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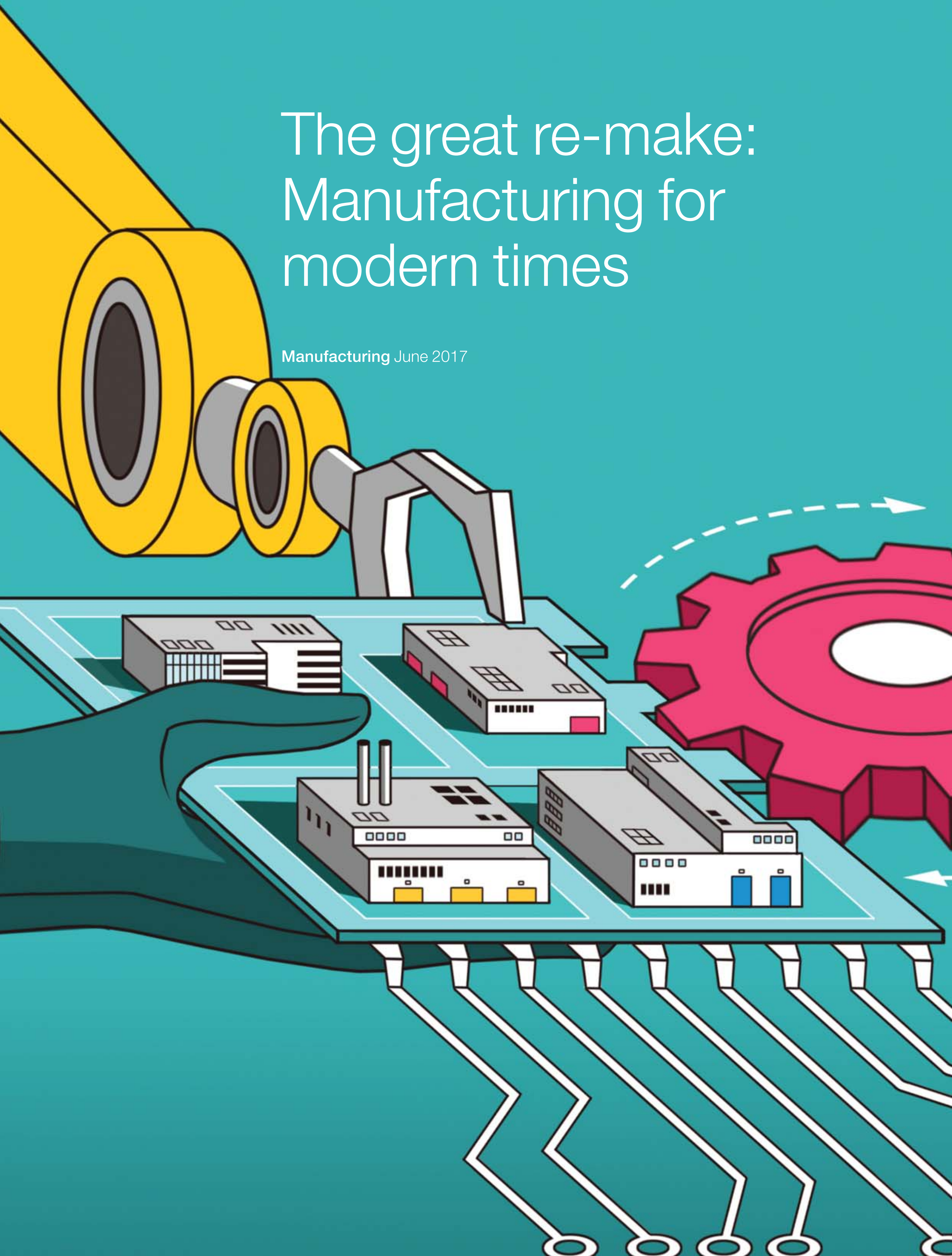
The great re-make: Manufacturing for modern times

Manufacturing June 2017



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The great re-make: Manufacturing for modern times

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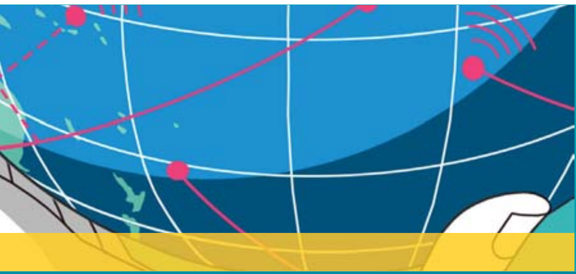
This compendium reflects the collective experience of McKinsey's Global Manufacturing Practice. It is based on our extensive work with more than 650 client organizations over the past five years across all industries. McKinsey also has broad experience serving these clients on matters related to commercial strategy, risk, emerging-market growth, the use of big data, and a wide range of other critical business challenges—reflecting the collective knowledge of our entire organization.

Our global presence and the knowledge we generate from our work in other industries enable us to deliver deep expertise to our clients. With our cutting-edge tools and leading practitioners, we offer a customized approach tailored to organizations' local, regional, and global aspirations. We are committed to partnering with our clients to solve their biggest challenges.

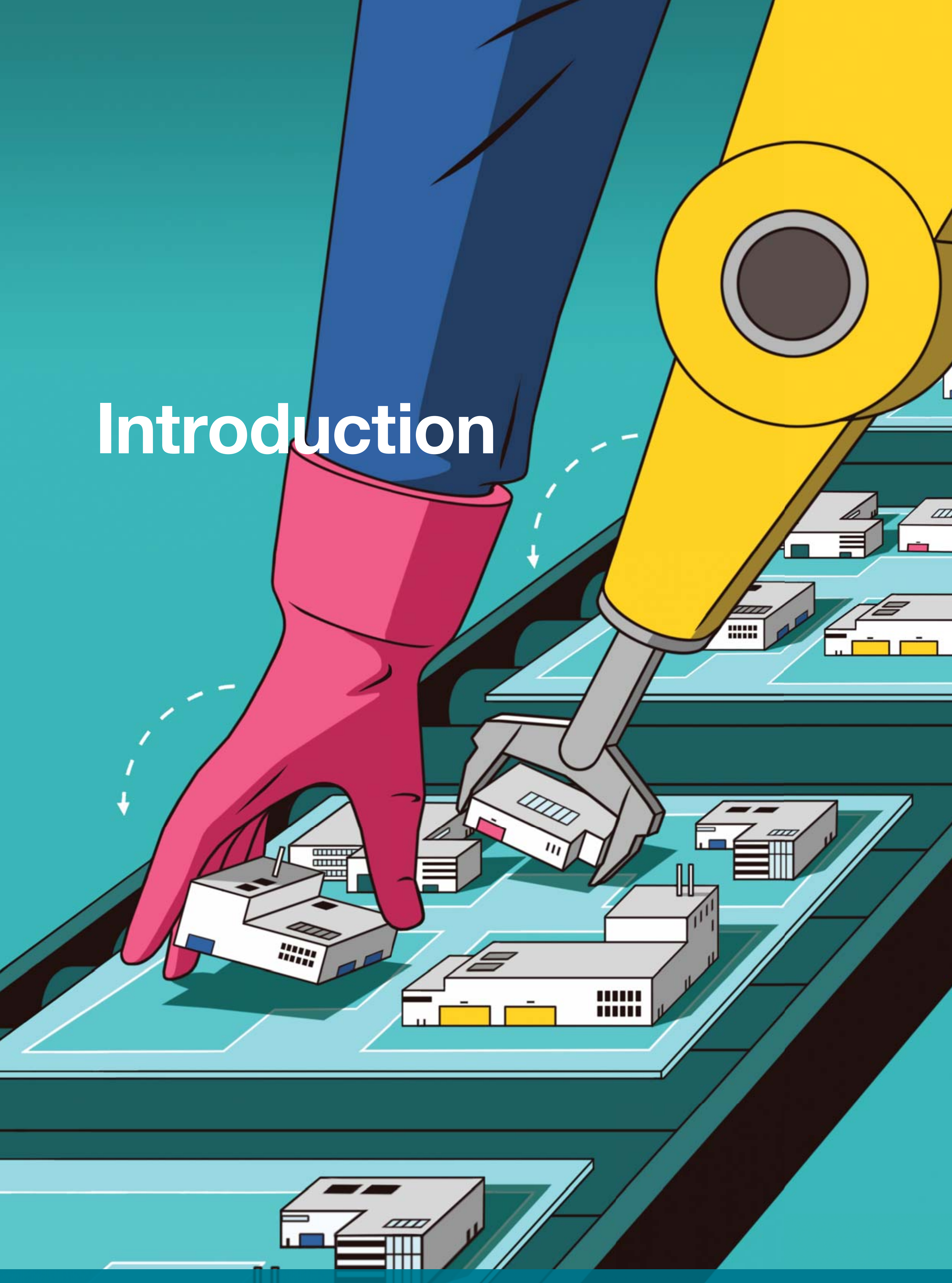
At the heart of our practice is a group of passionate and experienced leaders who seek to transform the world of manufacturing. We welcome your comments, questions, or inquires.

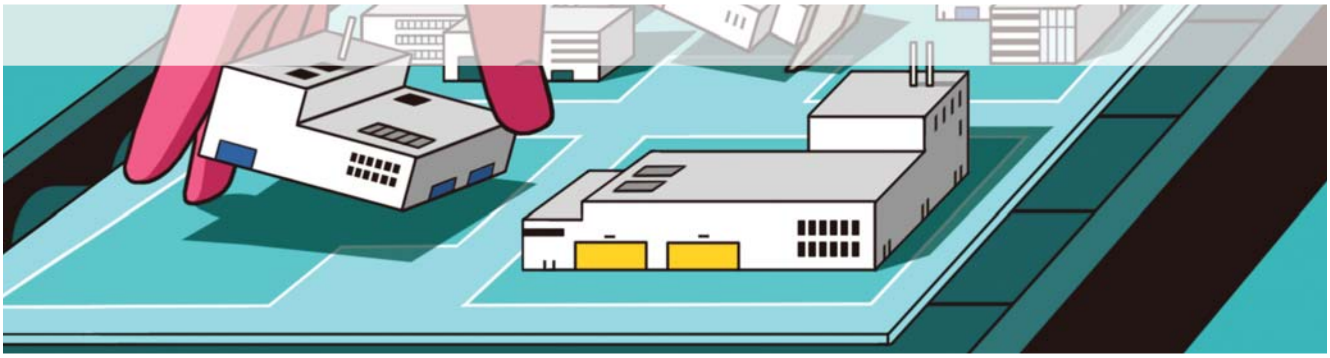
Please contact us at McKinseyMFG@McKinsey.com.

Inside



Introduction





The great re-make: Manufacturing for modern times

Erin Blackwell, Tony Gambell, Varun Marya, and Christoph Schmitz

A little more than 80 years ago, Charlie Chaplin's classic movie *Modern Times* was released. The scene in which he tries to keep up with the assembly line with his arms flailing as he twists wrenches in each hand, is one of the best-known in film, and it's still what many people (at least those who haven't worked in factories) think of when they think of manufacturing.

But those who know factories know how much they have changed since then: think of the differences between the factory of 2017 and 1937. Or 1977. Or even 2007. Think of the advances in automation, robotics, sensors, the Internet of Things, analytics, big data, artificial intelligence, and design methodologies. How much more will manufacturing change by 2027? By 2037?

How do manufacturing organizations keep up with this pace of change—and what will you, as a manufacturing leader, need to do to change with it?

We believe we have entered a new era of manufacturing for modern times, where it's at least as hard for organizations to keep up as it was for Charlie Chaplin. Today's modern times have brought unprecedented demands, and not only for the perennial goal of more product for less money. They have increased customer and regulatory scrutiny, in the name of frictionless convenience and flawless quality. They have enabled advances in the availability, storage, and use of data in manufacturing. They have exacerbated product and demand complexity. And as a result, they have compelled managers toward ever-greater productivity improvements, whether through operational or structural transformations.

As a result, we believe we are also on the cusp of a great re-make in manufacturing. We expect some companies and even whole industries to accelerate toward this future, largely based on two factors: first, the level and speed at which modern times require change and second, the degree to which new digital advances will unlock opportunities.

In the end, however, we believe that successful manufacturing companies will both embrace new advances, while staying true to enduring beliefs: that the foundational elements of manufacturing performance that were true in the industrial revolution, that were true for Henry Ford in the early 1900s, and that were true for Toyota in the 1980s remain true for all manufacturers today.

With that in mind, we expect you'll find some topics in this compendium that are intriguing, some that are challenging, and others that provide further support to your current practices and capabilities, with material that is relevant from the C-suite to the front line. We hope that you and your colleagues find this compendium a valuable resource as you aspire to a new era in manufacturing leadership.

We present this compendium of all new articles organized around three themes relevant to manufacturing companies today:

Modern times

In this first section, we explore the changing landscape of manufacturing across sectors. Over the next decade or so, global consumption is forecast to increase by about $23 trillion, and the consuming class by about 1.8 billion people. Consequently, the need to understand demand—and how, where, and when to produce—has become even more critical. As digital capabilities become more attainable and understandable, the adoption of these technologies will drive levels of competitiveness and enable faster and more agile production systems. However, the basics of operational excellence will remain the foundation of an organization's transformation and journey into the future.

Modern vision

For organizations to remain competitive, they must think about the value chain from beginning to end, through all aspects of production. In this next section, we dive deep into specific topics that we think are important for companies to consider. Some are technical concepts, such as advanced manufacturing, network optimization, and advanced analytics, while others focus on crucial mind-sets and behaviors, such as leadership and the workforce of the future.

Modern practices

With all of the concepts and theory for leaders to think about, it is often daunting to think about the actions necessary to make change happen. Trying

Over the next decade or so, global consumption is forecast to increase by about $23 trillion, and the consuming class by about 1.8 billion people.

to make everything happen at once can often lead to failure, while going too slow wastes an impossible-to-replace competitive advantage. In this section, we address some of the tactical steps needed to steer an organization on the right path forward.

If you are a COO or other member of the C-suite, we hope you will pay special attention to the section on where manufacturing is going, to help you think about your strategic imperative and the future of your business.

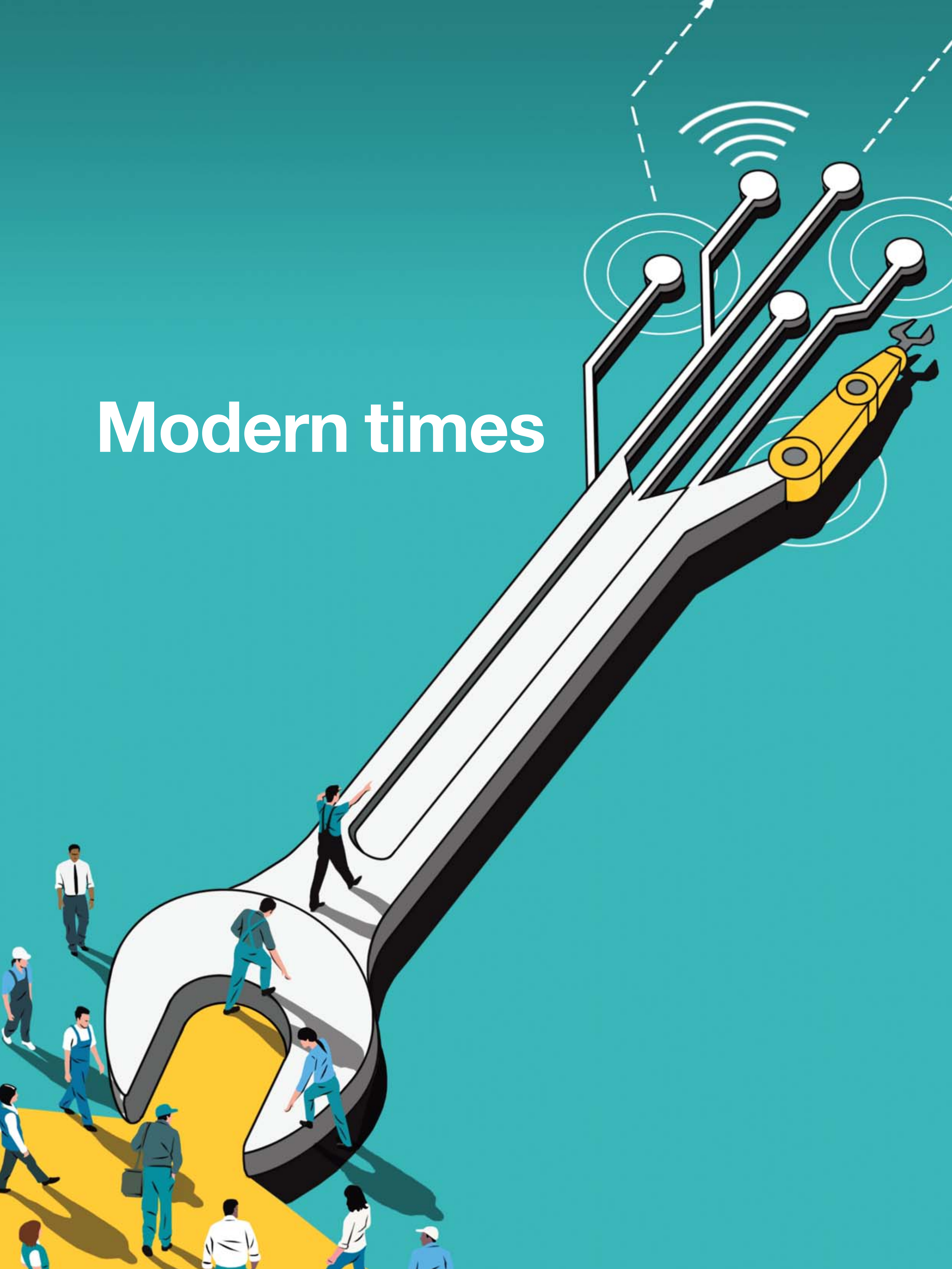
We hope the perspectives in this book prove to be both intriguing and instructional. Our aspirations are to help executive teams navigate the continually changing landscape of manufacturing more confidently and help them prepare for future disruption.

Get ready for **the great re-make.**

Get ready for **manufacturing in modern times.** We look forward to continued discussion on the topics most relevant to manufacturing today.

Best regards,
Erin Blackwell, Tony Gambell, Varun Marya, and Christoph Schmitz on behalf of McKinsey's Global Manufacturing Practice.

Modern times



Global growth, local roots: The shift toward emerging markets

Matteo Mancini, Wiktor Namysl, Rafael Pardo, and Sree Ramaswamy

New markets will drive growth in demand for manufactured goods in coming decades. To meet it, companies must innovate at the local level.

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The authors wish to thank Sudhir Arni for his contributions to this article.

Emerging markets will power global growth over the next 20 years. By 2025, overall global consumption is forecast to reach $62 trillion, twice its 2013 level, and fully half of this increase will come from the emerging world. In 2010, the "consuming class"—people with disposable incomes of more than $10 a day—had 2.4 billion members, just over a third of the world's population. By 2025, that will rise to more than half. Taking population growth into account, there will be an extra 1.8 billion consumers, the vast majority living in emerging regions.[1]

For manufacturers, the story is even more compelling. We estimate that emerging markets will be the destination for 65 percent of the world's manufactured goods by 2025. Consumption starts with the basics, and the purchase of capital-intensive goods (such as cars, building products, and machinery) is driving the shift. By 2013, emerging markets already accounted for 59 percent of total demand for building materials, 57 percent for iron and steel, and 47 percent for machinery.

A tale of many cities

Accessing these huge, important new markets won't be straightforward, however. While more than half of the world's population will likely live in cities by 2025, the fastest growth won't take place in today's emerging-market megacities, like Mumbai or Shanghai. Instead, during the next two decades the source of about 35 percent of the growth will be the several hundred million people projected to be living in more than 400 midsize cities spread across the emerging world.[2]

1 Homi Kharas; Angus Maddison; McKinsey Global Institute Cityscope 2.0.

2 Richard Dobbs, Jaana Remes, James Manyika, Charles Roxburgh, Sven Smit, and Fabian Schaer, *Urban world: Cities and the rise of the consuming class*, McKinsey Global Institute, June 2012, McKinsey.com.

Those cities will be as diverse in character as they are geographically. Take three examples. Surat, in western India, accounts for about two-fifths of the country's textile production. Foshan, China's seventh-largest city by GDP, is home to the world's largest wholesale markets for furniture and lighting products. Porto Alegre, the capital of Rio Grande do Sul, Brazil's fourth-largest state, is a major export center for agricultural products from soybeans to leather. While broadly similar in size and growth potential, these cities will probably differ widely in their patterns of consumption, much as their religious, cultural, and regulatory environments do.[3]

Certain cities in emerging markets will become as important economically as some entire countries are today. The GDP of the Chinese city of Tianjin is already the same as Stockholm's. By 2025, it will be as large as Sweden's.[4]

Get closer

The challenge for manufacturing companies isn't just to understand how demand is changing at the city rather than the country level (though research suggests that fewer than one in five executives currently makes location and resource decisions on a city basis).[5] It is also to ensure that production capabilities are developed sufficiently close to a company's most important new markets, since manufacturing is still predominately a local business. Two-thirds of global manufacturing value comes from industries that tend to locate close to sources of local demand, either to reduce transportation costs or to tailor products to local needs.[6]

Bigger manufacturing companies have the freedom to choose where and how they operate across the world. A key challenge for them in coming decades will be not just picking the right mix of production locations but also learning to operate as efficiently as possible in these highly diverse environments. To do so, we believe they will have to focus on three broad sets of skills. First, they must manage the complexity required to meet varied customer needs. Second, they need the organizational capabilities to accommodate that complexity without sacrificing productivity. Third, they must have the manufacturing agility to meet fast-changing customer demand more effectively than their competitors do. Let's look at each area in turn.

Meeting local needs

To meet the needs of consumers in emerging markets, manufacturers first have to understand those needs. To do so, there's no substitute for local insight. Companies clearly need to do their research on the ground to grasp not only the tastes and purchasing behavior of customers in key emerging markets but also the offerings of regional competitors. Moreover, customers aren't the only important stakeholders in these markets. Different regulatory regimes, political environments, input costs, and capabilities in local supply chains can all influence product designs and manufacturing decisions.

Insights must be gathered on a suitably granular level. A McKinsey study, for example, found that segmenting the Chinese market on a national or even a regional basis wasn't adequate. By analyzing consumer characteristics, demographics, government policies, and other factors, the study identified 22 distinct market clusters that can be targeted independently.[7]

3 *Urban world: Cities and the rise of the consuming class.*

4 Richard Dobbs, James Manyika, and Jonathan Woetzel, *No Ordinary Disruption*, PublicAffairs, 2015.

5 *Urban world: Cities and the rise of the consuming class.*

6 James Manyika, Jeff Sinclair, Richard Dobbs, Gernot Strube, Louis Rassey, Jan Mischke, Jaana Remes, Charles Roxburgh, Katy George, David O'Halloran, and Sreenivas Ramaswamy, *Manufacturing the future: The next era of global growth and innovation*, McKinsey Global Institute, November 2012, McKinsey.com.

7 *Manufacturing the future.*

An increasing number of companies are co-locating R&D capabilities with their emerging-market manufacturing facilities.

In emerging markets, the right combination of attributes can make or break products. Nokia achieved a dominant position in the African mobile-phone market, for example, with a simple, robust, and splash-proof handset incorporating a flashlight and a radio. And a manufacturer of consumer products was frustrated in its attempts to enter one emerging market until it conducted detailed on-the-ground research about the product it wished to sell: only then did it learn that consumers there, unlike those in every other country where it sold the product, required packaging that could be reused for other purposes after the contents were used up.[8]

Successful products require local development as well as local research. Shifting development closer to end users simplifies user testing and feedback, and also allows companies to employ designers and engineers who live and breathe the subtleties of local requirements. For these reasons, an increasing number of companies are co-locating R&D capabilities with their emerging-market manufacturing facilities. According to a McKinsey Global Survey, a majority of executives believe their R&D organizations should decentralize, with individual R&D sites operating as nodes in a global network. Thirty-eight percent say their companies plan to increase the offshoring of global R&D.[9]

Organizing for complexity

Regional manufacturing and R&D facilities need talented people. Acquiring and retaining personnel with the right technical skills is a challenge for manufacturers all over the world. But the problem is particularly acute in emerging markets, which may lack the educational infrastructure or pool of competitors to provide the right people.

Overcoming personnel shortages requires a systematic, multifaceted talent-management plan. Companies may need to bring in experienced people from elsewhere in their networks to assist in training and developing new staff. They can partner with local industry associations and academic institutions to create suitable training courses ensuring a supply of new recruits with the right basic skills. "Aviation Valley," in southeastern Poland, for example, is home to more than 100 companies that account for 90 percent of the country's aerospace sector. The nearby Rzeszów University of Technology has become a key supplier of the sector's engineers, designers, and technicians, especially staff qualified to run the advanced computer-numerical-control (CNC) machine tools widely used in the sector.[10]

8 *Manufacturing the future.*

9 *Manufacturing the future.*

10 Key National Cluster: Aviation Valley, dolinalotnicza.pl/en.

Such clusters have the advantage of increasing scale and reducing the cost of education and training facilities. But companies must ensure that their value proposition for employees is strong enough to minimize attrition to competitors.

Organizations in emerging markets must also be flexible. Products tuned to the diverse needs of local markets may, for example, use different materials and production methods, so manufacturing organizations in such a location may not look like their counterparts elsewhere. They need to be agile, too. Consumption patterns in emerging regions can be volatile and fast evolving, and companies must therefore respond quickly to keep up. That will require not only flexible manufacturing technologies (discussed below) but also flexible approaches to staffing (for example, the thoughtful use of contract and temporary labor to balance the ebbs and flows of demand).

Manufacturing agility

When companies design manufacturing systems for emerging markets, they need to balance costs, flexibility, and the ability to adopt standard methods and practices across their worldwide operations. Manufacturers in emerging markets must make the most of the additional agility inherent in their production systems: lower personnel costs will continue to let them adopt more labor-intensive methods, for example, so they can adjust the number of operators and relocate resources in response to changing demand.

Advanced design and manufacturing technologies will also play a critical role. In the design of production facilities, for example, modular approaches can reduce capital expenditures and improve flexibility, so companies can establish production quickly and then scale it up cost effectively, as demand requires. In the biopharmaceutical industry, modular manufacturing plants make it possible for new production facilities to become fully operational 12 months after the start of construction (compared with three to seven years for conventional facilities). Such plants are more energy efficient and less costly to build, as well.

The right product designs also help companies to balance standardization and scale with appropriate adaptations to local needs. Platform- or module-based approaches, like those common in the automotive industry, make it possible for companies to use standard-part product architectures in multiple markets and to add or remove features or to adapt customer-facing components to suit local markets. Platforms make companies more agile, too, so it is easier for them to alter the mix of final products according to demand.

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For manufacturers, emerging markets have become a significant source of growth. Capturing it will require companies to think and act more globally, and more locally, as well. To do so, they will need to invest in a range of areas. They must build a detailed, granular picture of varying customer requirements. They must develop truly global talent pools. And they must build agility into their technologies and processes to match rapidly evolving—and increasingly diverse—demand. The most successful organizations will manage to combine efficiencies of scale and standardization with the flexibility and insight to meet diverse customer needs.

We are living in a digitally disrupted world

Andreas Behrendt, Shyam Karunakaran, Richard Kelly, and John Nanry

Will the inundation of digital data power your business, or wash it away?

Andreas Behrendt is a partner in McKinsey's Cologne office, **Shyam Karunakaran** is a senior implementation coach in McKinsey's Cleveland office, **Richard Kelly** is a partner in the Stamford office, and **John Nanry** is an associate partner in the Chicago office.

Data levels are rising. The pipelines are in place, and the valves are starting to open. Manufacturing companies now face a stark choice: harness the power of data to redefine their offerings and transform the speed, efficiency, and flexibility of their operations, or lose out to competitors that do.

In recent years, the digital data generated across manufacturing value chains have grown dramatically in volume and variety. Those data come directly from smart products, customers, suppliers, enterprise IT systems, connected production equipment, the core manufacturing processes, and a host of external sources.

But the sheer scale of the influx has threatened to overwhelm organizations. The cost and complexity of storing, communicating, and analyzing the data generated in production environments has left most companies taking advantage of only a tiny fraction of them, whether in running and supporting their operations or in making decisions for the wider business.

That situation is changing fast. The cost of sensors, network hardware, computing power, data storage, and communication bandwidth have all fallen dramatically. The performance of data-analysis systems has increased, thanks to advances such as in-memory databases and artificial-intelligence techniques. Cloud computing systems and standard interfaces have made powerful applications cheaper and faster to implement at scale. Wireless communication and handheld or wearable devices have made access easier at the manufacturing front line or in the field.

No part of the modern manufacturing organization will be remain untouched by this flood of data, and digital-manufacturing techniques keep getting better while costing less. These twin realities are redefining the business case for digital solutions everywhere.

New insights to drive operations performance

To be competitive, manufacturers need to control their costs, maximize their productivity, and eliminate errors. Digital technologies are yielding significant improvements in all three dimensions, both inside the organization and with outside partners.

Maximizing productivity

Digital tools are boosting frontline productivity by giving production staff immediate, effortless access to the information they need to do their work. At one global aerospace company, staff on a wiring-harness production line use augmented-reality glasses to guide assembly operations. The innovation reduced the time taken to complete each harness by 30 percent and cut the error rate from 6 percent to zero.

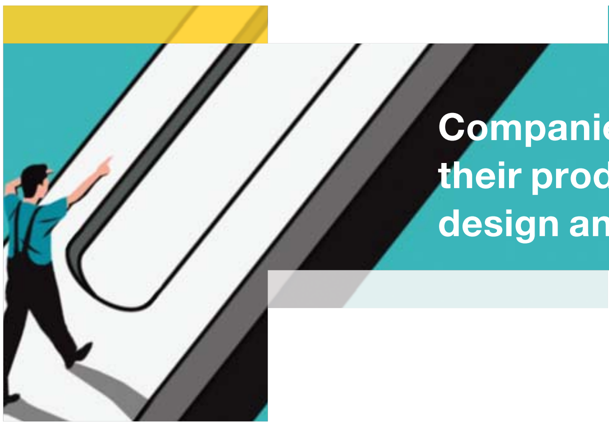
The ability to monitor and analyze multiple machine variables allows companies to find previously hidden ways to improve the performance, reliability, and energy efficiency of their assets. An established European maker of specialty chemicals used neural-network techniques to improve its industry-leading performance, reducing raw-material waste by 20 percent and energy cost by 15 percent (see “Automation, robotics, and the factory of the future” article on page 67).

Sensors can also deliver vital insights into machine health, showing when bearings require lubrication or are wearing out, for example. This allows companies to undertake preventative maintenance, reducing downtime and extending the life of their assets.

Advanced data-analysis techniques are helping companies better understand and control the intricacies of their production processes. The result is better consistency, higher productivity, and superior quality. One major biopharmaceutical company used such techniques to tackle highly variable yields in vaccine production, leading to a major expansion in production capacity with no additional capital outlay.

Breaking barriers, inside and outside the company

Companies have used digital models of their products to accelerate and improve design and development for many years. Now those techniques are being extended to incorporate models of the entire production process. These “digital twins” allow companies to optimize plant layouts and to design, test, and validate production operations before any manufacturing equipment is in place. This is especially relevant in prototyping new products, when experts from product design, procurement, and manufacturing test a new design’s manufacturability and solve quality and productivity issues upfront.



Companies have used digital models of their products to accelerate and improve design and development for many years.

The insights provided by advanced digital technologies don't stop at the factory gate. The Internet allows companies to integrate their own operations, and those of their customers and suppliers, to an unprecedented degree. One major oil company now monitors all its offshore drilling and production operations in the Gulf of Mexico from a single control room, for example. Manufacturers of equipment for aerospace, mining, and construction sectors using data generated by their products during operation to inform aftersales service and support activities—and to inform the design of future product generations.

Automotive companies are taking advantage of data generated both upstream and downstream to manage and predict future demand in hitherto unseen levels of detail. By combining information on supplier activities (even several tiers up the chain) with social-media-generated consumer insights, automakers can now better predict which options customers are more likely to choose. Getting that calculation right significantly reduces lead times and inventory costs.

Greater flexibility

Digitization doesn't just allow companies to get more out of their existing production processes. It is also changing the way manufacturing is done.

Robotics and automation

Cheaper, more powerful, and more highly integrated robotics and automation systems mean that much work that was once done by people can now be completed by machines. That is enabling some manufacturing activities to move closer to their customers, while also reshaping manufacturing in low-cost regions. China, a country that built its manufacturing base on a ready supply of low-cost labor, is expected to have one-third of the world's industrial robots by 2018.

Companies also have more choice in how they apply robotic systems. While an increasing number of manufacturers are choosing an extremely high degree of automation, operating "lights out" factories with hundreds of robots and a handful of human operators, the development of new safety technologies means robots can also be deployed on production lines alongside human operators (see "Automation, robotics, and the factory of the future" article on page 67).

Production agility

Advanced digital manufacturing systems also transform the agility of production systems. Operating characteristics that were once hardwired into machines or set manually by operators can now be encoded digitally and adjusted at will.

The implications for manufacturers are profound. Production lines can continually adjust their speed to match changing customer demand. Multiple products can travel down the same lines in arbitrary sequences without the need for manual tool changes. And products can be customized on the fly to meet specific consumer requirements. One food company developed an online configurator allowing customers to personalize the design of its packaging. The technology boosted sales by 20 percent among users of the service.

3-D printing

In traditional, high-volume manufacturing techniques, the final geometry of components is determined by the shape of the molds and dies used to form them. Some advanced manufacturing technologies allow even this information to be moved from the physical to the digital realm. Additive manufacturing systems, once the preserve of prototyping and very-low-volume production applications, are now being used to produce unique products in the hundreds or thousands. 3-D printers have been used to manufacture more than 80,000 titanium hip-joint implants, for example. Car manufacturers have already used 3-D printing technologies for motor-sports applications and the production of spare parts for out-of-production models. Many are now investigating the application of the technology in serial production applications to define the variant as close as possible to the point of fit, saving significant logistics cost.

3-D printing technologies are also letting manufactures create products that could not be manufactured at all using conventional technologies. In the pharmaceutical sector, for example, researchers are experimenting with such systems to manufacture pills with a geometry that fine-tunes the delivery of a drug to suit the needs of specific patients.

Disruptive business opportunities

Digital technologies are creating entirely new business opportunities and challenges for manufacturers. Digitization is eroding traditional barriers to entry in many sectors, enabling the development of entirely new categories of products and creating new alternatives for customers.

Current trends in the automotive industry provide a glimpse of the potential scale of the disruption from these effects. The growing importance of software in the vehicle itself is creating opportunities for new competitors to enter the industry— such as Google, creating new product offerings built on its digital expertise. Other new entrants are changing the business model entirely, with ride-hailing giants Didi Chuxing and Uber allowing customers to access mobility as a service. Established carmakers are scrambling to keep up with this rapidly changing situation, stepping up their internal R&D efforts in the digital space and making a spate of acquisitions and investments in companies with expertise in autonomous driving or mobility as a service.

Among traditional manufacturing companies, meanwhile, digital technologies are creating opportunities for new product types and new value propositions. Manufacturers of electric motors, bearings, and other basic building blocks of manufacturing technology are helping their customers reduce energy costs, increase uptime, and extend product lifetimes through the integration of smart sensors and monitoring technologies, for example. Alongside the hardware, many are also offering the expertise needed to monitor, analyze, and interpret the resulting data, a shift that creates useful ongoing service revenues and builds a closer and more strategic relationship with customers.

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Today's flood of digital data is reshaping the manufacturing landscape forever. While long-established territories may disappear, new ones are emerging all the time. We hope that they will help you navigate the threats and opportunities facing your business in this turbulent time.

Same lean song, different transformation tempo

David Beaumont, Joël Thibert, and Jonathan Tilley

Transformation isn't new to manufacturers—but sustained transformation is rare. It's even harder at today's fast pace, which calls for a different transformation approach.

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The fundamentals of making products remain the same now as ever. First, create something of sufficient value that customers are willing to pay for at a price higher than the cost of production. Next, keep pushing that cost lower while preserving—or, better still, increasing—value for customers. Rinse and repeat.

Much easier said than done, of course, especially over time. Companies may misunderstand what customers value, so that a highly refined, high-quality offering finds too few customers to become an economic success. Or the offering may be exactly what customers want, but the company fails to deliver it at the right time or in the right way.

Avoiding these outcomes is a principle reason companies hire leaders and managers, and invest in transforming themselves according to continuous-improvement disciplines. Those remain the same as ever, too, although our understanding of how they work has deepened. There are the technical systems that help work get done: the end-to-end process diagnostics, workload-allocation systems, and total-quality measurements. Management infrastructure ensures that leaders spend time seeing the work get done, that performance is constantly assessed and acted on, and that problems get raised and addressed. And finally, there are the mind-sets and behaviors, and the cycles of coaching, capability building, and feedback that help people get better at what they do.

So the song is the same. Unfortunately, so is the ending, with a key change from major to minor as initial optimism fades to disappointment. In a 2015 survey, only 26 percent of executives characterized their organization's most recent transformation as successful.[1] That's actually a decrease

1 See "How to beat the transformation odds," April 2015, McKinsey.com

from the famous "three in ten transformations fail" finding that Harvard Business School professor John Kotter (now retired) published more than 20 years ago.[2]

What has changed? The tempo. New technologies, new customer expectations, and new sources of competition—often from players that didn't exist five or even three years ago, and that follow entirely new business models—together are leaving companies with less and less time to react. Not only must they change but they must also do so quicker, faster, deeper, and with much greater odds of success.

The pace of change has quickened

Manufacturers are used to change: the survivors have transformed themselves time and again. They adapted to surging demand as economies boomed. They adopted production innovations such as lean management. They built new, global networks to take advantage of economies of scale and scope.

But those changes took years—sometimes a full generation—to take hold. Digital technologies won't allow that luxury. Think of the contrast between an automobile platform, whose basic mechanics may remain essentially the same for decades, with a mobile-phone operating system, which changes every few months, if not weeks.

That's the pace Tesla is now nearing with its vehicles, whose software updates bring new features several times a year. And that evolution represents only a small part of the new digital landscape that is disrupting value chains everywhere. Even where the competition is not yet visible, technology is changing customer expectations so quickly that high performers have a hard time keeping up.

Manufacturers are therefore having to rethink almost every aspect of the way they do business: from what customers want and how offerings should be designed to where components should be sourced, which manufacturing methodologies should be used, and how products should be sold and serviced. It's as if all of the changes they previously made are all happening again—and at the same time. And they must do so under enormous scrutiny, with activist shareholders demanding dramatic action and proving perfectly willing to bring in new leadership in order to get it.

What must change about change

Manufacturers must bring everything they know about transformation to bear, and then some, given that historically so few transformations have succeeded. They must begin by understanding why the traditional approaches have fallen short.

Our work with clients highlights three main problems. The first is a tendency to focus on the tools that support change, rather than on the core disciplines that the tools are designed to reinforce. The second gap centers on leadership, which too often proves inadequate to support the demands that transformation requires. And the third—and likely most important—reason is that transformations are too often thought of as projects with a clear timeline, including a beginning and an end.

In other words, transformations fail because leaders and managers misunderstand what "continuous improvement" truly means. It means that the improvement cycle never ends and instead becomes core to the way the company operates.

What a different approach looks like

The alternative comprises **four major components**. It starts with **high aspirations**, with an emphasis on quantifiable ideas that can be sized with some degree of confidence and that affect the bottom line quickly. Next, a **rigorous process** governs all of the initiatives and projects that come together in transformation. The third requirement is **tighter alignment**, both among

2 See John P. Kotter, *Leading Change*, Boston, MA: Harvard Business School Press, 1996.

the leaders in setting the organization's direction and between the leaders and the rest of the organization, who must see that direction turn into tangible goals they can work toward. Finally, there's the question of **speed**. Once an idea is sized and the risks assessed at a high level, the bias must be toward piloting quickly and making rapid adjustments as needed, rather than holding out for perfection.

No mountain high enough: Aspirations to give inspiration

Few transformations achieve more than the goals their leaders set—especially in a typical risk-averse business context. That's why high initial ambitions are so crucial. The instinct among leaders and managers to underpromise and overdeliver is so strong that only the strongest signals from the top can overcome them.

Moreover, there's the practical reality that fulfilling high goals is really difficult, typically requiring leaders to shepherd hundreds, or even thousands, of initiatives through to completion. Nevertheless, the experiences of several organizations show that it's possible, provided leaders plan for serious attrition rates. A recent analysis of high-stakes transformations[3] found that on average, initiatives lost about 70 percent of their value between the initial idea stage and final tallying of the benefits. Accordingly, in order to reach a given target, a company will need a set of initiatives whose estimated value is at least three times the target amount.

