SAP Thought Leadership Paper
R & D, Manufacturing, and Service

Idea to Performance

Maximizing Opportunity in a New, Technology-Driven Industrial Revolution

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Profound shifts in society, business, and technology suggest that a new industrial revolution is under way. Manufacturers must adapt to continuous change and find innovative ways to compete in global markets. Technological innovation can help them optimize existing processes and build new services and business models. SAP solutions that address the idea-to-performance process use Big Data, 3D visualization, cloud computing, and enterprise mobility to help firms create new insight, connect with partners and customers, and seize unexpected opportunities.

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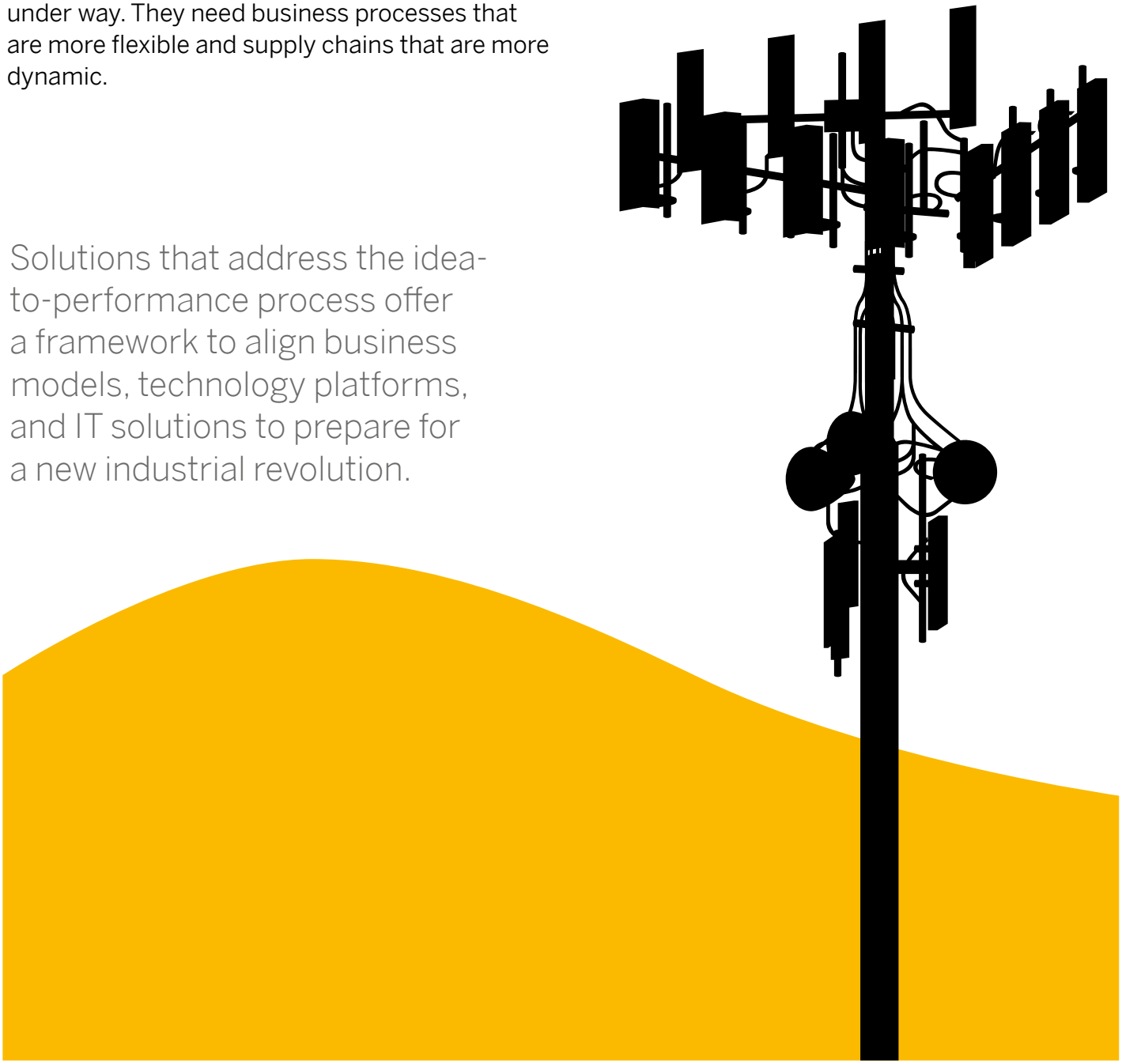
A Fourth Industrial Revolution Driven by Technology

