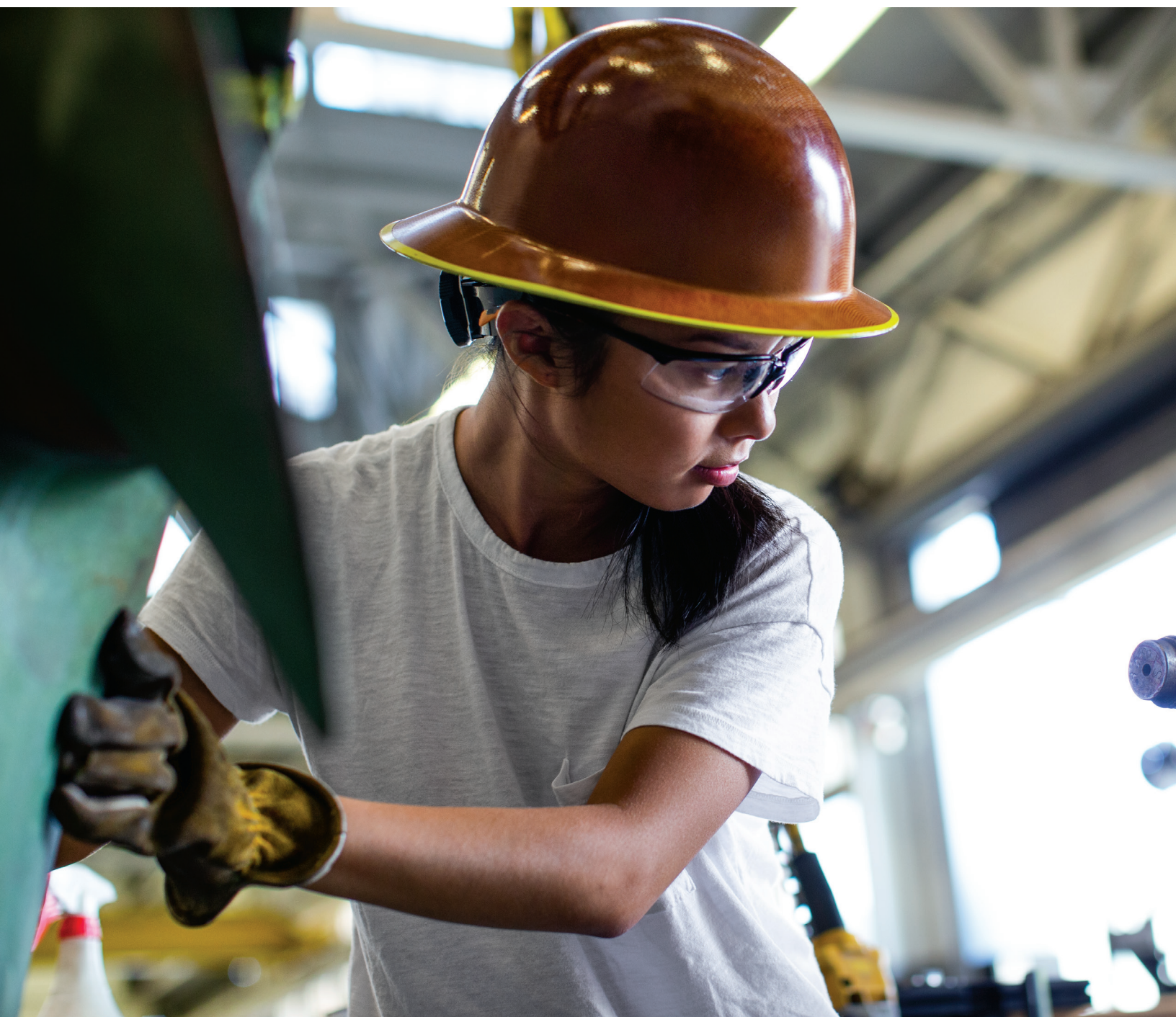# Top eight trends every COO should know about the future of manufacturing

Introduction

Since the beginning of the First Industrial Revolution, manufacturing has been the force pushing industrial and societal transformation forward. Today, as we not only turning the page on a new year, but on a new decade, we find ourselves in the midst of yet another industrial revolution. As a new generation of sophisticated technologies become more readily available, they are transforming manufacturing into a highly connected, intelligent, and ultimately, more productive industry. The man-powered shop floor of the past is being replaced by smart manufacturing facilities where tech-savvy workers, aided by intelligent robots, are creating the products of the future.

Modern manufacturers are no longer just makers; they are the thread that connects the entire lifecycle of a product. To thrive in this modern environment, they must increasingly rely upon technology to power breakthrough innovations and drive more intelligent operations.

In this year's trends report, we will explore eight emerging trends that every COO should know about the future of manufacturing so that they design more intelligent operations and increase the speed of doing business.

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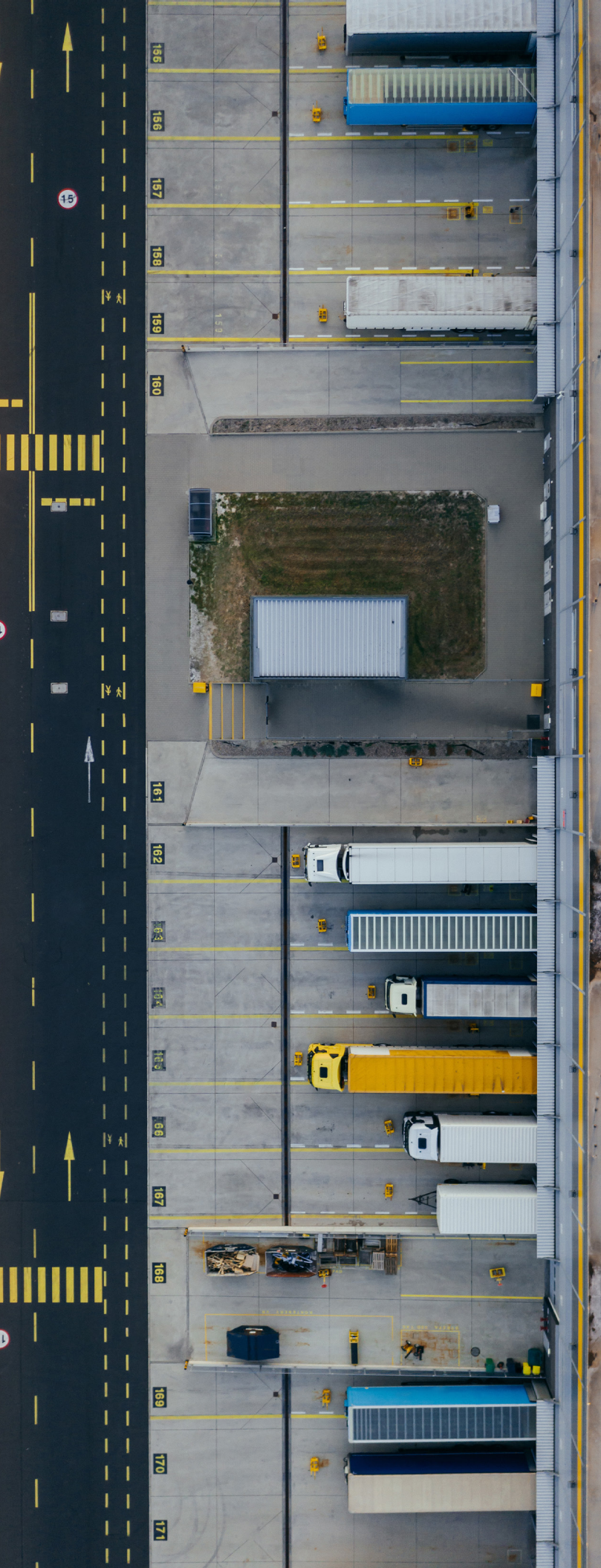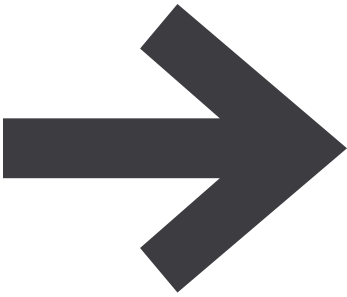
Unified data, intelligence
everywhere

02 /

Focus shifts from
technology to experience

03 /

Manufacturing becomes
more intelligent

04 /

Ethical manufacturing
inspires changes

05 /

Manufacturers adapt to a
changing workforce

06 /

Technology enables
advanced R&D

07 /

Supply chain becomes a
competitive differentiator

08 /

Businesses adapt to global
uncertainty

01 /
Unified data, intelligence everywhere

Unified data, intelligence everywhere

Unlike the other trends detailed in this report, which we have tried to make as independent and differentiated as possible, this first trend is more of a macro-level trend. It's a trend that, in some capacity, is either an influence or a force-multiplier of each of the subsequent trends. It is a trend that is as much about its individual elements as it is about the sum of its parts: the Internet of Things (IoT) and artificial intelligence.

Meet the new, fully connected business

For the last decade—and accelerated further in the last several years with the growing ubiquity of cloud computing— we have seen a push towards a more connected business. This transformation has been neither linear, nor has it been one dimensional; for many, it has been complex and evolved in key stages.

Executive summary

Fully-connected businesses are able to provide AI tools with more complete data. This helps these systems provide more accurate outputs and deliver intelligence to every corner of the business.

Highlights

- Global spending on digital transformation efforts is projected to reach $2 trillion by 2022.

- The AI market in the US is projected to reach $118.6 billion by 2025, up from $14.7 billion in 2019.

- Spending on AI automation in the US is projected to increase from $9.7 billion in 2018 to $15.4 billion in 2021.

First, companies digitized. Through computers, mobile devices, and sensors that enabled digital tracking of mechanical devices, this digitization process made it possible to capture data from any device. Next, they aggregated this data. For most, this data aggregation process happened in stages, in one team or department at a time. This approach left businesses with aggregated but siloed data. To connect these data silos, companies hacked together systems and APIs to help transfer data between siloed business units, often resulting in duplicate data sets, slow speeds, and increased security risks. To a degree, this system of interconnected data silos has been standard operating procedure for a while now, but as cloud technology matures, this model is starting to change.

Through advancements in cloud processing, data lakes, and software—as well as better business processes and governance—businesses are finally starting to tear down data silos and realize the potential of a fully connected business, one where all of an organization's data is aggregated into a central database, which both receives and sends data across the organization, in real-time, wherever it is needed.

For businesses, this presents a huge leap forward, and the implications and opportunities for unified, real-time data from across the organization are substantial. It means that business leaders can have access to live data to help make more strategic decisions with the latest information. It means that businesses can push updates to workers in the field, ensuring that they have the most recent information. It means that companies can track a customer's relationship with their brand through every touch point across their entire lifespan. And it means that financial reporting is both faster and more accurate.

"The implications and opportunities for unified, real-time data from across the organization are substantial."

These changes are not merely an update to existing tools, they represent the next phase in a company's digital transformation journey, and business leaders are making the investment. According to a recent study by eMarketer, about eight in ten US companies are currently investing in digital transformation to improve performance, meet customer demands, and remain competitive.[1] Globally, spending on digital transformation efforts is projected to reach $2 trillion by 2022 [2], providing organizations with the infrastructure and software they need to innovate and grow.

Digital transformation market revenue
in trillion USD

*Projected
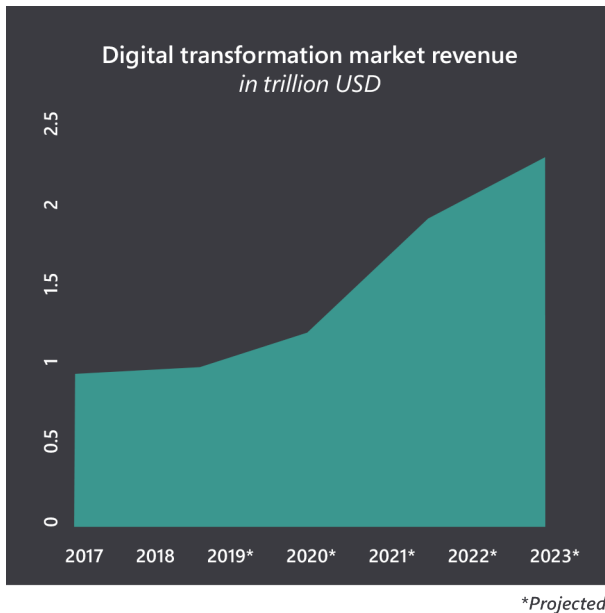
Business leaders gain visibility into performance and operations

One of the most significant gains from a connected business is the ability to leverage unified data from across the organization. Unified data provides business leaders with better visibility into both performance and operations. With a more complete picture, they are able to make faster, smarter decisions.

It also provides business leaders with a better opportunity to identify correlations from different parts of the business that would not otherwise be visible. This visibility can help companies improve forecasting and identify market trends faster, so they can shift strategies and capitalize on evolving consumer interests.

Furthermore, increased visibility into business operations and performance helps business leaders mitigate risk, either through early recognition of operational issues that need to be addressed or from identifying outlying data that may suggest an abnormality—such as an impropriety on the part of an employee or a data breach from an external threat.

"AI's output is only as good as it's input."

Unified data unlocks advanced analytics and artificial intelligence

Artificial intelligence (AI) has received a lot of air time these last few years, as improvements in computer processing and algorithms have introduced even more powerful solutions. And adoption is on the rise. The AI market in the US is expected to reach $14.69 billion in 2019—a 154% increase from last year—and is projected to reach $118.6 billion by 2025.[3]

However, for as great as modern AI solutions are, there remains one major limitation impeding their effectiveness: data quality. AI's output is only as good as it's input, and in years past, this has been a significant challenge. At best, AI analysis conducted using incomplete data sets can result in suboptimal outputs; at worst, it can steer companies in the wrong direction.

As connected businesses unify data from across the organization—providing a more comprehensive data set—it is unlocking the true potential of AI. This broader data set not only enables better data for primary analysis, but it also allows AI tools to discover connections and correlations in discrete parts of the business where no one would think to look, and these insights may help improve operations and performance. Unified data removes silos, which in turn enables intelligent tools to be leveraged across all business units, elevating every part of the business through applied intelligence.

Forecasted growth of the artificial intelligence (AI) software market worldwide from 2019 to 2025

154%	2019
154%	2020
154%	2021
147%	2022
138%	2023
133%	2024
126%	2025

Connected businesses empower automation

As business systems and machines push data into a unified database to be processed and analyzed using AI tools, this same interconnection also allows for information to be pushed back throughout the system. While we may not think of applied AI in these terms—sending data to a central database, analyzing that data, then pushing some response back to the source—this is often (in very simplified terms) how these tools work. This includes AI interfaces that humans interact with, such as virtual assistants, robo-investors, and smart speakers.

"Unified data removes silos, which in turn enables intelligent tools to be leveraged across all business units, elevating every part of the business through applied intelligence."
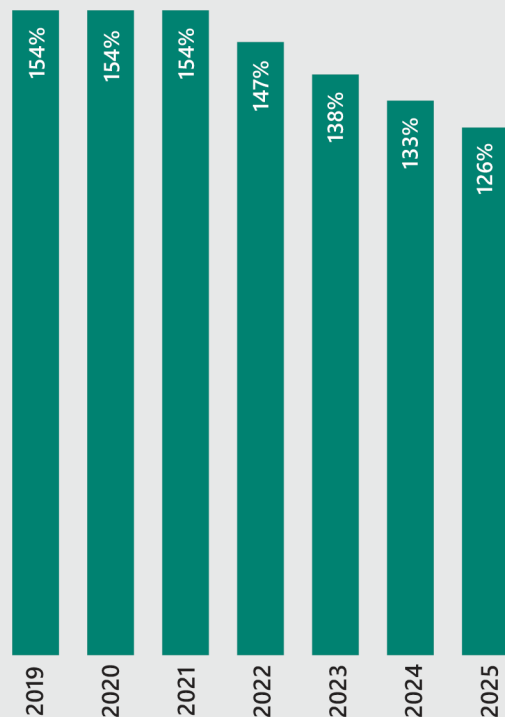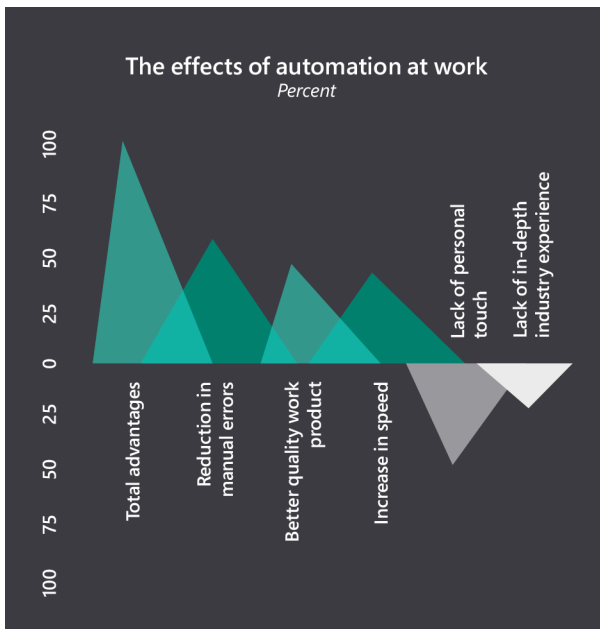
The effects of automation at work
Percent

This cycle enables intelligent automation: the ability to collect input data from a system, use artificial intelligence to automatically generate an output command, then push that command outwards to control the system. Put simply, the "muscles" that feed the data to the brain can then be controlled by output from the brain. And as this input-output cycle continues, it creates a feedback loop where the algorithms generating the output commands are able to learn from new results and improve their performance.

The impacts of automation at work are substantial. In a recent survey, nearly all business leaders (99%) felt that there are advantages to automation. Fifty-two percent of business leaders think that it leads to a reduction in manual errors, 45% believe it leads to better quality projects, and 43% feel it improves speed.[4]

This is not to suggest that automation does not come without risks. In the same survey, 47% of business leaders cited a "lack of personal touch" as a risk of automation, while 23% fear it will lead to a lack of in-depth industry experience. Despite these risks, businesses continue to invest in AI automation. Spending on AI automation in the US is projected to increase from $9.7 billion in 2018 to $15.4 billion in 2021, nearly a 60% increase.[5] It is clear that as businesses become more connected and more intelligent, more systems and processes will become automated. - -

@Microsoft

Connect and modernize

To stay competitive and innovate, manufacturing leaders need to connect their operations and leverage the latest intelligent tools. At Microsoft, we are empowering manufacturing leaders with the infrastructure, power, scale, and intelligence to help them modernize and transform their businesses.

Unify business data

Manufacturing leaders need real-time visibility into operations and performance to make informed decisions. From cloud-based data solutions on Azure to intelligent analytics tools in Dynamics 365, we're helping manufacturing leaders turn data into actionable insights so they can optimize operations and make more strategic business decisions.

Get greater visibility

To effectively guide their organizations, manufacturing leaders require visibility into all areas of their businesses. By combining unified data in the cloud with powerful data visualization tools, like Power BI, Microsoft provides manufacturing leaders with a single source of visibility into their operations—from technology to financial data—so they can make more informed decisions.

Automate workflows

As the pace of modern business accelerates, manufacturing leaders are looking to streamline processes and get more done. With Azure, Dynamics 365, and Office 365, we're providing manufacturing leaders with tools to automate workflows and simplify communication so they can improve efficiency, performance, and productivity.

02 /

Focus shifts from technology to experience

Focus shifts from technology to experience

Demands on manufacturers are greater today than ever before. Customers want higher quality products at lower costs, they're requesting greater transparency into inventory and operations, and they expect shipping to be faster and cheaper.

To meet these rising customer expectations, manufacturing leaders must optimize their processes for speed and efficiency. To accomplish this, they are turning to new technology solutions that make it easier to gain insight into operations, deliver better and more responsive service, respond flexibly to changes in customer demands, and improve customer confidence in product quality.

Across the board, technology is helping manufacturers become smarter, leaner, and more responsive to customers' needs, ushering in a bright new era of manufacturing.

Executive summary

As customer expectations rise, manufacturing leaders are turning to technology to help them deliver better, more consistent experiences.

Highlights

- 63% of customers switched to a competitor because they offered better service.

- The e-commerce subscription services market is now worth more than $10 billion.

- 53% of shoppers rated quality as the most important factor when making purchases.

Unified data allows companies to deliver better service

Responsive service and support

A recent survey found that 52% of customers would leave a brand without any warning.[6] This statistic is the harsh reality that companies face today. With competition growing by the day in nearly every industry and production standards rising across the board, it has become easy for customers to pick and choose between a plethora of high-performing products that offer few, if any, significant differences. As a result, customers are often enticed by deals and discounts, rather than quality-based features.

So, what happens when established brands become commoditized in the eyes of the consumer? How do manufacturers keep customers engaged after the sale of the product? Enter Service 4.0.

Fortunately for manufacturers, the same survey that reported a majority of customers would leave without warning also found that 63% of customers switched to a competitor because they offered better service. The study revealed that customers valued speedy service the most, followed by the quality of service.[7]

From hyper-convenient deliveries to no-questions-asked return policies, today's consumers have dramatically high service expectations. Companies whose products are not readily distinguishable to the average consumer must offer superior service to stay competitive.

63%

Percent of customers who switched to a competitor because it offered better service.
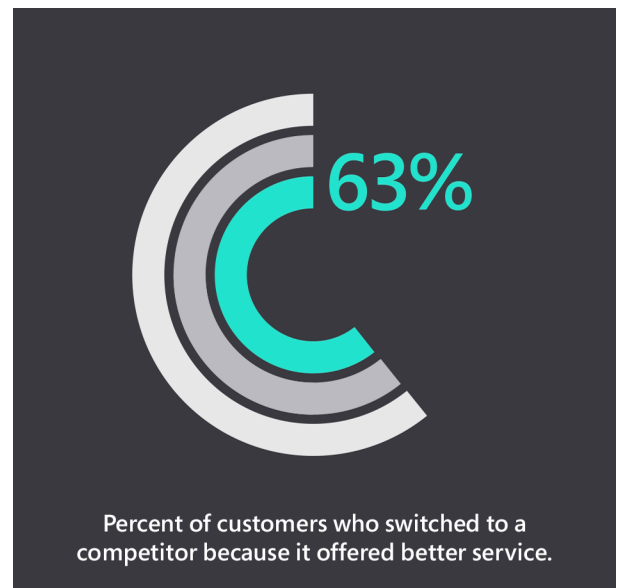
Servitization-centered manufacturing is becoming the new mantra for many manufacturers. In the B2C sector, this means not just keeping track of data such as who the end consumer is, how they're using the product, and why they're using the product, but also being able to engage and communicate with customers to identify future service and support needs. Once upon a time, a manufacturers' relationship with the consumer ended as soon as the product was delivered. Today, that's when the real customer relationship starts. Intelligent sensors have enabled manufacturers to gather real-time data on product usage and performance. Access to product usage information allows manufacturers to understand data, such as which product features are most used and how the product is being used. This information can then be leveraged to inform future product designs.

Similarly, product performance data allows companies to predict maintenance needs and repair requirements, where the manufacturer can reach out to the consumer to schedule service appointments prior to the equipment experiencing any actual breakdowns. Given the typical consumer's busy lifestyle, such responsive service and support is invaluable.

In a B2B setting, manufacturers' focus is shifting from selling equipment to gaining access to usage data and leveraging this information to provide superior post-sales service and support. New cloud-based solutions integrate the use of smart sensors and machine learning to help manufacturers move from a reactive, break-fix service model to a proactive, preemptive repair service model.

Using sensors, companies can gather data on product malfunctions and feed this information to predictive analytics models that forecast repair requirements and alert customers to service requests. This level of insight and engagement is particularly beneficial for OEMs since reducing equipment downtime is a critical requirement for their businesses.

"Once upon a time, a manufacturers' relationship with the consumer ended as soon as the product was delivered. Today, that's when the real customer relationship starts."

Blockchain offers transparency and speed

In a manufacturing environment, end-to-end process visibility is a must if you want to ensure smooth operations. Thankfully, blockchain has emerged as a powerful tool to generate the transparency required to maintain superior product quality and secure consumer trust.

Blockchain can be used to validate every transaction, from supplier to delivery, enabling manufacturers to manage a plethora of critical information such as material traceability, vendor certifications, fraud prevention, contract compliance, and more. The clarity and accuracy manufacturers gain by incorporating blockchain translates into better service for their customers.

AI improves production planning

Expectations surrounding the online shopping experience have created new challenges for manufacturers, as any lag between ordering and fulfillment is becoming increasingly unacceptable to consumers. Accordingly, manufacturers must continuously stay attuned to their internal data, such as inventory levels and variations in product demand, to ensure the right products are available and ready for shipping when needed.

Demand fluctuations due to changes in customer requirements or other operating conditions can create complexities in production planning and scheduling. By using machine learning, manufacturers can create digital systems that learn from these fluctuations and dynamically alter production processes to accommodate new requests.

The ability to manage and dynamically route manufacturing workloads remotely has ushered in a new era of contract manufacturing. With equipment-as-a-service (EaaS) and robotics-as-a-service (RaaS) offered as pay-as-you-go business models, manufacturers can now mass-produce customized products for their
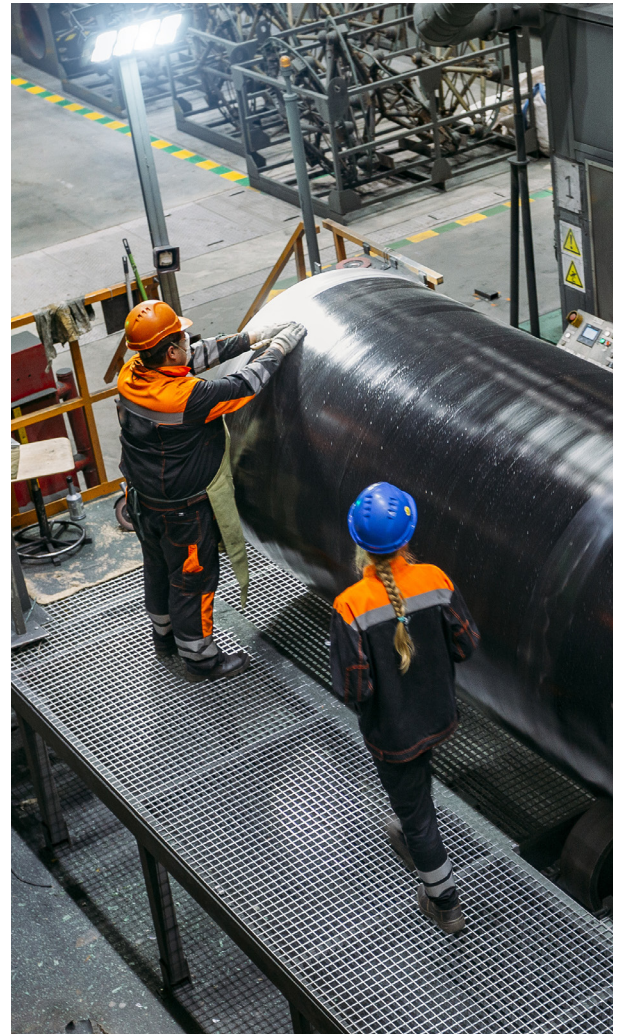
customers. These new manufacturing models provide the flexibility to change production volume and design specifications at the touch of a button, without manufacturers having to invest in their own factories or equipment. This enables small and medium businesses to scale up or down quickly based on demand fluctuations.

