The digital overhaul: Industry 4.0

Rethinking manufacturing in the digital age

IBM Institute for Business Value

Digital operations for today’s world

Digital operations are transforming businesses through analytics-led, Internet of Things (IoT)-enabled business strategies and operating models for optimized efficiency, customer centricity, economic growth and asset productivity. IBM Digital Operations includes integrated services, software and infrastructure solutions. Our portfolio includes Connected Solutions, Building & Asset Optimization and Next Generation Supply Chain. Connect with us to navigate this dynamic, rapidly changing landscape. Visit **ibm.com**/services/us/business-consulting/digital-operations-internetofthings/.

Manufacturing's digital revolution

The digital age has brought with it a new way of thinking about manufacturing and operations. Industry 4.0, often referred to as digital manufacturing, uses intelligent Internet of things (IoT) technology for dynamic response to product demands. Interconnectivity of machinery sensors and control systems allows real-time optimization of manufacturing and production processes and supply chain networks. Cyber-physical systems also extend to asset management for predictive maintenance, statistical evaluation and measurements to increase asset reliability and lifespan. These significant advances in technology are shifting the capabilities and value proposition of global manufacturing. In response, manufacturing and operations require a digital overhaul: The value chain must be redesigned and retooled and the workforce retrained – quickly.

Executive summary

Many sourcing and manufacturing decisions made since the 1990s have been based on the notion that Asia (specifically China), Eastern Europe and Latin America are lower-cost regions, while the United States, Western Europe and Japan are higher-cost regions. However, this view is increasingly outdated. Changes in wages, transportation and distribution costs, productivity and energy availability are upsetting the traditional equation to determine where to source, where to manufacture and how to go to market. Total delivered cost must be analyzed to determine the best places to locate sources of supply, manufacturing and assembly operations around the world.

Meanwhile, the age of digital manufacturing and operations is here and moving very fast. Technology advances and growth in areas such as big data and analytics, cloud, the Internet of Things (IoT), robotics and additive manufacturing are rapidly changing industry dynamics. These technologies are also generating a dramatic ripple effect as they change the nature of jobs in industries that supply, support and serve manufacturing as it becomes more knowledge intensive.

In the age of digital operations, information previously created by people will increasingly be generated by machines and things – flowing out of sensors, RFID tags, meters, actuators, GPS and more. Inventory will count itself. Containers will detect their contents. Manufacturing assembly will be robotic and analytically automated. The entire value chain will be connected – not just customers, suppliers and information, but also parts, products and other smart objects used to monitor the value chain. Extensive connectivity will enable worldwide networks to plan and make decisions in real time.

Changes in total delivered cost are forcing a value chain redesign.

New-era technologies are changing the manufacturing landscape.

The digital overhaul will create new knowledge-intensive manufacturing jobs.

In addition, advanced analytics and modeling will help decision makers evaluate alternatives against an incredibly complex and dynamic set of risks and constraints. Smarter systems will make some decisions automatically – increasing responsiveness and limiting the need for human intervention.

To thrive in the digital age, we suggest manufacturers embrace a value chain redesign based on today's changing cost dynamics, as well as exploit new-era technologies to make their value chains more instrumented and intelligent. As they do, they should be prepared to address the shifting talent needs that accompany the move to digital.

Global manufacturing's changing economics

Many companies have discovered that manufacturing closer to their customer base now makes the most sense. Corporate decision makers are increasingly aware of the need to adapt manufacturing activities and rethink global value chains to reflect changes in operating costs and conditions in traditional offshoring and production platforms. With rising labor costs in China and other emerging low-cost regions, high supply chain and logistics costs, and wide cost differentials around the world for electricity and natural gas, many organizations are once again relocating manufacturing and production.[1]

Some labor-intensive jobs are moving out of China to Southeast Asia or the next emerging low-cost region. However, in industries more sensitive to transportation costs, such as consumer goods and appliances, many companies are "near-shoring" – moving manufacturing to locations near or within their key markets. This trend has been most evident in Mexico and various U.S. states for the North American market and countries in Central and Eastern Europe for the European market.[2] As labor costs in China soar, manufacturing labor costs in the United States and the Czech Republic have decreased, further bolstering the argument for near shoring.[3]

Rapid changes in wages, labor productivity, energy costs and exchange rates have driven dramatic changes in relative manufacturing cost structures. Companies must evaluate their production locations based on total delivered cost and service levels, as they reassess and realign their global sourcing networks and production footprints. Although direct manufacturing costs may be cheaper in a given economic location, it is necessary to consider the multi-tiered value chain, including component parts and material supply, assembly, packaging requirements and added transportation and logistics costs. Also, it is important to consider the hidden costs of extended global value chains such as speed to market, greater agility, and increased ability to customize products and services for specific market segments.