That may not be possible at the very start. Instead, leaders will likely need to plan to "go back to the well" periodically to find additional opportunities. The consumer-products company, for example, set a goal of almost half a billion dollars in savings, and had to go back to the well several times in the first year to meet its goal successfully.

Rock steady: Rigorous structure for continuous improvement

Of course, meeting an initial target—even an aggressive one—is only "improvement." As important as that is, over time, what matters even more, is "continuous." That takes rigor, a combination of processes and tools that constantly reinforce a culture that seeks out ways to get better.

Some of this infrastructure is built as the organization progresses toward its initial goal. A survey of executives[4] published in 2015 asked about 24 practical actions that support organizational transformation, ranging from open communication by senior managers about the transformation's progress to capability-building programs for employees. The crucial finding was that the more actions an organization took, the better its odds of success in its transformation (Exhibit 1).

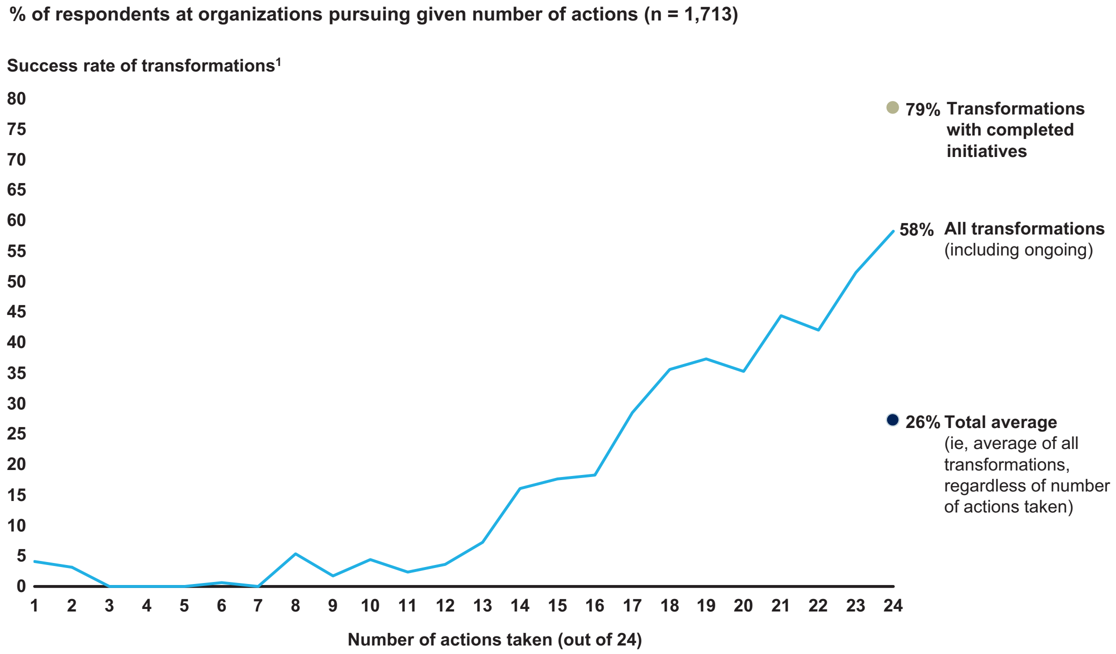
More specifically, the organizations that succeeded in transforming themselves were those that planned in advance for continuous improvement. At these organizations, employees understood how their work related to the organization's overall vision, everyone was actively engaged in identifying errors and defects, best practices were systematically shared and improved upon, the organization actively developed its people, and everyone was fully engaged in meeting targets (Exhibit 2).

But once the most intensive period of transformation is complete, progress may start to erode. Often the proverbial low-hanging fruit have been gathered, meaning that further improvement opportunities are harder to see and to achieve. Leaders may be tempted to reclaim time for problem solving, coaching, or best-practice codification to meet short-term goals. The unintended message: the changes we made were only temporary. Now things are getting back to normal. Before long, so does the organization's

3 http://www.mckinsey.com/business-functions/operations/our-insights/keeping-transformations-on-target

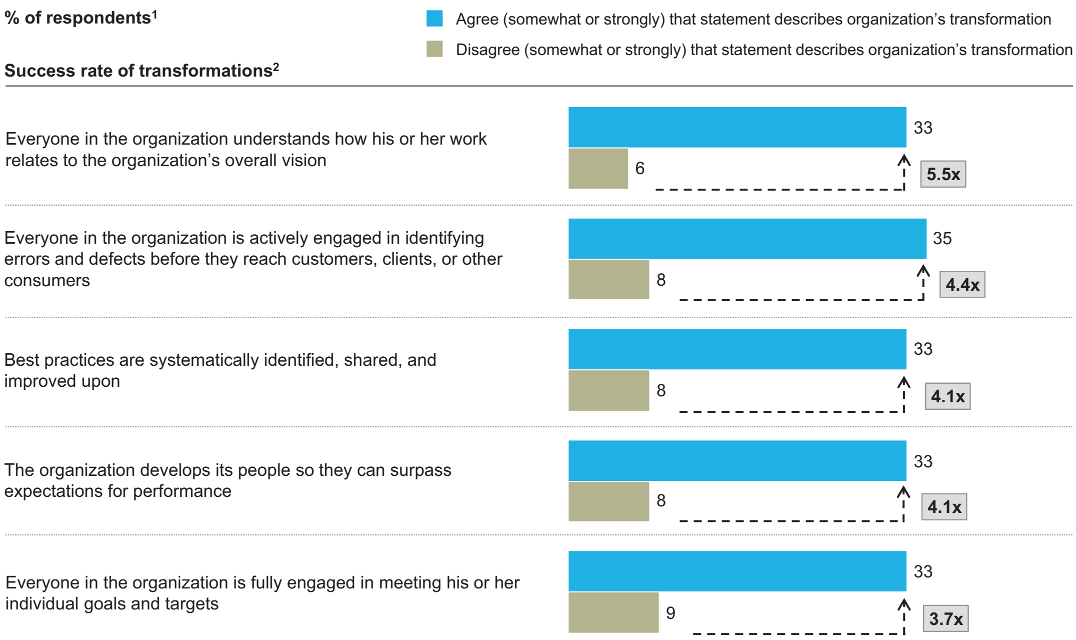
4 http://www.mckinsey.com/business-functions/organization/our-insights/how-to-beat-the-transformation-odds

Exhibit 1. When organizations follow a rigorous approach to transformation and take more actions, the overall success improves dramatically.



1 Respondents who report success say the transformations they are most familiar with have been very or completely successful at both improving performance and equipping the organization to sustain improvements over time.

Exhibit 2. When organizations plan for continuous improvement after a transformation, the likelihood of overall success also increases.



1 Respondents who answered "don't know/not applicable" are not shown.
2 Respondents who report "success" say the transformations they are most familiar with have been very or completely successful at both improving performance and equipping the organization to sustain improvements over time.

performance—to its pretransformation levels, or even lower.

Avoiding this vicious circle requires organizations to adhere to several interlocking disciplines. At a large state-owned enterprise, for example, performance metrics now focus not only on *what* people achieve but also on *how*—meaning how well they adhere to the organization's new way of working. Achieving good numbers the wrong way is not a career-building move.

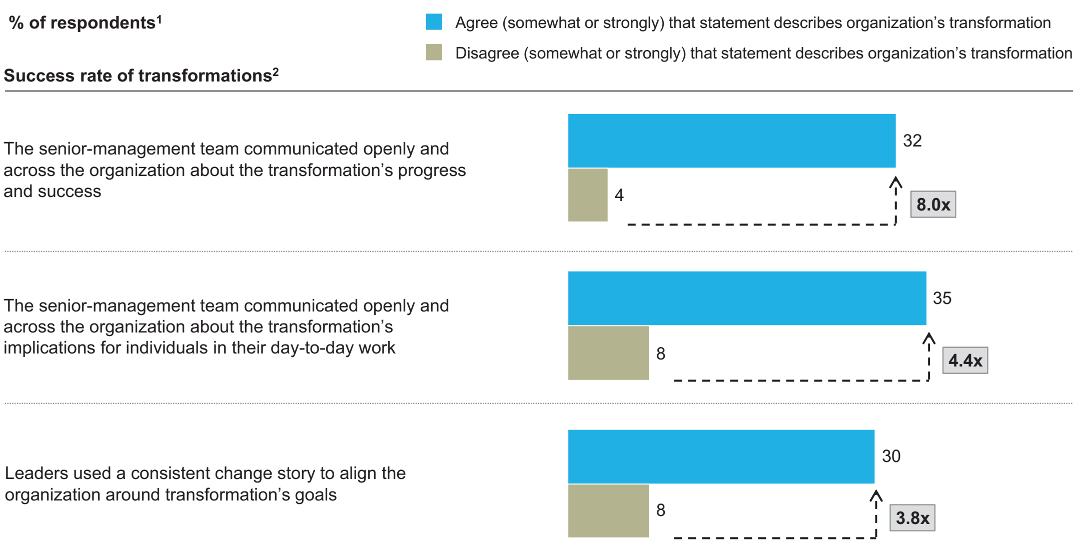
Other organizations, such as a food manufacturer with more than 100,000 employees, have adopted easy-to-use tablet-based tools that guide leaders and managers through their workdays, so that they can analyze data to ask good questions at morning huddles and make sure to complete their process-confirmation meetings in the afternoon. And a financial institution's senior executive sends video updates to all employees sharing his calendar and celebrating when people eliminate resource-wasting meetings.

Everyday people: Align, energize, and upgrade leadership capacity

The 2015 survey confirmed what many leaders intuit: a transformation must center its efforts on helping people change. For example, communication is critical. Transformations where senior leaders communicate openly about progress, success, and implications for individuals in their day-to-day work were between roughly four and eight times as likely to succeed as transformations where there was little or no communication (Exhibit 3).

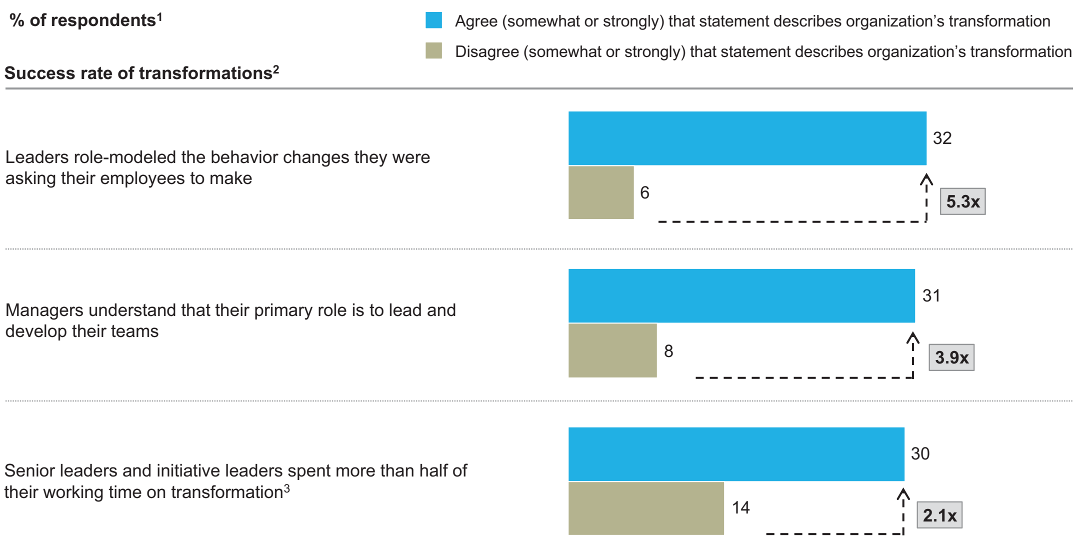
Accordingly, the role of the leader is crucial, and not just for official communication. What leaders do in their day-to-day work lives matters at least as much: for example, role modeling expected behaviors, demonstrating commitment to

Exhibit 3. Communication—especially about progress—is the action that links most closely with success.



1 Respondents who answered "don't know/not applicable" are not shown.
2 Respondents who report "success" say the transformations they are most familiar with have been very or completely successful at both improving performance and equipping the organization to sustain improvements over time.

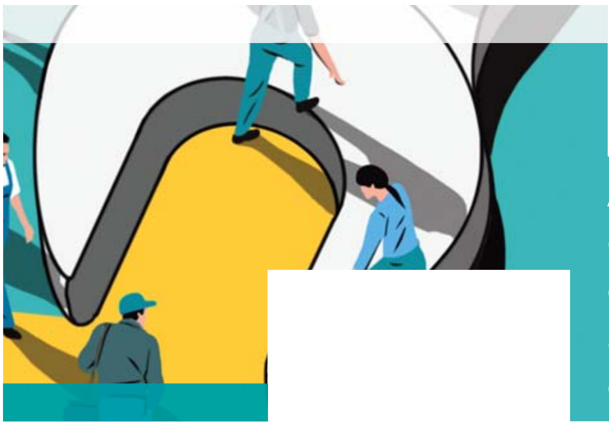
Exhibit 4. Transformations are more likely to succeed when company leaders are active and involved.



1 Respondents who answered "don't know/not applicable" are not shown.
2 Respondents who report success say the transformations they are most familiar with have been very or completely successful at both improving performance and equipping the organization to sustain improvements over time.
3 In a separate question from those asking about the 24 actions, respondents who identified themselves as senior leaders or leaders of transformation initiatives were asked how much of their overall time they spent working on the initiatives.

developing their teams, and even simply spending sufficient time on the transformation all had a major impact toward success (Exhibit 4).

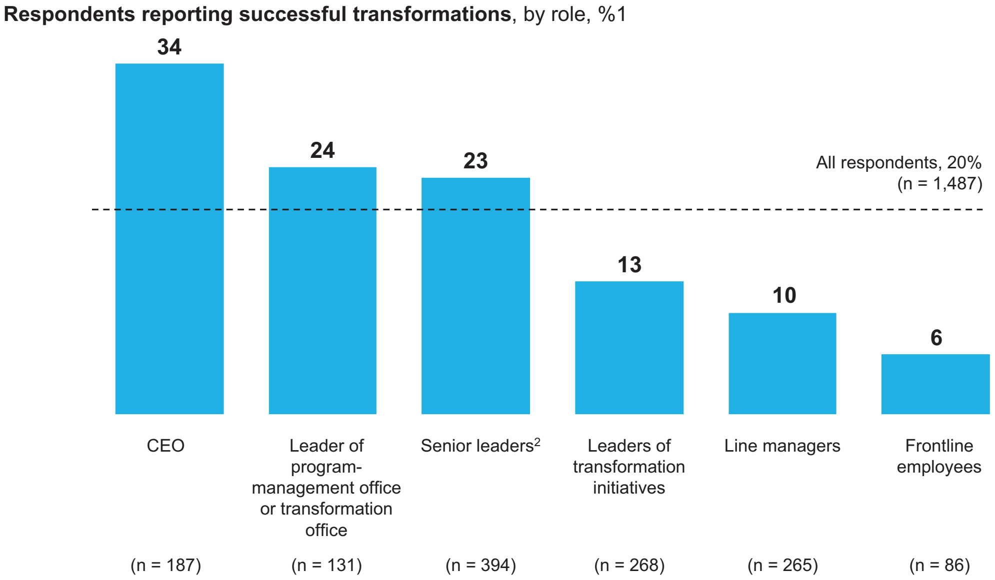
On the other hand, leaders must be more than simply visible. A 2016 survey of more than 1,600 transformation participants found that even in failed transformations, more than half of CEOs were very or at least somewhat engaged—suggesting that the CEO's role is necessary but not sufficient.[5] It turned out that that an even more critical differentiator than the engagement of the CEO in a transformation was the engagement of the front line. In successful transformations, 73 percent of respondents reported visibly engaged frontline employees, compared with just 46 percent in failed transformations. Engaging the front line is notoriously difficult, though, and



An even more critical differentiator than the engagement of the CEO in a transformation was the engagement of the front line.

5 See "The people power of transformations," February 2017, McKinsey.com.

Exhibit 5. Across roles, line managers and frontline employees are the least likely to report transformation success.



1 A successful transformation is one that, according to respondents, was very or completely successful at both improving organization's performance and equipping organization for sustained, long-term performance.
2 Includes chief human-resources officers.

it shows: of all respondents, frontline employees and line managers were the least likely to report transformation success (Exhibit 5).

Signed, sealed, delivered: Balance speed and discipline

Keeping up the pace is an essential element of the successful high-stakes transformations[6] studied earlier this year. Leaders maintained an aggressive pace of weekly reviews so they could oversee progress. Each initiative passed through a series of well-defined stage gates, with implementation keyed to a schedule of milestone reviews. Finding the right balance of setting milestones was essential: too many risked micromanaging initiative owners, who would spend too much time preparing for milestone assessments; too few, however, meant owners might not reveal problems until it was too late for leaders to provide support.

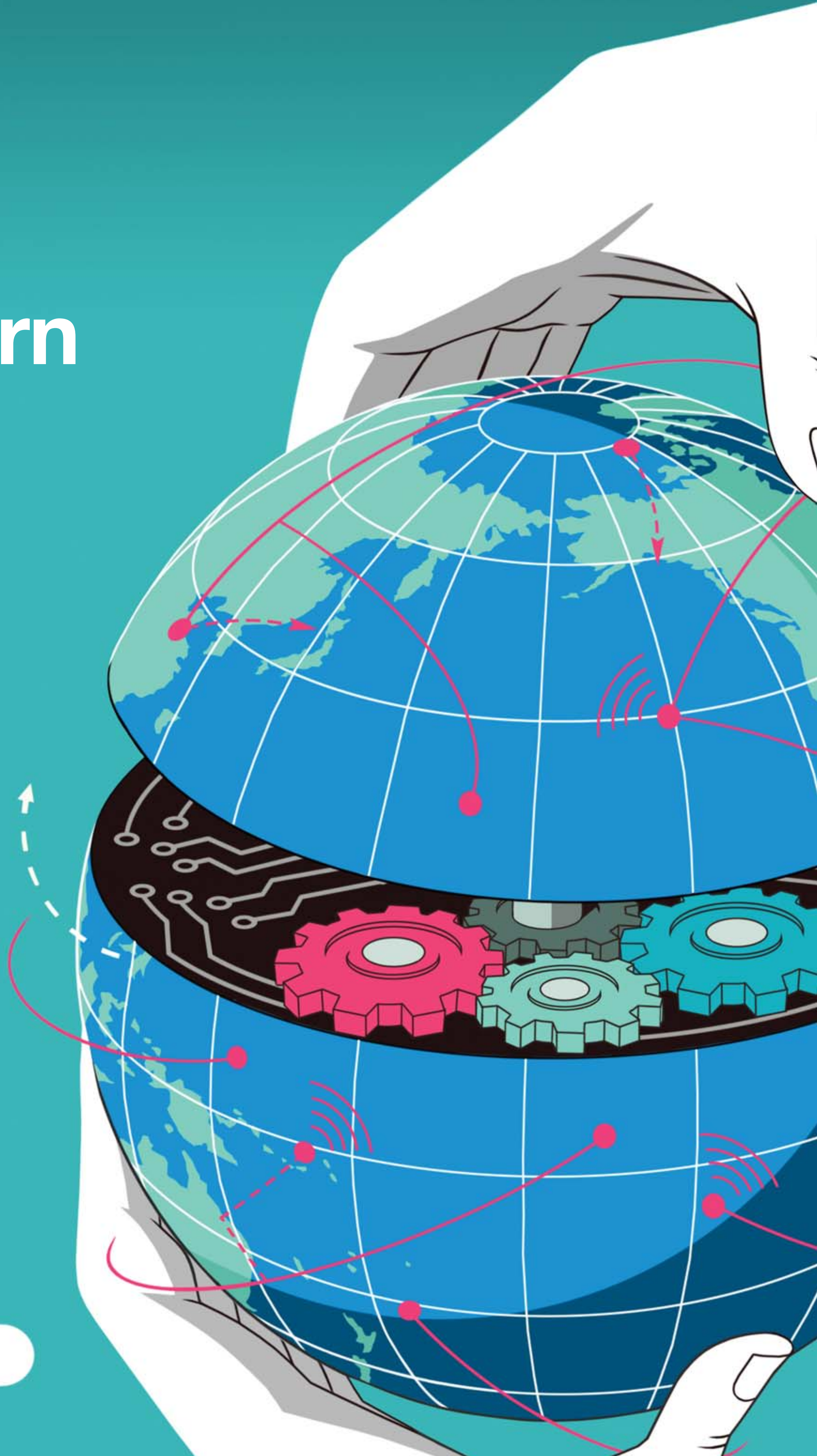
The happy medium took advantage of the weekly meeting cadence. Even between milestone reviews, every initiative was expected to make at least some progress each week, which the owner would report on briefly at the meeting. That encouraged owners to discuss signs of potential problems when they were still happening early enough to be fixed relatively easily.

□ □ □

In the end, the winners will be those who are able to adapt their technical systems to changing consumer demands, leverage their management infrastructure to drive both top-down and bottom-up innovation and mobilize their work force around common business objectives.

6 http://www.mckinsey.com/business-functions/operations/our-insights/keeping-transformations-on-target

Modern vision



Manufacturing network strategy in a world of unprecedented change

Tony Gambell, Parag Patel, and Anand Shekhar

A best-seller from two decades ago proves surprisingly relevant for today's manufacturing footprint questions.

Tony Gambell and **Parag Patel** are partners in McKinsey's Chicago office, where **Anand Shekhar** is an associate partner.

In the top-selling motivational business book *Who Moved My Cheese?*, Dr. Spencer Johnson describes two mice and two people who live in a maze and search for cheese. Through a series of allegorical scenarios, Johnson articulates several truths about change and suggests how managers should consider the organizational psychology associated with change. We believe the same principles are transferable to the topic of manufacturing network strategy.

For at least half a century, companies have developed their manufacturing network strategies according to relatively stable assumptions, often on multidecade time horizons. Decisions to make major investments in brick-and-mortar sites were typically straightforward, albeit nontrivial. The optimization of total landed cost was the dominant objective, and most network changes were motivated by the pursuit of low-cost-country arbitrage opportunities.

Today, the same economic principles still guide decision making and are top of mind for most manufacturing executives; however, many additional factors now render decision making much more complicated. Companies need not only to drive cost optimization, but also to fend off the headwinds of softening growth in developed markets, ever-rising factor costs, global regulatory and tariff uncertainty, and disruptive technologies. Heuristics and algorithms provide only a baseline answer, upon which a company must build strategic alternatives.

The world is changing dramatically, and so, too, must the lens through which we perceive manufacturing network strategy. The change principles outlined in Dr. Johnson's book provide a framework for guiding this transition.

Change happens

Through its manufacturing network strategy, a company aims to establish a web of factories that best serve its customers by providing the lowest-cost, highest-quality products and by meeting service-level requirements for lead times—all while satisfying the company's own aspirations. These usually include minimizing landed cost in order to deliver the greatest return to shareholders, providing predictability and security to the workforce, and ensuring reasonable fixed costs related to any changes to network design (such as consolidation, transition, and investment). Furthermore, the company must pursue these objectives while defending against competitive threats.

When optimizing these objectives, companies typically assume the decision factors will be "frozen" for a reasonable amount of time, often three to five years. In highly capital-intensive industries, it may be much more: the investment horizon for a chemical company's ethylene crackers is often 10 to 15 years. At the other extreme, an apparel maker might change locations every two to three years.

Today, consumer needs, factor costs, and factory economics are all changing—and faster than most executives have expected. Furthermore, they promise to change even more in ways we cannot fully anticipate.

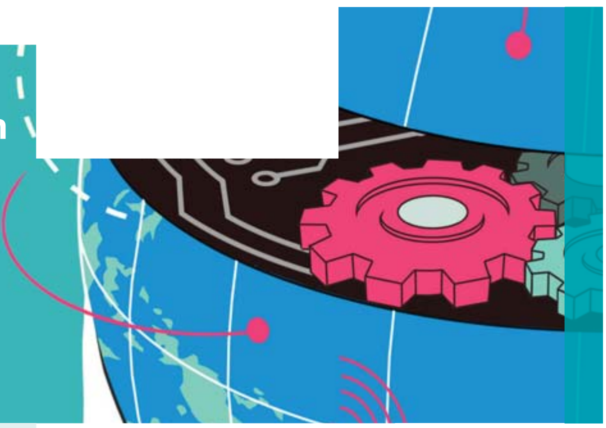
Anticipate change

In the past, the most unpredictable factor that manufacturing network strategies had to accommodate was uncertainty of demand. That's still important, but today change is coming from many additional sources all "moving the cheese" at once: from technological advances in equipment to digital and analytic techniques that are spurring innovation. New entrants, potentially disruptors from outside the industry, are seeking to take advantage of sleepy incumbents. And governments are considering or implementing changes to taxation, trade, and labor policies. Let's explore each of these changes.

Technology. Increased use of digital and analytics is already improving manufacturing productivity, efficiency, and effectiveness. The Internet of Things (IoT) and big data analytics are not only increasing responsiveness, but also improving outcomes, such as significant yield increases that have resulted from using advanced analytics to optimize input parameters. Digital advances and better human-machine interfaces will enhance problem solving, operator training, and overall visibility into performance. At the same time, lower automation costs are fundamentally changing discussions about when and how to use automation in manufacturing.

Changes in equipment use and design also are raising productivity. Additive manufacturing

Today, change is coming from many additional sources all "moving the cheese" at once.



(or 3-D printing), for example, could intensify localization in specific applications, such as spare-parts manufacturing. Installing sensors on manufacturing-line equipment will make significantly more data available, increasing equipment uptime through better predictive maintenance.

New entrants. Disruption is also coming from innovative players, often outside of incumbent industries, that are well equipped to take advantage of technology trends. Recent examples include Amazon's entry into brick-and-mortar retail with pop-up stores promising more-efficient shopping experiences, IBM's foray into healthcare technology with IBM Watson Health, and Uber's move into food delivery with the launch of UberEats.

Government policy. Finally, governments are taking a closer look at a wide range of measures that could upend long-unquestioned orthodoxies underpinning manufacturing network decisions. Among the furthest-reaching are proposed changes in corporate-tax structures, with potentially significant effects for manufacturers. In addition, major policy changes in global trade are affecting perceptions of manufacturing companies, whose decisions are more public—and therefore more constrained. And new regulatory provisions governing issues such as minimum wages and worker mobility add further wrinkles to strategic planning.

Monitor change

By now you may have accepted that change is imminent and must be anticipated, but can you anticipate everything? No. In a world defined by uncertainty, manufacturers must isolate the factors that matter uniquely to their businesses and focus more on the cost sensitivity of the outcome.

This means paying much more attention to the sensitivity of the network-optimization scenarios and understanding how different factors influence each other and the outcome. For some companies, managing capital intensity is the most important concern. For others, availability of skilled labor or relative factor-cost fluctuations will matter most.

One consumer packaged goods company's manufacturing economics were most sensitive to labor costs. Given the expected market mix, the company could produce in two countries. In the end, the relative factor-cost fluctuations between the two supply countries mattered more than the sensitivity of costs between the supply country and the demand market. This gave the company a strategic option to shift production volumes between two sources and recognize the labor-cost arbitrage every time.

Traditionally, network reviews are triggered by a major strategic action or event (such as a spinoff or acquisition) or conducted as part of a four- to five-year strategic review. Increasingly, companies are reviewing their network view every year. In the end, companies still need to make bets and take calculated risks, but as the frequency of the bet taking increases, companies are better able to dampen the fluctuations.

Adapt to change quickly and change

Given the magnitude of change today, manufacturers that are willing and able to adapt to the change quickly can capture significant first-mover advantages, such as in reputation, revenue growth, or standing with governments. Moreover, many of the forces of change, such as advanced manufacturing technologies and new digital capabilities, are creating new pools of talent that fast movers are better at attracting.

Most important, the ability to capitalize on changes quickly will allow companies to tap into new sources of value that boost their bottom lines. New factor-cost opportunities will keep emerging, as will microclusters offering deep talent specialties, such as Shenzhen or Tel Aviv in high tech and Boston in biotech. Low-cost natural gas is promoting a boom in downstream petrochemical production in North America, with up to seven million metric tons of ethylene capacity forecast to be added by 2019.

Although traditionally manufacturing has not been driven by technology innovation, many companies are now fostering innovation with strategic bets. Johnson & Johnson's Janssen pharmaceutical business, for example, has said that by the mid-2020s, 70 percent of its products will be manufactured via continuous manufacturing.[1] Meeting ambitions such as these will require new organizational capabilities and infrastructure to support innovation, with many companies creating roles such as for chief digital officers or heads of analytics and digital.

Enjoy change

Even after identifying the actions to take and the mind-sets to move, manufacturers still must ask how managers can motivate their people to embrace (and even enjoy) this cycle of ever-quicker responses to change.

Looking to history

Companies that have reinvented themselves have profited handsomely, while there are multiple examples of companies that failed to adapt, leading to their eventual demise. Blockbuster Entertainment, once the largest video-rental company in the United States, proved unable to respond quickly enough to competition—especially from newly viable video-on-demand services—and entered bankruptcy less than a decade after its peak. By contrast, Blockbuster competitor Netflix transitioned from mail-based DVD rentals to video on demand to becoming a content creator in its own right.

Similarly, Toyota provides an example of adaptation in automaking, from the creation of its production system (the basis for much of today's lean management) to its expansion of global production, to its early commitment to hybrid powertrains. And oil refineries have increased their built-in ability to manage complexity, which enables rerouting of production capacity to the most profitable products and encourages continuous cost optimization.

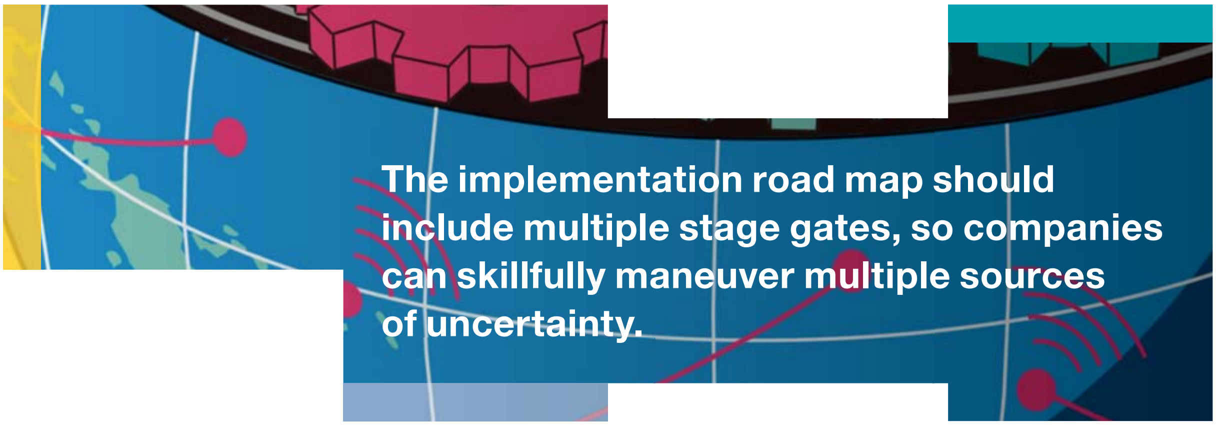
Apart from the long-term strategic wins, organizations that embrace this philosophy of frequent change experience almost an endorphin rush, just as occurs when a person exercises vigorously. Talented employees feel suitably challenged and motivated by opportunities for advancement, and they adopt an external focus—examining effects of changes on customers and competitors, rather than being bogged down in internal considerations.

Making change happen

As a practical matter, leaders and managers must take several steps to help their organizations embrace change as a force for good. First, they must develop a convincing change story—a strong narrative showing not only that the transformation is absolutely necessary, but also that it is achievable, with lighthouse examples of successful change from within the company or at least the industry. Next, they must disseminate and communicate the story, reaching out to key influencers (including a mix of the risk-averse and those more open to change) through cascaded communication by top- and midlevel leaders. Rewarding and recognizing team members who are eager to embark on the transformation journey helps the rest of the organization embrace this goal. And last, it is critical for leaders to role-model the new philosophy of embracing change by taking bold bets, encouraging external focus, and talking about changes and their implications.

Taken together, these steps could allow managers to succeed at transforming their organizations into a lean and nimble machine that not only is able to respond to change, but also enjoys the challenge it provides.

1 https://www.pharmamanufacturing.com/assets/Media/2016/1604/Janssen-CM.pdf



The implementation road map should include multiple stage gates, so companies can skillfully maneuver multiple sources of uncertainty.

Be ready to change quickly—and enjoy it again

In the current era of increased uncertainty, leaders need to maintain multiple options for responding to changing conditions. Increased optionality can be built into both the network design and the implementation road map.

To meet expectations for shorter lead times, companies must design their manufacturing networks to meet different levels of lead-time requirements, optimizing for efficiency in the short term and agility in the longer term.

Agility in design

To meet shorter lead times without adding cost, manufacturers can use three potential levers.

Late-stage differentiation in distribution. Although higher inventories may be required, building a more robust delivery infrastructure, such as by establishing partnerships with e-tailers, can help drive late-stage differentiation. But companies must beware that the partner can readily become a competitor in its own right.

Supply-chain localization. Manufacturers can shorten end-to-end lead times by establishing in-region supply chains while providing options for backups from outside the region.

Multi-capability sites. Many plants are monolithic, capable of manufacturing only a limited set of products under a single capability. This approach results from a desire for scale under an operations-centric view that scale will always reduce costs. Equipping plants with multiple (even redundant) capabilities, as at oil refineries, can build more optionality into the network structure and accommodate changes in the production plan without additional investment.

Agility in implementation

The implementation road map should include multiple stage gates, so companies can skillfully maneuver multiple sources of uncertainty.

Define clear milestones and trigger points. With uncertainty looming about tariff and related trade regulations, simply engaging with government—even on a regular basis—is no longer enough. Manufacturers must also incorporate scenario planning into their implementation road maps, with well-defined milestones and trigger points relating to different possible resolutions of the uncertainties. Setting out clear alternatives will help companies meet their overall strategic business objectives, including cost, under a wide range of outcomes.

Embrace disruptive change. Manufacturers should also embrace the disruptive change that technology companies are promoting and partner with them. For example, automotive companies are partnering with technology companies to develop driverless cars. When faced with disruptive manufacturing technologies, companies can mitigate risk by partnering on a limited basis with outside technology experts.

Pilot programs are an effective way to learn about disruptive strategies and break down a big decision into smaller, less risky initiatives. A large industrial-equipment manufacturer implemented a new IoT-based process that fed back quality issues arising from field use directly into the design and production process. Rather than making a big bet on technology that small-scale, disruptive vendors were offering in the market, the manufacturer decided to test out this new technology at one site and measure the impact on sales. When the resulting revenue was less than it had expected, it shut down the program and minimized losses.

Another agile strategy is to be open to acquiring technology start-ups. Some companies are now looking to acquire new manufacturing technologies only after they have matured, which means smaller start-ups take on a larger share of the risk.

What are the implications for manufacturing network strategy?

When thinking about manufacturing network strategy, companies should assume that the pace of change in today's global economy will continue to accelerate. Companies must no longer think of manufacturing network strategy as an intellectual exercise to be conducted once every five to ten years. Instead, they must now constantly evaluate their asset base and examine if it is best positioned to maximize returns in their business.

Manufacturers must liberate themselves from the constraints of conventional wisdom, inflexibility, and one-dimensional, landed-cost economics. Freed from these constraints, they can formulate multiple network scenarios that not only optimize for today's realities but also present options for dealing with tomorrow's uncertainties.

We end with a cautionary message in Dr. Johnson's book: "If you do not change, you can become extinct." But with the right moves, manufacturers can evolve with their environment—and thrive.

How the Internet of Things will reshape future production systems

Vineet Gupta and Rainer Ulrich

Rich data, ubiquitous connectivity, and real-time communication are changing the way companies work. For leaders, that transformation will extend much further than the machines on the factory floor.

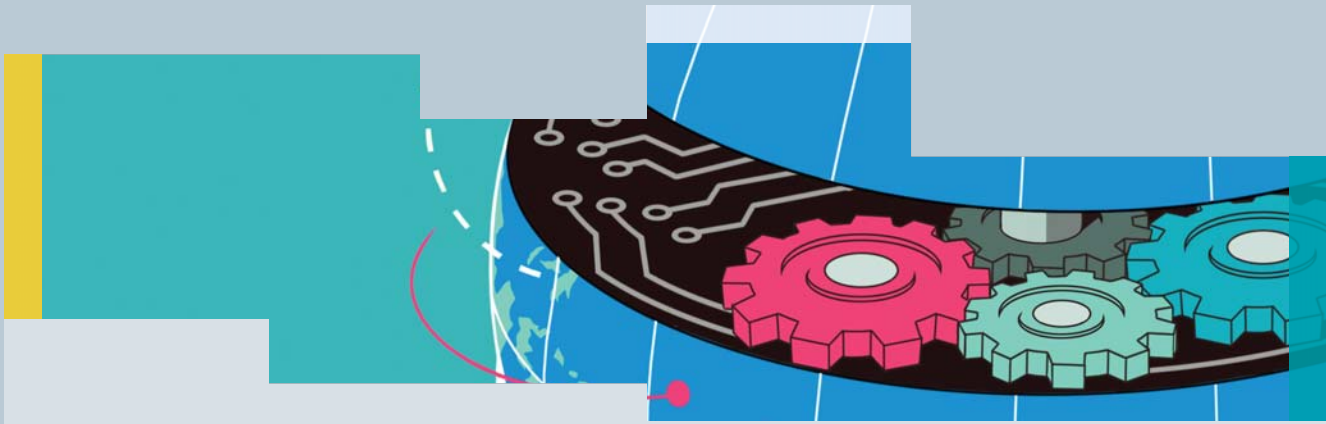
Vineet Gupta is a consultant in McKinsey's Kuala Lumpur office, and **Rainer Ulrich** is a partner in the Stuttgart office.

For decades, many of the world's best companies have used their production systems as a source of sustainable competitive advantage (see sidebar "What is a production system?"). But such a system isn't just about doing things well, with fast, efficient manufacturing processes and consistently high quality. What differentiates benchmark organizations like Danaher or Toyota is their ability to improve those operations continually, at a pace their competitors struggle to match.

Strong production systems have other powerful benefits too. They give companies a clear, precise picture of their own performance, allowing direct comparisons among plants, for example, and encouraging internal competition. They provide a common culture, vocabulary, and tool set that facilitates the sharing of best practices while minimizing confusion and misunderstanding. And by developing the skills of existing staff and creating an attractive environment for talented new hires, they help people contribute to the best of their ability.

The best production systems are simple and structured, and built around a company's specific strengths and challenges. That requires a good deal of self-knowledge. A company must not only understand what it wants to achieve but also identify the methods, resources, and capabilities it will need to get there. Ultimately, a good production system is a unique, bespoke management approach that's difficult for competitors to copy.

Today, even the highest-performing companies can boost their performance still further. That technology-driven opportunity comes from data—specifically, the huge volumes of data on processes and performance generated by new generations



WHAT IS A PRODUCTION SYSTEM?

A set of **elements** and **guiding principles** that determine how a company runs its **operations** and **continually improves** its performance is a production system:

- The **elements** of such a system include the staff's capabilities and incentives and the company's reporting systems, documented improvement methods and tools, organization, and culture.
- The **guiding principles** are expectations about the way methods and tools will be applied and people will behave.
- **Operations** include all processes in a business—not only production, but also the sales, product-development, and administrative functions.
- **Continuous improvement** includes ambitious yearly targets for gains in productivity, quality, and lead times.

A production system acts as the compass, tiller, and oar of an organization—setting its performance targets, guiding its daily practices, deepening its operational capabilities, and building them over the long term.

of network-connected devices: the Internet of Things (IoT).[1] To capture the opportunity, companies must revisit and reassess many of the processes and principles that have been so successful for them in the past.

Four dimensions of the IoT's impact

The advent of IoT technologies—and the more general move to digital tools that support operations, communication, analysis, and decision making in every part of the modern organization—won't change the fundamental purpose of production systems. It will, however, transform the way they are built and run, offering improvements across four main dimensions:

- connectivity
- speed
- accessibility
- "anchoring"

Connectivity

Traditional production systems embody a collection of separate tools bound together loosely by the rules governing their application. Usually, these rules are at best defined only on a paper document or a corporate intranet site. In future, such links will be much tighter and more automated, and fast digital connections will allow the whole system to operate as a seamless, cohesive whole.

Integration will change production systems in two ways. First, performance measurement and management will be based on precise data. Sensors will monitor the entire production process, from the inspection of incoming materials through manufacturing to final inspection and shipping. Companies will store the output of those sensors in a single, central data lake, together with a host of additional data from other internal sources, as well

1 "An executive's guide to the Internet of Things," August 2015, mckinsey.com.

as external ones (supplier specifications, quality indicators, weather and market trends). All these strands of data will combine to set the production system's targets and measure its performance continually, so the staff will be able to see, at a glance, if the system is performing as it should.

