Harvard Business Review
ANALYTIC SERVICES

White Paper

MANUFACTURING NEXT

Intelligent, Agile, Automated, and Cloud-Enabled

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SPONSOR PERSPECTIVE

The Future Manufacturing Enterprise: Intelligent, Agile, and in the Cloud

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The manufacturing industry is experiencing the Fourth Industrial Revolution, created by the "combinatorial" effect of waves of digital technologies peaking together. We see the advent of cyber physical systems, which are driving deep disruption in the industry value chain on one hand and enabling convergence of industry ecosystems on the other hand, leading to new digital technology-enabled capabilities.

A brand-new generation of agile organizations with their core competencies being reimagined as digital capabilities are moving to the cloud; embracing automation, robotics, and artificial intelligence and harnessing the abundance of data to create new business models that enable personalized customer relationships. The rich dividends harvested by these new-generation firms can be seen in the form of creation of new customer segments, attraction of capital, and development of innovative products and services.

The adoption of these new approaches is hastening the shift from the traditional business-to-business (B2B) model toward the business-to-business-to-customer (B2B2C) model. As traditional manufacturing firms get ready to battle with the new-age businesses, there is a need for them to reconstruct the traditional linear value chain as an integrated collaborative ecosystem model. We see the new competitive advantage emerge from the ability to build an intelligent, insight-driven enterprise that gives rise to new services and business models and innovative capability-centric differentiation.

The shift in business models is likely to have far-reaching implications not only for the manufacturing industry but also across adjacent industries and segments. For example, in the automotive industry, the vehicle is a convergence point for insurance, infotainment, and smart city services, among others, leading to seamless multimodal transportation models. Similar models can be seen from the convergence of aircraft, airlines, airports, and their enabling service provider businesses into a marketplace. From the revenue model viewpoint, the operational assumptions of asset ownership are being challenged by fractional ownership, asset-as-a-service, and pay-per-use models in the industrial machinery and shared mobility businesses. There is a need like never before to understand the rapidly changing market behavior and drive organization cultural change to adapt to the era of agile, ecosystem-led, collaborative growth as we have seen in the agriculture and chemical businesses.

As a partner to some of the world's leading manufacturers, including several Fortune 500 enterprises, we are seeing this change from close quarters even as we participate in their transformation and help them embrace technology-led business innovation. The TCS Business 4.0™ thought leadership framework is acting as a beacon, providing guided redirection of energy to embrace risk and balance the business models to achieve targeted outcomes. We see the future manufacturing enterprise as intelligent, agile, automated, and in the cloud.

We are pleased to sponsor this research project from Harvard Business Review Analytic Services that brings you insightful and engaging perspectives from industry and academia on this exciting journey. Read on.

MANUFACTURING NEXT

Intelligent, Agile, Automated, and Cloud-Enabled

Manufacturing is in the midst of a seismic shift, hastened by the emergence and convergence of technologies including cloud, big data, mobility, blockchain, augmented and virtual reality (AR/VR), machine learning, artificial intelligence (AI), and the internet of things (IoT). At the same time, a complex and uncertain geopolitical and regulatory environment is increasing pressure on manufacturers to consider more agile and flexible approaches. Increased competition—not only within the sector but also from adjacent industries and from technology-driven startups—is also pushing manufacturers to rethink not only their systems, processes, products, and services—but also their very business models.

Among the changes afoot is an evolution from a focus on creating value through product engineering and operational efficiency to targeting customer centricity and lifecycle services, from traditional products to smarter ones, and from conventional B2B approaches to a more involved B2B2C model.

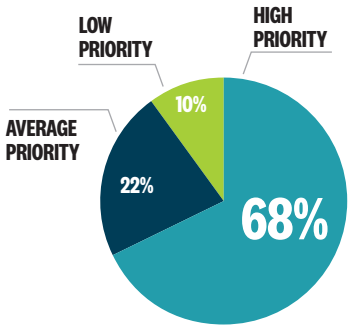
Industry 4.0—what some have called the latest industrial revolution and the next, and perhaps most transformative, stage in the digitalization of manufacturing—is taking hold. FIGURE 1 "[This] is a far more complex innovation than was the internet 25 years ago," says Marc Sachon, professor of production, technology, and operations management at the University of Navarra's IESE Business School. "It encompasses a broad range of new technologies, both digital and physical, that—taken together—will enable a significant acceleration of manufacturing processes while allowing companies to have factories that are able to mass produce and customize at the same time while being profitable—up to now impossible."

Leading manufacturers are doing more than digitalizing, however; they are rethinking their entire value chains and the ecosystems in which they will operate. Many established brands—including Delphi, Cummins, General Motors, Rolls-Royce, and Caterpillar—have embraced digital transformation and updated their business models to stay relevant. Others will need to follow suit. In order to do so in this dynamic environment, enterprises will need to be increasingly intelligent, agile, automated, and cloud-enabled. That foundation is necessary to tap into a host of increasingly intelligent and connected capabilities that can help manufacturers reimagine not just their products and services but also their fundamental business propositions.

FIGURE 1

TRANSFORMATION TOPS THE AGENDA

A look at the importance of digital manufacturing



SOURCE: MCKINSEY DIGITAL MANUFACTURING GLOBAL EXPERT SURVEY, 2018

"From there, you can do all kinds of things: automate different lines, create more flexible processes, reconfigure more quickly, better predict what will happen, improve product quality, and link more closely with suppliers and customers," says George Westerman, senior lecturer at the MIT Sloan School of Management and author of *Leading Digital: Turning Technology into Business Transformation*.

Disruption Comes to Manufacturing

The manufacturing sector has long been dominated by slim margins and moderate returns with a focus on cost and efficiency as differentiators. Traditional manufacturing and production methods, however, are in the throes of a transformation, with the potential for not just incremental improvements but also exponential change. Industry watchers have been predicting this evolution for some time, but it's now moving beyond hype and happening on the ground.

Change is happening in the forms of digitalization, automation, and new and distributed production systems. These technologies are enabling digital performance management; real-time and predictive maintenance; substantial yield, energy, and throughput optimization; next-gen robotics and automation; digital twins; cyber-physical production systems; and more collaborative, connected, and agile supplier and customer relationships.

After decades of downward pressure on price and competition based on operational efficiency, this change offers an opportunity for manufacturers to escape from the downward spiral of commoditization. As R "Ray" Wang of Constellation Research writes, this period of time "will not only jump-start growth but will also create the environment for a manufacturing renaissance."

Of course, this shift requires significant investment, leadership buy-in, change management, new skills and talent, and an appetite to embrace the risk that comes with disrupting the business. The full value of new capabilities like machine learning, cloud, and IoT emerges at their convergence. Piecemeal projects and pilots deliver only limited benefits; broad and strategic application is required for real change. "The old rules don't necessarily apply," says Dr. Jagjit Singh Srai, head of the Centre for International Manufacturing at the University of Cambridge's Institute for Manufacturing. "The ability to respond to fast-changing market requirements becomes the game changer."