TRENDS SETTING THE STAGE FOR FLEXIBLE BUSINESS PROCESSES AND DYNAMIC SUPPLY CHAINS

Manufacturers must "lean in" to new business models – and the technology that supports them – to keep pace with market changes that are under way. They need business processes that are more flexible and supply chains that are more dynamic.

Solutions that address the idea-to-performance process offer a framework to align business models, technology platforms, and IT solutions to prepare for a new industrial revolution.



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TURNING MANUFACTURING CHALLENGES INTO OPPORTUNITIES

Manufacturers are competing in far more competitive markets – driven by more demanding customers, digital native employees, and sustainability challenges.

Some of the most significant changes involve **customer demand**. Customers around the globe are becoming more educated and digitally experienced. They are less inclined to own products and more likely to subscribe to services. We've already seen this trend mature in the consumer market, where listening to music and watching movies from the cloud is preferred over owning CDs and DVDs. The same trend is occurring for durable consumer goods and business-to-business capital expenditures. As business customers increasingly seek to pay per outcome (for example, hour of generation, hour of flight), machine ownership is shifting to the producers – who must now optimize the full product lifecycle to protect their margins.

Both consumers and business customers are also demanding products that are highly customized, if not specifically tailored, to their individual needs. Manufacturers see the rise of the "batch of one." As lot sizes shrink, manufacturers find that moving production to emerging countries with cheap labor costs may no longer be a path to long-term success. To meet rapidly increasing demand, take advantage of low energy costs (such as natural gas in the United States), and leverage university educated workers for R & D and services, they find that production must be more local – for example, production is beginning to shift back to the United States.

Manufacturers must also address continued changes in **work environments** – driving personal empowerment into increasingly flexible, agile production processes required to meet the "batch of one" opportunity. To succeed, manufacturers must find new ways to connect with and engage employees with very different workplace expectations, balancing the expectations of aging experts with those of digital natives. Such a balance is critical for passing the tribal knowledge of older employees on to a new workforce.

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Industry 4.0 envisions a more active, autonomous, and self-organizing approach to production based on a digital product lifecycle.

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Another major area of change involves **sustainability**, where three trends will have a major impact on business. First, the era of cheap access to raw materials is ending. As supplies shrink, prices will both increase and become more volatile. Second, customers are using environmental and social performance criteria for their purchasing decisions. Third, government regulations for product and operational compliance continue to grow. As manufacturers try to meet customer expectations for environmentally friendly products, control costs, and comply with regulations, they will have to manage energy, water, and other resources as efficiently as they now manage their workforce and financials.

When manufacturers reimagine how they will do business in this new environment, they must explore advanced business models and technologies that can minimize their challenges, maximize their opportunities, and ensure sustainable growth.

TRANSFORMATION THROUGH TECHNOLOGY

Today, technology is helping manufacturers address these new challenges and opportunities in an unprecedented way due to the unlocking of value with greater connectivity provided by machine-to-machine communication. Manufacturers can now add sensors and microchips to tools, machines, vehicles, buildings, and even raw materials to make products "smarter." Ericsson, a leading telecommunications firm, estimates that 50 billion devices will be connected to each other or the Internet – or both – by 2020 and collect unprecedented amounts of data.

