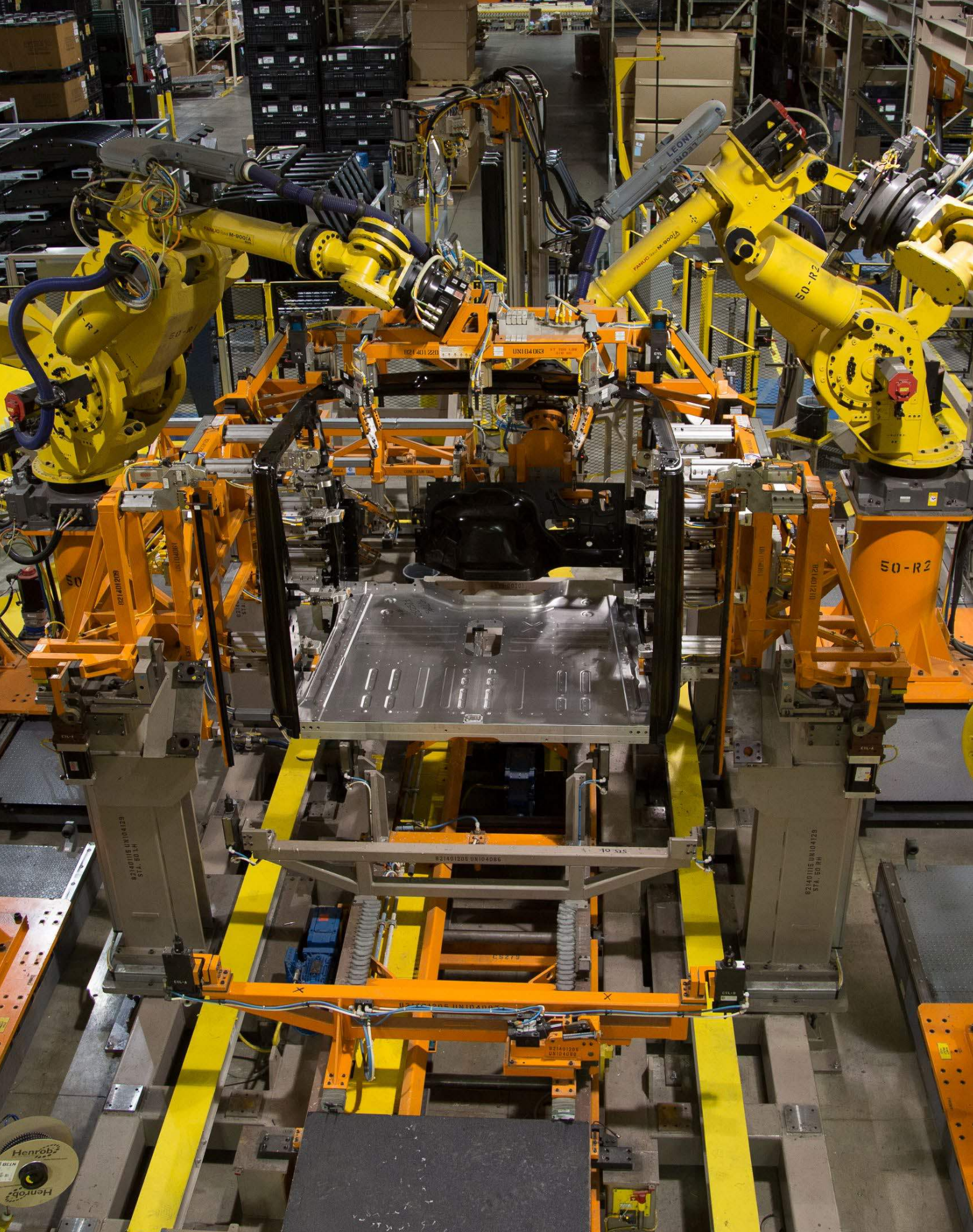


CONNECTING MANUFACTURERS WITH THE FUTURE:

How 5G is Transforming the Manufacturing Landscape



MANUFACTURING
Institute





The combinatorial power of 5G and manufacturing has broad implications.

It is a new day in modern manufacturing. Changing operational requirements are increasingly demanding data-intensive technologies. At the same time, the existing wireless network protocols are not fully suited to deliver everything the modern manufacturer needs. Increasing deployment of the fifth generation of cellular wireless technology, colloquially known as 5G, will empower manufacturers and their workers to meet this future.

5G will usher in faster speeds, greater throughput and lower latency. The network specifications also promise greater reliability, extended battery life for connected devices and support for massive device connectivity. Not only will these network characteristics combine to revamp current manufacturing activities, but 5G will also be a catalyst for innovation. 5G will empower workers across the factory floor in myriad ways, helping to support the men and women who make things in America.

The following paper presents new research exploring how manufacturers perceive 5G capabilities and their plans to fully utilize the unique potential of 5G connectivity. 5G is a key ingredient in defining the next generation of manufacturing in America. With its help, manufacturers will improve the quality of products, optimize workflow and deliver new products and services to internal constituents and external customers.

The combinatorial power of 5G and manufacturing has broad implications. Nearly all manufacturers believe 5G connectivity will be important to the overall future of their businesses. Crucially, the faster 5G technology can be deployed to manufacturing, the more competitive manufacturers feel they will be; the vast majority report the speed of 5G deployment will have a positive impact on their ability to compete globally. The rate of 5G uptake among manufacturers, and what they can accomplish with this transformative technology, could increasingly define the competitive landscape and thus manufacturing more broadly.

Executive Summary

Manufacturers believe 5G connectivity will be important to the overall future of their business.

- Nearly all manufacturers (91%) believe 5G connectivity will be important to the overall future of their business, with three-fifths (61%) indicating it will be “extremely important.”

Manufacturers are beginning to test and implement 5G solutions.

- More than half of manufacturers (56%) report they will be testing or using 5G in some capacity within their facilities by the end of 2021.
- In the long run, most manufacturers are likely to implement 5G technologies. Only a very small percentage of manufacturers (2%) believe they will never implement 5G solutions.

Manufacturers believe speed of 5G deployment is important for global competitiveness.

- Nine in ten (91%) manufacturers indicate speed of 5G deployment will have a positive impact on their ability to compete globally, with nearly two-thirds (62%) signaling it will have a “strong positive impact.” 5G will help define global competitiveness in the decade ahead.

5G can help manufacturers adapt to challenges in the aftermath of the COVID-19 pandemic.

- Manufacturers overwhelmingly believe 5G connectivity can help them adapt to challenges related to COVID-19. Nine in ten manufacturers (88%) indicate 5G connectivity will allow engineers to troubleshoot remotely. An equivalent number of manufacturers (87%) also report that remote visibility and monitoring enabled by 5G will help them adapt to the COVID-19 crisis.

5G will aid manufacturers with existing ways of doing business.

- Nine in ten manufacturers believe the utilization of 5G in their facilities will help with existing ways of doing business (92%) and will further advance existing processes (88%).

5G will drive new processes and create new business opportunities for manufacturers.

- The creation of new processes and businesses is an especially important outcome of 5G deployment. Beyond what manufacturers are currently doing in their facilities, nine in ten manufacturers also expect the utilization of 5G to lead to the creation of new processes (88%) and the creation of new businesses (86%).

91%

of manufacturers believe 5G connectivity will be important to the overall future of their business

56%

of manufacturers report they will be testing or using 5G in some capacity within their facilities by the end of 2021

91%

of manufacturers indicate speed of 5G deployment will have a positive impact on their ability to compete globally

88%

of manufacturers indicate 5G connectivity will allow engineers to troubleshoot remotely

5G will help transform supply chains and factory operations.

- Manufacturers expect 5G to have a strong impact on many facets of factory operations. Four-fifths of manufacturers indicate 5G technology will be important to inventory tracking (83%), facility security (81%) and warehousing and logistics (81%) within their facilities. Furthermore, three-fourths of manufacturers indicate 5G will also be important to inspection (76%) and assembly (76%) activities, with seven in ten saying packaging (72%) and employee training (71%) efforts will benefit from the deployment of 5G to manufacturing.
- Manufacturers also report 5G will impact specific applications on the shop floor, including equipment monitoring and control (89%), safety procedures that analyze sensor data in real time (87%) and employee safety (86%). The vast majority of manufacturers also report that 5G will aid remote analytics to support real-time decision making (84%), condition-based remote monitoring for predictive maintenance (84%), asset tracking (83%) and preventative maintenance (82%).

5G will drive cost savings for manufacturers.

- Nearly all manufacturers expect to see some level of cost savings (93%) as a direct impact of connecting their machines and equipment wirelessly with 5G. On average, manufacturers anticipate estimated costs savings of roughly 38%.

5G will increase machine and employee productivity.

- Nearly all manufacturers expect to see some level of productivity gains in machines (94%) and workers (93%) from the implementation of 5G. On average, manufacturers anticipate estimated equipment productivity will increase by roughly 42% and worker productivity will increase by 41%.

5G is expected to improve numerous manufacturing activities that rely on network connectivity.

- Compared to current connectivity technologies, two-thirds (65%) of manufacturers surveyed indicate 5G is superior in terms of increased efficiency, and more than half feel 5G will provide for improved quality

and service (56%) and greater flexibility (53%). In addition, two-fifths believe 5G will be advantageous as it relates to enhanced safety and security (45%) and increased competitiveness (41%), with one-third who believe it will provide for shortened lead times (35%) and lower cost (32%).

- When asked about a set of manufacturing activities, manufacturers report all are expected to become easier with 5G. Notably, reconfiguration of production lines, considered to be the most difficult manufacturing activity using current technologies, is expected to see the greatest improvement in terms of “ease” when 5G technology is utilized. Manufacturers also expect the utilization of 5G



to drive considerable improvements in “ease” surrounding remote control of equipment, utilization of augmented reality/virtual reality (AR/VR) applications, utilization of mobile robots and autonomous guided vehicles and automation.

The number-one driver of 5G adoption for manufacturers is the ability for quality control monitoring throughout the production process.

- More than half of manufacturers also report increasing machine productivity (53%) will drive 5G adoption.

Why 5G Matters for Manufacturers

Manufacturers are consistently looking for ways to improve operational performance and build greater resilience into their processes. One promising potential is the expanding deployment of 5G connectivity and the ensuing services and opportunities that will arise from pervasive and ubiquitous connectivity.

It is vital to recognize that 5G connectivity is fundamentally different from its predecessors. While the naming convention might suggest that 5G is simply a linear extension of previous cellular networks, 5G is a significant step beyond 4G. There is a common misconception that 5G will deliver better and faster mobile broadband but little more. In reality, each iteration of cellular network technology has unique characteristics and properties and, as a result, has ushered in entirely new use cases. This is especially true with 5G. The 2G network delivered massive mobile voice communication. The 3G network introduced basic mobile broadband functionality. And the 4G network empowered mobile streaming of graphic-rich content. Each iteration connected a wider and more diverse swath of objects and brought exponential increases in mobile traffic data.

5G has unique properties and attributes, which will define its disruptive characteristics. These include high data rates, higher system capacity, reduced latency and massive device connectivity. Commercial 5G deployment will expand network possibilities beyond any of the previous cellular network technologies. 5G is a technological paradigm shift, not just an extension of existing technology.

The unique characteristics of 5G will have an outsized influence on manufacturing and the industrial economy. High data volumes will enable augmented and virtual reality to be delivered over mobile networks, usher in 8K video capabilities and replace fixed broadband, meaning more objects can be connected in more places. Low latency enables mission-critical applications, such as remote mining, traffic control, holograms and real-time factory control. Massive device connectivity will change how and what is measured through applications such as smart meters, logistics tracking and smart biometrics. Reliable and resilient characteristics of the 5G network will enable driverless vehicles, the ability to control mobile robotics in real time and wider reliability on drones.

The 5G standard was designed with objectives that are entirely different from previous cellular networks. 5G removes barriers that exist in predecessor networks, enabling its ability to deliver new services not previously possible.



5G has unique properties and attributes, which will define its disruptive characteristics. 5G is a technological paradigm shift, not just an extension of existing technology.

What is 5G?

Nearly 50 years ago on a street in midtown Manhattan, Motorola engineer Martin Cooper made the first cellular call. While the wireless revolution started with voice communications, each subsequent iteration of the cellular network has represented a leap forward as wireless networks have accommodated another defining technological revolution: the rise of the internet. In doing so, each major wireless generation since that critical phone call has been defined by ever-improving data capacity and a wider array of services that can be delivered over the cellular network:

- **1G (1979):** voice calls
- **2G (1991):** digital voice, text messaging, dial-up data speeds
- **3G (1998):** email, pictures, web
- **4G (2009):** streaming video

5G represents the fifth major milestone for wireless communications. It ushers in a host of capabilities that include the following:

SPEED

5G networks can peak at a rate that is about 20 times higher than that of 4G networks, with even higher throughput possible in the future.

LATENCY

5G networks can send “roundtrip” data (send data to a destination and back) in less than 10 milliseconds, a number that may drop to under five milliseconds in the future.

CAPACITY

5G networks can capture data from hundreds of thousands of sensors per square mile.

RELIABILITY

5G networks can reach up to “five nines” (99.999%) reliability, making them an excellent option for mission-critical applications.

HANDOFF

5G networks can seamlessly hand off data to each other even when devices are traveling at hundreds of miles per hour, ensuring a robust connection for high-speed applications.

EFFICIENCY

Remote sensor devices applications connected via 5G low power can operate for nearly a decade on battery power.



5G offers three main types of communication services or use cases: enhanced mobile broadband services (eMBB), massive machine-type communication (mMTC) and ultra-reliable, low-latency communications (URLLC):

- eMBB improves what we normally think of in terms of cellular service: fast access to data from devices such as smartphones, laptops or vehicles for applications such as streaming video. Initial 5G deployments have focused on this service.
- mMTC brings 5G support for low-power devices such as sensors and other intelligent devices that may need to last in the field or factory for years on a single battery charge. It builds on LTE standards support for such devices.
- URLLC is for devices that need very responsive data connections (e.g., communication between two autonomous cars on a highway seeking to avoid a collision). URLLC is supported by 5G NR (New Radio). It can therefore achieve far greater performance than LTE and is key to realizing the full potential of 5G.

5G is also often associated with initiatives that are not an intrinsic part of the standard, but which are highly complementary. One such example is MEC (Multi-Access, or

Mobile Edge Computing). MEC is designed to improve performance of high-bandwidth, low latency applications (e.g., shared augmented reality or cloud-based games).

5G expands wireless technologies to a much wider range of industries and use cases.

MEC allows for more processing at the edge, which means reducing the need to move data from machine to cloud and back in the process of performing data-heavy activities. In this way, manufacturers can take advantage of MEC to reduce the latency for certain applications and can also prioritize mission-critical data. Manufacturers will be using MEC to control robots, drones and other equipment that will require low-latency, high-reliability, increased privacy and security, so their performance isn't hindered by the roundtrip time it takes data to move from machine to cloud.

As we are early in the 5G transition, we can draw some comparisons with the early days of the 4G networks we have used extensively for the past decade:

- Like 4G before it, which got faster over the years as the standard was improved, 5G is rolling out in stages and will get faster in the coming years. Its advances are defined by

releases created by a governing international body focused on many technical details covering the evolution of cellular standards. Release 15 defined the initial 5G standard in 2019. Releases 16 and 17, focused on improving efficiency and power management among many other things, were approved in 2020, and Release 18 is slated to be approved in 2021.

- Also, like 4G, it will take some time for carriers to make coverage widespread. While U.S. carriers have made good progress in building out their networks since 2019, we can expect both coverage and speed to improve in 2021 and beyond. Even so, 5G has been adopted more rapidly by carriers around the world than 4G was.
- Telecommunications company Ericsson estimates 5G coverage reached 15% of the global population by the end of 2020, up from 5% at the end of 2019. Furthermore, they estimate this will grow to 60% by 2026, making 5G the fastest deployed mobile communication technology in history.¹
- Just as 4G networks require devices such as smartphones to have 4G capabilities to take full advantage of the network's speed, so do 5G networks. In 2020, almost all major U.S. smartphone makers released at least one 5G smartphone.



Other device makers also released 5G-enabled laptops, tablets, and hotspots.

5G is not the only wireless network technology that has recently seen a major update or statement of support, although the others are focused on much different solutions and applications. They include the following:

- Wi-Fi 6e: Wi-Fi 6e represented a generational leap in terms of speed and network congestion management versus previous generations. More recently, however, the technology has been extended into a new spectrum band that offers more capacity than the previous bands did combined. While this should result in the best Wi-Fi performance we have seen to date, Wi-Fi can be an alternative to 5G where 5G isn't available.

5G provides network characteristics well-suited for crucial manufacturing activities and enables factories of the future.



However, it remains focused on local networking and cannot match the range or device density capacity of 5G.

- Bluetooth 5.2: The latest version of the popular standard linking smartphones to headphones and other peripherals will see improvements in terms of energy consumption and can be used for short-range precise object location.
- UWB: Like Bluetooth, ultra-wideband can be used for short-range precise object location. Leading smartphone makers are now integrating UWB into their smartphones.

