The State of
Manufacturing
Technology

Cloud Emerges as the
Innovation Platform for the
Shop Floor.

PLEX

THE MANUFACTURING CLOUD

Manufacturing has always been innovation-driven, from the first production line to the most modern sensors and robotics. Manufacturing technology advancements have enabled revolutions in transportation, communication, housing, energy production and almost every other aspect of life — revolutions driven both through imaginative new products and dramatic cost reductions.

130+
manufacturers surveyed

GLOBAL AND GROWING

For this report, we surveyed more than 130 manufacturers on the technologies they rely on and the tools they plan to incorporate in the coming years.

Respondents are both global and growing: 89 percent of respondents reported rising revenue during the past five years. Perhaps more impressive, 39 percent noted growth greater than 20 percent during that time period.

Of the companies surveyed, more than two-thirds operate multiple manufacturing facilities, and while the survey focuses on U.S.-headquartered companies, nearly half have international operations.

INNOVATION AND COST REDUCTION

The intersection between innovation and cost reduction is fundamental to manufacturing. Each new smartphone generation brings extraordinary features: screen size and resolution, touch sensors, heart rate monitors and so on. At the same time, prior-generation breakthroughs become standard features as production approaches are refined and costs are driven out. Each revolution climbs a ladder of low-cost infrastructure built by those that came before.

That ladder of continuous innovation starts at the shop floor, where new materials, processes and methodologies are developed every day. The technology that fuels those new capabilities is the focus of this report. A host of emerging technologies are poised to converge on the shop floor and transform how things are made. From wearables to sensors and connected tools, these technologies are creating an Internet of *Making* Things in manufacturing facilities. Together, such developments will lay

"At Plex, we often serve as the connection point for new manufacturing technology. We have the privilege of getting an early glimpse of how manufacturers are using new technologies, and we also have an R&D team in search of new tools to support manufacturers' never-ending pursuit to improve quality, efficiency, safety and productivity."

– JERRY FOSTER
CHIEF TECHNOLOGY OFFICER

the foundation for practical applications of Big Data in the manufacturing sector and drive the next era of productivity, quality, competition and innovation.

A central force in manufacturing innovation is the emergence of cloud technology. Proved in customer relationship management and back-office solutions, the cloud reaches from the supply chain materials to the shop floor machines to the customers' hands. For the first time in history, manufacturers have a unifying fabric for the entire supply-and-demand chain.

The cloud is a catalyst for new approaches to mobility, and an enabling technology for the Internet of Things. Cloud connectivity makes it possible for organizations of all sizes to consider Big Data, as the costs and technical hurdles of information capture and analysis continue to go down.

This report examines key technology trends influencing manufacturers to reveal how new technologies can strengthen competitiveness and unleash greater innovation on the shop floor.

CLOUD

Short implementation times, subscription pricing and lower cost of ownership were early catalysts for cloud software in manufacturing, just as in other areas such as customer relationship management and human resources. The cloud is emerging as a core platform for manufacturing innovation, enabling everything from rapid adoption of new plant equipment to real-time customer and supplier collaboration. Survey respondents list cloud software **among the most important technologies in strengthening their competitive edge in the next five years.**

Unlike other industries in which primary use cases involve casual desktop users, seek-and-find navigation and system-to-system (e.g., Human Resources and Expense Management) integration, the manufacturing cloud supports real-time connectivity among machines, materials, peoples, tools and systems on the shop floor. Fully 50 percent of manufacturing cloud transactions are machine-to-machine, meaning anything from an IP torque wrench to a barcode scanner is exchanging data with the system-of-record. The cloud also provides and supports continuous innovation, with a constant stream of new functionality and the ability for dynamic reconfiguration as plant and business requirements change.

"The cloud is becoming the core platform to rapidly integrate new technologies and a competitive advantage to drive plant connectivity, process integration and innovation itself. This transition is reflected by the technology adoption curve among manufacturers: companies are embracing tablets, webcams, scanners and sensors in their operations at a faster rate than any previous technology transition, along with plans to significantly expand their use of new technologies in the years to come."

– JIM SHEPHERD
VP OF STRATEGY

Notably, 90 percent of survey respondents said data security – one of the top areas often cited as a risk of moving to the cloud – either wasn't impacted or **actually improved with the adoption of cloud solutions.** In fact, manufacturers are embracing cloud solutions across the enterprise. Beyond core manufacturing and ERP, 44 percent of respondents use at least one other cloud application; the most popular include storage and file sharing, expense management and CRM.