Manufacturers are seeking to use this Big Data for a better understanding of their products, to drive more competitive products, optimize production processes, and lower costs delivering aftermarket services. Technology for collecting and managing Big Data, in-memory computing analytics, and prediction algorithms is now available. Leading companies are exploring the proactive triggering of service activities based upon predictive algorithms as well as interactive routings of parts through a production plant based on order priorities, machine capacity, and real-time data from enterprise resource planning systems.

85% of companies believe cloud computing will have a major impact on their organizations through efficiencies, innovation, or competitive differentiation.

Source: SAP Performance Benchmarking

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The ongoing digitalization of products and services, coupled with new manufacturing techniques such as 3D printing, can free manufacturers and their ecosystems from centralized locations. With 3D printers, for example, production can be moved closer to use. We already see a proliferation of 3D printing during the design phase of complex products, from autos to rocket engines. In the future, spare parts will also be produced at locations where the original parts fail, saving significant costs for transportation and inventory. This drive to local manufacturing will unleash a new level of competitiveness among small and midsize enterprises.

As technology fosters stronger vertical integration between a company's shop floor and its global business strategies – and horizontal integration across its design, planning, production, and service processes – the company becomes more responsive and efficient. It also benefits from agile, self-organized business networks that allow local execution of global business plans.

SAP solutions addressing the idea-to-performance process offer a holistic framework to help manufacturers align their business models, technology platforms, and IT solutions to meet today's challenges and prepare for a new industrial revolution.

NATIONAL STRATEGIES FOR A NEW INDUSTRIAL LANDSCAPE

Governments and industry associations see clear opportunities for using a new manufacturing environment to support long-term job creation and economic growth.

A good example is the United States, where experts expect labor price equalization and greater energy independence to bring manufacturing back from overseas. In 2012 the U.S. government launched the Advanced Manufacturing Partnership, which will install regional centers of manufacturing excellence that leverage university-created technology. The program builds upon an earlier private-sector initiative encouraging collaboration among leaders in research, business, and politics in the development of new manufacturing technologies.

The German government has similar technology initiatives. After funding research programs across business and academia, the government asked acatech, the National Academy of Science and Engineering, to make recommendations for German businesses and public authorities on taking advantage of a fourth industrial revolution. A central office now helps companies collaborate on future manufacturing scenarios.

Government-fostered convergence of business and university-led technology should soon become truly global as emerging economies seek further automation to protect their manufacturing base and ensure job and economic growth.

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A Fourth Industrial Revolution

MERGING PHYSICAL AND DIGITAL SUPPORTS TO PRODUCTION

Experts use different terms to describe the technology-driven changes for manufacturing that are under way to seize on the business model changes required to meet new customer demand, provide advanced work environments, and reach new levels of sustainability. Some use "advanced manufacturing" to highlight the increased efficiency that new technologies, processes, and materials will bring. Others use "industrial Internet" to emphasize a new level of connectedness among people, machines, and systems.

In Germany, the term "Industry 4.0" has been used to combine the multiple trends, highlighting the fundamental changes at hand as the advent of a fourth industrial revolution (see Figure 1). The term highlights the breadth and force of an upcoming transformation in manufacturing. It may best capture the sea of change that will fundamentally alter the role of humans in production.

CHANGING OUR WORK AND DAILY LIVES

Industrial revolutions are turning points in economic, social, and political history when people interact with new technologies that reshape their work and daily lives. During the first industrial revolution of steam and mechanics (at the end of the 18th century), mechanical production replaced manual production. This was followed by a second revolution involving electricity and mass production (in the early 20th century), which introduced the assembly line.

A third revolution of electric engineering and automation (during the 1970s) helped manufacturers optimize money, labor, and other resources as they globalized their operations. This has now given way to a fourth industrial revolution in which technology is merging physical and digital worlds throughout all layers of production. This convergence enables smaller lot sizes tailored to specific local markets and customers and has increased the importance of service offerings over products.

Industry 4.0 envisions a more active, autonomous, and self-organizing approach to production based on a digital product lifecycle. Products, machines, and resources will communicate

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"Cyber-physical" systems use sensors to collect data from the physical world for controlling production, logistics, engineering, and service processes.

