Manufacturers
ALLIANCE
FOUNDATION

Connectivity

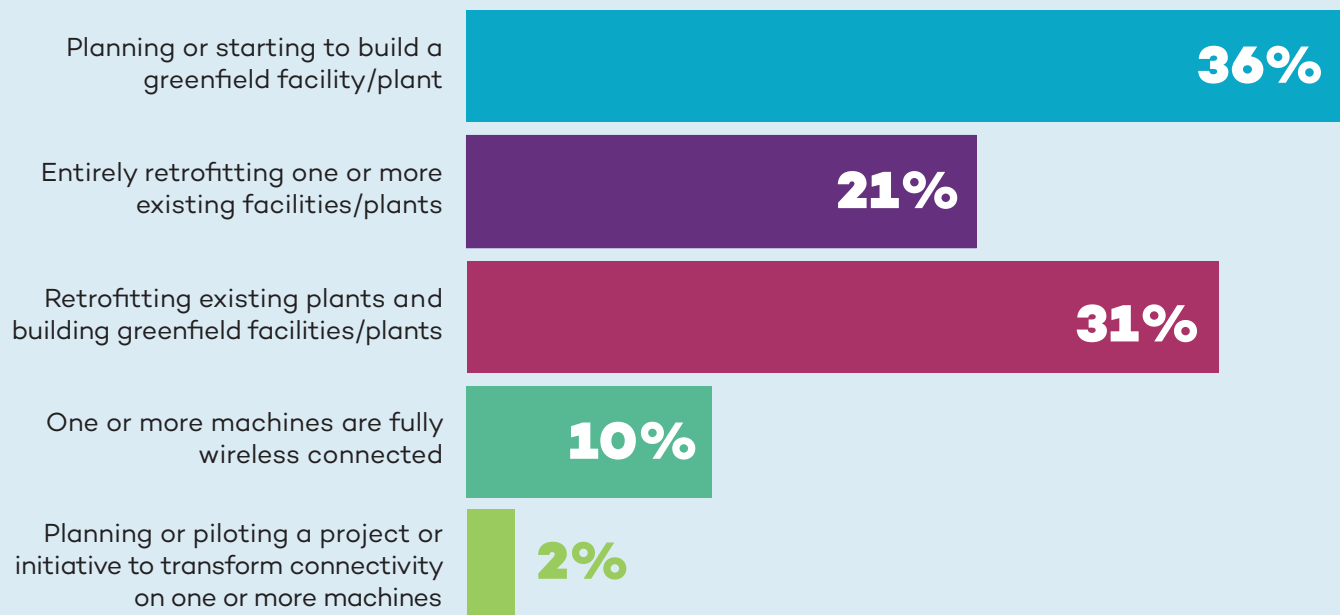## A Critical Differentiator for Digital Transformation

APRIL 2024

Building the Industrial Metaverse

The accelerated pace of digital transformation in manufacturing that started in 2020 continues as companies steer toward the vision of the industrial metaverse. Investments in new factories, plant expansions, and facility retrofits have outpaced predictions. Much of this activity is driven by the desire to bring production and supply chains **closer to the markets** they serve. Manufacturers are intent on maintaining momentum, with 36% planning or starting to build greenfield plants and 21% retrofitting one or more existing facilities. Many are actively engaged in both.

The vision of the fourth industrial revolution is starting to become reality as manufacturers layer in technologies such as advanced automation, cobots (collaborative robots), AMR (autonomous mobile robot), wireless cameras, IoT sensors, AI and machine learning, predictive analytics, and digital twins. With so much more intelligence being added to the factory every day, the industrial internet of things (IIoT) market is booming. According to **Grandview Research**, that market is expected to see a compound annual growth rate of more than 18% from 2024 to 2030.

Manufacturers Wireless Connectivity Status

Planning or starting to build a greenfield facility/plant	36%
Entirely retrofitting one or more existing facilities/plants	21%
Retrofitting existing plants and building greenfield facilities/plants	31%
One or more machines are fully wireless connected	10%
Planning or piloting a project or initiative to transform connectivity on one or more machines	2%

Source: Manufacturers Alliance and Verizon study

Manufacturers have more choices than ever about how to connect the machines and other equipment for the smart factory. Many still rely on a hardwired connection for core production machinery because of its perceived superiority in terms of reliability, performance, and security. But the latest generation of cellular technology – 5G – has come a long way from Wi-Fi, which has limited bandwidth, scalability, and signal propagation capabilities. In contrast to legacy Wi-Fi systems, 5G cellular technologies are better suited to operational technology (OT) networks in terms of speed, security, and capacity while offering greater mobility and innovative capabilities particularly relevant to smart factory requirements. For manufacturers concerned about future-proofing their connectivity choices, 5G represents state-of-the-art cellular technology with decades of support anticipated. By way of comparison, 3G cellular came online in the United States in 2001, and support continued until 2022.

