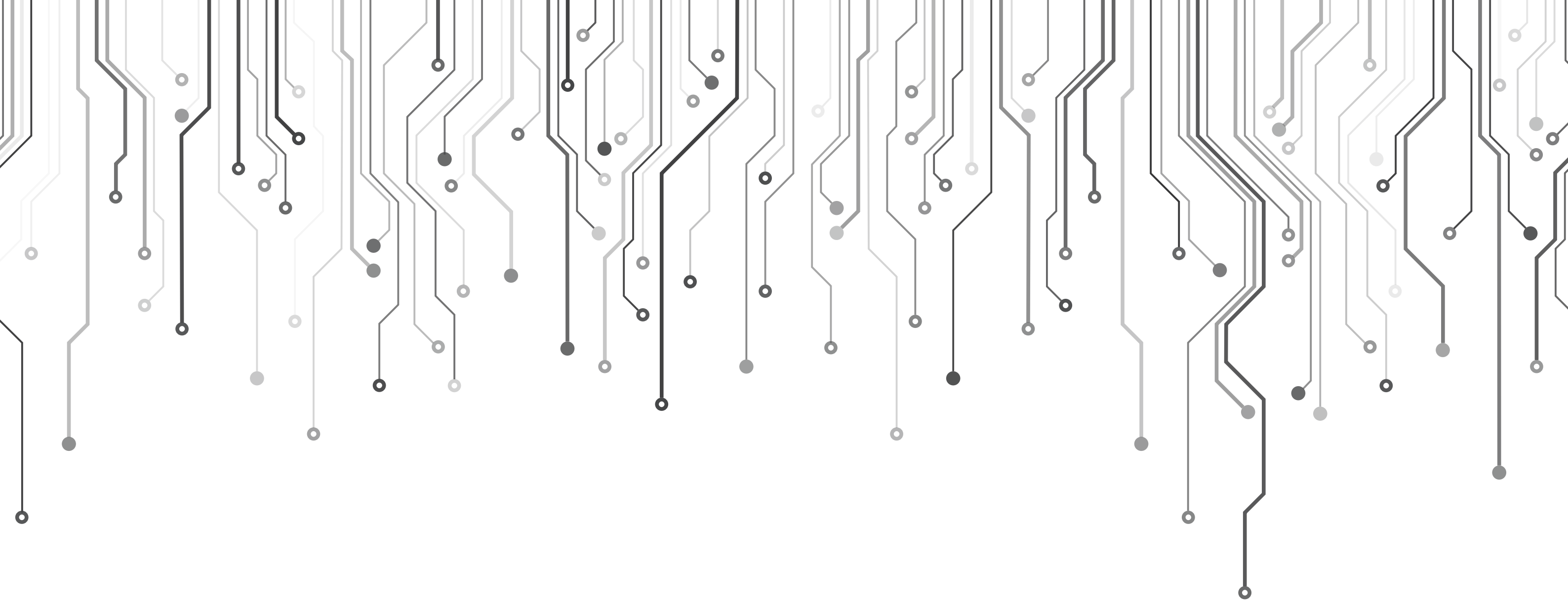
Fig. 10. Opportunities and challenges for OEMs in co-development activities.



Next steps

OEMs are naturally spoiled for choice when it comes to picking the right semiconductor for their products. Especially the consumer electronics industry must introduce new technologies faster than the automotive sector and therefore requires a broader product portfolio of standard semiconductors to ideally choose the closest to its own technical requirements.

Because automotive applications are spread across multiple technological nodes, achieving automotive-specific needs within the available standard product range is becoming increasingly difficult. As a result, leading automotive companies must take greater responsibility through co-development partnerships to further meet their technical requirements with semiconductors. Additionally, OEMs need to consider co-development not only on the semiconductor level but on the whole system level. This results in a much better possibility for semiconductor manufacturers to understand not only the requirements of one specific element, but the system itself, in turn enabling them to offer more specific products for their customers. Only in this way, OEMs can ensure a technological lead while simultaneously reaping competitive advantages through reduced complexity and more headroom for future advancements.

Many existing co-development partnerships proved their success, such as Apple's and TSMC's collaboration[13] on the development and production of the M1/M2 chip. Not only consumer electronics focus on strategic co-development activities; CARIAD and ST Microelectronics recently announced the joint development of the next generation chip for their future vehicle E/E architecture[14]. This shows that now is the time for OEMs to take more responsibility in order to increase their product differentiation and performance to generate more competitive advantages in the future.