These shorter-range technologies are highly complementary to 5G and should be broadly supported in smartphones and other devices in the coming years.

Banding Together

All cellular networks operate in certain parts of the radio wave spectrum. In general, the higher the frequency number, the faster the maximum data rate is but the shorter the range is. Today, 4G networks operate below 6 GHz. The networks offering the best range operate in “low bands” such as 600 MHz and 700 MHz frequencies in the United States.

5G networks can also operate in these ranges, but today deliver only marginally faster connections. This is because it’s been far more effective for carriers to roll out 5G using the same core technology used for LTE networks. In fact, LTE users benefit from the more efficient use of network capacity enabled by 5G. Over time, carriers will roll out standalone core networks (5G NR) that, in addition to offering greater speed, will bring tremendous gains

in reliability and guaranteed quality of service options.

5G can also operate in “mid-band” frequencies such as 3.5 GHz that offer a speed bump when compared to some of the lower frequencies; these have not been as broadly available in the U.S. as in other countries. Mid-band spectrum is home to a variety of critical operations. Additionally, the federal government auctioned off several blocks of spectrum in these frequencies in 2020 so we should see increased 5G-related activity in this band, (e.g., by using a technology called CBRS (Citizens Broadband Radio Service) intended expressly for private cellular networks).

The most impressive speed gains take place above 24 GHz. However, the ranges of these “millimeter-

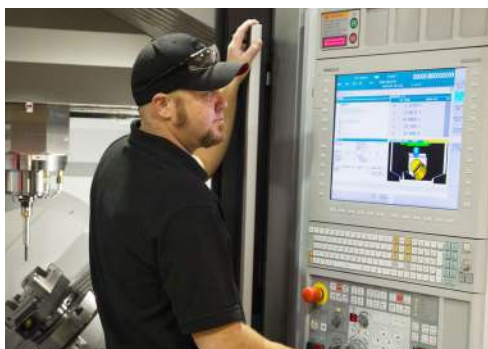
wave” implementations are limited; they have been deployed mostly in large open spaces such as parks and football stadiums but can also be effective for factories. The U.S. has been early to embrace these networks, but many carriers around the world plan to deploy millimeter-wave networks in 2021 and beyond.

Overall, 5G will evolve to become much faster than 4G. While 4G networks top out at about one gigabit per second, 5G networks are expected to reach up to 10 times that rate. In addition to speed, 5G offers other benefits, including much lower latency, the transmission time between when data is sent and received on the network, that may become as short as a few milliseconds. As a result, 5G will be a key enabler for manufacturing and industrial applications and innovations.



5G Manufacturing Applications

Manufacturing can often be a linear process that requires long lead times and carries significant risk of breakdowns and waste. As they face ever-growing global demand and ever more aggressive competition, however, manufacturers apply sophisticated approaches to monitoring and improving their operations. This adaptability is a key tenet of what is often called Manufacturing 4.0 or Industry 4.0. Factors include availability of production, which can be compromised by unplanned downtime; performance, or how well equipment is working versus its optimal capacity and production rate; and quality of output. As the global pandemic clearly demonstrated, factories must be increasingly flexible, able to be reconfigured with different production lines depending on what can be sudden shifts in demand.



5G can help realize the ideal of a modular factory where machinery can be quickly reconfigured to optimize production. It not only stands to improve the richness of communication among staff, but also keep them safer as it can facilitate data collection from a

dense population of sensors at a previously impossible scale. And it will be able to head off problems by enabling systems that automatically schedule maintenance or order replacements for consumables to

5G can help realize the ideal of a modular factory where machinery can be quickly reconfigured to optimize production.

ensure there is minimal downtime. It paves the way for self-configuring manufacturing lines, proactive equipment maintenance determined by analyzing sensor data and autonomous vehicles that can begin or perhaps one day complete outbound logistics.

Many technologies need to mature to realize this vision, with key components taking a leap forward due to 5G. Behind the “magic” will be billions of data points developed into sophisticated data modules, analyzed for optimal efficiency and visualized in dynamic ways. While many of these applications relate to each other, they also have value outside of their linked application. Five of the key applications are digital twins, the industrial internet of things, extended reality, autonomous vehicles and robotics and safety and security. While parts of these services can be enabled by existing cellular technologies, it will require 5G connectivity to deliver them at scale.



Digital Twins

For years, movie and video game studios have used motion-capture technology to create lifelike models of how actors move. What if that kind of sensor-driven modeling could be applied to an entire organizational process? That is the foundational idea of a digital twin, a computer model that represents its physical counterpart so well that it can be used to understand and predict changes with how people, products and processes interact.

Digital twins can be used reactively or proactively. When used reactively, they can be studied to pinpoint inefficiencies that may be difficult to detect using only visual observation. When used proactively, managers can conduct “what-if” scenarios that can be analyzed without disrupting production processes.



Digital twins usually require large datasets to be effective. 5G networks can not only facilitate the transmission of these datasets across vast distances at very high speeds but, with its low-power variants, can enable sensors for applications that may require far-flung sensors in remote locations such as stretches of roads or fields in agriculture applications.



A View from Manufacturing: A Conversation with Honeywell's Chief Commercial Officer **Usman Shuja**

What is Honeywell's vision for 5G?

We believe that every enterprise in the future will need enterprise performance management capabilities. This means there is a single pane of glass where you can see all of the assets, people and processes in one place and you can know all of the interdependencies that exist. We believe you should be able to monitor and operate your business from anywhere in the world. If you're a facility manager, for example, you could do that sitting at a Starbucks, because you have access to all relevant data. You know who is coming into the facility, what your maintenance needs are, how much energy you're using and when your contracts are being renewed. You have all of that in one place, because systems can talk to each other.

Today companies have very limited visibility, but once they gain real-

time visibility into their operations, they can know how their factories are performing, how their supply chains are working, where the risks are and ultimately where the opportunities are. The vision is to have a single view of enterprise-level risk and opportunities and to be able to address these remotely and autonomously.

Why is 5G needed to accomplish this vision?

For static reports, or other information that does not change on a daily or hourly basis, Wi-Fi or other connections might be sufficient. To have a global, enterprise-wide view, we need a single communication pipe that is everywhere. That is where the power of 5G comes in. It's global, and it can transport different types of data. It is not restricted.

The next evolution of this is autonomy. 5G allows us to make little things in the buildings, the facilities and in the supply chain act like a system of systems. It gives us much lower granular level of insights than we can achieve today.

For technology to be adopted, the ROI has to make sense, and the business case has to make sense. The power of AI and 5G and IoT put together is so big that you cannot ignore it. Moreover, in the early months of COVID-19, many manufacturers could not even operate their factories. So, the need for digitization and 5G is even stronger because of COVID-19.

5G enables continuity and richness of data so you can make real-time decisions. Richer and more continuous data provide greater visibility. When you collect machine information from sensors for example, you might be collecting it for maintenance. But the data can also be extended for different applications, and we can use it to build different applications. We can keep using data in multiple different ways. This is what we call extensibility

of the dataset. 5G will take this to a level previously unavailable to manufacturers.

How can 5G empower a system of systems?

Today there are systems that do not talk to each other. A fire system is separate from a BMS system because they were designed separately, and they were installed separately. But the problem is that is not the way it should be operating. With a system of systems approach, these could talk to each other. They could be context aware and dependency aware.



If one camera is broken, or is about to be broken, then it can call on the inventory system, and say, “It looks like this camera is going to break, and I need to either make a repair or I need to order a part to fix it.” This is enabled because it is aware of its environment, and it can talk to other systems like the inventory management system. So, all of these diverse systems can communicate in real time and act like one system.

What are some of the most promising aspects of 5G for manufacturers?

Latency and coverage are big issues for IoT. In a lot of manufacturing plants, there is no access to connectivity, so you cannot implement IoT solutions. Speed and dependency allow you to go autonomous. Autonomy cannot happen without 5G. 5G also enables supply chain visibility like nothing has ever done before.

Industrial Internet of Things

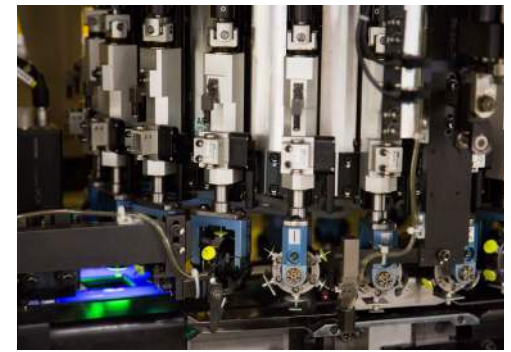
The Internet of Things refers broadly to the billions of sensor-driven devices that will connect to the global network in the coming years. Many of these will be part of the Industrial Internet of Things (IIoT). These device deployments focus on measuring the operation of and parameters around many production-related environments. This will include measuring how efficiently factory machines are operating and the environmental factors that can affect that operation such as temperature and humidity. Likewise, IIoT will also lead to energy savings and more energy-efficient operations.

IIoT devices can be a critical component in developing a digital twin application, but they can also have great value for other applications. For example, IIoT sensors can be used to provide real-time input to factory-floor workers on the operational health of machines, helping to ensure worker safety. They can also report on longer-term potential challenges, such as whether a part needs to be replaced or whether lubricant needs to be ordered to ensure its optimal operation. IIoT-driven data can even unlock new business opportunities in terms of allowing precise monitoring of costs for manufacturing-as-a-service scenarios.

One example of an IIoT-driven application is “track-and-trace.” Indoor tracking and tracing of assets usually consists of scanning barcodes or RFID tags to determine

their location. In the future, however, this may be augmented or replaced with technologies such as Bluetooth or UWB, resulting in a stream of real-time data that can be transferred

5G provides the capability and capacity to connect myriad sensors throughout manufacturing facilities and plants.



among facilities via 5G. The case for 5G is even greater for outdoor track-and-trace, where technologies such as GPS, 5G and, ultimately, smart roads can deliver real-time intelligence on variables such as load optimization and handoff between sites.

Another example relates to emergency stop switches. Historically, these have been permanently wired to machines, limiting their control to only that machine. Using 5G, which can be as reliable and responsive as a wired connection, switches may be able to shut down multiple machines in case of a malfunction or accident, improving worker safety.

Extended Reality

Extended reality, or “XR,” represents the set of technologies that runs the gamut from virtual reality—an immersive experience that completely shuts out the physical world—to augmented reality, in which digital objects appear and can be manipulated in the real world.

XR has many horizontal business applications. For example, several companies have developed meeting room collaboration applications for geographically dispersed teams; these include digital versions of many of the tools used in in-person meetings, such as whiteboards and sticky notes. Some even allow the inclusion of two-dimensional PC screen output for viewing webpages in a virtual environment. However, XR has particular value in sectors like construction and manufacturing, where participants can see detailed



models of complex machinery. Manufacturers can present data and information about machinery in spatially relevant ways, which in turn can aid workers in maintenance, repair and training.

XR applications are ideally experienced through a headset. These have ranged from inexpensive VR

products that work by putting a smartphone in front of your eyes to advanced systems that cost thousands of dollars and can match the resolution of the human eye. Newer products offer impressive image quality at less than \$1,000. In contrast, leading-edge augmented reality headsets continue to cost thousands of dollars or are in limited distribution.

For both VR and AR headsets, however, tradeoffs affect price, image quality, how wide a view one can see (field of view) and, in the case of headsets not tethered to a PC, battery life. The next few years should see great strides in these areas.

An emerging breed of headset connects to a smartphone via a cable, using that device for processing and connectivity while it is tucked away in a pocket as the headset handles the display and input. This allows the headsets to be much lighter, smaller and less expensive. Even so, many XR applications allow users to participate with currently available smartphones and tablets, providing a window into the virtual world, albeit one not as immersive as the one provided by a headset.

XR is already being used in a range of tasks related to manufacturing such as training workers via live interactions or prepared tutorials and troubleshooting problems remotely. By using augmented reality, this can occur right next to the parts of a machine that a technician must service. Headsets can be combined with biofeedback sensors to determine how effective training is or how well a trainee responds to stressful situations.

While the compelling 3D graphics of these technologies get most of the attention, the ability to look up content from a digital service manual hands-free is also a great productivity aid facilitated by 5G, particularly if a technician wishes to search tomes of technical manuals via voice commands. XR can also play a key role in product development, enabling engineers and designers to see the effects of changing specifications without having to build new prototypes and offering a level of detailed visualization that can reduce errors in manufacturing.

Autonomous Vehicles and Robotics

While the dream of the self-driving car has been with us for decades, the past decade has seen enormous progress as a range of efforts have leveraged advanced imaging sensors, computer vision and machine intelligence. These are combining to match or exceed the judgement and reflexes of humans. Self-driving cars have logged millions of miles. Even in the case where human drivers continue to operate accelerators, steering wheels and brakes, 5G can play a key role. It can not only help with tools that drivers use to have better understanding of their environment, but also in helping to keep them safe and comfortable.

The autonomous vehicle industry has identified five levels of autonomous driving (in addition to a Level 0 that includes no autonomy):

- **Level 1:** Driver Assistance, a single autonomous system such as cruise control
 - **Level 2:** Partial Automation
 - **Level 3:** Conditional Automation, in which the vehicle can perform most functions, but human interaction is still required
 - **Level 4:** High Automation, in which the vehicle generally handles all functions, but human interaction is still an option
 - **Level 5:** Full Automation, in which the vehicle fully handles all driving functions without human intervention
- Today, some vehicles can operate

autonomous vehicle technology at Level 3. But fully autonomous cars and trucks have clear commercial applications that can have far-ranging, if sometimes indirect, benefits for manufacturing. For example, autonomous vehicles



5G will enable manufacturers to respond to real-time upstream and downstream conditions and in turn be more agile during times of shifting market dynamics.

could deliver supplies to factories and deliver products from factories efficiently and safely. To reach their full potential, such vehicles will have to communicate with each other and other connected, intelligent parts of the transportation grid using technologies referenced under the umbrella term “vehicle-to-everything” (V2X).

Furthermore, not all autonomous vehicles navigate public roads. 5G can also be used to guide robots or forklifts through factories using many of the same core-enabling technologies such as advanced computer vision destined for passenger cars.

5G will drive next-gen mobile robots. One of the main requirements for remote-controlled robotics is low latency. LTE networks do not deliver latency levels low enough to make controlling robots at a distance feasible. But extremely low latency is one of the defining characteristics of 5G networks. 5G will help automate dangerous tasks by providing the ability to control equipment at a distance in near real time.

5G also has the potential to enable advanced automation through zero-touch approaches. From forklifts to drones to warehouse shelves themselves, 5G will connect autonomous modes of transportation. These, in turn, will impact a wide range of facility services. All forms of transportation within the future factory could be connected to the 5G network.

Manufacturers are increasingly moving from static configurations to more flexible and customized production. 5G will enable manufacturers to respond to real-time upstream and downstream conditions and in turn be more agile during times of shifting market demand and dynamics.

Safety & Security

Finally, 5G opens the door to multiple high-definition video streams from fixed cameras and drones (likely navigating via the 5G network as well) to ensure the security of facilities or monitor for any signs of disruption or failure, particularly when paired with a computer vision system that can analyze this video and detect aberrations or dangerous situations. Emerging imaging sensors can capture richer details about a scene, identify materials based on reflection patterns and even capture video in almost total darkness. These video feeds can provide proof of what may be inferred via sensors. Cameras can also help ensure compliance with maximum occupancy laws and to ensure that personnel are following safety protocols.



AT&T's Director
of 5G Center
of Excellence
Jason Inskeep



AT&T's Director of
Digital Transformation
for Manufacturing
& Operations
David LeBlanc

View From Network Carriers: **A Conversation with AT&T**

What are you seeing as the biggest drivers of 5G for manufacturing?

The need for data and operational visibility is growing faster than our current means and ability to connect using traditional methods for connecting. Manufacturers are hitting these major walls where you can't just push more of the same wireless and wired technology to enable more devices. 5G brings an entirely new way to connect at the exact time manufacturers need new ways to connect to bring the next generation of services, applications and products.

What's been the immediate driver of 5G in many instances is cost. Obviously, there are technical runways that manufacturers are aiming to achieve, but 5G really

changes the traditional paradigm around connectivity and return on investment. 5G is really about improving product process quality and increasing production velocity, which in turn reduces unit costs. Manufacturers are able to produce parts at a higher quality and at a higher velocity.

How do you see 5G enabling the manufacturing workforce, and where does automation fit in?

There is a lot of discussion around 5G and automation, but 5G automation isn't about targeting labor cost reduction. 5G is more about trying to meet demand for higher-quality requirements and higher velocity in terms of production operations. In this way, 5G is aligned with what manufacturers are

trying to accomplish and what the manufacturing workforce is working to achieve.

How should manufacturers approach 5G adoption?

First, manufacturers need to get educated on the baseline construct. Secondly, manufacturers should take an inventory of the things that are connected today. Notice we didn't say, "just focus on those things that need high bandwidth or need low latency." Manufacturers should start with looking at what is connected today because this will help them define opportunities that are unique to their business and business processes. Thirdly, manufacturers should look at the things they never thought would be possible.