As manufacturers digitize their operations, and the load of IIoT devices begins to tax their networks, manufacturers will quickly find it's not a matter of selecting wired for mission-critical use cases and wireless for everything else. Rather, the future of connectivity in manufacturing will be a carefully curated blend of hardwired, Wi-Fi, and 4G/5G. Finding that optimal mix will be the key to generating insights from data to make gains in productivity, performance, and competitiveness. As manufacturers inevitably increase the number of 5G wireless connections, they will unlock more agility in day-to-day operations, remove barriers (both physical and operational), and open up new business models and revenue streams.

Top-level findings reveal that manufacturers expect 5G to have the largest impact on manufacturing connectivity in the next three to five years, outpacing all other wireless technologies. While only a small share of those surveyed (2%) rely primarily on cellular connectivity today, 16% expect to within the next three years, an eight-fold increase. The vast majority will continue to deploy a mix of networks (wired, Wi-Fi, 5G) in their operations for the foreseeable future.

To gain a better understanding of where manufacturers stand with connectivity choices, Manufacturers Alliance partnered with Verizon to learn more about connectivity trends, best practices, and use cases. We conducted a survey of 172 U.S.-based mid-Cap to large-Cap manufacturing companies and interviewed executives representing a variety of company sizes and industries.

Investing in the Digital Backbone

No manufacturer wants to get caught unprepared by the next surge in demand or supply chain glitch. Within recent memory are the collapse and then sudden rebound of orders, record backlogs, material shortfalls, and the fierce competition for skilled talent. It is little wonder that manufacturers have focused over the last few years on long-overdue technology investments to weather the next disruption.

The first step for many is to strengthen their digital backbone. One manufacturer described an eight-year journey of ripping out consumer-grade networking gear and replacing it with critical network infrastructure. His company also updated policies around how network installations are done: "A lot of the manufacturing plants love to say, 'I'll send the maintenance manager out to wire.' When things go wrong, we discover they've installed a thousand meters of wire or something that was never going to work. So, we've made a lot of changes and put in a policy about how cables are run and certified."

In some cases, getting the communications infrastructure to the plant itself can be a challenge, especially in remote areas. Some companies are paying to lay miles of fiber optic cable in order to have any connectivity whatsoever to a remote plant. Backup connections may require satellite technology. While these are the exceptions, they nonetheless affect industries that must be located in remote areas such as paper manufacturing, mining, and oil and gas.

Sometimes the digital backbone is already in place but requires expansion. Dan Stuart, Senior Vice President and CIO at **Southwire**, talked about

the need to "increase the size of the bandwidth coming into each of our facilities" as well as the deployment of software-defined wide area networks (SD-WAN). "We needed more bandwidth within those facilities because of everything going to software as a service, IoT, sensors, and moving more of our infrastructure to the cloud."

Creating and improving the digital backbone often requires an infusion of IT and connectivity expertise. Dan Stuart shared: "We are starting to put IT resources in key manufacturing facilities because there's so much new IT gear out there nowadays, between the demand for OT security, the sensors, the IoT devices, and the new equipment – all of which are now connected to the network. This equipment cannot have downtime."

> **"We are starting to put IT resources in key manufacturing facilities because there's so much new IT gear out there nowadays, between the demand for OT security, the sensors, the IoT devices, and the new equipment – all of which are now connected to the network."**
>
> *— Dan Stuart, Senior Vice President and CIO, Southwire*

Just as IT knowledge is becoming more important on the factory floor, the 5G era will require a stronger understanding of the capabilities of cellular technology by OT teams. Manufacturers have historically relied exclusively on network operators for that expertise, but as 5G becomes more intrinsic to the value of the manufacturing process itself, building that expertise within OT teams will give them a better understanding of how to take advantage of the latest connectivity options.

# Manufacturers Are Steadily Increasing Wi-Fi Connections and Exploring 5G

As manufacturers expand and improve their networks, many of the new connections will be wireless. The devices that make up the IIoT will connect primarily via some form of wireless technology. In 2023, **47% of manufacturers** invested in Wi-Fi-enabled IIoT, up from 44% the year before.

