Managing the 2021 automotive chip famine

With chip supply constraints likely to persist until third quarter 2021, IHS Markit analyzes the short and long-term implications for the automotive industry.

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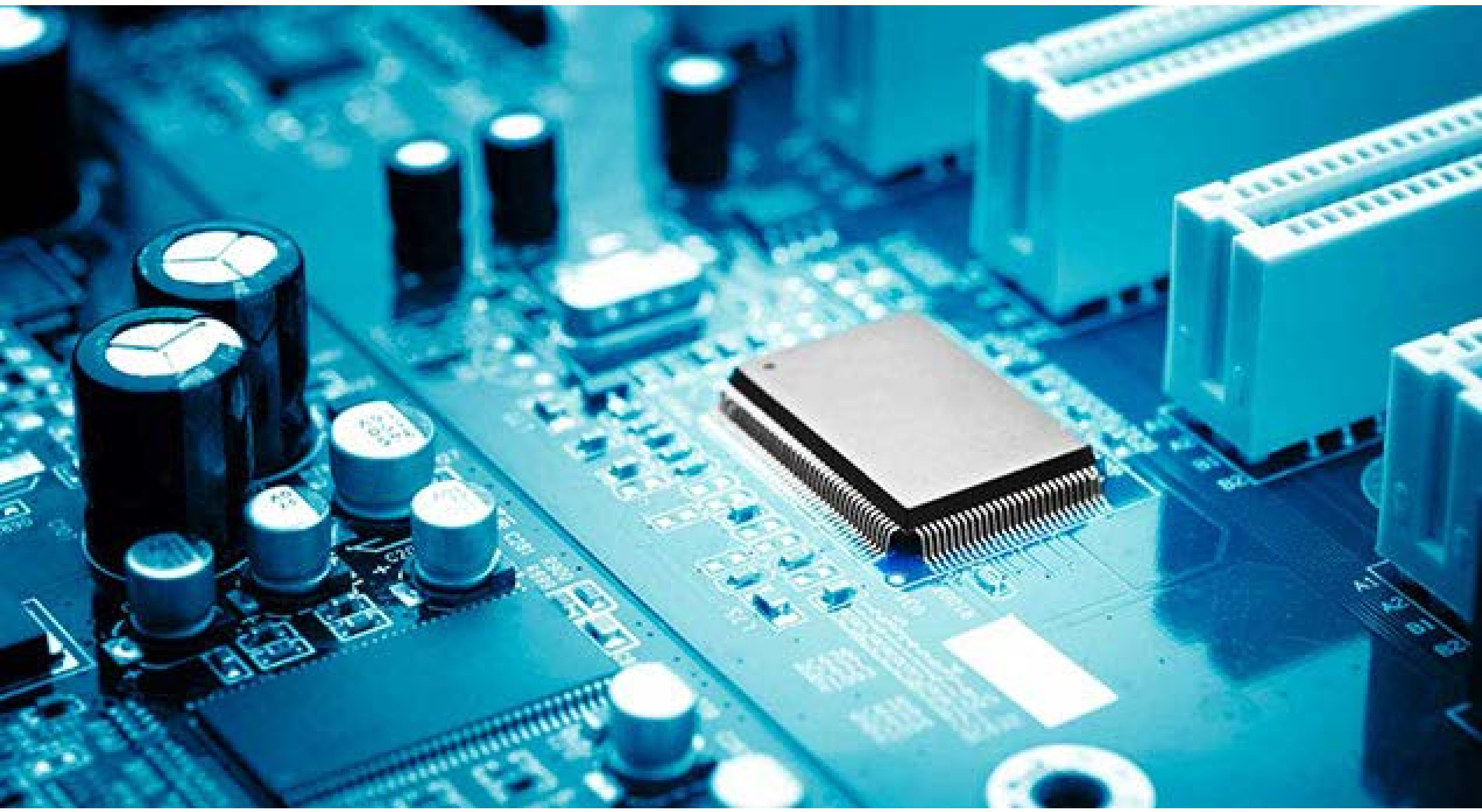


The crisis has highlighted the need for adjustments in capacity and sourcing patterns between automakers, tier-1 suppliers, semiconductor suppliers, and their foundries. In the short term, only industry-wide collaboration can help reduce the effect.