Digital twins accelerate innovation

Digital twins are another emerging technology that's making manufacturing more agile and responsive. These digital simulations can drastically accelerate the average prototyping timeline, enabling faster design-to-manufacturing cycles.

By connecting product designers directly to manufacturers via cyber-physical systems, digital twins foster an environment of rapid collaboration, cutting down on lengthy product design stages. The result is quicker product development timelines and faster delivery of new products to the customer.

Digital twins can also be used to model production processes on the factory floor. When combined with equipment sensors and consumer demand data, these models can be used to predict process anomalies or identify performance bottlenecks. In the case of EaaS, these sensor-based simulations can provide critical information about production equipment, creating a unique environment of total information transparency between the EaaS vendors and their clients.
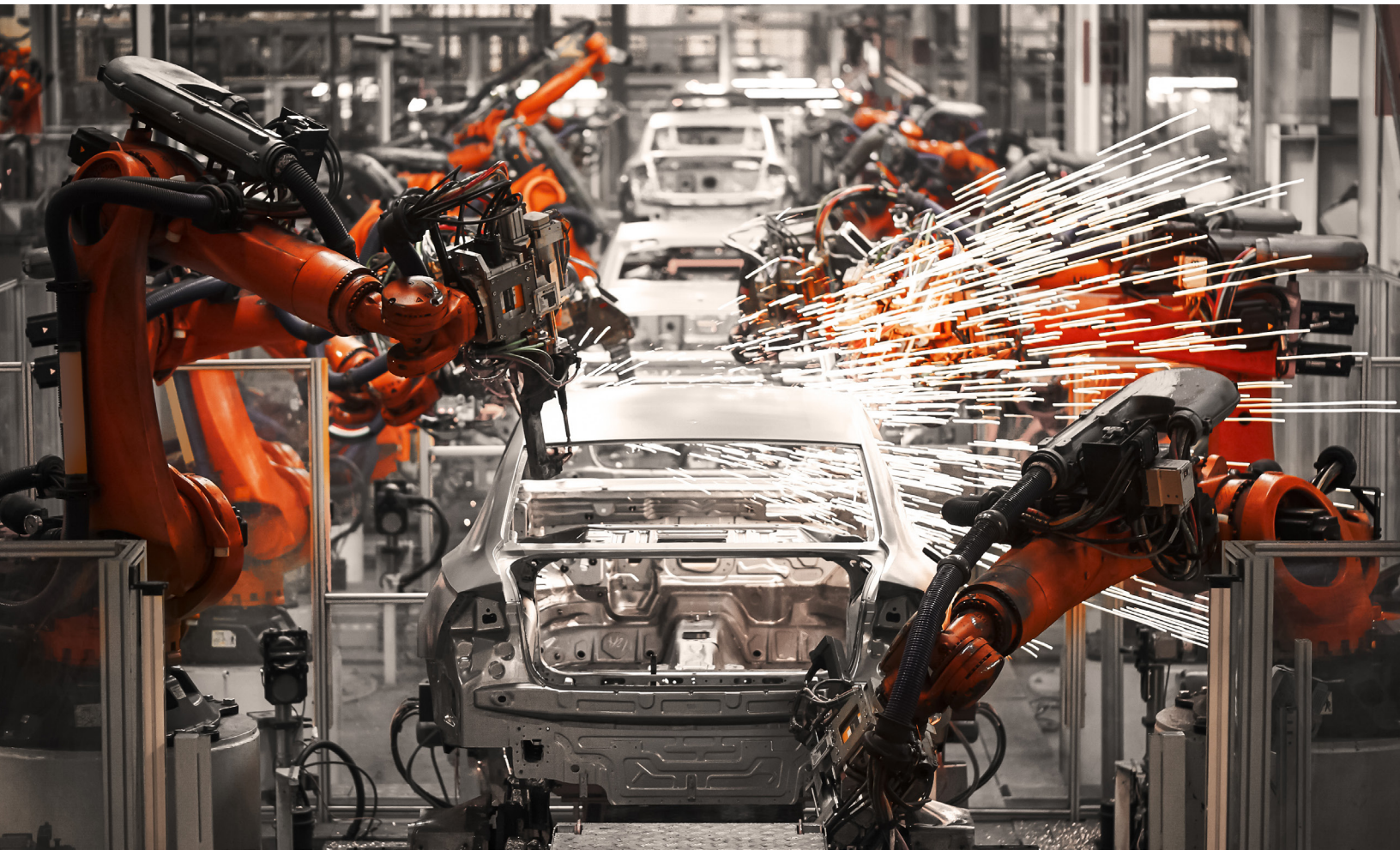
Agile manufacturing enables greater personalization

Innovation—from the printing press and combustion engine to computers and wireless internet—has always been a driver of demand, unlocking new possibilities and raising expectations. Today, we find ourselves at the intersection of rapid innovation and a new generation of consumers who have grown up empowered by technology.

Thankfully, recent developments in chatbots, data analytics, and machine learning are giving businesses greater insights into the customer journey and making it possible to deliver better service without a corresponding increase in time or labor.[8]

Custom and data-driven products

In a world that's obsessed with big data, manufacturers are continually looking for new data streams to incorporate into product and process design. Consumer feedback, purchasing patterns, product usage data—every information node helps manufacturers meet unique user requirements.

Fueled by the low cost of additive manufacturing and a heightened interest in product personalization, companies are steadily moving towards on-demand and micro-manufacturing. On-demand production is not only enticing for customers; it virtually eliminates inventory issues and dramatically reduces production waste. Rather than attempting to predict product needs, factories are able to meet the point of demand directly, producing appropriate volumes as needs arise.

Advances in AI and automation are helping companies to get creative with their products and allowing manufacturers to be more targeted in how they serve individual consumers, not just the market average.

Automation has long been a boon for the manufacturing sector, allowing companies to shorten production times while decreasing production defects. Soon, automation may show up in more unusual settings, like restaurant kitchens. Seattle-based Picnic recently showcased the food and hospitality industry's first intelligent automated assembly system for making custom pizzas. Picnic's system allows customers to pick and choose their favorite pizza toppings and sauces via an app interface. Using computer vision systems to monitor the pizza at various stages enables fast and accurate pizza assembly—up to 300 pies per hour—with very little supervision.
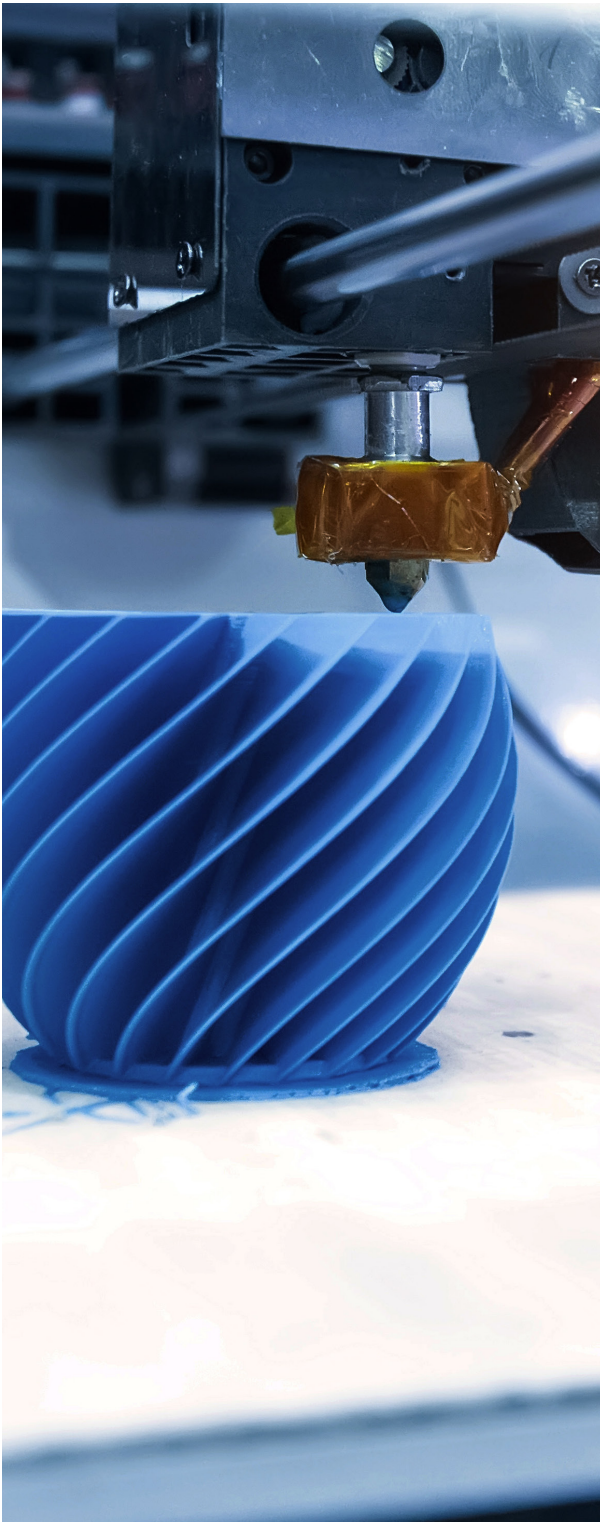
The cosmetics industry has always struggled to provide products that are personalized to an individual's hair or skin type. Shoppers have historically had to maneuver through aisles of mass-market products with confusing labels and competing claims, despite the fact that most formulas contain the same essential ingredients. For some cosmetics brands, automation may hold the key to offering a greater degree of customization. Prose, a newly launched custom haircare brand, is using the power of AI to create personalized haircare products. Data gathered via interview questions helps Prose's system identify the ideal hair care regimen for each customer, which is then formulated using a unique combination of ingredients perfectly tailored to the customer's

"Automation allows manufacturers to shorten production times while decreasing production defects."

needs. Mainstream cosmetics brands are also investigating new opportunities to leverage automation. At the 2019 Consumer Electronics Show, Neutrogena unveiled MaskiD, the first-ever 3-D printed face mask. The face mask can be printed to fit the shape and size of the customer's face and will contain custom skincare ingredients based on the individual's skin treatment requirements.

The UPS Store now offers small businesses and individuals to use 3-D printing services to create one-of-a-kind items such as engineering parts, functional prototypes, acting architectural models, fixtures for cameras, lights, and cables.[9] The shipping enterprise continues to scale these services nationwide as they look for new ways to support their customers.

Additive manufacturing is proving to be extremely beneficial in the medical industry as well. Stratasys, a leader in 3-D printing technology, recently launched a Digital Anatomy™ 3-D printer. The printer is the first of its kind to be able to replicate the feel, responsiveness, and biomechanics of various human anatomical structures and will help eliminate the need for cadavers for surgical training.

3-D printing is also having an unexpected influence in textile production. A team of researchers at Carnegie Mellon University's Textile Lab has discovered a way to translate 3-D meshes into instructions that can be read by industrial knitting machines.[10] The development would give factories the ability to create one-off and small-batch designs, something that was not previously possible given the time and expense typically involved in programming knitting machines to produce a new design. Using the new algorithm, factories could generate designs tailored to the exact size and colors a consumer ordered. At scale, this technology could potentially reduce the amount of inventory that distributors need to stock and allow manufacturers to produce goods for a broader range of customers.

In early 2018, Amazon received a patent for a new retailing system that would enable the company to accept online orders for custom 3D-printed items.[11] The resulting products would then be available either for pickup or delivery. As the demand for faster, more personalized products grows, so will the need for on-demand production and micro-manufacturing.

E-commerce subscription service market value

$10 billion

Brands go direct to consumer

To pursue larger profit margins and retain control of the customer experience, some manufacturers are bypassing traditional retail channels and going straight to the consumer. Manufacturers and retailers recognize that selling directly to consumers gives them greater access to consumer data, allowing them to have a more significant brand impact while increasing profit margins. A third of American consumers intend to do at least 40% of their shopping with direct-to-consumer (D2C) brands.[12]

One prominent example of this trend is the rise of D2C subscription services over the past decade. Fuel, a subsidiary of McKinsey, estimates that the market for e-commerce subscription services is now worth more than $10 billion.[13] One of the most successful D2C practitioners is Dollar Shave Club. The men's grooming company, a disruptor in its sector, was eventually purchased for $1 billion by Unilever in 2016.

"A third of American consumers intend to do at least 40% of their shopping with direct-to-consumer brands."

Dollar Shave Club has inspired other subscription-based D2C services, such as Gillette On Demand and the Tide Wash Club. Recently, Procter & Gamble launched Tide Cleaners, an app-based, on-demand mobile laundry service. The Tide Cleaners app leverages consumer data and enables P&G to increase its brand reach and establish brand loyalty.

Even major brick and mortar retailers are joining in with their own subscription box services, including Walmart and Macy's (coincidentally, both call their subscription services "Beauty Box"); Nordstrom,

which purchased Trunk Club in 2014; and Amazon, which acts as a platform for other companies to sell their subscription services, including flowers, camping supplies, pet toys, and workout gear. To succeed in this sector, subscription services must feature an offering that can surprise and satisfy customers on a recurring basis.

Subscription services aren't the only players that are faring well in the D2C market. Consider Casper, the internet upstart that's challenging the titans of the $17.3 billion mattress market. With $400 million in sales in 2018, Casper has sold more than a million mattresses since its founding and inspired a string of D2C mattress copycats. Like many other brands that were born on the internet, Casper intends to supercharge its growth with the addition of hundreds of physical stores over the next several years.[14] The company hopes that this clicks-to-bricks strategy will allow it to broaden its reach and increase customer engagement by providing store visitors with a more immersive, tactile experience. Casper's Dreamery is the first of its planned mega-expansion into physical stores. Located in the heart of New York City, customers can book naps for a small fee and truly experience Casper's products at the Dreamery.

Other entrants in the D2C market have found success because of supply chain innovation and vertical integration. Brilliant Bicycle offers quality cycles for less than competing manufacturers because it ships each order directly from the factory to the customer. Harry's, another contender in the men's grooming space, has focused on offering quality shaving gear at a lower price—a feat that's possible not only because Harry's sells direct to consumer, but also because the company purchased its own razor factory.[15]

Another promising niche made possible by the D2C market is the sale of artisan foods. Companies like GrubMarket allow small-scale growers and producers to connect with consumers, restaurants, and other businesses that want to feature local products but who previously couldn't because of the expense and difficulty involved in sourcing those goods.[16] This new model of commerce is made possible by technology; it's also made possible by venture capital firms like Evolv, a $100 million venture fund backed by Kraft Heinz, which invests in early-stage technology companies in the food industry, including GrubMarket.

For manufacturers and retailers alike, the biggest advantage of adopting a D2C model is the elimination of middlemen. When brands go through third-party retailers, they typically have little to no access to the end-users of their products. As a result, their branding and advertising activities are usually centered around generic consumer personas. In contrast, direct selling enables businesses to truly know and understand their customers, information they can leverage to create stronger relationships with their customers, market more effectively to their niche, and tailor products more closely to customers' needs.

"**Consumers are shifting towards a more minimalist style of living, purchasing fewer, longer lasting products and spending more of their disposable income on services, experiences, and entertainment.**"

Quality management is more critical than ever

The Industrial Age brought with it an era of global economic prosperity, where massive shifts were seen in the standard of living of people across economies. At the same time, we witnessed unprecedented technological advancements across industries, from energy to consumer goods. Companies learned to make new products faster and more efficiently, which in turn meant reduced costs of production and the ability to reach mass markets.

Paradoxically, this increase in production efficiency, coupled with the western world's environmentally conscious consumer, has brought us to a new "peak stuff" world, where the need to own stuff is being decoupled from happiness and the image of wealth. Consumption has reached a tipping point in places like the UK, where despite growing levels of both wealth and population, rates of material consumption have begun to decline.[17] In developed nations, consumers are gradually shifting towards a more minimalist style of living, purchasing fewer, longer-lasting products, while spending more of their disposable

53%

Percent of shoppers who rated quality as the most important factor when making purchases

income on services, experiences, and entertainment. The means to survive, for any company, then becomes providing consistently faultless products. According to a recent survey, 53% of shoppers rated quality as the most important factor when making purchases.[18] To stay competitive, companies are increasingly turning towards Quality 4.0.

Quality 4.0

Gone are the days of end-of-line quality management when adjustments to the manufacturing process were made after defects were discovered. Today's smart factories are combining the principles of total quality management (TQM) with the power of AI, advanced sensors, and cloud computing to enable improved product quality. A recent Quality 4.0 survey of executives and quality managers conducted by BCG found that for the manufacturing sector, predictive tools, machine vision technologies, and digital standard operating procedures (SOPs) were considered to have the most significant impact in quality control.[19]

Intelligent sensors are being deployed to transform factory tools into data gathering nodes that allow real-time monitoring of the production process. Using deep learning techniques, these data points can then be used to predict future product anomalies or machine breakdowns, enabling preemptive equipment repairs and maintenance.

Machine learning systems are being used to replace traditional machine vision technologies to discover defects during various stages of product assembly. One company working in this domain is California-based Instrumental AI. Unlike traditional vision-based defect discovery systems, Instrumental's system uses machine learning to identify known, as well as unknown, defects in real-time. This enables early discovery and diagnostics in the manufacturing process, leading to better quality control.

In the apparel industry, automation may be the key to meeting progressively high quality assurance standards. A McKinsey survey of apparel industry executives found that 51% of respondents felt that it was highly likely that the manufacturing of simple garments such as t-shirts and jeans would be fully-automated by 2025.[20]

New technologies, ranging from fully-automated sewing to the use of robotics for bonding fabrics, hold immense potential for providing uniformly excellent product quality. Hong Kong Polytechnic University's WiseEye is one such intelligent fabric defect detection system that can be used to avoid the production of substandard fabric.[21] Automation technologies in the garment industry have the potential to increase the value of fast-fashion clothing while simultaneously reducing production costs.

A key to providing quality assurance to customers is to ensure that data flows seamlessly from factory machines to enterprise systems, enabling these systems to continuously learn from production trends and gain end-to-end visibility into the entire manufacturing cycle. Coupled with intelligent sensors and machine learning-based pattern detection, these systems partake in a feedback loop that will detect, diagnose, and rectify quality issues in real-time.

Blockchain helps ensure better quality control

Limited visibility into any part of the manufacturing cycle can lead to quality control challenges. Defective raw materials or components can create a variety of quality issues in the end product. And when problems do occur, consumers won't blame the supplier who provided the defective part; they'll point to the company whose name is on the product. This is where blockchain can be a game-changer.

When integrated into the supply chain, blockchain can provide real-time track and trace capabilities to manufacturers. Pre-manufacturing raw material defects can be resolved before the materials reach the factory floor, enabling more robust control over the quality of the finished product. At the same time, this traceability data can be directly passed to the consumer, resulting in greater trust. For a consumer, gaining visibility on information, such as the origin, authenticity, custody, and integrity of the product, will reduce perceived risk and enhance quality assurance. - -

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Deliver amazing experiences
Manufacturers must be more responsive to new trends so they can deliver the seamless experiences customers now expect. At Microsoft, we're helping companies meet changing demands with the tools and technology to better understand customer needs, become more agile, and deliver amazing customer experiences.

Understand customers
Manufacturers must look beyond their customers' experience and consider their customers' customer experiences. Dynamics 365 enables companies to track product usage and performance so they can predict and prevent potential issues and create better product experiences for the end-user.

Improve agility
Modern businesses must work with greater precision and agility. By connecting data from across the value chain, Azure and Dynamics 365 help organizations improve communication between suppliers, predict and respond more rapidly to trends, and better manage changes on the fly.

Exceed expectations
Manufacturers must rely on technology to deliver the amazing service that customers expect, at scale. Microsoft is empowering organizations with the tools and technology to create innovative, frictionless experiences that delight customers and exceed expectations every time.

03 /
Manufacturing becomes more intelligent

Executive summary

As IoT connects data from across manufacturing organizations, intelligent systems are leveraging that data to make processes smarter and more efficient.

Highlights

- By 2020, there will be an estimated 9.9 billion IoT-connected devices worldwide.

- 60% of all manufacturing tasks can now be completed with automation technology.

- Spending for autonomous devices is predicted to approach $200 billion by 2022.

Manufacturing becomes more intelligent

The First Industrial Revolution—marked by a combination of power, machinery, and semi-skilled labor[22] [23]—led to the development of the first modern factory systems. The use of electricity to power mass production delivered the Second Industrial Revolution, while the migration from analog electronics to digital technology drove the Third Industrial Revolution.

We coin these periods "revolutions" not because they introduced technological advances to manufacturing but because of the broader implications these technologies had on socioeconomic and cultural norms across the globe.[24] Today, we're in the midst of a Fourth Industrial Revolution, driven by intelligent automation. As in the past, the significance of this revolution is not only about increasing productivity and decreasing costs in manufacturing; it's in how it's changing the way we work, communicate, and interact with the world on a global scale.

Industrial Revolutions

Late 18th century
First Industrial Revolution

Power generation

Beginning of 20th century
Second Industrial Revolution

Industrialization

1970s-2000s
Third Industrial Revolution

Electronic automation

2010-present
Fourth Industrial Revolution

Intelligent automation

The connected factory

Nearly two hundred and sixty years after the start of the First Industrial Revolution, we are in the midst of the Fourth Industrial Revolution, often referred to as Industry 4.0. Industry 4.0 is marked by automation and data exchange in manufacturing technologies, including cyber-physical systems, the Internet of Things (IoT), cloud computing, and big data analytics (BDA).[25] Together, these developments have resulted in a new era of smart factories and intelligent manufacturing that combines self-monitored manufacturing processes and machines, automated quality assurance of final products, and insights from outside the manufacturing process.

In this new model for manufacturing, AI-enhanced computers can detect and report on physical processes happening in the real world and make human-like decisions in real-time, sometimes referred to as a "cyber-physical production system." Cloud-based monitoring and management enable up-to-the-minute intelligence on asset function and health, facilitating predictive maintenance and servicing to avoid breakdowns and associated

downtime. Intelligent manufacturing isn't just about data; it's about using data to make automated decisions, predictions, and real-time optimizations across the end-to-end value chain.

As with previous waves of the Industrial Revolution, Industry 4.0 promises to dramatically reshape how we make and deliver goods. In the last twenty years, worker productivity in the US has increased by 47%[26], thanks in large part to the adoption and innovation of new technology. This technology is being used to bring down labor costs, reduce product defects, shorten unplanned downtimes, improve transition times, and increase production speed—all while making manufacturing more flexible. Intelligent manufacturing also promises to make industrial settings safer for human workers by leveraging technologies such as computer vision, image recognition, smart sensors, GPS data, and augmented reality.

Worker productivity in the US
Percent
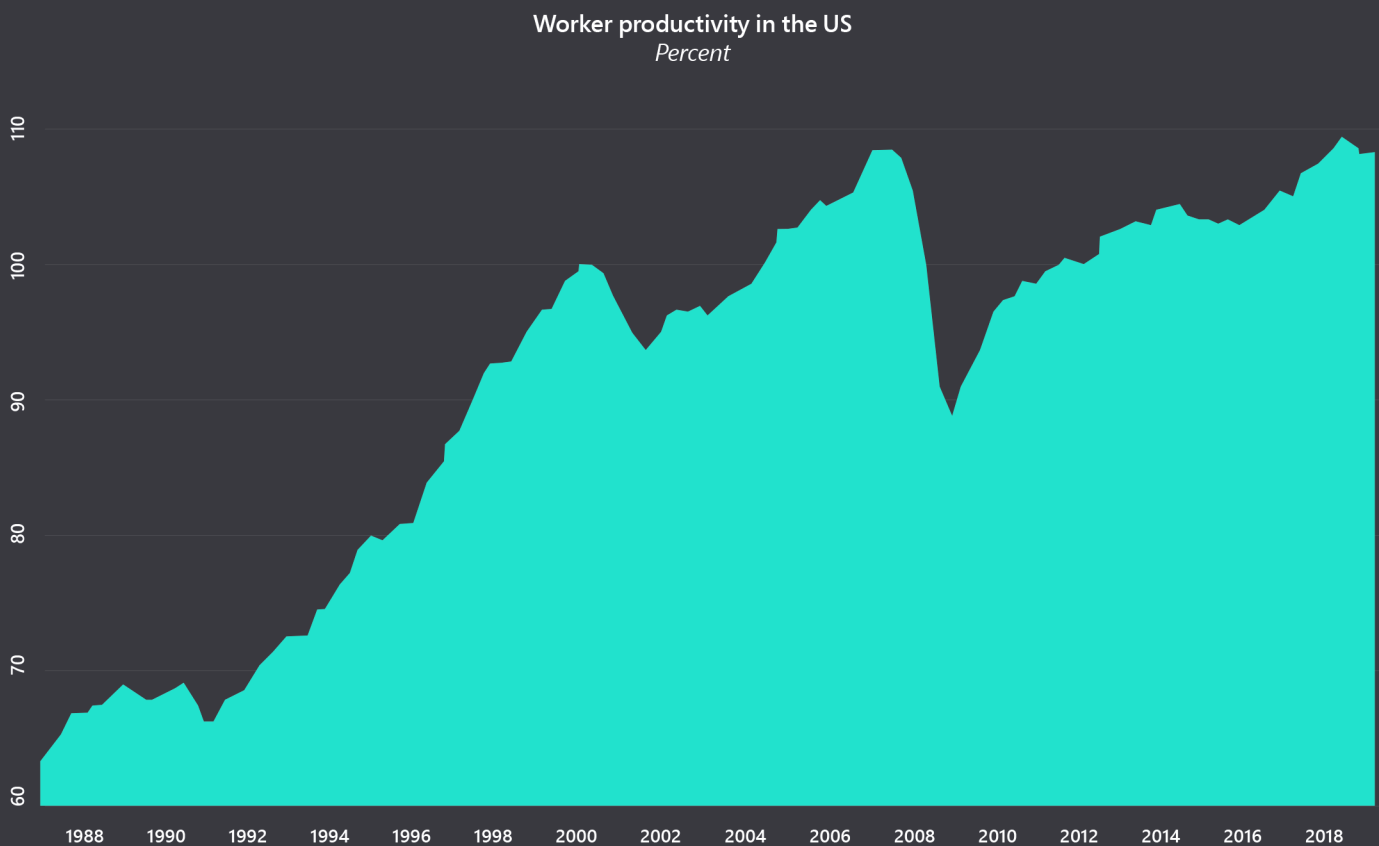
Number of IoT-connected devices worldwide by 2020

9.9 billion

15%

Percent of assets that are connected in production

Potentially dangerous gas leaks can now be monitored and quantified from up to two miles away with the Rebellion Photonics gas detection video cameras. The cameras use hyperspectral imaging technology to capture visible spectrum and infrared images in real-time, detecting and assessing a gas leak without exposing workers to potentially hazardous situations.[27]

One of the more exciting prospects of Industry 4.0 isn't in how it changes the day-to-day operation of factories but rather in its potential to transform how companies relate to partners at every level of their value chain. With Industry 4.0, companies will eventually be able to achieve vertical and horizontal systems integration, where firms, suppliers, and even customers are more tightly integrated thanks to robust data sharing.