Here's just one example of what we mean by thinking about what you never thought was possible. We are working with a manufacturer who has block concrete on the ground of their plant and underneath it they have pipes that carry chemicals from outside storage facilities into their fabrication area. In the past, they did not use temperature sensing on this part of their operations because they feared the return on investment would not match the cost of getting connectivity into those tunnels.

We were able to work with them, using 5G together with sensors, to penetrate through the block concrete. Suddenly, now a battery-powered sensor can tell them temperature changes, which can impact their ROI much greater than they had previously realized without having to add connectivity inside the underground environment. And they hadn't realized it because the technology available to them had limited their thinking about what was possible.

Manufacturers need to take a catalog of all of the processes they have

in place and how those processes work today—and now use that as an opportunity to brainstorm and ideate around opportunities to enable those processes in different ways, really open up the aperture to the art of the possible.

Are there things manufacturers should be thinking about differently as they approach 5G as opposed to any of the connectivity technologies that have preceded it?

There's a learning curve that most manufacturers are going through right now. Manufacturers are learning how 5G, and more broadly cellular in general, is fundamentally different than other connectivity solutions. And manufacturers are learning how to think differently. The knowledge set for network connectivity capability has historically been with OEMs or with the network operators for previous generations of cellular technology.

Moving forward in a 5G world, more of the knowledge will need to sit within the manufacturer working closely with

its integration partners. We are seeing a host of creative ways 5G can be deployed to deliver new services.

Are you seeing an acceleration of 5G adoption among manufacturers?

We have absolutely seen an acceleration in the manufacturing space toward 5G adoption. In many instances, they are taking a hybrid approach to connect new things. Manufacturers have already invested a tremendous amount into their current facilities and capabilities. Manufacturers shouldn't feel like they have to rip out and replace their existing infrastructure. 5G is about bringing in another means to connect in order to create operational efficiencies. Leverage what you have today and build on that. And as manufacturers employ 5G, they will also make those existing connections more efficient because they are not bogging down those historic connections with more devices and new service requirements. 5G will help manufacturers to augment their operations and help them achieve their digital transformation goals and requirements.



Private Networks

Private networks have long been an option for companies and other organizations seeking to have more control and personalization over a cellular network with early cellular networks serving voice applications for public safety and railways. These have continued on throughout successive cellular generations. However, because of their industrial capabilities, 5G networks are drawing strong interest for private network implementations.

There are a number of reasons for manufacturers to consider installing private 5G networks for the factories, plants and facilities. Manufacturers who have a strong belief in the benefits of 5G and see it as a strategic asset that provides competitive advantage will potentially want to share in or assume capital expenditures to build out a private 5G network. Private 5G networks will provide manufacturers with an ability to target 5G deployment to specific geographic areas, particularly outside of densely populated urban areas. Moreover, private 5G networks can provide enhanced privacy, security and control over network configuration, including options to enhance availability, quality of service, reliability or latency.

In general, companies are pursuing two main kinds of applications on these networks: high-bandwidth applications for tasks such as streaming video and real-time

applications that require very low latency. For the former, deploying LTE networks can be a great way to lay the foundation, particularly for enhanced mobile broadband applications in advance of availability of 5G network equipment availability. LTE and 5G are widely expected to coexist on the same private networks for at least the next five years.

Private 5G networks can help meet the security, privacy, and data isolation requirements of modern manufacturing.



Indeed, greater support for the kinds of real-time low latency performance enabled by 5G SA (standalone) networks continues to be addressed in the evolving 5G standard. Further details are expected to be rolled out with the Release 17 specification due to be finalized in mid-2022.

One of several options for building private 5G networks in the U.S. is CBRS (Citizens Broadband Radio Service), a swath of mid band

spectrum in the 3.5 GHz range that the FCC has designated for such networks. John Deere acquired a CBRS license and will use it to explore streamlining its manufacturing process and developing farming applications. It plans to deploy 5G in that spectrum next year. While mid band applications function well indoors, the high speeds and extremely low latency of millimeter-wave networks make them ideal for factory applications demanding high bandwidth. Already in 2019, Siemens has set up a private standalone 5G wireless network in Siemens' Automotive Showroom and Test center in Nuremberg, Germany in the 3.7-3.8 GHz band. Bosch and Nokia have partnered to deploy a private 5G network at Bosch's factory in Stuttgart-Feuerbach, which also operates in the 3.7-3.8 GHz band.

One alternative to having a completely private 5G network with private infrastructure is taking advantage of network slicing. In this scenario, companies partner with a carrier, which can create multiple virtual networks dedicated to business applications. Network slicing can also be complementary to a private 5G network for companies that want more control over wide-area applications where it would be logistically or financially challenging to deploy private infrastructure. Network slicing can be implemented under LTE with an eye toward transitioning to 5G.

Early Implementations

As 5G networks continue to advance, we've seen pilots on both sides of the Atlantic in implementing 5G-enabled factories, often in partnership with carriers.

- In Germany, Siemens has partnered with Qualcomm to deploy a private 5G network at the Siemens Automotive Showroom and Test Center in Nuremberg. This was the first private 5G standalone (SA) network in a real industrial environment using the 3.7-3.8GHz band. Since November 2020 Siemens has deployed its own in-house developed private 5G test network and is planning to roll this out to its own manufacturing locations in Amberg and Karlsruhe. In addition, Siemens also plans to setup a 5G test network at the Deutsche Messe fairgrounds in Hannover.
- In Spain, Gestamp, a manufacturer of major auto chassis components, has partnered with Telefonica to deploy 5G in a Barcelona factory. The initiative has included connecting robotic welding machines to 5G networks to capture and process data in real time and feed it into simulation models generated by a digital twin of the factory. Gestamp seeks to improve the flexibility of its facilities in response to increasing customization of car models by its customers.
- In Texas, AT&T collaborated with Samsung to explore ways to use a private millimeter-wave 5G network along with LTE and Wi-Fi to train new workers using mixed reality. Samsung can use augmented reality (AR) headsets such as Microsoft's HoloLens to bring new workers up to speed more quickly. Samsung touts the advantage of workers being able to navigate a factory floor without losing a connection to video training as well as the ability to connect with a remote expert if workers need help; they can instantly send photos or videos of what they are seeing since the headset has an integrated camera.
- In the U.K., Worcester Bosch has deployed 5G to enable preventative maintenance in real time. The manufacturer is using large numbers of sensors monitoring vibration, pressure and temperature and using analytics to predict equipment failures. Also, in the U.K., Ford is working with Vodafone to test 5G connectivity with welding machines on a private network. According to Ford, key components in an electric vehicle require about 1,000 welds that can generate half a million data points every minute, a good match for 5G's high-capacity data capture.
- In North Carolina, Corning is working to explore how millimeter-wave 5G can enhance factory automation and quality assurance at one of the largest fiber-optic cable manufacturing facilities in the world. The companies are testing how 5G can improve the navigation and functionality of autonomous guided vehicles. In addition, they are exploring how 5G can accelerate data collection, enable near real-time machine communication, and help wirelessly track materials with 5G-connected cameras.
- In France, Schneider Electric has partnered with Orange to trial 5G on an indoor, private network. The goal is to help the convergence of information technology and operational technology. Five indoor 5G antennas have been installed at a Normandy factory, covering nearly 2,000 square meters of production space. In addition to working with 5G-enabled tablets and laptops, the factory is testing use of a 5G-controlled telepresence robot to enable remote visits that can relay high-quality video and audio while helping to reduce travel costs.
- Drishti is working with DENSO, Ford, Nissan and other advanced auto and nonauto manufacturers to deploy cameras across manual assembly lines. It uses AI to analyze continuous streams of video, creating data and insights that are used to improve efficiency and reduce assembly defects. Drishti moves extraordinarily large volumes of data while performing AI inferencing in extremely short periods of time and believes 5G will provide a generational leap in speed and capacity for its plant operations and productivity solutions.

Perceptions & Reality of 5G Manufacturing Deployment

We are still in the very early days of 5G deployment,

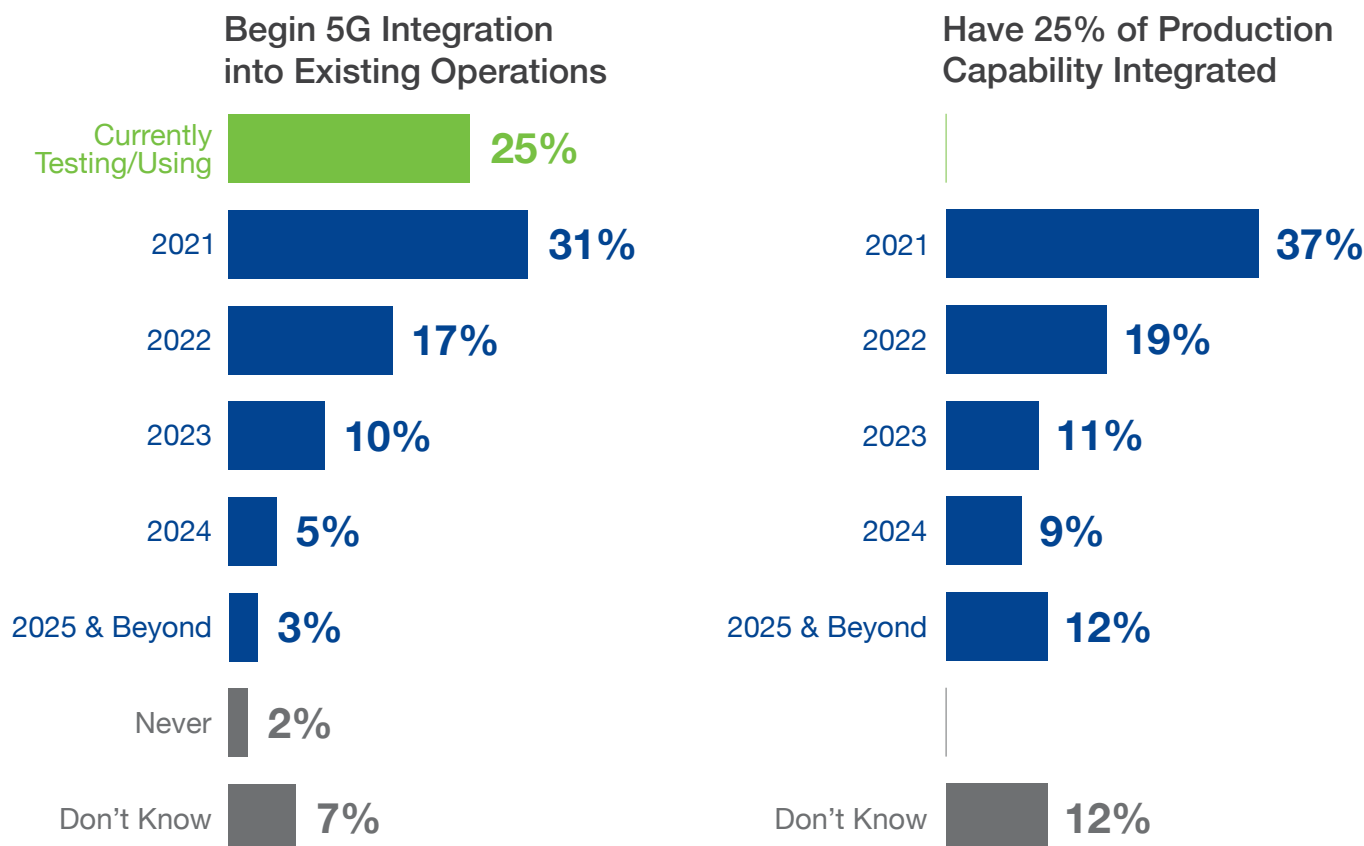
especially as it relates to manufacturers implementing 5G-enabled technologies and solutions. The full extent of 5G capabilities will be realized over the coming decade as the network comes more fully to fruition. But as this research reveals, manufacturers are already beginning to test 5G in their factories and facilities. At the present time, one-quarter (25%) of

the manufacturers surveyed report they are already testing or using 5G in their facilities. Moreover, more than half of manufacturers (56%) report they will be testing or using 5G in some capacity within their facilities by the end of 2021. Only a very small percentage (2%) of manufacturers report they do not expect to implement 5G solutions.

Manufacturers also have plans to implement 5G across a meaningful

portion of their operations. Just under two-fifths (37%) estimate they will have at least 25% of production capabilities integrated by the end of 2021. This research further suggests that by the end of 2022, more than half of manufacturers (56%) anticipate having at least 25% of their production capabilities integrated with 5G capabilities. Regardless of the actual uptake timeline, it is clear 5G is on the forefront of technology roadmaps for manufacturers.

Anticipated Timeline for 5G Integration²



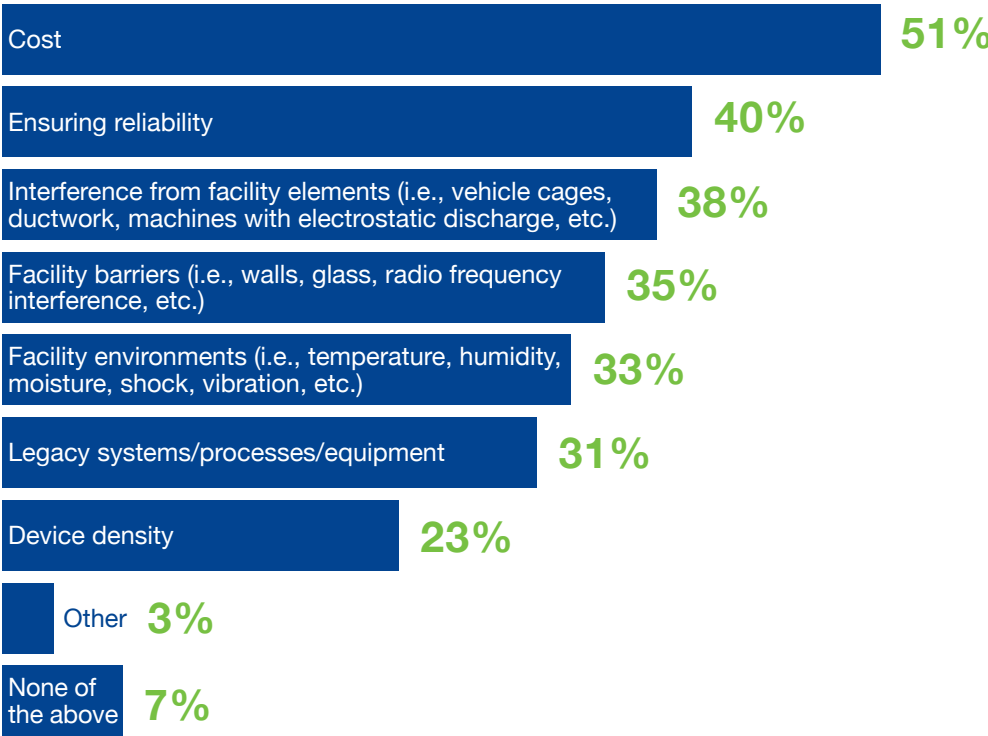
5G Will Help Resolve Current Manufacturing Challenges Related to Wireless Technologies

In recent years, wireless technologies have been a key focus for manufacturers, yet to date, there have been several inhibitors that have curtailed the extent to which wireless solutions can augment production and improve operations. About half of the manufacturers surveyed report cost (51%) is the number-one challenge related to the implementation of current, existing or anticipated wireless technologies. Unsurprisingly, manufacturers look closely at the return on investment of wireless solutions, and thus far, that has limited some of the deployment of wireless technologies in factories and plants. Manufacturers will be looking closely at ROI when it comes to 5G deployment as well.

Dependability of wireless technologies is another key challenge for manufacturers. Some 40% of manufacturers report that ensuring reliability is a key concern when deciding to implement wireless technologies. This is especially true for indoor environments that are notorious for radio interference. As previously noted, one of the key performance indicators (KPI) specified by 5G is Ultra Reliable Low Latency Communication (URLLC) service requirements. This translates into 99.999% reliability and 99.999% availability. 5G should significantly help mitigate this challenge for manufacturers and could allow many manufacturers to implement wireless solutions where they had previously resisted because they could not deliver reliable network connections.

Another challenge that has inhibited wireless technology adoption is interference from existing equipment and infrastructure. Many manufacturers have legacy facilities, equipment and processes, and some manufacturers have seen challenges with how existing operations combine with wireless technologies. For example, when it comes to implementing wireless technologies, manufacturers report challenges with interference from facility elements (38%), facility barriers (35%), facility environment (33%), integration with legacy systems, processes and equipment (31%) and density of devices (23%).

Challenges Related to Implementation of Wireless Technologies³



Many of these challenges can likewise be mitigated by 5G. For example, Wi-Fi networks can experience interference in dense settings, and fixed wired connections can be difficult to manage across large industrial complexes. 5G is expected to support up to 1 million connected devices per kilometer (0.62 miles), compared to a few thousand devices per kilometer with 4G. This will enable manufacturers to deploy wireless solutions where a density of connected equipment exists.