The semiconductor shortage crisis has hit the automotive industry at a time when the sector started to experience a moderate recovery in production levels following a pandemic-inflicted slowdown. The ramp-up in demand of chips from the automotive industry started when the supply lines were already stretched by significant demand for chips from the consumer electronics sector, for 5G phones and infrastructure, new gaming platforms, and IT equipment. There are no easy fixes to the capacity constraints owing to the long and complex manufacturing processes of semiconductors, which make new capacity building a capital-intensive and time-consuming affair. The shortage is expected to last until the third quarter of 2021, when re-allocation of capacity from semiconductor foundries and possibly some cooling-off of consumer electronics demand should provide greater supply security.

Although major semiconductor suppliers, such as Taiwan-based Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectronics Corporation (UMC), have announced investment plans to increase production capacities, these efforts will not bear fruit over the short term and will force automotive OEMs and their tier-1 chip suppliers to reformulate their conventional semiconductor sourcing strategies. The crisis has highlighted that the traditional short-term sourcing cycle that automotive companies have pursued may not bode well with production and scale cycles that the consumer electronics sector commands to semiconductor manufacturers. IHS Markit expects supply chains to introduce some changes in their approaches to inventory management to be better prepared in future.

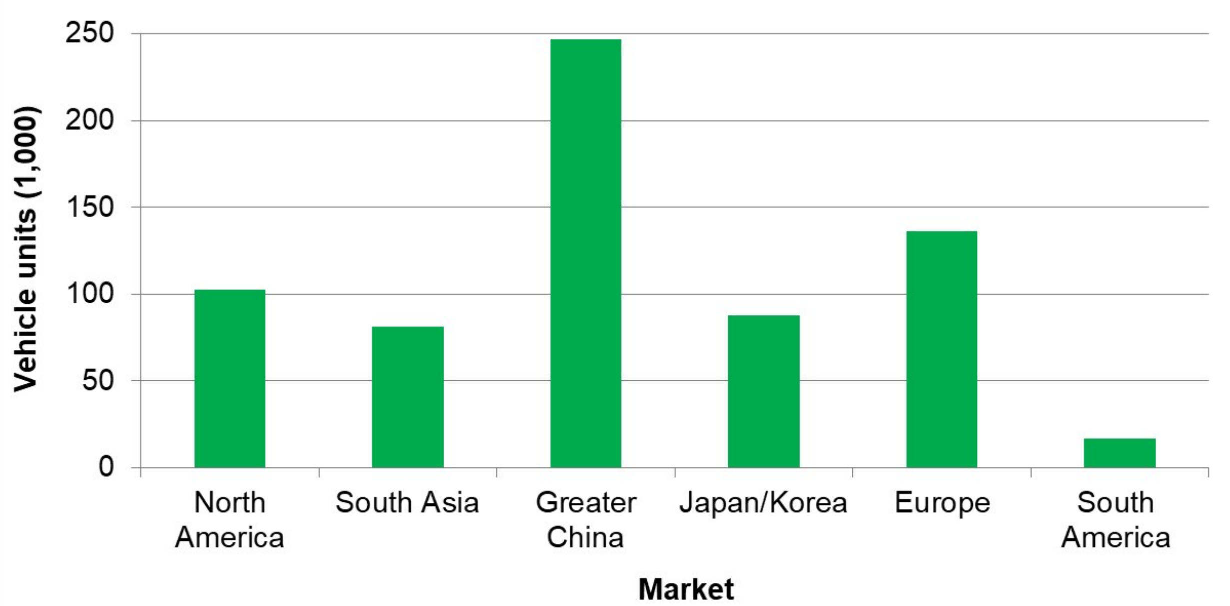
IHS Markit's Supply Chain and Technology team has been tracking the chip situation since April 2020. “Because the cause of these constraints is the result of increasing demand from OEMs and limited supply of semiconductors, it will not be resolved until both forces are aligned. If the cause was a natural disaster, then the supply chain would respond with the appropriate recovery plans and while that would still take months or quarters to implement, plans already exist. This is a case of balancing supply and demand and with microcontroller unit (MCU) lead times being 26 weeks or longer, the supply chain constraints will likely persist until at least the third quarter of this year,” said Phil Amsrud, senior principal analyst-ADAS, Semiconductors and Components, IHS Markit.