Going digital: Tire manufacturer

To better compete in the age of digital operations, a major tire manufacturer in Europe needed to redesign its supply network and production processes. Tire manufacturing uses multiple raw materials, including chemicals, rubber, metal and fabrics, in a complex process that requires hundreds of steps to produce each final product. Some tire components can be sourced only from a limited number of suppliers worldwide and require long lead times for delivery.

The manufacturer implemented a comprehensive forecasting, production planning and manufacturing execution solution to manage the company's diverse product portfolio. The new solution captures 10 million data elements that impact allocation and capacity planning, including individual plant, supplier, machine, product-related and workforce data; centralizes data to support a collaborative and iterative planning process across the global organization; and uses scenario-based analysis at the plant level for capacity planning and to anticipate potential bottlenecks.

The technologies behind the digital overhaul

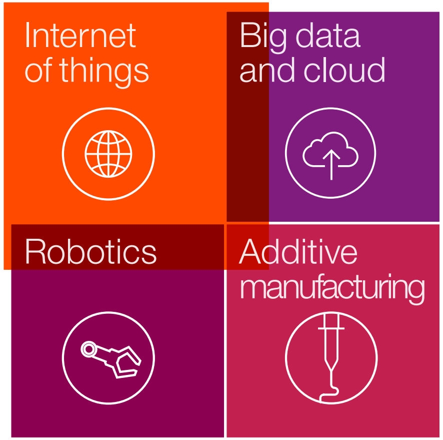
Continued advances in areas like big data and analytics, cloud, the Internet of Things (IoT), robotics and additive manufacturing are ushering in new opportunities to drive efficiencies and optimize manufacturing, with tremendous implications for global value chains (see Figure 1). These technologies facilitate the elimination of labor, help make regionalization and localization more economical, and enable improved customer service and production efficiency at every level.

Figure 1

Digital manufacturing technologies[4]

The IoT provides a foundation for digital technologies to transform manufacturing

The IoT could grow to **26 billion** units or more by 2020.[a]



71 percent of organizations use big data and analytics to develop innovative products or services.[b]

Robot installations are estimated to increase by **12 percent** per year from 2015 to 2017.[c]

3D printing has the potential to transform most aspects of manufacturing.[d]

Source: See endnote #4

Big data, analytics and cloud

In a 2014 survey of manufacturers, almost half indicated that big data and analytics will have a major impact on company performance, while over 70 percent expect these technologies will change the way manufacturing operations are managed in the future.[5] Operational executives realize that collecting and analyzing data from all aspects of the value chain in real time can be much more powerful than previous transactional, ad hoc data collection and analysis.

Operational analytics can be applied virtually within each operational process, ranging from network optimization to real-time event management and across all time horizons. Analytics can enhance manufacturing capabilities that allow inventory and production decisions to be made without human intervention and can also help determine the root cause of recurring defects or repeatedly late deliveries.

The increasing maturity of analytics capabilities in general, driven by advances in areas like cloud computing, mobility, and data storage and security management, will undoubtedly impact the adoption of operational analytics. Armed with historical as well as real-time data from the entire value chain, leaders can make more timely, insightful decisions, as well as optimize value chains to more effectively use resources to deliver the best products and services for their customers.

Underscoring innovation in big data and analytics is *cloud computing*. Cloud computing can help organizations pull more insights out of the massive floods of data they collect daily from transactions, social networks and mobile applications. Its adaptability provides a foundation for rolling out new analytics, social and mobile solutions and sharing data with partners and customers. By enabling businesses to quickly adjust their processes, products and services to meet the changing needs of consumers, employees and partners, cloud helps shorten innovation, prototype and time-to-market cycles for manufacturers.[6]

"In the IoT of hundreds of billions of devices, connectivity and intelligence will be a means to better products and experiences, not an end."[8]

Internet of Things

Early phases of the Internet included connecting people to static information and more recently, people to people. Now, the Internet continues to evolve as it connects people to physical things and physical things to other physical things, all in real time with billions of interconnected smart devices with chips, sensors and actuators that sense, capture, communicate and predictively respond to all types of data.