Given its many benefits, it's no surprise that businesses are adopting intelligent manufacturing. But even with the increased adoption of technology, its full potential is still far from being reached. By 2020, there will be an estimated 9.9 billion IoT-connected devices worldwide[28], but in production, only 15% of assets are connected. Sixty-percent of all manufacturing tasks can now be completed

with automation technology, but this level of penetration is rarely reached.[29]

As the adoption of these intelligent manufacturing capabilities increases, the effects of these new technologies and practices will help factories and supply chains become progressively more efficient. Artificial intelligence has the potential to add between $1.2 and $2 trillion of value in manufacturing and supply-chain management[30] resulting from decreased repairs and downtime, increased profitability, improved abilities to more accurately tailor sales, and by bridging the shortage of skilled employees.[31]

IT and OT converge

In the past, the management of industrial technology in manufacturing has been divided between IT and operational technology (OT). Where IT provided top-down technology support for management and the back office, OT was built from the ground up, monitoring and controlling machinery, equipment, tools, and assets. In this legacy role, OT has lived in a bit of a silo, where machines—manipulated by human input—were programmed to perform very specific tasks. But in recent years, with advances in connectivity, the growth of big data, and the expansion of

the IoT have opened the door for a new breed of intelligent manufacturing tech that is impacting both IT and OT.

Today, data-optimized smart machines can receive input from a wide range of sources—from customer order data to production data—to enable more agile manufacturing, improve production efficiency, and provide greater visibility into operational performance. For the modern manufacturer, data is no longer just the purview of IT; from supply chain management to the operations floor, data is now ubiquitous across the organization.

As data becomes unified across the organization, IT and OT can no longer operate independently and, as a result, are converging. This IT/OT convergence enables opportunities that have not been possible before. Through the integration of IT and OT data, business leaders can get access to live dashboards that provide visibility across all parts of the organization. Connected systems can communicate to detect unbalanced load flows and automatically make corrections to prevent outages. Intelligent machines can identify faulty parts and select new assets to restore production. And with integrated controls, production management systems,

and supply chain management systems that are integrated with other IT systems, manufacturers are able to intelligently route orders and automate workstreams.

Over the past several years, the trend towards IT/OT convergence has emerged across numerous industries, from healthcare and transportation to defense and utilities. As many of these industries rely on heavy, expensive equipment and highly specialized labor forces, the merger has been slow and tactful. But as technological advances in cloud computing, remote sensors, and connectivity improve, it is becoming faster and easier for manufacturers to integrate the management of industrial technology and integrate new systems with their legacy systems.

"The convergence of IT and OT is an inevitability."

In today's world of connected, intelligent manufacturing, the convergence of IT and OT is an inevitability, but that does not mean this transition comes without challenges. To start, IT and OT teams must integrate independent systems that were built and designed separately. This means finding common ground to develop new infrastructure and implementing protocols that enable data sharing across systems. Convergence also requires security enhancements. For many manufacturers, their OT standards are proprietary and very specialized. In the past, when these systems were set up as independent, stand-alone tools, the opportunity for a breach was somewhat limited due to the tightly defined perimeters of the system. But as OT systems become connected to widespread IT communication networks, the risk of a loss increases. As such, businesses integrating their IT and OT systems must implement well-defined standards that scale across their network to ensure data and IP security.

The migration to intelligent manufacturing does not mean starting with a blank slate but rather effectively integrating new technology within the existing manufacturing environment. As new technology transforms manufacturing into a highly connected, intelligent, and

ultimately more productive industry, businesses must also find a way to enhance their legacy systems to keep up with new and increasingly sophisticated technologies.

Integrating "dumb" machines with "smart" machines starts with enabling data collection from those legacy machines. Manufacturers are gradually retrofitting existing equipment with smart sensors that collect comprehensive data in real-time. This data can then be passed to execution, production planning, and ERP solutions to provide robust visibility into performance.

As manufacturers migrate operations to the cloud, companies that have invested heavily in on-premises platforms must wrestle with the challenge of leveraging these systems while simultaneously migrating more functionality to the cloud. In the coming years, more companies will likely embrace a hybrid data center model, which combines the increased control and access to data of an on-premises platform with the increased flexibility and functionality of migrating information to the cloud.[32] Doing so will allow companies to reduce overhead costs related to IT, take advantage of the flexibility and economies of scale afforded by XaaS offerings while making continued use of legacy systems.

IoT + AI

The broad adoption of smart sensor technology, connectivity improvements, and advancements in cloud computing have helped drive the adoption and evolution of Industrial IoT. Industrial IoT (IIoT) is poised to have a major impact on manufacturing and the global economy, with 50 billion machines expected to be connected by 2020.[33]

Not long ago, artificially intelligent machines seemed like a thing of science fiction; even today, when people think of artificial intelligence (AI), many still envision human-like robots, but in practice, artificially intelligent machines have been around for decades, making our lives better, safer, and more efficient. So why all the buzz now? In short, it's because these systems are only now getting really good. Correction: really, really good. AI technology now has the ability to write and analyze text and answer questions without being trained on a specific task.[34]

As the processing power and accuracy of these intelligent systems improve—with advances in technologies ranging from neural networks to natural language processing—the opportunities to leverage these technologies increase as well.

"There will 50 billion Industrial IoT machines connected by 2020."

To understand how artificial intelligence and machine learning will impact manufacturing, it's first useful to understand what these terms mean. While there are many types and definitions of AI, it can commonly be understood as a computer that performs a function that requires some form of cognitive intelligence. This may include visual perception, speech recognition, or decision making. Machine learning is a type of artificial intelligence where computers leverage new information to improve their outputs automatically. The power of these intelligent computers—which are increasingly cloud-based—is in their ability to process a large volume of data at a speed that humans are not capable

of achieving. While accomplishing tasks—such as speaking and writing—on par with human abilities is impressive, the true power of artificially intelligent systems is that they can do these same tasks in a fraction of the time. This proficiency makes artificially intelligent computers extremely effective in performing four categories of tasks: detection, classification, probability, and optimization.

Detection

Intelligent systems can be used to analyze large amounts of data and detect anomalies. In manufacturing, this may be used to help identify faulty products, predict when a machine will need maintenance, or detect potential safety issues in and around a factory. These tools are also being used to help mitigate risks by ensuring regulatory compliance, as well as flagging anomalies for further investigation.

Classification

Artificially intelligent systems can be used to organize and classify data categorically. Through classification—sometimes referred to as segmentation or clustering—businesses can leverage AI to sort materials, reconcile transactions, categorize expenses, and even look for interactions between categories to identify correlations.

Probability

AI systems can be used to conduct probability analysis. These tools give manufacturing leaders the ability to run faster, more accurate data models. This enables them to quickly test how changes to specific variables will impact outcomes, such as how making changes to the production line will impact output or how adjustments to a product formula will alter product performance.

Optimization

Lastly, these tools can be used to optimize systems, processes, and decision making. Through real-time data analysis, intelligent systems can calculate the probability of various outcomes and adjust accordingly. For example, during production, analytical models can be used to reduce injuries by slowing down machines when a sensor identifies a potential issue, or it can cut costs by automatically changing resource allocation across the organization to minimize waste.

AI gives manufacturing leaders an incredible degree of insight into operations and the market, allowing them to assess consumer data to forecast purchase and usage behavior, review economic indicators to predict market trends, and evaluate operations metrics to help streamline processes and cut costs. The merging of big data with new technology has made processing large data sets easier than ever, and from mining big data to predictive analytics, manufacturing leaders are increasingly relying on these new, intelligent tools to help them succeed. It's no surprise that with all these benefits, AI implementations tripled between 2018 and 2019.[35]

Edge computing

Cloud computing is revolutionizing the way manufacturers do business, but there are some cases where cloud computing can have concerning disadvantages, including outages or slowdowns, security risks, limited control, and high cost.[36] To solve for these limitations, many manufacturers are turning to edge computing. Edge computing allows manufacturers to run applications and store data with on-premises infrastructure that is connected to the cloud, as opposed to in a centralized data storage warehouse.[37]

Manufacturers are embracing edge computing for several reasons. First, using edge technology reduces the amount of data that has to be sent over the network. This speeds up decision making, reducing response times, as well as cloud computing costs. And by retaining data and analytics on-premise, edge computing minimizes the risk of security threats and increases reliability.[38] Going forward, expect to see manufacturers embracing edge computing, especially where speed, continuity of operations, or privacy are of the essence, and where it's also necessary to analyze large volumes of data pulled from disparate sources across the supply chain.
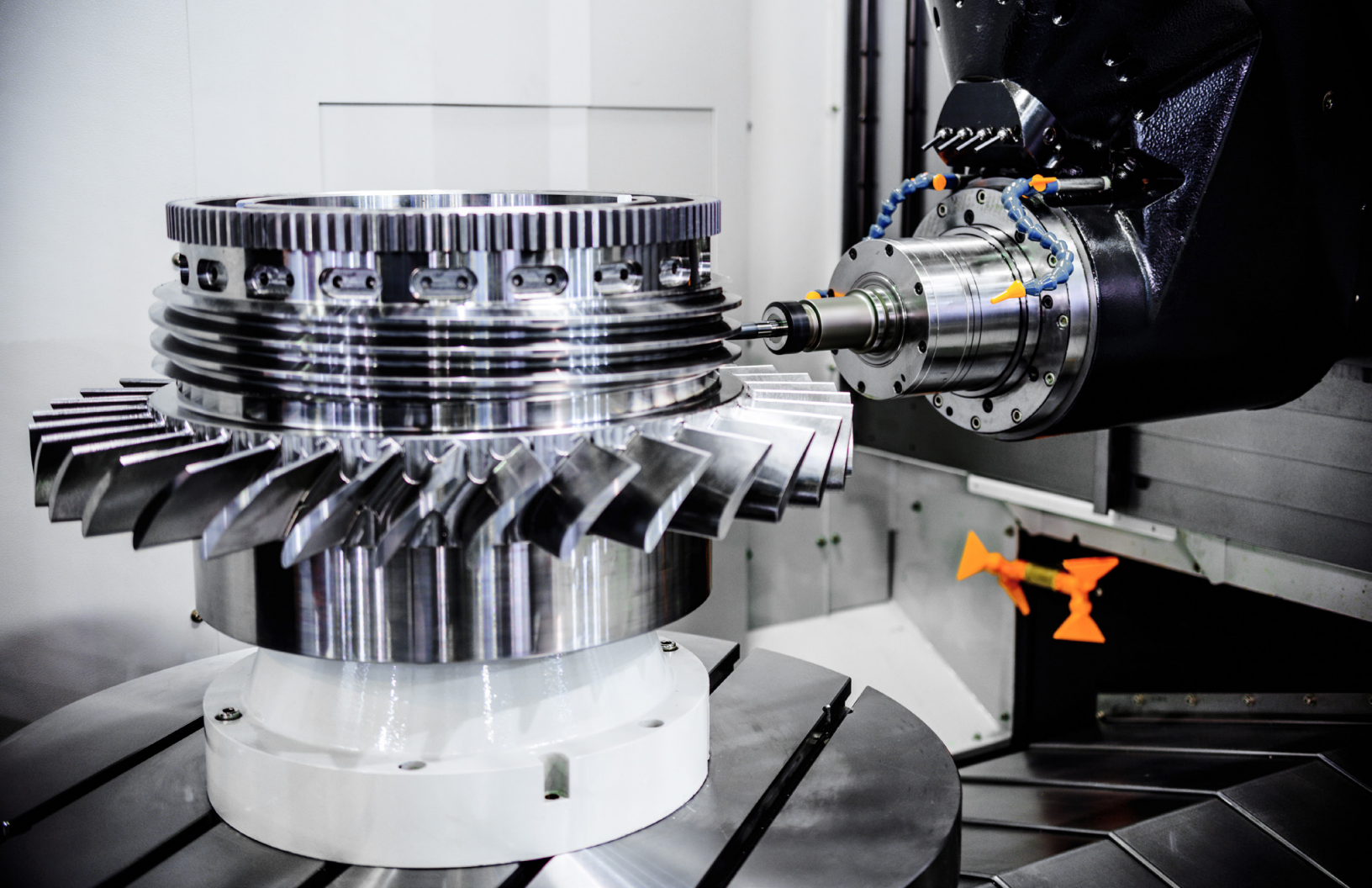
Advanced manufacturing

Intelligent planning and procurement

By leveraging new technologies, modern manufacturers can now capture an amazing amount of data from each phase of the value chain. With such granular data, manufacturing leaders now face the challenge of figuring out how to best turn these data into actionable insights that provide meaningful business results.

To help them aggregate, analyze, and act upon this data, manufacturing leaders are turning to sensor technology, the IoT, AI, and ML. Paired with other emerging technologies, such as cloud computing and 5G, these technologies are collectively known as digital supply networks (DSNs), and they're enabling more intelligent planning and fulfillment. By monitoring a host of variables, from real-time inventory levels, production status, and warehouse capacity to weather, upcoming holidays, and social media, manufacturers are able to generate more accurate forecasts and plan more strategically.

Among the world's largest manufacturers, General Electric has established itself as a leader in intelligent planning. The company has built seven "Brilliant Factories" that utilize AI, ML, sensor technology, and the IoT to holistically track and process everything in the manufacturing process, with the goal of linking design, engineering, manufacturing, supply chain, distribution, and services into one globally scalable, intelligent system.[39] The concept is being powered by an IoT platform it calls "Predix," which the company estimates will be processing one million terabytes of data per day by 2020.

"Manufacturing leaders now face the challenge of figuring out how to best turn data into actionable insights that provide meaningful business results."

Whether GE's planners will be able to keep up with all that data remains to be seen, but they will undoubtedly have assistance from AI-enabled technologies. Manufacturers who invest in this ground-breaking technology will soon have to contend with how much autonomy they are willing to give to machines. The rapid pace of technological advancements, combined with the right algorithms, could lead to semi-automated supply chain planning—and one day could yield fully-automated planning.[40]

Generally speaking, planning should precede implementation, but the breakneck speed of technology development has many leaders in the manufacturing field playing catch-up. It remains to be seen whether planning teams can keep pace with technological breakthroughs. Going forward, the way these technologies are implemented, and the full scope of their value, will undoubtedly be influenced by advances in quantum computing, the next significant evolution in tech.

Annual cost of unplanned equipment downtime

$50 billion

Predictive maintenance

Companies today are fighting a constant battle to achieve high product quality, low defect rates, and on-time delivery of products. Given the pressure to attain high operational efficiency and productivity, manufacturers may even run their machinery to the point of failure, resulting in equipment downtime. According to a recent study, unplanned equipment downtime costs manufacturers about $50 billion annually.[41] Thus, equipment maintenance is a crucial factor in gaining a competitive edge in the market.

There are three types of equipment maintenance that happen in a factory— reactive, preventive, and predictive. Reactive maintenance, as the name suggests, is conducted in reaction to equipment breakdowns. Since reactive maintenance often requires the temporary halt of an entire production line, most manufacturers prefer to proactively service their machinery. Planned preventive maintenance of equipment leads to lower repair costs and better operational flexibility. However, Industry 4.0 has

enabled manufacturers to take machinery maintenance one step further to predictive maintenance.

The predictive maintenance process starts by using intelligent sensors on factory equipment that continuously monitor performance by recording data on the machine's health, temperature, humidity, vibrations, acoustics, and more. Since these sensors generate a large volume of data, deep learning techniques are employed for data analysis. Complex algorithms process machine performance data to predict future malfunctions and maintenance needs. Scheduling algorithms help plan equipment maintenance in such a way that the production schedule undergoes the least disruption possible.

Several companies have started incorporating predictive maintenance on the factory floor and are observing considerable improvements in production efficiency. In its Fort Collins, Colorado brewery, Budweiser uses low-cost wireless sensors to predict equipment malfunction based on ultrasonic sounds. The sensors have already helped the beer brand save more than $200,000 in product loss due to equipment failure.[42]

Italian automotive supplier Italpresse Gauss' newly launched AMe technology utilizes AR to enable remote troubleshooting of machines. Local teams use camera-enabled tablets to frame an image of the faulty machine, which then overlays the image with 3-D maintenance documentation. Using the tablets, teams also have the option to receive remote video support from one of Italpresse Gauss' engineers.[43]

Honeywell's Forge is finding success in leveraging predicting maintenance for their aircraft hydraulics systems. Forge combines information gathered from the aircraft condition monitoring system, flight recorder data, and technician logs to predict defects and reduce flight disruptions.

A key benefit of predictive maintenance is its ability to evaluate equipment data from across the factory. Cloud technologies allow context-based diagnoses, where the entire manufacturing line is treated as a single unit. Instead of treating each machine as an isolated piece of equipment, manufacturers can analyze how machines impact one another, enabling them to develop a comprehensive maintenance plan.

Once these factory silos are broken, predictive maintenance can be taken a step further to improve parts management. Predicting breakdowns or parts failures well in advance can enable the early procurement of parts, avoiding lengthy delays and idle machines. Increased equipment uptime, reduced maintenance planning, and cutting equipment maintenance costs are just some of the many benefits manufacturers can unlock by implementing predictive maintenance in their facilities.

Automation

Autonomous and semi-autonomous devices are enhancing workflows across the supply chain, from improving shop floor operations to facilitating intelligent distribution management. While robots have been common in manufacturing for quite some time, sensor technology, AI, and the IoT are at the nexus of an emerging generation of autonomous devices, ones that are able to operate with little or no human interaction. FANUC, one o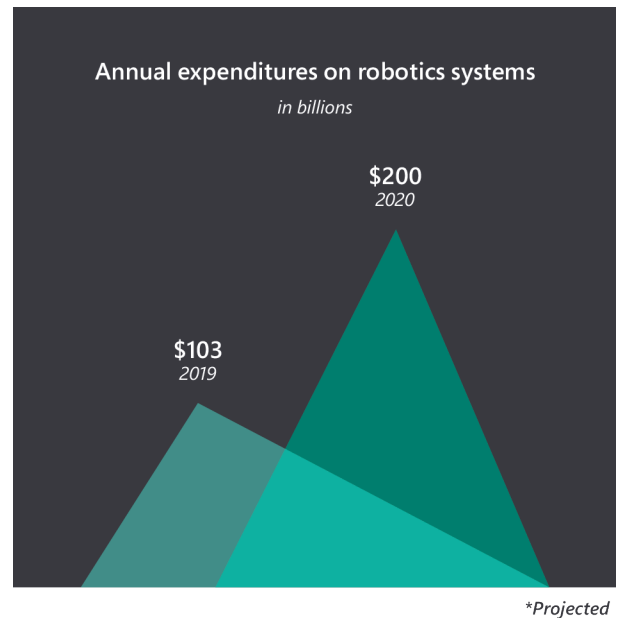f the world's largest producers of industrial robots, already operates entire factories where robots autonomously manufacture other robots.[44]

Spending for autonomous devices is on the rise. IDC, which had previously predicted that annual expenditures on robotics systems would reach $103.4 billion in 2019, now forecasts that global spending will approach $200 billion by 2022, with manufacturing accounting for more than half of all investments in robotics.[45] Similarly, the International Federation of Robotics reported that a record-setting
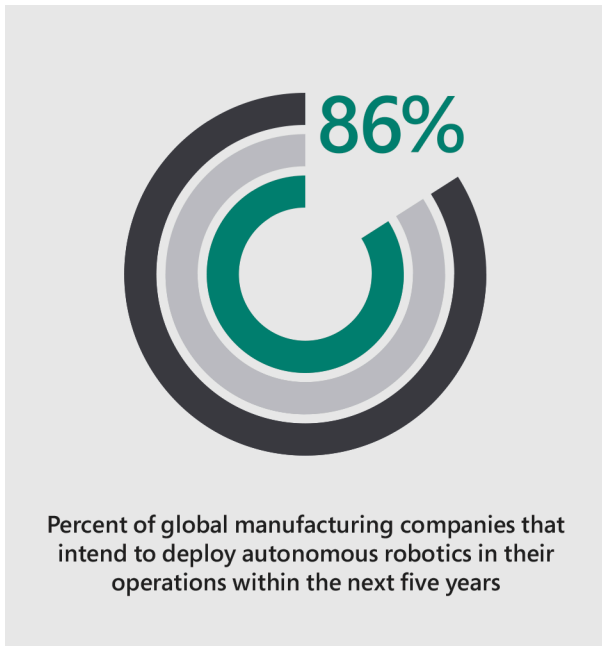
422,000 industrial robotic units were installed globally in 2018, a 6% increase from 2017, and almost 240% more than the 178,000 units shipped in 2013.[46]

This ever-growing investment suggests a massive potential for autonomous technology; the evolution—and application—of autonomous devices in manufacturing is still in its infancy. Autonomous devices have the potential to revolutionize numerous logistics, production, and quality assurance processes throughout the manufacturing sector. Advanced robots can learn from their surroundings and make independent decisions based on their programming. Current capabilities include everything from locating and transporting materials and products around the factory to independently changing tools on the production line.

In 2018, JD.com opened a fully-automated storage and shipping facility in Shanghai. The facility employs 20 industrial robots that can pick, pack, and transfer packages with no human oversight. This amount of labor that would otherwise require 500 workers to complete, rather than the five technicians it currently relies on to service the robots.[47]

Annual expenditures on robotics systems
in billions

$200
2020

$103
2019

Projected

86%

Percent of global manufacturing companies that intend to deploy autonomous robotics in their operations within the next five years

20%

Percent of global manufacturing companies that have created a holistic target picture and a comprehensive implementation roadmap

Numerous factory robot models can use sensors, AI, and the IoT to independently carry out tasks on the shop floor, such as changing tools or dyes, and the range of such autonomous capabilities is expanding rapidly. Rolls Royce is testing 10 mm miniature collaborative robots called "SWARM" that it plans to use to inspect the interiors of jet aircraft engines. Transported deep into the engine by an endoscopic snakelike carrier robot, the swarm of cockroach-size mini bots can be released where needed to semi-autonomously scan for potential problems.[48]
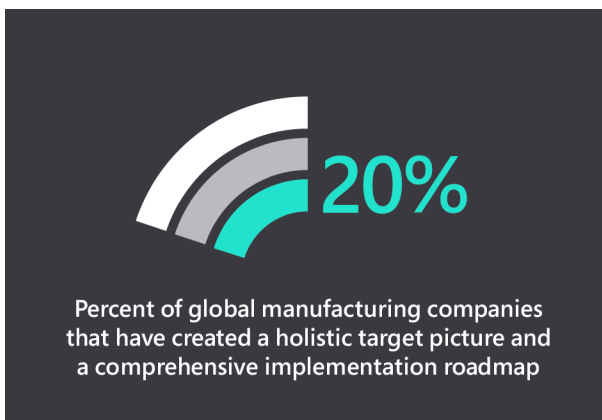
As autonomous devices become more advanced, less expensive, and as manufacturers become more confident in their ability and value, an increasing number of companies are likely to implement them; however, government regulation and concerns over autonomous device safety could prove to be barriers that slow the pace of adoption. Internal knowledge and culture will also play a role in the adoption, or non-adoption, of such technologies. While 86% of global manufacturing companies recently said that they intend to deploy autonomous robotics in their operations within the next five years, only 20% had created a holistic target picture and a comprehensive implementation roadmap.[49]

Examples of autonomous device applications in the manufacturing value chain:

• Picking, packaging, and palletizing

• Kitting

• Product and materials transport

• Materials processing

• Product assembly

• Mounting parts for installation

• Parts installation

• Quality assurance inspection

• Facility monitoring and security (e.g., drones)

Cobotics

Concerns about the safety of autonomous devices, along with an expanding unease over the prospect of robots replacing human workers, are being addressed in part by collaborative robots, now commonly called "cobots." Cobotics technology was initially developed in 1995 through research grants from General Motors[50], which sought to enhance human assembly line production work with collaborative robotic-type technology. While GM's early model cobots were revolutionary, their collaboration was remote, and their application limited to welding and painting, a job they still carry out in many GM plants. With today's advancements in IoT, AI, ML, sensor technology, cloud computing, and other digital advancements, cobot capabilities are expanding at an exponential rate, and many cobots no longer need to be fenced off from human workers for safety reasons.

Today's cobots are built with embedded AI and ML that power cognitive capabilities. They can use computer vision to quickly inspect large quantities of items for flaws, automate the transportation of materials throughout a facility, and avoid hazards using predictive intelligence. They can also

"We want to build intelligence that augments human abilities and experiences."

-Satya Nadella, CEO
Microsoft

be programmed to recognize and adapt to human movement, learning from being moved manually by a human worker until they can copy the movement on their own.

French aerospace company Safran sees cobotics as a key element of Industry 4.0 and a core technology in its transformation into a "factory of the future." Noting that people will continue to play a decisive role in the aerospace industry, Safran is using cobots to combine the capabilities of a robot—such as strength, precision, and repeatability—with people's specific skills—like know-how, analysis, and decision-making.[51]

In short, cobotics represents an augmentation of human labor rather than a replacement. Not only can cobots take on dangerous, physically strenuous, and repetitive tasks, but they enhance the capabilities of their human counterparts. Innovations in robotics have made cobots more adaptable, compact, safer, and more affordable. They are most useful when they are powered by AI and by humans who can enable their full potential.

Evolution of the manufacturing business model

Manufacturing has long been driven by a push for engineering excellence and operational efficiency, and over the last decade, this push has only accelerated. Lower cost of entry and new technology has pushed companies to compete on product features and functionality. The vast proliferation of Bluetooth-enabled smart devices in the market today is proof of this trend. In conjunction with the race for new features, the growth of online retail—driven by Amazon—has shrunk margins and led to cost-cutting efforts. The pressure to cut costs has made its way upstream, with manufacturers being pushed to deliver products faster, for less.

As a result, manufacturers have turned to technology to improve operational efficiencies, reduce waste, and support lean production initiatives. Even that may not be enough. With a market full of feature-saturated products and costs cut down to the bone, manufacturers are now shifting to a more customer-centric approach, exploring new service-based business models to build value and grow

relationships with customers in a modern, connected world. Adding services to their portfolios allows manufacturers to differentiate their offerings and gain a competitive edge in a rapidly changing industry.

XaaS

As cloud computing becomes ubiquitous, Anything-as-a-Service (XaaS) business models are also becoming more popular. XaaS enables businesses to provide better, more cost-effective solutions to customers via subscriptions or pay-as-you-go models, rather than via traditional software licensing models.

The most commonly known XaaS model is Software-as-a-Service (SaaS), which provides individual software applications and services through the cloud; however, Platform-as-a-Service (PaaS) and Infrastructure-as-a-Service (IaaS) models have also gained traction as a way for technology companies to expand their footprint. As sensors, apps, and software become integral to a growing number of products and services—including everything from home appliances, lightbulbs, cars, and home irrigation systems to ride-sharing, dog walking, streaming media, and fitness trackers—

more companies are harnessing the power of the cloud to transform what they sell into a XaaS offering.