Why it Matters: The ability to connect and manage all the resources on the shop floor has a dramatic impact on virtually every aspect of manufacturing, according to survey participants. Not only do respondents see improvements in information and process flows, but they recognize that the cloud has directly enabled improvements in product quality.

81%
say it improved mobile access to data.

With cloud solutions, access to both functionality and data requires nothing more than Internet access and appropriate credentials. Organizations can leverage both consumer and industry-specific mobile devices without any additional infrastructure.

74%
have better process integration.

Capabilities such as supplier portals are simply extensions of an existing cloud platform, making it simple for organizations to connect and change participants in their supply chain. The same is true for equipment and facilities.

"During the great recession, Plex's customers thrived. We lost three customers out of 200 in a year when the automotive sector shrank from 16 million units to 10 million units. Plex's cloud software played an important role, providing the intelligence and flexibility for companies to rapidly respond to the changes in the market. When the market turned, we were deeply concerned about the future of our customers and the company – it turned out to be our best year ever."

– JASON PRATER
 VP OF DEVELOPMENT

66% see improvements in plant productivity.

Virtually every component of the modern shop floor can be connected to an IP fabric, from torque wrenches and calipers to CNC machines and even retrofitted legacy equipment. Real-time data and instructions are managed in the cloud to drive efficiency, improve utilization and reduce energy consumption.

The cloud connects machines at Shape Corp., delivering information in real-time about product specifications and capturing rich data on production and quality.

61% report experiencing better quality.

Improvements in connectivity at the workstation, tool, materials and worker level have enabled transformation in both quality management and traceability. Testing equipment cannot only provide test data, but also report calibration and operator information. Traceability can span from suppliers and raw materials all the way to end-customers' experience.
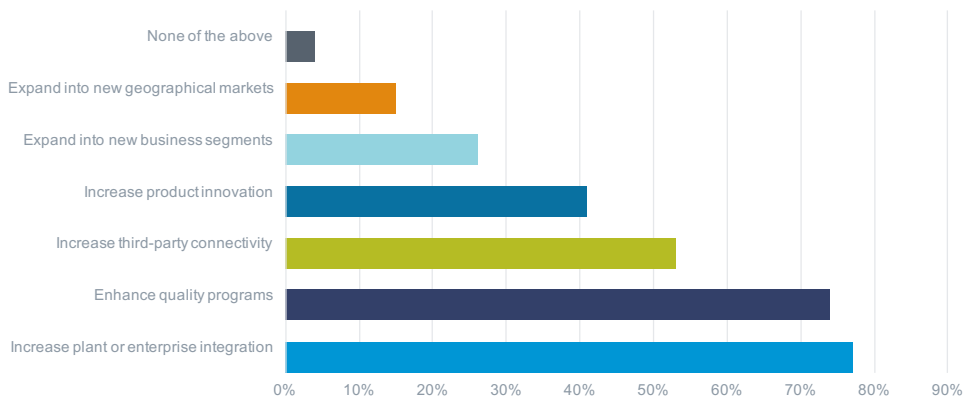
What's Next: The manufacturing sector is migrating to the cloud, having overcome early concerns about security, reliability and performance. This transition is accelerating as companies replace legacy systems that have become too complex or expensive to maintain. Cloud offers global access in a highly distributed economy where everyone in a global supply chain can access the system; such access is difficult or impossible with on-premise systems.

Manufacturers view the cloud as central to their ability to compete. Forty percent of survey participants draw a direct correlation between cloud technologies and their ability to innovate during the next five years. Additionally, 77 percent expect to increase plant or enterprise integration and 73 percent plan to enhance quality programs as a result of cloud technologies.

What initiatives will you be able to undertake in the next five years as a result of cloud technologies?

Category	Value
None of the above	~4%
Expand into new geographical markets	~15%
Expand into new business segments	~26%
Increase product innovation	~41%
Increase third-party connectivity	~53%
Enhance quality programs	~74%
Increase plant or enterprise integration	~78%

Cloud serves as a simple platform to deploy new technologies. It will support configurability and re-configurability of production lines, enabling continuous change in processes. It also is poised to provide dynamic connectivity to machines, systems, customers and suppliers. For example, manufacturers can add major new machines to the cloud with relative ease, immediately capturing data on production, scrap rates and quality that they can compare to similar machines across their operations. As recently as the early 2000s, few people in a company would know that a new capability even existed, and the company would not have had the tools needed to compare and optimize its usage across multiple facilities.