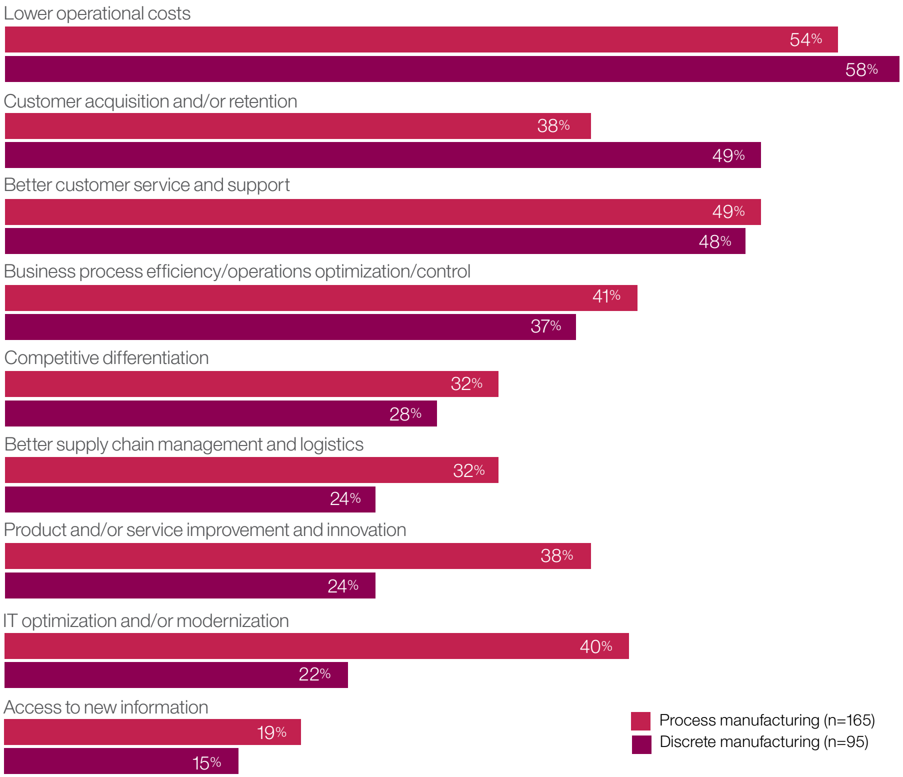
The IoT represents an evolution in which objects are capable of interacting with other objects without human intervention. There has been a shift from monitoring-based human decisions to real-time predictive insights and automated decisions. As the number of devices connected to the Internet continues to grow exponentially, an organization's ability to send, receive, gather, analyze and respond to events from any connected device increases as well.

Manufacturers are embracing the IoT for a number of reasons (see Figure 2). In general, they seek to instrument their value chains – from the sourcing of raw materials to the customer delivery and, in some cases, the maintenance and service of already-delivered items.

Intelligent IoT systems enable rapid manufacturing of new products, dynamic response to product demands, and real-time optimization of manufacturing production and supply chain networks through interconnectivity of machinery, sensors and control systems. IoT systems also extend to asset management via predictive maintenance, statistical evaluation and measurements to help increase reliability. Smart industrial management systems can also be integrated with the smart grid, thereby enabling real-time energy optimization. In addition, IoT and cloud-based GPS solutions can help increase visibility of goods in transit. These solutions make it possible to track individual items via chips that "talk" to each other, transmitting data such as identification, location, temperature, pressure and humidity.[7]

Figure 2

Manufacturers' drivers for IoT initiatives



Question: Which of the following areas have been identified as significant drivers of your organization's Internet of Things initiatives over the next 12–24 months? Source: IDC Perspective: The Internet of Things Gains Momentum in Manufacturing in 2015, doc #MI253743, January 2015.

Embracing the IoT for preventive maintenance

In the highly specialized and costly business of manufacturing and servicing huge multimillion-dollar pieces of mining equipment, preventive maintenance on critical components can save hundreds of millions of dollars. Recognizing the need to reduce machine downtime through faster diagnosis and correction of equipment faults and breakdowns, a mining equipment service provider sought a digital solution.