Some companies have adopted a wireless-first strategy. Will Durfee, Senior Vice President of Global Operations told us about **Hexagon's** decision a few years ago to go wireless: "Over the last five years, we have connected a lot in operations. The primary goal was to connect our homegrown MES tool, to the ERP, our service group, PLM and our CRM, effectively becoming one-stop shopping for the people on the manufacturing floor. They no longer have to go to a PC or do any transactions on an ERP. Everything is on a touch screen, from their work instructions to cycle counting to receiving. If it's an activity that had to be done on the shop floor, it's now done in Smart Factory Manager. Everything is connected via Wi-Fi."

Today Wi-Fi is the predominant form of wireless connectivity among the manufacturers we interviewed and surveyed. But there is widespread agreement that 5G will see significant growth in the near future. As of March 2024, there are 21 billion IoT connections on 5G globally with a little more than half in enterprises and the rest consumer. The **GSM Association** predicts that 5G enterprise IoT connections globally will more than double to 38.5 billion by 2030 with 24% of those being used in smart buildings and 16% of those being used in manufacturing.

Regardless of their current reliance on Wi-Fi, most manufacturers we surveyed see the writing on the wall: about half expect 5G to have the largest impact on manufacturing connectivity in the next three to five years. While only a small share (2%) rely primarily on 4G LTE or 5G cellular connectivity today (the rest rely on a mix of wired connections and Wi-Fi), 16% expect to rely primarily on 4G LTE or 5G within the next three years, an eight-fold increase. The rest will be mixed environments of hardwired, Wi-Fi, and some cellular.

Relying Primarily on Wireless (not Wi-Fi)
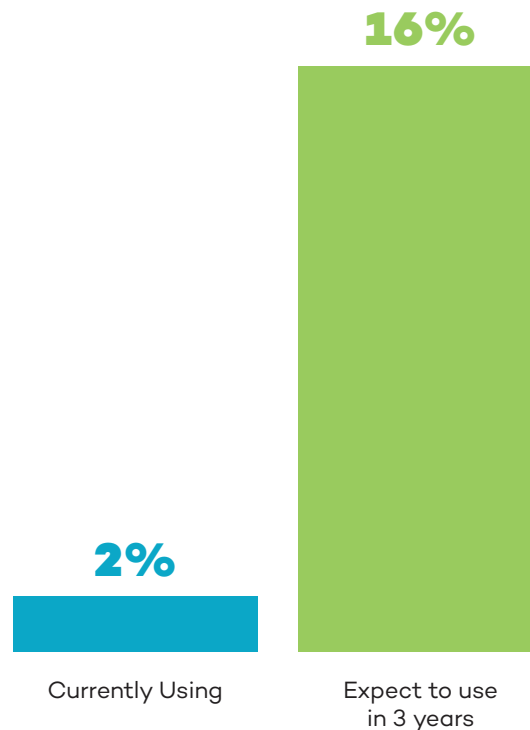
Source: Manufacturers Alliance and Verizon study

Most **5G deployments in manufacturing** are expected to be in the form of private 5G networks – standalone, non-public networks whose infrastructure is used exclusively by devices authorized by the user. Private 5G installation options range from working with a mobile network carrier, a mobile virtual network operator, or a managed service provider. A handful of manufacturers are buying spectrum and building their own private 5G networks. The number of private 5G/LTE networks worldwide is expected to grow from about 4,000 in 2022 to more than 60,000 by 2028. Of those, some 55% percent will be used by manufacturing, according to **Analysys Mason research**.

Most of the manufacturers we interviewed are in the research phase of exploring 5G, but a few have started experimental deployments. One manufacturer is piloting a private 5G network in China. Dan Stuart of Southwire told us about a 5G pilot that will begin in mid-2024 at one facility. "Coverage and performance are very important at every facility. We have AGVs (Automated Guided Vehicles) so coverage and performance needs to be flawless," Stuart said.

Siemens has deployed private 5G pilots at several factories including its production facility in Karlsruhe, Germany and **now offers a solution** enabling industrial companies to build their own private 5G networks optimized for automation applications. Experts recommend starting experimentation early so that successful pilots can be scaled and take on more complex environments as technologies mature.