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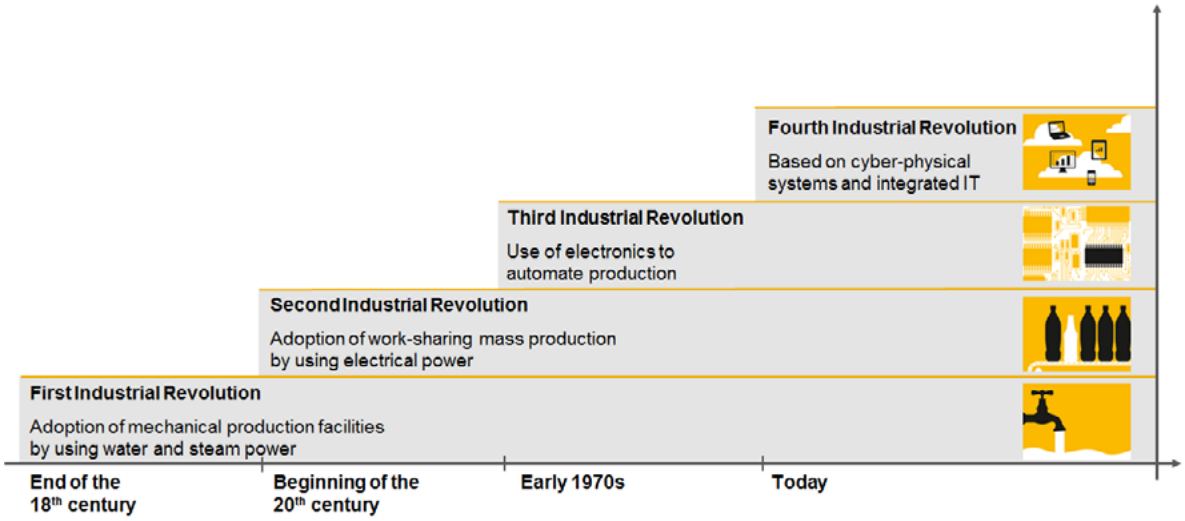
where they come from and how they should be handled and processed. All products and processes will have digital properties that provide essential information – from product design to production and recycling – and help manufacturers improve products and processes or offer new services.

As Industry 4.0 eliminates traditional data silos spread across the value chain, manufacturers will be able to integrate individual customer requirements in real time for global planning and quickly implement those requirements in local production. Rigid preplanning processes will become obsolete.

Thanks to a new level of transparency, manufacturers will also be able to identify problems in the supply chain or production in real time and address them without delay. Predictive analysis will even help companies solve problems before they occur. Manufacturers will continue to engage in long-term business relationships but increasingly do business through short-term networks. They will negotiate value-adding processes dynamically – taking into account quality, time, price, viability, sustainability, and other dimensions.

As manufacturers and other companies abandon their traditional industry silos and cut across value chains, the technology of Industry 4.0 will help them connect their systems, networks, and machines to enable smart factories, smart logistics, smart energy grids, and smart cities.

The Fourth Industrial Revolution
Figure 1



Adapted from "Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Final report of the Industrie 4.0 Working Group," acatech – The National Academy of Science and Engineering, 2013, based on a graphic from Wolfgang Wahlster, Deutsches Forschungszentrum für Künstliche Intelligenz GmbH, 2011.

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KEY OPPORTUNITIES IN INDUSTRY 4.0

As Industry 4.0 unfolds, all existing business processes will need to be redefined and integrated. The core technology of Industry 4.0 involves "cyber-physical" systems that use sensors to collect data from the physical world for controlling production, logistics, engineering, and service processes. These systems become smart and interactive through embedded software and connectivity that helps manufacturers collect, store, and analyze an exploding amount of data through local business logic.

The journey to Industry 4.0 offers the following opportunities:

- Evolution of business models
- End-to-end digital engineering
- Top floor–shop floor integration
- Real-time, value-added networks
- Enhanced work environments

EVOLUTION OF BUSINESS MODELS

Most of today's business models for manufacturing have their roots in previous industrial revolutions. They are based largely on mass production and automation and focus on design, production, and marketing processes. New business challenges require new ideas, processes, and technology for sustainable business models.