ABB, for example, has long been a pioneer in digital technology and automation control systems for its industrial customers and is several years into its own transformation. "Digital technology has been essential in our competitive differentiation; it's integral to our hardware, our software, and our services. But like every other company, we are also

TCS INSIGHT

TCS AND HONEYWELL: REVOLUTIONIZING THE AERO PARTS INDUSTRY WITH ADOBE COMMERCE CLOUD

There are over 20 aerospace e-commerce trading sites today, but no one has figured out how to move the industry to true e-commerce. Honeywell is bringing the ease of everyday online buying and selling to the aviation parts industry with GoDirect™ Trade. The new e-commerce platform will improve access to new and used aircraft parts for airlines, air transport, and business aviation customers by offering transparent pricing and the option to buy inventory directly from its website—a first-of-its-kind experience.

Previously, buyers looking for aviation parts such as avionics, auxiliary power units, and more would have to call numerous companies, wait days or even weeks to price a part, and risk buying from a company that did not have the inventory immediately in stock. On GoDirect™ Trade, Honeywell is using blockchain technology to ensure every listing includes images and quality documents for the exact part being offered for sale, giving the buyer confidence about purchasing the part. In addition, every part on GoDirect™ Trade is immediately available for sale and shipping. There is no need to wait days or even weeks for the seller to confirm availability.

Tata Consultancy Services (TCS) played a vital role from ideation to execution of Honeywell's vision of GoDirect™ Trade. Persona-based user journeys, right product fit to bring the vision to life, and continuous agile enhancements contributed to meeting the project delivery deadlines. The aerospace marketplace runs on e-commerce technology from Adobe Commerce Cloud, now a part of Adobe Systems Inc. Building upon experience from the Honeywell Aerospace Trading business, GoDirect™ Trade aims to build stronger connections between buyers and sellers. As with similar websites in other industries, online reviews of both buyers and sellers are encouraged.

evolving our value chain using digital technology," says Babu Kuttala, group vice president, data and analytics, at ABB. "There is strong momentum in the manufacturing sector for digitalization, which opens up opportunities for new revenue models and business processes."

Meanwhile, Dow—operating in an industry historically slow to adopt new technology—is in the midst of its own renaissance. The 122-year-old chemical company aims "to become the most innovative, customer-centric, inclusive, and sustainable materials science company in the world" after splitting into three parts. "We are building a foundation of cloud capabilities, data analytics, and new processes that will enable a digital Dow," says Anna Reuhl, the company's director of business process architecture and consumer solutions. "Over the next 10 years, we will see a focus on new technologies on the edge to gain efficiency and improve customer experience. We are a B2B company, but some of our customer-facing capabilities will start to look more B2B2C. And data and IP (intellectual property) will become more of a product or service in the future, creating additional revenue streams."

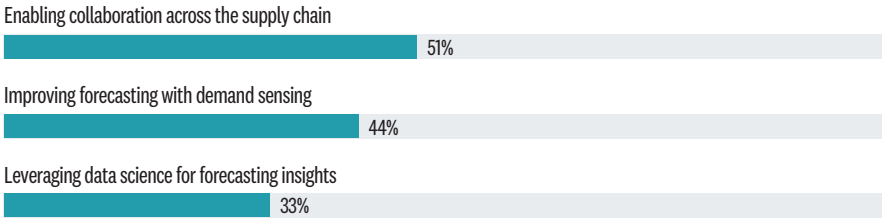
Bekaert, which manufactures wire for the rapidly evolving automotive industry, is embracing digital technologies to forge tighter relationships both with automakers and within its own supply chain to increase its agility. "It helps us to accelerate the intimacy we have always had as an organization with our customers and suppliers," says Jan Quagebeur, vice president of enterprise architecture at Bekaert.

Engine maker Rolls-Royce was one of the first big manufacturers to harness the power of data and machine learning to transform its products into value-added services for its customers—and that work has only accelerated. "One of the main cultural shifts is an increasing drive from top down to instill a very digital-centric culture within Rolls-Royce," says Ben Wilkinson, the company's head of solution delivery for group IT. "We had a very strong engineering and manufacturing culture, but now we see ourselves as a technology company, using digital innovation to drive efficiencies and make smarter decisions." The next five years, adds Stuart Hughes, chief information and digital officer (CIDO) of Rolls-Royce, will be focused on using predictive analytics and automation to optimize operations and deliver greater value with fewer resources.

FIGURE 2

THE AMAZON EFFECT

How companies are preparing the supply chain for rapid change



SOURCE: JDA 2018 INTELLIGENT MANUFACTURING SURVEY

A Focus on the Customer

The increasing demands of customers have driven more focus on them in consumer industries, and that has taken hold in manufacturing as well. Manufacturers must make changes now to address rapidly evolving and increasing customer needs. FIGURE 2 At Dow, the goal of increased digitalization is clear: creating a digitally enabled value chain to elevate the customer experience. "[We want] customers to be able to come to us just as they would go to Amazon to get what they want when they want it," says Lori Putt, Dow's global senior director of integrated supply chain and consumer solutions. "It's about delivering that same experience in the chemical industry." The company's digital initiatives, including increasingly sophisticated analytics and experiments with blockchain technology, are designed to increase productivity, improve time to market, and deliver more modern buying experiences.

CHANGE IS HAPPENING IN THE FORMS OF DIGITALIZATION, AUTOMATION, AND NEW AND DISTRIBUTED PRODUCTION SYSTEMS.

"We had a very strong engineering and manufacturing culture, but **now we see ourselves as a technology company**, using digital innovation to drive efficiencies and make smarter decisions," says Ben Wilkinson, head of solution delivery for group IT at Rolls-Royce.

TCS INSIGHT

DELIVERING PERSONALIZED CUSTOMER EXPERIENCE IN THE CHEMICAL INDUSTRY

Over the past decade, the chemical industry has seen a significant wave of M&A activity. Limited organic growth opportunities in developed markets have led to consolidation and portfolio realignment among major companies. According to Young and Partners, these opportunities have resulted in over $650 billion worth of M&A deals (size more than $25 million) over the past decade, with over $300 billion of deal closures in the past two years (2017 and 2018). The complexity of such transactions has also increased due to multiple mega deals exceeding $20 billion and the growing trend toward the "merger of equals."

As the industry continues to be reshaped by M&A, companies that are part of such deals need to ensure they focus on the often overlooked but most critical part of the deal—the customer. Several studies in the past have concluded that almost 50% of the M&A deals fail to deliver better business value. Customer satisfaction and loyalty can play a very crucial role in determining the deal outcomes and can also help in gaining more opportunities for cross- and upsell. In the "age of the digitally connected customer," M&A transformational plans of companies should focus not only on gaining better synergies, scale, and market access but also on providing a consistent customer experience across the merged entities.