5G Capabilities vs. Industrial Requirements

TYPE	5G THEORETICAL CAPABILITY	5G TRIAL CAPABILITY*	INDUSTRIAL REQUIREMENTS
Latency	1 ms	4 ms	0.5 ms to 500 ms
Reliability	99.9999%	99.999%	99.9% to 99.999999%
Jitter	/	4 ms	8 ms to 50 μs
Upload data rate	10 Gbps	1.3 Gbps	Several Gbps
Download data rate	20 Gbps	2.6 Gbps	Several Gbps
Positioning	Several decimetres	Several meters	Between 0.2 m and 10 m

*This table shows the peak capabilities exhibited in 5G trials conducted by multiple mobile operators in China at the end of 2023 using 100 MHz of bandwidth in frequency range.

Source: **GSM Association**

Wireless Benefits and Use Cases

In contrast to copper wired connections, which can be expensive and cumbersome not to mention bad for the environment, wireless is inherently mobile, cheaper to install, and easier to scale and maintain than hardwired connections.

Speaking of Hexagon's shift to Wi-Fi, Will Durfee spoke about the many benefits including becoming paperless, building a global community for real-time internal information sharing, and being able to do much more with the same employee base: "In some cases, going 100% wireless just brings a small improvement. In other areas, it takes half the people to do the job that it once took," Durfee said. "The overall measurement is our productivity. In operations we measure productivity as revenue per operations head. It doesn't matter if you're an indirect person, a supervisor, or a direct labor person. It includes everybody that supports the factory. In the last eight years (with the exception of the COVID year), we have seen a significant improvement in our revenue per operations head each year."

The most widespread use cases for Wi-Fi in the OT space currently are predictive maintenance, inventory management, supply chain visibility, and integration of IIoT devices. Manufacturers look to wireless to improve overall system interoperability, efficiency, and equipment effectiveness.

Even in organizations that have a strong preference for wired connections, there is still a place for wireless. At **Allison Transmission**, J.K. Pareek, Chief Information and Digital Officer, told us: "Where we have a fair amount of wireless installed is in warehouses and distribution centers to support the inventory check-ins, check-outs, and moves that use wireless radio frequency scanners. We also track AGVs (autonomous guided vehicles) in these locations."

The cutoff point for moving to wireless depends on the age of the equipment in the plant, according to J.K. Pareek: "We have some older plants that have equipment without network connectivity of any kind, and the operation is fairly labor intensive and manual without much automation or robotics. Those few locations have very minimal wireless coverage."

If you have a large, spread-out facility, Wi-Fi might not be as effective. Holland Ridge Farms built a private wireless network to handle the wide area of coverage needed as well as the spike caused by high-profile events that brought a lot of people (and revenue) to their main location in New Jersey. "Network connectivity is super important to us," said Casey Jansen, President and Owner of Holland Ridge Farms. "We have barns across 400 acres."

Barriers to Wireless Adoption — Why Some Manufacturers Have Not Moved Faster

The top barrier to more adoption of innovative connectivity technologies cited by manufacturers in our survey was inadequacy of IT infrastructure to fully operationalize the smart factory. Networks are outdated and lack scalability, flexibility, and resilience. Adding applications that require more bandwidth doesn't make sense if the network cannot handle the increased load.

Mike Weller, Practice Leader for Manufacturing, Energy, and Utilities at **Verizon Business**, said this is typical for many manufacturing companies right now. "When I'm talking to an operations or production person at a plant, I often hear, 'I wish I could take on more. We have a lot of ideas and innovation initiatives, but we're not sure the network can handle it. We can't risk our production and our quality because that's sacred.'" Overall, there is a reluctance to tax the network. "This means many manufacturers make do with existing production lines. The options for connectivity expand if a new production line is going to be added or if a new plant is being built," Weller continued.

Many manufacturers complain of an overall lack of strategy, governance, and ownership of the connectivity question as it relates to digital transformation. It can sometimes be left to plants to figure out for themselves.

As one consumer packaged goods manufacturer told us, "Our leadership team's attitude is basically, 'it's your problem.' As long as we're getting product out the door, they're happy. They don't care about the underlying technology." In other cases, the opposite is true with network decisions being made at the corporate level with little or no consultation of the OT team.