Manufacturing-as-a-Service

While contract manufacturing has always been a service, digitization is changing the way products are designed and the way contract manufacturers create those products. These changes have led to the expansion of Manufacturing-as-a-Service, where businesses can leverage a shared network of manufacturing infrastructure—from machines and maintenance to software and networking—to produce goods. In practice, this service may be a singularly managed network of manufacturing equipment or a network of self-managed manufacturers.

With a singularly managed network, a customer can send an order for a part, including appropriate design files and specs, and based on workload, materials, workforce availability, location, and scale, the network will dynamically route the order to a given facility, or set of facilities,

to most efficiently fulfill the request. The customer may not even be aware of the routing, but they reap the benefits of faster, more cost-effective production. With manufacturer networks, customers can research and submit projects to in-network manufacturers using a standardized set of files. The manufacturers can then automatically review the designs— including the geometrics, the pathways that cutting tools will be required to make, and the materials needed—and provide fast, precise quotes to prospective customers. This reduces both administrative burdens as well as manufacturing costs. Like many other XaaS business models, Manufacturing-as-a-Service helps businesses move money from CAPEX to OPEX, freeing up capital for additional investment in R&D, marketing, and sales.

There are many other benefits to the Manufacturing-as-a-Service business model, including faster, less expensive prototyping, helping manufacturers better balance workloads, and opening doors for manufacturers who may not otherwise have access to bid on individual projects.
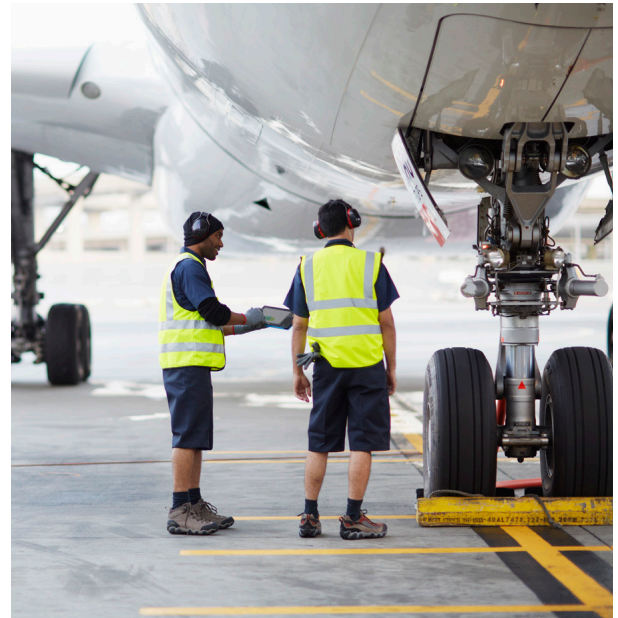
Product-as-a-Service

In Product-as-a-Service business models, the physical products, software, and support are delivered as a service or virtual experience, and the buyer no longer takes ownership of a physical product. Think of it as a modern, cloud-enabled twist on traditional rental and licensing agreements. BMW's Share Now on-demand car service is a form of Product-as-a-Service. Software-as-a-Service is another type of Product-as-a-Service that many people are familiar with—such as Office 365 or Adobe Creative Cloud. In some cases, companies have extended the Product-as-a-Service model to physical products, where customers pay for an output, not for the tool that

creates the output. A common example is copier leasing agreements where a third-party vendor owns and services the device, and IoT sensors are used to monitor the customer's monthly usage.

Other digital services

New technologies, such as IoT, AI, and ML, are providing companies with greater connectivity and visibility across their products and operations. Forward-thinking companies are leveraging this connectivity to create digital services that allow them to serve customers in new ways. Cloud-networked operations open up a broad range of services for companies to explore, including Manufacturing-as-a-Service, Design-as-a-Service, Experimentation-as-a-Service, Equipment-as-a-Service, Simulation-as-a-Service, Management-as-a-Service, Maintenance-as-a-Service, and Integration-as-a-Service.

Knowledge and intellectual property management

Since 1998, manufacturers have cited the Digital Millennium Copyright Act—a far-reaching copyright law that governs the intersection of hardware and software—for guidance on addressing IP issues. For example, the DMCA allows manufacturers to stipulate that a user who buys a smartphone is technically purchasing the hardware and a lifetime license to use the phone's operating system software. Despite the fact that the phone is useless without its software, the customer does not own the software.

This lack of ownership may not seem like a huge deal for products with relatively short purchase cycles, but as expensive, highly customized industrial products become indistinguishable from the software on which they run, there is a debate brewing around the ownership of these products in two areas.

"As manufacturers increasingly adopt service-based business models, the ability to have high-speed internet anywhere is critical for business success."

The first is around warranties. If someone makes modifications to their car engine, it is generally understood that these alterations would void any manufacturer's warranty. But the line becomes blurred when organizations customize the software running on their products to better fit their business model. Second, by retaining tight control over the software that runs on their equipment, manufacturers essentially make their customers dependent upon them for future updates, lest their multimillion-dollar investments be rendered obsolete because of poorly functioning software. As the line between software and hardware continues to blur, manufacturers and consumers will need to establish a balance that allows both parties to maintain appropriate levels of ownership and control.

The impact of 5G on after-sales service

New 5G networks will be a considerable boost to intelligent manufacturing, allowing businesses to process massive amounts of real-time data quickly and from virtually anywhere. As manufacturers increasingly adopt service-based business models, the ability to have high-speed internet anywhere is critical for business success. In the context of after-sales service, 5G networks will provide field service reps with fast access to information, ensure that IoT sensors and devices stay reliably connected to the network, and enable faster software and firmware updates on customers' equipment. The ability to remotely assess the health of client equipment opens up a host of possibilities. Manufacturers can deliver updates, proactively fix bugs, and alert customers to maintenance needs before problems occur, extending the life of their products while securing customer loyalty.

Extended reality (XR)

Manufacturing mistakes don't just cost businesses time and money; they put workers at risk. A growing number of companies have found that they can minimize and, in some cases, eliminate these mistakes with the help of extended reality (XR). The adoption of XR—a term that encompasses augmented reality (AR), virtual reality (VR), and mixed reality (MR) technology—isn't limited to a particular category of manufacturer. According to a PwC study, one-third of manufacturers either already use XR, or plan to begin using it within the next three years.[52] Whether it's adding a digital element to live screen views using AR, creating an immersive training experience using VR, or allowing workers to interact with an MR schematic to view a machine from multiple angles, XR is changing the face of manufacturing.

The widespread availability of smartphones and tablets and the ease of application development have paved the way for the increased adoption of XR[53], making it easier than ever to use XR to train employees. Jaguar Land Rover has implemented a training program that uses an augmented reality app to provide an "X-ray vision"

view into the car without the complicated and time-consuming process of removing and reinstalling the dashboard.[54] This saves the company time and money without diminishing training quality.

Other companies have found ways to leverage XR technology to discover and fix mistakes during the planning stage of projects. Workers at construction firm Trimble use Microsoft's HoloLens to review projects prior to completion. By using HoloLens' 3-D capabilities during the planning phase of a job, Trimble discovered that the plans for the plumbing were incompatible with the rest of the project. Since the company made this discovery prior to beginning construction, it avoided costly and time-consuming rework.[55]

33%

Percent of manufacturers who already use or plan to use XR with the next three years
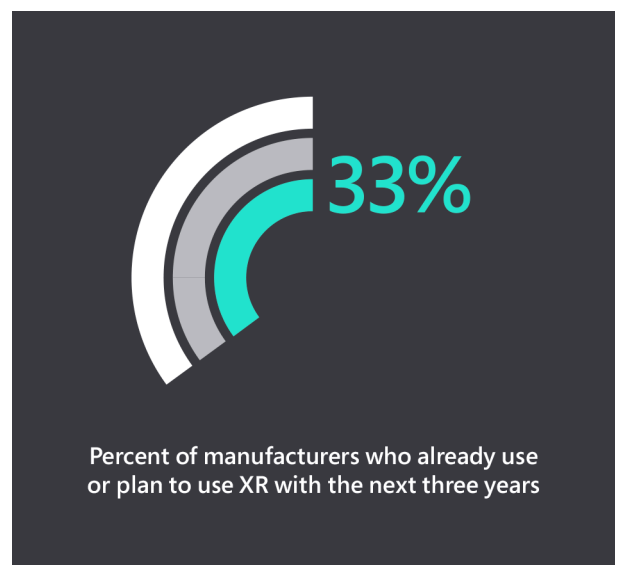
XR also has the ability to enhance communication and collaboration, since employees no longer need to be in the same physical location to collaborate. Some manufacturers are taking advantage of this by providing smart glasses to their parts inspectors. When the parts inspectors find pieces that require modification, they can then take a photo of the part, add a spoken note, and relay the information to the appropriate coworker. The entire process can be completed within a matter of seconds.[56]

With manufacturing jobs accounting for 7.9% of all US employment[57], even small gains in productivity and safety can have major implications for millions of workers. One especially promising area that could improve workers' lives is the use of XR in worker safety training programs. Researchers have used VR to simulate safety issues, which can help companies gain a better understanding of real-world responses to accidents or emergencies. Researchers at The University of Nottingham used VR to create immersive

Forecasted unit shipments of virtual (VR) and augmented reality (AR) headsets

cumulative; shipment in millions

VR AR
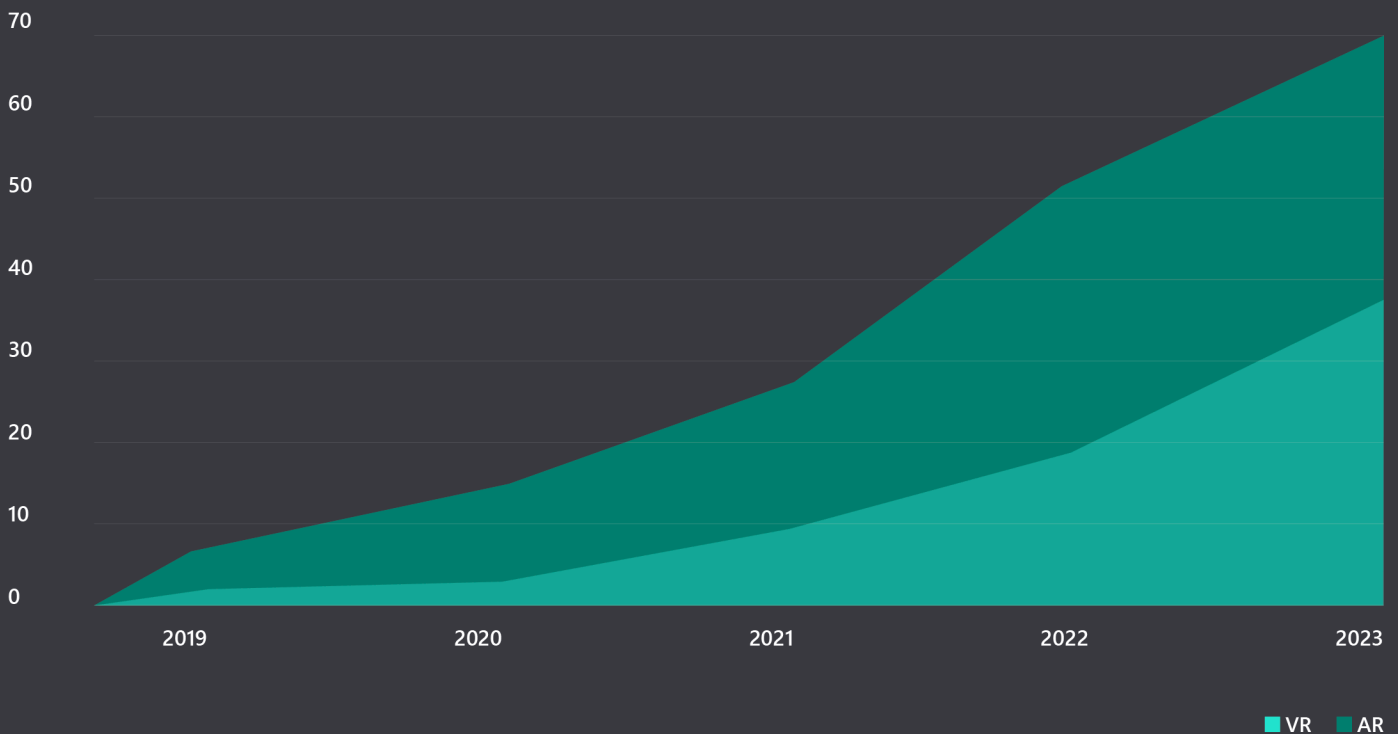
experiences in order to test how people would respond in the event of a fire and a gas leak. They found that the use of VR led to increased engagement and better retention compared with subjects who were only shown a presentation.[58] Used in this way, XR could improve the safety of millions of workers.

In 2016, a number of virtual reality devices hit the market, including HTC's Vive, Samsung's Gear VR, Facebook's Oculus Rift, Sony's PSVR, and of course, Microsoft's

HoloLens, the first self-contained, holographic computer. New generations of this technology soon arrived on the market, expanding AR's capabilities and reach. XR is expected to generate $160 billion in revenue by 2023 in content, hardware, distribution, software platforms, and delivery services. Significant growth is projected for both AR and VR headset sales, with both technologies expected to sell over 30 million units per year by 2023.[59] - -

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Work faster and smarter
From smart factories to intelligent supply chains, manufacturers must leverage innovative, intelligent solutions to optimize performance while fostering growth. At Microsoft, we're making manufacturing smarter and safer with unified data that powers intelligent, automated systems.

Get predictive insights
Modern manufacturing leaders require more accurate forecasts and foresight into emerging market trends. With artificial intelligence and machine learning embedded, Dynamics 365 provides manufacturing leaders with the data and knowledge to better predict trends, optimize processes, and grow their businesses.

Streamline operations
Manufacturers must streamline operations to provide greater transparency, improve delivery times, and build better products. From productivity tools, like Office 365, to the intelligent automation capabilities in Dynamics 365, Microsoft is helping manufacturers operate more effectively and efficiently.

Evolve your business
To meet the needs of today's customers, modern manufacturers must evolve beyond their existing business and operating models. From analytics solutions to collaboration tools to development platforms, Microsoft provides manufacturers with the technology and support they need to redefine manufacturing and their businesses.

04 /
Ethical manufacturing inspires changes

Ethical manufacturing

Since the publication of Milton Friedman's seminal article on shareholder theory in 1970, publicly held companies have been conditioned to equate profits with good, prioritizing shareholder value over just about everything else.

Today, we find ourselves in the midst of a sea change—both figurative and literal, as the accumulated impact of human activity causes global sea levels to rise—that has leaders in government and business reevaluating the role of the corporation in society and questioning the idea that profits are the only good that companies should strive to attain.

In the context of manufacturing, many leaders are investing in new ways to make their operations and products more sustainable, to prioritize employee safety and satisfaction, and to positively impact the communities they serve.

Executive summary

With mounting pressure from consumers, regulators, and shareholders, manufacturers are investing in practices that are more ethical and sustainable.

Highlights

- By 2021, US consumers will spend between $142.1 billion and $150.1 billion on sustainable fast-moving consumer goods.

- For every manufacturing job, another 3.4 full-time jobs are created elsewhere.

Innovation drives advances in sustainability

There are many compelling reasons for companies to pursue a triple bottom line. Among them: consumer demand. A recent study conducted by Pew Research Center found that 56% of American adults believe that protecting the environment should be a top priority for the President and Congress, with 44% feeling that climate change should be a top priority.[60] Similarly, Nielsen estimates that by 2021, US consumers will spend between $142.1 billion and $150.1 billion on sustainable fast-moving consumer goods, accounting for 25% of sales in that category.[61]

There's also evidence to support the idea that sustainability efforts can provide companies with a competitive advantage. Many experts agree that companies should willingly embrace the most stringent sustainability requirements that apply to their industry, even if they're not currently being enforced. When (not if) the bar for compliance is raised, companies that are already equipped to meet the new goals will have significant first-mover advantages over companies that did the bare minimum for as long as possible.[62]

Companies that are willing to take a hard look at their value chain, and ask what they can be doing to operate more sustainably, often unlock new ideas and possibilities. In some cases, they wind up creating products that are better than what they were making before—or that are so different than what any other company is producing that they invent a whole new niche for themselves. In that same vein, companies should involve their employees in their sustainability efforts. By challenging employees to identify ways to make operations leaner and more environmentally friendly, management may unleash insights that aren't apparent from the vantage point of the C-suite—while making employees feel more engaged and valued in the process.

In manufacturing, the companies that succeed in becoming more sustainable are often the ones who approach the manufacturing process with curiosity and a willingness to ask, "Why do we do it this way?" and "What if…?" The key is approaching sustainability not as a cost that must be borne, but as a driver of innovation.

One such organization is Dutch manufacturer Fairphone, which touts its handheld as "the world's most sustainable" phone. Fairphone's goal isn't to dominate the market for smartphones—the company has only sold 175,000 units since 2013. Instead, the company aims to

"The key seems to be approaching sustainability not as a cost that must be borne, but as a driver of innovation."

show other device manufacturers what's possible if you reimagine the sourcing and production process. Fairphone's devices are constructed using sustainably sourced materials, and unlike other smartphones, they're modular, meaning consumers don't need to replace the entire device if one of the components fails.[63]

As green business practices move from the realm of regulatory—and moral— imperative to a driver of profit, more and more manufacturers are taking concrete steps towards becoming environmentally conscious. This greening of the factory floor is happening in several ways. Manufacturers are optimizing their facilities and production processes to reduce their overall energy consumption. This includes steps like installing energy-efficient heating and cooling systems and lighting. Improvements in energy consumption not only reduce environmental impact, but they also reduce overhead costs.

Companies are also taking steps to reduce the amount of waste, greenhouse gases, and other pollution created as byproducts of the manufacturing process. Increasingly, manufacturers are investing in alternative energy sources, such as wind and solar, to power their operations, and using recycled,

recyclable, and reusable materials whenever possible.[64] Forward-looking manufacturers are also harnessing technology to reduce their environmental footprint. Cloud-based collaboration tools—from shared documents and video conferencing to digital twins and AR training—make it easier for teams to work together no matter where they're located. Companies are now deploying computer vision and smart sensors on the production line to improve efficiency, detect hazards, and reduce waste. And blockchain technology is proving a valuable tool in ensuring the source and efficacy of raw materials.

Many leading manufacturers, including Siemens, Unilever, HP, and Pratt & Whitney, have made commitments to greening their operations and products,[65] and the world's most valuable publicly-traded company has gotten in on the action too. In late 2019, Amazon announced that it intends to achieve net-zero carbon emissions by 2040 and to power its operations using 100% renewable energy by 2030. The company hopes that other organizations will follow their lead and pledge to meet the same goals.[66]

One sector that's currently experiencing a wave of innovation around sustainability is textile manufacturing. The fashion industry is one of the world's most resource-intensive and one of the worst offenders when it comes to pollution, but a growing number of companies are looking to change that. Los Angeles-based Mi Terro, for instance, has found a way to turn excess milk from dairy farms into eco-friendly shirts. The company can transform one glass of milk into five shirts. The process involves isolating the casein in the milk, solidifying the protein into fibers, and then spinning it into yarn.[67]

Sustainable clothing brand Everlane is another company that embraces ethical and sustainable manufacturing. Using Saitex, a denim factory known worldwide for its environmentally friendly practices, Everlane is able to recycle 98% of its water using clean energy. As a result, the factory only uses only a fraction of the 1,500 liters of water typically required to produce a pair of jeans. Other denim manufacturers like Warp + Weft, Levi's, and Frank and Oak are following suit.[68]

Thanks to companies like Thr3efold, it's easier than ever for fashion brands to establish relationships with sustainable manufacturers. Officially launched at New York Fashion Week in September 2019, Thr3efold is a SaaS provider that helps brands create an ethical and sustainable supply chain by connecting them with fully vetted manufacturing plants in the developing world. The company's ethical manufacturing platform enables businesses to find producers who match their budget and product specifications and to manage production using just one interface.[69]

Microsoft is proud to be a leader in sustainability. We have been operating at 100% carbon neutrality since 2012, and even though our data centers are already 100% powered by renewable energy sources, we continue to work to improve our energy sourcing. Additionally, we continue to invest in new energy technology, from biogas to fuel cells, to accelerate the availability of new types of clean energy.

"Microsoft has been operating at 100% carbon neutrality since 2012."

The human side of manufacturing

Manufacturing leaders are renewing their focus on one of their most valuable assets—their employees—with enhanced safety measures and new initiatives designed to build skills, improve job satisfaction, and provide clear and appealing career tracks for manufacturing professionals. In parallel with those efforts, manufacturers are taking a hard look at the impacts their operations and products have on customers and the broader community.

Factories become safer than ever

Today's manufacturing industry is considerably safer than it was during the height of previous Industrial Revolutions when worker safety was often the responsibility of workers themselves. While workplace injuries remain a risk factor in the manufacturing sector, as more manufacturers adopt Industry 4.0 technology for safety purposes, safety is rapidly becoming a core component of the manufacturing ethos.

"**In today's connected factories, worker safety can be monitored and controlled by AI, sensors, computer vision, facial recognition, and the IIoT.**"

In today's connected factories, worker safety can be monitored and controlled by AI, sensors, computer vision, facial recognition, and the IIoT, which enables seamless integration and coordination of safety technology and protocols within the broader context of holistic factory management. This emerging trend owes much to research from the past decade, which concluded that worker safety improves efficiency, productivity, and business performance. A study by the Aberdeen Group determined that best-in-class manufacturers gain a competitive edge by integrating safety technology with their standard automation systems and by managing safety in coordination with productivity, quality, and risk.[70]

The variety and application of safety devices in manufacturing are rapidly expanding. Automated equipment and robots, which used to be kept separate from human workers, now come with spatial capabilities and AI awareness that prevent them from moving in a way that could jeopardize human safety or production efficiency. Today's autonomous machines are more capable of handling hazardous materials and working in dangerous conditions without direct human assistance. Additionally, drones can be used to access and monitor manufacturing areas in conditions under which humans might be at risk, as well as safely transport parts and materials where needed.

All of these micro-level safety components are increasingly connected and integrated with the factory's overall macro-level operations via the IIoT—as are its workers. UK-based workforce safety company Wearable Technologies has developed

a line of "safety wearables" that monitor and share data in real-time. The wearables provide a range of information—such as proximity warnings, gas detection, noise levels, and worker position—to both workers and management, enabling faster responses when potential hazards are detected. Companies like Realware are coming up with innovative safety glasses that incorporate connected AR components, allowing on-the-spot visual reference guidance and interface sharing with co-workers and management.[71]

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Toyota's North American production engineering team uses Dynamics 365 to ensure that its factory operations are both safe and connected. The team uses Dynamics 365's Layout to produce digital twins of manufacturing floor equipment for safety and process verification and Remote Assist to enhance safety through remote equipment verification and incident response.[97]

Employee turnover

12 Number of times the average employee changes jobs in their career

24% Estimated employee turnover rate in the US

$1T Estimated annual cost of employee turnover

Manufacturers prioritize employee satisfaction

According to the Bureau of Labor Statistics, the average employee changes jobs 12 times over the course of his or her career.[72] That churn comes at a high price to employers; the cost to replace an employee who voluntarily quits his or her job can range anywhere from 50% to 200% of that person's annual pay. With an estimated employee turnover rate of 23.8% in the US in 2017, employee turnover could be costing American employers as much as $1 trillion each year.[73] It's no secret that improving employee satisfaction results in less voluntary turnover. In the manufacturing industry, which is in the midst of a massive crunch to recruit and retain skilled professionals, ensuring that employees are happy with their jobs is of paramount importance.

What's clear is that compensation alone isn't the key to ensuring job satisfaction. Although hourly wages have dipped slightly in recent years, manufacturing professionals still earn 13% more in total compensation—wages plus benefits— than non-manufacturing workers with comparable experience.[74]

So why is it so hard to attract and keep people in manufacturing jobs? While part of the problem can be attributed to an aging workforce and a well-documented skills gap, the fact remains that the industry has a perception problem. The general public still associates manufacturing jobs with low wages, poor working conditions, and tedious, repetitive tasks.[75]

A 2018 survey found that 70% of respondents believed that American manufacturing was in decline. The following year, the same study reported that 53% of respondents thought that the average manufacturing manager made less than $60,000 when the actual average salary is nearly double that.[76] To correct these erroneous beliefs and get a new generation of workers excited about the possibility of a career in manufacturing, companies need to paint a clear picture of today's cleaner, safer, tech-forward factories and the

rewarding, and intellectually challenging, jobs that these environments offer.

If correcting the industry's perception problem is one half of the solution, then engaging employees is the other. In a nutshell, employees want to like their company and feel proud of the work they do. Companies that want to increase levels of employee loyalty and engagement should focus their efforts on strategies that instill employees with a sense of purpose, pride, and belonging, particularly those that drive positive emotional experiences.[77]

Conversely, external benefits that are based on a physical or functional reward—such as free food, casual dress codes, and bonuses—may be helpful enticements when it comes to recruiting but are overall less effective at driving long-term employee satisfaction and retention. In the context of manufacturing, engaging employees means fostering creativity in the workplace, investing in workers by offering training and clear paths for career growth, and actively involving employees in process and product innovation.

Fostering creativity in the workplace can yield a number of benefits. Creating a workplace culture that prioritizes creativity

leads to increased engagement and higher levels of job satisfaction, makes employees work harder, results in greater flexibility and ability to handle stressful situations, and gives employees an enhanced sense of well-being and connection to their work.[78]

When Craft Tools, a precision tools manufacturer, changed ownership in 2014, they knew they needed to do something dramatic to spur innovation and growth. The company established an Employee Stock Ownership Plan—giving its workers a stake in the success of the company. They actively source ideas from employees at every level of the company. To encourage

employees to share their ideas and ensure that everyone receives fair credit, everyone who contributes to the development of a new product is mentioned in the patent filing.[79] Manufacturers would also do well to take a page from Toyota, which is famous for involving its employees in process improvement initiatives. Giving employees agency to suggest changes and to address problems has profound benefits for both employees and the company as a whole. Employees feel connected, valued, and like having agency in their position, while the company benefits from improvements that might not be obvious from the vantage point of company headquarters.

Number of US factory jobs created
since 2017

465,000

Community impact becomes a mainstream issue

When manufacturers open up a new production facility, it can have a dramatic, positive impact on a community. The addition of a new factory not only results in new jobs for production workers, it means architecture, engineering, and construction jobs for the workers needed to design and build the factory; new positions at company headquarters; and the need for a range of ancillary businesses that offer parts or services that support factory operations. It also creates an entire market for goods and services—such as housing, restaurants, healthcare, and retail—for workers and their families.