Second, connectivity will support better fact-based decision making. Access to comprehensive, up-to-date production information, together with a complete historical picture, will take the guesswork out of changes and improvement activities. As the collection and reporting of data are increasingly automated, frontline operators and managers will play a larger role in solving problems and improving processes. Root-cause problem solving will be easier: aided by advanced analytical techniques, staff will be able to identify the changed operating conditions that precede quality issues or equipment failures. Furthermore, stored information about similar issues solved elsewhere will help identify appropriate solutions.

Speed

Today's production systems are necessarily retrospective. While they aim to maximize responsiveness by emphasizing discipline, standards, and right-first-time practices), the reality falls short. Manual measurement and management mean that most opportunities for improvement cannot be identified until a shift ends and the numbers come in.

With the introduction of comprehensive, real-time data collection and analysis, production systems can become dramatically more responsive. Deviations from standards can immediately be flagged for action. The root causes of those deviations can therefore be identified more quickly, as will potential countermeasures. The entire improvement cycle will accelerate.

It isn't just the management of day-to-day operations that will get faster. Capability building will, too, thanks to focused, online training packages customized to the specific needs of individual employees. Finally, IoT technologies will speed improvements in the production system itself—for instance, by automatically identifying performance gaps among plants or updating processes throughout the company whenever new best practices are identified (see sidebar "The production-system transformation of the future").

Accessibility

Back-end data storage isn't the only thing that will be unified in the production systems of the future. So will access. Staff at every level of the organization will get the tools and data they need through a single application or portal. That portal will be the organization's window into the system's dynamic elements—especially minute-by-minute performance data—as well as more static parts, such as standards, improvement tools, and historical data.

These portals—with responsive, customized interfaces ensuring that the right employees get access to the right information and tools at the right time—will simplify and accelerate the operation of the production system. If it identifies a deviation on a production line, for example, it will be able to alert the team leader, show current and historical data on that specific process, and offer appropriate root-cause problem-solving tools, together with a library of solutions applied elsewhere.

Using secure and tightly controlled interfaces, the production-system portal will also be accessible beyond the organization's boundaries: it will allow suppliers to track consumption and quality issues in materials, for example, or external experts to review current and historical performance to find improvement opportunities. Using online support and predictive analytical tools, manufacturers of equipment will increasingly operate, monitor, and maintain it remotely. The portal will even allow companies to benchmark their own performance automatically against that of others.

Ultimately, manufacturing transformations will be quicker to plan, thanks to the speed and flexibility of digital tools.

THE PRODUCTION-SYSTEM TRANSFORMATION OF THE FUTURE

Highly integrated, digitally enabled production systems won't just work differently from today's—they'll be built differently, too. New technologies will have a significant impact on each step an organization must take along the evolutionary journey of its production system.

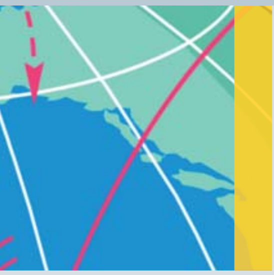
- **Prepare and diagnose.** Today, just getting a comprehensive picture of current performance takes too much effort: gathering data from disparate sources, talking to managers and team leaders about their issues and challenges, and then diagnosing improvement opportunities and capability gaps. In future, the data necessary to understand the production system's current performance will be much more readily available, often remotely. Automated analysis systems will parse these data much more rapidly to yield much more powerful insights, isolating subtle factors that influence the performance of production, from changes in humidity to the actions of individual operators.

- **Design and plan.** While diagnosis will be easier, the design of future production systems is likely to be more demanding. Today's focus on eliminating waste and optimizing material and information flows will remain crucial. But companies will also have to consider a host of new opportunities and requirements, such as the integration of new sensors and information sources, the potential for new production technologies (from 3-D printing to augmented-reality systems), and the design of a new digital infrastructure. And because few organizations will have already completed the journey, companies will be less able to rely on methods and blueprints that have been proved elsewhere.

  The translation of a design into a tangible change plan is likely to become easier, however. A new generation of design tools will automate much of this process, defining the necessary steps and determining the best sequence and timing given the available resources and skills.

- **Implement and sustain.** As in the design and planning phases, additional effort in the early stages of implementation will be repaid by dramatic improvements in flexibility, performance, speed, and sustainability. People will still have to carry out most physical changes to production lines and other facilities, and the initial introduction will be more complex for digital performance-monitoring and -management tools than for manual systems (see sidebar "The human factor").

  Once the basic elements are in place, however, the responsiveness and adaptability of digital systems will come into their own. The use of real-time data will make it simpler and faster to stabilize processes. Automated optimization



systems will adjust manufacturing sequences and speeds to help balance lines and match production more closely to customer demand. Digital performance-management tools and standards can easily be updated as the organization modifies and fine-tunes the system. Digital tools and automated work flows will help managers and frontline teams maintain the cycle of root-cause problem solving. And capabilities will be faster, easier, and more personalized thanks to digital training tools and digitally supported coaching programs for managers and change agents.

Digital tools will also simplify and streamline ongoing continuous-improvement activities by adjusting targets and tracking progress in real time while automatically escalating issues to the relevant personnel when required. They'll simplify the management of complex changes, too, by automatically identifying interactions and potential conflicts between different initiatives and recommending resolutions.

Ultimately, manufacturing transformations will be quicker to plan, thanks to the speed and flexibility of digital tools; faster to implement, given the tools' ability to align and engage all employees behind the same goals; and more powerful, since the underlying drivers of improved performance will be clear for all to see and address in a structured way.

THE HUMAN FACTOR

The production systems of the future will still require people in many of the roles they hold today, but the nature of those roles will change. Here's how:

- Operators will need new capabilities as low-skill tasks are automated and increasingly sophisticated equipment requires skilled people to run it. Frontline personnel can expect more support, however, since the allocation of work will be based on their proven capabilities, training will be customized to their individual needs, and they will receive instantaneous recommendations for course corrections when problems occur.

- Managers and supervisors will spend less time tracking and reporting on day-to-day performance and more time coaching their teams and looking for innovative improvement opportunities.

- Change agents will still have the critical and diverse roles they do today: identifying and fixing issues (for both machines and humans), developing and implementing solutions, building capabilities, and changing mind-sets in the wider workforce. Future production systems, emphasizing analytical capabilities for working with complex data, will change some aspects of those roles, however. Other capabilities, such as those required to guide colleagues through significant change, will become much more important in light of the transformation most organizations will need.

Anchoring

One of the most powerful effects of IoT and digital technologies, we foresee, will be to anchor the production system in the organization's psyche. This will overcome the most critical challenge many companies struggle with today: sustaining change, so that the organization improves continually.

That anchoring effect will be achieved in several ways. First, the unified data, interface, and tool set will not only help enforce the adoption of standards but also ensure that the right way of doing things is the easiest way. Staff won't need to improvise production plans or override machine settings if the optimum settings are just a button click away.

Second, future production systems will help the organization to collaborate more effectively. An end-to-end view of performance will break down barriers among functions and ensure that decisions reflect the interests of the business as a whole. The communication and sharing of information will be greatly enhanced, since a central knowledge hub and social-media tools will let staff in one area access support, ideas, and expertise from another.

Finally, future production systems will make performance far more visible: when the whole leadership can see the direct link between operational performance and profitability, for example, the production system will no longer be considered the concern solely of the COO. Digital dashboards on computers, mobile devices, and even smartwatches will show staff in every function and at every level exactly how the organization is performing, as well as the precise value of the contribution of their businesses, plants, or production cells. The result will be genuine transparency—not just about where the value is being created, but also about how.

Adopting IoT: Early wins

Although the fully integrated digital production systems described in this article don't yet exist, many of the building blocks are already in place. The oil-and-gas industry, for instance, is rolling out industrial-automation systems that can monitor the health of expensive capital assets in remote locations. These systems facilitate timely preventative maintenance by using sensor data to generate real-time performance information and provide an early warning of potential problems. Automakers already have production lines where hundreds of assembly-line robots are integrated with a central controller, business applications, and back-end systems. This technology helps companies to maximize uptime, improve productivity, and build multiple models (in any sequence) without interrupting production.

□ □ □

The next challenge for manufacturing companies is to complete the integration process. This will mean taking the tools and capabilities that now work on individual production lines or assets and extending them to the entire enterprise and then its entire supply chain. For companies that succeed, the reward will be greater efficiency, rich new insights, and dramatic, continual improvement in performance.

Optimizing production in the age of the machine

Alan Osan and Ken Somers

As machines play an ever more important role in production, companies need smarter and more holistic ways to optimize performance.

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The authors wish to thank Markus Hammer for his contributions to this article.

In many ways, human progress has been defined by its use of increasingly sophisticated machines, from the simple lever to the steam engine and the electric motor to the most highly sophisticated robots. Today, most of us are surrounded by machines, and we rely on a complex web of them to provide the food, products, and utilities we use every day. By transforming and adding value to materials, energy, and information, machines drive around 85 percent of GDP in developed economies.

Machines aren't just becoming more ubiquitous, however. They are also getting smarter, which is fundamentally reshaping how people use them. Traditionally—and to a great extent today—the performance of a machine depended on the performance of its human operators, relying on them to identify problems or opportunities for improvement and to make the necessary repairs and adjustments. Now machines are increasingly able to sense their own performance and health, to act on this information themselves, and to communicate it explicitly to operators and to other machines.

Together, these changes mean that getting machines right is becoming a key value driver in many organizations, by improving quality and flexibility, increasing yield, and reducing the consumption of energy and other inputs. We believe that the journey to optimal performance in the age of ubiquitous, intelligent machines will be driven by five fundamental principles (Exhibit 1).

Think lean

The lean approach has transformed the performance of human work in many settings. It is now time apply the same focus to the machine. As with traditional lean, this method is based upon the identification and reduction of the primary sources of loss that erode operational

Exhibit 1. There are five fundamental ways to get more from machines.

1. Think Lean	2. Think Limits	3. Think Profit/Hour	4. Think Holistic	5. Think Circular
Base machine performance improvements on lean principles and design for reliability	**Stretch aspirations by using theoretical-limit concept and robust design**	**Prioritize profit as main factor for final decisions**	**Involve whole organization to sustain change**	**Extend and expand machine life cycles and optimize asset productivity**
Extend and expand machine life cycles and optimize asset productivity	Use theoretical limits to set ambitious goals that foster creative thinking and deliver breakthrough impact	Drive sustainable profit by understanding relationships among throughput, yield, energy, and the environment	Reinforce benefits from technical improvements by improving and tailoring management systems, mindsets, and behaviors	Boost business opportunities and competitive advantages by optimizing across product and service life cycles

Source: Operations Extranet

performance and efficiency: inflexibility, variability, and waste.

The application of lean thinking to machines requires a change of perspective, however—one that considers the impact of losses on machine-specific attributes, such as energy consumption, yield, and reliability. If human operators are forced to wait for materials before conducting their work, for example, the losses each incurs will be very similar. Under the same circumstance, the losses incurred by machines may be very different. One machine may be able to shut down completely on demand, another may go on consuming energy and resources, and a third may generate large quantities of scrap as it brings its processes under control after the interruption.

Inflexibility

Human workers are inherently flexible. Flexibility has to be built, or programmed, explicitly into machines. Reducing the condenser pressure on a mechanical chiller in winter, for example, means it will consume less energy when the ambient temperature is lower. The efficiency of a gas boiler can be optimized by sensing the level of oxygen in the combustion chamber and adjusting it according to the required output. A fixed speed pump will consume excess energy any time its full output is not required; the addition of a variable speed drive on the pump's motor can reduce those losses by allowing it to match its output, and energy consumption, precisely to changing demand. Designing equipment that can be easily adjusted to operate efficiently and reliably across various operating ranges or for various types of products allows cost-effective production in the short term, with the potential to defer or eliminate future capital expenditure.

Variability

Lean companies fight a relentless battle against the variability that affects product quality and production efficiency. They seek to minimize changes in raw material quality, for example, and eliminate inconsistent work processes. Optimal machine performance depends on tight control of variability as well. That involves designing

The eight sources of waste identified in traditional lean thinking apply equally to machines.

machines and control systems that can deliver the desired output consistently over long periods, compensating for short-term changes in operating conditions, such as variations in temperature or humidity, and long-term ones, such as the effects of wear.

The traditional mechanisms used to control machine variability relied on rigorous processes to identify deviations in output, and the intervention of skilled operators to compensate for them. As machines become smarter and more adaptable, however, they can increasingly conduct this activity automatically, using closed-loop control systems to ensure consistency as internal and external conditions change. Even in very mature technologies, such as rolling mills, the latest smart control systems can increase machine performance over their counterparts by 2 or 3 percent, by identifying and predicting maintenance issues in advance and thereby allowing rapid repairs. This can translate into multimillion-dollar annual increases in output and a 30 to 50 percent decrease in associated costs.

Waste

The eight sources of waste[1] identified in traditional lean thinking apply equally to machines. Overproduction, for example might include the choice of machines with significant excess capacity, or the application of multiple planned maintenance activities when one—or even none—would be more cost effective.

Optimizing planned preventive and predictive maintenance activities based on known or anticipated failures helps to insure that the correct maintenance activities are carried out if and only when required. Inventory waste attributable to poor machine reliability can include excessive stocks of tools and spare parts.

Other sources are more particular to the machine environment. These include the use of older equipment that consumes more energy or performs less reliably than its modern counterparts, or a failure to standardize equipment types, resulting in complex training and support requirements and large spare-parts inventories (Exhibit 2). Similarly, the desired performance and life-cycle characteristics of an asset need to be balanced with those of the wider production system. There is little point investing more capital for an asset that can run for ten years without a shutdown if the rest of a plant requires turnaround maintenance every three years.

Companies are increasingly making use of design-to-value techniques, including designing for reliability and for maintainability, to optimize the life-cycle costs of machines based

1 The eight sources of waste identified in traditional lean thinking are transportation, inventory, motion, waiting, overproduction, overprocessing, defects, and skills.

Exhibit 2. Ten energy examples show how waste can be reduced.

Classic categories of waste	Resource waste equivalents	
	Definition	**Example**
1. Overproducing	▪ Producing excess utility	▪ Compressed air vent
2. Waiting	▪ Consuming energy while production is stopped	▪ Coal pulverizer on without throughput ▪ High energy use during shutdowns
3. Transportation	▪ Transporting energy inefficiently	▪ Leaks in compressed-air network
4. Overprocessing	▪ Designing processes that use more energy than necessary	▪ Machine operating at higher temperature than required
5. Inventory	▪ Storing inventory, which uses or loses energy	▪ Inventory cools in-between processes ▪ Excessive warm-up or cooldown cycles
6. Scrap rework	▪ Using resources for rework or for producing scrap	▪ Regrinding coal
7. Motion (inefficient processes)	▪ Using resource-inefficient processes	▪ Excess oxygen in steam boiler
8. Employee potential	▪ Failing to use people's potential to identify and prevent energy waste	▪ Employees not involved in developing energy-saving initiatives

Resource-specific categories of waste		
	Definition	**Example**
9. Equipment efficiency	▪ Using inefficient equipment	▪ Operating low-efficiency boilers ▪ Oversize pumps
10. System integration	▪ Failing to fully integrate energy use	▪ Poor thermal or pressure integration

Source: McKinsey analysis

on their required operating characteristics and maintenance requirements. For example, over its lifetime, the energy and maintenance costs of a simple pump can exceed the initial purchase cost by a factor of ten. Pumps that run more efficiently or that last longer between overhauls can recoup the higher purchase price many times over.

Think limits

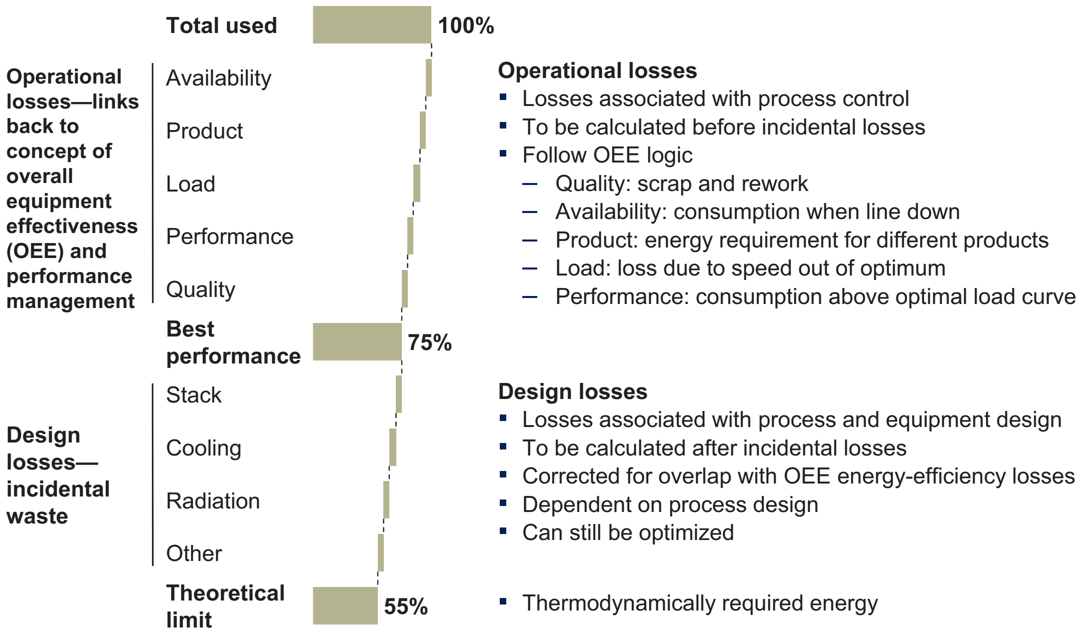
When organizations think about machine performance today, they usually look at their current operations and search for ways they might be improved. That is an understandable impulse, but it represents only a partial solution. A more powerful approach is to begin by mapping out the theoretical limits of the machines—how they might operate in ideal conditions without losses from mechanical inefficiencies, nonstandard processes, flawed raw materials, or other sources. No machine can achieve the maximum theoretical performance in the real world, but by comparing the current performance with the theoretically ideal state, companies can identify the areas of their current production systems where the losses are greatest, and focus on improvement efforts there.

Losses identified by the theoretical-limit approach fall into two categories: design losses, which are determined by the physical characteristics of the machines involved, and operational losses, which are determined by how those machines are run and maintained (Exhibit 3). Since operational losses can often be addressed with little or no capital investment, they should be the initial focus of any improvement effort.

Think profit per hour

Will it be more effective to focus on increasing the availability of a critical machine or on improving its yield? When companies seek answers to questions like these in their quest to improve machine performance, they often find themselves comparing apples with oranges. Without a good way to balance the trade-offs inherent in the production systems, they risk

Exhibit 3. Comparing actual machine performance to the theoretical optimum reveals improvement opportunities.



Source: McKinsey analysis

investing in suboptimal efforts, or worse, making local changes that actually reduce overall equipment performance.

There is a single, robust metric that everyone inside and outside the manufacturing operation understands, however: profit. The challenge in applying this measure to details of production systems has traditionally been that monthly or quarterly profit reports are too coarse a measure. Today, however, thanks to the advent of rich, instantly available data, companies have access to a powerful new performance metric: profit per hour.

Every aspect of machine performance has an impact on profit per hour. Excess energy consumption adds cost, driving profit down. Yield improvements reduce input costs, driving it up. Reductions in downtime and unplanned stoppages mean more time spent producing with lower costs—and higher average profit per hour. Rolling all these diverse elements into a single metric automatically accounts for the trade-offs among different operating strategies.

Adopting the profit-per-hour methodology has allowed companies to find hidden improvement opportunities even in highly refined manufacturing operations (see "Extended lean toolkit for total productivity" article on page 118). For some it is has been the key to dramatic overall performance improvements. One steelworks, for example, adopted the metric as the main performance indicator for its entire operation. Over a six-week period, the company introduced the metric to its full workforce, from production operators to the CEO. In the months that followed, profitability at the plant rose, and the impact was even more noteworthy, since it took place during a period when slumping global steel prices were forcing competitors to cut production and close entire plants.

Think holistically

Approaches such as the ones we've described so far are only part of the story. Creating an organization capable of getting the very best out of its machines will also require a comprehensive change-management effort. Companies will need to change people's underlying mind-sets so that they think holistically about machine performance. Equally important, they will need to support those new mind-sets with revised metrics and more frequent performance dialogues as part of a new management infrastructure.

Machine performance will not just be the responsibility of the production, maintenance, or engineering functions. All functions within a manufacturing organization will play a key role, and all functions must be aligned to the performance expectations outlined.

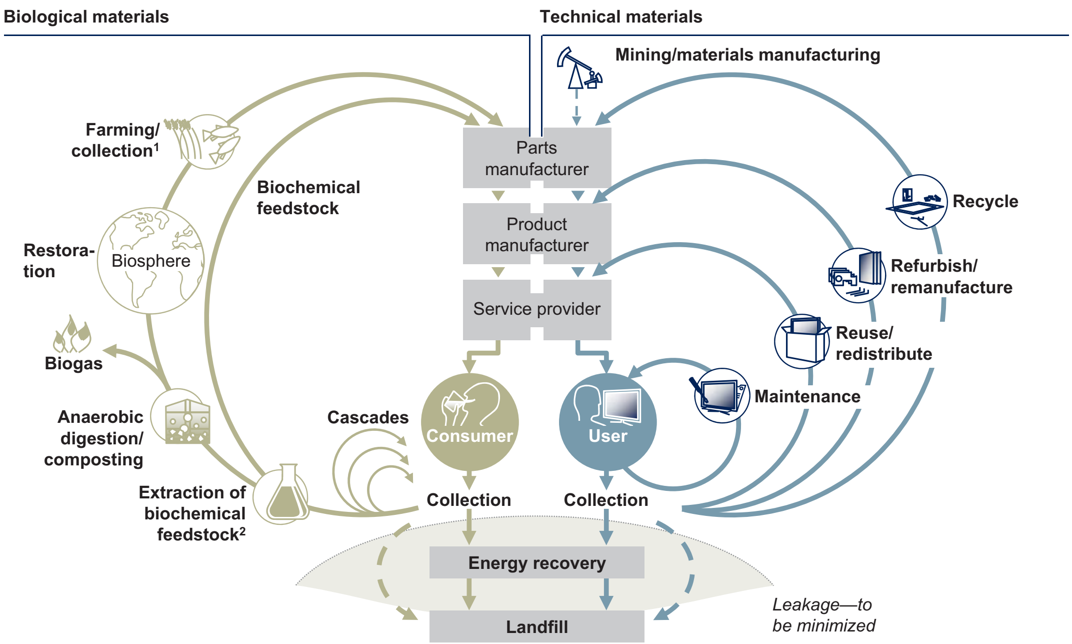
One large factor in eliminating machine downtime and improving performance is the mind-set and behavior of machine operators. Employees who interact constantly with equipment are in the best position to monitor ongoing performance and equipment conditions. Operators can take on simple maintenance tasks, leaving maintenance technicians the time for more complex preventative and corrective work, for example.

The final—and increasingly critical—requirement for companies seeking to get the most out of their machines is analytical skill. As machines record and store more detailed data on their own performance, advanced-analytics techniques are set to play an increasingly important role in the optimization of performance. Taking advantage of this resource will require new infrastructure and new human capabilities, including the software and hardware and processes needed to store and manage the data, practitioners with the ability to generate useful insights from it, and the continuous-improvement functions that turn the insights into sustainable performance changes.

Think circular

Biological systems have evolved to make efficient use of scarce resources. Organisms repair

Exhibit 4. Circular thinking results in machines that live longer and produce more value.



1 Hunting and fishing.
2 Can take both postharvest and postconsumer waste as input.
Source: Ellen MacArthur Foundation; McKinsey analysis

themselves and adapt to changing requirements. The waste products they produce become valuable inputs into other processes. Circular thinking aims to use the same principles to dramatically improve the efficiency and productivity of the resources used in human-made systems. Its aim is to use fewer resources and eradicate waste, throughout the entire extended life cycle of a production system (Exhibit 4).

Companies can apply circular principles to machines in a number of ways. They can design machines that operate more efficiently and reliably to reduce their consumption of energy, water, or other inputs. They can focus on increasing yields to ensure more of the input material is converted into useful product. And they can explore the opportunity to use alternative inputs, too, allowing virgin raw materials to be replaced with recycled ones.

This approach also extends the useful life cycle of machines. By designing for reuse or renewal, the same basic platform can produce multiple generations of product, reduce capital costs, and improve an organization's return on the machines it owns. A well-defined whole life-cycle approach means machines can keep delivering value longer. Sensors and control systems can be upgraded, for example, worn parts can be refurbished or remanufactured, and older machines can be reused in new applications and new locations—such as making simpler products for cost-sensitive emerging markets.

This article is adapted from ***Unlocking Industrial Resource Productivity: 5 core beliefs to increase profits through energy, material, and water efficiency*** (McKinsey & Co., 2016).

Manufacturing quality today: Higher quality output, lower cost of quality

Adriana Aragon, Evgeniya Makarova, Alessandro Faure Ragani, and Paul Rutten

Good quality doesn't have to mean higher costs—in fact, it often means lower recall and warranty costs as a culture of quality takes hold.

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The authors wish to thank Phil Duncan and Anil Sikka for their contributions to this article.

Disaster has a way of concentrating the mind. Massive recalls and lawsuits—over luxury cars, over-the-counter medicines, medical devices, or mobile-phone batteries—become almost totemic reminders of what a lapse in quality can mean. And for manufacturers everywhere, simultaneous increases in supply-chain complexity and media reach mean that the aftershock of a quality lapse is likely to be much larger than in the past.

But despite their impact, these events are only part of the story. Indeed, as important as it is to keep rare disasters from happening, focusing too closely on them can distort an organization's understanding of what quality really means. Fundamentally, quality is about meeting or exceeding customer expectations: every day, every shipment, year after year. That's where the true value is, measured not only in higher revenues from greater customer satisfaction but also in higher operational efficiency and effectiveness due to increases in productivity and innovation—and even employee engagement.

Yet organizations face constraints. Rising margin pressures, particularly in consumer-oriented industries such as fast-moving consumer goods and medical products, limit how much companies can spend on quality practices. Organizations therefore cannot just be good at quality—they need to be smart about it as well.

To achieve the right balance, organizations must learn to think about quality systematically. At the very earliest stage of quality awareness, organizations start to hear the voice of the customer more clearly, while stabilizing their operating systems and promoting greater transparency about quality problems (see sidebar, "More than compliance"). As these practices take hold, the next stage of maturity centers on strengthening cross-functional accountability and collaboration for quality—such as with new performance standards so that quality standards inform the design of products and the management of supply contracts.

At the third stage, quality informs much of the organization's decision making, embedding itself so deeply that it becomes a part of the culture and essential to the company's value proposition. Finally, among a small group of the very highest performers, quality becomes the basis for their reputation. These exceptional organizations expand their perspective on quality to address customer problems in ways that push their businesses into new areas, building on behavioral research and process analytics to develop deeper solutions and customer relationships.

Achieving these outcomes requires investment. But the good news is that the organizations whose quality practices are the most sophisticated are not necessarily the ones that spend the most on quality. Instead, these leaders prioritize, so that what they spend on quality is highly effective. At each stage of maturity, the advantages build: from essentially nonexistent to basic, from basic to average, from average to advanced, and from advanced to industry-leading.

For example, a multinational industrial manufacturer that was at an early stage reduced its cost of nonquality—such as for warranty claims, waste, and rework—by about 30 percent. A midlevel biopharma facility reduced product

Companies have substantial room to expand their understanding of quality to encompass the standards that customers want met.

MORE THAN COMPLIANCE

Especially in highly regulated industries such as pharmaceuticals or financial services, organizations often see quality mainly in compliance terms. There's good reason: as products become more complex, compliance and quality start to overlap, with some standards explicitly incorporating minimum quality targets. Medical-device manufacturers, for example, face a gauntlet of reviews both to win initial regulatory approval for a product and to keep that product on the market. Life insurers face similar reviews.

Yet even the most intricate of standards may not incorporate all of the factors that customers include in deciding whether a product is fit for purpose. Instead, regulators have traditionally focused on the most critical variables, usually centering on safety: physical for medical devices, financial for insurance.

And although at least some regulators are broadening their perspective on quality—for example, assessing new drugs based on holistic health or life-span effects rather than just control of symptoms—companies nevertheless have substantial room to expand their understanding of quality to encompass the standards that customers want met, and improve on them. That's what organizations build as they move through the stages of quality maturity.

deviations by more than 50 percent and waste by three-quarters, while also freeing more than 25 percent of the employees allocated to catching quality issues for reallocation to other activities. And, pushing still further, at a "best of the best" medical-device company, waste and rework costs were only one-fifth those of the median producer, while in pharmaceuticals the top producer's costs were a mere one-fourteenth of the median level (Exhibit 1). At every stage, therefore, companies across industries are achieving higher quality at competitive cost, building capabilities that prepare them for further stages of quality evolution.

Four evolution stages of quality 'maturity'

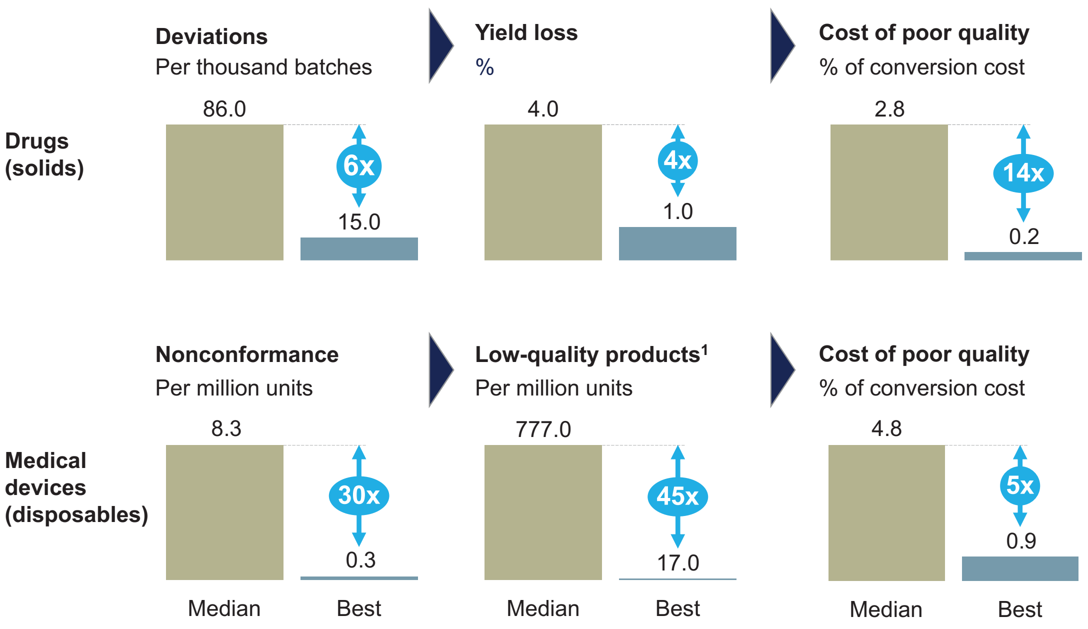
In assessing an organization's quality practices, we focus on three foundational elements of quality.

The first is the operating system—the manufacturing processes for an automaker or the service operations for a retail bank, for example—gauging how well it can contribute to quality. Second is the quality system itself, including enterprise-level capabilities such as measuring quality output, or incorporating quality standards into the design of products and processes. The third element is the cultural dimension of quality—the way employees think about their contribution to product quality, and how they behave to ensure good quality.

How an organization performs in these three areas determines its stage of maturity (Exhibit 2). Although the boundaries between the different stages are not precise, each nevertheless correlates with a few important characteristics.

From the experiences of organizations that are investing in quality, a few broad lessons stand out. Most important, investments can pay off at every possible starting point, from stage zero, when a company has very few quality capabilities, to

Exhibit 1. Best-of-best medical-product plants produce both better quality and lower cost.



1 Products subject to complaints or recalls.
Source: POBOS Quality

stage four, when it is among the standard-setting organizations that are redefining what quality can mean.

A further, related lesson is that the impact from investing in quality tends to increase with the organization's quality maturity. That's partly because of scale: as maturity increases, quality involves more and more of the organization. And it's also because quality increasingly informs strategy so that its effects are broader and longer lasting.

The final lesson, however, is that progress from stage to stage is neither smooth nor automatic—nor even necessary, depending on an organization's circumstances. Instead, progress

Exhibit 2. 'Triggers' push companies to new stages of quality maturity.

Maturity stage	Operating system	Quality system	Culture
0. Starting	Inconsistent manufacturing performance	Reactive, minimal compliance	Limited attention to quality
	Typical evolution trigger: Opportunity to reduce quality costs (e.g., financial, reputational), compliance requirements		
1. Basic	Progress toward repeatable, standardized manufacturing	Development of individual quality processes Establishing basic compliance standards Launch of separate quality function	Increased transparency about product quality Focus on improving compliance
	Trigger: Opportunity for quality to generate positive value and reduce quality risk exposures and failure costs		
2. Stronger	Robust manufacturing, some identification of improvement opportunities	Quality systems established in all functions Greater cross-functional accountability Active problem solving for quality	Quality as customer value Focus on reducing cost of quality
	Trigger: Opportunity for quality to rise from "table stakes" to substantial part of value proposition		
3. Embedded	Continuous improvement cycle for manufacturing	Quality and customer satisfaction drive product design and solutions, strategic decisions	Quality is the way the company works Focus on anticipating customer needs and continuous improvement
	Trigger: Opportunity to redefine what quality means		
4. Standard-setting	Adoption of advanced manufacturing and control technologies, and advanced analytics to inform new product and process design	Quality draws on unique capabilities and innovation, becomes a source of insight and an enabler of breakthrough products	Quality is one of the most valuable company attributes, focus is on developing solutions beyond the company's traditional boundaries

comes from triggers that share certain features, even though the details are inevitably specific to the organization.

Building the basics of customer focus, transparency, and stability

The first trigger typically occurs when the organization recognizes that simply reacting to quality problems is no longer tenable. Often, it simply costs too much—in recalls, warranty expenses, and lost reputation. And it's a lesson that applies equally to a start-up that has focused mainly on growth, a state-owned enterprise protected from market demands, and a company in a high-demand industry.

That was the case for the multinational industrial manufacturer, a giant in a sector that was suddenly becoming far more competitive as global demand plummeted. The leaders recognized that stronger quality would be essential to survive the industry's downturn. Current quality levels were not meeting customer expectations. At one facility alone, more than a tenth of production was defective in some way. Deliveries were often late—so often that it damaged the company's credibility with crucial customer segments. And claims costs were far too high.

The underlying issue, the company found, was a mentality in which quality was the responsibility of the quality organization—and no one else.

To change this long-standing mind-set, the company started by listening to customers more carefully. Partly as a result, it changed its most important performance metric from "units produced" to "quality units produced," a switch that dramatically increased transparency on quality throughout the enterprise. Equally important, a new quality council—headed by a C-suite executive and including business-unit and functional heads—set the tone with a weekly one-hour meeting focusing just on quality improvement. Following basic lean-management structures, a cascade of similar meetings carried the quality message through each level of the company, from plant general managers down to a daily ten-minute quality huddle for each operating shift.

The results? A more stable manufacturing environment in which customer complaints and quality-related costs both fell by more than one-quarter.

Strengthening the culture for tighter collaboration

Once an organization's quality becomes more transparent and stable, new opportunities often arise to increase quality's value and decrease its cost. Our latest research confirms that higher-performing manufacturing sites score better on culture-related factors than their peers (Exhibit 3). Accordingly, at this stage, the goal becomes to enable greater collaboration across the entire organization so that quality becomes embedded in the culture. That collaboration extends outside the organization as well, to include stakeholders, such as partners and regulators. Two pharmaceutical manufacturers illustrate how this stage evolves. One, a generics maker, was facing compliance issues and needed to establish better quality operations on the factory shop floor. The other, one of the world's largest branded pharmaceutical manufacturers, reexamined its already robust compliance practices for ways to improve its quality outcomes and risk profile even further, while reducing costs.

To reinforce the cross-functional nature of quality, both companies expanded their use of broad performance measures, such as error-free or right-the-first-time (RFT) production and on-time, in-full delivery. In team huddles throughout their production sites, the companies focused on daily tracking and discussion of the new indicators. In addition, tying these shared metrics to annual bonuses increased everyone's attention to quality—not just within their particular functional or operational units but also across organizational boundaries.

Exhibit 3. High performers consistently score better on culture-related factors.

Source: POBOS Quality culture survey

As these new practices took hold, productivity at the generic manufacturer's sites increased by more than 15 percent, while its end-to-end RFT percentage rose to more than 92 percent, from 83 percent. Individual sites started passing regulatory inspections more confidently and without any noted compliance issues or regulatory observations. For the branded pharmaco, the changes reduced both the number of quality incidents and its cost of poor quality, improving its risk profile with no added investment in IT, capital, or other resources.

Turning quality into the core value proposition

The third transition deepens the quality culture until it becomes the company's core value proposition. In effect, quality is no longer mainly a question of bottom-line savings but of top-line revenue generation. Tactically, this stage requires renewed investment in human and digital capabilities so that the company can consolidate all available customer data—from every internal touchpoint, and from external sources as well—to identify new openings.

A global logistics company's transformation of its quality approach illustrates the level of commitment required. Previously, the company's focus had been on fast delivery, a goal it had largely achieved. But customers increasingly looked to other factors, such as accuracy in predicted delivery times—speed was not necessarily helpful if a delivery arrived before the customer was ready to receive it. Moreover, the rise of a digital economy meant that deliveries were becoming far more complex: fewer large deliveries to warehouses and retail stores, and more very small deliveries to a vast number of residential addresses.

The new world demanded not just high quality but also quality leadership. The entire organization, from the executive suite to the uniformed drivers, immersed itself in capability-building sessions to understand the competitive reasons for higher quality and the implications for day-to-day work. Deeper problem-solving methodologies allowed people to identify new ways to serve customers. And new technologies crunched route data to enable wholesale restructuring of delivery practices that minimized the chance of error. The result was a major increase in customer satisfaction and renewed growth.

Setting a new standard with the latest analytics and technologies

The final stage applies the wider range of measurement and analytic technologies to develop solutions that push well beyond the organization's traditional business in predicting emergent customer needs—sometimes before the customers themselves are aware of them. One early example comes from commercial-vehicle manufacturing. Historically, most of the value a manufacturer could earn came from the initial sale. But one large commercial-vehicle maker now monitors more than 100 separate performance indicators in its vehicles. Based on advanced component-wear modeling, the company can deploy repair personnel to its customers before any failure occurs, increasing vehicles' utilization rates while reducing maintenance costs—and rapidly growing the service side of the business.

At the level of individual manufacturing sites, advanced analytics are increasing output and decreasing waste. A passenger-vehicle maker has cut downtime for its manufacturing equipment from days to hours. In chemicals, sophisticated modeling of energy inputs and demands can reduce energy usage by 5 percent or more. An appliance manufacturer used a cloud database to store several sources of information (for example, repair-technician notes, warranty-claims data, call-center records, product information, and manufacturing data), for which predictive analysis gave it early warnings of issues and allowed it to improve its design processes for both future and current products. And in less than two years, a biopharma site more than doubled its yield and RFT levels—with minimum additional process investments—by deploying advanced analytics to better understand important process variables and improve process specifications.

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Not every organization needs to achieve the highest level of quality maturity—and certainly not all in one go. But all organizations should recognize that when a trigger looms, an investment in quality capabilities can often open major new opportunities for competitive advantage.

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Seven rules for spinning analytics straw into golden results

Richard Kelly, Subu Narayanan, and Mark Patel

While IoT-enabled advanced analytics could be worth trillions to manufacturers, turning insights into outcomes requires more than just the right technology.

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Manufacturing may generate a wealth of data, but companies' efforts to use those data to drive performance improvement have only scratched the surface thus far. But now, lower-cost sensing, better connectivity, and ever-increasing computing capabilities are combining to push analytics and intelligence far beyond what was possible in the past.