Initial Impact

The impact on vehicle production is already significant, however, the situation remains fluid and our vehicle production team is tracking this impact on an ongoing basis. As of 29 January, IHS Markit anticipates 672,000 fewer light vehicles will be produced in the first quarter of 2021 (see graphic below), owing to supply interruptions. Audi recently furloughed 10,000 workers and announced consequences for premium models, such as the Q5. Meanwhile, Volkswagen (VW) has had to reduce production output at its German factories in Wolfsburg and Emden, and a component plant in Brunswick, “due to a lack of microchips”. Aside from stoppages in Ford’s Louisville plant for the Escape model, the automaker said production of the Focus at the Saarlouis plant, Germany, would be suspended for a month starting 19 January. Ford Plants in Chicago, Dearborn Truck, Kansas City, and Oakville are also impacted. Honda, Renault, Toyota, Mazda, and a few other OEMs have also made similar announcements lately.

The biggest volume disruption is noted in mainland China, whereby based on available information, the risk could be close to 250,000 units in the first quarter. Plants of automakers, such as FAW-VW, SAIC-VW, SAIC-GM, and Dongfeng Honda, have been affected with shutdown ranging from 5 to 14 days.

Estimated impact on light vehicle production volume in Q1 2021 due to semiconductor supply issues



Note: Estimates as of 29 January 2021
Source: IHS Markit

Context around the shortage

1. **Microcontrollers in focus:** Microcontrollers, single-integrated circuits typically used in embedded applications with processing requirements, as well as managing the interaction with digital, electromechanical, or analog components, are particularly in short supply and are required for all electronic control units (ECUs). MCUs are used across all domains including powertrain (engine ECU, transmission ECU), chassis (airbag ECU, anti-lock braking system [ABS]/ electronic stability control [ESC] ECU), body (door ECU, body control module), and advance driver-assistance systems (ADAS), such as parking ECU. This shortage of parts is expected to affect tier-1 suppliers broadly in similar terms. Bosch, Continental, and DENSO each make at least 30 or more different ECUs in all vehicle domains. Bosch and DENSO, both of which can boast in-house manufacturing of sensors and semiconductors, have confirmed that MCUs and analog integrated circuits (ICs), which they buy externally, are in short supply.

MCUs are manufactured on advanced process nodes (semiconductor manufacturing process) typically below 40 nm, an indicator of increasing sophistication as ICs become increasingly miniaturized. Owing to the very high capital expenditure associated with these processes, very few chip manufacturing plants (also called fabs) feature these processes. Most device manufacturers such as Integrated Device Manufacturers (IDMs) have been following a long-term strategy of outsourcing chip production to foundries, such as TSMC, which possess these advanced nodes. For MCUs there is consequently a very high concentration in one source — TMSC manufactures roughly 70% of all automotive MCUs shipping today.

2. **Bottlenecks at TSMC:** The Taiwan manufacturer announced capacity constraints last year across the board; sign that the genesis of this crisis dates back to 2020 and to an extent even before 2020. Automotive contributes only 3% of TSMC's total revenue. Although TSMC has said it would support car customers with increased investments, these are of a long-term nature, mostly to align with the automotive long-term trend toward high performance computing rather than to help solve current bottlenecks.

3. **Lead-time impact:** Lead times are significantly impacted— an MCU that typically takes 12–16 weeks to manufacture internally will need lead times of 26 weeks and even up to 38 weeks for in-demand components. That said, lead times for nearly all chips are currently longer by one-to-two months. Some car chip suppliers last November told IHS Markit that TSMC would not take orders for delivery before the third quarter of 2021.

Too many eggs in one basket

Semiconductor manufacturing is complex. A chip takes anywhere from 12–16 weeks from order to shipping for relatively complex devices like MCUs, and up to 26 weeks for an inertial sensor used in a vehicle stability system. The supply chain is complex and handling its dependencies along the chain through a carefully managed arrangement of ordering and maintaining an inventory balance is critical to on-time supply. This balance is easily disturbed by unusual market dynamics, such as the COVID-19 pandemic. And this crisis has highlighted the fragility of the ecosystem, especially when other dynamics are in play.

The semiconductor industry is served by more than 90 IDMs and foundries (contract manufacturers). Many of these are based on 200-millimeter (mm) wafer sizes and older process nodes of 180 nm (such as sensors) or greater and migrate down in feature size to 56 nm. The newer performance technologies— especially high-performance MCUs— are concentrated on process nodes below 40 nm on 200 mm and 300 mm wafers for reasons of higher manufacturing efficiency.