The company implemented a solution that collects and integrates thousands of data points streaming from hundreds of machine sensors and then analyzes the integrated data to determine machine-health status. Alerts and optimized service recommendations are sent to field technicians on their tablets to help prevent costly equipment failures. In addition, housing the integrated data in a cloud provides users in the field and at service centers a 360-degree view into equipment health status.

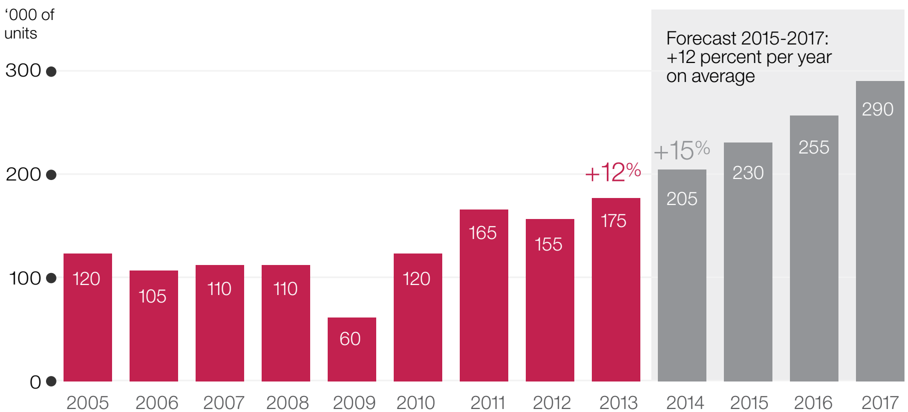
Robotics

The use of robotics in manufacturing continues to increase as new applications are found across the value chain – from production to warehousing, distribution and the customer. Robotics can help companies reduce or eliminate defects, optimize productivity and localize supply chains in a cost-effective manner. As part of the IoT, these robots serve as devices that send and receive signals from applications, making the robots themselves adaptable to changing production and logistics environments. While some technologies, such as driverless trucks, ships and drones, are still in development, others are transforming value chains today.

The International Federation of Robotics estimated 15 percent growth in robot installations in 2014 and expects that growth to continue at an average of 12 percent per year through 2017 (see Figure 3). And, while robotics' main customer – the automotive industry – drives much of this growth, robotics use is starting to increase in other industries as well, including electrical/ electronics, rubber and plastics, pharmaceutical, food and beverage, and metal and machinery.[9]

Robotics use could spark a field-leveling transformation by eliminating the need for some labor while increasing repeatability and, thus, quality. This decreased labor need means assembly tasks could occur anywhere, not just where low labor rates are available, enabling regionalization.

Figure 3
Worldwide annual supply of industrial robots



Source: "Industrial Robot Statistics: World Robotics 2014 Industrial Robots." International Federation of Robotics. http://www.ifr.org/industrial-robots/statistics/

Robotics and inventory management

From assembly line improvements to the use of robotics and lean production methods, auto manufacturers have sought ways to cut costs, improve efficiency and satisfy evolving customer demands. However, automakers do not operate alone. They are dependent on a complex global network of parts suppliers. And these suppliers typically try to maintain the lowest inventory possible while still delivering the right part at the right time.

Understanding this need for pinpoint monitoring of production, inventory and supply chain management, a parts manufacturer implemented a cloud-based manufacturing execution system to monitor and control when to insert its plastic injection-molded parts into the assembly process. The system automatically plans and executes production schedules that optimize the plant's production potential, allowing it to meet customer expectations for quality and on-time delivery. It uses real-time input from robotic machines on the shop floor and two-way communication with operators to help ensure equipment is working and that individuals and the plant as a whole are working toward the same goals.

Additive manufacturing

Additive manufacturing (commonly called 3D printing) includes a number of technologies based on several different physical mechanisms, the common feature being the generation of a three-dimensional physical object from a digital model. Because the process is additive in nature and materials are laid down only where needed, it results in significantly less material waste than traditional manufacturing techniques. Originally used for the rapid production of prototypes for form and fit testing, applications are evolving toward the manufacture of final products. Although advances continue, 3D printing of final products can still be relatively slow compared to traditional manufacturing methods. However, new design advances and raw material availability make the economic production of near final components more realistic. In fact, recent research conducted by the IBM Institute for Business Value indicates that 3D printing is reinventing the design, production, transportation and consumption of products around the world, making local manufacturing a real option (see Figure 4).[10]

Advancements in these technologies will continue to influence how and where work is performed and decisions are made. The implication for instrumented value chains is immense. Companies will need to reimagine their device strategies, information technology capabilities and manufacturing processes, as well as determine the most effective points of intervention to optimize the system. And they will have to hire and retain the talent needed to manage those interventions to work within this new landscape.