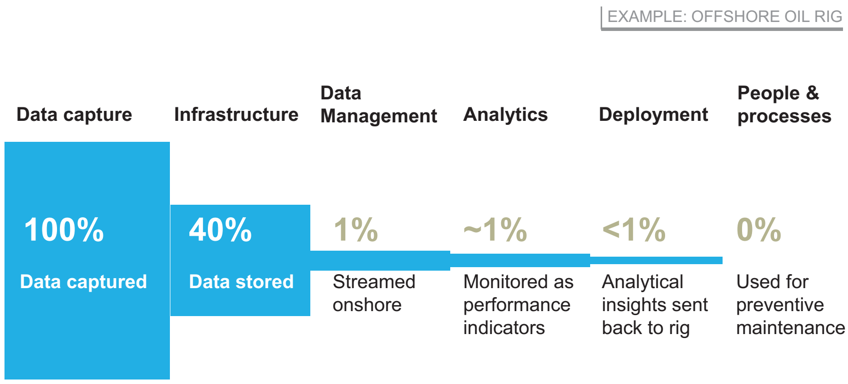
The challenge is knowing how to start— and how to achieve measurable, sustained impact. Our work with manufacturers around the world suggests that by following seven golden rules, companies can start capturing the benefits of IoT-enabled advanced analytics more quickly, and build a solid foundation to keep improving.

Rule #1: Start simple, with existing data

With the increased buzz around the Internet of Things (IoT) in manufacturing, many companies are excited about deploying thousands of low-cost sensors within their operations. While we do think this idea shows value, our experience shows that most of the data currently being generated is unused (exhibit). Simple analytics, done right, and with the existing treasure trove of data can yield tremendous value for manufacturers in the near term. Those early victories help win the hearts and minds of frontline employees while strengthening a data-driven decision culture—and the business case for further advanced-analytics investment.

For example, digitizing performance management—such as through real-time data visualization of human and machine performance—requires minimal resources, as it relies on simple, rapidly deployable solutions. Yet its easily quantified results can serve as the gateway to rapid improvement and management buy-in.

Exhibit. Most real-world data go unused.



One manufacturer seemed to be performing well: it was already mature in its implementation of lean management and had a robust problem-solving culture in place. Nevertheless, sensing an opportunity to improve still further, it deployed an analytical solution that applied sophisticated real-time analytics to existing (but previously unused) data, producing user-friendly visualizations. Up and running in just weeks at a capacity-constrained plant, the system delivered previously unavailable details to daily area huddles and operator-driven problem-solving sessions, revealing several previously unknown causes of slowdowns and minor stops. At the most important bottleneck, the ensuing changes increased overall equipment efficiency by 50 percent.

Rule #2: Capture the right data, not just more data

Having the right data is more important than having lots of data. One basic-materials company invested several million dollars installing a "smart" manufacturing system that tracked more than a million variables. When the company analyzed 500 data tags from the system pertaining to a specific analytical use case, however, half of them were shown to hold limited or duplicated information. Another 25 percent of the data was discarded by a panel of process experts and data scientists as not being helpful for analytics. Further into the exploratory-analysis stage, the company found 20 critical variables—including a key dependent variable—that were not being measured, making precise predictive analytics impossible. This formed the case for deploying new sensors in a targeted fashion within the plant, while the company used analytics to provide critical decision-support tools for the process engineers as a first step in a quest to increase yield by 1 percent.

Rule #3: Don't let the long-term perfect be the enemy of the short-term good

Missing data can threaten to stall analytics projects while they wait for a multiyear data architecture transformation. We acknowledge that capturing the full value of IoT-driven advanced analytics will require an investment in the technology stack. But companies don't have to be bogged down by long IT projects. Minor investments can deliver much value.

One no-regret move is to develop a "data lake"—a flexible way to integrate data across an enterprise and overcome silo-based data management without full centralization. Although data lakes need strong governance and accountability for data definition and quality, they can democratize data access. Typically, data lakes provide data to different user groups either by permitting access to raw data or through data distillation, which affords access to pre-defined data structures.

The development approach required to implement analytics adds to the case for an alternative IT architecture. Analytical experimentation and exploration require agile software-development methods with daily or weekly release cycles. This short cadence is often a challenge for established IT processes and data infrastructure. The solution is a parallel "fast-speed" IT and data infrastructure, often a cloud-based system offering a range of deployment environments and tailored databases.

Data lakes and cloud solutions get companies' analytics efforts off to a faster start, allowing them to develop, test, and implement new use cases quickly. That helps in the creation of the necessary proof of concept before the wider rollout of new solutions. It is also a valuable way to build the organization's analytical muscles as people become accustomed to new ways of working and decision making using analytics.

Rule #4: Focus on outcomes, not technology

Investment in digital products and solutions without knowing how they will deliver meaningful impact will lead to frustrating discussions with business leaders. An approach based on use cases can help (see sidebar, "Successful analytics uses cases"). When defining a use case, be sure to answer four fundamental questions together with their follow-ups:

- **What is the desired business outcome?** Is it a new business opportunity, a cost reduction opportunity, an increase in innovation capacity?
- **What are the value levers?** Should the focus be on energy savings, more-efficient maintenance, higher asset utilization, lower inventory, higher throughput?
- **What technical requirements must the proposed approach meet for it to scale across the organization?** Are new data sources needed? How will the solution integrate with legacy IT systems? How will we handle the volume of data securely? What analytical techniques will be used? What new dashboards are required?
- **How will the approach fit into our existing processes?** Who will use the new system? What behaviors and decision-making processes must change to take turn analytical insights into business outcomes?

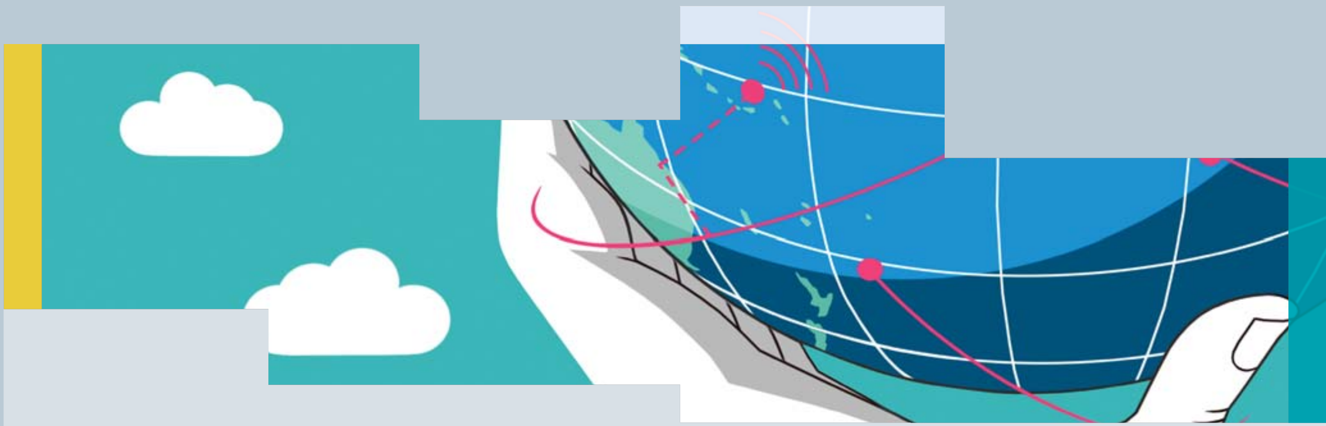
Rule #5: Look for value across activities as well as within them

While advanced-analytics methods have been applied very successfully to many specific activities that take place within the four walls of a manufacturing plant, much of the value of digitization lies in the whitespaces between organizational siloes—by bridging the gap between design and manufacturing, manufacturing and the supply network, and finally connecting with the end user. A manufacturer of highly specialized equipment recently conducted a "digital thread diagnostic" that identified more than $300 million of actionable productivity improvements that could be realized with using better data flow between design and manufacturing, real-time performance management, and other levers.

Rule #6: Break out of the pilot trap

A pilot project is a powerful, and important, way to demonstrate the value of advanced analytics, build momentum, and encourage buy-in. Capturing that value, however, means scaling the approach across the entire company. That's hard, and failure to scale can turn supporters into critics very quickly. Leaders must therefore think through the full end-to-end journey needed to turn attractive use cases into widespread impact. Some common pitfalls:

- **Focusing on the technology or approach, rather than the real source of value.** When defining the use case, it is important to start with the true source of value, which is often the user or customer needs. A software tool is almost never a panacea; moreover, the selection



SUCCESSFUL ANALYTICS USE CASES

The following four use cases, each applied within the four walls of a plant, have delivered significant value for companies in multiple sectors.

Real-time performance tracking: At the most basic level, manufacturers are seeing improvement just by tracking critical metrics in real time, applying simple analytics and visualization, and embedding the results into their regular root-cause problem-solving processes. As the solutions get implemented, a culture of data-driven decision making takes hold at all levels within a plant.

Multivariate process optimization: Several companies have adopted an integrated approach that optimizes a process's yield, energy usage, and throughput to maximize profit per hour, and has proven both simpler and more effective than alternatives. One European chemicals manufacturer, for example, found that it was seeing almost no impact from an expert system it had installed to stabilize its process and reduce energy consumption. The reason turned out to be that the system was too complex to use. The company then switched to a plant-level profitability-optimization approach, which used advanced-analytics tools and neural-network models to simulate its processes, and profit per hour as the primary performance indicator. The resulting analysis showed that optimizing a few important parameters in real time could reduce energy costs by 4 to 5 percent. Better still, the changes involved only minor process modifications that required little time or capital investment to implement.

Predictive maintenance: The concept of proactive and preventative maintenance is not new, but the ability to manage massive amounts of data through sophisticated analytical techniques can dramatically improve failure predictions and asset uptime. A resources company, for example, discovered that despite a preventive-maintenance strategy for its fleet of heavy of trucks, many critical components—such as transmissions—routinely failed before the planned maintenance interval. As a result, three-quarters of the company's maintenance effort was corrective. Applying advanced-analytics techniques revealed that a single, easily measured operating characteristic was a good indicator of developing transmission problems. By monitoring changes in that characteristic in real time, the company could alert operators days in advance, and with accuracy higher than 80 percent. Similar results have been seen in chemicals, semiconductors, transportation, oil and gas, and other industries.

Labor productivity: Advanced analytics applies equally well to the factors that drive human productivity, as one company found with its engineering staff. The approach pulled data from a wide range of sources, such as project records (for day-to-day project plans and timesheets), product-life-cycle-management systems (bills of materials and document version-control entries), knowledge-management databases (wikis and discussion forums), supplier data (vendor data, requests for proposals, and requests for quotations), and metadata (such as emails, calendar entries, and employee demographics). Putting this information through a machine-learning tool revealed many counterintuitive insights and quantified other "known truths." For example, project starts and stops resulted in an 8 percent loss in productivity. A 7 percent drop in productivity was observed for every 10 percent utilization increase over 70 percent—and another 7 percent drop for every engineer added to a project beyond seven. The analysis identified total productivity-improvement potential of between 15 and 25 percent.

of the right technology depends on the universe of use cases a company wants to deploy.

- **Solving for one use case at a time:** Focusing too closely on a single use case can lead to choices that limit scalability later on. Important technical requirements to achieve scale include advanced operational and analytical data architecture, such as data lakes and data-search layers, together with IoT platforms, tools for digitization and analytics, and a repository of modeling tools and techniques.

  In a factory setting, the right IoT platform can help analyze many functions regardless of the specific application, and thereby scale a variety of use cases at once. The underlying technology needs are essentially the same whether the organization is trying to optimize yield or to predict failure of critical equipment. An IoT platform can provide common capabilities for computing power or storage or security, while reducing the cost of developing and maintaining applications.

  In assessing IoT platform needs, companies should bear five factors in mind: the application environment and the proposed platform's connectivity to existing IT infrastructure ; the platform's ability to ingest high-velocity and-variety data streams while providing context to the data; its compatibility with a broader enterprise-cloud strategy; data sovereignty and security questions; and its capacity for edge processing and control, meaning it allows for processing and data storage close to the source, rather than only centrally.

- **Prematurely celebrating success:** Companies should think through the entire end-to-end journey, beyond the technical elements needed to achieve scale beyond a single proof of concept. Data-governance issues such as domains, critical data elements, accountability models, and role definitions can pose tricky organizational and personnel questions, especially given the new analytical and technical positions that may be required. And analytics-generated insights must be integrated into existing workflows, often with attendant changes to business processes.

- **Nailing the technical solution, but forgetting the people:** Technology is exciting—but it's people who capture the impact. While analytics can point to the right answer, people must act differently to capture the impact. Capturing the digital opportunity is a team sport, requiring close, cross-functional collaboration. A team of people with deep process knowledge, analytical acumen, and IT experience must work together to frame the problem, translate the business problem into an analytical problem, and define the right system and technical requirements from an IT perspective. Translating the analytical output into a form that can be used at the front line, and changing frontline behavior to make use of that new information, requires knowledge of human factors, persuasive design and change-management experience. Some companies find it useful to create a new role—digital translator—at the intersection of process knowledge, data science, and IT, to bring the required cross-functional teams together and steer the analytics effort from concept to bottom-line impact.

To avoid these pitfalls, companies need a structured approach to manage their analytics efforts, identifying and managing a pipeline of use cases, for example, and building the right technology stack. Once a use case is selected, companies need to systematically plan, pilot, scale, and embed analytics into their everyday processes through large-scale change management and capability building.

Rule #7: Build your capabilities

The application of analytics at scale will require organizational changes, too. For example, a company needs to define its talent strategy as new roles and new career paths emerge. There will be a need for data scientists, agile IT teams, and user experience (UX) designers, who play a crucial role in supporting real-world use of analytics. A persuasive design created with frontline involvement, is often the secret to high adoption levels for any analytical solution. Accordingly, UX professionals should be involved from the moment a use case is designed, not asked to apply a visual interface after a solution has largely been built.

In addition, a company needs "translators"—multi-skilled individuals who can shepherd the process from end to end. Translators need deep business knowledge and the ability to get into the workflow of operations and maintenance teams. They must be comfortable with analytics and able to challenge data scientists. They must understand IT systems and design thinking. And they must be able to communicate impact to the leadership team. That's a very tough combination of skills to find.

In addition to these internal roles, a clear partnership strategy is important. There is an explosion of both big companies and start-ups with unique IoT capabilities. The successful companies will very quickly home in on their unique value proposition and partner in areas that help accelerate their capabilities.

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The potential impact from IoT-driven advanced analytics is game changing. While it is easy for companies to get started and get some quick wins on the board, it is much harder to scale across the company and deliver consistent bottom-line impact. The most successful organizations will be those that think through all of the implications, invest in both technology and people, forge smart partnerships, and maintain sufficient leadership appetite to persist.

Additive manufacturing: A long-term game changer for manufacturers

Jörg Bromberger and Richard Kelly

To get the most out of additive manufacturing, companies need to think beyond prototyping and understand what the technology means for production.

Jörg Bromberger is a senior expert in McKinsey's Berlin office, and **Richard Kelly** is a partner in the Stamford office.

Additive manufacturing (AM)—the process of making a product layer by layer instead of using traditional molding or subtractive methods—has become one of the most revolutionary technology applications in manufacturing. Often referred to as 3-D printing, the best-known forms of AM today depend on the material: SLS (selective laser sintering), SLA (stereolithography), and FDM (fused deposition modeling) in plastics, and DMLS (direct metal laser sintering) and LMD (laser metal deposition) in metals.

Once employed purely for prototyping, AM is now increasingly used for spare parts, small series production, and tooling. For manufacturing with metals, the ability to use existing materials such as steel, aluminum, or superalloys such as Inconel has significantly eased the process of adopting AM.

Meanwhile, the number of materials that AM can handle is constantly expanding. A wide range of new plastics has been developed, along with processes and machines for printing with ceramics, glass, paper, wood, cement, graphene, and even living cells. Applications are now available in industries ranging from aerospace to automobiles, from consumer goods (including food) to health care (where artificial human tissue can be produced using AM) (Exhibit 1).

Additive advantages

Compared with traditional production methods, AM offers enormous benefits, including less hard tooling and assembly. In the long run, AM can completely change the way products are designed and built, as well as distributed, sold, and serviced (Exhibit 2).

Exhibit 1. Additive manufacturing is already a reality in many industries.

Aerospace	Industrial	Healthcare
▪ **Fuel nozzle** for flight engines ▪ **5x more durable, 25% lighter**	▪ **Repair of burner heads** for gas turbines ▪ Reduction of **repair time from 44 to 4 weeks**	▪ **Hearing aids** ▪ Mass production of **highly customized** parts
▪ **Thrust chamber** for aerospace rocket engine. **More reliable, robust, and efficient**	▪ Printing of industrial **filters with geometrical optimization** ▪ **15% pumping energy reduction**	▪ **Model to aid tumor surgery** ▪ **Reduction of surgery time and complications**
▪ **Metal brackets designed** for additive manufacturing ▪ Resulting in **up to 50% less weight** and less raw material input	▪ **Increase** of machine parts **performance through special design** ▪ Reduction of **production time from days to hours**	▪ **Artificial limbs constructed in 2 weeks**, replacing lower half of left leg ▪ Perfect **physical fit with aesthetic components**

Source: MarketsandMarkets; press reports

Exhibit 2. AM offers significant benefits.

Design and engineering			Manufacturing		Service	
Faster time to market	**Greater customization**	**Product enhancements**	**Faster/more flexible manufacturing process**	**Higher material productivity**	**Simplified supply chain**	**More efficient sales process**
▪ Fast proto-typing ▪ Fast design adjust-ments	▪ New cus-tomized applica-tions ▪ More differ-entiated products	▪ Better func-tionalities /product perform-ance ▪ New designs ▪ Less weight	▪ No setup time in production ▪ Fewer production steps/interfaces ▪ Fewer required parts ▪ Less assembly time ▪ More flexibility and better load balance ▪ Inherent quality assurance process ▪ Fewer dedicated machines	▪ Less material waste ▪ New material features	▪ Localized production ▪ Elimination of obsolete parts ▪ Refurbishment for specific components ▪ Less dependence on suppliers	▪ Customized product exemplifica-tion

Relevant for

Engineering-intensive business	*High-value/low-volume business*	*Spare parts-intensive business*

Adoption of AM has been highest in industries where its higher production costs are outweighed by the additional value AM can generate: improved product functionality, higher production efficiency, greater customization, shorter time to market (that is, improved service levels), and reduced obsolescence, particularly in asset-heavy industries. Engineering-intensive businesses such as aerospace, automotive, and medical can accelerate prototyping, allowing them to explore completely new design features or create fully individualized products at no extra cost. High-value/lower-volume businesses see faster, more flexible manufacturing processes, with fewer parts involved, less material wasted, reduced assembly time for complex components, and even materials with completely new properties created. And spare-parts-intensive businesses in fields such as maintenance, repair, and overhaul get freedom from obsolete parts, faster time to market, more local and on-demand production opportunities, and independence from traditional suppliers.

Manufacturing market potential

Several analyst reports expect that the direct market for AM will grow to at least $20 billion by 2020—a figure that represents just a fraction of the entire tooling market today.[1] However, we believe that the overall economic impact created by AM could be much higher, reaching $100 billion to 250 billion by 2025, if adoption across industries continues at today's rate. Most of that potential will come from the aerospace and defense, automotive, medical, and consumer-goods industries.

Meanwhile, various stakeholders are accelerating the overall market development for AM. Large OEMs are investing significantly in R&D and building internal centers of competence, while other large corporations—such as HP, from the traditional printing business—are entering the market. Major governments are setting up R&D funds, including the European Union's Horizon 2020 program, or are starting capability-building programs for their workforces, as in Korea.

Universities are partnering with manufacturers' research centers to create innovation centers for applied R&D, with examples including Advanced Remanufacturing and Technology Centre in Singapore and RWTH Aachen University/Fraunhofer Institute for Production Technology. Finally, a vibrant start-up scene has arisen as most patents on existing AM technologies have run out, leaving space for new (as well as established) players from various industries to enter at all points on the value chain. New design and service companies are being set up and new technologies developed, such as by BigRep and Carbon3D.

AM's limitations

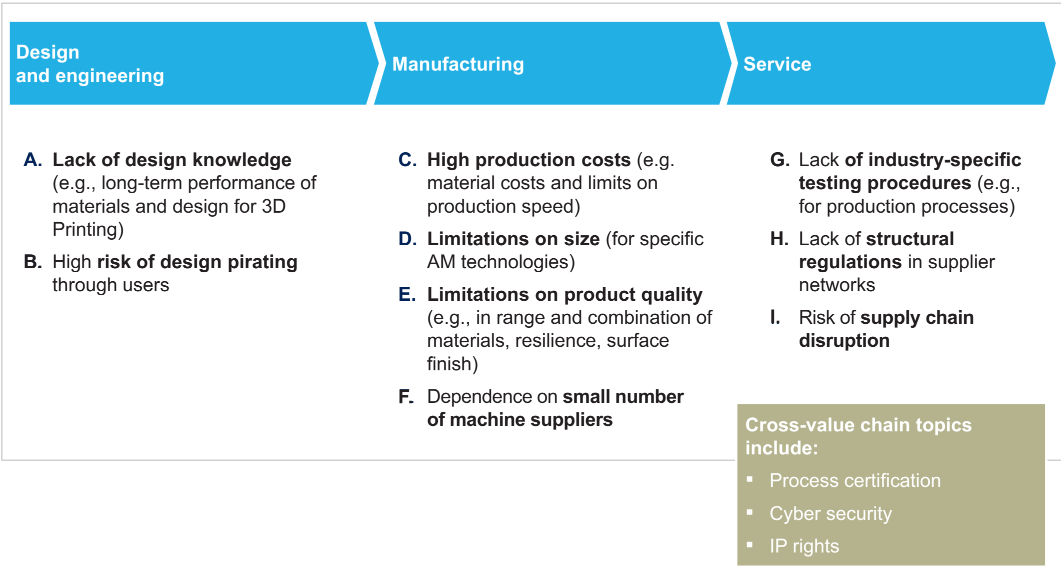
Despite all of the optimism about AM, there are still major challenges to be overcome before the technology enjoys truly widespread adoption (Exhibit 3).

- **Lack of design knowledge.** There is still a significant worldwide skills gap when it comes to product design for AM. Capturing the technology's full potential often requires completely rethinking the way products are designed, because AM allows nearly complete freedom: product designs can be calibrated to eliminate unnecessary materials, and inner or organic structures can be incorporated, thus overcoming the limitations of traditional milling or injection molding. Our sense is that companies are only scratching the surface of what is possible.

- **High production costs.** This is the major barrier to more widespread use of AM. Although AM avoids the high up-front tooling costs that traditional processes (such as injection molding) require, those advantages tend to fade quickly as production volume

1 Nancy Eigel-Miller, Joe Jablonowski, and Steven Kline Jr., *2014 World machine-tool output and consumption survey*, Gardner, February 27, 2014, gardnerweb.com.

Exhibit 3. Despite AM's many benefits, there are still technological limitations to be overcome.



SOURCE: Expert interviews; team analysis

increases. The good news, however, is that with plastics, the volume threshold where AM has an advantage is increasing, with one AM company claiming to have pushed it to 5,000 units for a relatively small, simple object. But even at low volumes, AM with metals often remains much more expensive than traditional methods because of several interconnected factors: high materials costs, slow build-up rates, and the long machining hours that result, high energy consumption, and postprocessing costs, which are often underestimated.

- **Limited production scale.** Because most current AM machines are made for prototyping rather than series production, mass production scale is hard to attain. The next-generation machinery needs to keep reducing production costs while adding capabilities necessary to support industrial production, such as process-stability management, in-process quality control, faster changeovers, greater reliability, and easier maintenance and repair.

- **Limited cybersecurity and IP protection.** Current-generation AM machinery is vulnerable to two especially important security issues. The first is the protection of original designs, including the identification of parts—particularly if parts are designed in ways that make them replicable after the product is sold. The second is protecting data from cyberattacks, the risks of which are increased by tighter integration with suppliers and customers.

Manufacturers of AM machines, however, are addressing these limitations with significant results. Specialized AM service companies, along with engineering and consulting firms, are now bridging the design-skills gap. In addition, regional governments are funding AM-focused production clusters for applied R&D. Several analysts predict that next-generation machines will cut current AM production costs dramatically because of factors such as patent expiration and reduced postprocessing needs. Manufacturers will also benefit from increasing economies of scale and sourcing opportunities in low-cost countries.

AM machine manufacturers are working on better in-process control, advanced quality diagnostics, and data storage along the entire production process for certification purposes. Large AM manufacturers, including Materialise and Stratasys, suggest that AM can achieve material properties in both plastics and metals comparable to those from traditional production techniques.

We are also seeing an increasing availability of materials with properties comparable or even superior to those of existing ones. These materials include polymers such as nylon, PEEK, and ULTEM that are becoming more heat resistant and lending themselves to more applications, and metals and alloys within the standard range of available materials: industrial metals such as steel, aluminum, titanium, and Inconel; precious metals such as gold and silver; and new materials including amorphous, noncrystalline metals.

The AM value chain—players and business models

The AM landscape is diverse. In the plastics printing market, larger, integrated players cover the entire value chain from supplying materials to manufacturing printers to providing printing services. Several have added services by making targeted acquisitions. The larger players are also very active in creating new use cases in particular industries, driving sector-wide adoption and sale of equipment. In the metal printing market, by contrast, relatively small players focus more on certain parts of the value chain, such as in printing equipment or in printing services.

Given the investments necessary for developing the next-generation machines, many of these smaller players are looking for capital. Consolidation in the market has therefore begun. Uncertainty about which manufacturers will survive will change the face of the industry, creating risk for manufacturers investing in equipment even as improving technology holds out the promise of surmounting current barriers to the adoption of AM.

Meanwhile, in addition to the traditional material, printing, and service businesses, fast-growing niche players are starting to arise. These companies ground their entire business models on AM, ideally combined with digital sales and service models. Align Technology, with its product Invisalign, provides an alternative to metal dental braces; there are similar examples from Sonova for in-ear hearing aids, Mykita with eyeglasses, and Shapeways with crowd design of consumer products.

New competitors are also entering the OEM market. Large players such as Stratasys and 3D Systems are certifying an end-to-end process for producing medical parts with newly developed

Larger players are also very active in creating new use cases in particular industries, driving sector-wide adoption and sales of equipment.

materials, using their own printing technology and offering printing services to customers such as hospitals, which formerly purchased from OEMs.

We see little evidence of a race toward a single technology, since—because of factors including variations in cost, available materials, and surface finish—the existing technologies serve different purposes. To explore the potential of AM, manufacturers therefore often need access to more than one technology, which they can get via specialized service providers that offer all the key ones. This picture may change, however, if new entrants dramatically increase performance by improving an existing technology or creating a completely new one.

Disruptive potential of AM for value chains and traditional company functions

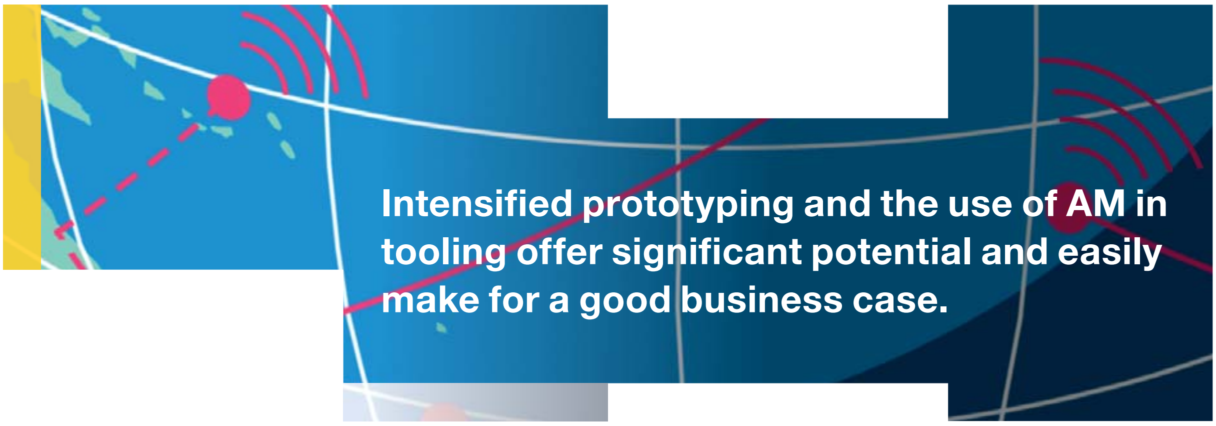
People tend to overestimate the short-term impact of technologies and significantly underestimate the long-term impact. Yet there is currently a lot of uncertainty about the long-term impact of AM on traditional value chains. Understandably, the issue is being raised by traditional players such as logistics companies that will be directly affected, and by governments that aim to prepare their manufacturing ecosystems and workforces for changes that may be coming soon.

How will the traditional way of serving markets change, and what are the implications for traditional plant setups and value chains? As far as production and distribution are concerned, a few things seem clear. Advantages from production in low-cost countries will likely diminish. New, customer-centric plants will emerge, allowing the finishing of products according to local demand and significantly reducing the need for long-distance transport of finished goods. We may also see new production-network models—for example, production of half-finished products in low-cost countries, with finishing done close to customers to adjust for local taste, seasonality, and similar factors.

With these changes in production capabilities will come equally dramatic shifts in company functions and their relative importance on the value chain. The ability to make completely customizable products will shift the traditional manufacturing mind-set of "What is feasible?" to one of "What is possible?" Design capabilities will therefore become an even more important strategic asset.

Company functions of today will also change when, for example, operators skilled for one production line will need to operate new AM production lines that produce a large variety of products. Traditional engineers will need to be trained in AM design. Marketing and sales, meanwhile, will need to learn how to market individualized products that can be produced anywhere in the world.

New, customer-centric plants will emerge, allowing the finishing of products according to local demand and significantly reducing the need for long-distance transport of finished goods.



Recommendations for manufacturers

Despite the uncertainties that remain about the impact of AM on the future of manufacturing, there are steps manufacturers can take now to begin adapting and preparing for what is likely to come. Here are four sets of recommendations:

Introduce technology selectively

Manufacturers can start by producing only a few components at first. We recommend selecting parts for manufacture via AM based on three criteria. The first identifies opportunities for better performance or customer value, through redesigns that use less material, enable higher customization, or add new features. Second, lower cost may be possible, such as through cheaper spare parts or less expensive tooling. Finally, a design may become more feasible because of greater material availability.

Manufacturers often focus on series production only, but should not let this blind them to the benefits of AM for more limited purposes as well. Intensified prototyping and the use of AM in tooling (e.g., for jigs and fixtures in assembly, or for molds for small series) offer significant potential and easily make for a good business case. They also provide quick wins to create acceptance and momentum for AM within an organization.

Build new organizational capabilities over time

Building partnerships with institutions such as universities, research consortiums, or related service providers can help ensure access to the latest technology. Companies will likely also need to invest in new technical skills in areas including AM design, engineering, and production, either through hiring or training. New internal processes and organizational structures may be necessary for purposes such as quality assurance and supply-chain agility. And, to support continuous improvement, centers of competence for training, knowledge sharing, testing, and expert support will require resources as well.

Prepare for wider range of rollouts of technology

The changes will only accelerate as AM develops more traction. Manufacturers will need appropriate infrastructure and capabilities for AM production, particularly in IT and in data intelligence for functions such as quality control. A rigorous technology launch process will help ensure product, supplier, and plant readiness. And they'll need to integrate AM efficiently into their existing manufacturing infrastructure, such as by designing a small AM facility within a larger plant.

Rethink manufacturing strategy and explore new business models

To take full advantage of new technology, leaders must explore new approaches to product development, leveraging increased design and customization possibilities. Opportunities include not only reducing time to market, but also leveraging untapped design creativity by involving customers in the development of AM prototypes. Distribution strategy will increasingly need to incorporate possibilities like local production on demand, and new profit pools will emerge and expand, such as from savings on import taxes and duties from a reconfigured manufacturing footprint.

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We believe AM offers huge potential for manufacturers to significantly improve their way of making goods and create additional business opportunities through radically new products or business models. The major question, at this point, is how fast to move on developing AM capabilities. Manufacturers should be prepared to start acting now in markets where significant opportunities are already generating movement toward AM.

Yet it is difficult to state with certainty how fast manufacturers should try to go. It takes a lot of time to build the right capabilities with current AM technology, and no one company will likely be able to get out ahead of competitors all that fast. Still, if more industries shift, these capabilities—particularly engineers skilled in AM—could quickly become scarce. Furthermore, given the funding that governments and large OEMs are putting into R&D, and the likelihood that start-ups may come up with radical new solutions or technologies that accelerate the shift to AM, the pace of change may turn out to be faster than we anticipate.

In the face of such uncertainty, the recommendations we offer above—starting slowly to get quick wins, building infrastructure and capabilities for wider AM use, rethinking strategy and business models, and developing new organizational capabilities—provide ways for manufacturers to get started now and prepare themselves for how technology and markets will develop over time.

Automation, robotics, and the factory of the future

Jonathan Tilley

Cheaper, more capable, and more flexible technologies are accelerating the growth of fully automated production facilities. The key challenge for companies will be deciding how best to harness their power.

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At one Fanuc plant in Oshino, Japan, industrial robots produce industrial robots, supervised by a staff of only four workers per shift. In a Philips plant producing electric razors in the Netherlands, robots outnumber the nine production workers by more than 14 to 1. Camera maker Canon began phasing out human labor at several of its factories in 2013.

This "lights out" production concept—where manufacturing activities and material flows are handled entirely automatically—is becoming an increasingly common attribute of modern manufacturing. In part, the new wave of automation will be driven by the same things that first brought robotics and automation into the workplace: to free human workers from dirty, dull, or dangerous jobs; to improve quality by eliminating errors and reducing variability; and to cut manufacturing costs by replacing increasingly expensive people with ever-cheaper machines. Today's most advanced automation systems have additional capabilities, however, enabling their use in environments that have not been suitable for automation up to now and allowing the capture of entirely new sources of value in manufacturing.

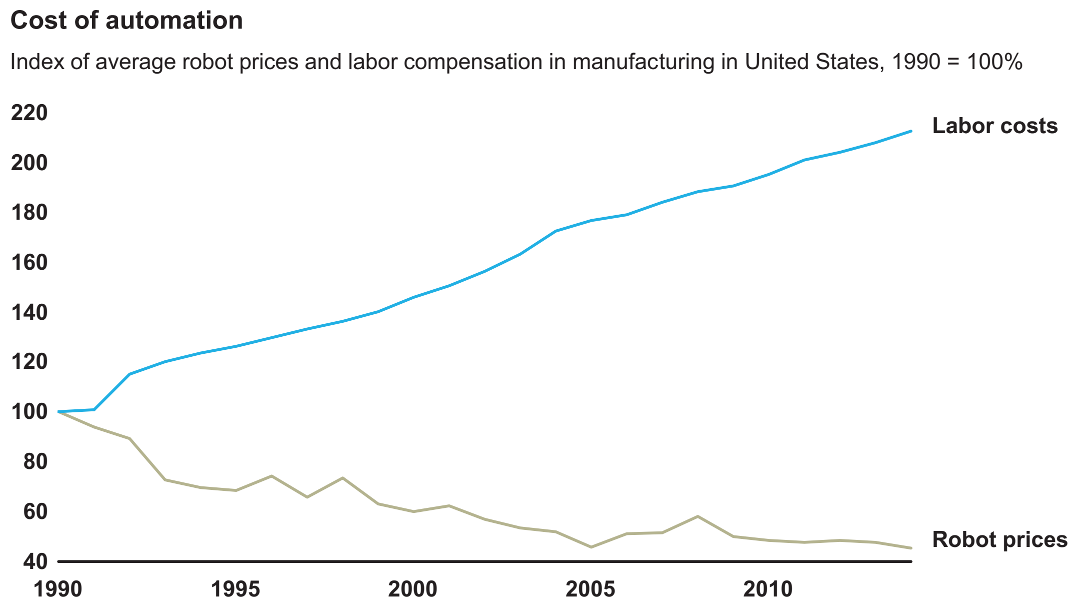
Falling robot prices

As robot production has increased, costs have gone down. Over the past 30 years, the average robot price has fallen by half in real terms, and even further relative to labor costs (Exhibit 1). As demand from emerging economies encourages the production of robots to shift to lower-cost regions, they are likely to become cheaper still.

Accessible talent

People with the skills required to design, install, operate, and maintain robotic

Exhibit 1. Robot prices have fallen in comparison with labor costs.



Source: Economist Intelligence Unit; IMB; Institut für Arbeitsmarkt- und Berufsforschung; International Robot Federation; US Social Security data; McKinsey analysis

production systems are becoming more widely available, too. Robotics engineers were once rare and expensive specialists. Today, these subjects are widely taught in schools and colleges around the world, either in dedicated courses or as part of more general education on manufacturing technologies or engineering design for manufacture. The availability of software, such as simulation packages and offline programming systems that can test robotic applications, has reduced engineering time and risk. It's also made the task of programming robots easier and cheaper.

Ease of integration

Advances in computing power, software-development techniques, and networking technologies have made assembling, installing, and maintaining robots faster and less costly than before. For example, while sensors and actuators once had to be individually connected to robot controllers with dedicated wiring through terminal racks, connectors, and junction boxes, they now use plug-and-play technologies in which components can be connected using simpler network wiring. The components will identify themselves automatically to the control system, greatly reducing setup time. These sensors and actuators can also monitor themselves and report their status to the control system, to aid process control and collect data for maintenance, and for continuous improvement and troubleshooting purposes. Other standards and network technologies make it similarly straightforward to link robots to wider production systems.

New capabilities

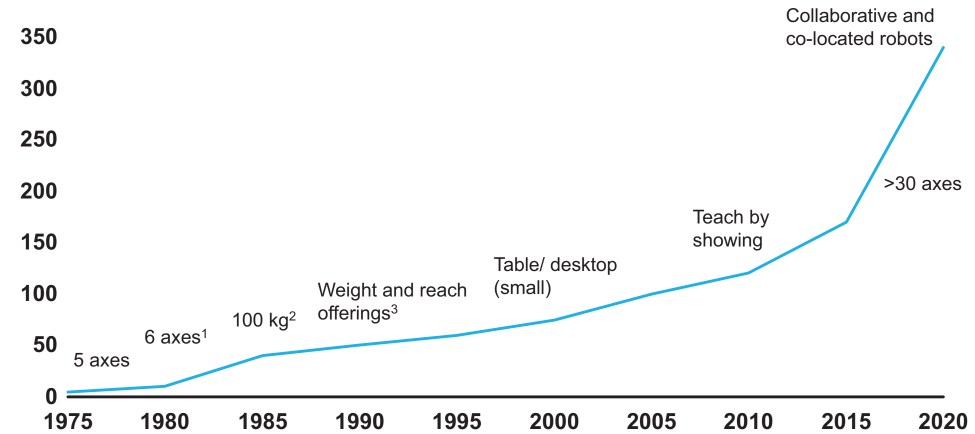
Robots are getting smarter, too. Where early robots blindly followed the same path, and later iterations used lasers or vision systems to detect the orientation of parts and materials, the latest generations of robots can integrate information from multiple sensors and adapt their movements in real time. This allows them,

Exhibit 2. The increasing variety, size range, and capabilities of robots have driven market growth.

ILLUSTRATIVE

Growth of robots on the market

Base quantity SKUs



	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020
Number of axes	5	6 to 8	12		21	27			32	
Kg capacity	6	60	90	>120				1,000		
Maximum reach (meters)	1		2					3		

1 Allows arc welding, adhesives dispensing, machine loading. 2 Spot welding, materials handling. 3 All application areas; right size for the task.

Source: McKinsey analysis

for example, to use force feedback to mimic the skill of a craftsman in grinding, deburring, or polishing applications. They can also make use of more powerful computer technology and big data–style analysis. For instance, they can use spectral analysis to check the quality of a weld as it is being made, dramatically reducing the amount of postmanufacture inspection required.

Robots take on new roles

Today, these factors are helping to boost robot adoption in the kinds of application they already excel at today: repetitive, high-volume production activities. As the cost and complexity of automating tasks with robots goes down, it is likely that the kinds of companies already using robots will use even more of them. In the next five to ten years, however, we expect a more fundamental change in the kinds of tasks for which robots become both technically and economically viable (Exhibit 2). Here are some examples.

Low-volume production

The inherent flexibility of a device that can be programmed quickly and easily will greatly reduce the number of times a robot needs to repeat a given task to justify the cost of buying and commissioning it. This will lower the threshold of volume and make robots an economical choice for niche tasks, where annual volumes are measured in the tens or hundreds rather than in the thousands or hundreds of thousands. It will also make them viable for companies working with small batch sizes and significant product variety. For example, flex track products now used in aerospace can "crawl" on a fuselage using vision to direct their work. The cost savings offered by this kind of low-volume automation will benefit many different kinds of organizations: small companies will be able to access robot technology for the first time, and larger ones could increase the variety of their product offerings.

Emerging technologies are likely to simplify robot programming even further. While it is already common to teach robots by leading them through a series of movements, for example, rapidly improving voice-recognition technology means it may soon be possible to give them verbal instructions, too.