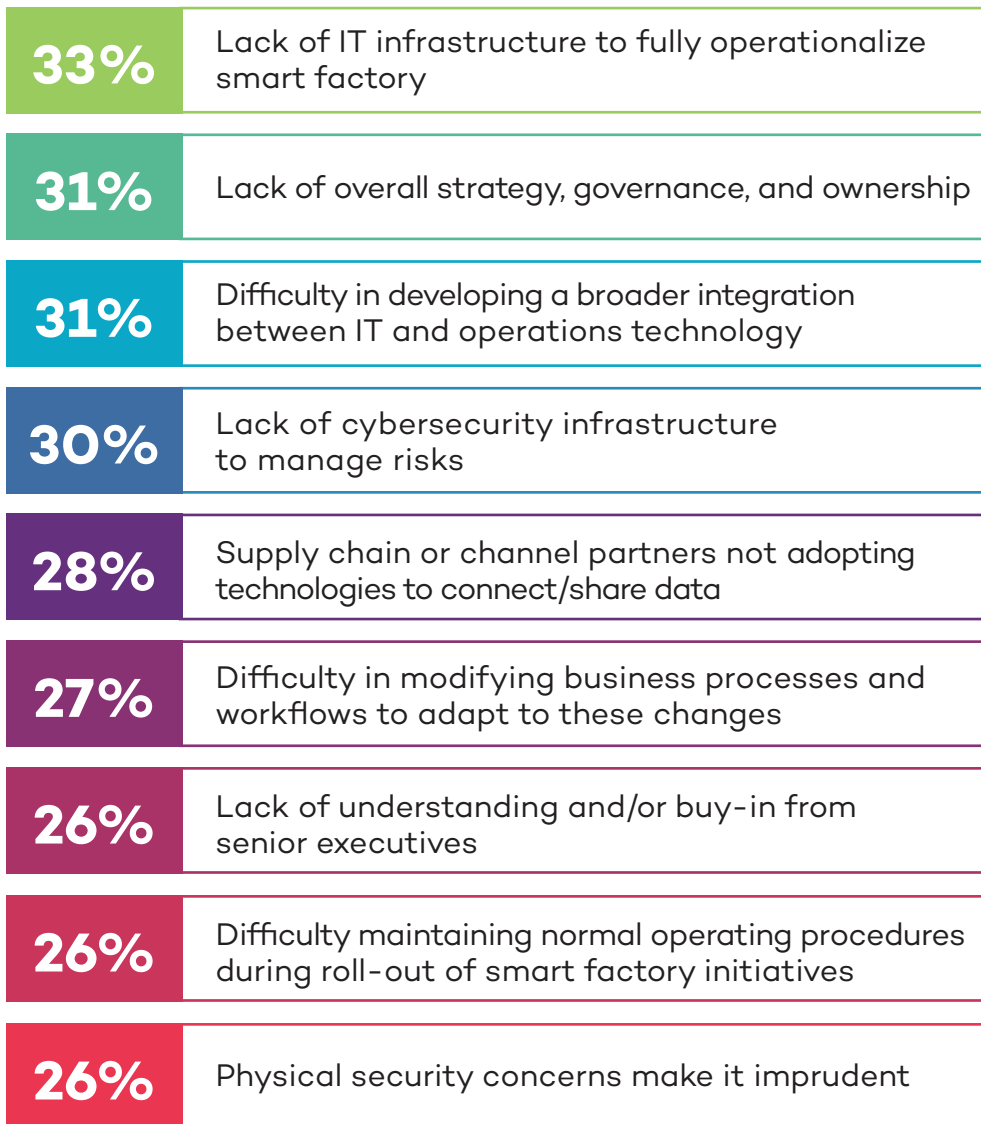This situation is compounded when senior executives do not have a firm grasp of the technology being used in the OT environment. Many manufacturers in our survey traced the problem to senior executives' insufficient understanding of technology in general. Finding a common vocabulary that everyone understands is even harder when there is friction between IT and OT departments, a challenge that many manufacturers face.

Lack of awareness of the benefits of 5G in particular is also a problem. According to studies published by EY, **poor grasp of 5G's relationship** to other emerging technologies was identified as the first and second most critical internal challenge to 5G in 2022 and 2023, respectively. In some ways, this lack of awareness is completely understandable.

As Mike Weller of Verizon Business put it: "It's absolutely fair for a manufacturer to have questions about moving on from wired connections. In the past, wireless connections didn't meet the standards for reliability, security, and performance. There has been a longstanding relationship with wired connections because in the past there weren't other good options available. With 5G, there are."