According to the Manufacturers Alliance for Productivity and Innovation Foundation (MAPI), manufacturing added $2.38 trillion to the US economy in the third quarter of 2018.[80] Experts estimate that the economic multiplier effect of manufacturing is 1.82, meaning that every $1 spent in manufacturing adds $1.82 to the economy.[81] The MAPI Foundation argues that if you take into account the entire manufacturing value chain (and not just factory output), the number is actually $3.60. Using this broader definition, the MAPI Foundation also estimates that for every manufacturing job, another 3.4 full-time jobs are created elsewhere; together, they comprise 32% of the American workforce.[82]

465,000 US factory jobs have been created since 2017; however, the majority of these are not in the industries that have been hardest hit by automation and offshoring, which resulted in the elimination of six million American jobs between 2000 and 2010. Instead, the wave of new hiring has been driven by growth in advanced manufacturing—led by companies like Tesla and SK Innovation (batteries for electric vehicles and other devices) and Volkswagen (electric vehicles)—and the oil industry, as well as by growth in craft brewing, wine, and spirits.[83] [84]

Unfortunately, this growth is being offset by the closure of manufacturing facilities elsewhere in the US. Despite the fact that reshoring and nearshoring are becoming attractive options for a growing number of manufacturers, a significant amount of factories in the US are closing as companies attempt to control costs or pursue new market strategies. The closure of these factories is having a devastating effect on the communities they once supported.

In late 2018, Siemens announced that it was closing a turbine plant in Burlington, Iowa, a factory that had been in continuous operation since 1870. This announcement by Siemens came on the heels of its decision to close two other North American turbine plants and the planned closure of another plant in 2020. Together, these closures will result in roughly 875 layoffs, part of the company's offshoring of approximately 1,700 American jobs since late 2016.[85]

Similarly, in July 2019, IKEA announced that it would close its only US factory and lay off 300 workers in the process.[86] The company cited the lower cost of raw materials in Europe as the reason for its decision.

In response to changes in consumer demand, many US automakers have decided to halt the production of traditional sedans and instead focus on making SUVs, trucks, electric cars, and autonomous vehicles. The result is the closure of a number of car factories across the country. In October 2018, GM announced that five of its North American factories would be "unallocated" and that the company would cut approximately 6,000 production jobs and 8,000 salaried positions.[87] Altogether, the layoffs represent a more than 10% reduction in GM's North American staff.[88]

Economists estimate that every job generated by the auto industry results in the creation of three or four other jobs for support industries, comprising everything from warehousing and logistics to specialized parts. Consequently, the closing of the Lordstown, Ohio GM factory, which was responsible for the production of the Chevy Cruze, is likely to affect 50 area businesses and has already forced two of its suppliers to close, resulting in the loss of 800 jobs.[89]

Some factory workers whose jobs are eliminated may be eligible for a transfer to another company factory, but for many employees—especially those who own homes or who are just a few years shy of being eligible for a pension—moving isn't an easy or desirable option. Many employees can't or won't uproot their families when assigned to a new plant. Instead of relocating, many opt to commute hundreds of miles, which can take its toll, resulting in divorce, nervous breakdowns, and in a few cases, suicide.[90]

A recent study by researchers at Duke University and the University of Massachusetts-Amherst showed that factory closures could have a profoundly negative impact on workers' families. For children of laid-off manufacturing employees, the closing of a factory is correlated with an increase in mental health issues, lower test scores, and decreased educational attainment.[91] There's even evidence that when a factory leaves town, it sets off a chain reaction that results in lower rates of marriage and births in the community, more children born to single mothers, and more children living in poverty as a percentage of the whole. When a factory leaves, some workers, predominately men, leave town in search

of other jobs. Among those who stay, rates of substance abuse, mental illness, homelessness, and incarceration rise.[92]

Although nearly half a million manufacturing jobs have been added since the beginning of 2017 and a number of companies are planning to open or expand factories in 2020[93], it seems that growth in domestic manufacturing is beginning to slow.[94] As manufacturers plan for the future, they need to consider their impact on the communities in which they live—their employees, employees' families, partners, and beyond.

Companies develop more inclusive products

When designers use their own bodies, abilities, and biases as a starting point for creating new products, they wind up making things that are safe and easy for some people to use, but difficult (and in some cases, potentially dangerous) for everyone else. As it stands today, a majority of consumer products are designed with a non-disabled adult male in mind. Left unchecked, the result is a world of products designed for people of a specific gender, age, language ability, tech literacy, and physical ability. This represents a very narrow view of the global population.

These unconscious biases find their way into everything from the size and number of toilet stalls in public bathrooms, the climate control systems of office buildings and public spaces, medical studies and health guidelines, and even the design of personal protective equipment and crash test dummies.[95] And increasingly, these biases are coded into the AI that runs the products and systems that consumers use on a daily basis.

One of the places that these biases are most evident to the consumer is in conversational AI. While the current generation of digital assistants has made technology more accessible and easier to use for many, it's clear that there's still room for improvement when it comes to their comprehension and responses to specific topics.

Other manufacturers are also taking steps to ensure that the design of their products represents the needs of all users, not just one subset of customers. The majority of car manufacturers still design their vehicles to safety standards set for male crash test dummies. The result is that women are more likely to be seriously injured in a car accident than men, so in 2019, Volvo shared more than 40 years of real-world collision data with the rest of the auto industry in the hopes that doing so would help make cars safer for everyone.[96]

Microsoft is proud to be a leader in accessibility and inclusivity. With intuitive, familiar tools that are easy to learn and cloud-based applications that allow individuals to access information from anywhere, Microsoft is making technology more accessible to more people than ever before, opening up untapped markets for talent and innovation. - -

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Our inclusive design principles
Exclusion happens when we solve problems using our own biases. As Microsoft designers, we seek out those exclusions and use them as opportunities to create new ideas and inclusive designs. There are 7.4 billion people in the world. Our ambition is to create products that are physically, cognitively, and emotionally appropriate for each of them. It starts with seeing human diversity as a resource for better designs. When it comes to people, there's no such thing as "normal." The interactions we design with technology depend heavily on what we can see, hear, say, and touch. Assuming all those senses and abilities are fully-enabled all the time creates the potential to ignore much of the range of humanity.

Recognize exclusion
Designing for inclusivity not only opens up our products and services to more people; it also reflects how people really are. All humans grow and adapt to the world around them, and we want our designs to reflect that.

Solve for one, extend to many
Everyone has abilities and limits to those abilities. Designing for people with permanent disabilities actually results in designs that benefit people universally. Constraints are a beautiful thing.

Learn from diversity
Human beings are the real experts in adapting to diversity. Inclusive design puts people in the center from the very start of the process, and those fresh, diverse perspectives are the key to true insight.

05 /

Manufacturers adapt to a changing workforce

Manufacturers adapt to a changing workforce

The workforce is changing. As Gen Z workers enter the workforce, they find themselves up against a growing population of older adults (ages 55 and up), who are now the fastest-growing segment of the American workforce.[98] By the year 2026, older Americans will constitute 26% of the manufacturing workforce, an increase of 12% from 2002.[99]

As the workforce becomes more diverse and inclusive—in all dimensions—manufacturing leaders are seeking the knowledge and resources to help manage this transformation. They are also embracing this change to help drive innovation; onboard new, more technical digital skill sets; and develop new processes to capture institutional knowledge, helping to ensure that the next generation of workers is capable of taking the reins when it's finally time to pass the torch.

Executive summary

As an older generation of workers delays retirement due to economic uncertainty, another—Gen Z—is anxiously waiting in the wings with unique skills, ideas, and new ways of working.

Highlights

- Millennials are forecasted to comprise 50% of the workforce by 2020.

- Despite accounting for 45% of all employees at the largest companies in the US, women occupy just 25% of C-suite positions.

- 79% of manufacturers have struggled to fill open positions, with 34% reporting that lack of staffing had forced them to turn down new business.

A multigenerational workforce creates challenges and opportunities

With life expectancies on the rise, older Americans are delaying retirement and working longer than was the norm in previous generations. There are now five distinct generations of people in the workforce—the silent generation, baby boomers, Generation X, millennials, and Generation Z—each with their own perspectives, priorities, experiences, and ways of communicating. As a result, today's leaders may find themselves in the precarious position of managing teams that include employees who are both older and younger than themselves. While this would initially seem to pose serious challenges, leaders who embrace their teams' diversity of perspectives and experience can generate powerful benefits for everyone involved. The trick is leveraging each employee's strengths for the benefit of his or her teammates.

Defining generations

Silent generation (born before 1945)
Currently comprising 2% of the workforce, the silent generation came of age in a hierarchical workforce. They are hardworking and loyal but view work as a means to a paycheck, not an identity.

Baby boomers (born 1946-1964)
As a generation, boomers are driven, focused on personal achievement and earnings, and **prone to workaholism.**

Generation X (born 1965-1980)
Deemed by some the "slacker" generation, Gen X is skeptical of authority and prioritizes work-life balance. Despite coming of age in an analog world, by many measures, members of this generation are as digitally savvy as their younger counterparts.

Millennials (born 1981-1996)
Forecasted to comprise 50% of the workforce by 2020, millennials are highly educated, collaborative, and entrepreneurial.

Generation Z (born after 1996)
More likely than other generations to feel they can make a meaningful difference in the world through their career, Gen Z believes that work environments should deliver a sense of purpose, identity, and fun.

132 133 134 135

For example, boomer and silent generation workers can help Gen Z develop the soft skills needed to ensure smooth interactions in a business environment.[100] And with decades of experience under their belts, older employees can model calm under pressure, share institutional knowledge, and offer problem-solving approaches to their younger counterparts.[101] Companies should also consider instituting reverse mentoring programs, where younger employees share best practices and insights about technology with older employees. Beyond the obvious goal of raising levels of tech literacy across the organization, reverse mentoring can be a powerful tool for increasing employee satisfaction and retention, as well as yielding benefits in the areas of diversity and inclusion.[102]

Above all, managers should understand that there's no one-size-fits-all management style that will fit every team (or every team member). Managers must be flexible, not make assumptions based on generational stereotypes, and be sensitive to the different work and communication styles of their direct reports.[103]

Diversity and inclusion are at the forefront

Data from the 2018 Census indicates that Gen Z is more racially and ethnically diverse than any other generation of Americans.[104] By the year 2045, fewer than half of all Americans will identify as white.[105] The face of the American population is changing, and with it, our expectations of who should occupy positions of influence and authority.

Representation matters, but in the media, the halls of government, and corporate America, change has been sluggish.

A study by UCLA showed that on average, movies and TV shows that feature diverse casts gross more, are more profitable, and get better ratings. Despite the findings, women and minorities are still underrepresented in the cast and crew of television and movie productions.[106] The story is the same in government. As of January 2019, the number of women and minorities in the US Congress is at an all-time high, but both groups are

Women in the workplace

Employees at largest US companies
C-suite
CEOs

6%

25%

45%
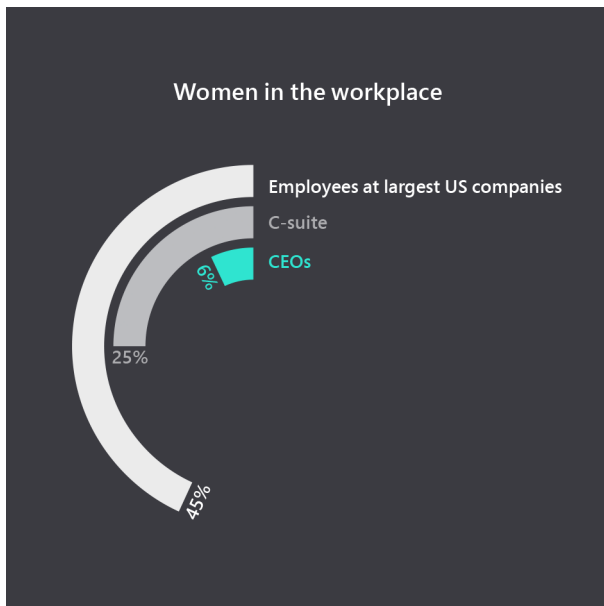
underrepresented by about 50% when you consider their share of the overall population.[107]

The stats for the business world are similarly skewed. Despite the fact that women account for 45% of all employees at the nation's largest companies, they occupy just 25% of C-suite positions in the United States, and only 6% of CEOs are women.[108] According to the Alliance for Board Diversity, women and minorities are on track to occupy 40% of all board seats at Fortune 500 and Fortune 100 companies[109], but they lack similar levels of representation among the ranks of executives responsible for day-to-day operations.[110]

Thankfully, that's all changing, albeit slowly. Companies like Accenture, Diageo, Medtronic, and Gap have each attracted attention for their recent efforts to ensure that women and minorities are better represented at all levels of their organizations.[111] Goldman Sachs has also generated waves for its efforts to become more diverse and inclusive. In March of 2019, the company announced new hiring targets aimed at ensuring that half of all new analysts and entry-level associates—two positions which comprise 70% of the company's new hires each year[112]—would

"Companies with greater levels of diversity reported that 45% of their income came from new products and services, compared to only 25% at less diverse firms."

be women, 14% would be Latinx, and 11% would be black. CEO David Solomon has also said that the company has goals to recruit more members of the LGBTQ, veteran, and disabled communities.[113] The new policy is a laudable effort to increase diversity in a notoriously male-dominated industry, and the bank has made it clear that these are more than vanity targets. Solomon has indicated that managers' pay increases and promotions will be partly contingent on their ability to make progress toward the firm's diversity goals.[114]

Other companies should take note, as there is substantial financial justification for pursuing workplace diversity. A study by BCG found that companies with above-average levels of diversity in their senior leadership experienced 9% greater EBIT than companies with more homogeneous leadership teams. In addition, BCG discovered a strong correlation between diverse leadership and innovation. Companies with greater levels of diversity reported that 45% of their income came from new products and services, compared to only 25% at less diverse firms.[115] Similarly, a 2018 study by the International Monetary Fund found that the presence of women on the boards of banks was associated with greater stability and improved ability to weather stress.[116]

79%
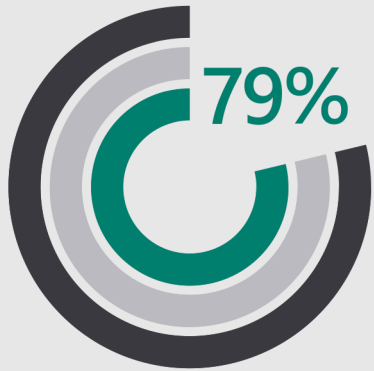
Manufacturers that have open positions
that they are struggling to fill

34%
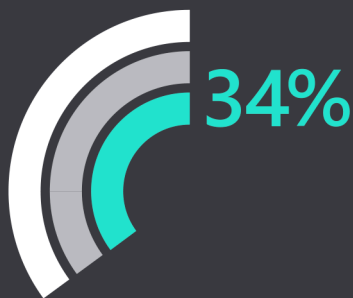
Manufacturers that have turned down
new business due to lack of staffing

Manufacturers seek new solutions to bridge the skills gap

Manual labor is no longer the primary component of manufacturing jobs. Instead, Industry 4.0 is driving the need for technically-skilled laborers whose work will be closely integrated with smart machinery. Whereas early-generation automation and computer technology helped workers with their tasks, today's manufacturing climate requires tech-savvy workers to help smart machinery with their tasks. This shift in labor force skills is challenging companies to find workers who can meet today's advanced manufacturing requirements.

Attracting and retaining qualified workers remains a top concern for manufacturing leaders. According to a recent National Association of Manufacturers' survey, more than three-quarters of respondents have struggled to fill open positions, with a third of companies reporting that a lack of staffing had forced them to turn down new business.[117] Underscoring the dearth of talent, almost 70% of respondents also reported that they were working their existing workforce more in an effort to bridge the skills gap.

These problems are not likely to subside anytime soon. Not only will manufacturers need to replace more than 2.5 million retiring baby boomers in the coming decade, but economic expansion could create almost two million additional vacancies over the same period.

A study by Deloitte and the Manufacturing Institute, which noted that there were more than a half-million open manufacturing jobs as of August 2018, determined that 2.4 million jobs would remain unfilled due to

the skills gap in the decade between 2018 and 2028.[118] This persistent skills shortage could risk $2.5 trillion of economic output over the next ten years.

The challenge of filling these jobs is exacerbated by the need for workers with technical backgrounds, especially in the STEM fields, which are also in high demand from other business sectors.[119]

Projected manufacturing output at risk due to skills shortage

US manufacturing output/GDP   *Manufacturing output/GDP at risk due to skills shortage*

in billion USD
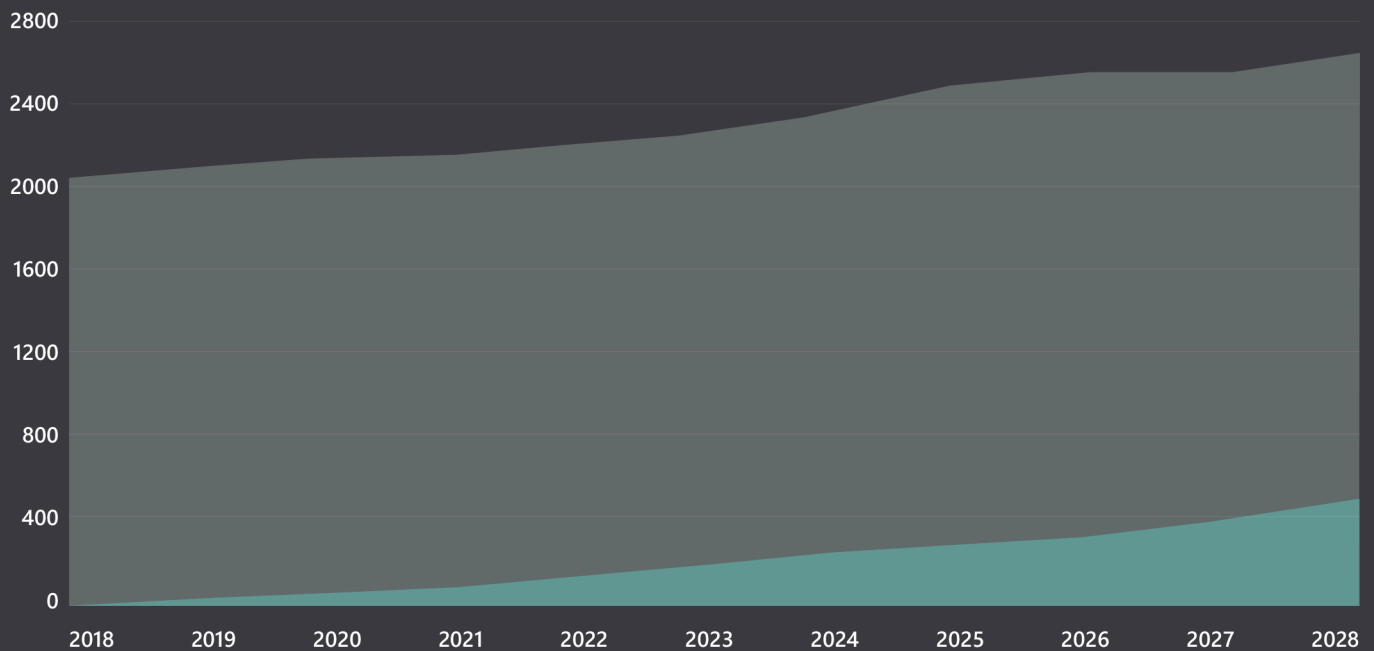
Attracting a new caliber of manufacturing professional

The technological advances that are powering Industry 4.0 are also redefining the manufacturing skills needed in the workplace. While many tasks formerly handled by human workers can now be accomplished using automation, workers are often needed in other capacities. Not only are employees needed to bridge the gaps between current and future operation models, but emerging technologies are creating a plethora of new job types. Some of these new job types don't even exist yet, but the rate of technological progress will make them necessary over the next few years.[120]

Because new manufacturing technologies are STEM-centric, companies need to actively recruit university students for their higher-level job talent. To compete with modern high-tech fields and their Silicon Valley cachet, manufacturing needs to rebrand itself as a dynamic business sector that offers a clear career trajectory with many opportunities for advancement.

For production workers, though, it's not necessarily high-level STEM skills which are needed, but rather the ability to

program machines and work with CAD/CAM equipment.[121] Long a respected and common path to manufacturing careers in Europe, US companies and other manufacturing stakeholders are rapidly adopting the industrial apprenticeship model. Companies, both individually and collectively, are investing heavily in developing apprenticeship programs with high schools, community colleges, and universities.[122]

IBM is one of 17 leading companies that partnered this year to form the CTA Apprenticeship Coalition to create thousands of tech apprenticeships to fill the millions of unfilled "new collar" jobs. IBM CEO Ginni Rometty, who notes that

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Along with recruiting new workers, manufacturing companies are investing in AR, VR, and other wearable technologies to speed up training through virtual simulation. The tools allow trainees and existing workers to virtually perform an unfamiliar task, while also allowing for on-the-scene remote guidance by supervisors or others with task expertise. Boeing uses Microsoft HoloLens to train employees on specific tasks and believes the tool can reduce training time by up to 75% per trainee.

91% of apprentices find employment after completing their programs, is one of the industry's strongest advocates for boosting the country's apprenticeship model.

The US government is also pushing the apprenticeship trend under the Department of Labor's Industry Recognized Apprenticeship Program, which has helped create more than half a million apprenticeships since 2017. The department announced the expansion of the program

in 2019, with the inclusion of more than $283 million in funding to support the training of more than 85,000 more apprentices and other close-the-skills-gap initiatives.[123]

Regions, states, local governments, and manufacturing organizations are also playing a role in nurturing a new caliber of manufacturing workers through the development of sector partnerships. Stakeholders in these partnerships determine employer demand, identify skill gaps, and initiate programs to help job seekers fill them.[124] A multi-stakeholder partnership called MakerMinded has delivered STEM skills and introduced modern manufacturing to more than 6,000 middle and high school students in seven states.[125] With its initial success and new government funding, the initiative is expected to soon expand into other states.

Racial minorities and women have been identified as an enormous untapped human resource for manufacturing jobs.[126] The US Employment Plan provides incentives that encourage manufacturers to increase the hiring of minorities and women, as have some initiatives on the state level. Some sector partnerships also incorporate outreach to minorities and women.

Employee retention becomes a key initiative

In a recent skills gap study by Deloitte, 66% of manufacturing executives reported that skilled workers were leaving their companies for higher-paying jobs. A similar percentage reported that offering higher pay to retain skilled workers had a moderate to significant impact in retaining skilled workers, with just over 30% reporting that increased pay had little to no impact.[127]

The Deloitte study data, combined with other recent studies, suggest that offering higher pay to retain manufacturing talent will not serve as a panacea to fix the emerging skills gap. In fact, sector-wide pay raises would likely just lead to more skilled workers jumping ship to take advantage of the next higher paying job offer.

A longtime buzzword in the high-tech sector, manufacturers now recognize "workplace culture" as a key component of worker retention. And this culture goes far beyond widely reported Silicon Valley workplace perks, like on-site gourmet food, spa treatments, and other pamper-

66%

Percent of manufacturers who are losing employees to higher paying jobs
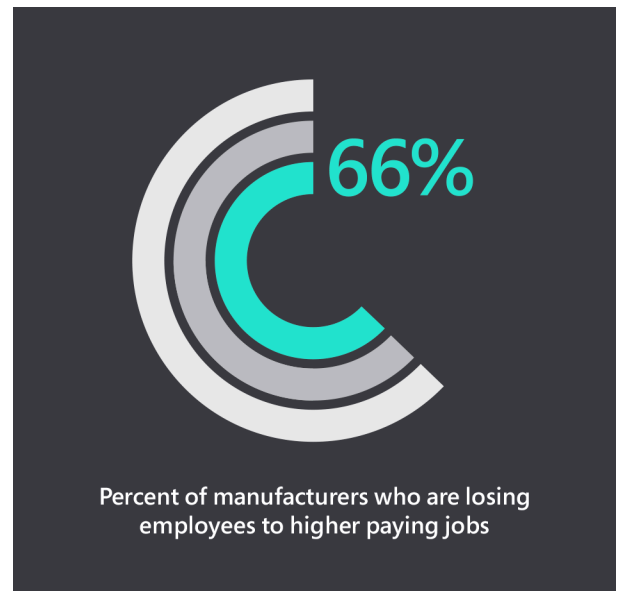
the-worker gimmicks. Not that such perks aren't appreciated, but they aren't meeting the deeper worker satisfaction needs that many employees seek— such as respect, appreciation, a sense of accomplishment, advancement clarity, and clear communications, to name the most significant.

These deeper needs were recognized more than a decade ago following a 10-year, 200,000-worker study on workplace turnover that found 79% of employees who quit their jobs cited a "lack of appreciation" as a key reason for leaving.[128] The study findings are gaining new cachet today as manufacturers look for ways to resolve the growing skills gap crisis.

Manufacturing training solutions company Tooling U-SME urges manufacturers to look at its workers as "appreciable resources worthy of ongoing investment."[129] To combat turnover, companies need to offer robust onboarding programs and provide clear professional development pathways. Career development includes learning new skills and exploration of different paths in the workplace that bolster personal interest and promote innovation. Companies that foster a culture of learning with a growth mindset for both workers and the company are more profitable and have better worker retention than those that don't.[130]

Manufacturers are also taking a closer look at their older employees. While only about 10% of manufacturing companies were creating "targeted roles" for their older workers as of 2018, companies are increasingly considering their experience, expertise, and institutional knowledge as an underutilized asset.[131] Michelin North America uses its off-boarding interview to recruit retiring employees to work as consultants for short-term projects, while Home Depot and numerous other companies are offering retiring workers flexible scheduling, part-time work, and gig options. - -

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Microsoft CEO Satya Nadella is recognized as much for changing the company's workplace culture as he is for boosting company profits since taking over in 2014.[136] These efforts have been noticed by Microsoft workers who have helped the company earn top ranking over similar size companies in almost two dozen company culture metrics over the past two years.[137]

Transform for the future
Manufacturing leaders must empower new talent with the vision, opportunity, and resources to create a meaningful impact. As we undergo our own cultural transformation at Microsoft, it informs and inspires our pursuit to empower our clients as they transform their organizations for the future.

Empower employees
Employees are a business's most valuable asset; today's organizations must empower their employees to do more. From tools like Office 365 that help teams get more done to role-based workspaces in Dynamics 365 that put the right information at each employee's fingertips, Microsoft is helping businesses empower their employees to do more.

Transform culture
To solve today's most pressing problems, manufacturing leaders must transform their cultures. From tools that improve communication to the platform on which a startup will build the app that will disrupt an industry, Microsoft is empowering businesses to redefine their culture.

06 /
Technology enables advanced R&D

Technology enables advanced R&D

Perhaps the most significant difference between the Fourth Industrial Revolution and its predecessors is the speed at which change is occurring. The digital revolution that enabled Industry 4.0 is having rapid, widespread impacts across the manufacturing sector. Advanced research and development is no exception, as R&D departments across the manufacturing industry adopt emerging technologies to improve efficiency and enhance their product development.

Today, many R&D departments have been tasked with developing products that utilize next-generation technologies such as cloud computing, IoT, AI, robotics, and big data. To meet time-to-market goals, R&D departments must adopt some of the same technology they are tasked with incorporating into their products. Not only is this potentially costly, but it can also be fraught with challenges for companies with limited digital capabilities. To surmount these challenges, some manufacturers are

Executive summary

New technologies and techniques, such as advanced prototyping and digital twins, enable advanced R&D and foster innovation.

Highlights

- Robots will soon become the preferred option for creating products, such as semiconductors, which require nanoscale assembly.