Highly variable tasks

Advances in artificial intelligence and sensor technologies will allow robots to cope with a far greater degree of task-to-task variability. The ability to adapt their actions in response to changes in their environment will create opportunities for automation in areas such as the processing of agricultural products, where there is significant part-to-part variability. In Japan, trials have already demonstrated that robots can cut the time required to harvest strawberries by up to 40 percent, using a stereoscopic imaging system to identify the location of fruit and evaluate its ripeness.

These same capabilities will also drive quality improvements in all sectors. Robots will be able to compensate for potential quality issues during manufacturing. Examples here include altering the force used to assemble two parts based on the dimensional differences between them, or selecting and combining different sized components to achieve the right final dimensions.

Robot-generated data, and the advanced analysis techniques to make better use of them, will also be useful in understanding the underlying drivers of quality. If higher-than-normal torque requirements during assembly turn out to be associated with premature product failures in the field, for example, manufacturing processes can be adapted to detect and fix such issues during production.

Complex tasks

While today's general-purpose robots can control their movement to within 0.10 millimeters, some current configurations of robots have repeatable accuracy of 0.02 millimeters. Future generations are likely to offer even higher levels of precision. Such capabilities will allow them to participate in increasingly delicate tasks, such as threading needles or assembling highly sophisticated electronic devices. Robots are also becoming better coordinated, with the availability of controllers that can simultaneously drive dozens of axes, allowing multiple robots to work together on the same task.

Finally, advanced sensor technologies, and the computer power needed to analyze the data from those sensors, will allow robots to take on tasks like cutting gemstones that previously required highly skilled craftspeople. The same technologies may even permit activities that cannot be done at all today: for example, adjusting the thickness or composition of coatings in real time as they are applied to compensate for deviations in the underlying material, or "painting" electronic circuits on the surface of structures.

Working alongside people

Companies will also have far more freedom to decide which tasks to automate with robots and which to conduct manually. Advanced safety systems mean robots can take up new positions next to their human colleagues. If sensors indicate the risk of a collision with an operator, the robot will automatically slow down or alter its path to avoid it. This technology permits the use of robots for individual tasks on otherwise manual assembly lines. And the removal of safety fences and interlocks mean lower costs—a boon for smaller companies. The ability to put robots and people side by side and to reallocate tasks between them also helps productivity, since it allows companies to rebalance production lines as demand fluctuates.

Robots that can operate safely in proximity to people will also pave the way for applications away from the tightly controlled environment of the factory floor. Internet retailers and logistics companies are already adopting forms of robotic automation in their warehouses. Imagine the productivity benefits available to a parcel courier, though, if an onboard robot could presort packages in the delivery vehicle between drops.

Agile production systems

Automation systems are becoming increasingly flexible and intelligent, adapting their behavior automatically to maximize output or minimize cost per unit. Expert systems used in beverage filling and packing lines can automatically adjust the speed of the whole production line to suit whichever activity is the critical constraint for a given batch. In automotive production, expert systems can automatically make tiny adjustments in line speed to improve the overall balance of individual lines and maximize the effectiveness of the whole manufacturing system.

While the vast majority of robots in use today still operate in high-speed, high-volume production applications, the most advanced systems can make adjustments on the fly, switching seamlessly between product types without the need to stop the line to change programs or reconfigure tooling. Many current and emerging production technologies, from computerized-numerical-control (CNC) cutting to 3-D printing, allow component geometry to be adjusted without any need for tool changes, making it possible to produce in batch sizes of one. One manufacturer of industrial components, for example, uses real-time communication from radio-frequency identification (RFID) tags to adjust components' shapes to suit the requirements of different models.

The replacement of fixed conveyor systems with automated guided vehicles (AGVs) even lets plants reconfigure the flow of products and components seamlessly between different workstations, allowing manufacturing sequences with entirely different process steps to be completed in a fully automated fashion. This kind of flexibility delivers a host of benefits: facilitating shorter lead times and a tighter link between supply and demand, accelerating new product introduction, and simplifying the manufacture of highly customized products.

Making the right automation decisions

With so much technological potential at their fingertips, how do companies decide on the best automation strategy? It can be all too easy to get carried away with automation for its own sake, but the result of this approach is almost always projects that cost too much, take too long to implement, and fail to deliver against their business objectives.

A successful automation strategy requires good decisions on multiple levels. Companies must choose which activities to automate, what level of automation to use (from simple programmable-logic controllers to highly sophisticated robots guided by sensors and smart adaptive algorithms), and which technologies to adopt. At each of these levels, companies should ensure that their plans meet the following criteria.

Automation strategy must align with business and operations strategy. As we have noted above, automation can achieve four key objectives: improving worker safety, reducing costs, improving quality, and increasing flexibility. Done well, automation may deliver improvements in all these areas, but the balance of benefits may vary with different technologies and approaches. The right balance for any organization will depend on its overall operations strategy and its business goals.

Automation programs must start with a clear articulation of the problem. It's also important that this includes the reasons automation is the right solution. Every project should be able to identify where and how automation can offer improvements and show how these improvements link to the company's overall strategy.

Automation must show a clear return on investment. Companies, especially large ones, should take care not to overspecify, overcomplicate, or overspend on their automation investments. Choosing the right level of complexity to meet current and foreseeable future needs requires a deep understanding of the organization's processes and manufacturing systems.

Platforming and integration

Companies face increasing pressure to maximize the return on their capital investments and to reduce the time required to take new products from design to full-scale production. Building automation systems that are suitable only for a single line of products runs counter to both those aims, requiring repeated, lengthy, and expensive cycles of equipment design, procurement, and commissioning. A better approach is the use of production systems, cells, lines, and factories that can be easily modified and adapted.

Just as platforming and modularization strategies have simplified and reduced the cost of managing complex product portfolios, so a platform approach will become increasingly important for manufacturers seeking to maximize flexibility and economies of scale in their automation strategies.

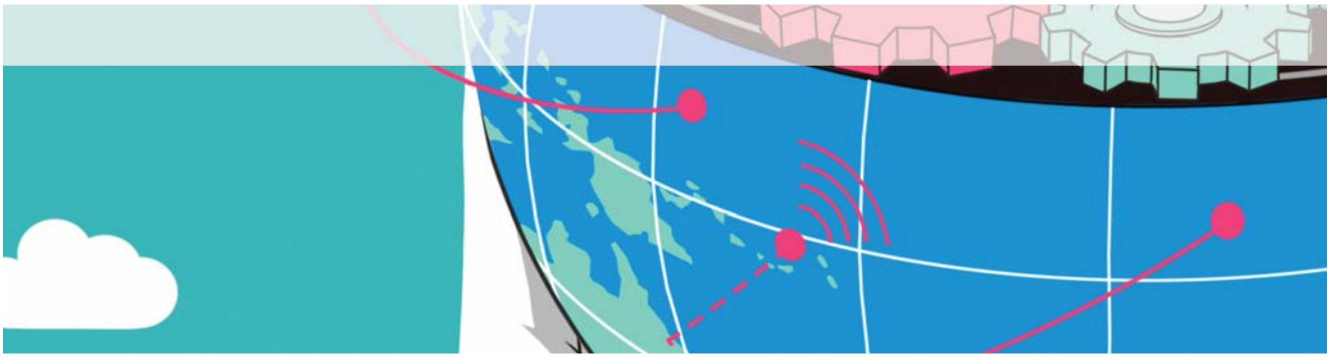
Process platforms, such as a robot arm equipped with a weld gun, power supply, and control electronics, can be standardized, applied, and reused in multiple applications, simplifying programming, maintenance, and product support.

Automation systems will also need to be highly integrated into the organization's other systems. That integration starts with communication between machines on the factory floor, something that is made more straightforward by modern industrial-networking technologies. But it should also extend into the wider organization. Direct integration with computer-aided design, computer-integrated engineering, and enterprise-resource-planning systems will accelerate the design and deployment of new manufacturing configurations and allow flexible systems to respond in near real time to changes in demand or material availability. Data on process variables and manufacturing performance flowing the other way will be recorded for quality-assurance purposes and used to inform design improvements and future product generations.

Integration will also extend beyond the walls of the plant. Companies won't just require close collaboration and seamless exchange of information with customers and suppliers; they will also need to build such relationships with the manufacturers of processing equipment, who will increasingly hold much of the know-how and intellectual property required to make automation systems perform optimally. The technology required to permit this integration is becoming increasingly accessible, thanks to the availability of open architectures and networking protocols, but changes in culture, management processes, and mind-sets will be needed in order to balance the costs, benefits, and risks.

□ □ □

Cheaper, smarter, and more adaptable automation systems are already transforming manufacturing in a host of different ways. While the technology will become more straightforward to implement, the business decisions will not. To capture the full value of the opportunities presented by these new systems, companies will need to take a holistic and systematic approach, aligning their automation strategy closely with the current and future needs of the business.



Leadership in innovation needs innovation in leadership

Ron Ritter and Ed Ruggero

As businesses face evolving challenges, four aspects of leadership will become dramatically more important: insight, integrity, courage, and agility.

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Ed Ruggero is a writer, public speaker, and trainer on leadership. He is the author of 11 books, including *Duty First: A Year in the Life of West Point and the Making of American Leaders (HarperCollins, 2001)* and *Combat Jump: The Young Men Who Led the Assault into Fortress Europe, July 1943* (Harper, 2003). After graduating from the US Military Academy at West Point, he served in the US Army for 11 years. Since then, he has spoken to audiences around the world (including at the University of Pennsylvania's Wharton School of Business and at Harvard Business School) on leadership, leader development, and ethics, and he has developed experiential learning programs centering on battle-tested leadership lessons.

It may be that advancing technology plays the most visible role in shaping manufacturing progress in the years ahead. But we believe that what will matter at least as much for manufacturing's future is something that's much less visible, even though it has long been the bedrock of performance: effective leadership. How individual leaders inspire and influence others will become a key differentiator between organizations that thrive and those that do not.

In our experience transforming large, complex organizations at scale, the bulk of the work is usually in creating operational and managerial solutions. Yet we also know that nothing will happen, let alone sustain itself over time, without effective leadership. Indeed, extensive—and remarkably quantitative—research confirms that there are roughly 20 fundamental components of leadership that correlate closely to organizational performance (exhibit).

We know that the list is hardly set in stone, and that what we define today as leadership is only one necessary part of organizational health. Yet what excites us about the list is that while some of the 20 may be seem almost self-explanatory (for example, "solve problems effectively"), collectively they actually work.

This foundation in hand, we recently interviewed colleagues with experience across a wide range of manufacturing environments, asking them what they saw as the next domains of great leadership. We all agreed that it's impossible (and likely counterproductive) to define all the answers here; future leadership will evolve rapidly and unpredictably. But those conversations nevertheless form a call to action showing where leadership must progress in order to support change and innovation.

We found that while the 20 fundamentals will likely remain essential, manufacturers

Exhibit. Today's 20 research-supported traits support the four leadership characteristics our interviewees see as essential for the future.

Traits	Characteristic
▪ Facilitate group collaboration ▪ Solve problems effectively ▪ Make quality decisions ▪ Offer a critical perspective ▪ Communicate prolifically and enthusiastically	1. Insight
▪ Role model organizational values ▪ Give praise ▪ Be supportive ▪ Develop others ▪ Foster mutual respect	2. Integrity
▪ Remain composed and confident in uncertainty ▪ Keep group organized and on task ▪ Operate with strong results orientation ▪ Develop and share collective mission ▪ Seek different perspectives ▪ Champion desired change	3. Courage
▪ Recover positively from failures ▪ Clarify objectives, rewards, and consequences ▪ Motivate and bring out best in others ▪ Differentiate among followers	4. Agility

SOURCE: Claudio Feser, Fernanda Mayol, and Ramesh Srinivasan, "Decoding leadership: What really matters," *McKinsey Quarterly*, January 2015, McKinsey.com

will need even more effective leadership to withstand the unavoidable forces pressing change on every level:

- The multidecade explosion in new materials, innovative process technology, labor-displacing robotics and automation, predictive-analytic tools, and vast data pools, which are now predicted to reach 180 zettabytes around the world by 2025.

- The evolution of supertransparent supply markets that have enabled widespread cleansheet costing and produced unprecedented challenges in defining products' design attributes, cost, and pricing. At the same time, as oceans, trade barriers, and long-standing relationships recede in importance, transparent buying markets constantly raise customers' standards around the world.

- The rise of "employee experience" in a workforce that rightly looks for more engagement, support, inclusion, and coaching and is increasingly able to draw critical comparisons with other work environments, leaders, and even industries.

- Highly dynamic political currents in which manufacturing has assumed a new prominence in policy makers' agendas.

Against this context, we believe the fundamental profile of personal and organizational leadership is about something more than the important basics. Four attributes will enable individuals and organizations to stand out and move forward at a distinctive pace. Effective leaders will have the **insight** to clearly see and calibrate what really matters in operations and people; the **integrity** to build deep wells of trust and conviction; the **courage** to take on really tough opportunities quickly; and the **agility** to know when they need to shift course and move on. The four build on one another: when we see opportunity clearly, we need to trust each other in committing to take bold action and know that we can adapt and overcome unforeseen barriers. A leader —or, better still, an entire organization of leaders—that can combine all four well can do great things.

Insight

In our interviews, we encountered a number of closely related stories about discipline, concentration, and persistent tracking of value. Great operational leaders have an incisive sense of what matters and the ability to see constant sources of opportunity (and resistance) relative to that objective.

Dedication to value and performance can help an organization constantly orient toward the next opportunity, without getting distracted by pure novelty. This ability quickly gets an organization moving with confidence. One basic-materials company executive "had a completely instinctive sense" of the areas of performance that would fuel a rapid turnaround—targeting the uptime and reliability of specific heavy equipment, a positive trend in water and energy demand, and sustaining high safety performance.

At the best organizations, this disciplined sense of direction cascades powerfully to the front line: one of the authors of this article will never forget standing in a major automotive stamping line, listening to three hourly team members energetically describe how they cracked a millimeter-level defect in the stamping of an entire car-body panel. Or an example from a major healthcare player suffering from a quality compliance shock. Once the storm passed, the organization had the wonderfully stubborn discipline to return right back to the long-range productivity and cost-performance focus its leaders had championed, recognizing that far from conflicting, the cost and quality imperatives reinforced one another.

Integrity

In our work, we live in the thick of major transformations that push organizations and teams to their limits. Invariably, the programs that succeed have high-integrity leaders who model behaviors and decisions and are relentlessly consistent to their declared aspirations: on safety, productivity, or any other objective. These leaders stay true to organizational values, commitments, and each other, and they build deep wells of confidence and trust that add tremendous strength to the organization.

This "trust dividend" inspires and earns the respect of the people, who will stay the course even in tough times and accomplish great things. The dividend's value is most obvious when things are not going well—after the exciting start gives way to the long sustainment, for instance. This genuine integrity builds organizational resilience.

At the critical point in the transformation of a basic-materials company, an executive site manager gave up her top role to personally lead a transformation that many in the company had dismissed as "just another program." She recognized a moment of truth, took what was arguably a lower-rank role, cleaned out her office, and handed the keys to a more-junior leader. This was a clear act of self-sacrifice and a very real professional risk. Had the transformation failed under her leadership, she would have had no easy path to reinstatement. Her actions confirmed what she had been saying was the most important priority—the transformation. By taking the role of change-program leader, in a traditional organization that valued classic line-leadership roles, she strongly reinforced the transformation story.

High-integrity leaders also demonstrate a great personal generosity and humility, identifying their own personal success or a subordinate's lapse as something "we did." Such leaders also regularly demonstrate authentic caring and interest in their team—almost as a head of a family, speaking and acting with a distinctly personal sense of duty to their team members.

Courage

Courageous leaders demonstrate bold, informed risk taking and the grit to persist in the face of challenges. They impel the organization forward, accepting uncertainty and taking on major stretches of hard work in areas that show potential for real reward—and, more seriously, real risk of loss as well. It is the ethos of doing "the harder right instead of the easier wrong."

In the basic-materials case, the courageous act was a determination not only to invest publicly in a major review of water use and impacts across all sites but also to publicly reach out to environmental organizations that had criticized the company. It would have been far easier to hold back, run the operation as is, and react only to a failure event.

It's also important to distinguish bold ideas, in the pure-innovation sense that's so visible in high tech, from bold application of those ideas in an actual business. Innovation is important; making big moves based on innovation, including decisions that may involve long-term and even irreversible outcomes, is another matter. Ford's dramatic decision to convert its global best-selling vehicle, the F-Series pickup trucks, from industry-standard steel to aluminum, illustrates the point well. Ford changed far more than a material: it changed its supply-chain structure, its tooling, its procedures, and its entire workforce experience. We saw a similar story at a heavy-vehicle manufacturer that made a bold bet on an entirely different assembly process that, counterintuitively, increased its flexibility and speed.

While most organizations will eventually progress toward better, more advanced ideas, it is speed that sets some apart. We see too many examples of cautious leadership creating long, multiyear gaps between the recognition of a great idea and real adoption. Successful organizations also have the grit to move beyond the idea or the proof-of-concept pilot to implementing at scale.

Boeing provides a great example in its adoption of moving assembly lines for whole-aircraft manufacturing. Traditionally, airplanes were built in single, old-school stations, absent much of the rigor typical of high-volume assembly lines in the automotive sector. The idea of moving lines in aircraft assembly took hold in the late 1990s for the comparatively low-volume Boeing 717. Boeing then adapted the idea to its core 737 production lines, and then to the far more complex production of the 777. Testing a moving line is hard work, and deploying a new operations model takes courage—the kind of bold path that might not normally be taken.

A similar path is currently unfolding at SpaceX, whose Falcon rockets and Dragon capsule spacecraft have already helped dramatically reduce the cost of orbital delivery. Yet aggressive

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levels of design cost targeting are just part of the story, which also relies on major progress in new technologies such as advanced friction-stir welding, and a determination to in-source virtually the entire production process at US wage rates. The company's willingness to absorb substantial risks and recover quickly from setbacks has thus far kept it on track to achieve its ambitious mission of launching humans—potentially to Mars.

Agility

Great military leaders recognize that no plan, regardless of preparation, survives first contact: "the enemy always gets a vote." The world is under zero obligation to conform to any leader's strategy. Great leaders and organizations have the humility, situational awareness, and organizational skills to adapt to the world as it is and as it evolves. They combine flexibility with a disciplined ability to look down-range to see real and imagined bumps in the road, both threats and opportunities.

Retired astronaut Fred Haise, one of three flight crew on Apollo 13, recently shared an experience. On April 14, 1970, the crew's moon mission aborted when a cryogenic oxygen tank exploded, catastrophically disabling the vital Service Module spacecraft. The odds on a safe return were extremely long.

Haise spoke about the apparent lack of contingency plans and the now-famous problem-solving struggle to bring his crew home. He was clear: the reason there was no backup plan was not because someone hadn't imagined the failure—it was because NASA had determined this type of event to be nonsurvivable. Haise's personal story is an iconic example of agile leadership: a team adapting to the world as it is and not as they planned it to be. The team demonstrated the humility necessary to discard an original, deeply invested plan; oriented itself quickly (in a matter of minutes) to a new situation; adapted; and overcame. Agile leaders hold fast to a clear intent (value, innovation, or any other goal) but quickly and intelligently create new plans that rely on new insights, better ideas, and *more reality*. Like that Apollo flight crew, they constantly solve problems and keep going.

From four to more

Insight, integrity, courage, and agility—backed by the 20 fundamentals—will help serve as the practical navigational points for innovative future leadership. While there are no textbook answers to what this will look and feel like, a few essential questions can help organizations begin to think about what they will need of their leaders:

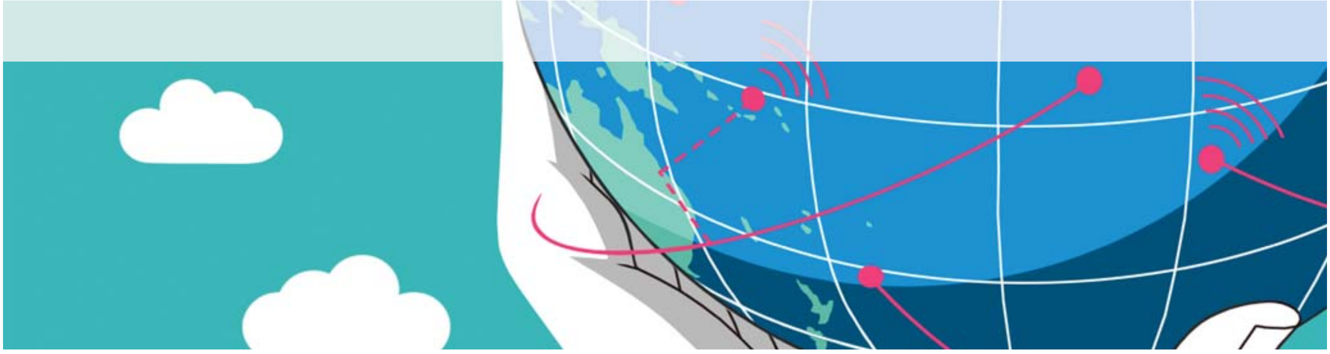
1. How can a leader and a team create the space, mindfulness, innovative relationships, and objectivity that foster insight?

2. What can build our integrity, trust, and a moral and professional sense of purpose of who we are, what we do, and why we are so deeply committed?

3. What can increase our courage to confront tough situations and high-risk opportunities positively, even amid genuine fear?

4. What will allow us to see, understand, and rapidly recalibrate to a shifting landscape in ways that progressively challenge our people?

Much of what will be called innovation will actually be the recycling and rediscovery of existing ideas—perhaps in digital or even robotically supported formats. But that adaption is itself an innovation worth doing. Whatever form it takes, the next horizon of operations leadership will increase the velocity of organizational performance, particularly in the deeply technological, high-stakes and (still) very human environment of 21st century manufacturing.



Human + machine: A new era of automation in manufacturing

Michael Chui, James Manyika, Mehdi Miremadi, and Katy George

New technologies are opening a new era in automation for manufacturers—one in which humans and machines will increasingly work side by side.

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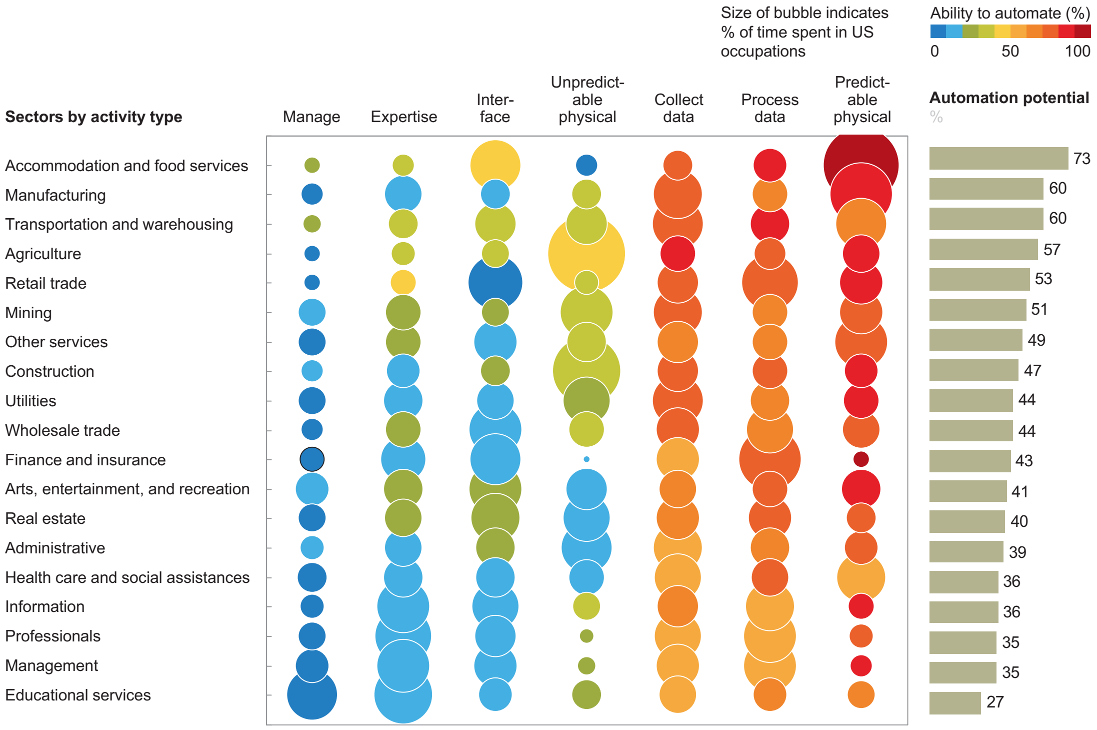
Over the past two decades, automation in manufacturing has been transforming factory floors, the nature of manufacturing employment, and the economics of many manufacturing sectors. Today, we are on the cusp of a new automation era: rapid advances in robotics, artificial intelligence, and machine learning are enabling machines to match or outperform humans in a range of work activities, including ones requiring cognitive capabilities. Industry executives—those whose companies have already embraced automation, those who are just getting started, and those who have not yet begun fully reckoning with the implications of this new automation age—need to consider the following three fundamental perspectives: what automation is *making possible* with current technology and is *likely to make possible* as the technology continues to evolve; what *factors besides technical feasibility* to consider when making decisions about automation; and how to begin thinking about where—and how much—to automate in order to best *capture value from automation over the long term*.

How manufacturing work —and manufacturing workforces— could change

To understand the scope of possible automation in the manufacturing sector as a whole, we conducted a study of manufacturing work in 46 countries in both the developed and developing worlds, covering about 80 percent of the global workforce. Our data and analysis show that as of 2015, 478 billion of the 749 billion working hours (64 percent) spent on manufacturing-related activities globally were automatable with currently

Exhibit 1. Automation potential varies across sectors and specific work activities.



SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis

demonstrated technology.[1] These 478 billion working hours represent the labor equivalent of 236 million out of 372 million full-time employees—$2.7 trillion out of $5.1 trillion of labor—that could be eliminated or repurposed, assuming that demonstrated technologies are adapted for use in individual cases and then adopted. These figures suggest that, even though manufacturing is one of the most highly automated industries globally, there is still significant automation potential within the four walls of manufacturing sites, as well as in related functional areas such as supply chain and procurement. As McKinsey research has shown, manufacturing is second, among industry sectors, only to accommodation and food services in terms of automation potential (Exhibit 1).[2]

We emphasize that the potential for automation described above is created by adapting and integrating *currently demonstrated technologies*.[3] (See sidebar, "Understanding automation potential.") Moreover, it is notable that recent technological advances have overcome many of the traditional limitations of robotics and automation. A new generation of robots that are more flexible and versatile, and cost far less, than those used in many manufacturing environments today can be "trained" by frontline staff to perform tasks previously thought to be too difficult for machines—tasks such as picking and packing irregularly spaced objects, and resolving wiring conflicts in large-scale projects in, for example, the aerospace industry. Artificial intelligence is also making major strides that

1 The baseline we used to determine which manufacturing activities are "automatable" is "current activities" as defined by the US Bureau of Labor Statistics. This includes activities that currently have some elements of automation (for example, sending email).

2 For more, see "Harnessing automation for a future that works," McKinsey Global Institute, January 2017, on McKinsey.com.

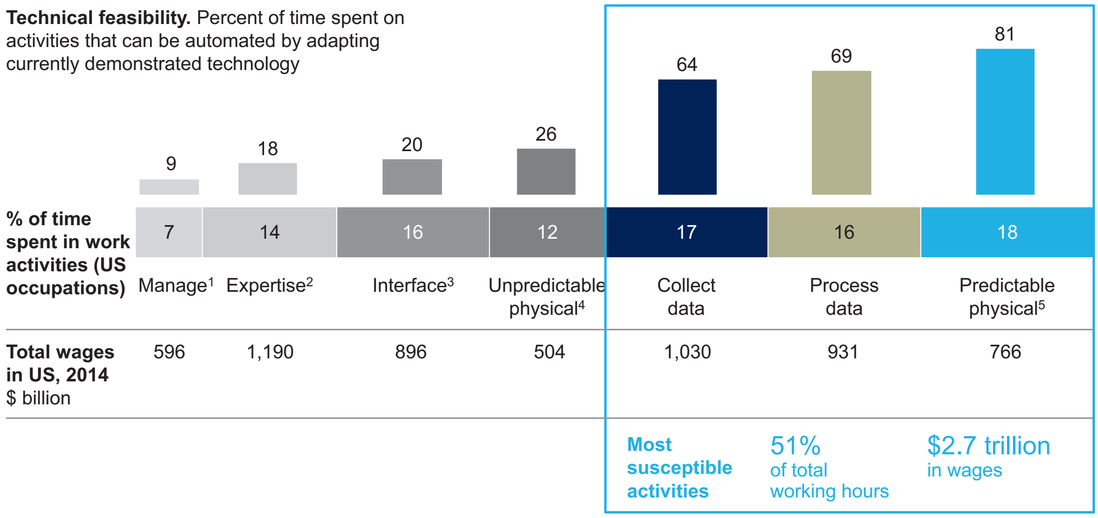
3 We define "currently demonstrated technologies" as those that have already exhibited the level of performance and reliability needed to automate one or more of 18 capabilities involved in carrying out work activities. In some cases, that level of performance has been demonstrated through commercially available products, in others through research projects.

UNDERSTANDING AUTOMATION POTENTIAL

Analyzing work activities rather than occupations is the most accurate way to examine the technical feasibility of automation. Every occupation is made up of multiple types of activities, each with varying degrees of technical feasibility when it comes to automation. The figure below shows the susceptibility to automation of each of seven top-level groupings of activities as well as the time spent on each across all occupations in the United States. Just over half of all working hours in the United States are spent on activities that are the most susceptible to automation: performing physical activities and operating machinery in a predictable environment, and collecting or processing data (exhibit).

Occupations in manufacturing involve activities including, among others, collecting or processing data, applying expertise, and operating machinery (which we classify as physical work) in both predictable and unpredictable environments. Since these and other constituent activities each have a different automation potential, we have arrived at our estimates of automatability for the sector (64 percent of total working hours spent on manufacturing-related activities globally, 87 percent of hours spent on activities performed by workers in production occupations, and 45 percent of hours spent in nonproduction activities) by examining the time workers in manufacturing spend on each of them during the workweek.

Exhibit. Different work activities have different automation potential.



1 Managing and developing people.
2 Applying expertise to decision making, planning, and creative tasks.
3 Interfacing with stakeholders.
4 Performing physical activities and operating machinery in unpredictable environments.
5 Performing physical activities and operating machinery in predictable environments.
NOTE: Numbers may not sum due to rounding.

SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis are increasing the potential for automating work activities in many industries: in one recent test, for example, computers were able to read lips far more accurately than professionals.

Our study also looked at the automation potential for specific types of activities and jobs within the manufacturing sector. We found that 87 percent of the hours spent on activities performed by workers in production occupations are automatable—the most of any manufacturing occupation. Even among other occupations in manufacturing (for example, engineering, maintenance, materials movement, management, and administration), however, there is still significant opportunity, with approximately 45 percent of these working hours automatable as well.[4]

When comparing various subsectors within manufacturing, we see a wide variation of automation potential that can be explained partly by the nature of the activities themselves, and partly by differences in the skills levels required of workers and in the technological complexity of the manufactured product:

- **Low-skill labor/low product complexity.** Apparel/fashion/luxury (82 percent of hours worked are automatable), agriculture processing (80 percent), food (76 percent), beverages (69 percent). The predominance of repetitive, low-skilled activities in this group makes it highly susceptible to automation.

- **Medium-skill labor/moderate product complexity.** Furniture (70 percent), basic materials (72 percent), chemicals (69 percent), medical devices (60 percent), pharmaceuticals (68 percent), auto/assembly (64 percent), electric power and natural gas (53 percent), and oil and gas (49 percent).

- **High-skill labor/high product complexity.** Aerospace and defense (52 percent), advanced electronics (50 percent), high tech (49 percent), and telecom (43 percent).

As for the monetary value of the automatable labor in various manufacturing subsectors, the differences can be up to threefold, depending on the mix of labor in a given subsector ($27,000 per year in apparel/fashion/luxury, compared with $75,000 per year in oil and gas). Comparing the groupings listed above, on average we see a 1.6-fold increase in wages per hour automatable increase going from low- to-high skill/complexity, and a 1.4-fold increase going from low- to-medium skill/complexity.

Finally, we find that even though technical automation potential does not vary greatly across the global economy, the fact that 81 percent of the world's automatable manufacturing hours and 49 percent of automatable labor value reside in developing countries means that an upswing in automation in the developing world could have significant global impact. Considering that 68 percent of the automatable manufacturing hours in the developing world (and 62 percent of automatable labor value) are in China and India alone, we see potential for major automation-driven disruption in India and China, although how long that could take will depend, in part, on the speed with which the costs of automation solutions fall to below wage levels in these countries. A radical shift toward automation in India and China could have major employment implications in both countries and would also inject a substantial boost to economic growth there.

What to automate: Factors to consider

Technical feasibility is, of course, a necessary precondition for automating a given work activity or set of activities. Yet it is far from the only factor companies need to take into account when

4 While management and engineering activities account for only about 2 percent of automatable working hours in manufacturing, because managers and engineers are the highest-paid workers in manufacturing, the automatable activities they perform represent about 11 percent of automatable labor dollars—behind only production and materials-movement occupations. Substantially automating these activities will likely require further technological advances, especially in natural-language understanding and generation—advances that seem entirely plausible even if they are not imminent.

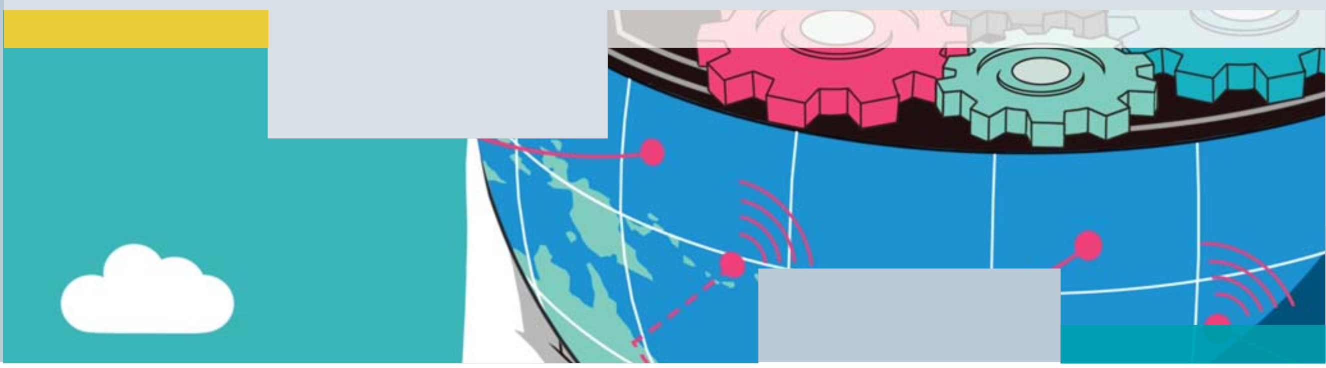
deciding what and how to automate. A second factor to consider is the cost of developing and deploying both the hardware and the software for automation. The cost of labor and related supply-and-demand dynamics represent a third factor: if workers are in abundant supply and significantly less expensive than automation, this could be a decisive argument against it—or for automating only to a limited degree. For example, an automotive supplier in India has found that after introducing low-cost automation of a few steps on its production line—which reduced staffing levels from 17 to 8—its costs are now equivalent to those for a Japanese company running the same kind of

ADAPTING AND ENHANCING HUMAN CAPITAL

It is important to point out that the implications of automation for a company's workforce are not just about replacing human workers with machines. According to our analysis, fewer than five percent of occupations can be entirely automated by adapting currently demonstrated technology. However, about 60 percent of them could have 30 percent or more of their constituent activities automated. In other words, just by adapting and integrating current technology, automation could change—at least to some degree—the majority of occupations. This will necessitate significant job redefinition and a transformation of business processes and workplace cultures.

Indeed, the most vital component in successfully deploying automation over both the long and short terms may be the hard work of preparing and adapting human capital to work in tandem with technology. Almost every job will eventually change, and every workflow will eventually be transformed. Many workers will have to be continually retrained to work alongside machines as their jobs continue to evolve. This will require changes not only in skills but in mind-sets and culture as "coworkers" come to include not only other people but also machines.

As roles and processes get redefined in these ways, the economic benefits of automation will also include freeing up and repurposing scarce skilled resources. Particularly in the highest-paid occupations, machines can augment human capabilities to a high degree and amplify the value of expertise by freeing employees to focus on work of higher value. In aircraft maintenance, for example—where drones and insect-size robots could someday perform inspections, robots could deliver parts and tools, and automated tugs could move planes in and out of hangars—fewer technicians would be needed on the maintenance hangar floor, but those who remained would spend more time problem solving for nonroutine issues. These workers will, however, need continual retraining to keep up with developing technology.



production line with a higher degree of automation and a staffing level of only two.

A fourth factor to consider is the benefits beyond labor substitution, including higher levels of output, better quality, and fewer errors (see sidebar, "Adapting and enhancing human capital"). While it is tempting for a manufacturer to view automation primarily as a labor-savings lever, these other benefits are often larger than those of reducing labor costs. Automation options should be considered and evaluated using a clear strategy focused on reducing the total cost of operations. We find that companies typically use automation to address a number of opportunities, including increasing throughput and productivity, eliminating variation and improving quality, improving agility and ensuring flexibility, and improving safety and ergonomics.

In addition to technical feasibility, cost of hardware and software, labor supply and demand, and benefits beyond labor substitution, a fifth factor to be taken into account in deciding whether and where to automate is regulatory and social-acceptance issues, such as the degree to which machines are acceptable in any particular setting, especially where they will interact with humans. The potential for automation to take hold in a given sector or occupation reflects a subtle interplay among all five of the factors we have listed and the trade-offs among them.

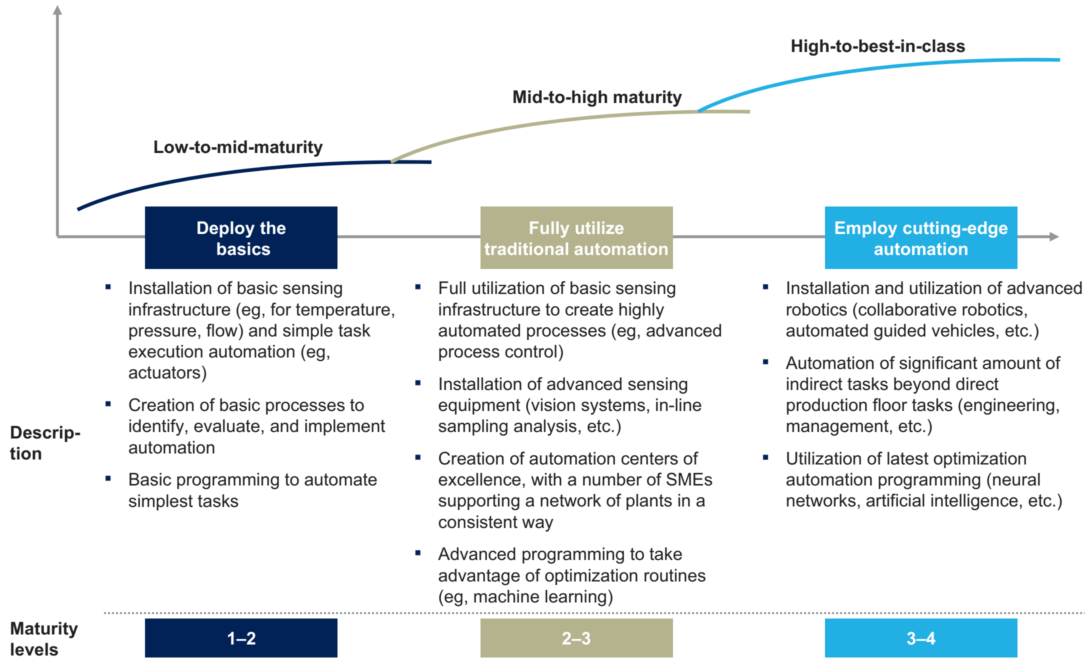
Capturing long-term value from automation

The ultimate goal for manufacturers as they weigh the various factors described above is to capture as much long-term value as possible from automation. How to go about achieving this depends, in part, on how far along the spectrum of automation maturity a given manufacturer is. We see this spectrum as having four stages:

- **Low maturity.** There is limited infrastructure for employing automation—for example, lack of robotics, sensors, and data-collection systems.
- **Mid-maturity.** There is significant automation infrastructure in place but it uses only a fraction of the potential—for example, many sensors are installed but the majority of data are not utilized; numerous data-capture systems lack interconnectedness; programming optimizes local processes but not global value streams.
- **High maturity.** There is full utilization of traditional automation infrastructure on the manufacturing floor, but not employment of cutting-edge automation technology and realization of potential of automating managerial, support-function, and back-office tasks.