Semiconductor manufacturing and implication of foundry company TSMC

Component type	Domain	Subsystem	Wafer size (mm)	Process nodes* (nm)	Exposure to TSMC
AI chips, SoCs, GPU	ADAS, Infotainment	High performance FV camera, ADAS domain controllers, Head-units, Cockpit Domain Controllers, Instrument Clusters. Vehicle Domain Controller	300	16, 14, 7, 5	Very high
Microcontrollers (MCU)	All	Across all domains, every ECU has an MCU	200,300	16 to 40 nm	Very high (about 70% of automotive MCUs with TSMC)
Memory IC (DRAM, Flash)	Infotainment, ADAS	Infotainment Head-Unit, Instrument Clusters, ADAS front-view camera, ADAS Domain Controller	300	10 to 18 nm	Low (market leaders Micron and Samsung have own fab)
CMOS Image sensors	All	Cameras	200, 300	5 to 65 nm	High (#2 supplier Omnivision with TSMC)
Display Driver ICs	Infotainment	Digital instrument clusters, head units, other displays	200, 300	55 to 180 nm	Moderate, number of other foundries available.
Analog/mixed signal, power management ICs, RF components	All	Specific power management ICs required with every SoC and modem. Analog ASIC/ASSP in every ECU across all domains. RF components for telematics and ADAS	200	56 to 180 nm	Moderate. Significant in-house production. Number of other foundries available.
Power Discrete	xEV, Chassis	Power electronics for xEV, Chassis	200	90 to 110 nm	Low (mostly in-house fabrication)
MEMS Sensors	All	Pressure, flow, inertial, humidity, infrared	200	180 nm	Low. Significant in-house production.

Notes: *Process node: The industry describes each generation of semiconductor manufacturing process of technology/process node as designated by its minimum feature size.

Source: IHS Markit

The amount of IDMs’ coverage exponentially decreases in smaller process nodes; and at the sub-10 nm cutting-edge process nodes used for artificial intelligence (AI) chips and powerful graphics processors (GPU), automotive IDMs’ are currently solely relying on TSMC, Samsung, and Intel. While the AI and GPUs have less implication for the average car— as they are featured in more premium vehicles with higher autonomy levels and/or advanced infotainment systems— the impact of this manufacturing concentration is more significant for MCUs that are used across the board in all ECUs. About 70% of all automotive MCU manufacturing takes place at TSMC of Taiwan, creating a bottleneck across the industry.

CMOS image sensors (CIS) used in front-view cameras are exposed to disruption owing to the reliance of Omnivision, the second best-selling supplier in this space, on the Taiwan-based manufacturer. Memory is less exposed to TSMC, with Samsung and Micron featuring their own fabs for these devices. Such reliance on TSMC has been built over time, as several IDMs pursued a “fab-light” strategy, thus reducing their level of vertical integration to lower capital expenditures in new-generation process nodes and often owing to lack of scale. Top-seven MCU suppliers make up some 98% of the demand, and only few of them, with STMicroelectronics being a prominent one, retain a higher level of vertical integration.

Going Fab-light: Top suppliers of MCUs and their dependence on TSMC

Automotive MCU supplier	Share of automotive MCU supply	Process node (nm)				
		16	28	40/45	65	110/130
Renesas Electronics Corporation	30%		MCUs - outsourced from 2016 to TSMC	MCUs - outsourced from 2012 to TSMC		MCU - outsourced from 2005 to TSMC
NXP Semiconductors	26%	MCU - outsourced to TSMC	MCU - outsourced from 2016 to TSMC			
Infineon	14%	MCU - outsourced from 2017 to TSMC		MCU - outsourced to TSMC	MCU - 32-bit TriCore, outsourced 2013 to TSMC	MCU - outsourced in 2011 to TSMC
Cypress Semiconductor (acquired by Infineon)	9%			MCU - outsourced to UMC in 2016		
Texas Instruments	7%			MCU - outsourced to TSMC and UMC	DSPs – own fab	
Microchip Technology	7%			Multiple foundries	Multiple foundries	
STMicroelectronics	5%		Majority in house, small portion outsourced (probably TSMC)	Majority in house, small portion outsourced (probably TSMC)		
Total	98%					

Source: IHS Markit

Why are MCUs to blame?