TCS was part of the transformational effort of one of the mega M&A deals in the chemical industry to create a "web presence" for the separate business entities, shaped after the deal. Deploying agile methodology, TCS helped create a unified online digital experience irrespective of the origin of the brand. The resulting system provides a browsing experience based on analytics of the users' habits and interests. It also provides a precise tracking of how each product advertisement is reaching the customers and thus helps in quick planning of changes required in the promotion and enables a campaign targeted on a "segment of one," referred to as personalization. The implementation resulted in strong customer engagement and improvement in turnaround time for new customer experiences. This is the new world of MARTECH—marketing enabled by technology. Reduction in downtime, cloud shift, agile execution, and change in technology solutions stack helped in reducing operational costs. The agile model of systems transformation was one of the key elements in making this initiative successful.

Industrial conglomerate Honeywell likewise wanted to create a more user-friendly online buying experience for its aerospace customers. Building upon its experience in aerospace trading, the $41.8 billion company utilized blockchain technology to modernize its online aviation parts sales. The new platform will improve access to new and used aircraft parts for airlines, air transport, and business aviation customers by offering transparent pricing and the option to buy inventory directly from the website—a first-of-its-kind experience in the industry. Previously, buyers hunting for aviation parts such as avionics, engine parts, or even specific nuts and bolts would have to call numerous companies, wait for days or even weeks to price a part, and risk buying from a company that did not have the inventory in stock. The use of blockchain technology ensures authenticity. Every listing includes images and quality documents for the exact part being offered for sale. In addition, each item is available for immediate sale and shipping, and both buyers and sellers are encouraged to write reviews of their experience.

A Call to Services

Rolls-Royce's civil aerospace customers now expect the company to deliver digital solutions. It was once enough to produce an engine and make sure it operated efficiently. Today, "customers want to see all that data from the engine; they want access to and insights from a digital twin of that engine to help them make better decisions," says Rolls-Royce's Wilkinson. "And we're delivering that information not just through user interfaces but also APIs to provide them access to intelligence to help them run their business."

For example, Rolls-Royce offers airlines advanced data analytics to track factors such as passenger load, fuel burn, wind speed, altitude, and weather patterns, and to make predictions to reduce fuel consumption across their fleets. They've also implemented analytics to enable better predictive maintenance

processes. "That's given us better ability to manage efficiency of our maintenance shop, aligning staff and inventory," says Wilkinson. "We're now looking to take that a step further to predict when specific parts of an engine will need to be replaced so we can do things like just-in-time delivery, reducing the time and disruption related to engine maintenance for our customers."

In order to deliver better customer experiences and solutions, manufacturers are working to increase efficiency in their supply chains and better connect with both their suppliers and customers. Indeed, the supply chain is the leading focus for digitalization efforts in the industrial sector. FIGURE 3

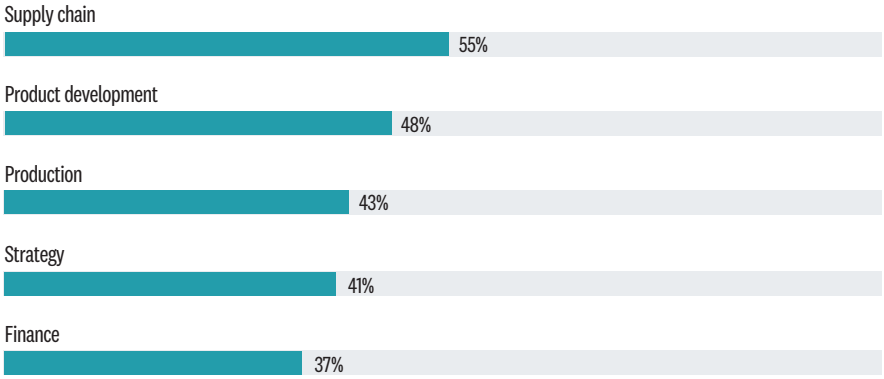
Bekaert makes products that are crucial in the reinforcement of tires. The quality of steel that goes into the wire it produces can impact its customers' production processes. "Better connecting and integrating with tire manufacturers to increase cost efficiency and quality on both sides is a selling argument for us," says Bekaert's Quagebeur. To do that, the company exchanges data not only with its customers but also with its steel suppliers so that they can adapt their production quality to Bekaert's end customers' needs more effectively. "We link their data with our shop floor to understand what the circumstances are that might help them produce a more enhanced quality of steel," Quagebeur adds.

Rolls-Royce is making similar inroads with its suppliers. "One of the most difficult things we face in manufacturing today is managing the short lead time of customers with the long lead times of suppliers," says Hughes, the company's CIDO. "The way that is playing out [at Rolls-Royce] is that our supply chain is becoming much more integrated—both in terms of mindset and IT systems." By opening up systems, Rolls-Royce's suppliers can see when the priorities of its customers change and make adjustments accordingly. "In the past, manufacturers tended to treat their suppliers with mistrust," Hughes says, "but with the modern customer expectation for speed and agility, we have to be very open with one another."

FIGURE 3

FUNCTIONAL IMPACTS OF DIGITALIZATION

Manufacturers are prioritizing supply chain, product development, and production.



SOURCE: STANTON CHASE 2018 GLOBAL INDUSTRIAL EXECUTIVE SURVEY

Dow's value chain involves thousands of raw material suppliers along with hundreds of service providers that help move their goods around the world. The company has been working to create end-to-end connectivity with suppliers, logistics providers, and customers to create a more demand-driven approach to its supply chain operations. As Dow works to ensure visibility with customers and logistics providers, it is creating an end-to-end connectivity of the value chain. Creating such a fully integrated digital supply chain takes significant investment and effort. Only a minority of companies have achieved such integration today. FIGURE 4

THE SUPPLY CHAIN IS THE LEADING FOCUS FOR DIGITALIZATION EFFORTS IN THE INDUSTRIAL SECTOR.

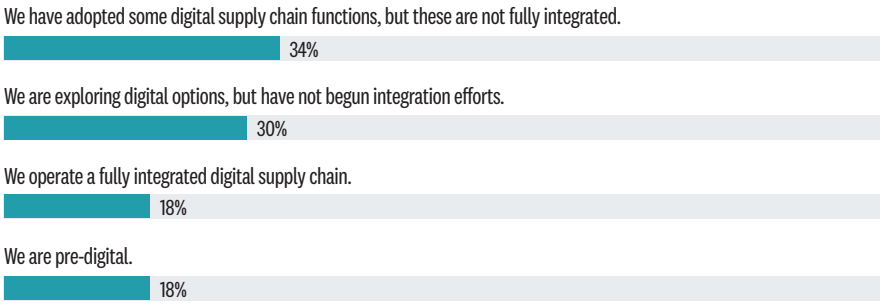
Tapping into a New Tech Ecosystem

Many manufacturers have spent the past few years evolving their application and usage of existing enterprise technologies such as ERP in order to extract the full value of those systems and get a better data-based picture of their operations. With that foundation in place, they have the opportunity to explore a host of emerging digital capabilities that will accelerate their Industry

FIGURE 4

SUPPLY CHAIN INTEGRATION

Where organizations are today



SOURCE: JDA 2018 INTELLIGENT MANUFACTURING SURVEY

TCS INSIGHT

EMBRACING SAFETY WITH TIRE MONITORING SYSTEMS

In the modern era of connected and autonomous vehicles, "sensorization" of components has led to the integration of real-time information on vehicle and environmental aspects such as traffic and road conditions with vehicle dashboards and driving systems. As a result, smart tires with embedded sensors are moving beyond the traditional tire pressure management system (TPMS) applications.