Company Challenges Regarding the Launch or Execution of Innovative Connectivity Technologies

33%	Lack of IT infrastructure to fully operationalize smart factory
31%	Lack of overall strategy, governance, and ownership
31%	Difficulty in developing a broader integration between IT and operations technology
30%	Lack of cybersecurity infrastructure to manage risks
28%	Supply chain or channel partners not adopting technologies to connect/share data
27%	Difficulty in modifying business processes and workflows to adapt to these changes
26%	Lack of understanding and/or buy-in from senior executives
26%	Difficulty maintaining normal operating procedures during roll-out of smart factory initiatives
26%	Physical security concerns make it imprudent

Source: Manufacturers Alliance and Verizon study

Security Concerns About Wireless and How They Are Addressed by 5G

When we asked manufacturers to identify their number one concern about deploying wireless of any type, security was by far their top concern. This is hardly surprising since manufacturing has become the **number one target** of hackers. The dramatic proliferation of IIoT devices on the shop floor increases the size of the attack surface and therefore vulnerability. The fact that 5G can handle much more device density compared to Wi-Fi (**Wi-Fi 6 supports 1,024 devices per access point versus 5G which supports 1,000,000 per square kilometer**) seems to compound the problem.

Cellular communication experts point out that security capabilities built into 5G communications are more sophisticated than those of 4G or other previous generations. Instances of cell phone hacking typically occur when users expose their devices to unsecure public Wi-Fi, charging stations, infected laptops, or suspicious apps. "When you look at cellular and the embedded security characteristics, such as double the rate of encryption over LTE and two-way authentication, there are lots of embedded capabilities that prevent these types of networks from being compromised," Mike Weller explained.

Weller notes that each company must determine its own security posture to define the right balance between security, agility, and flexibility. "If you want to be 100% secure at all times in all ways, the behaviors and practices that you impose on your employees and processes can become very prohibitive, so in order to maintain that agility and flexibility, you have to find the optimum balance," Weller said. For most manufacturing organizations looking at 5G, "security is not a showstopper that precludes them from moving forward with cellular deployments," he added.

Conclusion: Find the Right Balance

Manufacturers are in the process of rethinking their connectivity strategies and testing when and where they can add more wireless including Wi-Fi, 4G LTE, and 5G. New production lines and greenfield plants provide a blank slate on which to test new wireless strategies. As Mike Weller explained: "When you look at the 20- or 30-year lifecycle of a building, we see a lot of customers looking at the cost to wire the facility. By opting for wireless, they recognize they can take out literally tens of millions of dollars from their infrastructure cost in certain size spaces. This doesn't mean that they will go 100% wireless, but it does mean that they greatly reduce the amount of investment in cabling infrastructure including the cable cost, labor, telco closets and their electronics, plus the cost of MAC (moves, adds, changes) that comes downstream. All that copper you're not buying is going to support your ESG goals as well."

Even companies that have a clear commitment to using wired connections on core production machinery are open to 5G in the future. As Dan Stuart of Southwire told us: "When we build new warehouses, our focus is to automate as much as possible — that means wireless where we can, access points to cover all devices, and from a security standpoint, we still want certain machinery to be segmented and have static IP addresses. I think wireless becomes more interesting when you're building a large factory or facility, but security, coverage, and speed must be top priority."

Most manufacturers expect to have a mixed landscape of hardwired, Wi-Fi, and cellular connectivity for the near term. This is especially true as wireless connectivity options expand to include both licensed and unlicensed spectrum, lower bands, and multiple flavors of 5G. Each manufacturer will have the flexibility to align the right spectrum with the right use case to optimize costs and performance. "It's going to be a combination of things and 5G will be part of the overall wireless connectivity solution portfolio that manufacturers will look for," Mike Weller of Verizon pointed out.

> **"Our customers are really interested in being able to hit ESG targets as a result of wireless investments."**
>
> *— Mike Weller, Practice Leader for Manufacturing, Energy, and Utilities for Verizon Business*