MOBILITY

In advanced manufacturing environments, mobility has always meant much more than consumer handhelds. A host of industrial devices has been used in plants for decades to provide information and access to personnel across large production facilities. Manufacturers are increasingly leveraging consumer technologies for the shop floor: 93 percent of survey respondents use consumer tablets in their manufacturing operations. For example, a quality engineer armed with a tablet can audit a production line, taking photos and notes that are instantly captured in the cloud.

While Windows PCs remain the computer of choice on the shop floor, the landscape is changing: 64 percent of survey participants provide

Tablets like this one at Dominion Liquid Technologies offer real-time access to information anywhere on the production floor.

Apple phones or tablets to employees and 45 percent equips employees with Android devices. It is important to note that the cloud plays a pivotal role in mobile adoption, enabling seamless browser and application-based connectivity without a major corporate investment in a mobile-capable IT stack.

Why it Matters: Industrial mobile devices – such as scanners, printers and label machines – have long been an essential manufacturing element. These devices are hardened for the manufacturing environment; are based on different software designs, hardware designs and operating systems; and are expensive as a result. Consumer mobile devices increasingly offer alternatives in terms of both cost and features.

What's Next: The emergence of wearable technology – from activity trackers to smart glasses and smart watches – has the potential to deliver real-time, location-specific information, capture rich data and even improve worker safety. Everything from quality and traceability data becomes easier to capture, along with worker productivity and even location, which bodes well for shop safety. Many of the social obstacles to consumer adoption of wearable technology disappear on the shop floor: factory workers already expect to wear specialized eye protection and smart devices. Manufacturing requires freedom of movement; wearables deliver hands-free access and information capture.

Attitudes about practical applications for wearables are mixed, as with most emerging technologies: 36 percent of survey respondents are likely to incorporate smart glasses such as Google Glass into its technology portfolio in the next five years, while another 35 percent say smart glasses are overhyped.

In the next five years, the distinction between industrial and consumer mobile categories will blur. Just as the OtterBox was created to protect the iPhone from rugged conditions, consumer devices will be hardened and reconfigured, and many industrial devices will likely disappear because of their high relative cost. There is significant M&A activity among the industrial mobile device makers, while new devices such as the Apple Watch boast robust software development platforms and integration capabilities. Furthermore, many of the older devices are based on software technology that has not been consistently updated, and there are tens of thousands of such devices in the field that might need to be replaced. Rapid adoption of consumer products, along with

Mobile tools drive efficiency. Today we use tablets in our distribution warehouse to deliver real-time information on inventory quantity and location, improving accuracy and eliminating paper pick lists.

– PAUL WRIGHT
DIRECTOR OF IT, ACCURIDE

A leading maker of wheel-end systems for all of the major north American commercial vehicle equipment OEMs

"Tools like webcams and tablets enable communication anytime and anywhere and will serve to more tightly integrate people into the network of manufacturing technologies."

– JERRY FOSTER
CHIEF TECHNOLOGY OFFICER

manufacturers' willingness to experiment with new technologies, make the mobile segment ripe for transformation, if not disruption.

MOBILE MAINTENANCE, REPAIR & OPERATIONS

For maintenance technicians who venture to different machines and different locations in the plant every day, mobile access to information is essential – equipment manuals, maintenance records, remote advisors and online communities form a vital support network. What's more interesting is the use of consumer technology in previously unanticipated ways. Technicians are utilizing inexpensive consumer tech such as webcams to monitor and diagnose complex machinery on the shop floor. One-third of respondents reported taking advantage of webcams for everything from equipment repair to interfacility communication.

Real-time video or time-lapse capture can be used to see inside spaces the technician cannot access without a major disassembly effort. Those same captures can be sent to offsite technicians or back to the machine manufacturer for further diagnostic information. Upon completion of the diagnostic, repair parts can be ordered directly from the technician's tablet, having never left the workstation.