- 50% of industrial companies will use digital twins by 2021.

collaborating with outside specialists to conduct all or part of their R&D.[138] Other companies, such as Stanley Black & Decker, are going all-in by spending millions on new R&D departments devoted specifically to working with and on cutting-edge technologies.

Currently, AI, robotics, VR, and AR are having the most significant influence on R&D. 3-D printing has become mainstream in modern R&D, though its capabilities and applications continue to evolve. Chemical and materials sciences companies are increasingly using AI to help sort through reams of data, a trend that will likely expand into other manufacturing sectors.

Because of their speed, precision movements, and ability to do things that humans can't, robotics are taking an increased role in some R&D processes. Robots will soon become the preferred option for creating products such as semiconductors, which require nanoscale assembly.[139]

One of the major aims of R&D is to convert the conceptual into reality, making it a discipline that's highly dependent upon visualization. Using AR and VR, it's possible to create 3-D and holographic simulations that can help R&D teams dramatically reduce the time required to design, iterate, and get new products to market.[140] This helps make virtual and augmented reality design programs among the most potent tools in today's R&D environment.

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US medical device manufacturer Stryker Corp. uses Microsoft's HoloLens to help it design tools for the operating room of the future.[160]

Advanced manufacturing enables advanced prototyping

While it's too early to say where advanced R&D will end up taking the manufacturing industry, recent advances in prototyping may offer a good indication. Prototyping represents the last stage of R&D before production. 3-D printing, which was originally referred to as "rapid prototyping," currently represents the most noteworthy Industry 4.0 technological advance in prototyping. The need to increase speed to market is partially responsible for the adoption of 3-D printing as a tool for prototyping. Unlike traditional manufacturing techniques, 3-D printing can yield working prototypes within a few hours, meaning R&D teams can potentially create and test multiple iterations of a product in one day.[141]

But even as 3-D printing capabilities continue to expand, the technology may be overshadowed by a new development in prototyping: 4-D printing. This emerging technology uses 3-D printing to produce solid components that are programmed to change shape based on specific stimuli, such as temperature or light. This transformation represents the fourth dimension of 4-D printing.
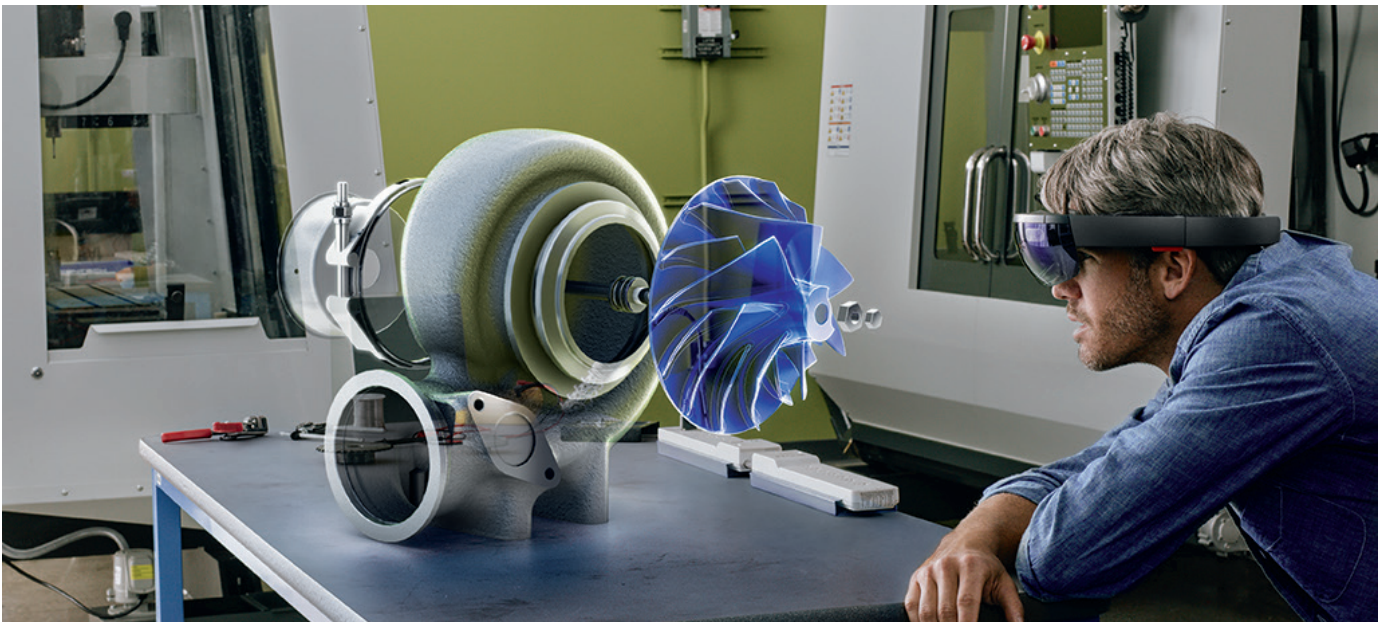
Digital twins increase manufacturing innovation and efficiency

Digital twins are virtual representations of a product, asset, or process that allow manufacturers to determine how different variables will impact their performance, production, and even revenue. Digital twins can be used for everything from predicting future equipment maintenance needs to modeling entirely new revenue streams.[142] Because of their versatility, digital twins are an integral cyber component of Industry 4.0. By 2021, 50% of industrial companies will use this technology, resulting in an estimated 10% increase in efficiency as a result.[143]

What makes digital twins invaluable is their ability to cut operational costs drastically. Digital twins enable real-time monitoring of machine performance, providing clear visibility across various manufacturing facilities. Since digital twins can be used to simulate machine failures, manufacturers can use the data they yield to proactively schedule maintenance before issues arise. Digital twins can also be used to train and

educate factory personnel on machine operations and troubleshooting.

Being able to visualize a digital replica of a physical object or process enables faster and more efficient decision making. Companies can eliminate critical delays caused by lengthy fault diagnostics and assessment processes, consequently enhancing overall system performance. Furthermore, digital twins have the power to create processes and data transparency across teams, and coupled with VR systems, digital twins empower factory workers to make educated decisions to better manage machine and process breakdowns.

50%

Percent of industrial companies that will use digital twins by 2021
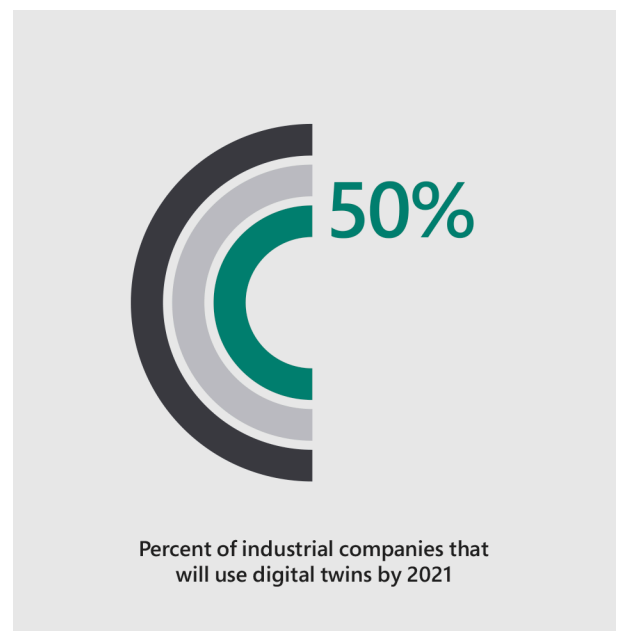
*Projected

Digital twins hold limitless potential for the manufacturing sector. The design and prototyping phases are two of the longest and most painstaking stages of product development. By digitizing these phases, product features can be altered and tested in an incredibly short time. Rolls-Royce uses digital twin technology to conduct safety evaluations of engine parts and has been able to cut test analysis times in half.[144] The Vietnam-based car manufacturer, VinFast, created digital twins of an automotive plant and car design, and in doing so, created the entire production timeline in less than half the average time required to build an automotive manufacturing plant.[145]

Jointly developed by Siemens and Bentley, PlantSight™ is a digital twin solution optimized for process manufacturing.[146] The technology creates a digital twin of plant operations by contextualizing, validating, and visualizing raw data collected from individual plant entities. PlantSight™ utilizes the combined features of Bentley's OpenPlant and Siemens' Comos software to enable plant owners and operators to gain control of plant operations in real-time via a 3-D model of the entire plant.

Aside from the traditional manufacturing setting, digital twin technology is increasingly being used in infrastructure and urban planning to create digital replicas of buildings, cities, and airports. Hong Kong International Airport (HKIA) is in the process of creating a digital twin of itself as part of its smart airport vision.[147] A lifelike model of the passenger areas of Terminal 1 has already been completed as part of the initiative. The digital twin of the airport enables design review for new construction projects and provides efficient resource management for maintenance needs.

As digital twin technology becomes increasingly mainstream, companies will have to ensure that a continuous stream of data is being collected through high-quality sensors. Insufficient or erroneous data could result in faulty digital replicas, with potentially disastrous consequences for manufacturers and their stakeholders. Manufacturers must also ensure that they're using a consistent set of 3-D modeling standards to maintain parity amongst the multitude of models used within a digital replica. Lastly, cross-functional teams will have to work in sync to create coherent digital models that meet the information needs of each group.

Users provide insights that enable rapid iteration

Industry 4.0 technologies help gather an endless stream of consumer data— information that manufacturers are using to derive actionable insights that directly impact product innovation. Using big data analytics, manufacturers are collating product performance data and customer feedback to improve their products. Fueled by the unbridled courage to voice their opinions on social media, today's consumers are driving product innovation and co-creating products with manufacturers.

"Manufacturers are collating product performance data and customer feedback to improve their products."

At LG's New Business Center in Korea, researchers analyze anthropological and psychological data obtained from consumer and product usage behavior. This enables LG to understand customer expectations and develop innovative products such as the LG HomeBrew™, a home appliance for brewing craft beer. The device was showcased as part of the LG Innovation Gallery at CES, alongside other customer-driven product innovations, including the Snow White (personal ice cream maker), TIME + SPACE (wall clock displaying time and weather information), Shine (earphones that can be used as jewelry pieces) and more.[148]

Samsung's TV, The Frame, is another example of how manufacturers utilize consumer feedback to develop revolutionary products. When not in operation, The Frame converts to an elegant art piece displaying artwork from Samsung's Art Store. The QLED TV combines function with beauty and transforms a mundane electronic appliance to a piece of home décor.[149]

Following the success of open innovation, manufacturers are entering a new space of co-creation, where consumers are given a platform with which to engage

and provide opinions on new products under development. Swedish furniture manufacturer IKEA recently launched a digital platform for co-creation where customers are encouraged to share product ideas and feedback, which are then used by IKEA's design teams to inform product updates.[150]

A critical factor in the success of customer-driven product innovation is the ability to quickly and easily modify product designs without spending time in lengthy product prototyping. This design agility has largely been possible due to the recent advances in intelligent sensors, which allow design teams to improve product designs based on real-time performance data. Similarly, the creation of digital twins lets manufacturers test changes without the need for an actual production line. Both technologies enable rapid prototyping by reducing the time and effort needed for testing.

Intelligent sensors play another important role in the R&D process. Sensors placed on products themselves can gather product usage data and provide relevant insights into user behavior. Data—including product feature and functionality usage,

product performance, and operational conditions—provide manufacturers with valuable information that can be applied to future product enhancements. Mattress manufacturer Sleep Number is one such company that continually monitors product usage data through a multitude of sensors placed within its smart mattresses. Based on insights gathered from the consumer data collected via its earlier models, the company is planning to launch an improved version of its mattresses in 2020 to provide an even better sleep experience to its patrons.[151]

Big data analytics, cloud computing, and smart sensors are some of the many Industry 4.0 technologies that are available to manufacturers today to truly listen to their customers and create innovative products.

Emerging technology unlocks new opportunities

Emerging technologies are not only influencing how products are made, but they are also leading to the development of new materials. New advanced materials are proving themselves in numerous applications, such as biomaterials for health care, lightweight alloys for improved transportation, and electronic materials for information technology. Scientists have developed self-healing materials that can automatically fix themselves with exposure to air and sunlight, as well as related biomimetic materials that can self-lubricate and self-clean. They have also developed a variety of materials that can change from flexible to rigid or soft to hard, and vice versa, depending upon various stimuli.

This still-nascent field of technology—the first international conference devoted to self-healing materials was only held in 2007—may also be on the cusp of changing how we think about the composition of matter. In fact, scientists in the UK recently discovered a new state of physical matter in which potassium atoms can exist as both a solid and liquid, simultaneously. Currently

known as a "chain-melted state," recreating this unusual composition in other materials could have all kinds of applications.[152]

Computing processing advancements are significantly streamlining the field of materials development and allowing companies to more efficiently and cost-effectively design materials with the exact properties they seek. Consider that Thomas Edison and his team manually tested thousands of materials before finding one that would work as a filament for his incandescent light bulb. Today, an open-source US Department of Energy program uses supercomputers, advanced mathematics, and quantum mechanics to "virtually simulate thousands of compounds every day to find the best candidates for further laboratory testing." Known as "Materials by Design," the project's ever-growing database and vast computational power are expected to design materials that are lighter, stronger, and cheaper to produce; easier to make; and consume less energy in the production process.[153]

Materials that once seemed unfathomable are now becoming a reality with real-world applications likely to soon follow. Swedish engineering firm Sandvik recently unveiled the first-ever 3-D printed diamond composite; this following its unveiling of a 3-D printed metal composite electric guitar that the company touted as "unsmashable."[154] While the possible application for the guitar may be limited to wayward heavy metal guitarists, given that Sandvik specializes in tools and tooling systems, the diamond composite application potential is likely broad.

Meanwhile, commercial adoption of thermoelectrical materials that can be used to convert waste energy into thermal energy for cooling and heating has been thwarted in large part to the high cost of the materials and difficulty making the reactions work at room temperature. However, researchers from the University of Houston and M.I.T. have created a new inexpensive thermoelectrical material that does work efficiently at room temperature[155], a huge advancement with even bigger implications.

The aerospace industry, which was instrumental in the development of numerous metal alloy and composite carbon fiber materials, is now leading the charge with even more advanced materials. The industry continues to improve its metal alloy and composite carbon fiber material development and is testing numerous other materials. Last year, engineers from the UK unveiled the world's first graphene-skinned airplane (drone)[156], while a European aerospace consortium recently produced a leading-edge design for an Airbus A350 horizontal tailplane.[157] In the United States, aerospace giant Boeing has introduced a compressible formulation of aerogel called "Microlattice" that it plans to use in future aircraft designs.

Advanced materials development typically requires a significant upfront investment; however, material development and production costs tend to decline over time as benefits accrue. The US Department of Energy notes that, along with offering new applications, advanced materials provide manufacturers with subsidiary benefits, including reductions in costs, energy use, and pollution, as well as enhanced product quality.[158] The resulting products can also provide significant cost savings to the industry as a whole. Consider that every 2.2-pound reduction in weight in an aircraft can save between $2,200 and $3,300 in annual operating costs.

Nanotechnology and Nanoparticles

Nanotechnology allows scientists to manufacture materials at the molecular level, which has the potential to transform a wide variety of products. Nanoparticles are able to take on unique physical, chemical, mechanical, and optical qualities; scientists can take advantage of this by incorporating nanoparticles into materials.

About 200 times stronger than steel, one of the thinnest materials on earth,

and considered by many as the "wonder material" of the 21st Century, graphene may be the future of nanotechnology and is currently its most prominent nanoparticle.[159] Nanotechnology is a method for manufacturing materials at the atomic, molecular, and supramolecular levels, and is expected to revolutionize advanced materials production. While graphene currently maintains its prominence in the nanotech field, researchers are examining numerous nanomaterials and a vast range of possible applications. - -

Some advanced materials impacting manufacturing

Graphene
200 times stronger than steel and thinnest material on earth

Thermoelectric materials
Convert waste heat into useful energy

Bio-inspired plastic
Ultra-lightweight, yet strong and flexible

Mega magnets
Rare earth materials with powerful magnetic properties

Designer nanocrystals
Size and composition applicable for semiconductors, filtration, and wear resistance

Electric ink
High-speed semiconducting properties

Metal foam
Lightweight foamed metal

Physical and chemical vapor deposition
Materials processing that produces coatings stronger than steel

Aerogel
With ultra-low-density and internal fractal structuring, it is 100 times lighter than water yet can carry 20,000 times its own weight

Carbon nanotubes
300 times stronger than steel and offering ballistic electron transport for semiconductors

Willow glass
Paper-thin, flexible, strong glass that can be produced similar to how newsprint is made

Metamaterials
Providing unusual optical properties based on their structure

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Innovate and evolve

Technology is changing the way manufacturers design and build products. From digital twins to artificial intelligence, modern manufacturers must leverage the latest technology to deliver innovative products and evolve their businesses. At Microsoft, we're empowering manufacturers with the innovation and tools they need to build the products of the future.

Leverage new tech

Modern manufacturers must leverage the latest technology to stay ahead of the competition. Microsoft provides manufacturers with the innovative technology—like HoloLens—knowledge, and flexibility they need to improve operations, design next-generation products, and deliver amazing product experiences.

Create new products

As the pace of change accelerates, modern manufacturers must always be looking to the future, seeking new trends and innovating new products. Dynamics 365 gives manufacturers the data and insights they need to uncover tomorrow's trends and the tools and technology to create the products of the future.

Drive innovation

Innovation is the lifeblood of modern manufacturing. To innovate, manufacturers must build on an adaptable platform that provides flexibility and scalability. Dynamics 365 enables manufacturers to drive innovation with an intelligent application that is easy to tailor, extend, and connect to other services.

07 /
Supply chain becomes a competitive differentiator
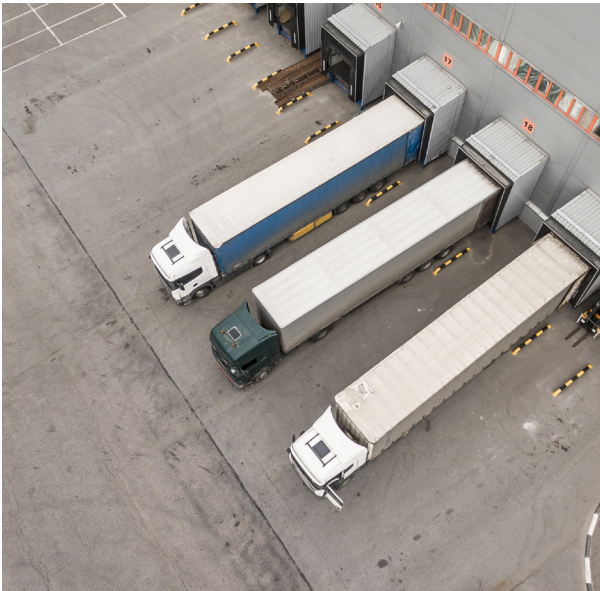
Supply chain becomes a competitive differentiator

From free shipping to two-day delivery, Amazon has reshaped customer expectations for fulfillment and delivery. While Amazon held a competitive advantage for years, manufacturers have made vast improvements to improve inventory management, warehousing, and distribution to help increase transparency and ensure faster, more efficient delivery.

Supply chain management is no longer just a back-office concern, something to be streamlined in the pursuit of greater profit margins. In an Amazon Now kind of world, intelligent supply chains are critical to delivering the fast, flexible, and reliable service that customers expect—and manufacturers are quickly realizing they need to keep pace.

Advances in AI, sensor technology, data analytics, and blockchain are making intelligent supply chains possible, and

Executive summary

As customer expectations around fulfillment and delivery have shifted, manufacturers are developing more agile warehouses and leveraging intelligent order routing to help stay ahead of the competition.

Highlights

- Consumer spending on e-commerce purchases is expected to reach $1.8 trillion by 2023.

- The average warehouse in the United States is 34 years old.

- 83% of executives see compelling reasons to use blockchain.

"Supply chain management is no longer just a back-office concern."

they're revolutionizing how manufacturers approach planning, inventory management, storage, and fulfillment. AI and machine learning are powering intelligent, autonomous systems that can streamline processes at or in between any stage of the supply chain. Ubiquitous connectivity and computing are improving communication across the supply chain, and blockchain will provide greater transparency and trust.

Intelligent supply chains enable seamless synchronization between supply, demand, and fulfillment. Having greater visibility across supply chain and manufacturing operations facilitates collaboration and helps companies improve forecasting, optimize inventory levels, and make operations more efficient, saving time and money.

Intelligent planning capabilities improve product availability

Emerging technologies offer the ability to capture so much data from each phase of the value chain that the question on manufacturing executives' minds is no longer "What can we track?" but rather "How do we make the best use of this data?" Today's manufacturing leaders face dual challenges. First, they must contend with a supply chain that is evolving from a linear model to a dynamic network model powered by interconnected processes and systems. Second, they must figure out what to do with the flood of real-time and near-time data that's now available to them thanks to advances in IoT and AI. Fortunately for planning professionals, the same technologies that are rapidly transforming supply chains can be used to improve planning strategies.

AI, ML, IoT, and sensor technology are among the most prominent buzzwords in the fast-evolving world of value chain management. These technologies, along with other technologies such as cloud computing and 5G, are collectively known as digital supply networks (DSNs), and they're revolutionizing how manufacturers approach planning and fulfillment. The IoT serves as the linchpin of these DSNs and

is proving fundamental to their overall success in the value chain. DSNs enable companies to optimize staffing for their production workforce, warehouses, and carriers based on projected demand; monitor real-time inventory levels and route products between locations as needed; offer flexible fulfillment and returns; and provide responsive customer care.[161] DSNs can also provide manufacturers with greater visibility into upstream operations, allowing them to project how fluctuations in the availability of supplier feedstocks and inventory could impact production schedules, product availability, and variable costs. Amazon uses DSNs to monitor real-time customer shopping patterns, competitor's prices, profit margins, inventory, and numerous other data points to set and adjust its product prices—pricing that can change every 10 minutes, on average—with an algorithm-boosted strategy that has helped lift the company's profits by 25%.[162]

With a business value-add-on expected to exceed $3 trillion by 2030, according to Gartner, blockchain is another emerging technology likely to prove valuable to supply chain planners. Blockchain's unique ledger structure boosts efficiencies in the supply chain through improved accuracy, tracking and tracing, and auditing.

The rapid pace of technological advancements combined with the right algorithms could lead to semi-automated supply chain planning—and one day, could possibly yield fully automated planning.[163]

"Blockchain is expected to add $3 trillion of business value by 2030."

Inventory management becomes more intelligent and transparent

The business of manufacturing is becoming more complex by the day, and for many manufacturers, inventory management can pose a serious challenge. Manufacturers must manage orders coming in from different channels, maintain a high enough stock level to avoid sellouts (but lean enough to prevent markdowns due to overstocking), and handle shipments to

and from multiple distribution centers. To handle these challenges, companies are turning to new technologies to make their inventory management more intelligent and transparent.

Much of this new technology allows retailers to make decisions based on real-time, streaming data. As the Internet of Things (IoT) continues to grow, anything that can be connected will be connected. The IoT allows retailers to tap into reliable, real-time data, which can increase the speed and accuracy of decisions and help minimize waste.

AI is also revolutionizing inventory management. By improving sales forecasting, AI helps manufacturers anticipate stock demands at each store to avoid selling out of a product and losing sales.[164] AI can even be used to predict customer purchases before they happen, allowing businesses to stock items appropriately.

Walmart uses AI to better handle inventory management, leveraging internal and external data, such as weather forecasts, to make more accurate predictions. For example, if a hurricane is expected,

"By analyzing data for patterns, AI can predict customer purchases before they happen, allowing businesses to stock items appropriately."