5G Will Enable Smart Factories & Industry 4.0

While connectivity is a key aspect of smart factories, ultimately it is data that will enable this future. Here, too, we see manufacturers face a number of related challenges. Manufacturers report their biggest challenges with respect to facility analytics include ease of integrating data from multiple sources (44%), volume of data (40%) and cost (39%). These are followed by speed of systems response (37%), integration with legacy systems, processes and equipment (37%) and security challenges or concerns (33%). 5G is purpose-built to resolve many of these inhibitors to full facility analytics.

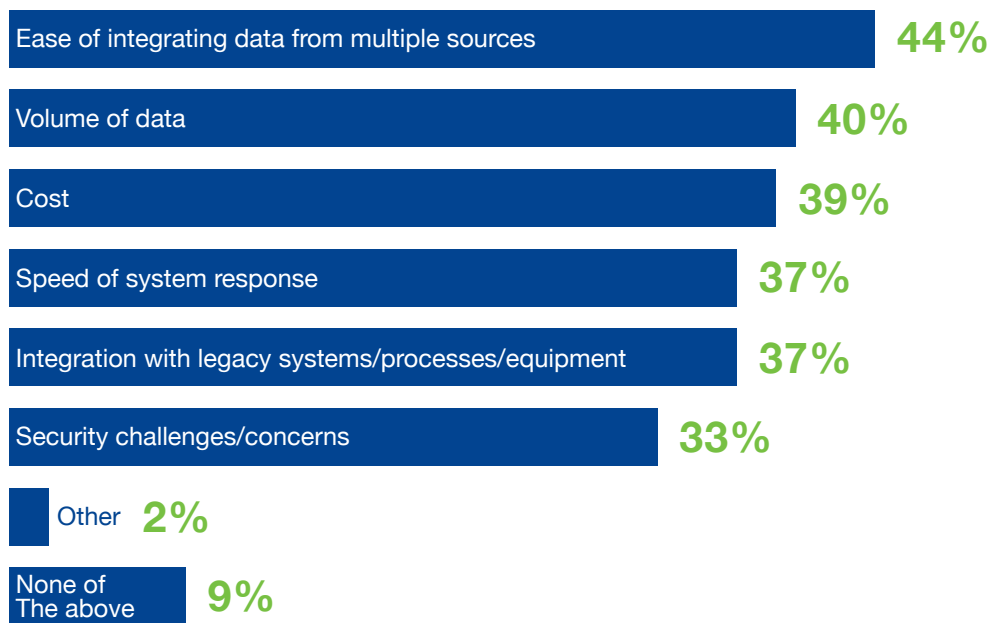
Factory machines generate information related to monitoring, maintenance and the management of production. Until recently, much of this information went uncaptured in the normal course of operations. Historically, much of the monitoring on a shop floor would be performed by workers as part of their regular business. If machines needed repair, they would be taken offline and repaired. Management might look for ways to improve production outcomes, but much of this was done using data from prior weeks and

months, or in the absence of data, instinct that might differ from person to person.

In recent years machines have been outfitted with sensors that enable manufacturers to turn information into data by capturing this information both digitally and continuously. But much of these data still reside in information silos within the factory. Manufacturers continue to struggle with turning these data into real-time insights that will help them anticipate needs on the shop floor. For example, roughly one in three (33%) manufacturers report unexpected breakdowns is their biggest pain point when it comes to real-time resource tracking. Other pain points related to real-time asset tracking include identifying process inefficiencies (33%), cost (33%), human error (30%), inventory estimations (28%), elimination of redundant assets (26%) and identifying asset location (25%).

5G will have a particular impact on the industrial and manufacturing sector because it will help factory and plant operators alleviate some of these pain points. This will be a crucial step in ushering in a new era of AI and machine learning techniques that can help

Challenges Related to Manufacturing Facility Analytics⁴



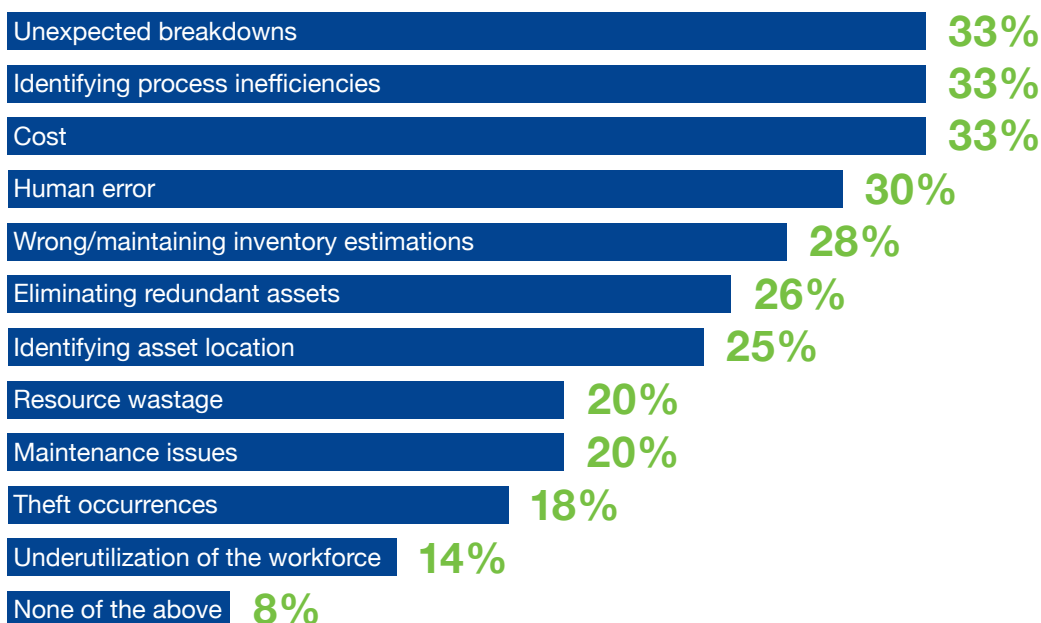
companies better ascertain real-time knowledge about their ongoing operations. 5G is also optimized to facilitate real-time information gathering that can help automate processes within the manufacturing environment. In all of these cases, it is about getting the right data to arrive at the right time and in the right place so it can influence the right process. Previous networks focused on data centralization in the cloud, but 5G will enable greater compute capabilities within the network, closer to the end user, the end machine and ultimately the end process.

5G enables manufacturers to apply AI to data in much faster timeframes by being able to support a high population of endpoints within a small geographic area. This will allow for precision analytics, and in the case of control implementations, precision manufacturing. Better analytics in a 5G environment will allow manufacturers to perform tasks at a much more granular and precise level.

Enabling machines to share information and insights directly with other machines on the shop floor in real time will allow manufacturers to automate certain activities and free workers to focus on higher-value tasks.



Challenges Related to Real-Time Asset/Resource Tracking⁵

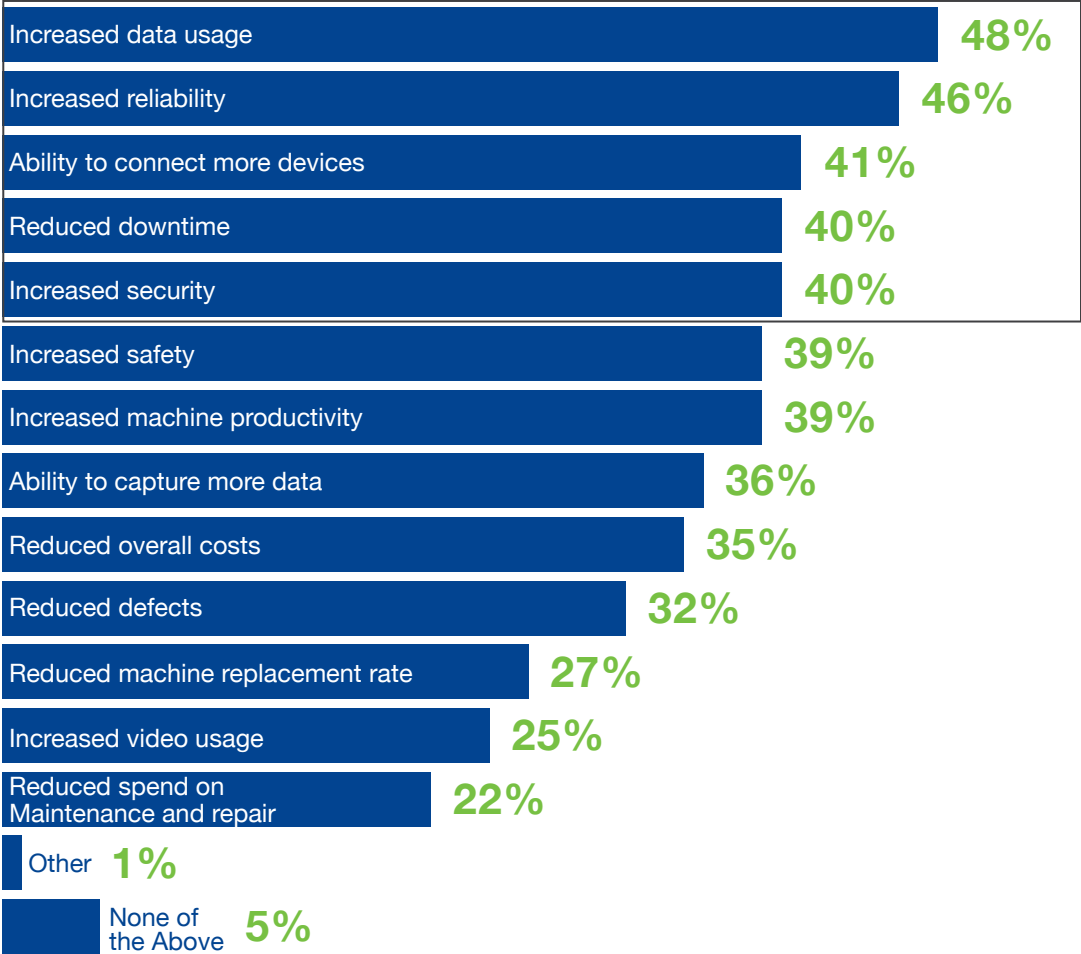


Benefits of 5G Connectivity

Manufacturers see a number of benefits to 5G connectivity. Among those surveyed, nearly half indicate 5G will likely aid their manufacturing processes through increased data usage (48%) and increased reliability (46%). Furthermore, two-fifths of those surveyed believe their processes can be improved through the ability to connect more devices (41%), reduce downtime (40%), increase security (40%), increase safety (39%) and increase machine productivity (39%).

Nearly half of manufacturers surveyed indicate 5G will likely aid their manufacturing processes through increased data usage.

Ways in Which 5G Will Aid Manufacturing Processes⁶



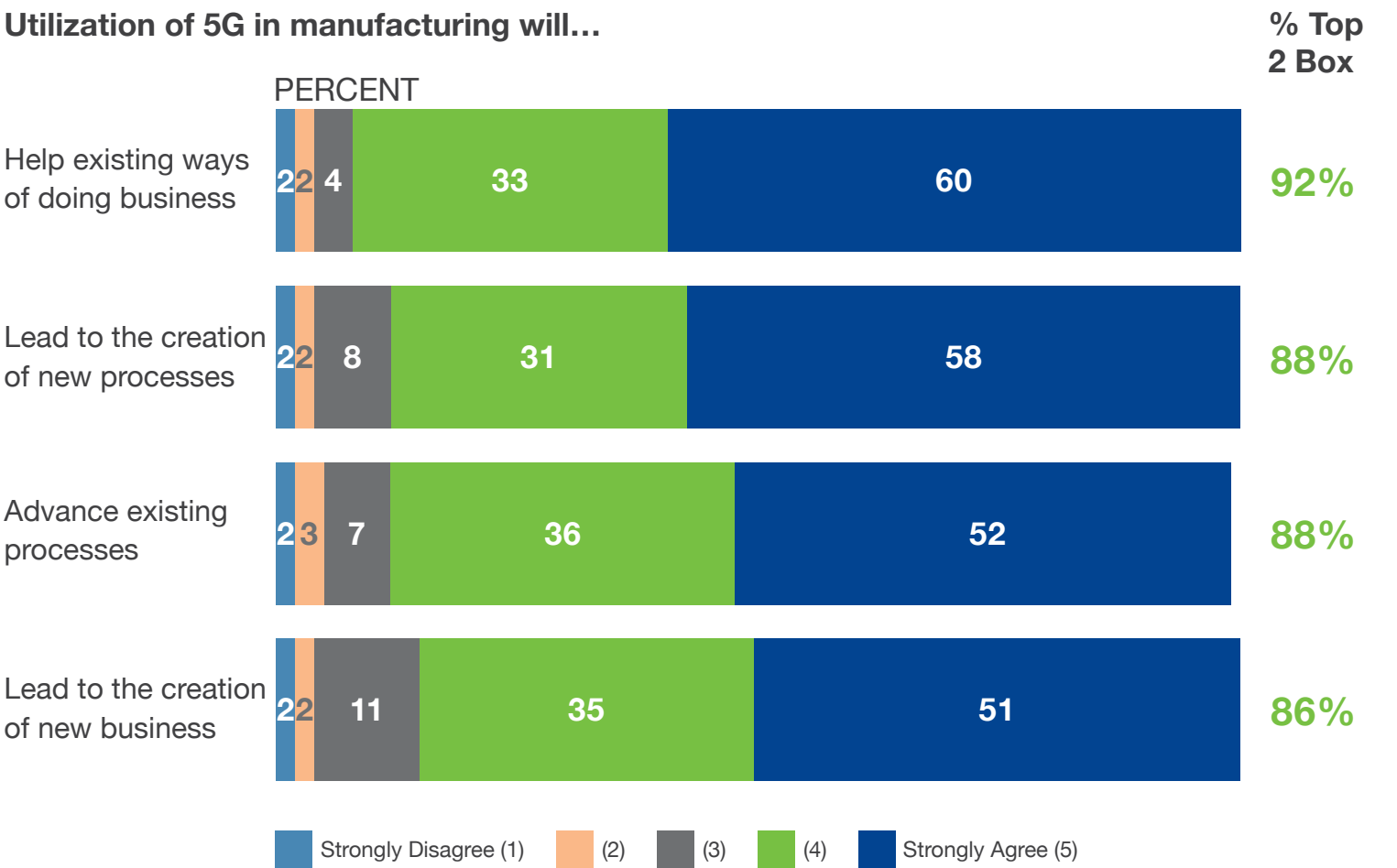
5G Will Help Extend Existing Processes & Drive Entirely New Products and Processes

There is strong agreement among manufacturers that 5G will help existing business processes and procedures. Nine in ten manufacturers believe the utilization of 5G in their facilities will help with existing ways of doing business (92%) and will further advance existing processes (88%).

There is also strong consensus that 5G will empower entirely new ways of doing business by helping manufacturers create entirely new processes and procedures. Beyond what manufacturers are currently doing in their facilities, nine in ten manufacturers also expect the utilization of 5G to lead to the creation of new processes (88%) and the creation of new business (86%).

The creation of new processes and business procedures is an especially important outcome of 5G deployment because suggests second-order benefits that might be captured by manufacturers. Manufacturers point to several areas when asked specifically what these new products and processes might be. They included creating customer support infrastructure in augmented reality, AR training tools for employees and remote maintenance support. Some manufacturers reported they hope 5G will help improve first-time fix rates (FTFR) and create greater remote access to their services. Manufacturers also noted they expect 5G to usher in new processes around factory automation and control systems. Manufacturers believe 5G will be a catalyst for change.