Evaluating a manufacturer's operations along the spectrum of automation maturity can help determine what kind of approach will best help to capture full long-term impact.

Exhibit 2. Manufacturing companies and sites can capture more value at each stage of automation maturity.

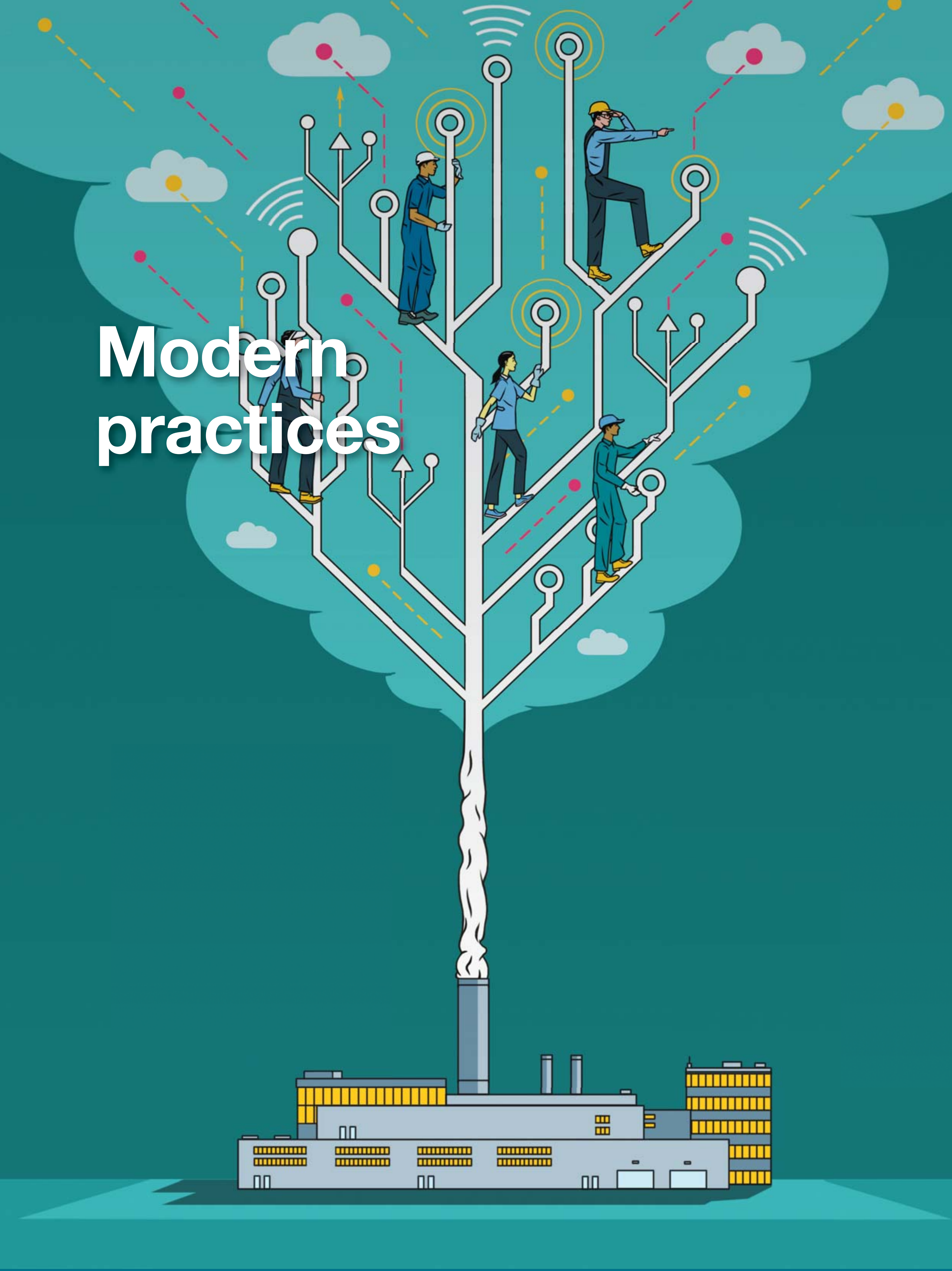


SOURCE: McKinsey analysis

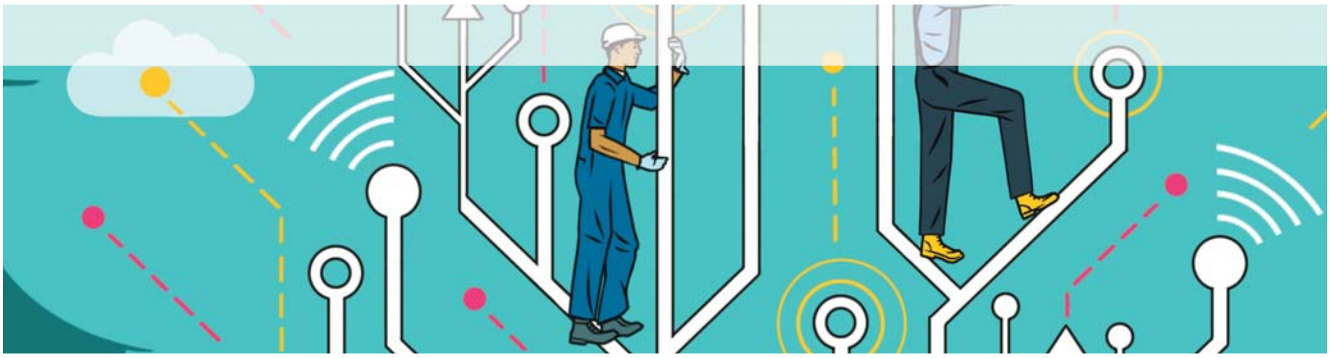
- **Best-in-class.** Full potential of automation is captured with latest technology across all spectrums of the operation.

Evaluating a manufacturer's operations along this spectrum of automation maturity can help determine what kind of approach will best help to capture full long-term impact. For example, lower-maturity operations will benefit more from "clean sheeting," while more mature operations can focus on fully utilizing their already robust automation infrastructure to get to best-in-class. Exhibit 2 describes in more detail the steps manufacturers can take to move along the spectrum.

Wherever a given company is on the maturity spectrum, it is essential to keep the focus on value creation. To help diagnose where automation could most profitably be applied to improve performance, business leaders may want to conduct a thorough inventory of their organization's activities and create a heat map of where automation potential is high. Business processes shown to have activities with high automation potential can then be reimagined under scenarios where they take full advantage of automation technologies (rather than mechanically attempting to automate individual activities using current processes). Finally, the feasibility and benefits of these automation-enabled process transformations can be used to prioritize which processes to transform using automation technologies. Such an approach can help ensure that automation investments deliver maximum impact for the enterprise.



Modern practices



A better fit: Tailoring the deployment model to suit the organization

Marco Avila and Alessandro Delfino

The right way to deploy a transformation depends on the nature of its goals, and on the structure, resources, and capabilities of the organization.

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The authors wish to thank Gonzalo Blanco, Henrique Fagundes, and Rafael Pardo for sharing their success stories using the performance-cell deployment model and the role-confirmation tool.

As our research has consistently shown, transformations are three times more likely to fail as to succeed.[1] That elusive success depends on a host of factors (see sidebar, "The 24 actions of transformation" on page 93), but one thing many of those factors have in common is the early and consistent role played by the organization's top and middle managers throughout the transformation.

In practice, a company's choice of deployment model has a significant effect on its site-level leadership requirements: some models ask much more of plant managers and supervisors than others. Companies should therefore choose their deployment model with the capabilities of site-leadership teams firmly in mind.

Deployment-model choice

The right deployment model for a transformation depends on many different variables. Before choosing an approach, transformation architects should think carefully about the purpose of the transformation, the structure of their organization, and the current capabilities of its people, processes, and management systems:

- **Bottom up or top down:** Where in the organization is change required? Is the process highly manual, requiring significant frontline input? Or is it more automated, meaning change must come from the top?

1 "How to beat the transformation odds," April 2015, mckinsey.com.

- **Leadership engagement:** How engaged are leaders expected to be in the transformation? Are there several significant remote sites that could be transformed independently?

- **Capability building:** What capabilities will the organization need? Where are the current capability gaps, and how they be filled?

- **Pace/urgency:** How is the organization performing today? How quickly do improvements need to be found and scaled across the network?

- **Resources:** What resources are available for change activities? How are they distributed between the central change team and individual sites?

- **Standardization:** What level of standardization is needed across sites? Do sites have similar organizational structures and process designs?

- **Complexity:** How radical is the planned process redesign? How complex are the processes undergoing change?

- **Centralization:** To what degree must activities by managed centrally? Does the organization have the right IT systems to manage performance and measure impact?

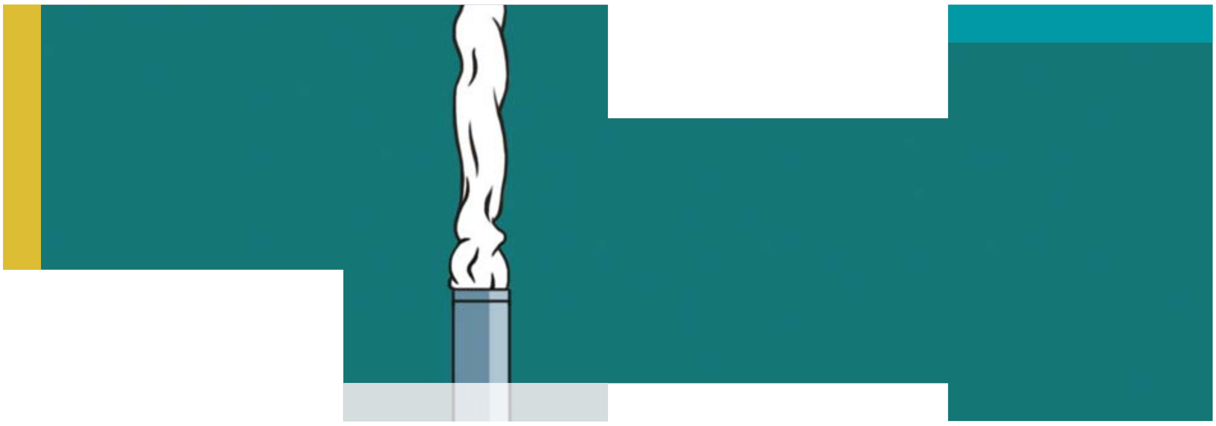
Each of the various deployment models available has advantages and disadvantages. The answers to those questions will help an organization decide which of the available models is best suited to its needs:

- **Mini-transformation:** Mini-transformations are the bread and butter of transformation approaches. In this model, discrete portions of a value stream are addressed individually, each completely transforming its way of working from the bottom of the organization toward the top. Compared to other deployment models, a transformation based on this approach typically takes longer to achieve its full impact. It is a very effective way to build the organization's capabilities, however, since each mini-transformation goes through the full cycle of diagnose, design, plan, and implement. That said, the speed at which this approach can be scaled across different value streams and locations is highly dependent upon the availability of enough change leaders to support each mini-transformation effort.

- **Turbo-transformation:** Turbo-transformations are a development of the mini-transformation that makes greater use of benchmarks and other rapid diagnostic tools to set targets for the value-capture phase. The initial phase involves top-down site-by-site assessments to set targets with capability building to train change agents, followed by rapid on-site mini-transformation deployments and scaling across the network.

- **Academy-based:** An academy-based approach, also known as "field and forum," is most appropriate when there is strong focus on capability building and where sites are significantly different in terms of organization and process (necessitating the development of strong local teams). The transformation is rolled out via an alternating series of "forums"—team development, skill-building and aspiration-creating sessions—and "fieldwork," in which change agents deploy prioritized initiatives. Site staff also receive ongoing feedback through daily and weekly coaching sessions from a central team of change agents.

- **Total operational performance:** The total operational performance (TOP) program is appropriate for companies that need to achieve quick, decisive, and lasting cost-reduction impact involving improvements across the whole business rather than in a few specific functions—but resource limitations allow for only a small transformation team. TOP's main objective is to quickly identify significant cost



reductions that can be achieved in less than two years, are sustainable, and are not limited to one specific area as in a mini-transformation. TOP typically does not focus on capability or skill building but does include a structured methodology to identify improvements throughout the whole organization. Executing a TOP program is typically a good start toward the journey of operational excellence, providing a basis for the structured rollout of a future mini-transformation program.

- **Fast-to-impact:** The fast-to-impact approach revolves around the idea of full implementation from day one, solving one issue at a time, with a focus on the solution of each issue. This approach entails identifying the top issues one at a time, completing a root-cause diagnostic and solution design within 24 to 48 hours, and then moving straight to implementation. A strong central project-management office (PMO) is required to enable a fast-to-impact approach to create transparency, build cross-functional tools, and inject capability building where it's needed.

- **Cluster-based:** The cluster-based model is appropriate when an organization has many relatively similar sites across its network. The approach involves a deep-dive diagnostic at a central site, which generates a rapid, fact-based view of opportunities. These are then rolled out simultaneously to a cluster of related sites elsewhere in the network. Change agents from these cluster sites are trained and accredited at the central site before leading their local transformations. Throughout, a control-tower support model develops accreditation and tracking tools to ensure sustainability and accountability. This approach is typically combined with an academy-based model to support capability building and help maintain momentum.

- **Restructuring:** Restructuring is useful for organizations that are in distress or extremely cash-strapped. The approach focuses on three phrases: top-down target setting, in which high-level savings opportunities are identified and accountability assigned for savings targets; bottom-up planning, in which initiatives are generated and validated to achieve or exceed the savings target; and implementation, in which a detailed plan is developed with rigorous PMO oversight to ensure delivery of savings is on track.

While each of these models has been used successfully in many transformations, none of them can escape the fact that an organization cannot transform any faster than its slowest element. Even dramatic frontline-performance improvements may have little impact, for example, if the layers of management above them have not adapted their own processes to reflect new ways of working. In recent years, a new approach has evolved to address this challenge. It has proved so successful that it merits deeper discussion.

Deep dive: The performance cell—a new deployment model

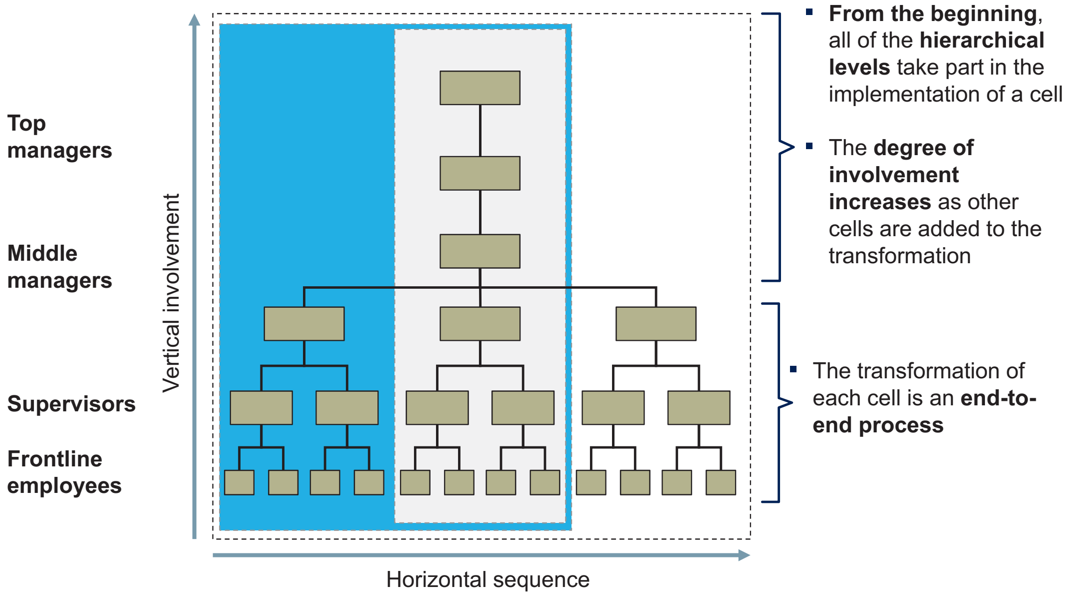
In order to avoid the pitfalls of deployment approaches that rely on a step-by-step sequence of changes, this new model operates on complete vertical "slices" of the organization, from top management to the front line. This top-to-bottom slice of the organization is called the "performance cell." Implementation begins by focusing on a single vertical cell, then moves to adjacent cells until the complete area is transformed (Exhibit 1). Like the first steps in any transformation, the first performance cell is a pilot for the transformation, acting both as a test bed for the planned approach and an example to the wider organization. As a result, the choice of this first cell is critical, and should be based not only on the potential impact that the cell (or the area it's part of) can achieve, but on the favorability of other factors, including the skill level of the teams involved, the readiness of every level of leadership to participate in the change effort, and the credibility of those managers in the organization as a whole.

During the transformation, the performance cell will evolve, and along with it, the role of top and middle management within the performance cell must also change. This evolution can be divided into two broad phases:

Phase one: Line management acts as a chief designer. While frontline employees collaborate on the design of the elements of the transformation, like standard operating procedures (SOPs) and performance dialogues, their direct supervisors lead the design within their teams, collaborating on the definition of roles and co-leading the design of their standard-work schedules (DILO/WILO). Middle managers also participate in the design of these elements but even more importantly, lead the design of the DILO/WILO of the manager directly below them. This involvement extends all the way to top management—typically the COO—as even his or her routine is designed and modified to match the future state.

The transformation initiatives for each level of management are launched simultaneously, and

Exhibit 1. In the performance-cell transformation model, every level in the organization plays an active role



refined as the performance cell gains experience in the new way of working. For instance, after designing the elements of the performance management system, such as key performance indicators, dashboards, and review cadence, all performance dialogues are launched at once across the cell, immediately testing end-to-end dynamics and the overall coherence of the performance indicators. This simultaneous change process helps to overcome resistance by frontline employees, who can see that the changes are not simply focused on them, but are taking place throughout the organization.

Phase two: Line-management coaching as "line change agent." Once the elements of the transformation are tested and implemented, frontline employees continuously improve their designs—for example, redefining existing standards or creating new ones under the direction of their direct supervisors, who begin to play a new leadership role: that of the lean manager. As lean managers, they have the responsibility of developing four critical capabilities:

- *Challenging teams:* Lean mangers reject the status quo with ideas that challenge and develop frontline employees, who in turn are in charge of detailing and designing new solutions.

- *Training:* Rather than delegating the responsibility for training to HR and other specialized (and often outsourced) services, lean managers are fully accountable for developing their teams through the new transformation elements, such as process confirmation and performance dialogues.

- *Coaching and providing feedback:* Lean managers provide feedback and coaching, which are critical for capturing impact, ensuring sustainability, and promoting the continuous improvement of solutions and people.

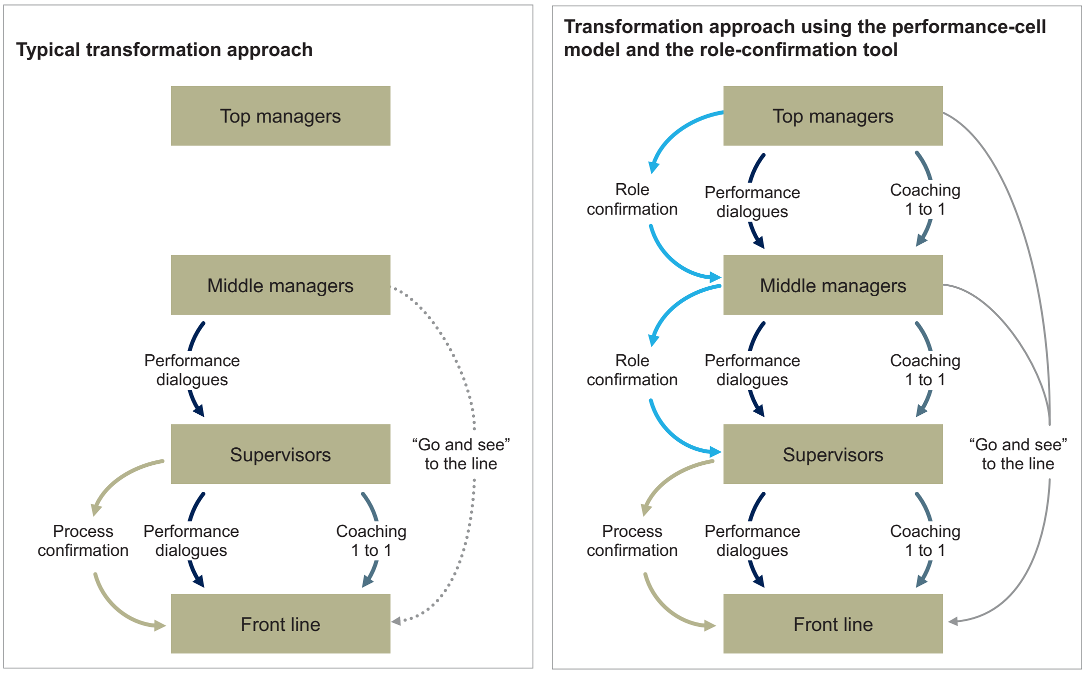
- *Acting as role models:* The new management leads by example. In their new role, lean managers are visible to all their team members, walking the shop floor and observing performance.

Middle and top managers undergo the same role transformation from phase one to phase two as they become the "change agents" required to maintain the transformation. This is the real beauty of performance cells: having a transformation design led and sustained by leadership, with minimal support from external agents. To ensure that leaders and managers at every level in the organization play their part in this process, managers include role confirmation as a central element of their standard work, supported by an observation grid for three critical lean practices: leading performance dialogues, leading problem-solving sessions, and providing structured feedback and coaching (Exhibit 2). After introducing the role-confirmation concept at the beginning of the transformation, managers can observe, calibrate, and improve the implementation of the different elements of the lean transformation. Role confirmations help managers at every level of the organization to understand what is expected of them: identifying improvement opportunities in key elements of the transformation (and implementing them), assessing where the transformation currently stands and where it is desired to be, and generating an understanding of what needs to be done to reach the desired end state in every critical process.

An executive who experienced one of the first transformations using the performance-cell model and the role-confirmation tool specifically cited their impact in helping people grow as leaders. At every level in his organization, managers now expect to give and received genuine feedback, especially in coaching problem-solving skills. The observations they make now form the basis for development plans that help people develop further in their careers.

After its initial development in the retail industry, the performance-cell deployment model has been tested and used in many companies as a cross-functional concept. A company in the forestry

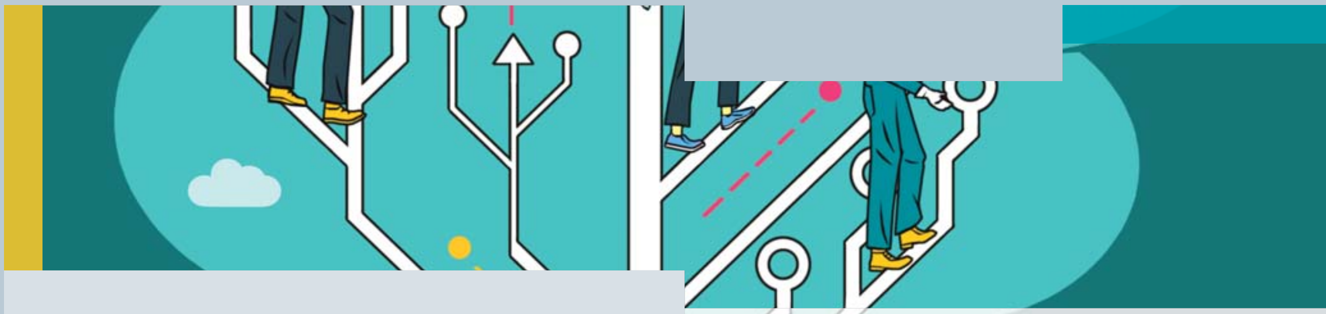
Exhibit 2. In a performance cell, 'role confirmation' reinforces the behavioral changes required of middle and senior managers



sector, for example, applied the performance-cell concept to its transportation division, organizing cells on a geographical basis. In the company's first cell, truck productivity was increased by more than a third. A third company, this time in the oil and gas sector, was able to find $20 million in incremental revenue following the introduction of a performance cell that stretched from its COO to the operations of its main pipeline pump and discharge station.

□ □ □

There are many different ways to deploy a transformation, and the right choice for your organization depends on the purpose of your change effort, the nature of your business and the capabilities of your people. What all transformations have in common, however, is a reliance on commitment, communication, and leadership from top management down. The most successful transformations address these factors explicitly from day one, asking for fundamental changes in behavior from all staff from senior leadership to the front line. One way to achieve that is by through the simultaneous top-to-bottom transformation of individual performance cells within the business, with change supported and reinforced through the introduction of role confirmation for every layer of management.

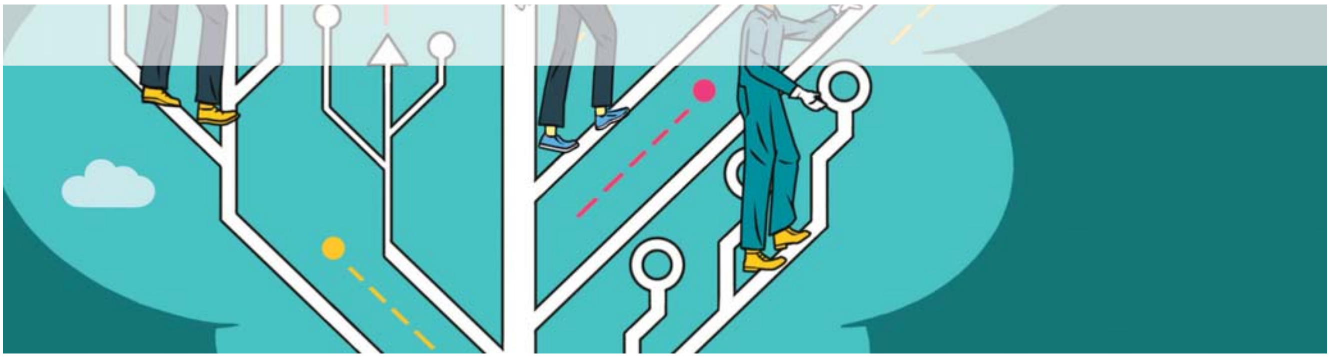


THE 24 ACTIONS OF TRANSFORMATION

In 2015, McKinsey published the results of a survey of almost 2,000 executives on 24 specific actions an organization can take to implement a transformation successfully.[2] According to the results, below are the specific actions in order of their impact (from greatest to least) on the likelihood of a transformation's success.

1. Senior managers communicated openly across the organization about the transformation's progress and success
2. Everyone can see how his or her work relates to organization's vision
3. Leaders role-modeled the behavior changes they were asking employees to make
4. All personnel adapt their day-to-day capacity to changes in customer demand
5. Senior managers communicated openly across the organization about the transformation's implications for individuals' day-to-day work
6. Everyone is actively engaged in identifying errors before they reach customers
7. Best practices are systematically identified, shared, and improved upon
8. The organization develops its people so that they can surpass expectations for performance
9. Managers know that their primary role is to lead and develop their teams
10. Performance evaluations held initiative leaders accountable for their transformation contributions
11. Leaders used a consistent change story to align organization around the transformation's goals
12. Roles and responsibilities in the transformation were clearly defined
13. All personnel are fully engaged in meeting their individual goals and targets
14. Sufficient personnel were allocated to support initiative implementation
15. Expectations for new behaviors were incorporated directly into annual performance reviews
16. At every level of the organization, key roles for the transformation were held by employees who actively supported it
17. Transformation goals were adapted for relevant employees at all levels of the organization
18. Initiatives were led by line managers as part of their day-to-day responsibilities
19. The organization assigned high-potential individuals to lead the transformation (e.g., giving them direct responsibility for initiatives)
20. A capability-building program was designed to enable employees to meet transformation goals
21. Teams start each day with a formal discussion about the previous day's results and current day's work
22. A diagnostic tool helped quantify goals (e.g., for new mind-sets and behaviors, cultural changes, organizational agility) for the transformation's long-term sustainability
23. Leaders of initiatives received change-leadership training during the transformation
24. A dedicated organizing team (e.g., a project management or transformation office) centrally coordinated the transformation

2 "How to beat the transformation odds," April 2015, mckinsey.com.



Deployment models: How mature are your operational practices?

Ron Fardell, Nils Müller, Peter Odenwälder, and Rainer Ulrich

Before setting out toward operational excellence, companies must see where they stand. A good maturity assessment provides more than a set of coordinates; it also maps out the first steps.

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The authors wish to thank Marc Bielitza for his contributions to this article.

Many companies seek to use the power of lean to transform the productivity, quality, and reliability of their operations. For any such company, the right starting point is a dispassionate assessment of its current processes, capabilities, and culture. Without knowing where it is today, an organization cannot determine a realistic future-state vision or design the journey needed to get there.

Yet for too many businesses, misunderstanding their current lean and employee capabilities can make this journey more difficult than it needs to be as they attempt to accelerate their pace of change. This common mistake can lead to misjudged priorities and investment efforts in the wrong areas. Eventually, it can even overwhelm the organization, leading to another failed project or transformation.

Let's look at two relatively common real-life examples. In the first, the CEO of a manufacturing company is excited about the possibilities created by the emergence of digital technologies. She asks her management team to explore the opportunities to increase automation and make better use of digital data across its manufacturing and product lines. The team does as they are asked and promptly comes back with a list of exciting and innovative ideas. When implementation begins, however, the company quickly learns that a lack of basic building blocks—like stability and standardization in its manufacturing processes, or a robust planning system in the maintenance function—means most of the ideas prove unsustainable in practice. This company would have done better first spending time to build a simple, robust lean culture and mastering its fundamental tools. This would be the right foundation for more sophisticated improvements later on.

In the second example, consider a company with a global network of manufacturing sites. Such an organization will often pick a single site as a location to begin its transformation—perhaps the largest, the newest, or the one located closest to headquarters. After assessing the maturity of operations of that site, the company identifies some significant improvement opportunities, designs a transformation program, and begins to roll it out across the network. When it does, however, it quickly learns that differences in approach, capabilities, technologies, or culture at its other sites around the world mean many of the improvements are not applicable to these sites, even though they were implemented successfully at the first.

Either of these situations could have been avoided with a more effective reflection or a maturity assessment at the start. In this article, we'll look at the characteristics that make some approaches to maturity assessment better than others, and we'll go on to see what companies can do once they *really* know where they stand today.

Measuring maturity: Four key principles

In our experience, a good maturity assessment should follow four guiding principles.

First, the assessment should be conducted by an independent team, either part of a company's central operational-excellence team or a third party. It should not, however, take place in an "ivory tower" or office environment (especially with operations further away from the headquarters). It needs to be done on the shop floor, where the work happens. This philosophy, known as *genchi genbutsu*, or "go and see," is already seen as a fundamental tenet of lean management. Firsthand scrutiny of real working practices by independent evaluators is important, because managers may take a rose-tinted view of their plant's capabilities if asked to fill in a questionnaire about their practices. Even raw productivity and quality data rarely give a full and accurate picture of the issues and challenges at a site. It also matters because direct observation of working practices helps those making the assessment to better understand the culture and atmosphere of the facility. In addition, establishing a face-to-face contact and conversation with frontline teams can start a communication-and-change process that will be fundamental in enabling improvement over the long term.

Second, the assessment should take account of the conditions that surround the site under review. For example, the main challenges and improvement opportunities for a site operating in a low labor-cost country may be very different from those seen in Western countries. Similarly, the overall level of education, skills, and experience in the workforce may vary significantly from site to site, as might attitudes toward teamwork or flexible labor practices. Critically, the mind-sets and skills of managers are every bit as important as those of frontline teams, and these can be even more variable across sites and regions.

Third, the assessment should look at what really defines the success of the company's operations, rather than simply checking whether certain productivity-improvement tools are in place. For example, single-minute exchange of dies (SMED) is a widely used approach. It helps companies decrease downtime and increase production flexibility by reducing the time required to switch between different product variants on a production line. Merely using such a tool as a de facto best practice without reviewing its suitability for the production site in question will typically not yield the expected productivity leaps, however. If lines already have excess capacity, a reduction in downtime won't earn the business any additional sales. Rather than checking for the existence of a tool ("Do you use SMED?"), the maturity assessment should ask whether the business has a

specific problem in this area ("Is your production constrained due to inefficient changeovers?").

Finally, the aim of the assessment should be to identify concrete improvement actions, not just to rate current performance. Learning that process reliability at their site is 30 percent lower than others gives managers no indication about how that might be improved. A more useful maturity assessment would identify some of the underlying causes of that poor performance (like delays in getting maintenance teams to respond to unplanned stoppages) and suggest appropriate solutions (like an efficient information flow based on standard failure notifications to trigger the repair process).

Assessments in practice

To meet these guiding principles, an effective maturity assessment approach will have certain characteristics; these include what is assessed, how the assessment is made, who carries out the assessment, and when the assessment is done.

What

The assessment needs to take a holistic view of site performance. This can be done by ensuring the assessment covers all relevant categories. These categories will vary depending on the processes under review. In technical processes (like manufacturing, maintenance, and logistics), they need to include the technical system that defines the site's processes; the management system it uses to control, monitor, and continually improve those processes; and the people system it has in place to develop the capabilities and culture of its workforce.

To evaluate management principles, the assessment needs to consider whether sites are able to connect strategy goals and meaningful purpose, enable people to lead and contribute to their fullest potential, discover and deploy better ways of working, and deliver value efficiently to the customer.

Beneath each of those categories, maturity is defined by a site's ability to demonstrate certain characteristics across a dozen or more specific topics, ranging, for example, from target setting to health and safety and employee development.

How

As discussed earlier, assessments should be based on firsthand observations, supplemented by interviews with site managers and operators. Online forms or self-evaluations done by site managers simply do not provide the objectivity and accuracy of insight needed to translate the findings into an actionable implementation plan. However, conducting both an internal assessment and an external assessment and then comparing the two viewpoints can lead to very powerful discussions, especially about differences.
To ensure applicability and acceptance, the assessment (especially the language it uses) needs to take into account the context of the plant and industry in question, and the language terminology commonly used there.

Who

Assessments should be conducted by experienced evaluators with sufficient knowledge of the business, the industry, and lean principles and tools. Typically, the assessor should be someone external, not from the area being assessed, such as someone from a different site or business unit or even fully external. It typically also helps if the assessors are also at least partially involved in the implementation of any subsequent transformation program.

When

Every transformation effort should begin with a maturity assessment effort, but an assessment is not a one-time process. As companies implement changes, repeating the assessment at regular intervals (typically every 9 to 12 months) is helpful to check that the current transformation plan is working, to identify deviations from the plan that may require additional efforts, and to uncover new improvement opportunities.

Prioritizing for action

Based on the individual answers and observations, a maturity assessment should provide a clear definition of a company's starting point and lay out a set of tailored improvement initiatives. As a company cannot usually hope to tackle all these initiatives at once, it will need to prioritize them accordingly (typically based on likely impact of each idea against how easy it will be to implement).

Some companies will already have the internal capacities and abilities they need to start working on these prioritized initiatives. In many cases, especially where they are at the beginning of their lean journey, companies may struggle to identify the individual actions needed for implementation. Here it is helpful if the maturity assessment also describes a step-by-step guide to implementation, with clear action items. Ideally, these will be highly detailed, explaining resource requirements, including training documentation and suggesting expert contacts. For example, the introduction of a good performance-management system on the shop floor will typically start with the definition of meaningful key performance indicators and the design of an appropriate review board. These steps will be followed by training for shift leaders, a sequenced rollout over different shifts and areas and processes that help sustain these changes (for example, implementing leader standard work and process confirmations).

Such a sequential list of actions can be developed into a cohesive and workable plan with a defined timeframe for completion, tailored to the available resources. This tactical implementation plan (TIP) will dramatically help a site make progress in its transformation, boosting its chances of success. The details of the TIP will be different for every site, depending on its own goals and starting point. While two sites may share the same overall objective in one area, for example, they may plan to proceed at different speeds.

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Companies can only make rapid, sustainable improvements to their performance if they know exactly what to do next. The maturity-assessment process is a critical part of any organization's journey to operational excellence: a navigational device that pinpoints its current location, shows where it needs to go next, and helps it on its way.

Secrets of successful change implementation

Alasdair Johnston, Frédéric Lefort, and Joseph Tesvic

What do successful implementers of change initiatives do differently from other companies? Our survey of more than 2,000 executives yields actionable answers.

Alasdair Johnston and **Joseph Tesvic** are partners in McKinsey's Sydney office, and **Frédéric Lefort** is a partner in the Gothenburg office.

Any executive who has led a major change program knows that even the most carefully planned programs can fail because of mediocre implementation. Turning plans into reality isn't easy, and certain companies seem to be better at it than others. To learn how some of the world's leading companies ensure implementation excellence, we conducted a survey of more than 2,000 executives in 900 companies across industries.[1] We asked respondents to evaluate their company's implementation performance, capabilities, and practices.

Our survey revealed that "good implementers"—defined as companies whose respondents reported top-quartile scores for their implementation capabilities—achieved superior performance on a range of financial-performance metrics. Perhaps more important, two years after a change effort has ended, good implementers sustain twice the level of financial benefits as poor implementers do.

So what can other companies learn from successful implementers?

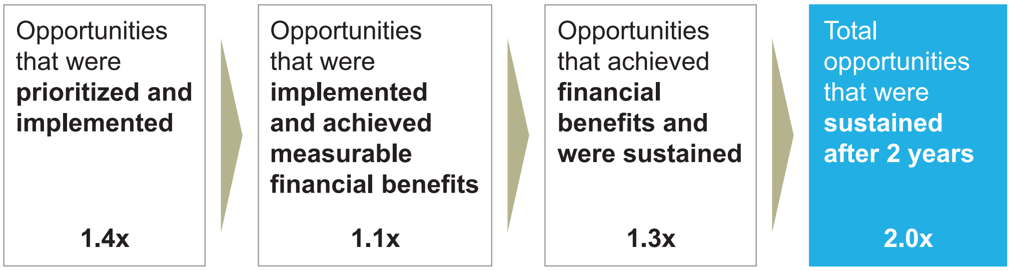
The factors that matter most

Every transformation leaks value at various stages of the implementation process: some prioritized initiatives are never done, others are implemented but don't achieve bottom-line impact, and still others may fail to sustain their initial good results. But at every stage of the process, good implementers retain more value than poor implementers (Exhibit 1).

1 The online survey was conducted from January 14 to January 24, 2014, and garnered responses from 2,079 executives representing the full range of regions, industries, company sizes, functional specialties, and tenures. The results reported in this article also include responses from an additional 151 global executives surveyed at an earlier date. To adjust for differences in response rates, the data are weighted by the contribution of each respondent's nation to global GDP.

Exhibit 1. 'Good implementers' retain more value than their peers at every stage of implementation.

Proportion of opportunities that good-implementer companies retain at each stage of implementation, relative to bottom-quartile companies



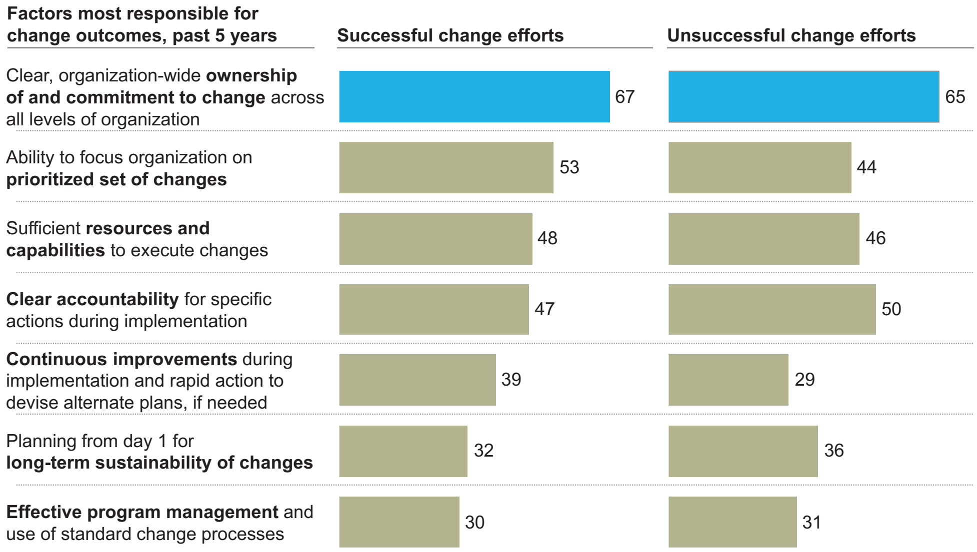
Clearly, implementation is hard to get right. Fewer than half of respondents say that most or all of their change efforts in the past five years met their initial goals and sustained results over time. Probing deeper into the responses shows that the root causes of this failure cluster around three critical themes: organization-wide ownership of and commitment to change, regular and effective prioritization, and deployment of the right resources and capabilities (Exhibit 2).