What connected devices do you employ in your manufacturing operations today?
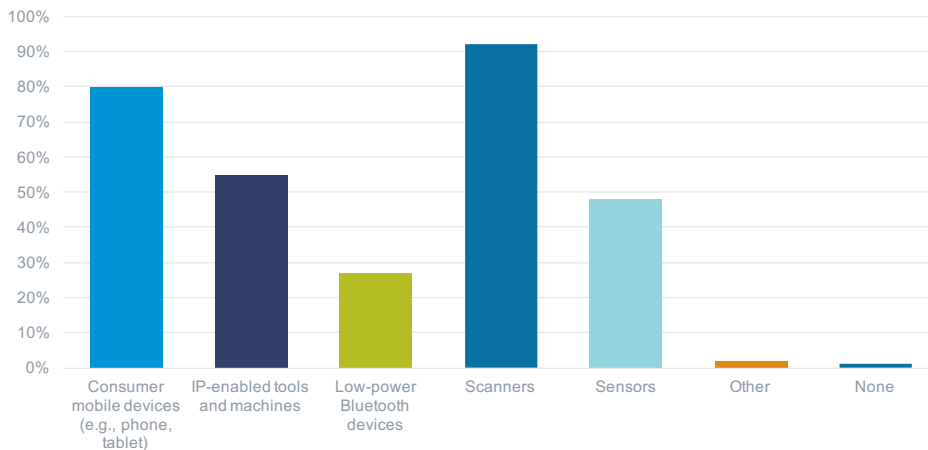
INTERNET OF THINGS

While consumer technology companies are starting to weave the Internet of Things into everything from refrigerators to smoke alarms, manufacturing has for years depended on a rich network of machines, tools, materials, products and people. Those highly customized networks are transforming into a standards-based Internet of Making Things on the shop floor, encompassing suppliers, customers and transportation systems. Among manufacturers surveyed, nearly half use connected tools and sensors, and 80percent says they incorporate consumer mobile devices into their manufacturing operations. Additionally low-power Bluetooth – a technology that is just emerging – is already in use by a quarter of respondents.

Why it Matters: Networks connecting all aspects of production enable manufacturers to see and act on live data and shop floor transactions incorporating people, machines and materials to control, manage and continuously improve manufacturing activity. Historically, Programmable Logic Controllers (PLCs) offered communications capabilities on the shop floor, but such communications were limited to the operator in front of the machine or participants in the plant's private network. By connecting PLCs to the cloud, machines can talk to the company's information system and provide access to real-time information about its operations through any browser or mobile device, across a shop floor or a facility, and even across a global organization. This is just one example of how the Internet of Things marries communications to information systems to provide rich context and inform everyone from shop foremen to end-customers.

Smart tools and machines that connect to a plant's manufacturing or ERP system are a key aspect of this network – they make complex production lines possible. For example, connected torque wrenches and CNC Machines automatically adjust based on individual product specifications, as well as what's going on in the plant to accelerate the speed of production, improve accuracy of execution and support quality and traceability.

Sensors also play a central role. It's no longer acceptable to have pieces of production disappear from view for long periods of time. Smart tags, low-power Bluetooth, and in some cases RFID tags can track the movement of materials and offer continuous visibility for a manufacturing product that is constantly moving. Products begin as raw material

"Between mobility and the Internet of Things, I'm convinced that the PC will disappear from the shop floor in the next five years. Manufacturers won't need them. Computers will be everywhere – though many will be hidden – in tablets, phones, wearables and smart tools and machines."

– JASON PRATER
  VP OF DEVELOPMENT

Scanners such as the ones at Sanders Fine Chocolatiers automatically access data and feed personnel instructions specific to a given product.

at a supplier; are then transported via truck, ship and rail; and then are transformed into a final product in multiple stages. Materials and components can travel thousands of miles before they become part of the final product. The Internet of Things provides the crucial ability to see and monitor materials and components, know where they are and trace them.

What's Next: In the coming years, this network will expand to include more and more production aspects, gather increasingly sophisticated data and extend beyond the plant's four walls. More than 50percent of the traffic in the Plex manufacturing cloud is machine to machine. Verizon recently examined the volume of global connections, including cellular, fixed line, satellite, and short-range wireless connections, and found that the manufacturing sector led adoption of connections in 2014, an increase of more than 200 percent from the prior year.

Connected tools and machines will increasingly interact with manufacturing systems for a continuous, two-way data exchanges. Smart tools are getting smarter, and smaller tools and equipment are getting connected. Manufacturers stand to achieve significant benefits in speed, accuracy and safety by eliminating any data entry steps at the end of a process. Throughout time, manufacturers will accrue data about the performance of connected tools and machines to inform maintenance programs.