Tire-related crashes claimed 738 lives in the United States in 2017, according to the National Highway Traffic Safety Administration website. Due to a surge in accidents, TPMS became a legal requirement for all the vehicles sold in the U.S. in 2007 and in the European Union in 2014 in order to alert the drivers of underinflation events. Properly inflated tires maximize tire life by 4,700 miles and save 11 cents per gallon on fuel. For truck and bus fleet operators, tire monitoring systems have helped reduce the overall operating costs while improving fleet safety. Tires used in off-road applications such as construction, earthmoving, and mining are expensive and designed to carry heavy loads. The optimal usage of these tires has a significant impact on fuel and tire maintenance costs.

TPMS offers information on the tire temperature, which helps indicate misalignment of wheels and senses acceleration and direction of wheel spin. The system reports dangerous conditions of the tires and alerts if any need to be replaced. Additionally, tires can help keep a check on environmental factors such as the road surface conditions. When integrated with the vehicle control system, TPMS helps the drivers adjust their driving style for the tire and road surface conditions.

TCS has worked with a leading tire manufacturer to build a tire monitoring system based on cloud storage that enables tracking of real-time information on tread depth, inflation pressure, and other key parameters. Mobile-enabled advanced reporting indicators such as cost-per-hour, cost-per-ton, and so on help operators optimize tire performance and lower operating costs, thereby creating a win-win situation for tire manufacturers and their customers.

4.0 evolutions. "There is a whole raft of new technologies: automation, robotics and co-bots, machine learning, and analytics connecting digital information through organizations and through the supply chain," says the University of Cambridge's Srai. "Manufacturers are going through a phase of technology experimentation."

Adoption of emerging technology in other sectors has been rapid and rampant—in large part because they were disrupted by digital upstarts much sooner. Manufacturers have only recently begun tapping into this new technology ecosystem, which can be challenging. In January 2019, *IoT Analytics* identified more than 300 leading vendors that supplied new products and services that are driving the Fourth Industrial Revolution.

Keeping on top of the fast-moving tech space is one of the Rolls-Royce IT group's biggest struggles. "Part of the issue is seeing the woods for the trees," says Wilkinson. "There is a huge set of technologies we could pick, but we've found it better to talk to others and rely on our partners to make the most informed choices. The idea of collaboration and being tech-aware becomes ever more crucial." The days of relying on a couple of enterprise architects to plan for the future are over. "We increasingly need to build strong networks and continually review and assess our choices," Wilkinson says, "and make sure we have the right architecture in place that allows us to switch new technology in and out."

In late 2017, Rolls-Royce launched its R2 Data Labs, which is an acceleration hub for data innovation. A small team is tasked with looking at new technologies to solve difficult business problems. "It's one of the important ways we understand the opportunities of new technology," Hughes says. "Test and learn, test and learn."

While the company would be unlikely to consider a small startup to support core business processes, it nonetheless engages them to solve one-off problems. For example, it invited advanced analytics companies to determine the best way to position its

"THERE IS A WHOLE RAFT OF NEW TECHNOLOGIES: AUTOMATION, ROBOTICS AND CO-BOTS, MACHINE LEARNING, AND ANALYTICS CONNECTING DIGITAL INFORMATION THROUGH ORGANIZATIONS AND THROUGH THE SUPPLY CHAIN." DR. JAGJIT SINGH SRAI, UNIVERSITY OF CAMBRIDGE

TCS INSIGHT

BUSINESS 4.0™: DIGITAL TECHNOLOGIES DRIVING THE FOURTH INDUSTRIAL REVOLUTION

Through its Business 4.0™ thought leadership framework, TCS helps clients leverage digital technologies in their growth and transformation journey. The framework defines the transformation efforts required to build the differentiating competencies that drive competitive advantage in the digital era. Big data analytics, artificial intelligence, and the internet of things, which have peaked together, are now being combined with an elastic cloud-enabled scalability to create cyber-physical systems. These systems are now the major drivers of the Fourth Industrial Revolution.

Digitally "prepared" organizations are in a better position to harness the abundantly available resources, talent, capital, and more important, data for their new businesses and operating models. Firms that have adopted the Business 4.0™ behaviors—driving mass personalization, embracing risk, leveraging the ecosystem, and creating exponential value—will not only offer their clients better value but will also enhance their financial performance.

TCS recently surveyed 1,231 respondents from firms across 11 industries and 18 countries to understand their digital transformation plans. The sample included 186 executives from the manufacturing sector. Manufacturers that have adopted Business 4.0™ behaviors assert that their top and bottom lines have seen a direct benefit. They are also finding that inculcating such practices in their corporate cultures sets them on the path to delivering higher business growth and not just greater efficiency. The barriers to progress can be formidable, particularly where these involve people and culture, but the industry's strengthening digital foundations offer hope that they can be surmounted.

TCS' research[1] brings forth a few lessons to guide manufacturers as they progress on their Business 4.0™ journey:

New Businesses and Business Models Mean Everything
It is no exaggeration to say that the rise of digital technologies threatens traditional manufacturers with extinction. Many established brands have embraced digital transformation and updated their business models to stay relevant. Others must prepare to follow suit.

Strong Leadership Is Key to Business 4.0™
To adopt the Business 4.0™ behaviors vital for transformation and for success in the digital world more broadly, strong and consistent messages from the top are required. Without this, entrenched risk aversion can defeat ambitions to develop new revenue streams or to share data and germinate ideas in platform-based ecosystems.

Agile Should Guide Businesses from the Factory Floor Up
Agile practices benefit manufacturers across the business, not just in the IT department. Accelerated development and fail-fast approaches make it easier for managers to experiment with new product and service ideas.

For Process Redesign, Think Machine First™
Business 4.0™ demands that automation technologies, already prominent in product development and on the shop floor, become the default in executing all processes in the business.

1 To learn more, visit www.business4.tcs.com/manufacturing

turbine engines in the kiln to increase yields and lower failure rates. "It was a point problem, not a system we would need forever," says Hughes, "and they brought special skills, a hunger, a different attitude."