Conclusion

The framework presented here helps executives in purchasing, technology development and strategy to meet the challenges of semiconductor management in a structured way. The Porsche Consulting strategy for successful semiconductor management is presented in its eight fields of action and explained in detail with tangible examples out of the semiconductor ecosystem.

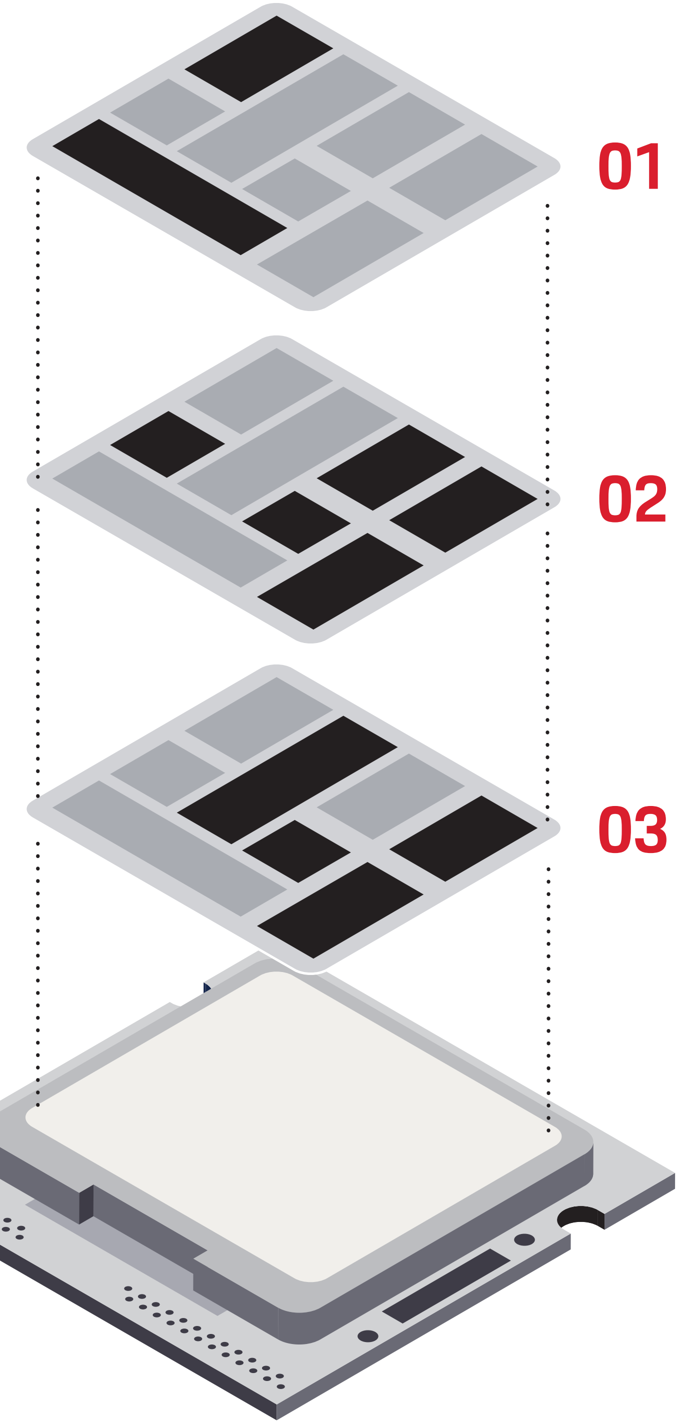
To intervene in the semiconductor business, OEMs need to know their built-in semiconductors and their products supply chain in detail. Transparency and risk management are the first steps to an effective risk management.

It was found that automotive OEMs could have reduced production losses by simply collaborating more closely with the semiconductor industry instead of letting a third party take over. At the latest now, OEMs need to make reliable demand forecasts and communicate directly with the semiconductor industry.

Due to the fact that OEMs are responsible for semicoductor volume while component manufacturers earn the profit, the logical response is that complexity management with the aim of a semiconductor portfolio and volume bundling must become mandatory for the OEM to obtain more control with respect to technology and purchasing. The key to long-term supply security and profit is direct sourcing of semiconductors—which is currently done by very few.

