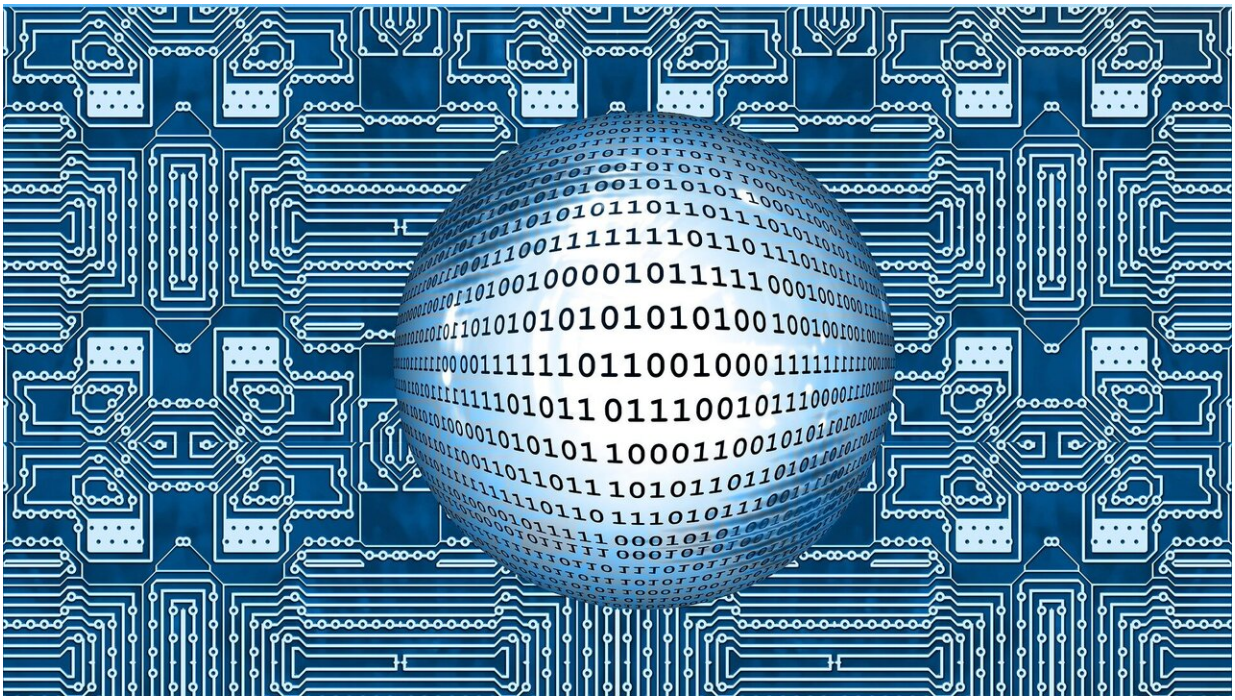
Why the semiconductor shortage won't end soon

March 22 2021, by Brandon Baker



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Your smartphone? It runs on a semiconductor. The innards of your PlayStation? It runs on a semiconductor. The display in your car? Yes, that too runs on a semiconductor.

It's no exaggeration to say that much of what we rely on in our daily lives is powered by these tiny, waferlike circuit chips called semiconductors.

Today, 40% of an automobile's value is estimated to be related to its electronics. This makes the shortage of the essential part very concerning to the United States' economy, enough so that President Joe Biden signed an executive order on Feb. 24 authorizing a long-term supply chain review of six sectors of the economy, and a short-term review of semiconductors and the materials needed to make them.

To understand the scope of the shortage, precedent for it, and whether the shortage might end any time soon—freeing up supply for everything from medical diagnostic equipment to smart fridges—Morris A. Cohen, the Panasonic Professor of Manufacturing & Logistics in the Wharton School, explains the ongoing situation.

What is a semiconductor, and what are some typical things they power or are necessary for?

Just about everything, now. Your phone, your TV, your home appliances, your car—you name it. We use semiconductor chips to control and modify processes that, as consumers and individuals, we own and use. We also use them for industrial equipment, airplanes, automobiles—they're ubiquitous.

The media conversation seems to focus on automobiles. Why is that?