The trend toward customization is a key driver of these new models – offering customer-specific products, selling services over products, and creating value within business networks.

As the shift toward individualization continues, manufacturers will offer customer-specific products, getting down to lot-size one and "make-to-me" products and services for their business customers and consumers. New business processes can help them handle sudden shifts in demand and ad hoc, make-to-order requests. Manufacturers can tightly integrate customers into the engineering process, configuring products to their specific needs, authorizing access to data describing their actual use of products, or analyzing customer sentiment through social media.

In more service-oriented industries, manufacturers shift their revenue from products to services, creating new value-added services for existing products, such as after-sales services or asset benchmarking. Manufacturers may guarantee uptime for an asset and then provide the necessary maintenance. In more advanced scenarios, they will sell outcomes rather than products, transforming their businesses into service offerings. For example, an engine manufacturer could

Companies have a 14% shorter time to market for new products when they have a formal product lifecycle management process.

Source: SAP Performance Benchmarking

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charge customers for the power its engines provide instead of selling engines, a forklift provider could sell hours of service rather than the physical forklift, or a printing press manufacturer could charge by the page printed.

It is also likely that borders between different industries will continue to disappear, bringing processes and information closer together. As this happens, manufacturers can create value within business networks – offering unused production capacity in a marketplace to companies that temporarily need more capacity, for example.

END-TO-END DIGITAL ENGINEERING

Integration of the complete product lifecycle with the value chain will be the cornerstone of "digital chains," innovative business processes, and new business models. In this environment, it will be necessary for manufacturers to identify existing data sources, combine and analyze these sources, and model the product lifecycle. They will need technology to generate, collect, filter, and analyze data from different sources and integrate existing IT solutions.

Before modeling a product as a physical part, manufacturers will digitize its design and engineering and simulate production. This would require that the digital models available today in computer-aided design or engineering systems be incorporated into a production planning system that could simulate the whole production line.

During production, manufacturers will turn data into context-sensitive information that will be leveraged to reduce the risks and complexity involved in their production processes. Full transparency and traceability will help them identify the reasons for costly waiting times on the shop floor and better integrate feedback about maintenance or other processes into the product design.

After production, a product's digital structure will also be shared with the manufacturer's service department, so it can predict the areas where the product might fail. Feedback loops from the production and service departments to the engineering department based on digital information should help cut service time and costs and optimize production.

Companies have 40% lower scrap when the quality system supports supply chain planning, root cause analysis, quality notifications, and advanced product quality planning.