Agreement with Statements⁷



5G Will Transform Supply Chains & Factory Operations

Manufacturers expect 5G to have a strong impact on myriad facets of factory operations. Four-fifths of manufacturers indicate 5G technology will be important to inventory tracking (83%), facility security (81%) and warehousing and logistics (81%) within their facilities. With the help of 5G, manufacturers and logistic service providers will be able to provide real-time updates to downstream customers and upstream suppliers. This will allow manufacturers to streamline both inbound and outbound logistics

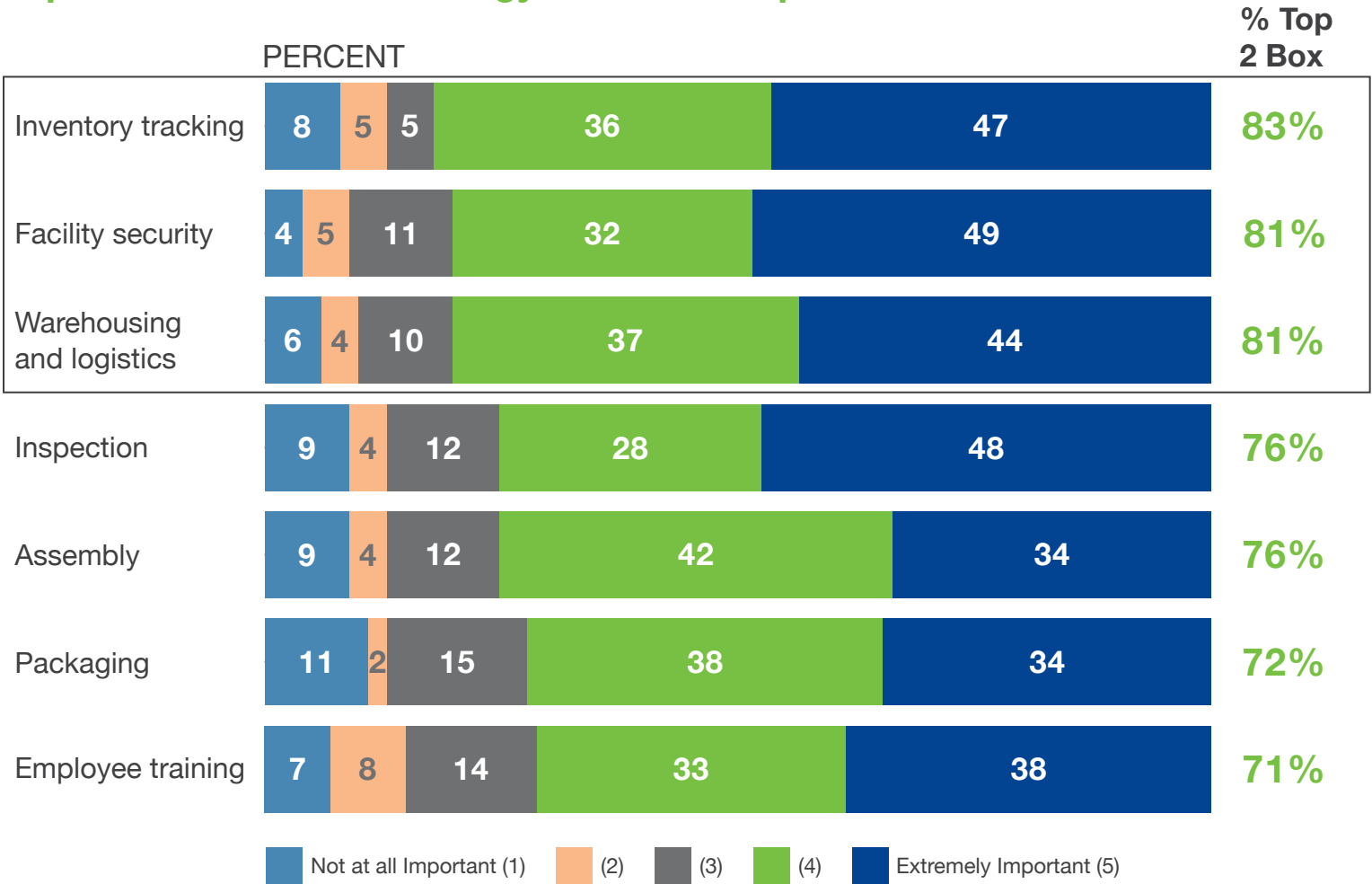
and in turn manufacturers will have greater assurance that shipments have been received and delivered. They will be able to expedite delivering and receiving goods and will be able to synchronize information across the supply chain more closely.

Manufacturers will also be able to understand potential shipping delays in real time, communicate information to supply chain partners and adjust as needed. Together with AI, they will be able to optimize

fleet routes and related logistical services and improve warehouse management.

Furthermore, three-fourths of manufacturers indicate 5G will also be important to inspection (76%) and assembly (76%) activities, while seven in ten believe packaging (72%) and employee training (71%) efforts will benefit from the deployment of 5G. Ultimately, many of these benefits will help lower the cost of operations while at the same time improving production efficiency.

Importance of 5G Technology to General Operations⁸

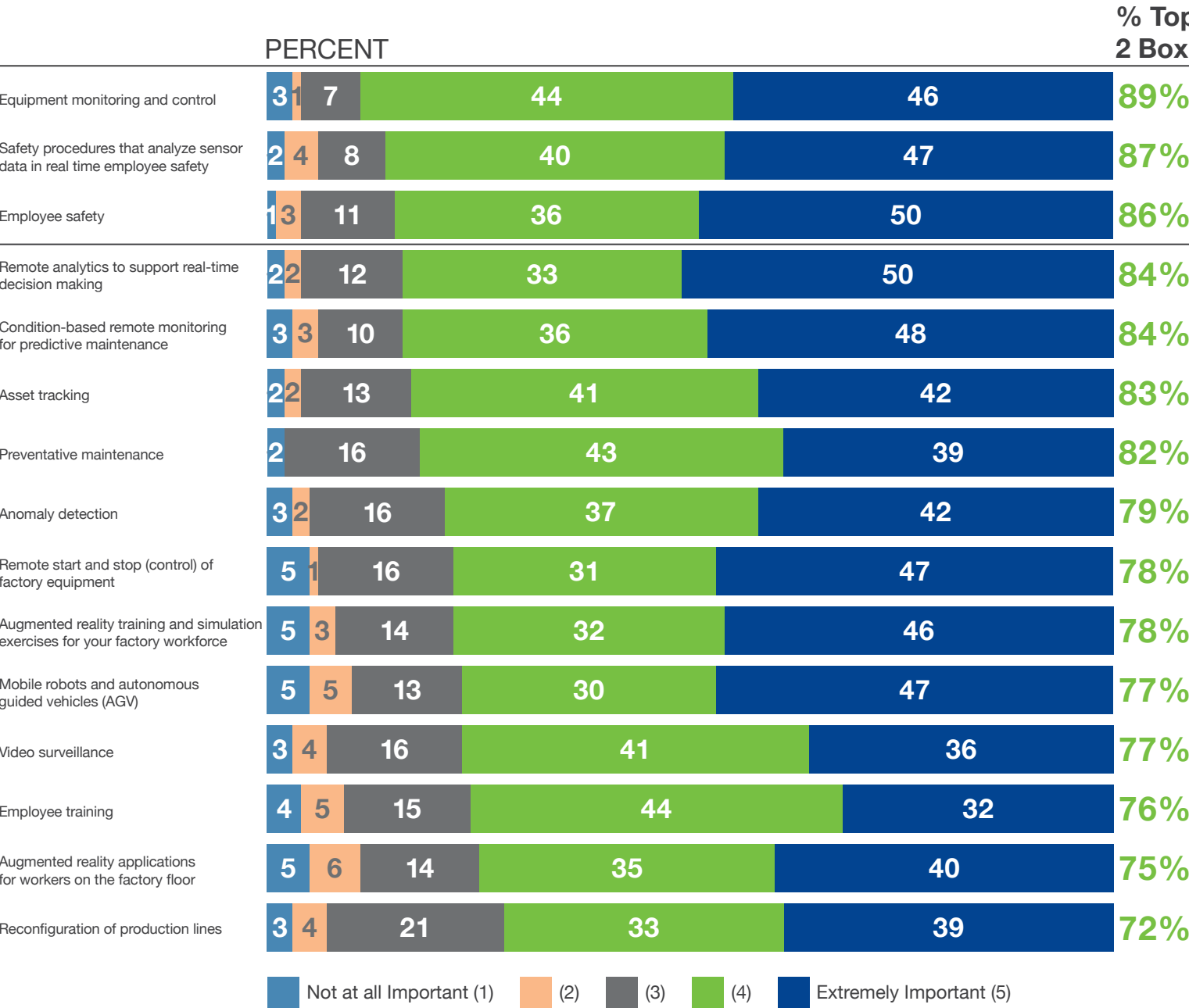


When asked how important 5G connectivity will be to specific operational procedures and processes, manufacturers indicate equipment monitoring and control (89%), safety procedures that

analyze sensor data in real time (87%) and employee safety (86%) will benefit most from the technology. The vast majority of manufacturers also report that 5G will aid remote analytics to support real-time

decision making (84%), condition-based remote monitoring for predictive maintenance (84%), asset tracking (83%) and preventative maintenance (82%). 5G will improve data decision-making.

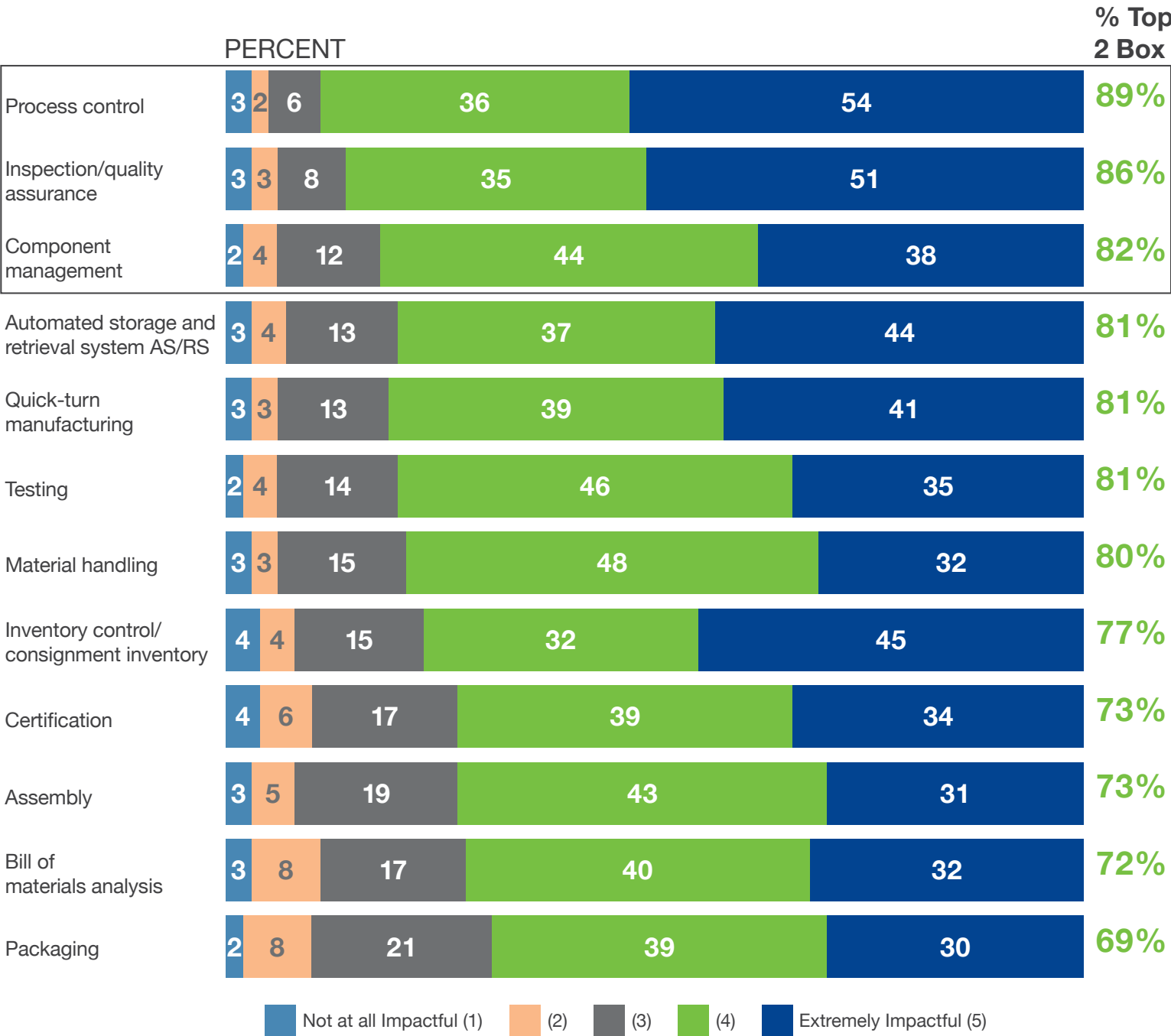
Importance of 5G Technology to Operational Procedures/Processes⁹



When asked to what extent value-added services will be aided by 5G, manufacturers indicate process control (89%), inspection and quality assurance (86%) will see the greatest impact. Manufacturers also note

component management (82%), automated storage and retrieval system (81%), quick-turn manufacturing (81%), testing (81%) and material handling (80%) will all benefit from 5G.

Impact of 5G on Value-Added Services¹⁰

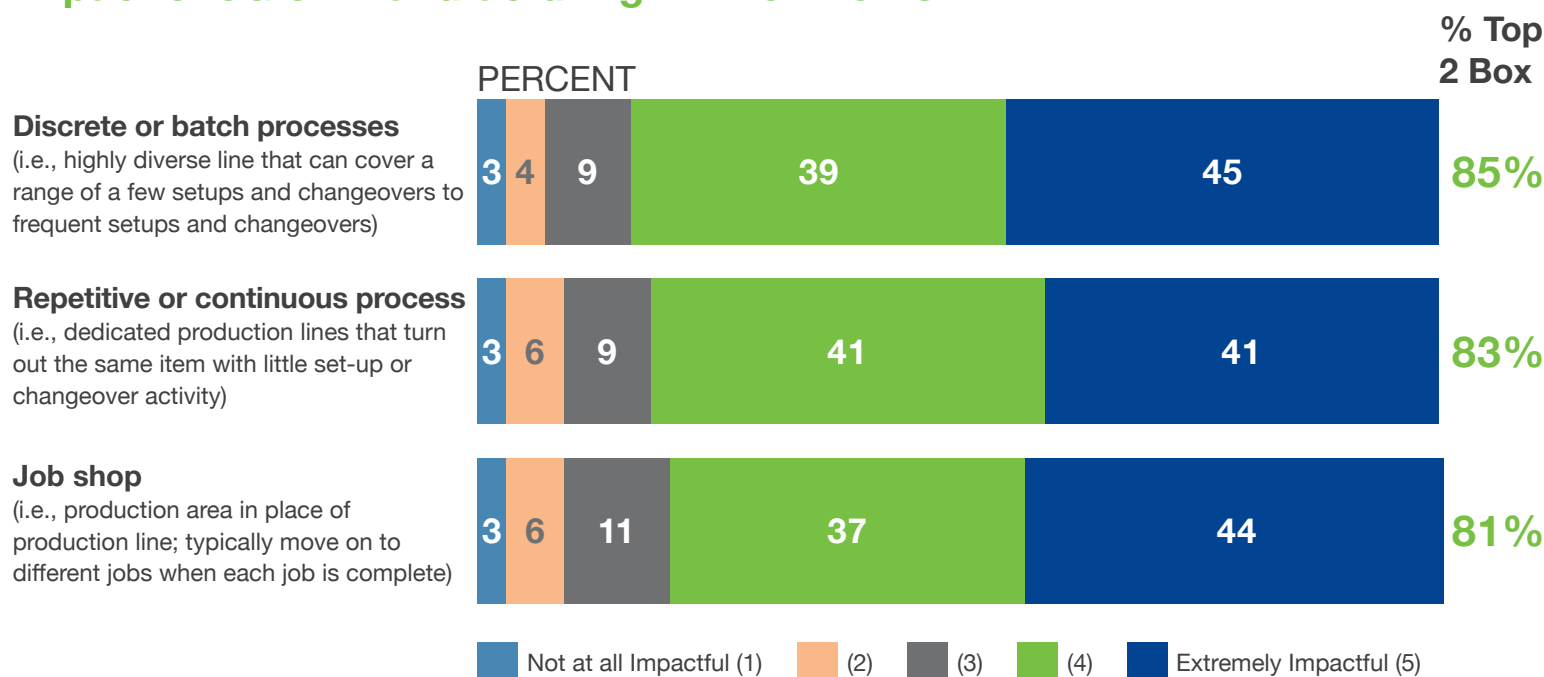




When asked to what extent value-added services will be aided by 5G, manufacturers indicate process control (89%), inspection and quality assurance (86%) and component management (82%) will see the greatest impact, along with automated storage and retrieval system (81%), quick-turn manufacturing (81%), testing (81%) and material handling (80%).

Deployment of 5G to manufacturing is expected to have a strong positive impact across all manufacturing environments. Specifically, more than four-fifths of manufacturers surveyed believe 5G connectivity in manufacturing will be highly impactful to discrete or batch processes (85%), repetitive or continuous processes (83%) and job shop (81%).