Most vehicle and components production stoppages are ascribable to shortage of MCUs. First, MCUs are ubiquitous in today's vehicle owing to the proliferation of ECUs in vehicles. The average vehicle has in excess of 20 MCUs. For example, a Chevy Equinox features 27, while an Audi Q7 as many as 38. Multiple MCU suppliers are being used, often appointed by a "directed-buy scheme", whereby the OEM will indicate the tier-1 supplier which tier-2 supplier to use. Each vehicle relies on multiple MCU suppliers. For instance, the 2018 Honda Accord uses as many as eight different suppliers. However, at the tier-3 level, there is little choice as 7 out of 10 MCUs originate from one foundry, as outlined before.

List of functions using microcontrollers in selected brands

Domain	ECU using microcontrollers
ADAS	Park assist ECU, radar, front-view camera, ADAS domain controller
Body and convenience	HVAC ECU, lighting ECU, door ECU, seat ECU, gateway
Chassis and safety	Airbag ECU, satellite airbag, anti-theft ECU, electric park brake ECU, electronic stability control ECU, fuse and relay boxes, steering ECU, suspension ECU
Infotainment	Amplifier, head unit, CD player, instrument cluster, screen, microphones, rear-view mirror, telematics ECU
Powertrain	4WD ECU, transmission ECU, cooling system ECU, engine ECU, fuel pump ECU

Source: IHS Markit © 2021 IHS Markit

In addition, MCUs (and system-on-chips and ASICs) do not easily allow for second sourcing with a component from another supplier. MCUs have proprietary architectures and are therefore difficult to move from one supplier to another. Memory ICs, discrete and power devices, standard analog ICs, sensors, actuators, and logic ICs are generally more interchangeable. Therefore, if MCUs are limited, suppliers must increase capacity, but nearly all go to TSMC to do this. This explains why OEM and tier-1 suppliers will all be similarly affected. It does not matter how many sources they have, in terms of MCU capacity, currently it is "too many eggs in one basket" kind of scenario that the industry is grappling with.

MCU sourcing for the Audi Q7, the Chevrolet Equinox, and the Honda Accord reveals a wide dependence on different MCU suppliers, even within domains. Some of these vehicles are among those affected by the current chip shortage.

Audi sourcing 38 MCUs on luxury SUVs from 7 suppliers

Source: IHS Markit

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Honda sourcing 20 MCUs on mid-size vehicles from 7 suppliers

Source: IHS Markit

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Older technology adds to the problem

TSMC is not the only bottleneck. Many semiconductor chips are produced on 200 mm wafers and are very mature—180 nm nodes emerged in 1999 and are still being used today to manufacture parts for many other products, including mobile phones. Contrary to expectations, demand for 200 mm wafers has actually increased owing to various consumer electronics still adopting them. For instance, 5G handsets, which began ramping in 2020, contain a much higher number of radio frequency (RF) power amplifiers, CMOS image sensors, and power management ICs.

For several years, pressure has been growing on these production lines manufacturing the 200 mm wafers, including foundry companies such as UMC, to expand capacity for these nodes, which albeit their maturity, still found many applications. However, this has been hindered by a reluctance to invest in mature technology, coupled with dearth of new and even second-hand equipment for this wafer size. As IDMs outsourced more and more to 200 mm companies such as UMC in Taiwan, which has seven 200 mm fabs, this also led to a growing capacity constraint around this wafer size, since most capacity was allocated to a handful of suppliers.

For the past few years, as fabs were upgraded to 300 mm lines, there was a vibrant market for used, inexpensive 200 mm equipment that companies used to upgrade their manufacturing facilities. However, that 200 mm equipment is not available, and companies have been forced to upgrade to 300 mm lines instead of relying more on external foundries. This chip shortage that the automotive industry is facing has laid bare the limitation of the aggressive and little diversified “fab-light” strategy that several IDMs have pursued in recent years to control their capital expenditures.

Outlook

In summary, this is not an allocation event— and hopefully this will not become one— and will continue to be a supply constraint event. There are limited opportunities for additional supply capacity to come online. Given that MCU lead times are 26 weeks or greater, this situation will likely extend into the third quarter. The automotive electronics supply chain is taking this very seriously and attempting to keep all OEMs running at reduced levels. There have been limited cases of OEMs double or triple ordering, which means the supply chain can be confident in the demand data. However, that does not change the fundamental problem that automotive demand exceeds MCU supply.