They are facing a shortage, a crisis. There is a lack of sufficient supply, which has led them to actually shut down factories and cut back production and lay off workers around the world. The reason is, they don't have chips, and many people haven't thought about this, but we have many, many chips inside our cars today. You can look at a car as a moving computer. Every car has all kinds of systems—heating, air conditioning, entertainment, the engine—and they are all controlled and

monitored by electronic chips. And as you well know with manufacturing, when the manufacturer is short one part, it doesn't matter how small it is: You can't finish assembly or ship the product, so you have severe disruption. And this has happened before, by the way.

So this is precedented?

Yes. In 2011, we had the famous earthquake in Japan, Fukushima, and the consequence of that was that there was a company called Renasas that produces chips, primarily for the auto industry but for others as well. It turned out that this one factory, not far from Fukushima, was a major supplier of chips that go into automobiles around the world. And because of the tsunami and the earthquake, the factory was shut down. And as a result, worldwide capacity was reduced significantly, by about 25%—very noticeably. And factories all over the world had to curtail production and shut down—Japanese manufacturers, German, Chinese—you name it. And it turned out that all these manufacturers were installing modules required for assembly, called 'subassemblies," i.e., the entertainment system, the fuel monitoring system, or the climate control system. All of these modules, produced by various vendors, are then assembled into the automobile. These days, many components and subassemblies use a lot of chips. It turns out that for a lot of manufacturers around the world, this one plant was a major source of supply. So, when it went down, everybody was disrupted. What was interesting was that most companies didn't even know this factory was a supplier to their suppliers. That's the nature of supply chains. They do not just include first-tier suppliers but require that all the levels—tiers—below the first satisfy demands as well. And this led to what we call a 'diamond shape' supply chain, i.e., one with a perfect choke point. All material flow has to go through this one point and when it is disrupted, the whole system breaks down.

This happened in 2011, and it took many months for the major

manufacturers to recover production levels. Four months, six months—it depended on the manufacturer. Everybody said, "We learned our lesson and know where we are vulnerable. Surely it won't happen again."

It happened again.

It sounds like a house of cards.

Now it's not just Japan, but it's Toyota and Samsung who are the major suppliers of chips to the auto industry. And it's not that they were disrupted, they just didn't have enough capacity because of enormous demand changes. This was the case, not for the auto industry alone, but also for all of the consumer electronics producers who use far more chips than the auto industry. Consider what has happened during the last year, because of the pandemic. We're at home watching TV, using our devices, people are purchasing more, and the demand for consumer electronics and other devices has gone way up. In addition, in the first two quarters [of 2020], demand for cars went way down. People just weren't buying cars. So, all manufacturers assumed they'd have to scale back and they did not order a lot more inventory. They are efficient; it's called 'just-in-time' inventory management, or 'lean' manufacturing. As a result, they didn't order extra inventory.

In the second half of last year, demand exploded—people all of a sudden started buying cars. When the manufacturers went to order more chips, they discovered that there wasn't enough capacity because it had already been allocated to other industries, like consumer electronics.

Is it just the pandemic that caused this?

Well, I would say the pandemic was the root cause. It disrupted the demand patterns significantly, and the way that companies responded to

this demand shock or failed to anticipate it led to a problem. Manufacturers are supposed to be able to manage these things—that's what we teach in our supply chain management courses: how to minimize risk and match supply with demand. Unfortunately, they fell down. You could point the finger and say they made bad decisions and make a variety of after-the-fact explanations, but this was primarily caused by unprecedented shifts in demand. On one hand, consumer electronics exploded, and the auto industry tanked, and then it exploded.

Is there a push toward manufacturing chips in the U.S.?

That's a big reaction. The federal government has come up with a program, "CHIPS for America," which promotes domestic manufacturing. And we know about supply chain disruptions now, all of us. I've studied this topic for years and no one knew what I was doing. [Laughs] The argument is, "If we had more factories in the U.S. making chips, we wouldn't be so dependent on foreign suppliers and we'd be less vulnerable during a disruption." Which is true. So the U.S. government now is coming up with incentives to try to essentially bring back U.S. manufacturing of semiconductors back, this is called 'reshoring." The U.S. used to be dominant in chip production, and now it's down to 12% of world capacity, which is significant, but it used to be much higher. Semiconductors is a major industry and it's vital, not only for domestic economy but also for defense. These chips are used a lot in aerospace and military systems.

So, that's the argument. But, to build a semiconductor foundry—a factory that produces chips—the price tag now is $4 to $5 billion. It takes years to assemble a factory and even once it's open, it can take up to a year to tune the process to get the yields to the point of being viable. For the first six to nine months, they're testing and modifying. You can't

flip a switch and bring factories back home.