Impact of 5G on Manufacturing Environments¹¹

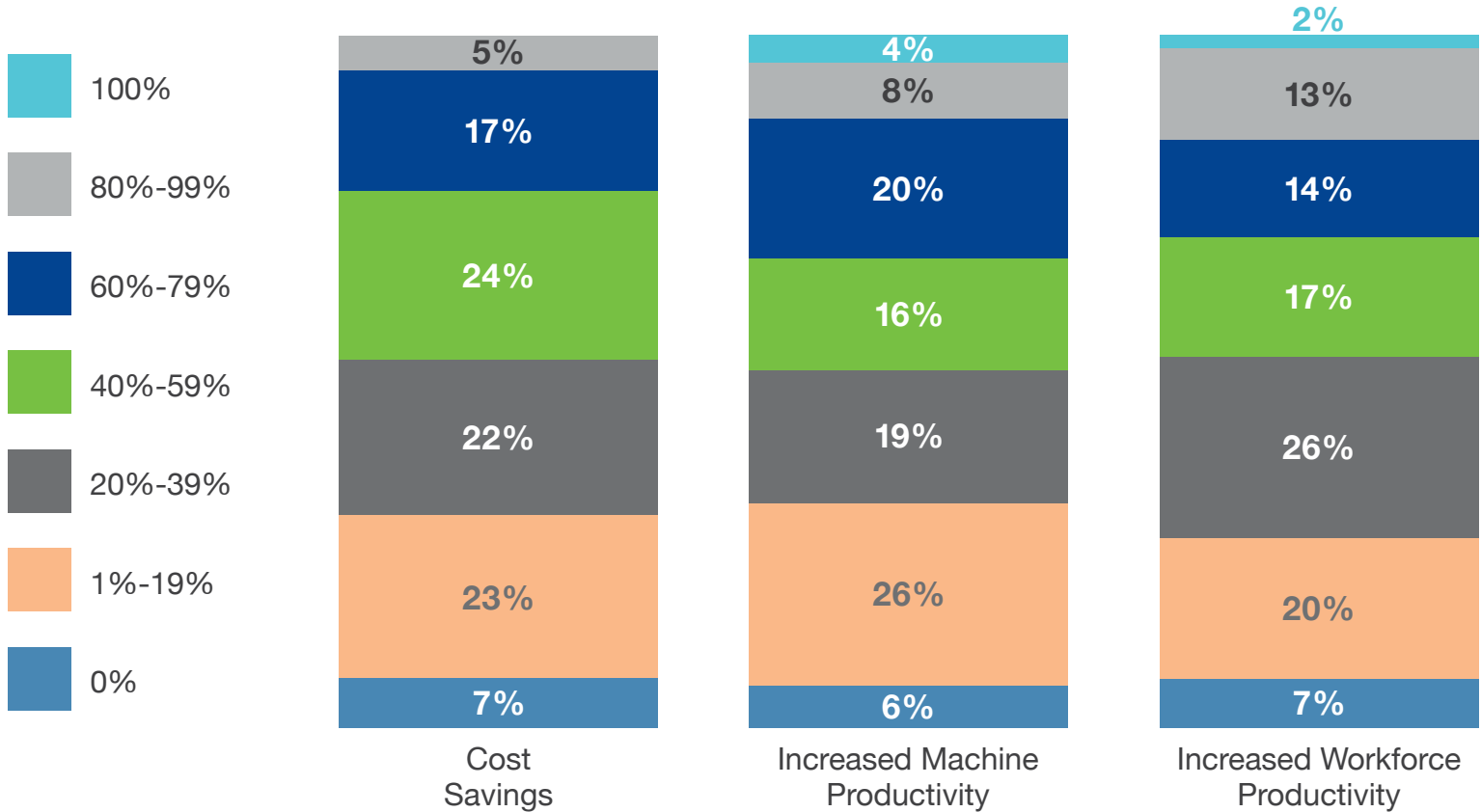


5G Will Drive Cost Savings & Increase Machine & Employee Productivity

Nearly all manufacturers expect to see some level of cost savings (93%) as a direct impact of connecting their machines and equipment wirelessly with 5G, along with increased machine productivity (94%) and increased workforce productivity (93%). While one-fifth (22%) expect to see cost savings of 60% or more, roughly one-third anticipate increased machine (32%) and increased workforce (29%) productivity of 60% or more. Notably, very few do not believe they will experience any cost savings (7%), increased machine productivity (6%) or increased workforce productivity (7%) as a result of 5G deployment. On average, manufacturers believe 5G can help lower costs by an estimated average of 38%, while increasing machine productivity by an estimated 42% and workforce productivity by 41%. Bottom line, 5G will have significant impact on profitability and productivity industry wide.



Anticipated Impact of 5G¹²

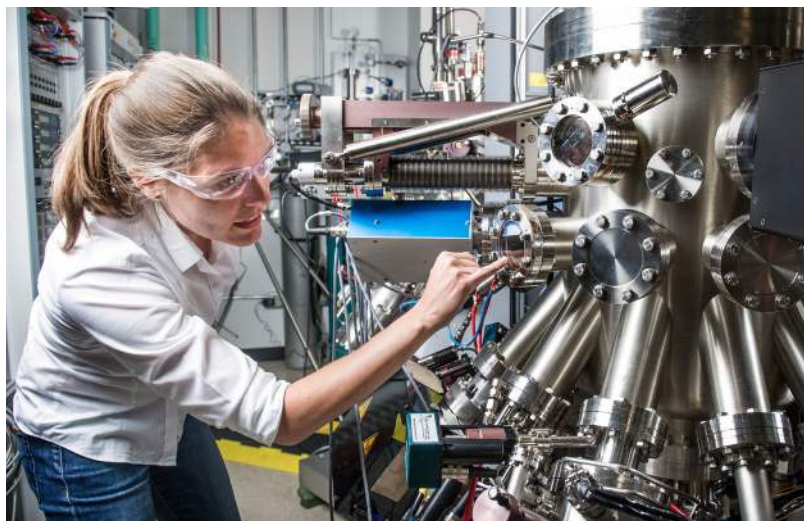


Perceived & Expected Advantages of 5G Technology Versus Current Technologies

Manufacturers expect 5G connectivity to provide many advantages over current technologies being utilized within manufacturing environments. Already, two-thirds (65%) of manufacturers indicate 5G is superior in terms of increased efficiency, while more than half feel 5G will provide for improved quality and service (56%) and greater flexibility (53%). In addition, two-fifths believe 5G will be advantageous as it relates to enhanced safety and security (45%) and increased competitiveness (41%), and one-third believe it will provide for shortened lead times (35%) and lower cost (32%).

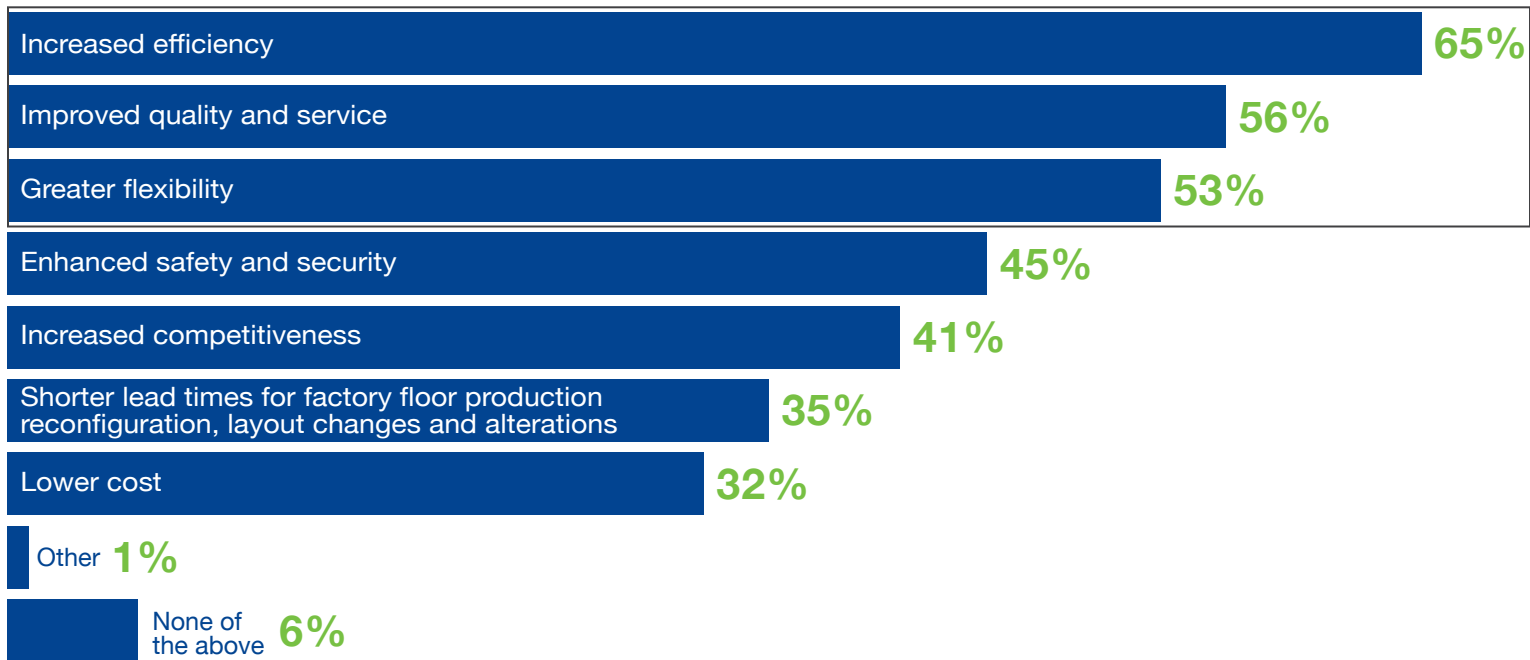
It is important to remember that these are early impressions of a technology that hasn't yet been fully deployed. 5G is still a very new technology for many companies and the majority of manufacturers are just now beginning to test and implement it. With new technologies, the benefits and use-case scenarios become apparent after companies gain exposure to and experience with them. Current manufacturers may not be fully aware how much 5G can do for them because they do not yet have

direct experience with it. Manufacturers should begin testing and implementing 5G technologies in order to realize the potential benefits that can be realized



above and beyond existing technologies. As noted earlier, nearly all manufacturers (91%) believe 5G connectivity will be important to the overall future of their business, and three-fifths (61%) indicating it will be “extremely important.”

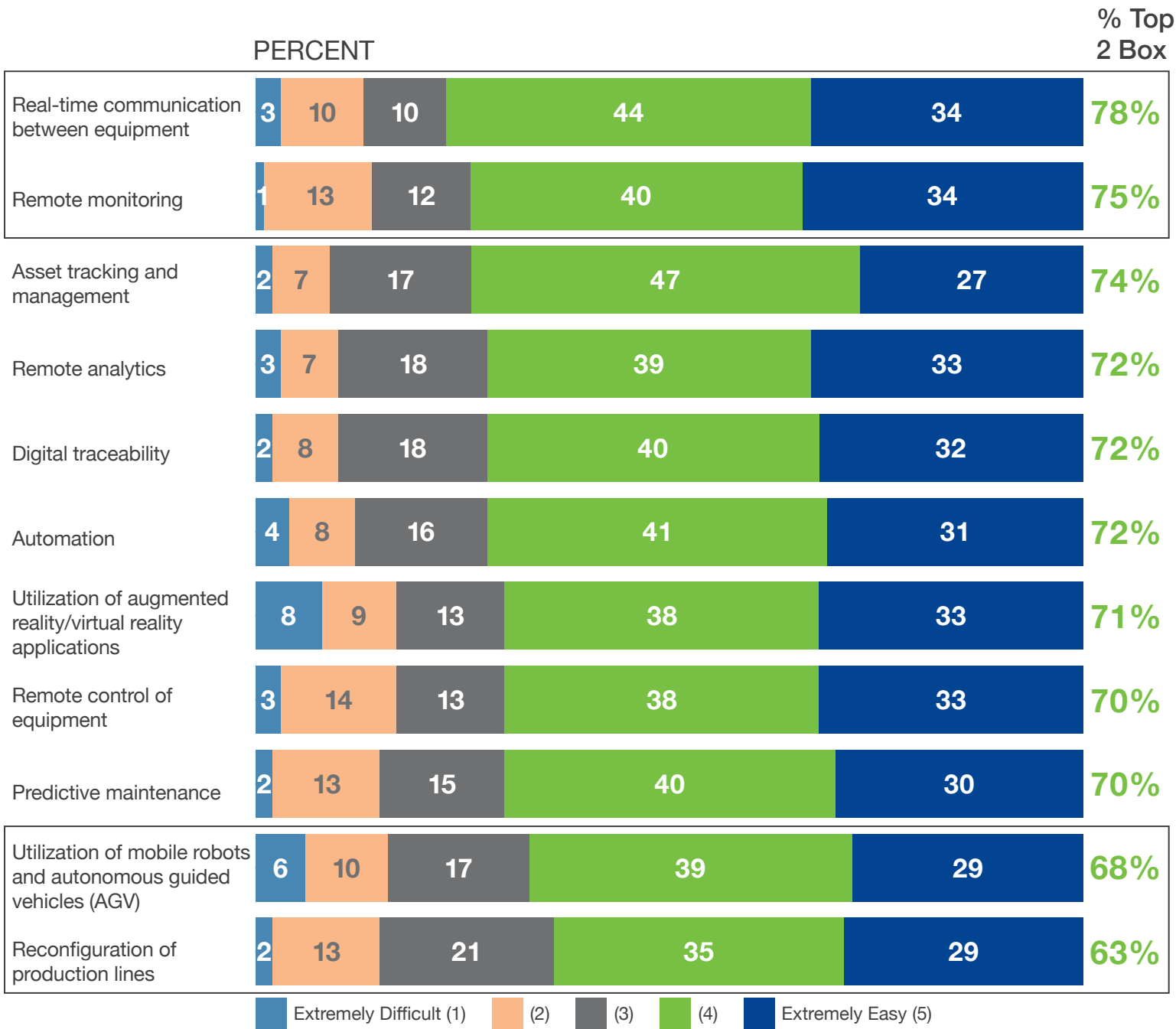
Advantages of 5G Over Current Technology¹³



When asked about ease of using current fixed or 4G network connections to perform manufacturing-related activities, real-time communication between equipment and remote monitoring are perceived to be easiest, while, conversely, reconfiguration of

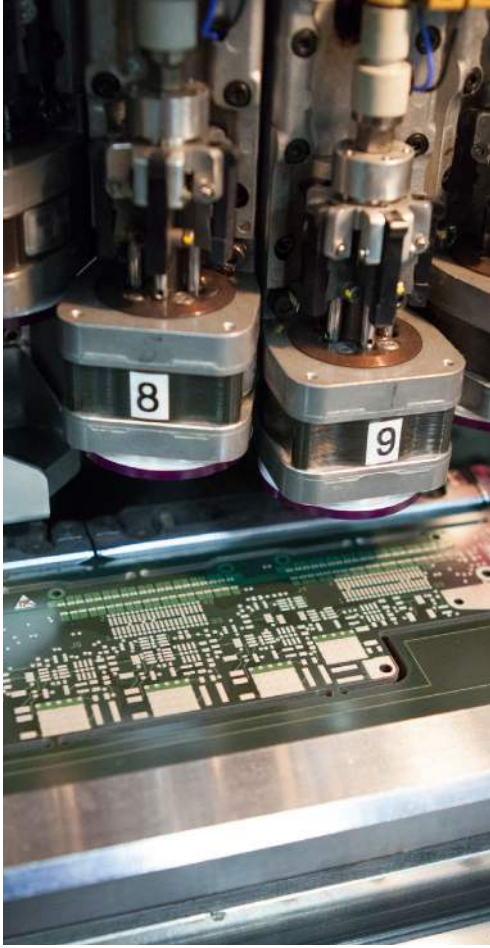
production lines and utilization of mobile robots and autonomous guided vehicles (AGVs) are considered to be the most difficult. This provides important insights into how 5G technologies might be employed by manufacturers.