Some of those use cases for advanced wireless connectivity will be those processes that require high-resolution visual inspections for quality, automated mobile robotics, AGVs, remote control of machines in hazardous areas, and inventory control. These processes require the kind of high bandwidth and low latency provided by 5G. Many of these use cases will rely on edge computing which was identified by 52% of the respondents in our survey as a top connectivity priority for the next three to five years.
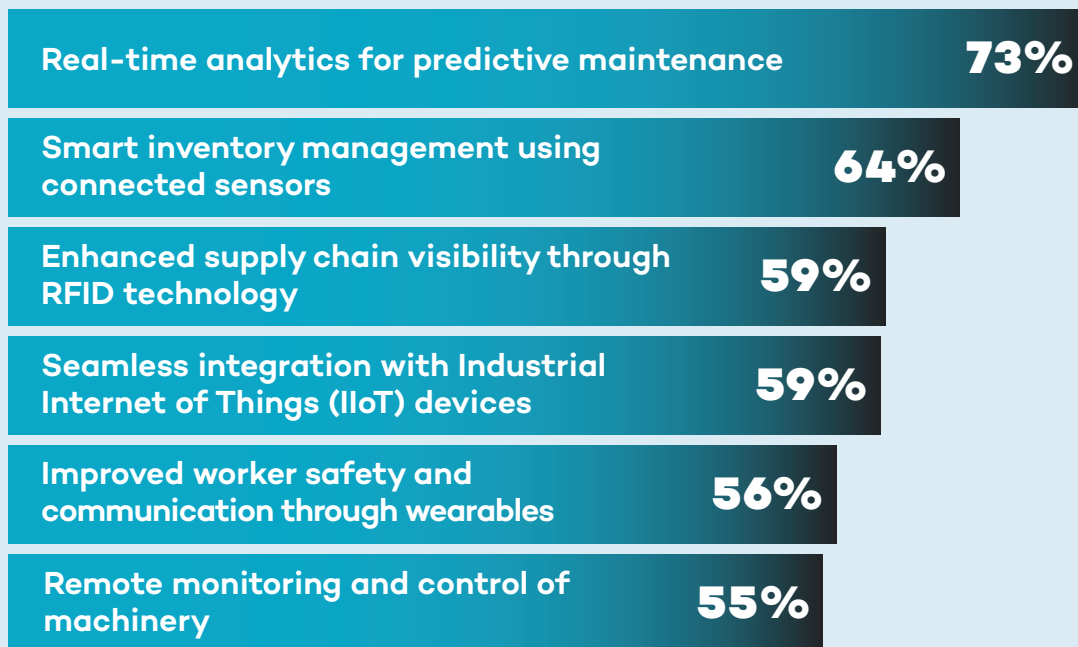
As manufacturers continue to acquire knowledge and experience with 5G, new use cases that are unique to 5G technology will gain traction. With "network slicing" manufacturers can carve up spectrum on their private network and prioritize different applications and services that make sense for their business. For example, at the end of the day, when production ramps down and warehouse operations ramp up, the network can reallocate more bandwidth to warehousing and shipping on a dynamic basis. This is where 5G distinguishes itself from all other types of wireless technology which force all users to share the same bandwidth.

Above all, manufacturers can look to 5G to break down barriers between the physical and digital worlds in a way that was not possible with less powerful connectivity options. Increases in speed, capacity, reliability, and security open up more use cases for mobile wireless connections. Entirely new functionalities offer manufacturers the ability to re-engineer and streamline existing processes and imagine new ones that were previously impossible.

Perhaps most promising is the potential to use advanced connectivity to create new business models and revenue streams based on aftermarket services and solutions powered by 5G. For companies that manufacture 5G-enabled products, such as automotive companies, heavy equipment makers, and automation suppliers, there is a clear desire to develop an early expertise with 5G in their own operations to create more valuable connections with their end customers to feed into the innovation lifecycle.

Top 6 Applications that Manufacturers Are Leveraging Through Wireless Connectivity

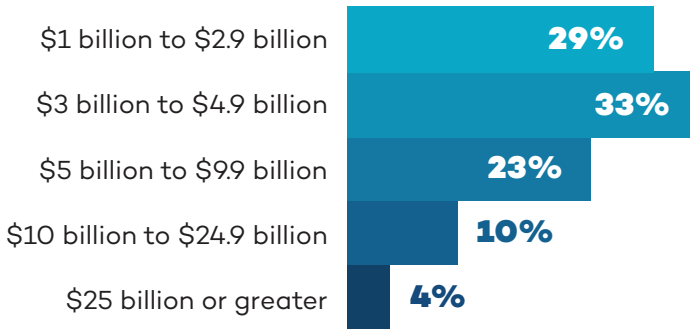| Application	Percentage
Real-time analytics for predictive maintenance	73%
Smart inventory management using connected sensors	64%
Enhanced supply chain visibility through RFID technology	59%
Seamless integration with Industrial Internet of Things (IIoT) devices	59%
Improved worker safety and communication through wearables	56%
Remote monitoring and control of machinery	55%