Figure 4

3D printing could diminish the importance of manufacturing location

3D printing could reduce prices while improving selection and fulfillment

Price
Less material waste, reduced labor and fewer transportation costs could allow retailers to lower prices without losing revenue

Selection
Selection becomes unlimited as availability depends on designs rather than warehousing space

Personalization
Every product can be easily customized, and at no additional cost

Delivery
As production can take place closer to demand or even in-home, significant chunks of the current supply chain and related transportation needs become irrelevant

3D printing has the potential to transform most aspects of manufacturing

Quality
Determined by the 3D printer, its configuration, and the quality of the raw material inputs

Scale
Becomes almost irrelevant for every aspect of production except delivery of raw material inputs

Automation
Becomes irrelevant to the production process

Labor
Becomes irrelevant to the production process, enabling labor to focus more attention on design, personalization, etc.

Design
Cost and complexity trade-offs fade away as each individual producer is empowered to make personal decisions about what to produce

Source: Peterson, Steve; Mark Bedeman; and Daria Godunova. “Shifting transport paradigms: Understanding the implications of 3D printing on the global transportation industry.” IBM Global Business Services. September 2014.

The digital overhaul requires knowledge workers

Understanding the "ripple effect"

Manufacturing has a larger multiplier effect than any other major economic activity. The multiplier effect extends to include the indirect creation of jobs in the industries that supply, support and serve smart manufacturing.[11]

Advanced manufacturing technologies are rapidly transforming the global competitive landscape by marrying industrial automation with information technology to optimize the efficiency, productivity and output of plants and supply networks. These new technologies and the use of more non-manufactured supplies, high-tech services, IT support, heavy analytics and higher-end equipment generate a "ripple effect" that can create millions of jobs in other sectors.

Smart manufacturing hubs are surrounded by layers of dynamic supplier networks, external support firms and outside service organizations – creating waves of indirect jobs necessary to supply, support and serve them. Understanding these new manufacturing ecosystems will help industry leaders illustrate once again the pivotal role manufacturing plays in creating jobs. To operate in the digital age of smarter manufacturing, more professional and higher-skilled workers are required, including technicians who maintain the highly automated and IT-driven manufacturing processes, data analysts, financial planners, R&D innovators, logistics and transportation specialists, customer service and technical support specialists, regulatory affairs and safety professionals, and modeling and simulation experts to optimize factory throughput.

On average, the manufacturing multiplier is 1.58, which means that a typical manufacturing facility employing 100 people actually supports 158 jobs. As factories become more advanced, the multiplier increases significantly.[12] Recruiting and training the right people to help move the industry forward no longer simply involves finding people with the necessary skill set to perform more traditional manufacturing roles (such as engineering). The digital age requires a mobile, connected and cloud-enabled workforce. Many companies are struggling to find the technical and managerial talent necessary to develop and run innovative manufacturing tools and systems.

Educational systems must adapt to meet these critical needs across industries and geographies. A recent study by the IBM Institute for Business Value found that academic leaders are aware of the curriculum changes they need to make to address disruptions caused by new technologies. Actually, 73 percent of academic leaders acknowledge that technology is disrupting the traditional education model, and 56 percent of educational service providers understand that keeping workforce skills current with rapid advancement of technology is one of their greatest challenges.[14]

Clearly, it will be necessary to enhance workforce knowledge-based skills with additional training. Many companies are also reaching out to partners in their extended value chains to acquire the skills needed for a digital overhaul.

"Technologies always become outdated by new technological change. The innovative industries of yesterday are shedding jobs today."[13]

Recommendations

Redesign your value chain network

Increased visibility from highly instrumented and interconnected value chains will help companies identify and eradicate global manufacturing and delivery bottlenecks and quality problems. In addition, big data and analytics enable the evaluation of myriad alternatives in terms of supply, manufacturing and distribution – and the flexibility to reconfigure as conditions change.