Beyond Pilot Purgatory

As manufacturers embrace new technology capabilities and partners, "the key challenge is the change of mindset: from mechanical engineering to computer science," says the University of Navarra's Sachon. "Even more importantly, they need to learn to modify their business models." Manufacturers are doing significant experimentation in this Industry 4.0 era. "But they are struggling with adoption," Srai observes. "There's a phrase we use—pilot purgatory. They conduct some very nice pilots that make their organizations feel that they're not missing the boat. But they fail to scale up." While the majority of manufacturers surveyed by McKinsey in 2018 had completed digitalization pilots in the areas of connectivity, intelligence, and automation, fewer than 30% of them had completed enterprise-wide implementations. FIGURE 5

ABB has always had a strong engineering culture. In 2016, the company began to bring more digital leadership on board to infuse the company with more of a digital mindset. "The digital world innovates at a pace that is much faster than the physical world. As digital represents an increasing share of the value proposition of manufactured products, this leads to a culture clash in established manufacturing companies, as they have to shift mindset from '100% reliable' to 'testing on client,'" says Sachon.

ABB did what Srai says many leading manufacturers have done: create a separate unit to explore and expand the use of game-changing technologies. In that way, legacy processes and cultural norms don't hinder transformational efforts. Indeed, agile practices benefit manufacturers across the business, not just in the IT department. Accelerated development and fail-fast approaches make it easier for companies to experiment and improve upon new product and service ideas.

Dow likewise has digital innovation centers prototyping, piloting, and scaling the use of new capabilities in the areas of AI, robotics, big data analytics, blockchain, and more. Rolls-Royce's R2 Data Labs has mixed-discipline teams of data experts working in collaboration with other teams across the company. They utilize DevOps practices to explore data, uncover and test new ideas, and turn those ideas into new predictive, data-based services in areas such as asset availability, efficiency, maintenance, and compliance.

Perhaps most importantly, organizations need leaders with a strategic vision for transformation in order to move beyond the experimentation phase to enterprise transformation. At Rolls-Royce, for example, digital strategy has been elevated to an executive-level priority, and the leaders created new functions within the business to ensure that there is continued focus on it.

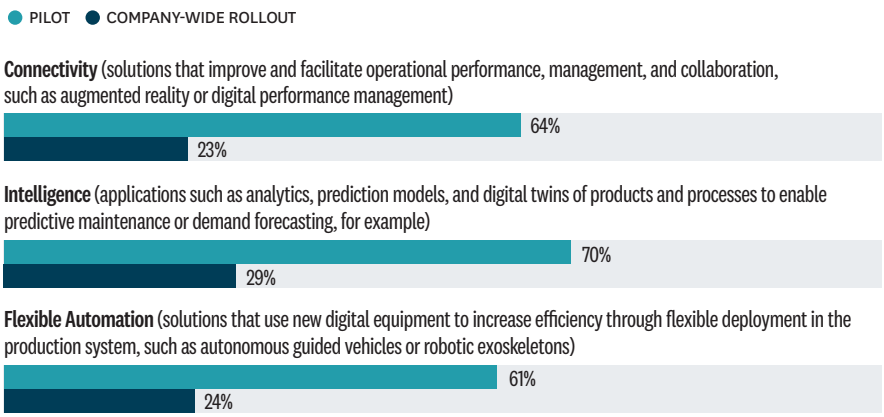
THE DAYS OF RELYING ON A COUPLE OF ENTERPRISE ARCHITECTS TO PLAN FOR THE FUTURE ARE OVER.

FIGURE 5

MANUFACTURERS STRUGGLE WITH ENTERPRISE-WIDE DIGITALIZATION

Doing pilot studies doesn't necessarily speed up adoption.

At what stage are you in adopting specific digital manufacturing solutions at your company?



SOURCE: MCKINSEY DIGITAL MANUFACTURING GLOBAL EXPERT SURVEY 2018

Industry 4.0 also demands a new approach to adopting, implementing, and optimizing new technology applications—one that is increasingly intelligent, agile, automated, and cloud-based.

MANUFACTURERS HAVE SIGNIFICANT WORK TO DO TO FULLY CONNECT NEW AND EXISTING DATA STREAMS TO THEIR SUPPLY CHAINS, PRODUCTION FACILITIES, AND EMPLOYEES.

A Foundation for Sustained Change

In order to take advantage of these increasingly advanced digital capabilities, manufacturers need a modern IT environment. "You need an infrastructure that allows you to collect all the data from different types of sensor devices and integrate it and analyze it. That is a big challenge," says Tom Davenport, President's Distinguished Professor of IT and Management at Babson College and digital fellow at the MIT Center for Digital Business. "It's one of the big reasons why IoT has yet to take off in a bigger way."

Clean, extractable data and a robust data management discipline are needed. "It's a challenge, but we know it's something we had to do," says Kuttala. Success in Industry 4.0 initiatives is in part determined by the quality of data available. Bekaert's Quagebeur strongly agrees. "We have seen quite a few analytics projects hit roadblocks because of data quality issues," he says. "That puts even more pressure on us to further digitize and automate our shop floors."

ABB has been implementing cognitive computing and machine learning capabilities to improve factory floor productivity. "We are focused on developing common information models and master data management practices. This ensures data quality and integrity so that we can link data seamlessly within our business process value chain," Kuttala says. "Information models are the foundation of digitization."

As ABB links machine data with ERP data, it will be able to optimize the factory floor.

Industry 4.0 also demands a new approach to adopting, implementing, and optimizing new technology applications—one that is increasingly intelligent, agile, automated, and cloud-based.

Many of the advances Rolls-Royce has made have also been enabled by the cloud. "We have a cloud-first strategy in many areas," says Wilkinson. "For example, our Monte Carlo simulations for predictive maintenance are very computationally complex and would be expensive if we weren't able to use cloud computing on demand. It not only saves us money but also reduces the barrier of entry to do these things in the first place. We're now able to use big data and IoT and connect our systems to our assets and process it all."

Rolls-Royce first began using machine learning to provide customers with a full-service package for its engines two decades ago. As it is able to process even more of the data it collects, it can begin to predict when an engine is likely to need attention and address it before it fails, so airplanes spend more time in the air and less on the ground. It is also able to use AR/VR to guide engineers remotely through repairs out in the field and will be using the same technology to upskill its workforce and reduce error rates. It also has plans to apply AR to validate quality during assembly. Data being collected on digital twins of its engines is also being used heavily to guide informed decisions on the design of future engines.

Smarter, Nimbler Manufacturing

A modern IT infrastructure and approach is also enabling those in manufacturing to adopt transformative technologies on the shop floor. Smart robotics, increasing automation, and additive manufacturing are all integral to the future of manufacturing, says Sachon. "Their impact will be significant, as they change the playing field at the physical level, allowing for acceleration," Sachon adds.

"Real-time data in itself is useless if you cannot act on it."

Manufacturers have significant work to do to fully connect new and existing data streams to their supply chains, production facilities, and employees. FIGURE 6 In addition, this next phase of manufacturing demands that automation technologies, already prominent in product development and on the shop floor, become the default for all process execution in the business. Moving more boldly in this direction to upgrade old equipment and digitalize production requires a roadmap for the future to guide investments, solution choices, and implementations.