That's probably a skilled-labor job, too, right?

These factories are completely automated. You might see the odd person, but not too many. And we have a major semiconductor equipment industry that produces the hardware that goes into the chip factories. They're selling billions of dollars per year. One of the biggest is Applied Materials, for example. The main component of the cost of producing a chip is the equipment, which is highly automated. There's a lot of skilled labor that goes into assembling equipment, and a certain amount in running the factories. Maintenance also is a big issue because if a machine goes down, the factory goes down and stops producing, and this disruption can cost $100,000 per hour.

It's a capital-intensive, complex industry. And capacity is subject to enormous technological change as well. Every two or three years, the manufacturers change technology as they come up with better designs of either the chips or the equipment. As a result, this industry is governed by Moore's law that says every 18 months the cost of producing a chip goes down by half. And this has been going on for 40 years. And because of this, we have amazingly cheap electronics that do amazing things.

But the technology that produces such products is constantly being modified and updated. I have spent a lot of time working with this industry. It's a challenging industry. And with a disruption like COVID that causes demands of major customers to go back and forth like this, there are going to be disruptions. And there have been.

Will we see price increases soon?

We've seen shortage allocations. If you want to buy a car today, you'll probably have to wait to get what you want. This is also true for a lot of other products. Some prices will go up and there will be more delays.

What does Biden's executive order do?

Everyone understands now that the operations of supply chain are critical for the economy and our wellbeing. I guess it all came home when the COVID crisis started and we went to the supermarket and saw no toilet paper, right? And people panicked. We had all this panic-buying of toilet paper. And it turns out there was lots of toilet paper, it just wasn't in the right place. Managing supply chains is now recognized as essential and President Biden has put together a task force to look at this. It's not the first time that's happened either—and I think it's wonderful and a great idea. But I think the changes that need to be made must come from companies; government has limited impact. They can promote things and provide incentives, and they do, and this will modify but not dictate the decisions of companies.

I participated in a study a few years back, working with a group of professors and factories from around the world, about the sourcing of manufacturing: What drives decisions of a company to locate or relocate manufacturing from one country to another? This is a critical issue for semiconductors now. "Let's bring them back." One of the task force's goals is to promote that. But it's not a simple decision for a company to make. There are tradeoffs and risks to be considered. It used to be dictated strictly by labor costs—"Go to China because the labor costs are lower." That is no longer true and solving this problem is not that simple.

So, I think it's great that we have recognition at all levels of government that we have to modify policy that influences supply-chain decisions, such as taxes, incentives, and tariffs. These things are important and will affect the trajectory of decisions, but there are many other factors that

go into a company's global supply chain strategy. And every country in the world is trying to do the same thing; everyone wants citizens to have good jobs and to have access to low-cost products. Governments want to facilitate that. You have the Chinese and U.S. government, for example, competing for the same thing and each incentivizing their economy to achieve the same outcomes. It is now a situation where supply chains are competing with each other.

How does this problem get solved?

I don't think it's going away soon. You can't create capacity overnight, so we will have to live with the consequences.

Companies can make decisions now that will achieve resiliency and, thus, mitigate risks going forward, and that's what they are all trying to do. This could be based on finding other suppliers or redesigning products and processes, or building up inventory of components. This is being done as much as possible. And that will have some effect. But going back to toilet paper, when the crisis started, you went to the supermarket and saw empty shelves. But as I said before, it wasn't because of a shortage of capacity; manufacturing of toilet paper was sufficient to meet demand. I'm not an expert, but I'd think consumption was not going to change that much. So, it's a question of, "Where is all the toilet paper going?" More than half of it was being produced in large rolls that go to institutional users, like schools and factories. And they were all shut down. You can't buy big rolls for a home; it wouldn't fit. So, you had to repackage production. That took time, but not years or months—a few weeks to retool the machines. Because it's basically the same product. They also had to reallocate available supply to rebalance supply and demand, dynamically. They did all of these things, and as a result, there was lots of toilet paper on the store shelves a month later. That problem was solved.

You can try to do the same with semiconductors, but it won't work as well. You can't just repackage them.

Chips used in automobiles are also highly specialized for the design of a car. You can't take a Chevy Bolt chip and use it for a Tesla. Thus, you can't pool supply and reallocate it. You can do this with toilet paper because it's a commodity. But these chips are highly specialized, and that limits the ability to pool supply to mitigate this crisis.

Provided by University of Pennsylvania