Connectivity can and will expand to materials movement. Inexpensive sensors attached to shipments can track and report data about the temperature and turbulence materials endure en route. A collaborative mechanism will emerge as more supply chain participants join the network. Cloud technologies will further enable collaboration by sharing complex manufacturing, design and costing data and even help identify the right company or person within the chain to contact with an idea or problem. Networks won't end when the product leaves the factory – in many cases, connections are already being integrated into end-products, ultimately providing both intelligence about product upkeep and improved customer experience.

"At Accuride, we already see the early benefits of greater enterprise integration and now have better insight into trends. For example, if orders decline, we can determine if it is limited to a specific geography or reflects an overall shift in the market. If a supplier's lead-time changes, we can uncover the commodity causing the delay and pinpoint which parts of production will be affected."

– PAUL WRIGHT
 DIRECTOR OF IT, ACCURIDE

OPERATIONAL IMPACT

The Internet of Making Things within a manufacturing facility has tremendous potential to improve many aspects of operations as the network grows to include more and more production elements. Here are just a few examples of the possible impact:

Smarter buildings: Building management systems already have the ability to turn lights or HVAC on and off. The building management system becomes smarter by integrating these operations into the plant's network. Power and HVAC represent major operations costs and significant sources of potential savings as these systems become more intelligent.
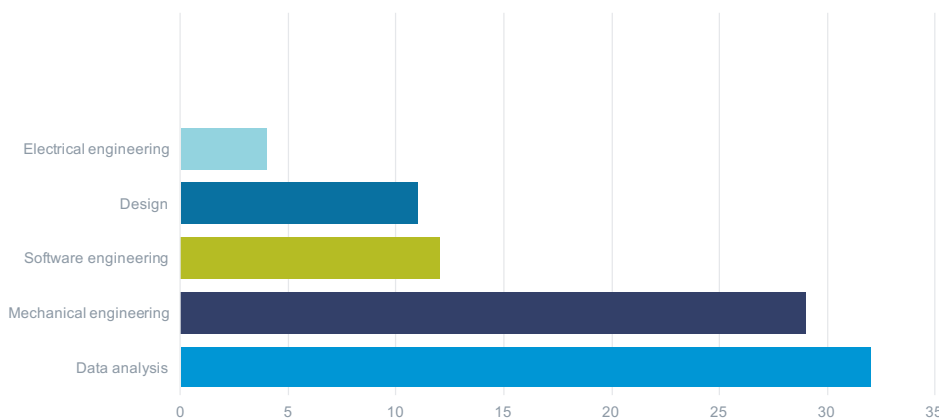
Safety: Connecting the people within a plant to the Internet of Things creates an opportunity to improve safety. Take forklifts. According to Compliance and Safety, one of six workplace deaths are related to forklifts, and 80 percent of forklift accidents involve pedestrians. Many manufacturers require that employees wear orange safety vests to make them visible to forklift drivers. These vests could easily be embedded with a Bluetooth device, and forklift drivers could be equipped with a wearable such as Google Glass, or leverage consumer-style lane divergence seat shakers. Together, these technologies can alert the driver of nearby co-workers before they come into view.

Efficiency: For more than 100 years the torque wrench has been an essential and valuable tool for manufacturers because it applies specific torque to a fastener, such as a nut or bolt. By connecting that torque wrench to the cloud, its capabilities grow exponentially. In the assembly of a complex part, the sensors on a part flow up to the cloud; the cloud identifies the specifications for the part, and instructs the wrench to automatically apply the correct level of torque. Mistakes – especially operator error – can be essentially eliminated, even on a dynamic production line. The data also flow in both directions. The cloud automatically captures the torque applied to a given part, the specific wrench that was used, when that wrench was last calibrated and the employee who used it. If a company later learns that the wrench was faulty in some way, the cloud can identity every part affected. A recall can be both fast and keenly focused on just the relevant products.

BIG DATA

The intersection of the cloud and the Internet of Making Things opens the door to a new source of intelligence for manufacturers. While the concept of big data is gaining attention, the volume of data produced by manufacturers has been growing exponentially for many years, and with it, demand for better analytics and insight. Embedded quality management is a great example of the use of connectivity and data analysis to track problems and improve processes. While the opportunity is still emerging, the larger potential for big data technologies in manufacturing is considered significant: 66 percent of survey respondents say that cloud technologies have already improved insights into its business. Thirty-one percent say they are currently evaluating big data needs and opportunities or plans to explore this area in the coming year. What's more, 35 percent say that data analysis is the most important skill set for the next generation of employees, above historically vital skills such as mechanical engineering.