The next level of OEM capabilities involves customization of the company's own semiconductors: joint development partnerships with semiconductor suppliers lead to greater technological and economic advantages for OEMs. This successfully shifts the status quo from security of supply to the generation of competitive advantages.

IN BRIEF



01 Transparency & Risk Management

Transparency over built-in semiconductors are the first step to an effective risk management. Data-driven information about current supply chain then form a strong risk management.

02 Supply Security & Profit

OEMs need to make reliable demand forecasts and communicate directly with the semiconductor industry. Managing the complexity to bundle volumes enables higher profits.

03 Competitive advantage

The key to long-term supply security and profit is direct sourcing of semiconductors. Joint development partnerships with semiconductor suppliers lead to greater technological and economic advantages.

Let‘s check your semiconductor readiness

We invite you to assess the maturity level of your semiconductor strategy by filling out our Quick Check Survey. The results will be evaluated by Porsche Consulting and discussed with you individually afterwards.

01

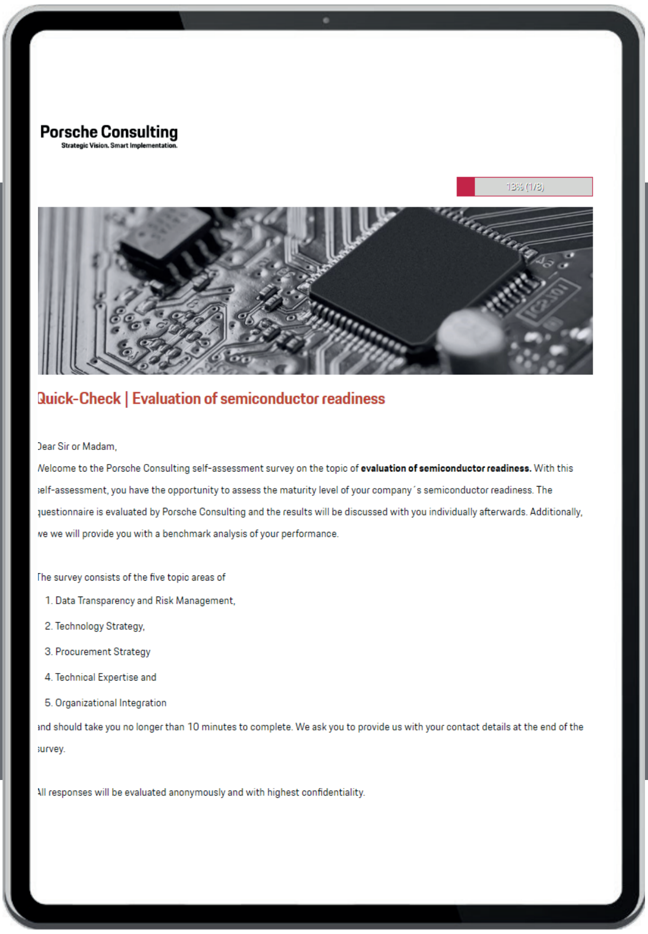
Follow the link here or the QR code below

02

Receive your results via e-mail

03

Get individual advice from our experts



Quick-Check | Evaluation of semiconductor readiness

Dear Sir or Madam,

Welcome to the Porsche Consulting self-assessment survey on the topic of **evaluation of semiconductor readiness.** With this self-assessment, you have the opportunity to assess the maturity level of your company´s semiconductor readiness. The questionnaire is evaluated by Porsche Consulting and the results will be discussed with you individually afterwards. Additionally, we we will provide you with a benchmark analysis of your performance.

The survey consists of the five topic areas of

1. Data Transparency and Risk Management,
2. Technology Strategy,
3. Procurement Strategy
4. Technical Expertise and
5. Organizational Integration

and should take you no longer than 10 minutes to complete. We ask you to provide us with your contact details at the end of the survey.

All responses will be evaluated anonymously and with highest confidentiality.

Appendix

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Appendix

List of abbreviations

CAGR	compound annual growth rate
DSP	digital signal processor
E/E	electrical/electronic
ECU	electronic control unit
EV	electric vehicle
IC	integrated circuit
KPI	key performance indicator
LED	light-emitting diode
MOSFET	metal oxide semiconductor field-effect transistors
OEM	original equipment manufacturer
PCB	printed circuit board
PDP	product development process
SoC	system-on-a-chip

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