Bekaert has implemented data lakes at its plants, where data science professionals help managers assess and improve operational effectiveness based on the correlation of data from back-end enterprise systems with that from programmable logic controllers (PLCs)—the computers that monitor inputs and outputs and make logic-based decisions for automated processes and machines.

Digitalizing and automating factories requires significant investment, particularly with many of the older assets in place at Bekaert. "We have a global footprint with a legacy history of machinery," Quagebeur says. Indeed, sunk costs in existing assets have been a hurdle for many manufacturers. But the returns for Bekaert have been substantial. "We see significant advantage in bringing data analytics nearer to the shop floor," says Quagebeur. "There is also potential in digitalizing and automating our whole shop floor so we are much quicker in responding to incidents and can free up operators to focus on higher-value work." That not only increases efficiency and uptime, Quagebeur says, but also can deliver substantial energy savings.

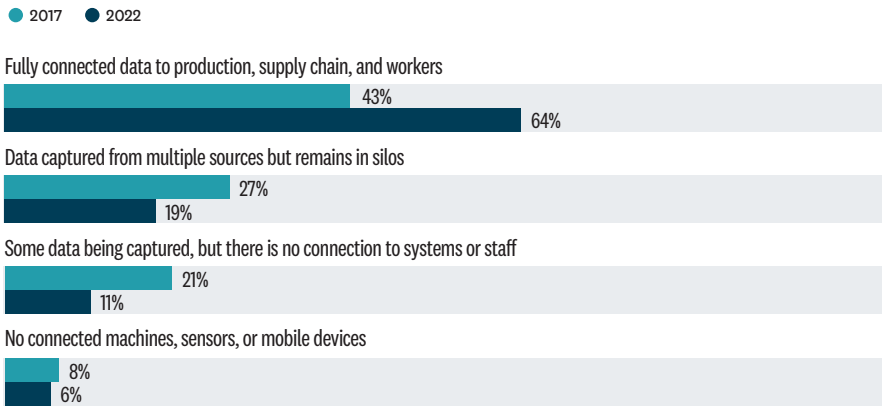
Technologies like digital twins and 3D printing are also opening up new ways of thinking about manufacturing. Digital twins, which Gartner predicts will soon enter mainstream use, FIGURE 7 create the ability to distribute capacity around the world while maintaining knowledge centrally, while additive manufacturing changes the economics of production. "Normally companies seeking economies of scale would centralize manufacturing," says Srai. But both digital twins and 3D printing present an opportunity to distribute production and explore making more customized products. "We may see manufacturers move toward micro factories enabled by digital twin technology producing a variety of products," Srai says. "We're working with a number of facilities embracing smaller-scale production lines for fast-moving consumer goods and assembling products using 3D printing technology."

Over time, that could transform the way manufacturers think about operations. "Large-scale remote factories become less attractive and smaller, regional operations become more desirable. Response times become faster. Holding large inventories becomes unnecessary," says Srai. "When [that is] combined with digitalization, manufacturers can become faster and more agile in responding to real market demand with a completely different, connected supply chain that can enable them to identify individual preferences."

FIGURE 6

A FUTURE FOR CONNECTED FACTORIES

Most manufacturers have significant opportunity to connect their factories.

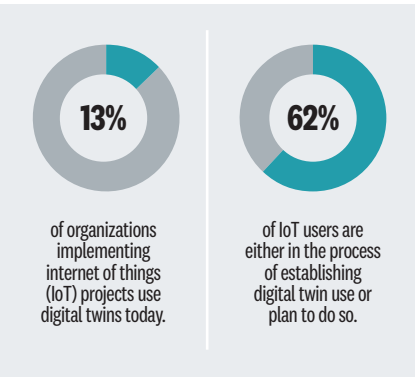


SOURCE: ZEBRA TECHNOLOGIES 2017 MANUFACTURING VISION STUDY

FIGURE 7

DIGITAL TWINS POISED TO TAKE OFF

Current or near-future implementation of digital twins is apparent in organizations.



SOURCE: GARTNER IOT STUDY, 2018

TCS INSIGHT

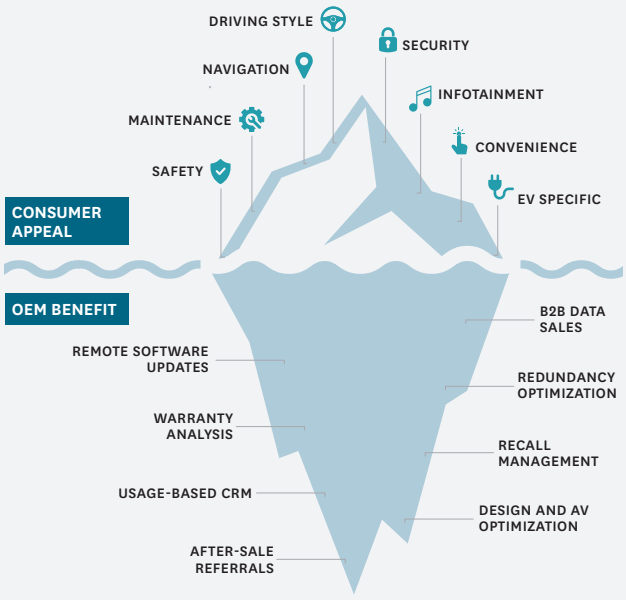
CONNECTED CARS 4.0: AGILE, INTELLIGENT, AUTOMATED, PERSONALIZED, AND IN THE CLOUD

SBD Automotive is a global team of specialists in automotive technology research. For more than two decades, SBD has focused exclusively on connected, autonomous, and secure cars. Its industry thought leaders and experienced professionals understand the day-to-day challenges the industry faces. Through a unique understanding of the "bigger picture," SBD helps anticipate opportunity and avoid unnecessary costs.

Automotive manufacturers face incredible opportunities (and challenges) when it comes to optimizing the value of connected cars, as do critical stakeholders such as dealers, mobility service providers, third-party developers, and most importantly, the vehicle owner and enabling a better and safer overall end-user experience.

For the first time since automakers started to integrate cellular phone connectivity into vehicles, beginning in 1996, the questions are no longer whether we can or should connect cars. Based on SBD Automotive forecasts, 42% of all new vehicles sold in 2019 globally will be shipped with a built-in connection to the cloud, and by 2025, that number will nearly double (82%).

WHY WILL NEARLY ALL CARS GET CONNECTED?