Ownership and commitment

For both successful and unsuccessful transformations, roughly two-thirds of respondents indicated that the single most

Exhibit 2. The greatest impact on a major change effort's outcome comes from ownership of and commitment to change.

% of respondents,[1] n = 2,079



[1] Respondents who answered "don't know" are not shown.

significant factor influencing a transformation's outcome is the degree of ownership and commitment of the organization's leaders. To be clear, "ownership" and "commitment" involve much more than just "alignment." People seeing someone else's car being stolen may reasonably be expected to take down the number and call the police. How might they react differently if it were their car? Commitment is a level of psychological investment that drives personal, proactive action—and becomes even stronger when failure may have adverse consequences. At a very basic level, successful transformations typically reinforce ownership through clear accountability for specific targets and individual incentives for key players that are strongly aligned to success.

The right leadership style. Organizations that excel at implementation foster a leadership style that sets bold aspirations with clear accountability—emphasizing the challenging and supportive dimensions of leadership over the authoritative and consultative qualities that may be effective in other situations. Successful leaders are relentless in pushing and encouraging their reports, while also greasing the wheels through tough decision making.

Keeping this pace of change going represents a significant investment of time and attention. For example, the global head of the transformation program at a big healthcare company ensures that she or a direct report participates in every critical milestone-report meeting. Her presence as an active role model reinforces the transformation's importance for the company and encourages the involvement of local leadership.

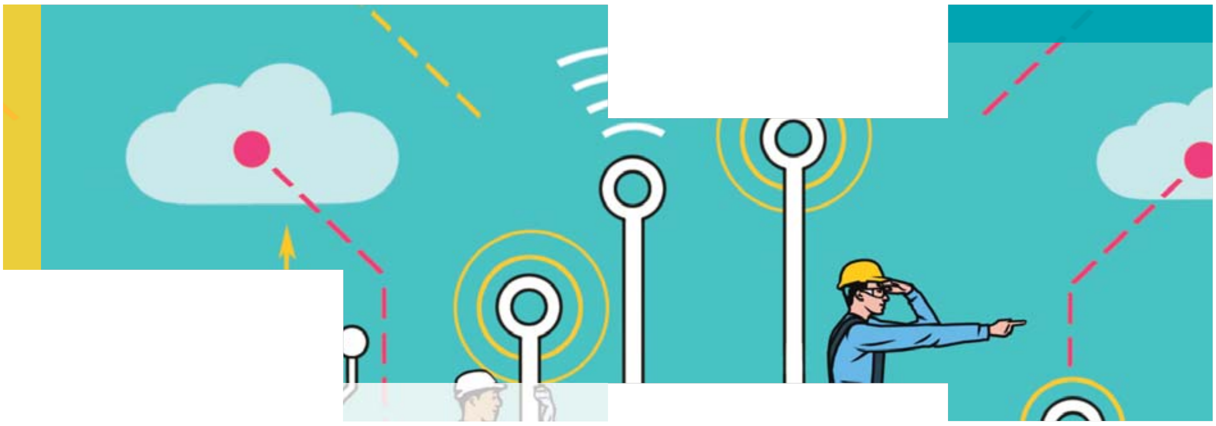
The right buzz. Great implementers also create the right buzz around change by engaging the broader organization. They recognize that few employees have any interest in their employer's share price, let alone its return on equity. Rather than spamming everyone with generic communications materials, leaders instead methodically cascade a compelling change story through the entire business. It's a difficult balance: the core message must be meaningful to as broad a range of the workforce as possible yet also be personal and relevant to the specific audience.

Implementing a transformation is a long-term effort, and the demands it places on personnel will evolve over time. To keep people engaged, the change story must adapt as well. At a basic-materials company facing closure of several of its operations, the change story focused on moving away from a victim mentality. Once the transformation began to take hold and the facilities were no longer under immediate threat of closure, the message—and the team's energy—easily could have dissipated. Instead, the transformation team harnessed the earlier momentum and adapted the story to celebrate pride in being a world leader, within both the company and the industry as a whole. Since then, the business has continued to deliver year-on-year improvements and outperform its competitors.

The right supporting organization. Finally, the ownership and commitment are difficult to maintain in a major transformation without the support of an effective and empowered project-management office (PMO)—a formal entity directly responsible for leading the change effort and monitoring its progress. The PMO should be led by a relatively senior person who reports to a C-level executive and carries that executive's authority. The role of PMO leader is therefore an important stepping-stone for a high performer, and it should be filled by someone who is seen as a future C-level executive. Although the ideal PMO leader will be chosen from within the company, we've found that it's more effective to bring in a skilled leader from outside than to appoint an insider who lacks the leadership skills to rally the troops.

Prioritization of initiatives

Some transformation efforts founder because too many initiatives are going on at once, spreading the organization's resources too thin. Accordingly, what an organization chooses not to do is every bit



as important as what it does. But for a prioritization process to help a transformation succeed, its scope must be broad. For example, existing initiatives must be scrutinized with the same rigor as new ones, because zombie projects drain precious resources—especially leadership attention.

Understanding risks. The starting point in any strong prioritization process is a robust fact base, with a clear understanding of the size and nature of each opportunity, its timing, and any impediments to delivery. Usually, prioritization applies the twin lenses of value and ease. While this approach can be effective, the "ease" criteria are often subjective and reinforce bias. As a result, teams may underestimate risk on projects they deem attractive and undervalue opportunities that superficially seem less promising.

For this reason, a critical step is to conduct a rigorous assessment of the risks associated with each change in the transformation portfolio, typically based on probability and severity. A risk review should cover the full gamut of unintended outcomes that can derail implementation or cause material damage to the business—including safety or regulatory compliance, customer or talent attrition, and benefit leakage. Done well, the review counters the seductiveness of big numbers and the resulting tendency to overlook challenges. And by incorporating the perspectives of a broad range of stakeholders, it keeps the prioritization process from being gamed into promotion of pet projects.

Mitigating and re-ranking. Factoring in mitigation strategies (such as preemptive measures, contingency plans, and monitoring), then racking and stacking initiatives according to their risk-adjusted value gives leaders a portfolio perspective. With that information, and based on the total incremental risk they are prepared to accept, they can make informed decisions as to the business's aspirations.[2] At a large refining business, this approach made the risk-effort trade-offs much clearer, shifting the dialogue from "That's too hard" to "How do we make this easier?" The result: faster implementation of priority initiatives and deferral of ones that were easy to implement but carried hidden risks.

Prioritization should not be a one-time event, but rather should serve as a core tool to assign resources flexibly as dictated by available facts. Effective implementation pilots are therefore an important investment. Organizations that execute well typically have well-grooved approaches that not only manage pilots tightly, but also ensure that the key lessons are drawn from the experience. Rather than using the pilot as a box-ticking ritual, successful organizations use it both as an opportunity to refine an initiative and as a critical go/no-go gate.

Resources and capabilities

At the best implementers, change programs can count on having enough people with the skills and motivation required to manage a fast-moving and often ambiguous set of challenges. Rather than looking only to people who happen to be available,

2 Many initiatives may well decrease risk by increasing stability, introducing standardization, improving transparency, etc.

> **A stringent process for evaluating skill-building progress fosters a continuous learning cycle as people at every level develop new talents.**

these organizations fill pivotal roles based on merit and free the successful candidates from their current duties. Each person's role is well defined, and expectations and responsibilities are aligned with the resources available. Employees' duties lie solidly within their areas of specialty or are appropriate for their skill levels. All employees receive feedback and ongoing coaching.

Unfortunately, most organizations don't start out from this position, leading to mismatches between the skills of the team and the requirements of the transformation. This is hardly surprising, given the way that transformations act as a discontinuity: after the change, the organization will make very different demands on its people, from the technical requirements of their roles to the way they interact with peers, managers, and subordinates.

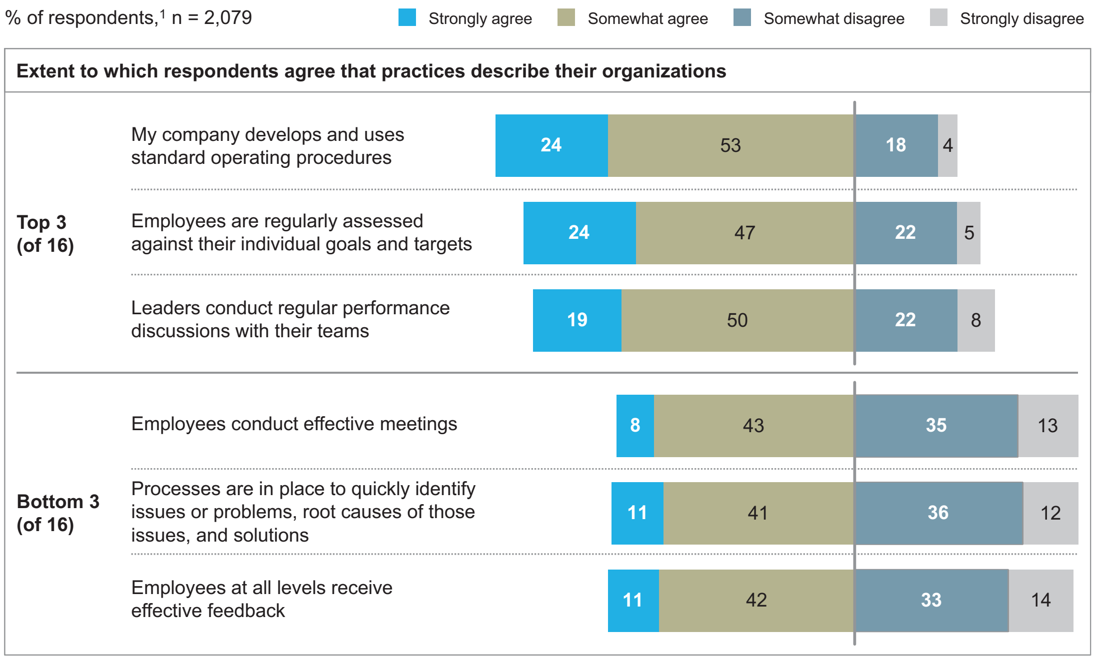
Capability-building programs are therefore central to any successful transformation. The most comprehensive ones cover functional, managerial, and technical skills and are tailored to match requirements across the breadth of roles involved in the transformation. A typical starting point is the creation of a detailed skill matrix showing the skills that each role requires and that each employee has, which highlights important gaps and training needs by role. A stringent process for evaluating skill-building progress then fosters a continuous learning cycle as people at every level develop new talents.

A powerful force multiplier in large transformations is the development of a limited number of organization-wide management standards that govern behavior from the front line to top management. One company implemented a simple tool that required every employee to know the same five elements about his or her job, including how the role contributed to the business and what the employee could do without asking permission. By setting clear and tangible expectations, the standard gave people clarity and confidence about their role, freeing up valuable leadership time and highlighting key areas of friction that needed to be addressed. Over time, management standards become a set of organizational reflexes within the business, reducing much of the effort of delivering and sustaining change.

Implementation practices

As for specific implementation practices, the executives we surveyed said their companies do fairly well at some practices associated with successful transformations. A majority said they develop standard operating procedures and regularly assess employees against their individual goals (Exhibit 3). But many said their companies falter when it comes to conducting effective meetings, having processes in place to identify problems, and giving employees effective feedback.

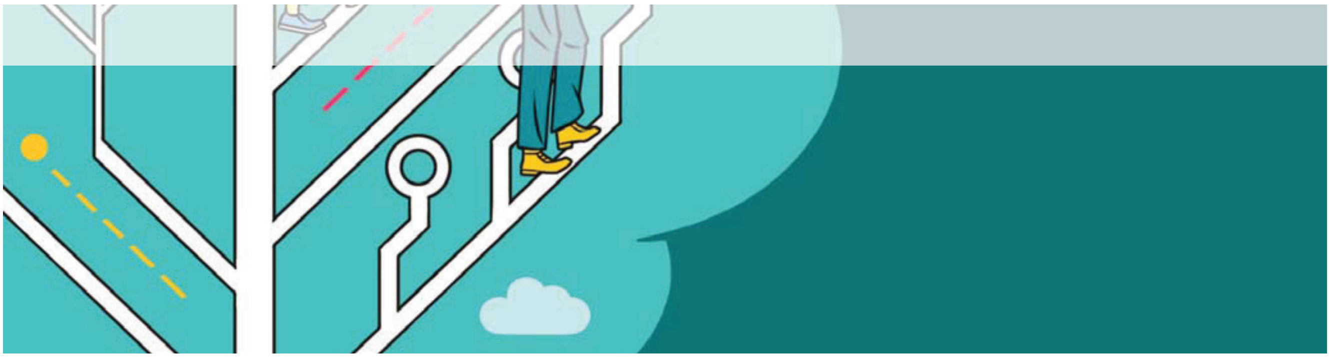
Exhibit 3. Many companies' performance lags on important transformation practices.



[1] Respondents who answered "don't know/not applicable" are not shown, so figures may not sum to 100%.

Improvement often depends on examples from above. A vice president at one global company found that members of his management team were spending up to three-quarters of their time in meetings. He therefore decided to forbid morning meetings altogether, freeing time for value-adding activities such as coaching staff members or helping solve issues at the front line. For the remaining meetings that were truly necessary, he imposed a one-hour time limit and required that all meeting hosts send an agenda and clear objectives in advance. As the role model, he made a point of leaving meetings after 55 minutes, and whenever an agenda and objectives had not been sent by a meeting's starting time, he would ask that the meeting be rescheduled.

Getting these most important factors lined up from the very beginning is a big aspiration. The survey data reinforce that implementation is a discipline that develops with practice: good implementers were 1.4 times more likely than poor implementers to have change leaders who had personally led multiple change efforts. For organizations undergoing transformation for the first time, a strong starting stance is a focus on ownership and commitment, prioritization of initiatives, and capabilities and resources.



Advancing manufacturing leadership

Alison Jenkins

Transforming a manufacturer's performance usually means changing its culture—and that means its leaders must change how they lead.

Alison Jenkins is an associate partner in McKinsey's Washington, DC, office.

Few manufacturing organizations undertake a transformation with the goal of changing their own culture. Their focus is on the transformation itself: an intense, organization-wide program to boost both performance and organizational health.[1] But once they start realizing benefits, they want to keep achieving it. They quickly realize that the new ways of working are so different that making them stick is impossible without a cultural change.

That means the leaders will need to change themselves.

The transition is not easy. As with everyone else in the organization, leaders will need to know not only what they need do differently, but why changing their behavior matters—not just to the organization's success, but to their own. Moreover, almost by definition leaders have more years of old habits to unlearn. As a result, most will need meaningful support over an extended period of time to master this new way of leading.

That support will typically take the form of an integrated learning journey that builds their understanding, conviction, and ability to lead in a new way. The investment that leadership transformation requires is therefore substantial. But without it, an organization risks losing the continuous-improvement momentum that was the crucial reason for changing in the first place.

So what must leaders change?

Three essential, fundamental **behavioral shifts** illustrate the challenge of building everyday leadership, with each representing a profound break from the typical way that large organizations have long encouraged leaders to behave (exhibit).

1 Michael Bucy, Stephen Hall, and Doug Yakola, "Transformation with a capital *T*," *McKinsey Quarterly*, November 2016, McKinsey.com.

Exhibit. Three fundamental behavior shifts are essential for leaders.

From	To
1. Providing the right answer	1. Asking the right questions
2. Looking for immediate fixes	2. Digging for root causes
3. Setting general goals for everyone to follow	3. Connecting the organization's goals to individuals' work

The first is **asking questions rather than giving answers.** It reflects three foundations of lean manufacturing: that everyone, at every level, should build new capabilities; that the people closest to a problem generally understand it best; and that one of a leader's primary responsibilities is to provide effective coaching to their teams. Yet leaders often see their main value to the organization as providing answers—indeed, some may think that's what coaching means. Learning how to listen, reflect, and trust in the team on the ground takes practice and time, but ultimately some of the most successful leaders let go of the idea that they should be at the center of problem solving. One senior executive at a large US company told us that she was willing to let her team try their ideas out—"so long as I'm there to give them the guidance they'll need to get to the real solution." She eventually realized that her questions were more valuable than her answers, but it took coaching and repetition for her to get there.

The second shift, **digging for root causes of problems** rather than looking for quick fixes, recognizes that when problems aren't fully solved they inevitably return—creating still more waste that the organization could have avoided. But the discipline and time required for root-cause problem solving are demanding for busy leaders, who may be tempted to redirect the effort toward taking actions with more immediate payoffs. As a utility construction-and-maintenance supervisor put it, "Every minute that my team isn't working on their service calls is work that they aren't getting rewarded for." But demonstrating what it means to eliminate a problem rather than paper it over is an essential form of role modeling. And one that the utility now incorporates into everyone's performance-development plans, so that frontline staff and managers are recognized for solving problems and leaders are recognizing for building people's problem-solving capabilities.

The third behavior involves **connecting the future to today**—not by making grand pronouncements, but by translating the organization's purpose and business objectives into practical targets that people can work toward each day. That constant cycle requires more than simply setting targets: it requires leaders to understand and explain how their people's work contributes to the organization's ambitions. And they must understand their people's goals as well, recognizing that work is more engaging when it has meaning to the individual. One senior vice president noted that "Seeing that our people really wanted to be proud of what they were doing for our customers was really eye-opening for a lot of our managers. They realized that they could explain our new way of working not only as making a better product but also as creating more ways for to do right by our customers. Reaching this point was hard but worth it."

Indeed, the challenge is to make these feel second-nature to leaders who have spent entire careers leading very differently.

One transformed company now initiates every executive-learning journey with a minidiagnostic on its current leadership performance.

How to build better leaders

Building understanding and conviction is a personal journey for each individual leader. That said, several experiences can help leaders both envision the future and harness the will and skill to change.

Understanding the need to change

Many organizations use external or internal go-and-sees to help leaders see the potential of a transformed organization and how it differs from their current environment. However, these visits often focus only on the behavioral shifts that are happening at the front line, when an even more critical step is to help senior leaders understand how and why they must change their own behavior in order to sustain and amplify the change they want to see. One transformed company now initiates every executive-learning journey with a diagnostic on its current leadership performance, providing an evidence-based analysis to show leaders how well they are setting direction, solving problems, and developing team members. This builds a much greater conviction among the leaders to use the new management concepts in addressing problems in their own work.

Helping leaders learn

Once leaders are ready to change, they will need support to build the skills and capabilities required of successful leaders. Most organizations develop structured leadership learning programs to address this need. Adult learners typically retain roughly 10 percent of what they learn in lectures but two-thirds of what they learn by doing, so it is important that these programs include a mix of learning experiences. One organization has therefore developed a structured learning program for leaders at all levels, from frontline supervisors to top executives, incorporating prework, group learning sessions, and fieldwork supported by experienced internal coaches. Another offers senior leaders access to a coaching pair—one with technical expertise and another with an executive coaching background—who work in tandem to support each leader through on-the-job coaching in priority areas.

Building a supporting infrastructure

Once leaders have made the initial steps toward leading in a new way, organizations must put the infrastructure in place to continually reinforce this behavior. The idea is to create transparency into whether leaders are spending their time in a way that is aligned with desired principles and behaviors. Additionally, organizations often need to adjust their formal talent system, particularly competency models, performance ratings, leadership-development programs, compensation, and promotions, to ensure that they are rewarding desired leader behaviors.

Standard performance indicators remain important for meeting practical business targets. But over time, behavioral indicators—such as how well leaders develop their people—are what enable the business to make good decisions about what its targets should be. With the view that ideal behaviors drive ideal results, a large conglomerate restructured its performance-management process such that 51 percent of a leader's annual evaluation is informed by behavioral elements. This same company implemented a monthly all-employee pulse survey to understand whether every employee was receiving the agreed standard of two hours of one-on-one coaching each month, and whether it was meaningful. The results of this survey are now regularly discussed in monthly management meetings.

Following good examples

Finally, to sustain their new behaviors, leaders should see their role models behaving differently too. In a large organization, the CEO is an obvious focal point, but not every CEO will adopt the new behaviors right away. Indeed, as important as the CEO's support is, a recent McKinsey survey underscored that the real differentiator in successful transformations is the engagement of line managers and frontline employees, not the CEO.[2]

Instead, leaders may find their role models in many places—among their own senior leaders or teammates who are going through the same transition, in a frontline leader of an early management-system deployment, or among their external network. While each individual leader will need to connect with role models who are personally inspiring, organizations can increase the likelihood of a match by identifying, supporting, and celebrating potential role models.

Practically, this can take many forms—asking leaders who are embracing the new form of leadership to participate in town halls or leadership panels, investing in senior leaders early to tap into their formal influence, including great leadership stories in company communications. One North American company has pushed this idea even further by initiating leadership-transformation deployments at the vice president and director levels. These leaders learn to apply the core concepts to their own work before cascading down within their organizations. As a result, the leaders are already role models for supporting broader transformation.

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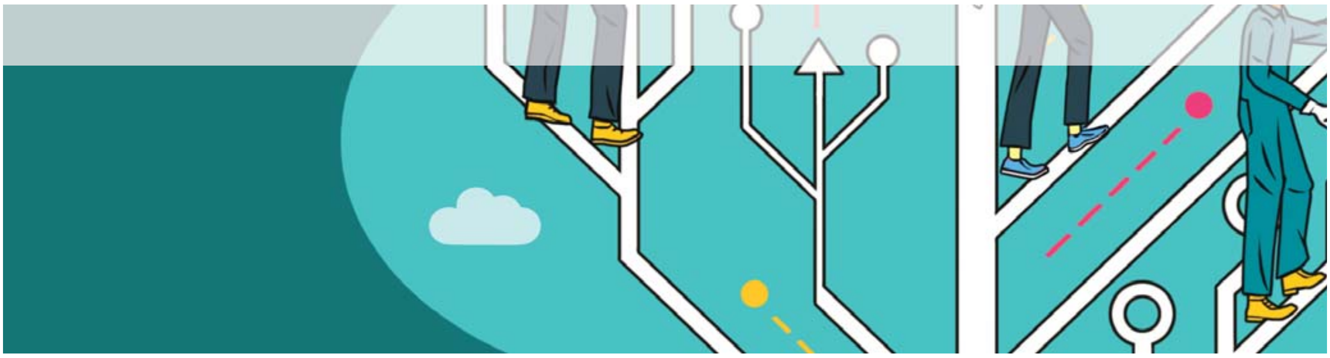
Leading an organization through an extraordinary change takes more than simply telling people what to change. It means embodying that change in a way that few leaders have been trained to do. But learning how creates an organization that can keep evolving and improving over time.

An earlier version of this article was published in ***The work of leaders in a lean management enterprise*** (McKinsey & Company, 2017), under the title, "Advancing Lean Leadership."

2 "The people power of transformations," February 2017, McKinsey.com.



Performance management: Why keeping score is so important, and so hard

Raffaele Carpi, John Douglas, and Frédéric Gascon

The elements of a good performance-management system are simple, but integrating them into a business's fundamental operating system is more difficult than it seems.

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Effective performance management is essential to businesses. Through both formal and informal processes, it helps them align their employees, resources, and systems to meet their strategic objectives. It works as a dashboard too, providing an early warning of potential problems and allowing managers to know when they must make adjustments to keep a business on track.

Organizations that get performance management right become formidable competitive machines. Much of GE's successful transformation under former CEO Jack Welch, for instance, was attributed to his ability to get the company's 250,000 or so employees "pulling in the same direction"—and pulling to the best of their individual abilities. As Henry Ford said, "Coming together is a beginning; keeping together is progress; working together is success."

Yet in too many companies, the performance-management system is slow, wobbly, or downright broken. At best, these organizations aren't operating as efficiently or effectively as they could. At worst, changes in technologies, markets, or competitive environments can leave them unable to respond.

Strong performance management rests on the simple principle that "what gets measured gets done." In an ideal system, a business creates a cascade of metrics and targets, from its top-level strategic objectives down to the daily activities of its frontline employees. Managers continually monitor those metrics and regularly engage with their teams to discuss progress in meeting the targets. Good performance is rewarded; underperformance triggers action to address the problem.

Employees have to believe their targets encourage meaningful achievement.

Where do things go wrong?

In the real world, the details of performance-management systems are difficult to get right. Let's look at a few common pitfalls.

Poor metrics

The metrics that a company chooses must actually promote the performance it wants. Usually, it can achieve this only by incorporating several of them into a balanced scorecard. Problems arise when that doesn't happen. Some manufacturing plants, for example, still set overall production targets for each shift individually. Since each shift's incentives are based only on its own performance, not on the performance of all shifts for the entire day, workers have every incentive to decide whether they can complete a full "unit" of work during their shift.

If they think they can, they start and complete a unit. But if they don't, they may slow down or stop altogether toward the end of the shift because otherwise all of the credit for finishing their uncompleted work would go to the following shift. Each shift therefore starts with little or no work in process, which cuts both productivity and output. A better approach would combine targets for individual teams with the plant's overall output, so workers benefit from doing what they can to support the next shift as well as their own.

Poor targets

Selecting the right targets is both science and art. If they are too easy, they won't improve performance. If they are out of reach, staff won't even try to hit them. The best targets are attainable, but with a healthy element of stretch required.

To set such targets, companies must often overcome cultural barriers. In some Asian organizations, for example, missing targets is considered deeply embarrassing, so managers tend to set them too low. In the United States, by contrast, setting a target lower than one achieved in a previous period is often deemed unacceptable, even if there are valid reasons for the change.

Lack of transparency

Employees have to believe their targets encourage meaningful achievement. Frequently, however, the link between individual effort and company objectives is obscure or gets diluted as metrics and targets cascade through the organization. Different levels of management, in an attempt to boost their own standing or ensure against underperformance elsewhere, may insert buffers into targets. Metrics at one level may have no logical link to those further up the cascade.

In the best performance-management systems, the entire organization operates from a single, verified version of the truth, and all employees understand both the organization's overall performance and how they contributed to it. At the end of every shift at one company in the automotive sector, all employees pass the daily production board, where they can see their department's results and the impact on the plant's performance. The company has linked the top-line financial metrics that shareholders and the board of directors care about to the production metrics that matter on the ground. Frontline employees can see the "thread" that connects their daily performance with the performance of their plant or business unit (Exhibit 1).

A senior leader at another manufacturer aligns the whole organization around a shared vision through quarterly town-hall meetings for more than 5,000 staff. Managers not only share the company's financial performance and plant-specific results but also introduce new employees, celebrate work anniversaries, and recognize successful teams. Most important, if targets are missed, the senior leader acts as a role model by taking responsibility.

Lack of relevance

The right set of metrics for any part of a business depends on a host of factors, including the size and location of an organization, the scope of its activities, the growth characteristics of its sector, and whether it is a start-up or mature. To accommodate those differences, companies must think both top-down and bottom-up. One option is the hoshin-kanri (or policy-deployment) approach: all employees determine the metrics and targets for their own parts of the organization. Employees who set their own goals tend to have a greater sense of ownership for and commitment to achieving them than do those whose goals are simply imposed from above.

Lack of dialogue

Performance management doesn't work without frequent, honest, open, and effective communication. Metrics aren't a passive measure

Exhibit 1. Leaders adapt and cascade performance indicators to all staff levels.

Level	Performance indicator	Action
CEO	▪ EBITDA[1]	"Our key value driver is production."
General manager	▪ Annual production	"We must identify bottlenecks and recurring equipment problems."
Operations manager	▪ Daily production ▪ Compressor OEE[2]	"Compressor trip is a major recurring problem. We need to resolve root causes."
Supervisor	▪ Shift production ▪ Staff training	"Root cause identified. We need to train operators to follow cleaning procedures."
Operator	▪ SOP[3] adherence	"OK, we will follow these procedures."

Everyone understands and does something

Targets must be tailored to each level to be meaningful

1 Earnings before interest, taxes, depreciation, and amortization
2 Overall equipment effectiveness
3 Standard operating procedure

of progress but an active part of an organization's everyday management. Daily shift huddles, toolbox talks, after-action reviews, and the like all help to engage team members and to maintain a focus on doing what matters most. Applying the "plan–do–check–act" feedback loop, based on pioneering research from Charles Shewhart and W. Edwards Deming, helps teams learn from their mistakes and identify good ideas that can be applied elsewhere. And in many high-performing companies, supervisors act as coaches and mentors. One-on-one sessions for employees demonstrate concern and reinforce good habits at every stage of career development.

Lack of consequences

Performance must have consequences. While the majority of employees will never face the relentless "win or leave" pressure typical of professional sports, weak accountability tells people that just showing up is acceptable.

Rewarding good performance is probably even more important than penalizing bad performance. Most companies have various kinds of formal and informal recognition-and-reward systems, but few do enough of this kind of morale building, either in volume or frequency. In venues from lunchroom celebrations to town-hall announcements, employee-of-the-month and team-achievement awards are invaluable to encourage behavior that improves performance and keeps it high. One COO at an industrial-goods company keeps a standing agenda item in the monthly business review for recognizing the performance of individuals and teams. Employees on the list may find a gift waiting at home to thank them (and their families) for a job well done.

Lack of management engagement

The words of Toyota honorary chairman Fujio Cho—"Go and see, ask why, show respect"—are now famous as basic lean-production principles. Yet in many companies, senior managers rarely visit plants except during periodic business reviews, and they appear on the shop floor only when a major new capital improvement is to be inspected.

Management interactions with frontline personnel are an extremely powerful performance-management tool. They send a message that employees are respected as experts in their part of the business, give managers an opportunity to act as role models, and can be a quick way to solve problems and identify improvements.

One company's machinery shop, for example, had developed such a reputation for sloppiness and missed deadlines that managers suggested outsourcing much of its work. When a senior manager was persuaded to visit the workshop, he was appalled at the dirty, cluttered, and poorly maintained environment. Employees reported chronic underfunding for replacement parts and tools, and asked the manager what it would take to save their jobs. He told them to "clean up the shop and give me a list of what needs to be fixed." Both sides lived up to their commitments, and in less than a year the shop became a reference case for efficiency within the company.

Building a strong performance-management system

The best companies build performance-management systems that actively help them avoid these pitfalls. Such systems share a number of characteristics.

Metrics: Emphasizing leading indicators

Too often, companies measure and manage performance through lagging indicators, such as compliance with monthly output or quality targets. By the time the results are known, it is too late to influence the consequences. The best companies track the same metrics—but also integrate their performance-management systems into critical process inputs. Industrial Internet technologies, such as the SCADA[1] architecture and distributed-control systems,

1 Supervisory control and data acquisition.

let manufacturing staff know within minutes (or seconds) about variations in performance, even in remote parts of a plant. That lets people react long before the variation undercuts output or quality.

Some changes require almost no investment in technology. At the end of each workday, for example, production and functional teams can complete a checkout form assessing how it went. A combination of quantitative and qualitative metrics and simple graphics (such as traffic lights and smiley faces) provides an easy, highly effective tool for identifying and correcting issues or problems before the next day's work begins.

As performance-management systems evolve, the metrics they use will become more complex, incorporating continuous rather than discrete variables: "everyone showed up on time today" will become "the team achieved 93 percent on the schedule-performance index using 90 percent of the labor-performance index." The extra detail better informs decisions such as whether to add more labor to meet a delivery date or to push out a schedule for delivery.

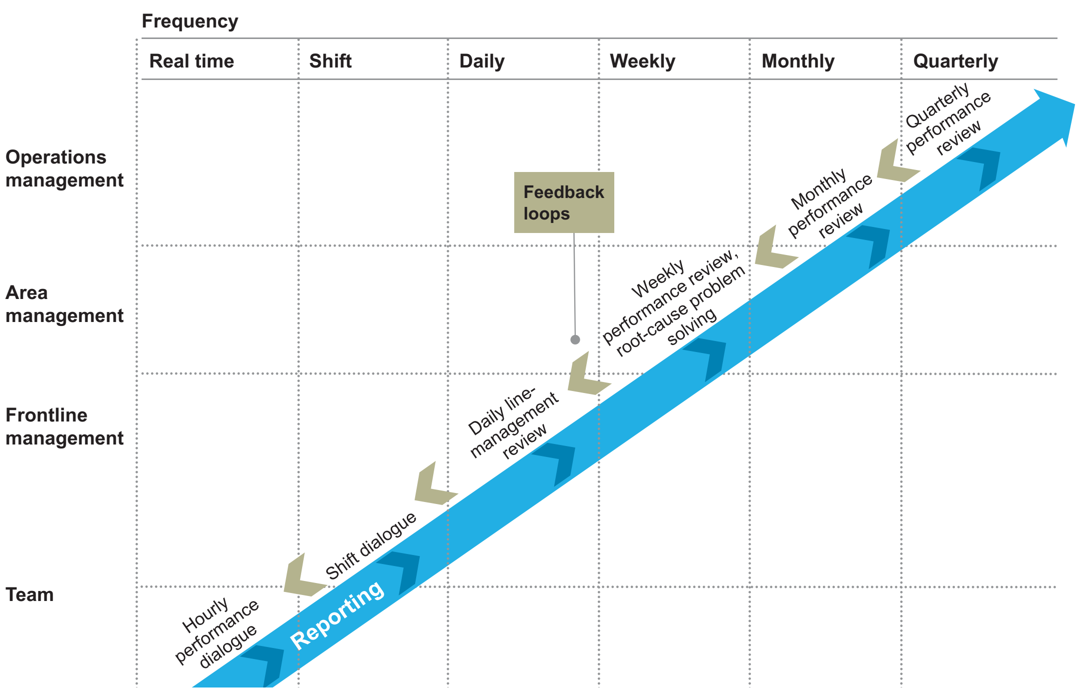
Sustainability: Standard work and a regular heartbeat

Regardless of changes to metrics and targets, the best companies keep the cadence of meetings and reviews constant, so they become an intrinsic part of the rhythm of everyday operations (Exhibit 2).

The emphasis on regular, standardized processes goes beyond explicit performance-management activities and extends deep into every aspect of a company's operating models. Standard work, for example, is based on three simple rules. First, there should be a standard for all activities. Second, everyone must have the knowledge and ability to meet that standard. Finally, compliance with it must be monitored and measured.

In many functions, the business cycle forces a regular rhythm or cadence: the weekly payroll, the monthly accounting close, or the quarterly inventory review. Good companies take advantage of these requirements to define a few central metrics, such as cycle times and accuracy, thus

Exhibit 2. A regular performance-review cadence allows issues to be identified and resolved in an appropriate time frame.



driving continuous improvement across every function.

As part of a lean-manufacturing excellence program, one industrial-commodities company encourages employees to indicate “what went well today, what didn’t go well today, what management can do to help” on their production-area boards every day. Supervisors collect the information on index cards and post them on a lean-idea board. Representatives of each function meet with the plant manager every morning and accept or reject the cards or return them for more information. Every accepted card gets an owner and timeline for completion. Company leaders estimate that the boards generate at least $2 million a year in cost savings or higher output—but the impact on employee morale and engagement is “priceless.”

A checklist or standard operating procedure that defines the steps and sequences for every key process usually enforces standard work. In employee onboarding, for example, one company noted that small details—assigning email addresses, telephone numbers, and software and hardware access—were especially important for retaining employees early in their tenures. A checklist is now at the front of each new hire’s personnel file, with a copy in the supervisor’s file. The performance reviews of supervisors now assess how well they handled the onboarding of new employees, and everyone who resigns completes a mandatory exit interview.

Continuous improvement: Standard work is for leaders too

Standard work is essential at all levels of an organization, including the C-suite and senior management in general. Standard work for leaders forces a routine that, while uncomfortable at first, develops expectations throughout an organization. It is those expectations, along with specific metrics, that ultimately drive predictable, sustainable performance.

One global resources company now requires managers to demonstrate that they spend 50 percent of their time on a combination of coaching their people and attending safety briefings, shift huddles, improvement reviews, and production meetings. To free up time, other meetings are scheduled only on one day a week—and conference rooms no longer have chairs.

Taking this approach even further, every autumn a field-services organization commits itself to a comprehensive, enterprise-wide calendar for the entire following year. The calendar sets dates for all conferences, monthly and quarterly management meetings, formal performance reviews, and succession-plan meetings, as well as training and development opportunities. All agendas are fixed, and all meetings are subject to strict time limits. There is little need for additional leeway because internal reporting follows tight guidelines for transparency and timeliness: financial results are published internally every month, while data on the performance of teams and units in meeting annual incentive-plan goals are updated and published monthly on bulletin boards.

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Most industrial companies have access to rich data on the performance of their operations. The technological advances associated with increasing use of automation, advanced analytics, and connected devices mean that this resource constantly improves. But how can organizations best use their data? A crucial part of the answer is instant feedback loops, daily performance dialogues, and routine performance reviews. Maintaining the willingness and ability to hardwire these performance-management processes into the rhythm of daily work isn’t sexy—but over the long run, it’s the most effective route to real, sustainable performance improvements.

To make a transformation succeed, invest in capability building

Elena Dumitrescu, Erhard Feige, Cinzia Lacopeta, and Amy Radermacher

Companies can vastly raise the odds of success if they take the time to build the needed capabilities.

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Not all transformations or organizational-excellence programs succeed. But, on average, companies that implement effective capability-building programs as part of their transformations beat the odds: their transformations are 4.1 times as likely to succeed and derive 2.2 times the benefits from earnings before interest, taxes, depreciation, and amortization as those of other companies.

Capability building is particularly critical in manufacturing transformations. The "second machine age," in which virtually all manufacturing processes are being digitized, requires an equally sweeping upgrade of skills and capabilities as manufacturers compete with new and agile "digitally native" competitors. The digitized factory of the future—and, increasingly, of the present—requires expertise and skills in the Internet of Things and data analytics, for example. And not only for running highly automated processes more efficiently; manufacturers must also develop digitally enabled business models that let them maximize the value that data and digital can create.

There's little question that manufacturers need new types of employees, such as data scientists and cloud computing specialists. Overall, companies need talent with more complex skill profiles and employees who combine functional, technical, and leadership competencies to drive performance in increasingly competitive markets. What's more, companies need to build these capabilities at a rapid pace, to match the new speed of business. But outside hires alone won't be enough to fill all of these demands at once. Current employees will need training to work in new ways and master their new digital tools.

Most companies fail to invest in capability building

It is easy to underestimate the challenge that manufacturers face as they contemplate business transformations, digital or otherwise, and think about how to acquire and develop the capabilities they need. Yet most companies struggle to fill capabilities gaps in their "business as usual" operations. In a 2014 McKinsey survey of 1,448 executives around the world, half of all respondents agreed that capability building was among their organization's top three priorities. Yet only 14 percent of these executives rated their company's learning programs for frontline staff and senior executives "very effective" at preparing employees to drive business performance.

Companies also recognize that they are not doing a good enough job in developing digital capabilities among their leaders, who will be increasingly important to future success. In a 2015 survey of corporate learning officers, 94 percent said that their company's leadership capability offerings were at least "average." But for digital and technological capabilities, the number fell to 76 percent.

Success factors

Even as digital business processes take root, the basics of successful capability building remain the same. We identify four essentials for success:

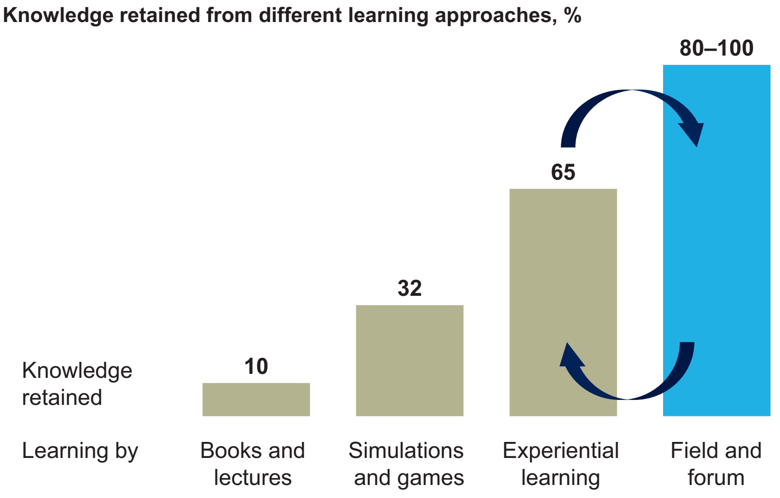
- **Build the capabilities that matter most** for the value drivers of your business. Effective programs contribute to business strategy and meet clearly defined business needs. There is no point in building capabilities for capabilities' sake.

- **Tailor training** to the organization's unique starting point and specific requirements. Start with a rigorous diagnostic to understand where the organization is today and where it needs to be tomorrow.

- **Use adult learning principles.** Adults learn most effectively by doing. To ensure that training is directly relevant to the employee's everyday work, the "field and forum" approach wcombines classroom-based instruction with experiential learning (Exhibit 1). After being trained on a new process or technology at an off-site "forum," employees go back to their jobs in the "field," where they must carry out specific assignments that reinforce the new skills in their daily work.