Walmart will stock products such as bottled water, sandbags, and grocery staples.[165] AI can also make the movement of inventory throughout a warehouse more efficient. Ocado, an online British supermarket, uses AI in its warehouses. There, robots gather most of the groceries, but they struggle to understand how to handle some more delicate groceries, such as oranges. Ocado is using AI to train robots to handle these more delicate items. Based on the success of this program, other supermarket chains have purchased Ocado technology for use in their own warehouses.[166]

Manufacturers are using RFID tags to streamline the entire inventory tracking process, from receiving to inventory counting. RFID can also be used to track in-store product and customer movement, such as how an endcap display is performing, traffic patterns on different days, how often customers pick up items but don't purchase them, and it can even help prevent shoplifting.[167] The result is improved inventory tracking across multiple channels and an in-store inventory accuracy of over 98%.[168]

Target, Lululemon, and Levi Strauss have all implemented RFID and seen an increase in fulfillment and inventory accuracy.[169] RFID also gives retailers the ability to create "magic mirrors." These touch screen mirrors reside in fitting rooms to track what's being tried on and can show shoppers product information, other colors or patterns the store has in stock, how these alternatives may look, and other complementary items to complete their outfit. Other companies are combining RFID technology with blockchain for enhanced tracking. Citizens Reserve uses what it calls its SUKU system to tag and track livestock, increasing the efficiency and transparency of the livestock's entire journey.[170]

Warehouses become smart and agile

E-commerce is skyrocketing and doesn't appear to be slowing any time soon, with consumer spending on e-commerce purchases expected to reach $1.8 trillion by 2023.[171] Customers expect fast and accurate shipment and delivery, but one of the biggest obstacles in meeting customer expectations is finding warehouse space that meets e-commerce needs. The average warehouse in the United States is 34 years old[172] and is too small, too cramped, and too far away from city centers to be practical for e-commerce purposes. Even facilities built as recently as the early 2000s are outdated and impractical for efficient e-commerce delivery since they typically feature low ceilings, small spaces, and poor

Warehouse space in the US
in billion sq ft

2018

2008

10

9

8

7

6
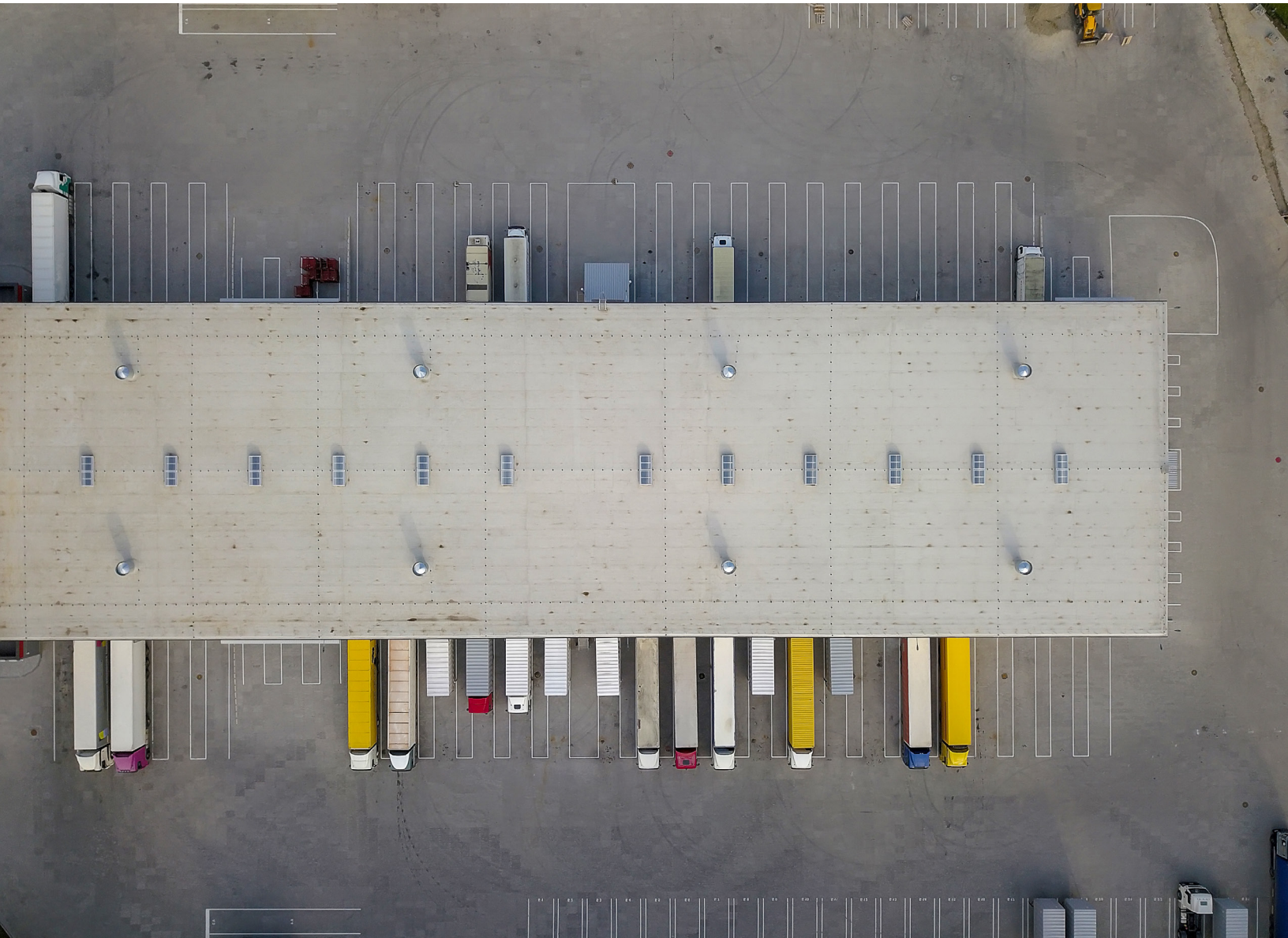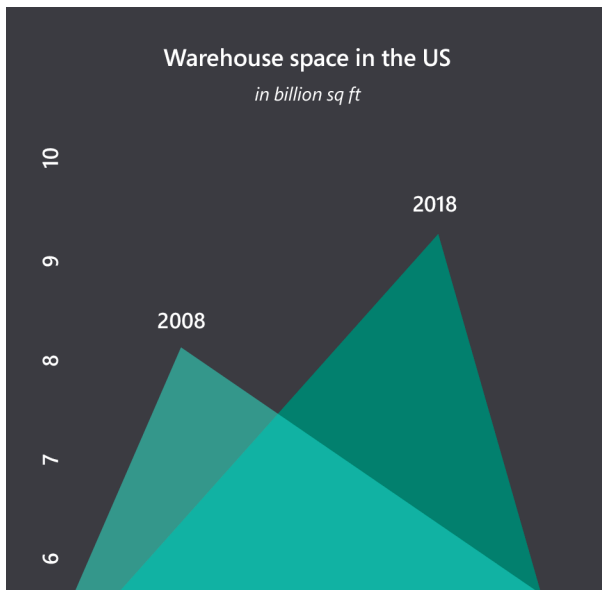
"The average warehouse in the United States is 34 years old."

docking access. As a result, the market for new warehouse construction is booming. From 2008-2017, about 100 million square feet of warehousing space was added each year in the US, and in 2018 alone, 183 million square feet were added.[173] This growth has been centered in and around cities to allow quick delivery to customers.

In recent years, companies have explored a variety of innovative solutions to help solve the e-commerce warehousing issue, including warehouse automation, third-party logistics, vertical warehousing, small format warehouses, and on-demand warehousing. Today, 90% of Fortune 500 companies outsource parts of their warehousing, distribution, and fulfillment[174]

The best example of warehouse automation comes from JD.com, a Chinese company that opened a fully automated storage and shipping facility in Shanghai in 2018. Without the 20 industrial robots that can pick, pack, and transfer packages with no human oversight, the company would need 500 workers rather than the five technicians it relies on to service the robots.[175]

When it comes to e-commerce warehouses, the sky is the limit. Just ask Goldman Sachs, which has plans to build a three-story vertical warehouse in Brooklyn. Vertical warehousing is warehousing that is built up as opposed to out and then serviced by automated technology, such as drones. In the case of Goldman Sachs' warehouse, the second floor will be accessible to trucks via ramps, while the third floor will be accessible to forklifts via specially designed elevators. Amazon is taking the vertical warehousing trend to a new level by announcing plans to create an airborne fulfillment center. Drones would fly into the blimp-like structure, gather packages, navigate out, and deliver the packages.[176]

Due to many of the same market pressures faced in the United States, combined with China's high population density, Asian markets—especially China—have already adopted the vertical warehousing concept and the use of more automated delivery technologies. China has become the leader in drone technology, due in large part to Da-Jiang Innovations (DJI). DJI is responsible for 70% of the global market share of consumer drones.[177] China's automated

technology has also surpassed competitors due to a massive amount of investment capital. Between 2014 and 2017, over $50 billion was invested in Chinese e-commerce platforms and automation technology. A lack of a regulatory framework keeps China's automated delivery technology from drastically pulling ahead of other countries; however, if a regulatory framework is put in place soon, it seems unlikely that other countries will have much chance of catching up in the near future.[178]

90%

Percent of Fortune 500 companies that outsource parts of their warehousing, distribution, and fulfillment

"Small box" facilities, which are 50,000-200,000 square feet, are another warehousing option. Though small box facilities show potential in certain areas, the biggest trend in warehousing appears

to be on-demand warehousing, which provides merchants with flexible, short-term storage. At any given time, up to 30% of warehouse space is not in use. The on-demand warehousing model seeks to take advantage of this massive amount of wasted space and creates a flexible option that's halfway between a warehouse and a distribution center. Though the term may be new, the concept is not. Fulfillment by Amazon is a well-known example of on-demand warehousing. Other companies ranging from KFC to Exploding Kittens have used the on-demand warehousing model.

On-demand warehousing is still an emerging concept but shows a lot of potential. One of its biggest selling points is that it gives smaller businesses a chance to compete with Amazon's fulfillment options.[179] Demand is high, but not many warehouses want to lease space short-term. UPS hopes to meet this need with its Ware2Go platform, which offers on-demand warehousing[180] that matches merchants with warehouses.[181]

30%

Percent of warehouse space that is not in use at any given time.

# Intelligent tracking provides visibility into supply chain performance

First described in 1991 by Stuart Haber and W. Scott Stornetta[182], blockchains are decentralized, shared ledgers where all transactions are recorded securely by encryption in near real-time and are immutable (incapable of being altered or deleted). Despite being nearly three decades old, blockchain technology remains in the early adoption phase, but attitudes and spending are changing fast. More than half of the executives polled in

Deloitte's 2019 blockchain survey felt that the technology was a critical priority for their company, and 83% saw compelling reasons to use blockchain.[183] Overall, the global blockchain market is projected to grow at a CAGR of 83% between 2018 and 2025, reaching an estimated value of $165.5 billion in 2025.[184]

While it's most commonly known as the technology at the heart of cryptocurrencies like Bitcoin, there are actually a number of other exciting use cases for blockchain. For example, a blockchain can connect ledgers from across an organization's supply chain (supplier, manufacturer, distributor, shipper, retailer, and end-consumer) to make tasks, like tracking a product's journey, much more accurate and efficient. Tracking a product's journey via blockchain can turn a manual process that once took days into an automated process that can be done almost instantaneously and yield real-time information.[185]

"83% of executives say they see compelling reasons to use blockchain."
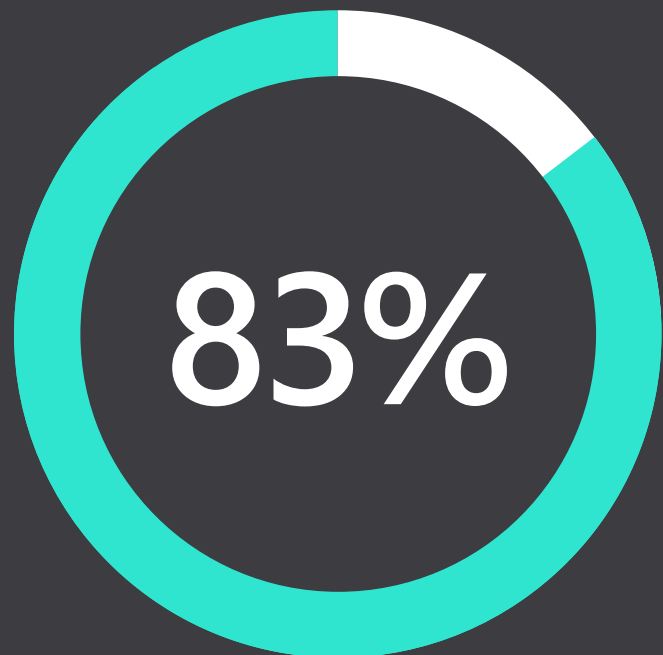
83%

"Tracking a product's journey via blockchain can turn a manual process that once took days into an automated process that can be done almost instantaneously."

Likewise, blockchain offers the potential to create continuously updated, incorruptible accounting ledgers—an exciting prospect that could help streamline processes, optimize data quality, improve transparency, and achieve better internal controls.[186] In 2016, KPMG partnered with Microsoft to introduce Digital Ledger Services, an offering designed to help companies realize the full potential of blockchain for their financial operations. Using Microsoft's Blockchain Service platform, the joint service helps companies reduce costs, streamline and automate back-office operations, and make transactions both faster and more secure.[187]

Companies are looking to blockchain to solve other business problems, too. One promising application of blockchain is with contract and document management— digitizing and moving the governance of paper certificates, warranties, and contracts into a blockchain—which can automatically update the documents when a triggering event occurs. And testing has already been implemented in the food safety
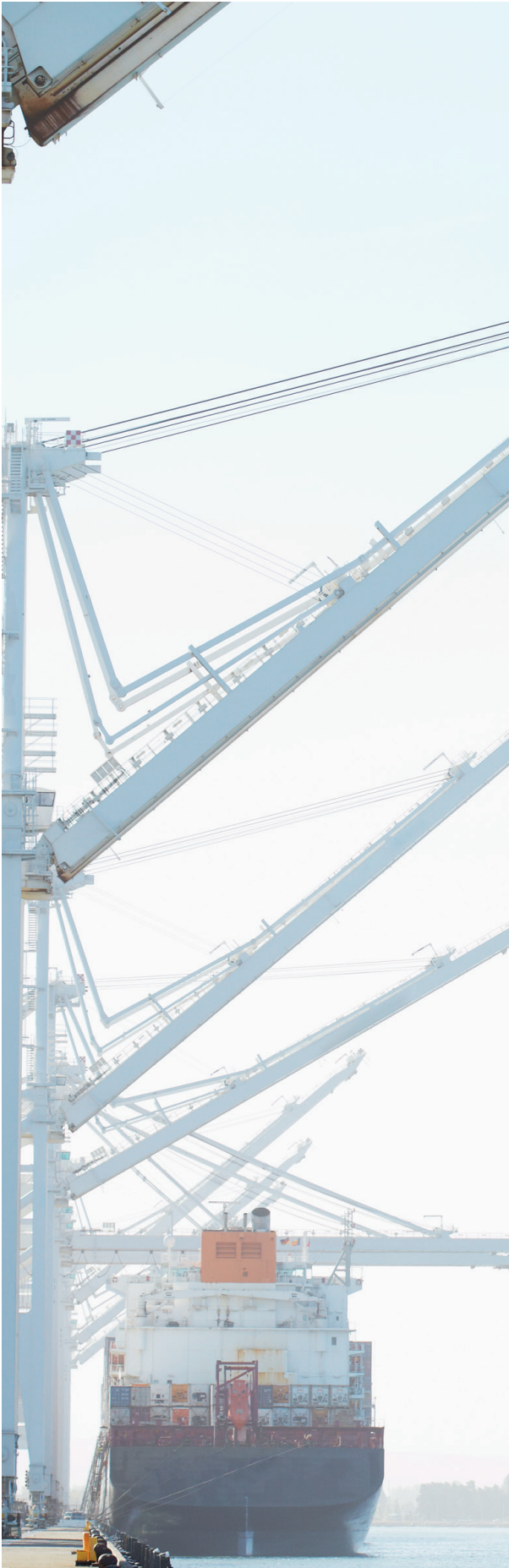
industry, where blockchain allows food to be granularly tracked, so when a producer identifies an issue like a tainted batch of spinach—they can contain the problem by isolating the source and issuing a recall for only the affected products.[188]

Along those lines, blockchain is also being used to help companies verify the provenance and authenticity of goods from raw materials to finished products. Other potential benefits of employing blockchain technology include reduced risk of fraud, fast and secure cross-border payments[189], reduced time to complete transactions, better-networked loyalty programs, and increased customer trust.

Technology transforms fulfillment

Intelligent Order Management improves delivery speed while reducing costs

Today's empowered customers now expect more from businesses. They want to be able to see product inventory availability at stores and online, they want personalized products, they want flexibility in how they purchase—with cheaper and varied choices for fulfillment—and they want it all to be faster and less expensive.

To adapt to these modern demands, the supply chain of the past has morphed into a supply network, where data flows between participants and products can be purchased and fulfilled from multiple channels. Manufacturers may serve as the manufacturer and retailer, and a retailer may serve as the retailer and distributor. As these supply networks grow increasingly complex, Distributed Order Management (DOM) systems are making order management more intelligent and more efficient. By taking a global view of all inventory across the network, a DOM system can intelligently broker orders

based on a defined set of rules, such as minimizing shipping costs and optimizing inventory availability. In doing so, it helps save money, improve fulfillment times, and ensure inventory availability, all of which leads to happier customers.

There are several elements that need to be in place before a retailer can deploy a DOM system. The first involves centralizing inventory from across the company into a single inventory management system. This provides visibility and access to inventory from across the organization, regardless of its current location, which provides a critical input for the DOM to leverage when brokering orders. The second involves connecting the endpoints—purchase channels and fulfillment channels—to this unified system. This enables orders to be placed from any channel and fulfilled from any channel. It also enables inventory volumes to be properly tracked as products are purchased or returned.

DOM systems offer distributors a number of compelling benefits. With access to more inventory and fulfillment options, DOM systems enable distributors to more reliably promise delivery dates. Greater visibility into inventory and purchase patterns across the organization allow distributors to more intelligently manage inventory volumes and distribution. By intelligently routing orders to the most efficient fulfillment channel and location, manufacturers are able to speed up the sales lead time and delivery time, reduce waste, and save

money on fulfillment. DOM also allows distributors to treat their best customers like royalty, optimizing fulfillment for a given customer based on variables such as the lifetime value, loyalty, and social influence. One of the biggest challenges for modern retailers is managing both their brick-and-mortar locations as well as all of the infrastructure required to operate an e-commerce business. With DOM, retailers can leverage existing brick-and-mortar locations as fulfillment centers both for shipping and pickup, to help maximize the

DOM scenario

Minimum inventory constraints

All stores (Dress: 1; Handbag: 1)

Split orders: Yes
Location offline: No
Maximum orders: No constraint
Location priority: No
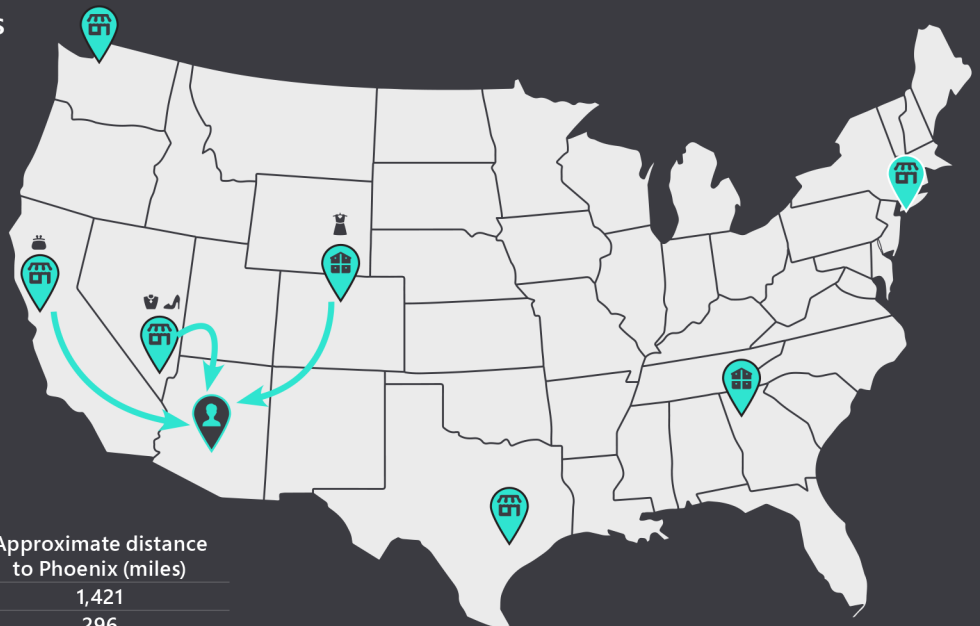
	Inventory				
	👗	👛	👠	💍	Approximate distance to Phoenix (miles)
SEA	2	3	1	1	1,421
LAS	1	1	1	1	296
SFO	1	2	1	0	752
DEN	20	14	5	7	850
IAH	1	3	2	4	1,174
ATL	10	7	20	20	1,806
NYC	2	3	1	2	2,405

value of existing assets, provide customers with more flexible fulfillment options, and to improve delivery times and costs by shipping from a nearby store opposed to a warehouse in a remote location.

Regional distribution centers

Some of the largest brands are now providing services that have further increased customer expectations. Amazon now offers one-day shipping, Amazon Prime Air promises to deliver to customers in 30 minutes, and Post Mates can have any type of food delivered in a matter of minutes. With all these options, consumers no longer feel that it's reasonable to wait more than two days for a delivery. Smaller retailers are struggling to meet these expectations, but a number of companies are providing solutions to help these smaller retailers keep up.

FedEx and UPS have launched their own fulfillment solutions aimed at small and medium enterprises. Launched in 2017, FedEx Fulfillment offers warehousing, packaging, fulfillment, and transportation. The service uses FedEx warehouses to handle storage, ship the inventory in packaging branded with the client's brand, and handle returns.[190] In a similar vein, UPS Ware2Go matches merchants with available warehouse space with the goal of helping smaller businesses remain competitive.[191] A startup called Darkstore turns underutilized retail locations into fulfillment centers for online sales. Darkstore rents out unused retail space in malls, bodegas, and the like same-day fulfillment for brands that don't have warehouse space of their own.[192] This allows brands without local storage facilities to store inventory in a Darkstore location and then offer next-day shipping.

For businesses that are exclusively online, ShipBob promises to help. The order fulfillment startup gives small and medium brands a chance to compete with Amazon on delivery speed and price. The Chicago-based startup launched in 2014, and in 2018, it raised $40 million in funding.[193] ShipBob has five warehouses, all located in big cities. ShipBob allows over 2,000 e-commerce retailers to offer one to two-day fulfillment, and more than four million shipments have already been made.

Customers include I Heart Keenwah, Interior Define, and baKblade. ShipBob's software allows it to not only manage order logistics but also to track customer demand, which it can then use to make recommendations on when and where inventory should be restocked. This allows for even quicker and less expensive shipping going forward.[194] As this trend progresses, more third-party logistics companies will likely enter the delivery space and start working with smaller businesses to help them stay competitive.[195]

## Exploration in last-mile fulfillment

As a general rule, B2C residential deliveries tend to be less efficient and more expensive than B2B deliveries, because they require carriers to travel between many different destinations to deliver a small volume and value of packages at each stop. With the explosion of e-commerce, it's no wonder that distributors are exploring a variety of options to make last-mile fulfillment less expensive and more efficient.

Delivery is one of the last friction points in automation, but a number of companies are working to eliminate this friction using autonomous vehicles. In collaboration with TuSimple, an autonomous trucking startup, UPS has begun a pilot program featuring driverless semi-trailer trucks.[196] As part of the pilot program, TuSimple autonomous trucks carried deliveries from UPS distribution centers in Phoenix, Arizona, to distribution centers in Dallas, Texas. Kodiak Robotics recently announced that its self-driving long-haul trucks would also begin making commercial deliveries.[197] Similarly, Waymo, a company that began as Google's driverless car project, is also piloting self-driving trucks.[198] Two of the team members behind Waymo are responsible for the development of another autonomous vehicle, Nuro[199], which is currently being

tested as part of a pilot program for grocery deliveries in Scottsdale, Arizona. Autonomous delivery vehicles show a lot of potential, but the technology is still in its infancy. Companies experimenting with the autonomous trucks currently require a "safety driver" behind the wheel of every autonomous truck. Delivery vehicles, such as Nuro, can go only 25 MPH, which limits their delivery capabilities—ice cream melts, hot food becomes cold. The cars are also quite small, holding only six grocery bags. And the consumer still must meet the car at the curb and carry all the groceries inside, limiting the potential uses for the disabled or infirmed.

Amazon Prime Air and Amazon Scout are Amazon's efforts to incorporate more automated technology into the delivery process. Amazon Prime Air has been in the works since 2013 and uses drones to deliver packages. Amazon's Scout is an autonomous, six-wheeled robot that drives on sidewalks. Since sidewalks pose even more of a technological challenge than roads for autonomous technology, Scout still requires a human chaperone for all deliveries.[200] - -
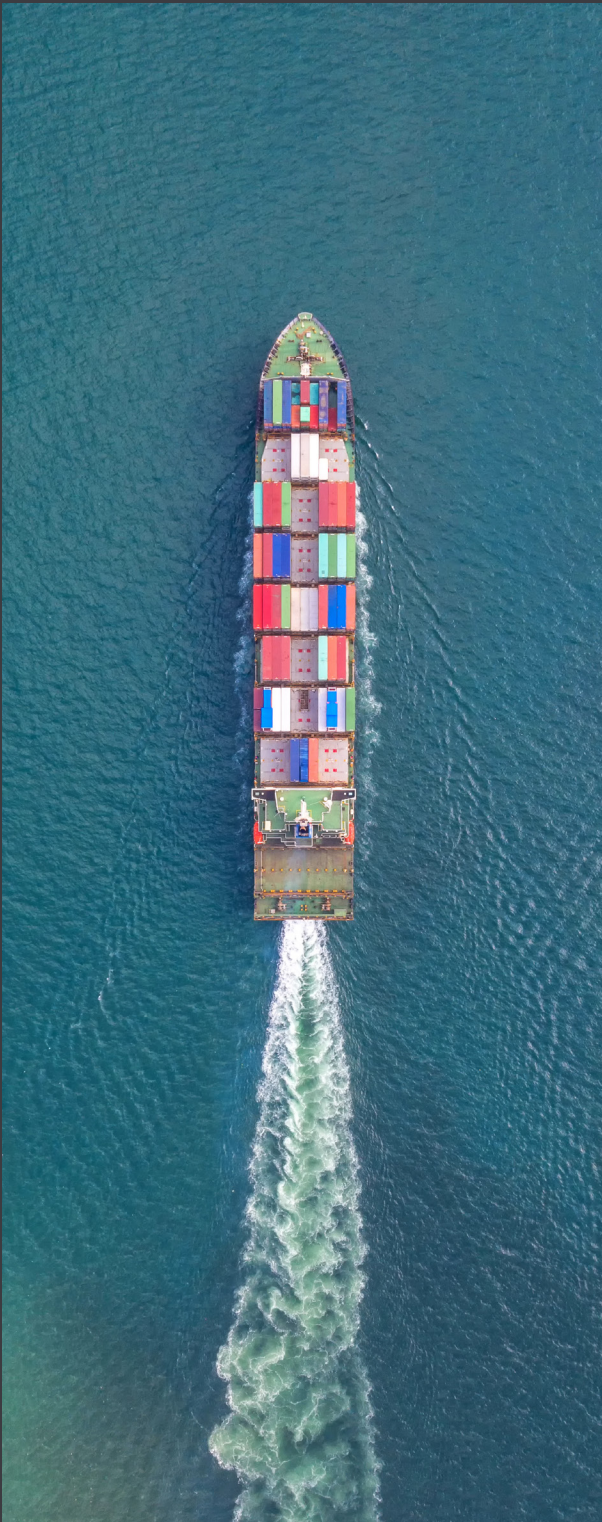
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Supercharge supply chain management

As demands on manufacturers increase, modern manufacturers must gain greater visibility and control into their supply chain. At Microsoft, we're empowering manufacturing leaders with tools to help deliver more predictable performance and reliability through unified data and intelligent tools.

Improve operations

To compete in today's fast pace environment, manufacturers must work faster and smarter. With tools that streamline processes, provide greater visibility into operations, and deliver actionable insights, Microsoft is helping manufacturing leaders improve their operations so they can meet growing demands.

Be more proactive

To grow their businesses, manufacturing leaders must look beyond the past and into the future. Microsoft empowers manufacturing leaders with tools to help them identify emerging trends, predict outcomes, and automatically optimize workflows. This allows manufacturers to become less reactive and more proactive with their business strategies and operations.

More intelligent fulfillment

To meet customer demands, manufacturers must not only work faster, but they must do it for less. Microsoft powers modern manufacturing with intelligent tools that help optimize inventory, storage, and fulfillment, improving delivery times while saving money.

08 /

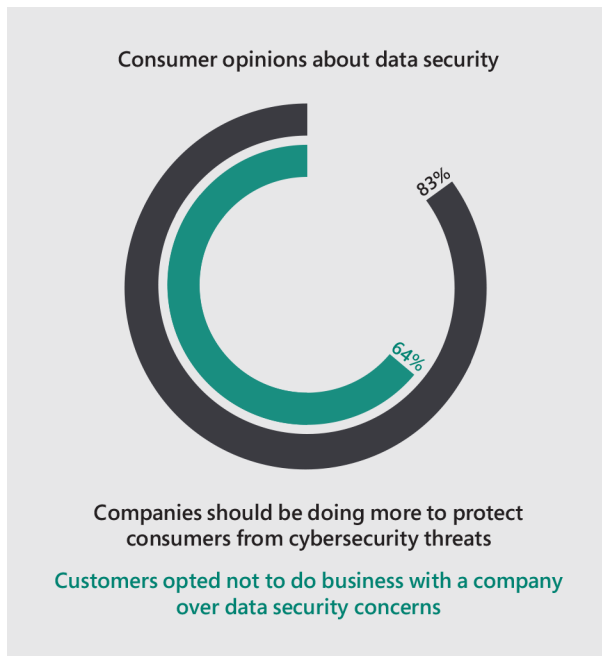# Businesses adapt to global uncertainty

Technology creates new challenges

More data means more problems

The universe of data is growing steadily each day. A recent study by Deloitte showed that data management and data integrity topped executives' lists of concerns and challenges when it came to managing cybersecurity.[201]

With more potential sources of data than ever—and more systems both inside and outside the organization that can potentially access that information— many companies find themselves either improvising or managing patchwork efforts when it comes to data security. The executives surveyed by Deloitte reported that although digital transformation and cybersecurity are both high priorities for their companies, the two functions typically aren't well integrated.[202] The result is that, by and large, companies aren't addressing the impact that introducing new technologies could have on their—and their customers'—data security.