SOURCE: SBD AUTOMOTIVE, WWW.SBDAUTOMOTIVE.COM

It is no longer about simply connecting the vehicle, but about the value that connection adds on a daily basis so the vehicle experience gets better over time, much like a consumer expects from his/her mobile device. Forward-looking automakers are leveraging connectivity, software-as-a-service, and platform-as-a-service enablers from leading partners like TCS to enable a 4.0 connected car experience and enable groundbreaking use cases, such as:

- **Shared Mobility:** Leading car-sharing service providers already leverage fully connected cars to unlock and start vehicles, create analytics to optimize asset locations, and increase utilization as well as to offer advanced connected services to drivers and passengers.
- **Over-the-Air (OTA) Updates:** These include remotely updating and fixing software code on the vehicle, keeping navigation map content fresh, reducing trips to the dealer, adding new features on demand enabling new revenue streams, and personalizing the vehicle—especially important for increasingly shared assets.
- **External Data Monetization:** This refers to selling or trading connected car data to third parties—connectivity unlocks new revenue streams, but partners must manage complex privacy, consent management, and regulatory challenges.
- **Advanced Diagnostics and Prognostics:** Leveraging connected car data offers internal benefits such as reducing warranty claims by predicting failures before they occur, improving overall vehicle quality, and accessing data for future vehicle development.
- **Autonomous Vehicle (AV) Fleets:** AVs on the road need to share new observations about their surrounding environment, improve their AI algorithms, and enable a near real-time learning loop in the cloud, which feeds other vehicles through robust connections.
- **Electric Vehicles:** Connectivity and real-time data are absolutely essential for communicating with the charging infrastructure and grid, optimizing the time to charge, identifying station locations and availability, and remotely managing and optimizing battery systems.

TCS plays a key role in working with leading automakers and its partners around the globe in enabling innovative solutions to fully leverage the promise of vehicle connectivity, cloud, and analyzing the underlying data enabling the promises of Connected Cars 4.0—agile, intelligent, automated, personalized, and in the cloud.

"It makes sense that this intelligence and rapid reconfiguration will allow much smaller batches and even custom manufacturing," says Westerman. "Just as marketing is rapidly evolving toward an analytics-enabled way of addressing market segments of one, manufacturers may be able to do the same."

Workforce 4.0

Industry 4.0 transformation can be enabled by new digital capabilities and increased intelligence and automation on the shop floor. However, the biggest hurdle to transformation is not technology but people. "The change in mindset required to make this work is substantial," says Quagebeur.

Legacy cultures and skills have proven to be significant issues across the industry. "Manufacturers are finding they have a skills deficit—and not just on the shop floor, at every level in the organization, all the way up to senior management," says Srai. "Yes, there's a general deficit in digital skills, but all this is a secondary issue to how you manage this level of transformation where technology is changing so quickly beyond what you understand."

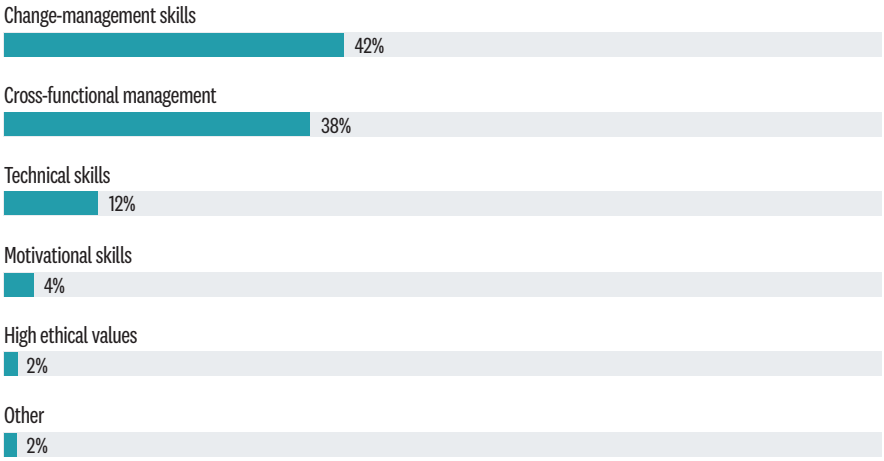
It's taken time for Rolls-Royce to build a "prevailing digital culture" in an engineering organization with a 100-plus year history. "We had to think carefully about the best way to promote digital culture and engagement," Wilkinson says. "We created a digital community and made digital training available so people had access to various ways to learn." In the beginning, many employees had little understanding of what new analytics tools could do, for example. "When new systems come through, that can be a real shock," says Hughes.

More immersive learning has proven valuable, sending new users to work in another division already applying new systems or processes or using VR or minimally viable products that enable employees to try the new technologies before they are fully implemented. "Because once the system is live, they need to be able to change and adapt their ways of working," Hughes says.

FIGURE 8

MANAGING CHANGE

Most important skills for leaders working on Industry 4.0 projects



SOURCE: STANTON CHASE 2017 GLOBAL INDUSTRIAL SURVEY: LEADERSHIP IN THE INDUSTRIAL LANDSCAPE

Manufacturers should expect—and know how to manage—resistance to change. FIGURE 8 To adopt new behaviors vital for transformation and adapt to the digital world, strong and consistent messages from the top are required. Without this, entrenched risk aversion can defeat ambitions to develop new revenue streams or to share data and germinate ideas in platform-based ecosystems. That has been the case at Rolls-Royce where, Wilkinson says, there has been an "increasing drive from the top down" to instill a very digital-centric culture.

"An interesting cultural shift has happened here. We have 2,000 people working on big data and digital at R2 Data Labs. But we are also offering courses and training for non-IT people to learn about the opportunities digital offers, to go through agile boot camp, or understand how user-centric design can enable users to create new technologies quickly," Hughes says.

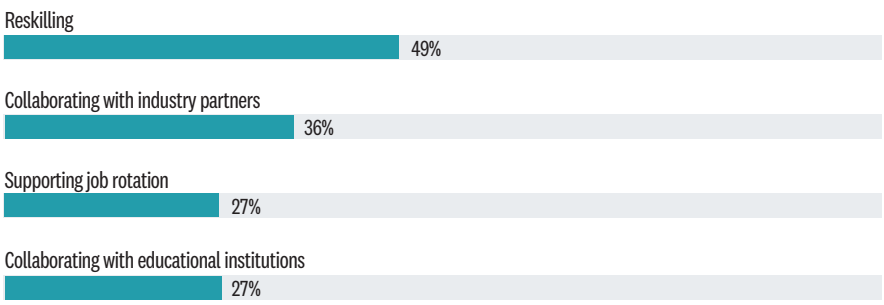
Design thinking has also been a game changer in the cultural shift from engine manufacturer to tech company. "We can take a problem and work as a group to solve it in the simplest way," says Hughes. "Of course, that works well for developers. But the true value

"Industry 4.0 is not one but **many new technologies** that have to be orchestrated across the global value chain. This is a **highly complex undertaking**, and so it will not come overnight," says Marc Sachon, professor of production, technology and operations management at the University of Navarra's IESE Business School.

FIGURE 9

COMBATING A GLOBAL TALENT SHORTAGE

What are the most effective methods of developing skills and competencies for successful transformation?