- **Measure and track progress.** Just as individuals' progress must be measured and tracked, so must a capability program's. Otherwise, it may not scale quickly enough to

Exhibit 1. Hands-on learning is the best way to develop new skills and set new aspirations to execute a successful transformation.



Source: John Whitmore, *Coaching for Performance: GROWing Human Potential and Purpose - The Principles and Practice of Coaching and Leadership*, fourth edition, Boston, MA: Nicholas Brealey, 2009; McKinsey interviews help the organization meet its performance targets and sustain long-term health. Aligning training content and delivery mechanisms with the organization's existing processes and systems (for example, its performance-management programs) helps keep capability building on course.

Design and implementation

Broadly speaking, companies fall into two camps in defining the scope of their capabilities programs. The first designs a light intervention that supports the implementation of technical-system improvements. The second commits to a more rigorous program that serves as the transformation's starting point. We emphatically recommend the latter. The most effective capability building we have seen embeds itself deeply in the organization, and it is delivered by people who can design and implement a new, improved way of working that underpins the entire transformation.

The next step is to define which competencies the program will attempt to impart to different types of employees. Competencies must be relevant to the business requirements for each role and tenure level. At the same time, training should also provide employees with a well-rounded set of general functional, technical, and leadership skills that are essential across a broad range of roles.

Once the type of program is selected and the required skills are identified, appropriate learning programs can be designed using a wide range of delivery techniques (Exhibit 2). We find that a 70/20/10 mix of on-the-job, peer-led, and instructor-led training usually provides the right emphasis on experiential learning.

Exhibit 2. A combination of training delivery techniques enables effective and scalable learning.

Lectures in classroom	Web-based games and simulations	Site visits and diagnostic assessments	Coaching
▪ Lectures on concepts and new approaches ▪ Held by internal and external experts	▪ Simulate effects of real-life decisions ▪ Risk-free environment to test and learn	▪ See and feel best practices in action at model factories ▪ Clients located globally	▪ Selective support by experts and coaches ▪ Discussion of personal learning-and-development agenda
Group work with cases	**Podium discussions and dinner talks**	**Quiz and web-based tests**	**Conferences and events**
▪ Work in teams of 3–5 on real-life cases ▪ Groups present results, judge best group	▪ Dinner-table discussion with experts and renowned speakers ▪ Informal setting	▪ At end of day, web-based test of learning ▪ Serves participants as self-test only	▪ Annual conference and awards program
Role plays	**Gallery walks**	**External practitioners and best-practice companies**	**Experiential learning sessions at model factories**
▪ Real-life experience by putting self in shoes of CxO or department head	▪ Facilitate reflection of thoughts via gallery walks	▪ Learning from best-practice companies ▪ Interactions with company and subject-matter experts	▪ Offer distinctive functional modules for experiential capability building

Source: McKinsey analysis

Creative instruction formats that raise employees' motivation levels while imparting needed skills often lead to better individual and organizational performance. For example, online lessons let employees easily access, share, and update their training sessions on their own schedules rather than the company's, while "gamification" makes lessons more engaging and memorable. Group case competitions encourage innovation and develop teamwork skills. Model work environments replicating real-life situations provide risk-free experimentation with new equipment, technology, and ways of working.

Implementing the program

Before starting the capability-building program, companies should find small, high-impact, and—crucially—job-relevant projects that will show the impact capability building can have. In tandem, data-based assessments, at both the individual and the process level, will help clarify the right starting point and aspirations for the capability-building efforts. The next question is ownership. HR cannot own capability building by itself: instead, it should be owned jointly by HR and the various business functions, whose expertise is essential for establishing high-quality field-and-forum programs.

The program should be rolled out systematically, with careful attention to how the program will scale across the organization. Train-the-trainer and digital delivery are two ways to scale quickly and effectively.

And finally, there need to be regular progress checks at every program stage. In rough order of validity (and complexity), progress can be measured by collecting feedback forms, testing the knowledge employees have acquired, observing behavior change, and looking for operational or financial impact.

Sustaining the gains

Capability building never really ends: continuous improvement of operations depends on continuous improvement of the individual. Some companies therefore set up corporate academies or centers of excellence to support learning on an ongoing basis. Companies can also create knowledge platforms that enable employees to share and refine their best practices, or hire external experts to continually update learning. Whatever the method, the goal is for learning to become routine, with capability development a core part of the culture and how people work.

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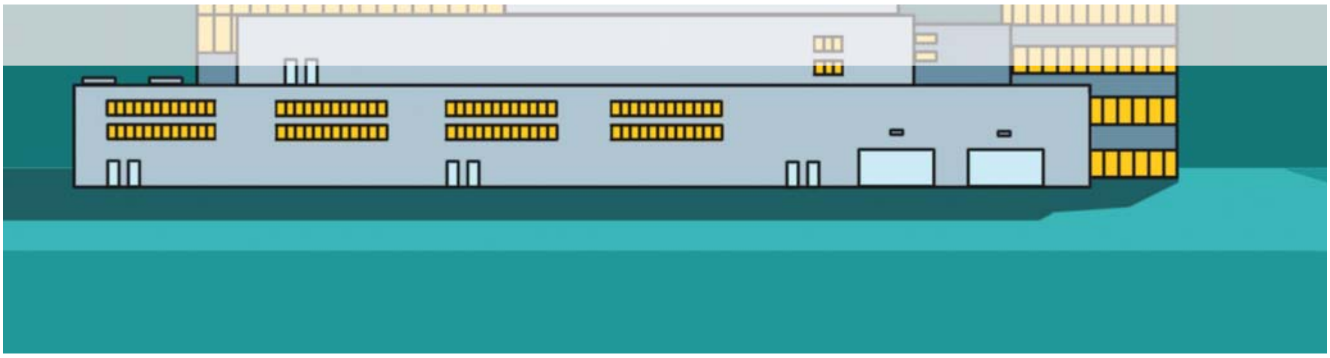
The digital transformation of manufacturing—or Industry 4.0—requires skills that few manufacturing workforces currently have. Problem solving and creative thinking have long been at a premium, and now companies also need entirely new capabilities in areas such as technology implementation and big data analysis.

As a result, understanding operations from a digital perspective will present a unique challenge, one that companies must face head-on. They'll need experimentation and unconventional ideas, new business models, and new solutions. Much of this innovation can come from within, from the people who already know the business best. A new commitment to capability building can help unlock the potential.



Extended lean toolkit for total productivity

Matt Gentzel, Carl March, Alan Osan, and Ken Somers

Technology is on manufacturers' side, but their next challenge is to create tools, infrastructure, and processes that turn rich data into real performance improvement.

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Lean continues to help manufacturing and service companies the world over improve their performance. Yet at the same time, "optimal" production-system performance is becoming ever harder to define, let alone achieve. The next step in productivity and performance improvement will therefore require companies to take lean beyond the traditional focus on maximizing efficiency.

New challenges

In the future, companies are likely to face constraints on many different resources, including energy and clean water as well as raw-material inputs and the environment's capacity to absorb waste products. They'll need to design new types of equipment and production systems that can do more with less and that can move seamlessly between different types of products. And they'll need to make complex trade-offs to operate those systems in a way that maximizes their overall resource productivity and the lifetime value of manufacturing assets.

Today's lean practitioners also need to think far beyond the factory walls or even the boundaries of their own organizations. Volatile demand, fluctuating input prices, and complicated, extended supply chains require production systems that can respond appropriately to support changing commercial needs. Companies will constantly need to reevaluate the bigger picture, too, from make-versus-buy decisions for components (or complete products) to choices about whether to repair or replace aging equipment.

Meanwhile, manufacturing technologies are changing rapidly. Rising labor costs, along with cheaper robots and other automation technologies, are driving a dramatic increase in automation. And the nature of that automation is evolving: smart, flexible machines can increasingly take on complex, highly variable, or low-volume tasks. Intelligent machines can diagnose their own maintenance needs. And in hybrid manufacturing approaches, humans work alongside robots or share tasks with them.

New resources

Companies won't have to navigate these challenges blindly. Technological change has brought with it a host of new resources that companies can draw upon to inform and support continuous improvement and transformation efforts.

First, there is data. Products, and the machines that make them, are studded with sensors collecting reams of data on everything from the temperatures and pressures inside production processes to the habits of customers in the field. Companies today are scratching at the surface of potential uses for the data: on a modern oil-production platform, for example, only 1 percent of the data generated by the 30,000 sensors is ever examined.[1]

And companies aren't limited to their own data to inform process improvement. They also have the potential to access vast external data resources from a wide variety of public and proprietary sources. Social-media streams give unprecedented, near-real-time insight into levels of customer satisfaction with products and services. Government agencies provide data on everything from atmospheric conditions to traffic flows on highways.

Second, there is communication. Network technologies allow companies to share and combine data across great distances in real time. Manufacturers can see exactly how well their equipment and processes are performing. And companies don't just monitor their remote assets; they can control them, too. Many companies now use central groups of reliability and process experts to troubleshoot critical equipment remotely, providing instantaneous, specialized support. One industrial-supply company operates its production plants entirely from a distance, sending maintenance teams into sites only when required.

Fast, high-bandwidth communication technologies are complemented by exploding data-storage capabilities. The "digital universe" of stored data is doubling every two years. By 2020, it is expected to reach 44 zettabytes.[2] That's the equivalent of 1.5 billion years of HD video content, or enough space to store an audio recording of all the human speech ever spoken. Smarter organization, search, and retrieval technologies make that data increasingly accessible—allowing companies to compare today's production conditions with similar events across the lifetime of the asset, for example, or to look at manufacturing process data for the root cause of product failures in service.

Finally, there is intelligence. Fast computers and smart analytical technologies can spot trends and patterns in huge data sets. Digital models can test thousands of different scenarios to find an optimal solution. Decades of human experience can be embedded in knowledge bases, allowing process-control systems to make decisions faster and more accurately than human operators. Artificial-intelligence technologies allow computers to learn from experience, improving their performance over time.

Using new tools for improved decision making

A crucial task facing manufacturing companies today is to adapt and extend their existing improvement capabilities to make the best possible use of these new resources in solving the challenges they now face. Examples from some

1 "Unlocking the potential of the Internet of Things," McKinsey Global Institute, June 2015, McKinsey.com.

2 *The digital universe of opportunities: Rich data and the increasing value of the Internet of Things*, executive summary, IDC, April 2014, available at emc.com.

of today's best companies give a glimpse of the potential of this extended lean toolkit.

Optimizing systems with complex inputs

Some conventional approaches to production optimization can have undesirable side effects. For example, focusing on maximum yield when running a process plant can lead to excessive energy consumption, needless wastewater-processing costs, or greater downtime and maintenance costs. As companies gain access to more data on historical performance, and use that data to build comprehensive models of plant behavior, they can take a much more holistic approach to their process management and control efforts.

A particularly powerful way to do this is by expressing plant performance in terms of profit per hour.[3] One mining company used this approach when declining ore quality caused output to fall at a major site. The company structured its historical data to express processing performance in terms of profit per hour and then used a neural-network model (a type of artificial-intelligence technology that emulates the way biological brains learn) to explore the relationship between certain process variables, such as the concentrations of reagents used, and material recovery.

This analysis revealed that optimizing a handful of variables had the potential to boost the quantity of materials extracted from a given grade of ore by more than 7.5 percent—with a slightly greater increase in profit per hour, since the optimized process also reduced the consumption of other inputs. That surprising finding ran counter to the engineering department's previous beliefs about how best to optimize processes. Reducing the material wasted in processing not only helped the mine meet its production targets, but also cut costs significantly because the mine extracted and processed less material and could run in a less demanding manner. Consequently, profit per hour increased by 9 percent.

Scenario modeling

Modern manufacturing systems and their related supply chains are highly complex. Materials and components are sourced from multiple suppliers at varying prices and quality levels. These inputs may flow through different production routes and through different equipment within individual plants, or through processes that take place at different plants or with different subcontractors. They may be transformed into different products, subproducts, by-products, and waste products, with associated interactions and restrictions. Different customers in different markets may buy those various products, at prices that change frequently. All that complexity makes it hard for manufacturers to be sure they are making the best decisions about what they buy, make, or sell at any given time.

Historically, the models manufacturers use to support these decisions have relied heavily on lots of assumptions and simplifications, such as the use of approximate "transfer pricing" to determine which raw material to buy, which individual product to make, and even which manufacturing unit or location should produce each product. These assumptions and simplifications can lead to poor decisions. Artificially high transfer prices may generate suboptimal use of network assets or make high-potential opportunities appear unprofitable.

Today's powerful computer systems allow companies to build detailed models of their entire value chain, from procurement all the way to customer demand and final delivery. Advanced optimization packages, using detailed data, can rapidly test hundreds or even thousands of different combinations of products, manufacturing facilities, and processes, with the aim of maximizing the margin for the organization within defined constraints. Critically, while the behind-the-scenes analysis in such systems is highly advanced, the latest tools are simple to operate, with straightforward spreadsheet-like interfaces.

3 Markus Hammer and Ken Somers, "More from less: Making resources more productive," *McKinsey Quarterly*, August 2015, McKinsey.com.

One European manufacturing company used such an approach to identify immediate tactical changes that delivered cost savings of several million euros per year. The company started manufacturing a key intermediate product on an underutilized line instead of buying it from a third party. It also shifted the production of another key intermediate to different equipment that offered higher yields, reducing raw-material costs. The company then identified several short-term strategic opportunities to increase capacity through the application of an operational- and reliability-excellence program for key production assets. Incremental sales volumes resulted, thanks to increased production capacity across several high-margin product categories. Together, these changes allowed the organization to boost its earnings before interest and taxes (EBIT) by more than 50 percent in a commodity industry historically used to low returns on sales.

Using real-time data

Fast data collection and analysis allow companies to fine-tune process parameters in real time or "near" real time. One chemical company used such an approach to optimize yields in a continuous-reaction process. The company applied a neural-network model to adjust the operating point of the reaction based on feedstock quality and catalyst life. The new approach boosted yields by 0.5 percent, a significant jump in a highly optimized process that was already more than 90 percent efficient.

Automated learning and decision making

The availability of more data and the processing power to deal with huge data sets are changing the way manufacturing systems are controlled. Sites can use historical process data to adjust their control systems automatically, resulting in systems that recognize and react instantly to disturbances, such as a change in the quality of the material entering a process. Machines can also use such data to continuously improve their performance over time.

Advanced-analytics techniques are also becoming much better at dealing with the kinds of fuzzy issues whose solutions once required deep operator experience or trial and error. A change in the output of a manufacturing process might have numerous root causes—from tool or part wear to upstream materials contamination. Armed with data on the characteristics of the system, fault-detection-and-classification (FDC) systems can use statistical models to interpret the most likely causes and then either automatically adjust process parameters to compensate or recommend to operators the best corrective actions.

Integrating across activities/functions

Companies can now integrate data on the production system's activities with data on the system's outputs, revealing correlations between the activities and the outputs. These correlations help to ensure that the lean system is operating effectively so that issues can be quickly identified and fixed.

An example is overall equipment effectiveness (OEE), a familiar measure of operating productivity. By combining historical OEE levels with information from other organizational functions, such as supply-chain and sales data, companies can assess and understand the true business impact of process and equipment losses stemming from problems such as unplanned downtime, slow-running equipment, and slow changeovers.

Leading lean companies use benchmarking to set stretch targets for their higher-level asset-productivity measures (such as machine utilization) and operational-efficiency ones (including cost per unit, per plant, and per product). By linking business-performance metrics with OEE data on individual lines, companies see the likely impact of missed targets on financial performance, helping them prioritize the implementation of countermeasures to avoid loss.

When parts of a production system do underperform, data analysis can aid root-cause identification—for example, by correlating OEE measures with adherence to operating standards for measures such as staffing levels or the use of standard operating procedures in changeovers. The same approach can help prove the value of lean activities, such as leader standard work, in boosting performance and productivity, which has until now been difficult to do.

Cross-functional data can also directly improve manufacturing planning. Rather than adjusting their standards for batch sizes, production sequences, and product changeovers on an ad-hoc or periodic basis, companies can combine historical data and forecast trends to create schedules and production plans almost in tandem with changes in demand.

Capturing and sharing knowledge

Advanced software tools are also revolutionizing the way organizations store and communicate their know-how across the enterprise. Leading companies have always made efforts to capture and codify best practices, from waste reduction ideas to techniques for fine-tuning equipment-operating parameters and maintenance activities. The latest generations of these software systems have become more powerful (thanks in part to built-in calculation engines) and better integrated, with links to an organization's planning, maintenance, and manufacturing-control systems.

This combination of power and integration helps companies use their knowledge to the fullest extent. If an energy-saving idea is implemented successfully in one plant, for example, such systems can identify other facilities in a company's worldwide network that could use the same approach. They can even calculate the likely savings, so staff can prioritize the change in their ongoing improvement plans.

Presenting information in new ways

In consumer sectors, increased processing power and advances in display technology have produced a user-interface revolution. High-resolution displays, 3D graphics, and motion-sensing technologies promise to bring a similar revolution in manufacturing.

Augmented-reality systems add digital information directly to an operator's field of view, using wearable devices including smart glasses. In trials, these advances helped warehouse staff find and pick products faster and more accurately, boosting productivity by 25 percent. One industrial manufacturer is developing an augmented-reality system that can lead technicians through maintenance activities—guiding them through the steps for inspection and parts replacement, and even locating the necessary parts. Certain airlines are testing video-camera-equipped glasses that allow maintenance personnel to review live images of faults and engage in problem solving with colleagues thousands of miles away.

Capturing the benefits

As with so many promising new approaches, companies are challenged to move from experiments, pilot projects, and isolated success stories to a sustainable, organization-wide approach to total productivity improvement as part of their production system. To do that, they will need three enabling components: a strong technical infrastructure, the right skills and capabilities, and new thinking about organization and management methods.

Technical infrastructure

The technical foundations of the new approach will start with data. And the first challenge for many organizations will be ensuring they have sufficient access to data, either their own or what is available from outside resources. The makers of manufacturing machinery are likely to be every bit as interested in the data generated by their equipment as their customers are, for example. OEMs are already making access to their customers' use and performance data part of their ongoing service-and-support agreements. Likewise, manufacturers weighing the short-term convenience of outsourcing will need to ensure they do not sacrifice access to valuable data and the improvements it can bring.

The next challenge will be having the right systems and tools for storing, cleaning, organizing, and visualizing the data companies have. Today, data assets are typically widely distributed in different systems and formats. A total productivity approach requires greater integration so that all parts of the organization are operating on a single version of the truth. Creating a suitable architecture and the systems to handle it in large organizations will be a formidable challenge.

The development of a production infrastructure that supports this level of integration will call for new partnerships, too. Today, different (and sometimes proprietary) standards make it hard for companies to pull together inputs from all their equipment. Efforts to change this are under way. An example is the draft API (application programming interface) standard for onboard technology in mobile mining machinery, published by the Global Mining Standards and Guidelines Group, a consortium of operators, equipment manufacturers, and third parties.

Capabilities

Total productivity improvement will require new capabilities, too. The approach will demand all the traditional lean and process-improvement skills that manufacturing companies have worked so hard to develop over the years. It will also need new skills, especially in the areas of data management and advanced analytics.

Companies will need to create new roles for data scientists and IT specialists to work alongside their existing operations teams. But they will also have to invest in the development of cross-functional skills, with specific training in data-driven decision making for operations personnel. Managers will require new capabilities, too, as the ability to understand, interpret, and act upon data will become increasingly important to their roles. Care must be taken, however, to ensure that decisions are made at the proper level in the organization. A data-rich future will make it even easier for senior-level people to get lost in the weeds.

Organization and management

Manufacturing organizations will need to change in order to accommodate a larger, more tightly integrated IT function, together with more specialized data handling and analysis in support of production roles. But they will also need to redefine every role in the organization, from the operational front line to the CEO. Targets and key performance indicators will have to evolve, for example, to avoid creating incentives for suboptimal performance.

Companies will also need new ways to monitor progress, such as by measuring the rate at which staff are trained in new techniques, and their level of acceptance of new improvement tools and approaches. Technology will have a role to play here, too. Software tools can collect data on how and where they are used, for example, giving managers insight into the maturity of application use across the organization.

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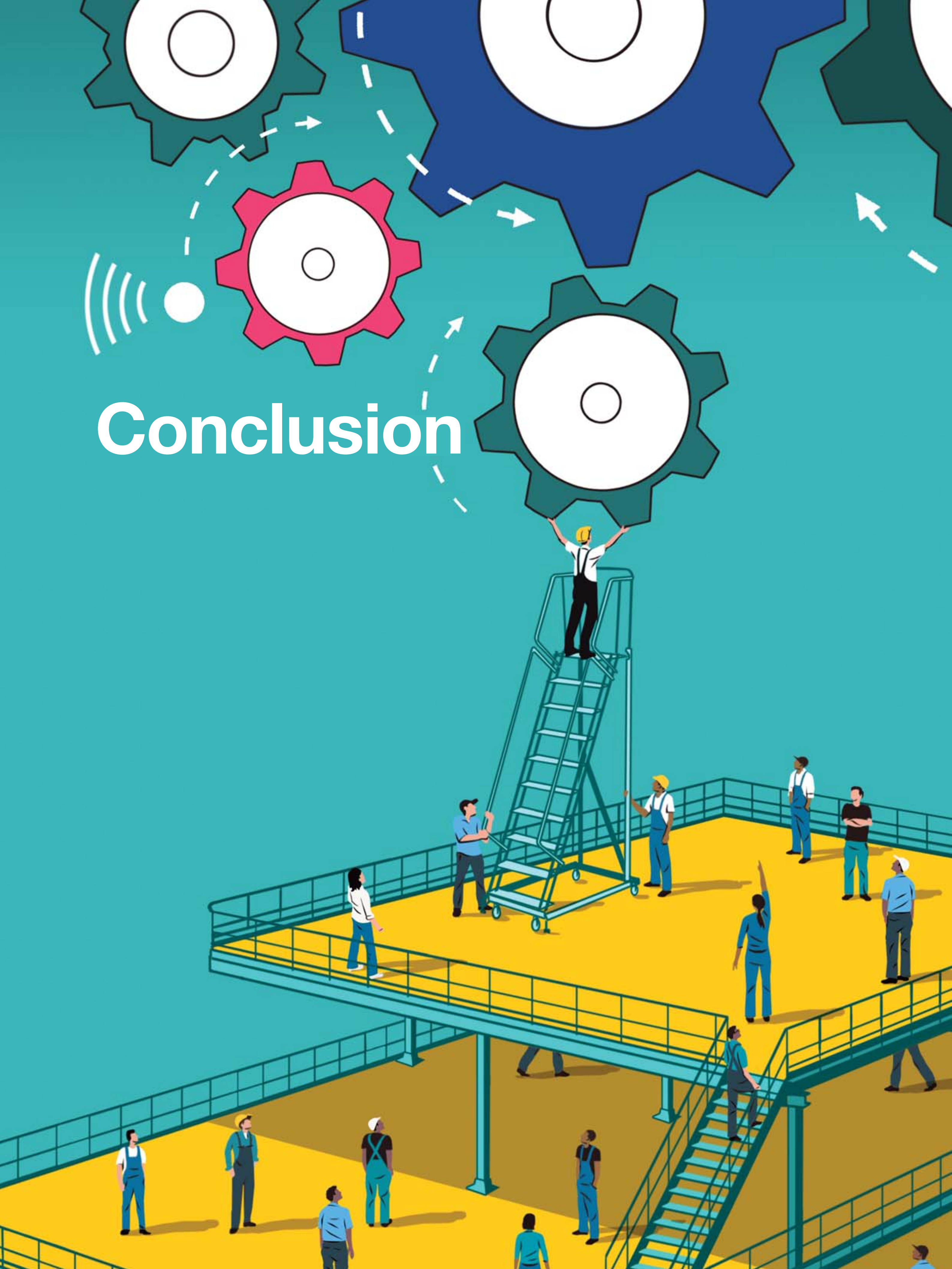
The engineers and managers running tomorrow's manufacturing plants will face increasingly relentless pressure to improve performance. Their targets won't just be more stringent, they'll be more complex, too, with the need to balance a host of factors including quality, yield, energy consumption, and cost-effective asset life, all set against a background of rapidly changing demand from customers and the wider business. To meet these challenges, companies will need to systematically embrace, create, and evolve new technologies, methods, and analytical methods. We've described some of those in this article; others surely are yet to be invented.

Conclusion



Don't burn the ships: Sail for a new world of manufacturing performance

Erin Blackwell and Tony Gambell

While there's no going back to a predigital, pretechnology age, much of what manufacturers already know will still be of great value as they transform their performance.

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"Burn the ships!"

The leader most often credited with the infamous command is Hernan Cortes—who, in 1519, landed on the shores of Mexico in search of riches and scuttled his ships to eliminate any notion of retreat.

The phrase has now become commonplace in modern boardrooms, particularly in reference to digital and other technological changes in manufacturing. It seems to be driven by three assumptions:

- There is no going back.
- Conquer or be defeated: you and your team have no middle option.
- What got you *here* will not get you *there*.

Together they suggest that to take advantage of the digital revolution, companies must forget everything they have learned about manufacturing in order to embrace the new world.

On balance, we disagree. In our view, manufacturers must instead reconcile a difficult duality: embrace the ongoing disruption, but continue to reinforce foundational insights about manufacturing performance that have proven successful for decades.

Before we explore whether the three assumptions underlying "burn the ships" apply to the digital revolution, let's first describe the New World of performance that digital manufacturing promises to deliver.

The new world of manufacturing performance

It's 2030 and you are visiting a newly built manufacturing plant. By this point, "lights-out" plants—with no direct human labor—

are now the norm rather than a visionary goal, accounting for six in ten of all factories. Instead, off the factory floor, skilled operators work hand-in-hand with advanced robots capable of learning, training them, and solving improvement opportunities on the shop floor. Efficient, flexible additive-manufacturing capabilities have finally fulfilled their promise of making highly customizable products both inexpensive and readily available.

In the 40 percent of plants still requiring direct labor, operators with digital skills perform only value-adding tasks and actively manage their own work. Many companies have adopted augmented reality in their assembly areas and are performing all hazardous tasks remotely and virtually. Production performance information is available in real-time, triggering frontline decision making and rapid escalation of problems. Digital sensors detect leading indicators of equipment breakdowns and preemptively signal preventive actions.

The plant manager is not on site but is fully engaged: she checks her metrics from a remote location, and, if the analytical forecast anticipates major changes in demand, she "talks" to the machinery to make changes to the production plan. The manager oversees a network of plants but spends very little time reacting to problems. Her job is less stressful than it used to be overseeing just one plant: robust, stable processes and learning machines leave fewer decisions for her to make, and the remaining ones truly require her knowledge and experience.

Is this new world a point of no return or the beginning of a journey? To find the answer, let's test the assumptions inherent in the phrase "burn the ships." The new assumptions that emerge will allow us to set a course that is appropriate for manufacturers across industries.

Assumption 1: There is no going back

New assumption: There really is no going back—but choose the new direction wisely

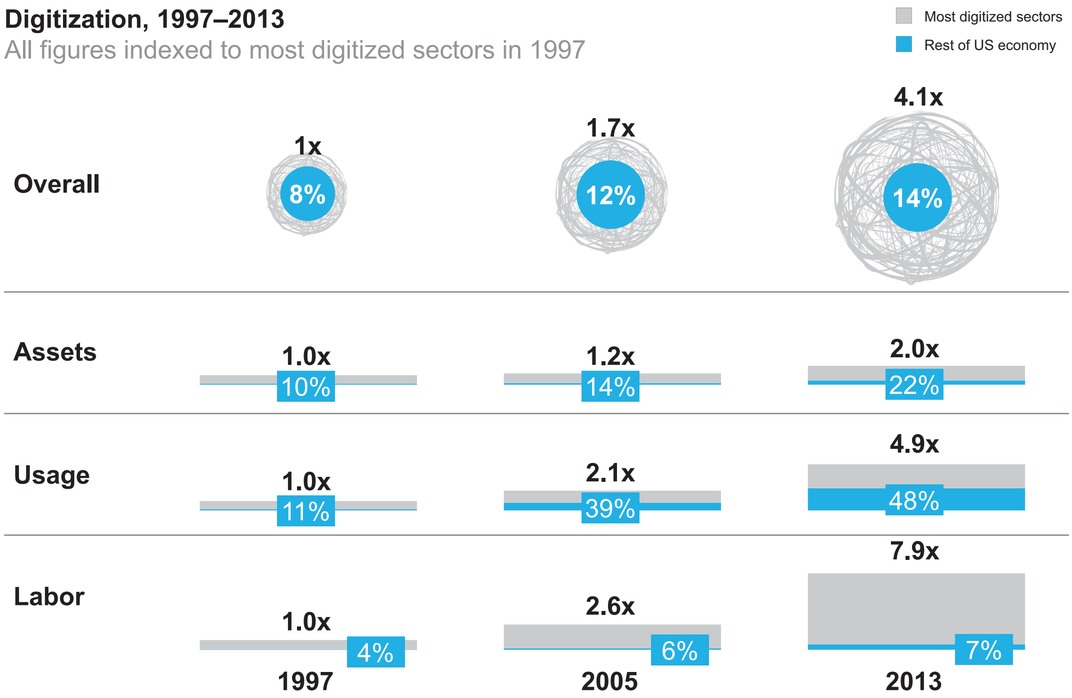
Manufacturers are under significant pressure to embrace the latest technologies, completely transform the entire organization through lean, apply advanced analytics, and the list goes on. But this frenetic activity often comes at a cost: too little of it ends up creating real value. As a result, the company ends up losing long-term competitive advantage rather than strengthening it.

There's little question that sectors that have embraced digital have achieved a competitive advantage over those that have not. As shown in Exhibit 1, firms that invested in digitization as early as 1997 have subsequently expanded their use of digital by 400 percent, whereas the rest of the US economy experienced relatively modest growth in digitization. This competitive advantage can be measured overall and in terms of assets, usage, and labor. The advantage was already evident a decade ago and has increased considerably in recent years.

But it raises a crucial question: Digitization of what? Throughout industries, companies are demonstrating the value of getting digital right by making thoughtful choices about where they invest, looking outside their organizations to understand the latest trends:

- **Using analytics to accelerate time to market.** A healthcare company used an enterprise-analytics platform to improve clinical-trial-site selection and predict the time required to complete trials. To get beyond the usual improvement levers, it identified and examined a set of counterintuitive factors

Exhibit 1. The most digitized sectors maintain a considerable lead in digitization.



that impact how its products are brought to market. One key insight was the significance of trial-site allocation. To ensure fewer resources are expended on specific trials, the company optimized its geographically dispersed sites. A centrally governed process of data entry facilitated the approach, identifying opportunities to consolidate sites. The impact was significant: the company reduced both cost and time to market by more than ten percent.

- **Printing a car.** An automotive company partnered with a full ecosystem of Internet of Things specialists to design and manufacture a 3-D-printed car. Using the company's open-innovation platform, the design process required only two months to develop a prototype. Approximately 75 percent of the car was printed, including nearly all of the body panels and the chassis.

- **Offering digital solutions.** An equipment manufacturer has transitioned from selling products to offering digital solutions that help its customers increase productivity, performance, and profits. To make the transition, the company adopted a new business model of embedding software- and data-driven digital services in the core of its business.

- **Enabling autonomous freight handling.** A logistics company has created the world's first fully automated terminal for handling freight. The automated system utilizes remotely controlled cranes to transfer freight between vehicles. Labor productivity at the site has increased by more than 80 percent.

- While there are many sources of value, successful companies pursue a focused portfolio of initiatives to optimize return on investment (Exhibit 2). And they must continue to conduct research and benchmarking to determine which technologies are applicable and best suited to their situation.

Assumption 2: Conquer or be defeated—you and your team have no middle option

New assumption: To conquer, you must embrace new tools and accelerate digital adoption

To capture the competitive advantages of digital manufacturing and advanced technologies, manufacturers must move now, before the tipping point arrives (Exhibit 3). Throughout industries, innovative start-ups have created disruptive business models, which early adopters have eagerly embraced. Recognizing the need to transform, advanced incumbents adapt the new models to their established businesses. Once mainstream customers adopt the new models, the industry reaches the tipping point: advanced incumbents and established start-ups constitute the industry's new normal. The laggard incumbents die.

There are notable examples of incumbents that failed to adapt: Blockbuster did not move fast enough to offer movies streamed via the internet, Kodak was too slow in transitioning to digital photography, Borders did not offer online sales, and Palm lagged in changing its technology.

To accelerate to the tipping point, companies must achieve excellence in the following three topics:

- **People and capabilities.** To keep pace with disruptions, companies need to develop more complex skill profiles that merge functional, technical, and leadership competencies. The right capabilities are essential for accelerating the pace of change and building a problem-solving mind-set. However, people remain the foundation of success, including senior leaders with the ability to set a vision for the future. In some cases, recruiting expertise from outside the company is necessary to ensure that the right people are in place.

- **Mind-sets.** Experimentation must be in the organization's DNA and be backed by the structure and discipline to generate

Exhibit 2. A focused portfolio of initiatives helps optimize return on investment from disparate sources of value.

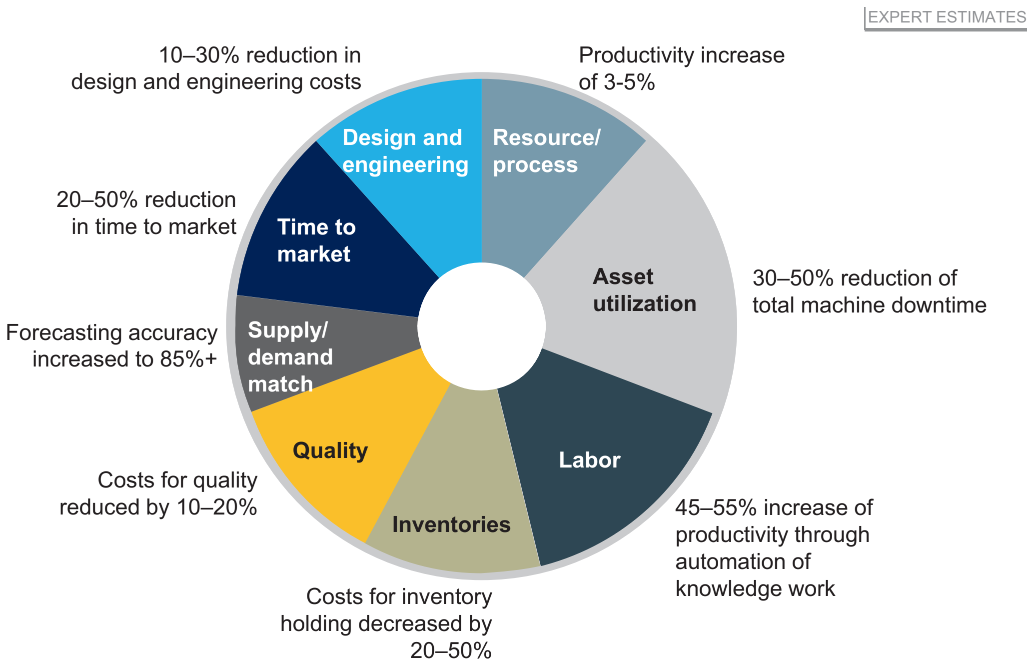
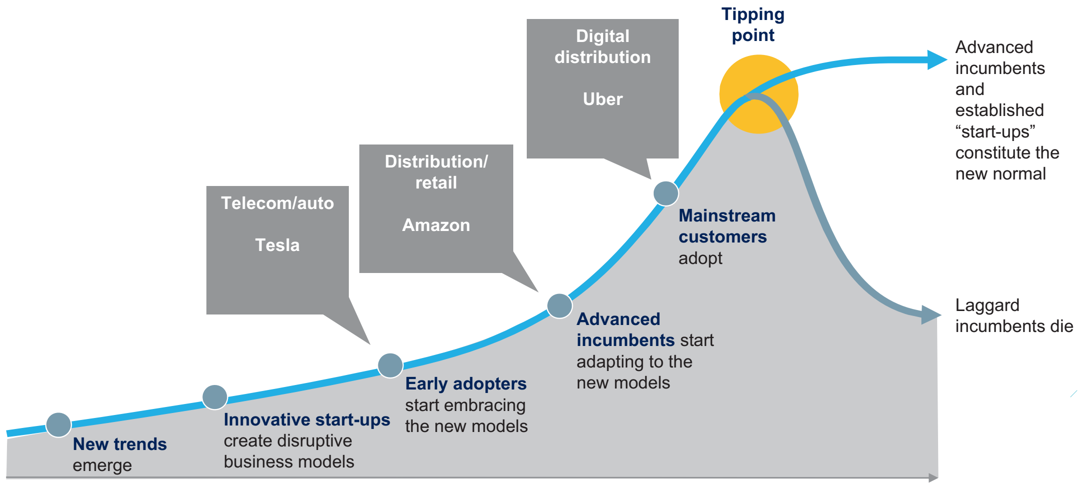


Exhibit 3. Manufacturing companies must move now, before the tipping point arrives.



measurable progress. Organizations that are wired to say "why not" and pursue opportunities proactively (versus staying the course) will accelerate change. They will move faster to an objective, fact-based point of view by reducing the lag time between the arrival of something new and an appreciation of what it means for the organization. Although it is not literally the case that the company must conquer to stay in business, all employees should feel a sense of urgency.

- **Tools.** A transformation is more than just the tools. But introducing tools, such as advanced analytics, benchmarking, and diagnostic surveys, to name a few, can significantly accelerate your assessment of operational improvement opportunities and, ultimately, the speed and accuracy of day-to-day operations.

Assumption 3: What got you here will not get you there

New assumption: Don't burn the ships. What got you here will still get you there

Even as more disruptions and new technologies descend on manufacturing plants, the underlining sources of value remain unchanged. Digital simply unlocks ways to accelerate the rate of improvement, and new process technologies are replacing old ones and promoting new degrees of freedom. It can be tempting to go after the shiny object of digital or advanced analytics or the quick wins, but companies that truly understand where opportunities exist and the potential price and time to implement change are much more likely to succeed.

Companies should first carefully consider whether digital initiatives are aligned with their operations objectives. For example, one global manufacturer found that implementing a digital production-tracking system actually encouraged supervisors and managers to become disengaged from the shop floor. Instead of going to the floor to solve problems, supervisors and managers remained in their offices and discussed problems in meetings.

The following imperatives that lead to high performance in execution today will lead to even higher performance in the new world of digital and advanced technologies.

- **Set high aspirations.** Define aggressive cascading targets and end dates. Digital investments should deliver measurable returns as other business investments do.

- **Put the customer or client first.** Strive for long-term competitive advantage while relentlessly focusing on customer value. As lean principles prescribe, always focus on what the customer or client wants and will pay for. Any investment in digital should be viewed as value adding from the eye of the customer.

- **Relentlessly eliminate waste.** Waste is one of the three evils that all transformation programs address (in addition to variability and inflexibility). Although it is impossible to fully eliminate waste from a production system, strive to reduce the use of any resource that does not add value. Seek out digital solutions to automate mindless tasks and release mental capacity for more value-adding activities.

- **Respect people.** People make change happen, which makes it imperative to know, understand, and foster a thriving culture. We have seen countless instances in which the idea of change is exciting, but people at either the leadership or frontline levels are not ready to implement the changes. Whether through training or recruiting, leaders must be onboard to create the vision and have the required integrity, courage, and agility. As with any change, the organization must be agile to support disruptive change and continuously adopt new and better technologies.

The journey has only just begun

Let's review how the journey to the new world of digital and advanced technologies changes the assumptions underlying "burn the ships":

- **Assumption 1.** "There is no going back" becomes "There is no going back, but standing still is also not an option." Leading companies are investing heavily in digital manufacturing and advanced technologies

- **Assumption 2.** "Conquer or be defeated: Your team has no middle option" becomes "To conquer, you must embrace new tools and accelerate digital adoption." Technology is becoming more available and easier to understand. Leading companies are investing in and creating tools to help with both day-to-day activities and the development of future processes.

- **Assumption 3.** "What got you here will not get you there" becomes "Don't burn the ships. What got you here will still get you there." Leading companies know that digital tools and approaches can be helpful, but only if they continuously pursue operational excellence at the foundational levels of manufacturing performance.

In the past, leaders exclaimed "burn the ships" to announce the end of their journey. But for the global manufacturing sector, the journey to the digital future has only just begun. Today, your company has reached a unique stage within its journey. The capabilities and culture that brought you to this point will remain the fundamental enablers of the journey that lies ahead. To reach the new world and thrive in its as-yet-unexplored environment, you must apply these fundamental enablers while actively embracing digital and advanced technologies. Leaders should exhort their organizations to onboard new tools and methods and set a course for the new world!

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