Ease of Performing Activities Using Wired, Wi-Fi or 4G Connections¹⁴

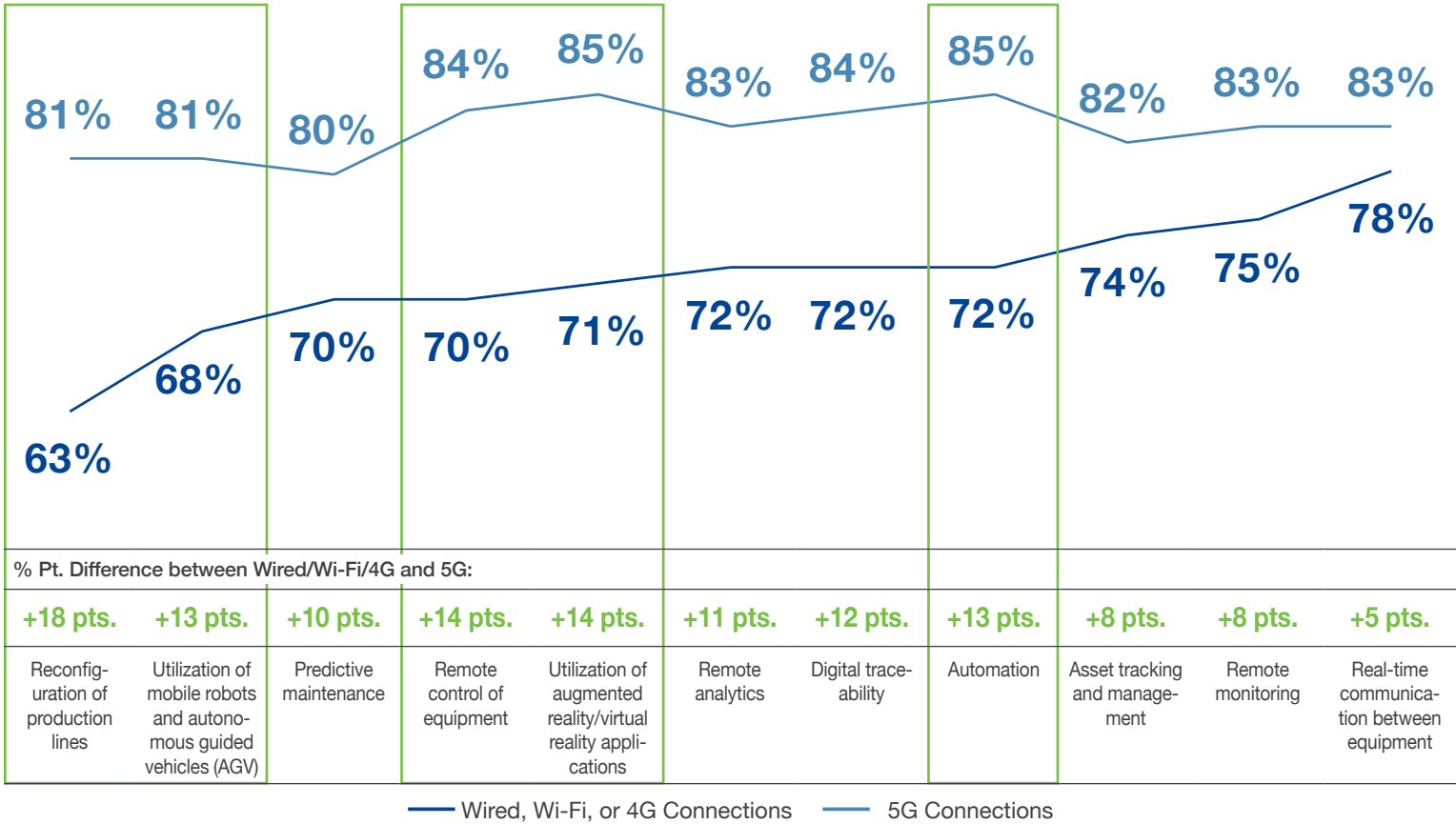


Manufacturers anticipate the deployment of 5G in manufacturing environments will make many activities associated with manufacturing easier. Notably, reconfiguration of production lines, considered to be the most difficult manufacturing activity using current technologies, is expected to see the greatest improvement in terms of “ease” when 5G technology is utilized. Manufacturers also expect the utilization of 5G to drive considerable improvements in “ease” surrounding remote control of equipment, utilization

of augmented reality/virtual reality applications, utilization of mobile robots and AGVs and automation, which will dynamically reshape the way manufacturers operate in the future. As the accompanying chart highlights, the ease of performing numerous manufacturing tasks is expected to improve with 5G. Notably, some of the most difficult tasks to perform in manufacturing environments using today’s available technologies are expected to see the greatest increase in ease of performance when coupled with 5G.



Ease of Performing Activities: Wired, Wi-Fi or 4G Connections vs. 5G Connections¹⁵



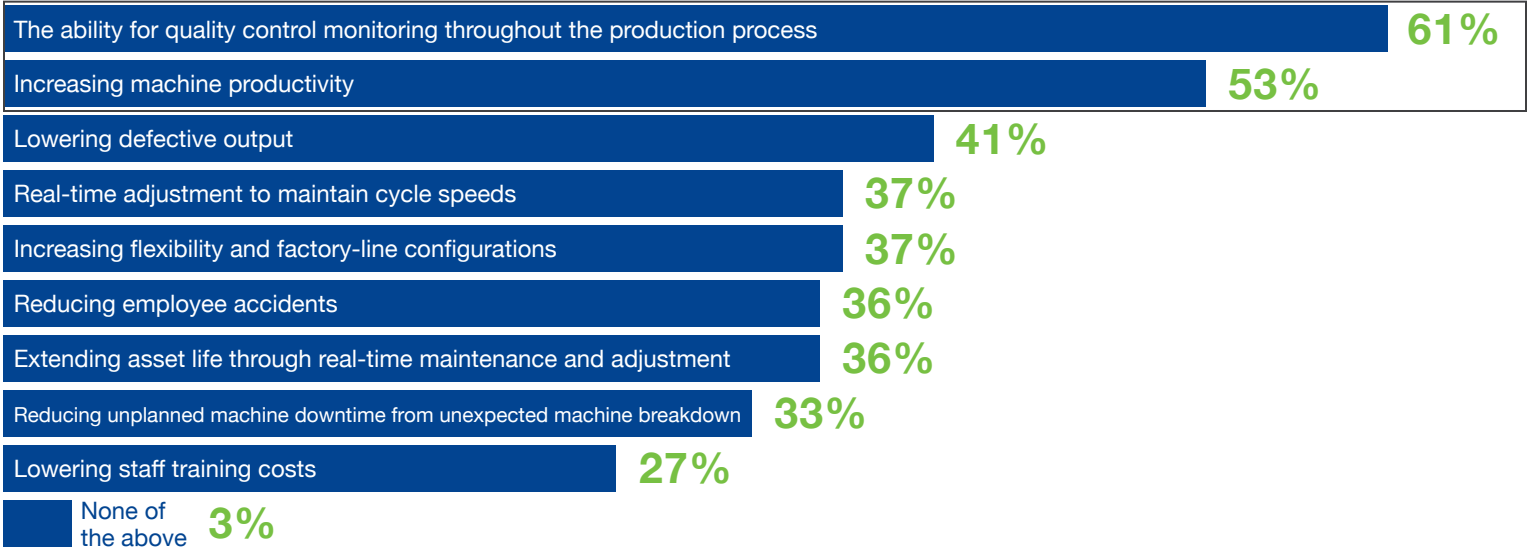
Drivers and Barriers to 5G Adoption & Implementation

Drivers of 5G adoption are wide and varied; however, two rise to the top among manufacturers as being primary drivers: ability for quality control monitoring throughout the production process (61%) and increasing machine productivity (53%).

(53%). Additional drivers include lowering defective output (41%), ability to make real-time adjustments to maintain cycle speeds (37%), increasing flexibility and factory-line configurations (37%), reducing employee accidents (36%), and

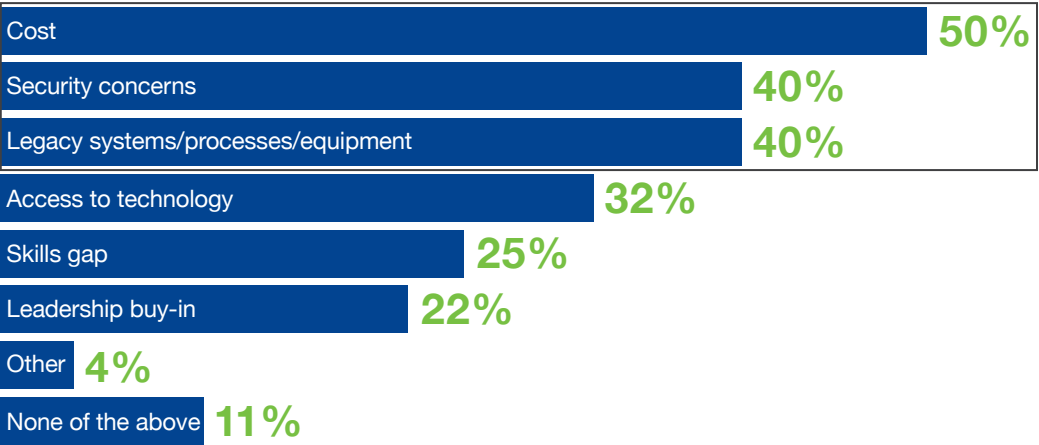
extending asset life through real-time maintenance and adjustments (36%). Manufacturers also note that reducing unplanned machine downtime from unexpected breakdowns (33%) and lowering staff training costs (27%) will help drive 5G adoption.

Drivers of 5G Adoption¹⁶



Consistent with cost being named as the top challenge associated with the implementation of current, existing or anticipated wireless technologies, cost is also cited as the primary barrier to 5G adoption and implementation with half (50%) of manufacturers indicating it might prevent deployment to their factories and facilities. Additional barriers include security concerns (40%), integration with legacy systems, processes and equipment (40%) and access to the technology itself (32%).

Barriers to 5G Adoption and Implementation¹⁷



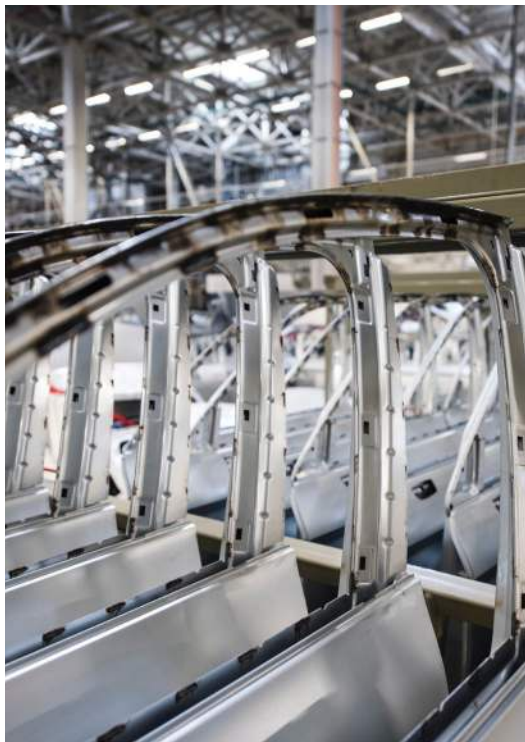
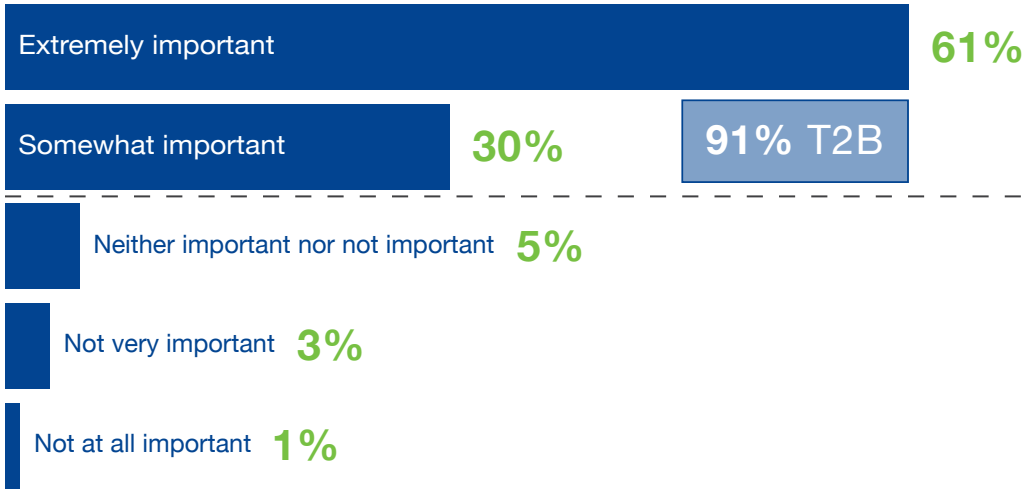
Looking Toward the Future

Nearly all manufacturers (91%) believe 5G connectivity will be important to the overall future of their business, with more than three-fifths (61%) indicating it will be “extremely important.”

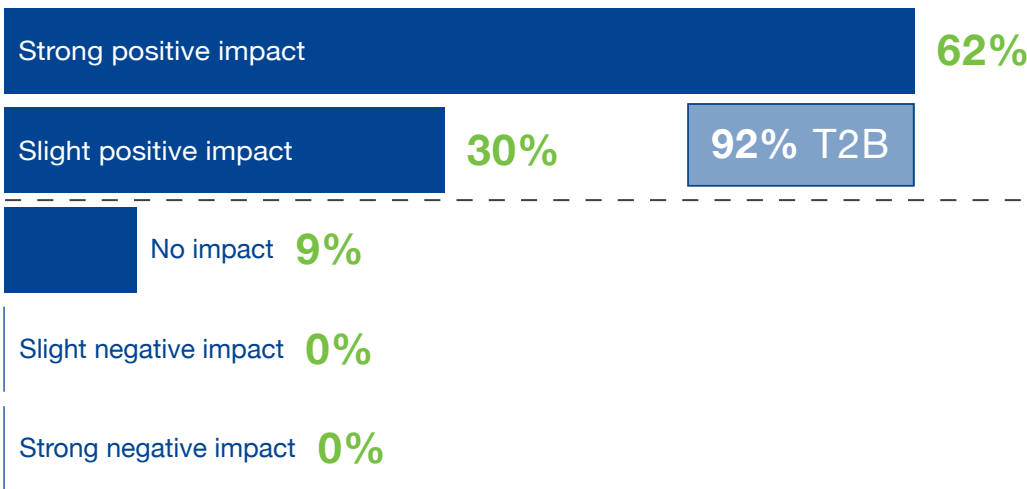
The faster 5G technology can be deployed to manufacturing, the more competitive manufacturers feel they will be. More than nine in ten (92%) manufacturers indicate speed of 5G deployment will have a positive impact on their ability to compete globally, with nearly two-thirds (62%) signaling it will have a “strong positive impact.”



Importance of 5G Technology to Overall Future of Business¹⁸



Impact of Speed of 5G Deployment to Manufacturing on Ability to Compete Globally¹⁹





How 5G Can Help Manufacturing Adapt in the Covid-19 Era

It is no surprise that COVID-19 has impacted nearly every industry worldwide, with manufacturing being particularly hard hit in the early months of the pandemic. Changes in consumer behavior, lockdowns that derailed global supply chains and public measures to stop the spread of the virus that necessitated changes in operations, among a variety of other factors, brought many manufacturing facilities to a standstill at different points throughout 2020. As the world continues to grapple with the pandemic, manufacturers are left trying to figure out how to operate in the “new normal.”

Manufacturing activities like new product introductions (NPI) were especially impacted by the pandemic. To maintain what

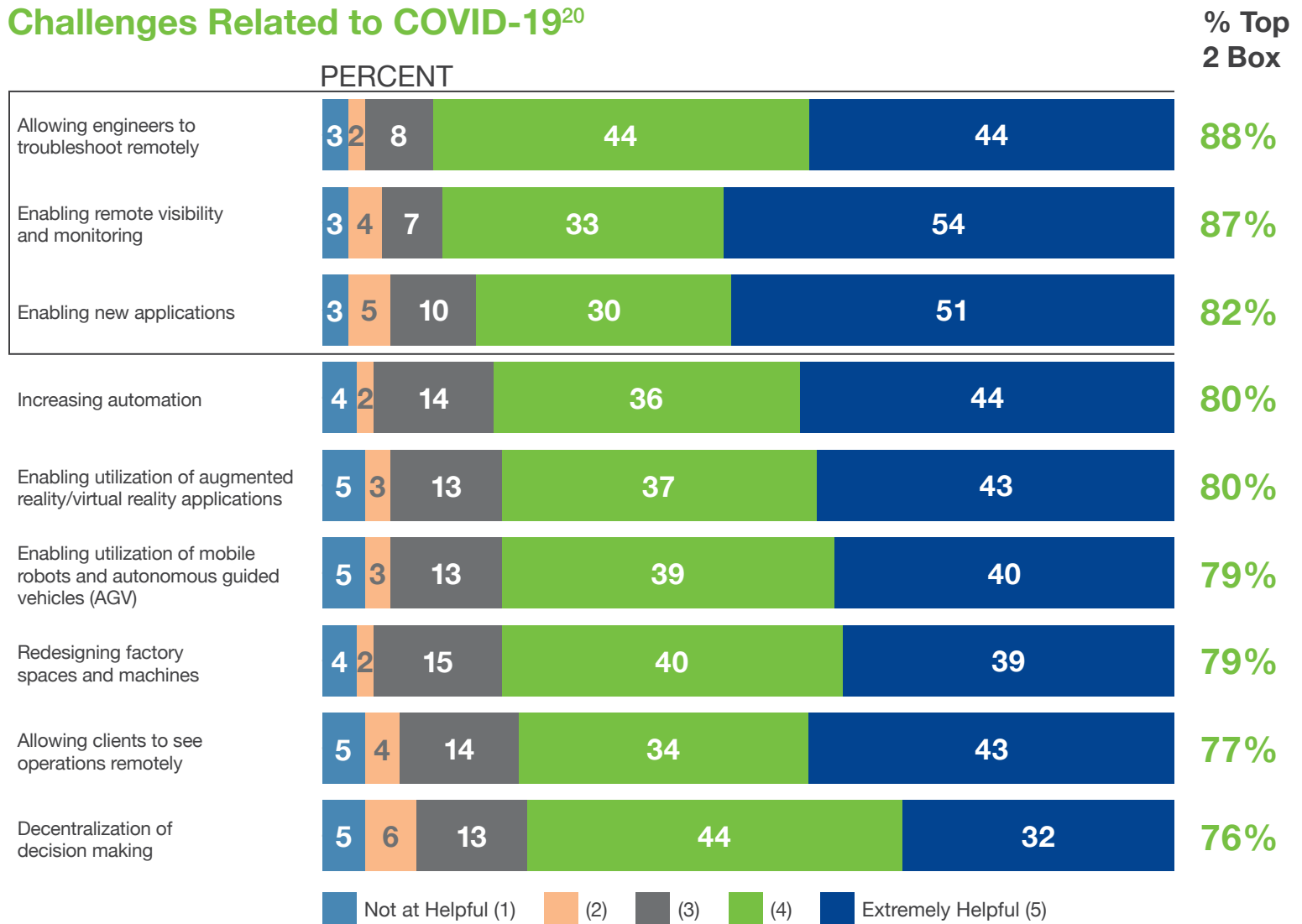
has often become a tight design and production cycle for many companies, NPIs often require engineers to be physically in factories at different points throughout the process so they can troubleshoot tooling issues in real time and ensure production timing goals are met. In today’s global economy, this can often necessitate international travel, and that of course was curtailed by the spread of the virus.