Executive summary

With new cyber risks, geopolitical shifts, and new regulations, manufacturing leaders are looking for ways to navigate the uncertainty.

Highlights

- 64% of consumers have opted not to do business with a company with which they have data security concerns.

- A statistical index the World Trade Organization uses to measure uncertainty in economic policy around the globe hit its highest level ever, more than three times as high as the average for the period 1997-2015.

Consumer opinions about data security

83%

64%

Companies should be doing more to protect
consumers from cybersecurity threats

Customers opted not to do business with a company
over data security concerns

Evidence shows that consumers are beginning to demand change. In a study conducted by the Harris Poll for IBM, 83% of people surveyed said that companies should be doing more to protect consumers from cybersecurity threats, and 64% said they have opted not to do business with a company if they have doubts over whether their data would be secure.[203]

Adopted by the EU in May of 2018, the General Data Protection Regulation (GDPR) is one of the most ambitious efforts to date to guarantee the privacy of individuals' data in all formats. Among other things, GDPR obliges companies and other organizations

to 1) explain how they collect and use data on individuals, 2) grant those individuals the right to access and correct data that is collected about them, 3) be informed of data breaches, and 4) have their personal data deleted (a.k.a., the right to be "forgotten").[204]

GDPR had an immediate global impact because it applies to any company or organization that offers goods or services in the EU or that monitors the behavior of individuals there. The full extent and nature of that impact remain unknown, however. One obvious outcome of the law is the privacy notices that seem to pop up on most websites these days. It's unclear whether these pop-ups are effective; anecdotal evidence suggests that most consumers either ignore them or don't know what they can do with the information. Corporations and the EU itself have mostly responded by adding new bureaucracies. GDPR obliged companies to establish data protection offices, but those new offices' mandates often overlap or conflict with existing corporate functions, such as cybersecurity or legal, and many organizations are still struggling to draw clear lines.[205]

"As new and existing technologies mature, they will continue to reshape how companies relate to their suppliers and customers."

EU regulators have seen a sharp jump in the number of data breaches reported to them, but the threat of large fines against companies that violate the GDPR has mostly remained just that. In the policy's first year, regulators only levied 55 million euros in fines, and a single 50 million euro fine imposed on Google in January 2019 accounted for nearly all of that total.[206]

In 2019, California adopted an ambitious new data-privacy law partially modeled on GDPR; however, the law does not go into effect until 2020, and companies—including Google—continue to lobby for ways to curtail its scope.[207]

Competition increases as technology drives industry convergence

As new and existing technologies mature, they will continue to reshape how companies relate to their suppliers and customers—with companies most likely facing competition from businesses in previously unrelated sectors.[208]

A recent report from PwC argues that tech-driven industry convergence isn't anything new. In fact, they say, such convergence is actually cyclical, pointing to similar patterns of cross-industry activity during periods of economic expansion in 1998-2000 and 2004-2007. According to their analysis, the most recent wave of convergence, which began in 2016, has affected companies in technology, telecom, media, automotive, retail, manufacturing, healthcare, consumer goods, transport and logistics, energy, and financial services.[209] Of these industries, the coming decade will largely be defined by seismic changes in insurance, healthcare, and consumer products.[210] Clusters of industries tend to converge

around particular market opportunities, such as how changes in the transportation sector have opened up new avenues for automotive companies as well as businesses in the energy, tech, and logistics industries.[211]

There's reason to feel hopeful, not fearful, about the unpredictable shifts that industry convergence will bring. Unconventional partnerships and cross-industry collaboration will be key to addressing issues like healthcare, global warming, and the rapid growth of urban centers around the globe.[212]

"Unconventional partnerships and cross-industry collaboration will be key to addressing issues like healthcare, global warming, and the rapid growth of urban centers around the globe."

Leaders try to navigate a highly politicized environment

In August 2019, a statistical index the World Trade Organization uses to measure uncertainty in economic policy around the globe hit its highest level ever, more than three times as high as the average for the period 1997-2015. From Brexit negotiations and shifting trade alliances to changes in immigration and environmental policies, the unpredictability of today's political and economic landscape can be daunting for businesses to navigate.

How leaders can help their companies succeed during periods of elevated risk depends on a number of factors.[213] To respond effectively to an uncertain or politicized environment, leaders must first consider whether the market for the company's products and services is strong or declining. They also need to consider whether the company is poised for growth or whether it faces strong challenges from competitors. Additionally, they must assess if the risk is time-limited or ongoing and determine whether the element of uncertainty is specific to the company or industry or whether it's a global concern. By understanding these factors, business leaders will be better positioned to develop strategies to thrive in uncertain times.

Manufacturers diversify their global footprint

Manufacturing moves closer to home

Nearshoring and reshoring are becoming increasingly popular options for manufacturers that are looking to gain a competitive edge. Industry 4.0 has led to an unprecedented level of integration of cross-functional teams, and with it, a greater need for real-time collaboration to expedite decision making. Companies can no longer afford to wait for decision making to pass through several time zones. As a result, low-cost outsourcing isn't the silver bullet that it used to be; companies are now looking to diversify their production facilities and place them geographically closer to the end consumer.

A recent survey of sourcing executives in the apparel industry showed that 43% of respondents believed that nearshoring is a winning strategy for the fashion industry. Nearshoring fabric industries makes fabric production more sustainable and resource-efficient. At the same time, these factories help reduce waste by deploying an on-demand distribution and sales model.[214]

43%
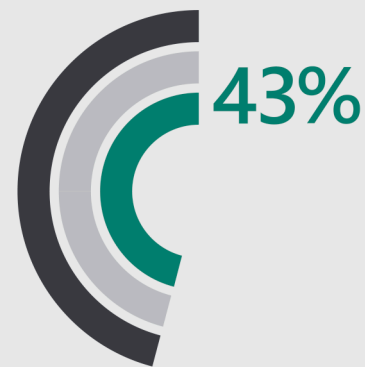
Percent of sourcing executives who believe that nearshoring is a winning strategy for the fashion industry

Additionally, the global labor market has changed tremendously over the past few years. The factory wages of Asian workers have increased nearly tenfold over the last 15 years. Add to this the increased cost of freight and duties, and it becomes clearer why offshoring is no longer a viable option for many manufacturers.

As a result of these changes, Mexico is becoming an increasingly popular choice for American manufacturing companies due to the low cost of shipping and easier team communication from overlapping business hours. Moreover, for many European and Asian companies, Mexico provides an excellent point of access to North and South American consumers. In an effort to establish production facilities closer to North American consumers, BMW became the 12th auto manufacturer to open a factory in Mexico. The assembly lines have been built such that they may be quickly modified to manufacture a variety of BMW models.[215]

A key benefit of reshoring is the ability to tightly control quality. Proximity to the manufacturing facility allows auditors and quality controllers to make frequent visits and to manage quality issues directly. Furthermore, in-house manufacturing

translates to better intellectual property management and reduced fraud risks, one of the major issues US manufacturers face while dealing with suppliers abroad. With reshoring, manufacturers are also better situated in terms of managing their raw material supply chain, leading to increased quality control across the product life cycle and a consistently high-quality product.

Another important factor driving the reshoring trend is the increased use of advanced manufacturing techniques.

Robotics, additive manufacturing, and automation are all helping to offset the higher cost of labor in domestic and nearshore markets. The International Federation of Robotics predicts that the number of industrial robots in factories will double worldwide, to over 3 million, by 2020.[216] Thanks to quickly scalable Robots-as-a-Service offerings, even small- and medium-sized manufacturers can take advantage of automation and keep operations close to home.

Estimated worldwide operational stock of industrial robots
in thousands
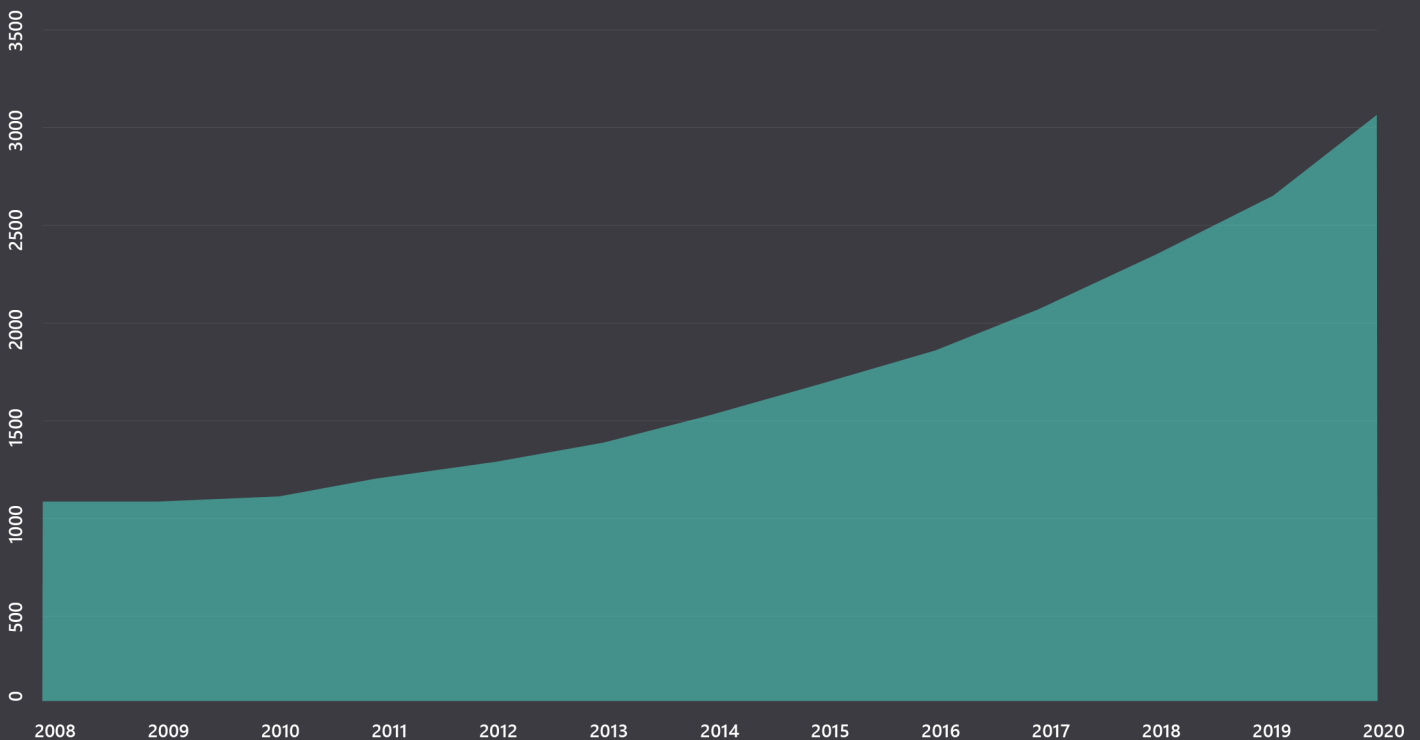
Regulation changes create uncertainty

Interest rates become more dynamic

In 2019, concerns about the sustainability of US economic growth prompted the Federal Reserve to cut interest rates for the first time since the financial crisis of 2008. The initial reduction came in July when the Fed trimmed the federal funds rate by one-quarter point. The Fed acted again in mid-September, lowering rates by another quarter of a percentage point to a range of 1.75 to 2.0%. In announcing that second cut, the Fed also said that it was prepared to take further action if signs of a slowdown in the US economy start to accumulate. At the time, many officials expected the Fed would make one more move on interest rates in 2019, but few anticipate rates falling below 1.5% before 2022.[217]

Across the Atlantic, the European Central Bank (ECB) took even more aggressive action in 2019 as fears mounted of a recession in some of the continent's largest economies. In September, the ECB cut its interest rate for deposits to -0.5%, a level meant to prod banks to lend their cash instead of sitting on it. At the same time,

the ECB announced it would restart other stimulus programs it had halted less than a year earlier, including printing more money and buying more than $20 billion in bonds and other financial assets each month.[218]

Tariffs

Despite repeated rounds of bilateral talks, tensions between the US and China remain high, with widespread impacts on global trade and production. By September 2019, the US had imposed tariffs on more than half a trillion dollars' worth of Chinese exports, while China had reciprocated with tariffs on nearly $200 billion in US products.[219]

These tariffs have driven up the prices of raw materials and reduced real income in many affected countries.[220] Since January 2016, the prices of many raw materials

have risen at double-digit rates, reversing a years-long deflationary spell, and tariffs on things like steel and aluminum have contributed to this upturn.[221] Meanwhile, the International Monetary Fund estimates that American and Chinese tariffs will reduce global economic output by about 0.3% in 2019[222] and by as much as 0.5% in 2020.[223]

The trade fight and its fallout have prompted many US companies with operations in China to scale back or deprioritize that part of their business.[224] Some manufacturers have shifted supply chains out of China entirely, while others have redesigned products to reduce dependencies on manufacturers there. In cases where neither of those approaches is an option, producers are often passing the price increases associated with tariffs along to their customers.

More broadly, the persistence of sharp tensions between the world's two largest economies has exacerbated uncertainty about the future contours of the global economic landscape. In McKinsey's September 2018 Global Economic Survey, one-third of all respondents identified uncertainty over trade policy as their top concern, and three-quarters of the

surveyed companies said they were adjusting their strategies in light of this trend.[225]

Many businesses are responding to this heightened uncertainty by delaying or trimming investments in their factories and workforces.[226] Manufacturers are also looking to increase their resiliency against this "new normal" by making their supply chains more flexible, more local, or both. A recent McKinsey report notes that many companies are moving supply chains closer to key markets as the costs and risks of global operations continue to increase, partially reversing the globalization of manufacturing that occurred in the preceding two decades.[227] Others are inking contracts with suppliers who produce their goods in multiple countries, allowing them to quickly shift production as conditions change. New digital technologies are also playing a role, giving manufacturers ways to manage more complex workflows and allowing them to generate more accurate forecasts of local demand.[228]

Uncertainty at the borders creates planning challenges

For manufacturers who source raw materials from overseas and those who have production facilities abroad, emerging geopolitical conflicts and pressures are creating new challenges at the border. Even minor delays at customs can lead to significant production issues and late deliveries. While some of this uncertainty rests beyond the control of a business, manufacturers are already adapting to this new risk in a few ways.

First, manufacturers are diversifying their global footprint. As discussed above, they are adding new production facilities and moving these facilities closer to home. With reduced transportation times and faster communication, both nearshoring and reshoring can help provide more speed and predictability to the customs process.

Second, manufacturers are using new tools to improve collaboration and document management, helping to ensure that they have the needed paperwork and that it is accurate, two common issues that can lead to long processing delays.

Lastly, they are turning to intelligent planning tools to help better manage production and sourcing, including planning for scenarios where materials are delayed at customs. Real-time access to information—such as potential delays—allows manufacturers to respond to changes faster, while advanced planning tools and intelligent routing help ensure that production is not impeded by these obstacles.
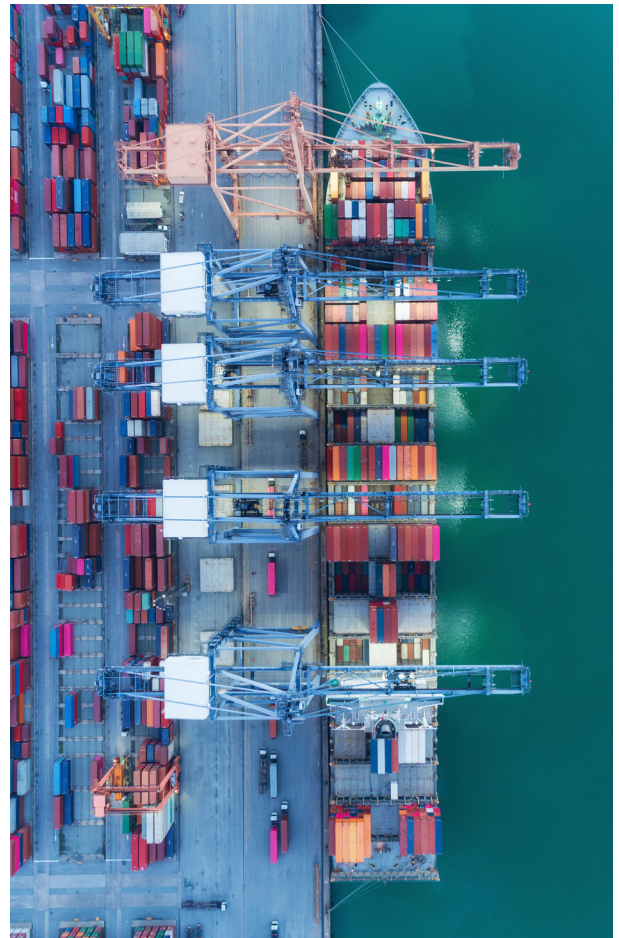
Brexit uncertainty continues

In a June 2016 referendum, the UK stunned the world by voting narrowly in favor of leaving the EU. As of January 31, 2020, the UK has officially exited the EU, as the tumult sparked by the Brexit referendum continues to reverberate through the global economy.

The defining feature of the Brexit process so far has been uncertainty—over what kinds of new relationships the UK might forge with its neighbors and trading partners in a post-Brexit world and how that transition will affect the economies of the UK, the EU, and the globe. In a recent iteration of the Decision Maker Panel, a monthly survey of thousands of UK CFOs, nearly 60% of respondents identified Brexit as one of the three most important sources of uncertainty for their businesses—about as high as that figure has risen since the referendum and much higher than in 2016 and 2017.[229]

As negotiations continue, the economic consequences of the Brexit vote are already substantial. An academic paper published in late 2019 reported that, over the three years since the referendum, Brexit had reduced investment by 11% and shrunk UK productivity by two to five percent. And in the July 2019 update to its biannual World Economic Outlook, the International Monetary Fund identified a no-deal Brexit as one of the "adverse developments" that could dent growth in the global economy in 2020.

International cooperation wanes

In 2019, rising tensions between powerful nations reinforced the sense that international relations have become less cooperative and possibly more dangerous than they were just a few years ago. The struggle between China and the US over trade continued to heat up. Meanwhile, relations between the US and Russia eroded further in August 2019, when both countries withdrew from a key nuclear arms–control treaty.[230] In South Asia, longstanding tensions between nuclear-armed rivals India and Pakistan flared into numerous border skirmishes in 2019, and, in the words of Pakistan's foreign minister, threatened to slide into an "accidental" war.[231] And in the Middle East, the United States and Iran traded threats and accusations after oil tankers were attacked in the Straits of Hormuz and Iran downed a US drone.[232]

Even if the likelihood of open warfare between major powers remains low, these tensions represent a form of political risk that can hurt corporations in other ways. The rise of protectionism and nationalism in the wake of the 2008 financial crisis have eroded the international cooperation that helped soften the last crash, meaning future crises might be even more pronounced.[233]

Global and regional tensions can hamper economic growth, drive up the price of commodities and other goods, and impede or foreclose business opportunities in affected countries. They also hinder cooperation on transnational problems that require a collective response, such as counter-terrorism, nuclear proliferation, and climate change.

Organizations prepare for an election year

Some of the world's largest economies are holding elections in the next two years with potentially significant consequences for businesses within and outside their borders. In the United States, the next presidential campaign cycle is well underway, and control of both houses of Congress remains up for grabs. The outcomes of those contests could produce substantial changes in domestic and foreign policy.

In the UK, national elections are not due again until 2022, but discord over Brexit has already cost Teresa May the job of Prime Minister, and her successor, Boris Johnson, is pushing for an early vote in a gambit to solidify parliamentary support for leaving the EU.[234] Across the channel in Germany, longtime chancellor Angela Merkel announced in late 2018 that she would not seek reelection to that post in 2021, and speculation that she will step down before the end of her term continues to bubble up in the press from time to time.[235] - -

@Microsoft

Pivot and adapt
Today's manufacturing leaders face many difficult decisions as they navigate through a time of considerable ambiguity and uncertainty. At Microsoft, we're empowering these leaders with greater visibility into their business operations and performance to help them identify emerging hazards and the flexibility to adapt quickly and scale with ease.

Better manage risk
From cybersecurity to compliance, manufacturers must address a wide range of threats to their business. With Azure's security, privacy, transparency, and industry-leading compliance coverage, manufacturing leaders can better manage cyber risks, and with unified data in the cloud, manufacturing teams can improve reporting speed and accuracy.

Scale with ease
Businesses face many challenges as they look to scale at home, abroad, and into new verticals. Dynamics 365's cloud deployment options make scaling easier than ever, whether a company is looking to scale up or down to better manage seasonal demands or duplicate a Dynamics 365 instance on a server in a new country they're entering.

Increase agility
To succeed in a world of uncertainty, manufacturers must be flexible to quickly pivot and adapt as market conditions change. With Azure and Dynamics 365, manufacturers have the flexibility to deploy how and where they want, leverage extensions to quickly add new capabilities, and easily manage system updates and new features across the organization.

Move from reactive to proactive operations

Transform your manufacturing and supply chain operations with Dynamics 365 Supply Chain Management. Use predictive insights and intelligence from artificial intelligence and the Internet of Things across planning, production, inventory, warehouse, and transportation management to maximize operational efficiency, product quality, and profitability.

Supply Chain Management

Microsoft Dynamics 365 Supply Chain Management provides manufacturers, distributors, and retailers with the real-time visibility and intelligence they need to move from reactive to proactive operations. It unifies data and uses predictive insights from AI and IoT—across order fulfillment, planning, procurement, production, inventory, warehousing, and transportation—to maximize operational efficiency, product quality, and profitability.
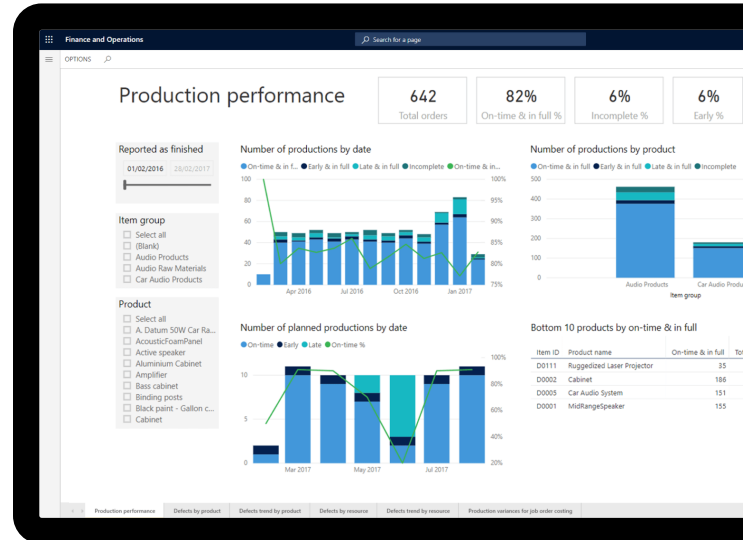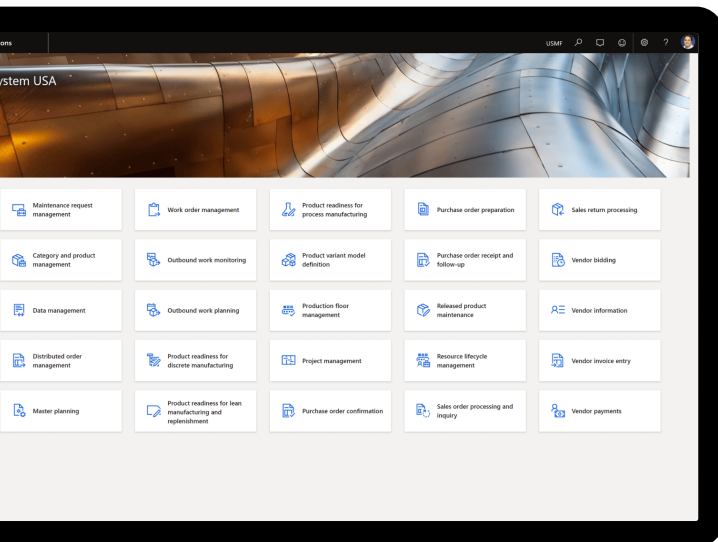
Innovate with intelligent manufacturing operations

Bring speed, agility, and efficiency to your manufacturing to connect and optimize production planning, scheduling, operations, and cost management.

Streamline your supply chain planning and logistics

Maximize customer satisfaction and drive profitability by optimizing material sourcing, fulfillment, and logistics.

Modernize your warehouse and asset management

Manage inventory and assets with precision using machine learning-enhanced guidance that recommends optimal inventory volumes, optimizes asset deployment, and streamlines processes.

How Microsoft can empower your business

01 /
Unified data, intelligence everywhere

Customer Insights   Power Platform   Cognitive Insights

Azure IoT Hub   Cognitive Services   Dynamics 365 Platform

IoT Intelligence   Artificial Intelligence   Process automation

02 /
Focus shifts from technology to experience

Quality management   Process manufacturing   Excel   AppSource

Lean manufacturing   Discrete manufacturing   E-commerce

Demand forecasting   Dynamics 365 Customer Service   Bot Services

03 /
Manufacturing becomes more intelligent

Intelligent manufacturing   Mixed reality   Connected Field Service

AI-builder   Predictive maintenance   Machine Learning

Shop floor management   Asset management   Power Platform

04 /
Ethical manufacturing inspires changes

Computer vision   Blockchain Service   HoloLens   Azure

IoT Intelligence   Azure Active Directory   Quality management

Workforce management   Mixed reality   Potency management

05 /
Manufacturers adapt to a changing workforce

LinkedIn Talent Solutions   Time and Attendance   HoloLens

Excel   Workspaces   Subcontracting   Office 365   PowerApps

Human Resource Management   Bot Services   Power Platform

06 /
Technology enables advanced R&D

Mixed reality   Azure IoT Hub   Digital twins   Cognitive Services

Virtual Machines   PowerApps   GitHub   Azure   Xamarin

Process automation   Visual Studio   Product Information Module

07 /
Supply chain becomes a competitive differentiator

Procurement and sourcing   Transportation management

Vendor collaboration   Warehouse management   Route management

Inventory management   Supplier relationship management

08 /
Businesses adapt to global uncertainty

Dynamics 365 Platform   Master planning   Blockchain Service

Azure Active Directory   Dynamics 365 Finance   Office 365

Power Platform   SharePoint   Microsoft Teams   Azure

Drive operational excellence with Dynamics 365 Supply Chain Management

→

Visit the Dynamics 365 website to learn more about
how Dynamics 365 Supply Chain Management can help
you move from reactive to proactive operations.

http://dynamics.microsoft.com/supply-chain-management

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