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Can the IDMs bring some manufacturing back in-house?

IDMs will not likely announce plans to build a new line any time soon. However, those who have yet to outsource 100% of their production to foundries and have kept some limited in-house capacity can expand their existing line. It might take anywhere between six and nine months. Therefore, if suppliers started at the end of 2020, any meaningful effect of such measures will not be seen before the third quarter of 2021.

There are significant hurdles in restarting lines or adding new capacity, and automotive manufacturing requires lengthy qualification of any new processes, albeit faster certification is a possibility. The reasons for a semiconductor supplier to outsource foundry operations were valid in the first place, and the prospect of bringing capacity back in-house to solve a short-term crisis only to end up with excess capacity down the road has little appeal.

New plants?

Any new fabs will take years to be up and running. In January, TSMC responded to the crisis by pledging up to USD28 billion of investment to ease the problem, including a new fab in North America. However, this is not expected to be operational before 2024. Most investment will again be on the cutting-edge nodes and in part reflects Intel's anticipated intention to outsource some of its production to TSMC in the future.

Can political pressure help reduce constraints for the automotive sector?

On 24 January, the German, US, and Japanese governments, among others, called on TSMC to address the car chip shortage issue. IHS Markit believes any impact of this initiative will be limited, as foundry players pursue where the largest demand is, and automotive at the moment is not the largest demand driver. Western governments have recognized the importance to reduce the reliance of their industries on Asian-based semiconductor suppliers and are working toward plans that in the medium term would address this risk. For example, the German Ministry for Economic Affairs and Energy (BMWi) announced last October its intention to invest EUR522 million (USD613 million) in research, development, and implementation of new technologies in microelectronics in Germany since 2019. In the context of Important Project of Common European Interest on Microelectronics (IPCEI), this program is approved by the EU Commission involving 29 companies from France, Germany, Italy, and the United Kingdom, which supports the set-up of chip factories developing high-performance microelectronic components right up to mass production. As noted above, this takes years and cannot be considered an answer to the 2021 shortage. However, it is a signal of the awareness of the underlying issue at a governmental level.

Are there tier-1 or tier-2 suppliers that could still supply OEMs?

No single tier-1 or tier-2 suppliers will be more or less affected by the chip shortage. A high dependency of the semiconductor suppliers on a single source in Taiwan for MCUs, combined with a general capacity constraint at IDMs and foundry businesses, will cause shortages until the third quarter. This is exacerbated by general infrastructure deficiencies on older semiconductor processes, as well as high demand for performance chips from adjacent industries.

Will this result in price hikes?

OEMs can expect an increase in prices of automotive chips in the next few months owing to the demand-supply imbalance. Price hikes in the region of 10–15% as a function of this imbalance are plausible, and several foundries are believed to explore this. However, this impact will be limited compared with the cost of keeping a vehicle production line closed or exposed to continuous start and stops.

What else can be done?

Over the next few quarters, collaboration between OEMs and the semiconductor supply chain will be necessary to manage the situation. Collaboration will allow all OEMs and tier-1 suppliers to get some supply of MCUs, instead of a few getting all they want and others getting nothing. The challenge will be to direct MCUs to the locations where OEMs are able to build the models that they want— since they are not going to be able to build everything they want. Currently, there are limited cases of double and tripling ordering parts, which is a good thing because the more transparent the information is now the better. As the recovery continues, the industry will need to have confidence in the data to make good decisions.

What are the longer-term effects?

This situation will definitely raise greater awareness at OEMs, tier-1 suppliers, and IDMs to reevaluate the long-term mix of outsourcing of foundry operations, with some players possibly exploring some reduction of their reliance. The chip shortage, the COVID-19 pandemic, and other events that have happened over the past decade will help raise awareness over the importance of supply chain risk monitoring and management at OEMs and tier-1 suppliers. A macroscopic issue, such as the over-reliance on a handful of external foundries and erosion of excess capacity on 200 mm equipment, was a well-known issue to industry observers, and it could have been identified and acted upon beforehand. While the feasibility of implementing a solution offering complete visibility of potential capacity choke points in the different tiers remains to be proved, more solutions to improve visibility within the automotive supply chain will be considered.