Manufacturers believe 5G connectivity could help them adapt to challenges like those created by COVID-19. For example, nine in ten manufacturers (88%) believe 5G could enable engineers to troubleshoot remotely. This capability could enable engineers to remotely manage some of the

tasks they have historically had to manage onsite. Manufacturers also report that 5G could enable remote visibility and monitoring (87%), which could again help them manage facilities and processes when physical presence is restricted.

Manufacturers see other possible 5G benefits to help them adapt to COVID-19 dynamics. The vast majority of manufacturers believe 5G would help through its ability to enable new applications (82%), increase automation (80%), enable utilization of AR/VR applications (80%), enable utilization of mobile robots and AGVs (79%), redesign factory spaces and machines (79%), create line of sight into operations remotely (77%) and decentralize decision making (76%).

Ways in Which 5G Connectivity Could Help in Adapting to Challenges Related to COVID-19²⁰



Empowering the Manufacturing Workforce with 5G

Factories of the future will require employees to work in close collaboration with complex machines. In these dynamic environments, real-time information will be paramount. For example, knowing the precise location of

each worker and every machine will help increase productivity, safety and security. This research has revealed a number of ways that 5G will empower workers with the information they need to more effectively and safely

perform their jobs. 5G will also improve employee training to ready tomorrow's workforce. 5G is a key enabling technology for the future of manufacturing, but it will require a strong workforce to transform manufacturing fully.

Real-Time Decision Making

5G will help provide workers with the information they need to perform their jobs. For example, the vast majority of manufacturers report 5G will aid remote analytics that will in turn support real-time decision making. Access to real-time data will allow workers to make better informed decisions throughout their shifts and will help manufacturers



improve important operational and quality processes that will drive stronger performance metrics for things like inventory turns, production output and quality standards. 5G will enable manufacturers to collect data from existing systems that are dispersed across the company, giving workers access to context-aware information and keeping workers continuously in the loop whether they are onsite or offsite.



A View from Manufacturing:

A Conversation
with John Deere
first-ever CTO

Jahmy Hindman

Why is 5G important for manufacturers like John Deere?

The benefits of lower latency and increased bandwidth enable additional applications for manufacturers. For example, lower latency opens up the potential for additional wireless real-time control applications in manufacturing environments. This comes without as much infrastructure as would be required with an ethernet and Wi-Fi network and it remains flexible. For example, IoT devices can be moved around a manufacturing environment while still remaining connected.

What will John Deere accomplish with 5G?

We hope to increase our footprint of IoT devices in the manufacturing environment and enable greater flexibility in our

ability to redeploy those devices. The additional data that is generated will make us more knowledgeable about our manufacturing process and enable us to identify opportunities to improve product quality and remove manufacturing inefficiencies.

The other direction that is interesting is how 5G impacts our end products and our agricultural customers. This brings to the forefront the need for rural 5G as



the operations of our customers are often rural, but the latest precision agriculture technologies depend on communication networks that enable high data bandwidth transfer to best optimize the agricultural process and inform time-sensitive decisions by the farmers.

How do you think other manufacturers should approach 5G?

Every manufacturer is different. My counsel would be to understand the technical benefits of 5G (i.e., latency, bandwidth, transmission distance) and evaluate where in your business these disruptions could potentially add value. In general, there are

opportunities that are created by the technology to automate more operations for manufacturers, which drives consistency in process and improves quality outcomes.

What are some of the cutting-edge things Deere is doing on this front?

We have leased our own 5G spectrum through the most recent FCC CBRS auction. Our intent is to



create our own private 5G network in some of our largest manufacturing locations and deploy 5G capable IoT devices at scale in these environments to improve our process control and real-time decision-making capability in manufacturing processes.

Partnerships are a big component of early 5G deployment. Why is this important for manufacturers?

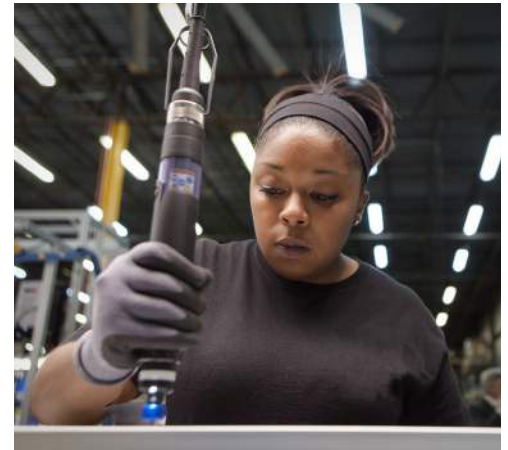
The technology changes quickly, and there is value associated with partnerships that allow manufacturers to stay on the forefront to take advantage of the latest technology.

Worker Safety & Security

Workers will also realize improved efficiency by using 5G-enabled tools. For example, workers can use 5G-enabled AR for troubleshooting when human intervention is required. 5G will also help engineers and other employees troubleshoot remotely.

Most manufacturers believe 5G will be vital for employee safety. As already noted, real-time data and connectivity will enable quicker response times. 5G will also enable safety systems that rely on real-time sensor data and systems that rely on rich media like streaming video. Workers will be able to control equipment from afar, especially important in unstable or dangerous

environments. Low latency will enable workers to work in close proximity with other machines. 5G will enhance the safety around individual equipment and more broadly across entire facilities.



Worker Training & Performance

A 2018 study from The Manufacturing Institute and Deloitte found that manufacturers would need to fill an estimated 4.6 million manufacturing jobs through 2028. A key aspect of filling these open positions will be training workers to perform increasingly complex tasks. As previously noted, 5G will enable XR applications that will improve the speed and effectiveness of training. Some 71% of manufacturers report 5G will aid in employee training.

5G-enabled XR training is especially well suited for preparing employees for high-stress situations like

emergencies or safety-sensitive tasks where the wrong actions can lead to injury or harm. While XR training is being used in some cases by companies today, the full potential of these tools will only be achieved with the help of 5G.

Nearly all manufacturers expect to see some level of worker productivity gains because of the use of 5G. Interestingly, manufacturers expect comparable productivity gains for both machines and workers from 5G, meaning workers will continue to play an invaluable role in manufacturing.

Final Thoughts: Stepping Up to 5G

As compelling as 5G's benefits for manufacturers are, each company will need to decide where, when or whether they deploy 5G. The leading concern in moving to a mobile wireless network like 5G is security. As an inherently mobile technology, 5G expands the footprint for a potential cyberattack. Other factors that increase security risks include the networks' inherent reliance on software and potential for poorly implemented configurations given the lack of specialist expertise in the market.

As time goes on, however, more best practices will be established. 5G ultimately improves on today's wireless security protocols and includes improvements for both recognizing and limiting the damage from breaches. Wireless carriers and other companies helping manufacturers to implement 5G technologies are working to develop new security solutions to stay ahead of threats that will arise as a result of wide 5G deployment. 5G will utilize 256-bit encryption, a significant improvement from the current 128-bit encryption. 5G will also use encrypted identity, instead of using permanent ID, which will help to keep both identity and location private and secure. 5G will also use flexible software that doesn't rely on a single company. Data will be routed through virtualized network nodes, which will further reduce reliance on a single company. This will allow vulnerabilities to be





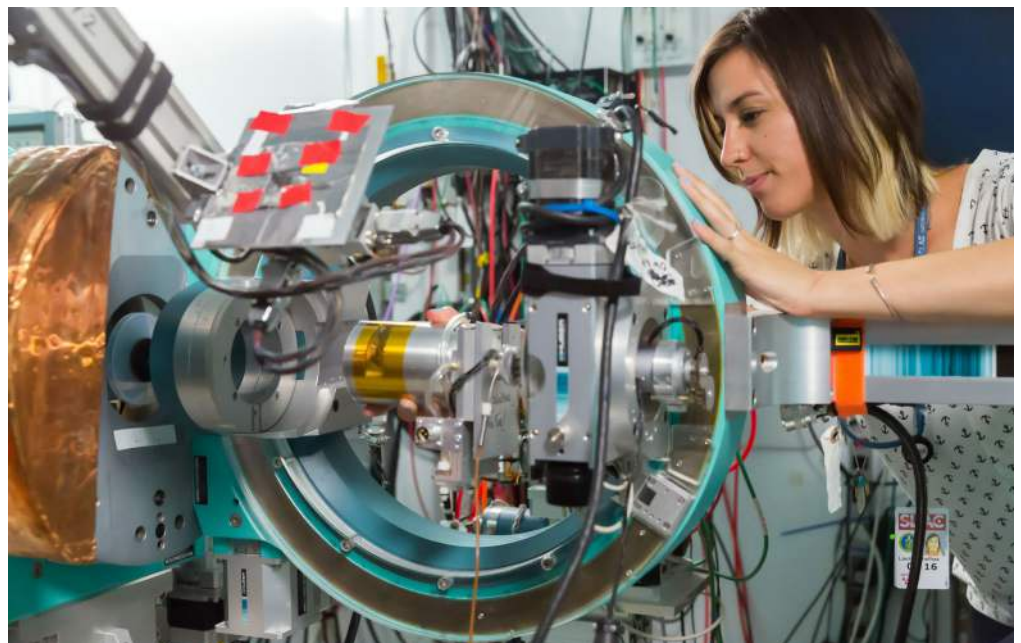
patched more quickly and problems to be isolated and fixed.

Companies also need to consider usage scenarios. While 5G is capable of powering new classes of applications, it may also simply function as a more reliable enabler of voice telephony in some settings; in others, it may replace wired or wireless local networks.

Indeed, some manufacturers have equipped their facilities with fiber or LTE; these may be recent

for infrastructure and client devices come down with scale. Ultimately, however, 5G offers more flexibility in configuring factory machinery than fiber while offering better speed, capacity, latency and, of course, better futureproofing than LTE.

5G will enable the future of connected manufacturing. It will become the underlying fabric of a network of connected intelligent sensors and will, in turn, provide manufacturing with unprecedented access to information and a source



investments that companies are reluctant to quickly abandon. This is particularly true given that 5G is a new technology that will see a stronger coverage, improving performance and flexibility-enhancing features added in the coming years. These improvements will help manufacturers gain confidence and experience in its capabilities, particularly as costs

of new insights. 5G will unlock new uses of AR and VR technologies, AI applications, predictive maintenance and intelligent, autonomous and semi-autonomous robotics. 5G will also empower autonomous mobility that will transform manufacturing facilities. 5G is needed to fully scale these innovations over entire manufacturing facilities and enterprise-wide systems.

Methodology

This white paper represents the findings of an online quantitative survey fielded among n=105 manufacturers between Oct. 14 and Nov. 20, 2020. A mixed approach to sampling was used in the fielding of this study, with respondents being sourced from both the National Association of Manufacturers membership database (n=18) and a proprietary research panel (n=87). The sample consisted of those in leadership positions across a wide variety of industrial classifications.

SAMPLE SOURCE

Membership	17%
Panel	83%

JOB TITLE

Executive/C-Level	46%
Senior-Level Director/Manager	31%
Director/Manager	22%
Team Lead	1%

NUMBER OF EMPLOYEES

Fewer than 10	2%
10–24	3%
25–49	4%
50–99	9%
100–249	14%
250–499	10%
500–999	17%
1,000–2,499	20%
2,500–4,999	8%
5,000 or more	15%

NUMBER OF EMPLOYEES

Less than \$5 million	9%
\$5 million to <\$10 million	7%
\$10 million to <\$25 million	11%
\$25 million to <\$50 million	11%
\$50 million to <\$100 million	8%
\$100 million to <\$250 million	9%
\$250 million to <\$500 million	13%
\$500 million to <\$1 billion	10%

INDUSTRIAL CLASSIFICATION

Electrical Equipment, Appliance and Component Manufacturing	17%
Computer and Electronic Products	14%
Machinery	12%
Fabricated Metal Products	11%
Food Manufacturing	11%
Apparel Manufacturing	8%
Plastics and Rubber Products	6%
Chemicals	3%
Furniture and Related Products	3%
Primary Metals	3%
Non-Metallic Mineral Products	2%
Paper and Paper Products	2%
Transportation Equipment	2%
Beverage and Tobacco Products	1%
Petroleum and Coal Products	1%
Printing and Related Support Activities	1%
Textile Mills and Textile Product Mills	1%
Other	4%

Footnotes

- 1 <https://www.ericsson.com/4adc87/assets/local/mobility-report/documents/2020/november-2020-ericsson-mobility-report.pdf>
- 2 Base: Total Responding (n=105), Q26. When do you expect to begin 5G integration into your existing operations?
Base: Manufacturers Currently Integrating or Planning to Integrate 5G (n=100), Q27. When do you expect to have 25% of your production capability integrated with 5G?
- 3 Base: Total Responding (n=103), Q28. Next, what are your company's biggest pain points related to the implementation of current, existing, or anticipated wireless technologies? Please select all that apply.
- 4 Base: Total Responding (n=104), Q29. What are your company's biggest pain points related to manufacturing facility analytics? Please select all that apply.
- 5 Base: Total Responding (n=101), Q30. What are your company's biggest pain points related to real-time asset/resource tracking? Please select all that apply.
- 6 Base: Total responding (n=105), Q19. Which, if any, of the following 5G benefits will aid your manufacturing processes? Please select all that apply.
- 7 Base: Total responding (n=103-104), Q14. Please indicate your level of agreement with each of the following statements.
- 8 Base: Total responding (n=103-104), Q6. Thinking about your business, how important will 5G connectivity be to each of the following:
- 9 Base: Total responding (n=103-105), Q10. Again, thinking about your factories and facilities over the next 10 years, how important will 5G be for each of the following:
- 10 Base: Total responding (n=101-104), Q24. To what extent do you think each of the following value-added services will be aided by 5G?
- 11 Base: Total responding (n=104), Q17. Next, to what degree will 5G impact each of the following manufacturing environments?
- 12 Base: Total responding (n=98), Q21. Next, what do you estimate the cost savings would be from connecting equipment wirelessly with 5G versus connecting with physical wires? Q22. How much more productive would your machinery be if it were all connected via 5G? Q23. And how much more productive would your workers be if your equipment were connected via 5G?
- 13 Base: Total responding (n=103), Q18. What do you foresee as the greatest advantages of 5G versus that of current technologies? Please select all that apply.
- 14 Base: Total responding (n=102-104), Q15. How easy or difficult are the following activities using wired, Wi-Fi or 4G connections?
- 15 Base: Total responding (n=102-104), Q15. How easy or difficult are the following activities using wired, Wi-Fi or 4G connections? Q16. How easy or difficult do you believe the following activities will be using 5G connections?
- 16 Base: Total responding (n=105), Q20. Which, if any, of the following would lead you to prioritize 5G adoption in your business? Please select all that apply.
- 17 Base: Total responding (n=103), Q32. Specifically related to 5G technologies, what do you perceive to be the primary barrier(s) that might prevent 5G adoption and implementation in your factories and facilities? Please select all that apply.
- 18 Base: Total responding (n=105), Q8. Thinking about your factories and facilities over the next 10 years, how important will 5G connectivity be to the overall future of your business?
- 20 Base: Total responding (n=104-105), Q33. To what extent do you think 5G connectivity in your facilities could help with adapting to issues related to COVID-19?

PHOTO CREDIT

Page 38-39:

Copyright © 2019 Deere & Company. All Worldwide Rights Reserved. THIS MATERIAL IS THE PROPERTY OF DEERE & COMPANY. ALL USE, ALTERATIONS AND/OR REPRODUCTION NOT SPECIFICALLY AUTHORIZED BY DEERE & COMPANY IS PROHIBITED.





“Connecting Manufacturers with the Future: How 5G Is Transforming the Manufacturing Landscape” is a digital publication of The Manufacturing Institute. All rights reserved.

The contents of this report consist of insights and analyses developed by MI staff and Dr. Shawn DuBravac of Avrio Institute, working on the MI’s behalf. All listed companies and product names are the trademarks or registered trademarks of their respective companies.

This report is not for sale or redistribution. The use of this report or its content for publicity or advertising, or for any commercial or income-generating purpose, is strictly prohibited. No elements of this report, in part or in whole, may be used to promote any specific individual, entity or product, in any manner without the consent of the MI. The use of this report and its content for informational purposes and for the inclusion of brief quotes is encouraged. The content must not be changed, and full acknowledgement of the source must be clearly stated.

This report was made possible through the financial support of Qualcomm Technologies, Inc. Shawn DuBravac and MI staff are exclusively responsible for this report and all the analysis and content contained herein. The analysis and metrics developed during this research represent the independent views of Shawn DuBravac and MI staff and are intended to contribute to the conversation on the role of 5G and manufacturing.