SOURCE: MANUFACTURING IN MOTION: TRANSFORMING FOR A NEW INDUSTRIAL ERA, THE ECONOMIST INTELLIGENCE UNIT, 2017

is in working with nontechnical teams where, with the facilitation of design thinking coaches, they become part of the process and the changes are less scary for them." The best way to get people on board is to demonstrate to them a "sea change in operations that enables them to imagine what was previously unimaginable," says Wilkinson. "It's very powerful to be able to go into parts of the business, show them what is possible with big data or cloud, and then witness their realization that it could materially affect or transform their area of the business."

To get to that point, of course, manufacturers need people with the digital skills to envision what's possible. Many companies may need to look to consultants or technology providers for this, observes Westerman. "Reskilling is becoming a new priority for firms, and digital is providing new opportunities to do it well," Westerman says. FIGURE 9 Those companies that are unable to do so may find themselves dependent on consultants or vendors for the capabilities required, Westerman adds.

The Way Forward

Much of the new technology and processes adopted by manufacturers in the past have been incremental and experimental. But leaders are recognizing that they need to embark on a strategy for end-to-end transformation. "Within five to 10 years, we will see significant adoption of digital technologies, automation, and emerging production technology," says Srai. "That means adoption needs to happen in the very near term. If it's not in your plans in the next three years, you will be part of the legacy manufacturing story."

The road to Industry 4.0 will be a long one, but leading manufacturers are already seeing benefits from their investments in new technologies, processes, people, and skills. "Industry 4.0 is not one but many new technologies that have to be orchestrated across the global value chain. This is a highly complex undertaking, and so it will not come overnight," Sachon says. "The overall effect will be an increased agility of global value chains."

THE BEST WAY TO GET PEOPLE ON BOARD IS TO DEMONSTRATE TO THEM A "SEA CHANGE IN OPERATIONS THAT ENABLES THEM TO IMAGINE WHAT WAS PREVIOUSLY UNIMAGINABLE," SAYS BEN WILKINSON, HEAD OF SOLUTION DELIVERY FOR GROUP IT AT ROLLS-ROYCE.

There are a number of actions that manufacturers can take to accelerate their transformations today.

GATHER BASELINE DATA ON EXISTING OPERATIONS.

"You've got to know what's happening in your systems and processes first," says Westerman. "Take advantage of existing monitoring systems, gather the data, and from there you can begin to think about digitization and automation and restructuring."

BUILD A STRONG IT FOUNDATION.

Technologies like machine learning, AI, and IoT demand a modern technology environment and sound data management to provide value. Manufacturers who are further along in their transformations first addressed their existing enterprise systems and processes, ensuring that they can support the data life cycle needs of these technologies.

DEVELOP AN INNOVATION ECOSYSTEM.

Think about the types of skills and technologies that hold the most value for the organization, and begin to partner with startups, innovators, providers, universities, suppliers, and customers who are exploring the same areas.

CULTIVATE A DIGITAL CULTURE.

Historically, manufacturing has been about repeatable processes, increasing efficiency, and cutting costs. This new manufacturing era, however, requires new thinking. Many manufacturers have created entirely new business units to drive the kinds of change required for digital transformation and then seek to scale that throughout the enterprise.

EXPERIMENT HEAVILY; SCALE SELECTIVELY.

Industry 4.0 offers nearly endless opportunities that manufacturers might benefit from. But no one company can—or should—pursue them all. "Understanding what the most important things are to your company is crucial," Srai says. "Manufacturers must go through a phase of experimentation to very quickly identify which make the most sense for them."

SHARE SUCCESSES WIDELY.

Fear, uncertainty, and doubt naturally accompany significant change. One of the best ways to overcome organizational resistance to change is to celebrate victories and make the possibilities—and their benefits to areas of the business and individual employees—clear.

RETHINK TRADITIONAL TRAINING AND UPSKILLING.

Industry 4.0 can fundamentally alter a multitude of roles. Employees will need to get comfortable with new ways of working sooner rather than later. Immersive forms of learning—spending time in areas of the business that are already working in new ways, AR/VR assisted training—can prove more effective than traditional training programs.

START WITH ONE OR TWO TRANSFORMATIONS TO PROVE IT WORKS.

Prioritize areas that can unlock several waves of potential value and then consider building on those successes for exponential growth. Initial successes can serve as proof points, leading to a greater willingness to take a chance on more substantive investments.

STRIVE FOR ONGOING ITERATION.

Industry 4.0 technologies are evolving rapidly, and the opportunities for new processes, products and services, and even business models will continue to emerge over time. Those organizations that approach this period as an opportunity for learning and growth and integrate lessons learned over time into their long-term strategies are more likely to succeed in the future.

Manufacturing is at a tipping point. It's become clear that the old approaches—wringing additional costs and efficiency out of the system—have reached a point of diminishing returns. At the same time, an abundance of increasingly sophisticated technology capabilities now exist that are enabling forward-thinking companies to reimagine their operations, their products and services, their customer and supplier relationships, and even their fundamental value propositions.

This shift will require strategic vision to move from pilots to enterprise adoption, new skills and talent to deliver on that vision, and an appetite for risk and experimentation necessary to overcome inertia and shake up the status quo. But the biggest risk, it seems, is not embracing this new paradigm of manufacturing for the post-digital future.

ABOUT TCS MANUFACTURING BUSINESS UNIT

As a preferred partner, TCS helps leading manufacturers globally to future proof their business through strategic interventions and transformation programs. Leveraging its rich experience across the manufacturing value chain and the ability to connect the boardroom to the shop floor, TCS Manufacturing Business Unit (MFG BU) brings to them a vision of the "Manufacturing of the Future" and a complete implementation road map to realize their aspirations. Helping customers leverage new-age digital technologies to drive growth and transformation while continuing to work with them to reduce operational expenditure and drive increasing levels of efficiency and productivity enables TCS MFG BU to build capabilities for their sustainable growth.

ABOUT TATA CONSULTANCY SERVICES

Tata Consultancy Services (TCS) is an IT services, consulting, and business solutions organization that has been partnering with many of the world's largest businesses in their transformation journeys for the past 50 years. TCS offers a consulting-led, cognitive-powered, integrated portfolio of business, technology, and engineering services and solutions. This is delivered through its unique location-independent, agile delivery model, recognized as a benchmark of excellence in software development.

A part of the Tata group, India's largest multinational business group, TCS has over 450,000 of the world's best-trained consultants in 46 countries. The company generated consolidated revenue of US $20.9 billion in the fiscal year ended March 31, 2019, and is listed on the BSE (formerly Bombay Stock Exchange) and the NSE (National Stock Exchange) in India. TCS' proactive stance on climate change and award-winning work with communities around the world have earned it a place in leading sustainability indices such as the Dow Jones Sustainability Index (DJSI), MSCI Global Sustainability Index, and the FTSE4Good Emerging Index. For more information, visit www.tcs.com.

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