- Take advantage of millions of smart objects (IoT) that can report on whereabouts, temperature fluctuations and even theft or tampering.
- Capitalize on real-time connectivity across the extended value chain to respond in a rapid, coordinated fashion by modeling and simulating operations across the entire network.
- Implement intelligent systems to assess constraints and alternatives, allowing decision makers to simulate various courses of action.
- Supplement business knowledge with analytics knowledge. To begin, pilot new technologies that enable digital operations.

Retool your value chain for the new digital age

Instrument your operations with robotics and the IoT. Sensors, RFID tags, meters, actuators, GPS, and other devices and systems will increasingly generate value chain information previously created by people. Shipping containers, trucks, products and parts reporting on themselves will replace labor-based tracking and monitoring.

- Work with your logistics and other business partners to instrument operations.
- Where appropriate, implement additive manufacturing, robotics and IoT into your manufacturing and assembly processes to automate, create efficiencies and lower operational costs.

- Interconnect your value chain transactions with the objects and the machinery that makes your products – in real time.
- Innovate your value chain to differentiate your products and services from competitors by interconnecting it.

Retrain your employees and connect with partners
Make sure your workforce has the required skills for the future of manufacturing. As manufacturing jobs become increasingly analytical and technical, finding the right talent will be a challenge.

- Develop a strategic workforce plan that identifies the requirements for both building within the organization through training and buying talent outside the organization.
- Supplement skill gaps from your partner network while optimizing your global network of talent.
- Establish a formal career path for analytics professionals, with rapid skill development programs.
- Apply workforce analytics to manage the supply and demand of human capital, just as you apply advanced analytics to manage your physical capital.

Are you ready for digital?

The financial impact of implementing digital manufacturing and operations is vast, as new technologies bring an enhanced level of automation, control and, therefore, quality. As your organizations prepares for a digital overhaul, consider these questions:

- Based on today's global economic framework, how will your company rethink and redesign its sourcing and manufacturing footprint and its overall value chain network? Will you consider total delivered cost in making these important decisions or continue to seek low-cost labor solutions?
- How will you leverage big data with advanced analytics to gain instantaneous reaction to operational disruptions and customer demand volatility?
- To what extent does your company engage a specific digital operations strategy that includes the deployment of new-era technologies such as the IoT and robotics?
- Why might your organization be reluctant to implement the latest technologies, especially those that can increase operating efficiencies, improve the customer experience and drive innovation? What can be done to remove barriers?
- How will your company reconfigure and retrain your global talent resources (within your organization and with your extended partner network) to support digital manufacturing and operations?

About the authors

Karen Butner is the Business Strategy and Analytics Digital Operations Leader for the IBM Institute for Business Value. Karen is frequently invited to speak at international conferences and is widely quoted in leading business and industry publications. With over 30 years of experience in strategy development and transformation, her passion is to assist clients in developing improvement agendas to bring significant value by transforming their global performance. Karen can be reached at kbutner@us.ibm.com.

Dave Lubowe is a Vice President and Partner in the IBM Global Business Services Business Analytics & Strategy practice and is the North American Leader for Digital Operations Consulting. Dave has over 30 years of industry and consulting experience, primarily in operations management and large-scale transformations. His consulting work has focused on designing, implementing, managing and continuously improving business processes. He can be reached at dave.lubowe@us.ibm.com.

Contributors

Jena Collier, Senior Consultant, Operations Strategy, Global Business Services.

Christina Alexander, Consulting by Degrees Program, Business Analytics & Strategy, Global Business Services.

For more information

To learn more about this IBM Institute for Business Value study, please contact us at iibv@us.ibm.com. Follow @IBMIBV on Twitter, and for a full catalog of our research or to subscribe to our monthly newsletter, visit: ibm.com/iibv

Access IBM Institute for Business Value executive reports on your phone or tablet by downloading the free “IBM IBV” app for iOS or Android from your app store.

The right partner for a changing world

At IBM, we collaborate with our clients, bringing together business insight, advanced research and technology to give them a distinct advantage in today’s rapidly changing environment.

IBM Institute for Business Value

The IBM Institute for Business Value, part of IBM Global Business Services, develops fact-based strategic insights for senior business executives around critical public and private sector issues.