"Big data creates an opportunity for a company like Plex – a multi-tenant cloud provider – to deliver aggregate data that is not easily available elsewhere. For example, a food processor might own a single, very expensive piece of equipment. It will take that company years to assemble information about the optimal maintenance schedule. Yet Plex might have 100 customers with that same machine. The Plex manufacturing cloud will have a much richer data set for predictive analytics much faster than any single manufacturer."

– JIM SHEPHERD
   VP OF STRATEGY

What skills are most important for the next-generation of employees?

Why it Matters: Most manufacturers use operational analytics to manage their business and monitor cost and efficiency. In the future, manufacturers will start using the predictive aspects of big data to monitor operations against quality specifications. As a result, a manufacturer will be able to anticipate when a machine or tool will break before it starts producing faulty parts.

For example, Inteva, a tier 1 automotive supplier that makes major automotive components, conducts an audio test on each motor that goes into its sunroofs to ensure it meets volume requirements. Inteva runs thousands of such tests every day and stores each audio file, generating 1.2 gigabytes of data on a daily basis for just one product line at one plant – Inteva operates 42 facilities worldwide. As data storage and analysis technologies develop, these recordings will become more accessible for tracking quality and have the potential to provide insights for product development.

What's Next: The ability to capture, handle and analyze massive data sets is still in early adoption stages. While predictive analytics have been available for some time and have powerful applications, the high cost made it practical for only very expensive products or shop equipment. The advent of new tools will make such analytics ubiquitous. Additionally, as the Internet of Things materializes, manufacturers will be able to capture vast amounts of data automatically. As big data is implemented across industries, companies and even whole industry sectors will be able to bring together disparate information sources to analyze operations, benchmark performance and unlock efficiencies. Data ubiquity only matters if it is easily accessible and updated, and this is where tablets and, soon, wearables become all the more valuable.

TECHNOLOGY IS TRANSFORMING MANUFACTURING WORLDWIDE

According to Federal Reserve economic data, while growth has slowed slightly in recent months, the U.S. manufacturing sector has fully recovered from the Great Recession and is on a clear growth trajectory. The resurgence is under way; technology plays a central role.

Cost is no longer the chief driver of manufacturing: quality, speed and innovation are the new keys to competitiveness. Emerging technologies will play a central role in helping manufacturers deliver continuous improvements in these areas. Cloud software, once a low-cost path to plant automation, serves as the foundation for manufacturers to capitalize on new technologies, collaborate across the supply chain, glean operational insights, foster innovation and dramatically improve efficiencies throughout the supply chain, from sourcing to manufacturing to customer delivery.

"The possibilities of data on the shop floor are endless. Greater insights from production directly support lean manufacturing and Six Sigma initiatives to optimize repeatable processes and reduce variation.
Data that rapidly reveals a problematic process empowers manufacturers to respond faster. As a result, new insights will enable companies to be more predictable in everything that we do."

– PAUL WRIGHT
  DIRECTOR OF IT, ACCURIDE

New technologies and their intersections promise to improve safety, deliver end-to-end quality management, unlock new efficiencies, enable greater customization and support more complex production lines, ultimately powering innovation.

"As big data technologies mature, there is the potential for data insights to guide real-time decision-making, such as in-memory approaches to unify transactional and reporting data. What emerges is an efficiency model the likes of which would have seemed impossible a few years ago, but will be very much a part of the new manufacturing model in just 3-5 years. Ultimately, data will become the product, a feature of what manufacturers sell, and a company will no longer deliver just a part, but all of the information about the part."

– JIM SHEPHERD
 VP OF STRATEGY

ABOUT PLEX

From diesel engines to ice cream, Plex is transforming manufacturing in the cloud. It delivers industry-leading ERP and manufacturing automation to more than 400 companies across process and discrete industries. Plex pioneered Cloud solutions for the shop floor, connecting suppliers, machines, people, systems and customers with capabilities that are easy to configure, deliver continuous innovation and reduce IT costs. With insight that starts on the production line, Plex helps companies see and understand every aspect of their business ecosystems, enabling them to lead in an ever-changing market. Learn more at www.plex.com.