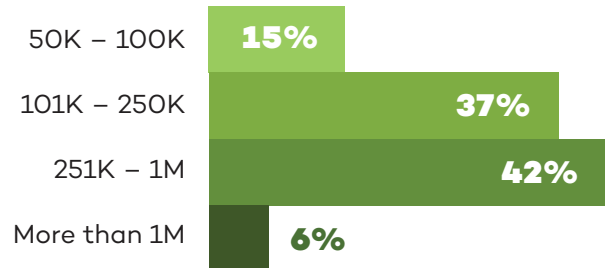Source: Manufacturers Alliance and Verizon study

About this Research

Manufacturers Alliance and Verizon surveyed 172 leaders in manufacturing to better understand connectivity trends, best practices, and use cases. The Alliance has highlighted some statistics about the companies surveyed.
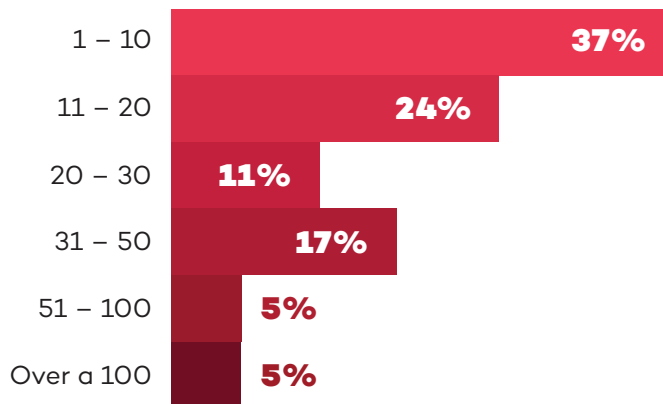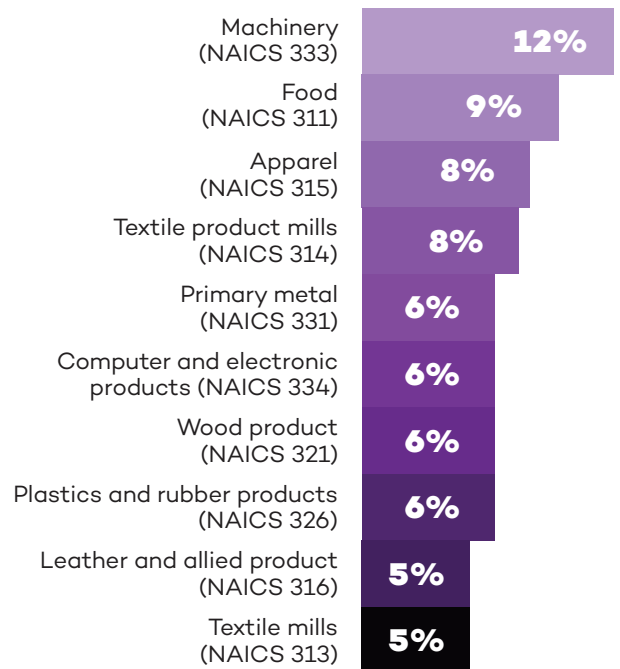
Annual Company Revenue

- $1 billion to $2.9 billion — **29%**
- $3 billion to $4.9 billion — **33%**
- $5 billion to $9.9 billion — **23%**
- $10 billion to $24.9 billion — **10%**
- $25 billion or greater — **4%**

Average Factory Size
(in Square Feet)

- 50K – 100K — **15%**
- 101K – 250K — **37%**
- 251K – 1M — **42%**
- More than 1M — **6%**

Number of Factories in the U.S.

- 1 – 10 — **37%**
- 11 – 20 — **24%**
- 20 – 30 — **11%**
- 31 – 50 — **17%**
- 51 – 100 — **5%**
- Over a 100 — **5%**

Primary Industry

- Machinery (NAICS 333) — **12%**
- Food (NAICS 311) — **9%**
- Apparel (NAICS 315) — **8%**
- Textile product mills (NAICS 314) — **8%**
- Primary metal (NAICS 331) — **6%**
- Computer and electronic products (NAICS 334) — **6%**
- Wood product (NAICS 321) — **6%**
- Plastics and rubber products (NAICS 326) — **6%**
- Leather and allied product (NAICS 316) — **5%**
- Textile mills (NAICS 313) — **5%**

Source: Manufacturers Alliance and Verizon study

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For more information, visit **ManufacturersAlliance.org/foundation**.

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