Notes and sources

1 Shih, Willy C. "What It Takes to Reshore Manufacturing Successfully." *MIT Sloan Management Review*. August 7, 2014. http://sloanreview.mit.edu/article/what-it-takes-to-reshore-manufacturing-successfully/

2 IBM Institute for Business Value analysis.

3 "Unit Labor Costs in Selected Countries." Manufacturing Institute website, accessed April 16, 2015. http://www.themanufacturinginstitute.org/Research/Facts-About-Manufacturing/Costs/Unit-Labor-Costs/Unit-Labor-Costs.aspx; "China Wages Seen Jumping in 2014 Amid Shift to Services." Bloomberg Businesss. Jaunary 6, 2014. http://www.bloomberg.com/news/articles/2014-01-06/china-wages-seen-jumping-in-2014-amid-shift-to-services-

4 a) "Gartner Says the Internet of Things Installed Base Will Grow to 26 Billion Units By 2020." Gartner press release. December 12, 2013. http://www.gartner.com/newsroom/id/2636073; b) 2014 IBM Innovation Survey. IBM Institute for Business Value in collaboration with the Economist Intelligence Unit; c) "Industrial Robot Statistics: World Robotics 2014 Industrial Robots." International Federation of Robotics. http://www.ifr.org/industrial-robots/statistics/ (acccessed April 1, 2015); d) Peterson, Steve, Mark Bedeman and Daria Godunova. "Shifting transport paradigms: Understanding the implications of 3D printing on the global transportation industry." IBM Global Business Services. September 2014. http://www-01.ibm.com/common/ssi/cgi-bin/ssialias?subtype=XB&infotype=PM&appname=GBSE_GB_TI_USEN&htmlfid=GBE03623USEN&attachment=GBE03623USEN.PDF#loaded

5 Colombus, Louis. “Big Data Analytics, Mobile Technologies and Robotics Defining the Future of Digital Factories.” *Forbes.* February 15, 2015. http://www.forbes.com/sites/louiscolumbus/2015/02/15/big-data-analytics-mobile-technologies-and- robotics-defining-the-future-of-digital-factories

6 Chambliss, Kelly. “How To Move From Systems That Record To Ones That Engage.” *Forbes.* November 6, 2014. http://www.forbes.com/sites/ibm/2014/11/06/how-to-move-from-systems-that-record-to-ones-that-engage/

7 Robinson, Adam. “What is the Hyperconnected Era & ‘The Internet Of Things’ and What does it Have to Do with Manufacturing & Logistics?” *Cerasis.* February 25, 2015. http://cerasis.com/2015/02/25/internet-of-things/?utm_source=linkedin&utm_medium=social&utm_content=Oktopost-linkedin-group&utm_campaign=Oktopost-Cerasis+%232

8 Brody, Paul, Pureswaran, Veena. “Device democracy: Saving the future of the Internet of Things.” IBM Institute for Business Value. September 2014. http://www-935.ibm.com/services/us/gbs/thoughtleadership/internetofthings

9 “Industrial Robot Statistics: World Robotics 2014 Industrial Robots.” International Federation of Robotics. http://www.ifr.org/industrial-robots/statistics/ (acccessed April 1, 2015).

10 Brody, Paul, and Veena Pureswaran. “The new software-defined supply chain: Preparing for the disruptive transformation of Electronics design and manufacturing.” IBM Institute for Business Value. July 2013.

11 Nosbuchand, Kenneth D., and John A Bernaden. “The Multiplier Effect: There are more manufacturing-related jobs than you think.” *Manufacturing Executive Leadership Journal.* March 2012. http://www.google.com/l?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CB8QFjAA&url=http%3A%2F%2Fwww.rockwellautomation.com%2Fresources%2Fdownloads%2Frockwellautomation%2Fpdf%2Fabout-us%2Fcompany-overview%2FMultiplier_Effect pdf&ei=bhscVdH4J4uZgwS2t4GQDA&usg=AFQjCNH9nVHQfq1z1nFvXkeOW_ZVBrmrWQ&bvm=bv.89744112,d.eXY&cad=rja

12 Ibid.

13 Sanz, Francisco Caballero. “European manufacturing ‘a powerful engine for growth.’” *The Parliament Magazine*. September 28, 2014. https://www.theparliamentmagazine.eu/articles/opinion european-manufacturing-%E2%80%98powerful- engine-growth%E2%80%99

14 IBM Institute for Business Value Higher Education Survey 2015.

Route 100
Somers, NY 10589
Produced in the United States of America
June 2017

GBE03847USEN-00