Source: SAP Performance Benchmarking

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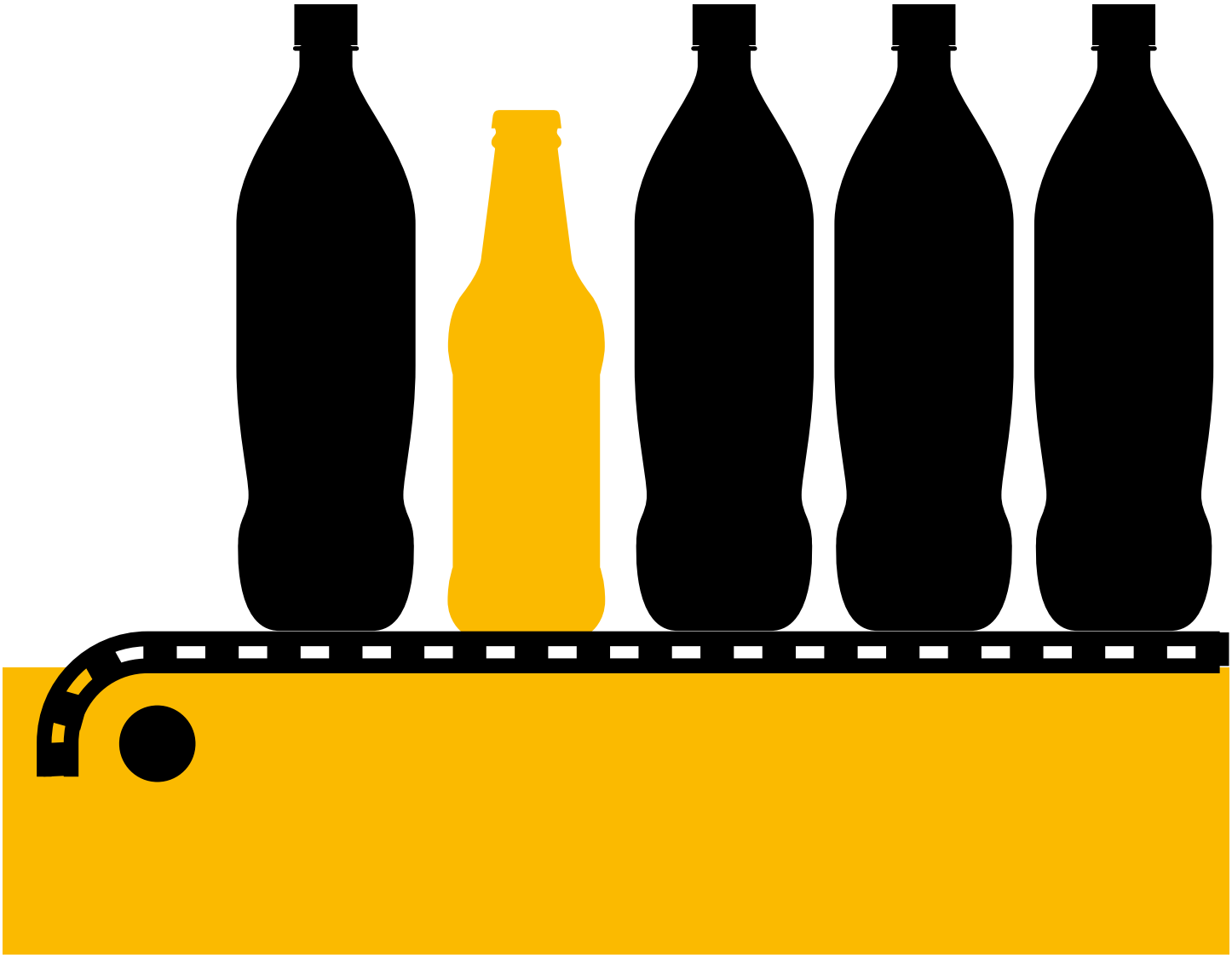
New product revenue is 36% higher for companies that use compliant and sustainable components and materials.

Source: SAP Performance Benchmarking



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Finally, at the end of a product's lifecycle, information about design, production, and usage can help companies weigh various remanufacturing and recycling options.

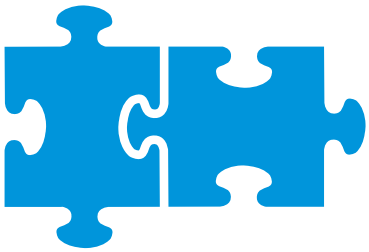
To integrate all resources, products, and processes, manufacturers will need to identify existing data sources – from the assembly line to social networks – and combine and analyze the different sources. Modeling product lifecycles will be a central task and the basis of collaboration across boundaries. This might involve designing and engineering products using insights from customers to adapt manufacturing processes in real time and connecting with customers and partners for predictive maintenance or local, just-in-time production. We could easily see the rise of a new profession – the lifecycle engineer.

TOP FLOOR–SHOP FLOOR INTEGRATION

Machines in automated production processes are already connected by business and production systems. Usually, they receive instructions from a manufacturing execution system based on a central production plan. Going forward, we will see increasing convergence of information technology and operational technology for new business scenarios.

Smart machines will have more flexibility to change previously fixed production and logistics plans and will do so via increasingly decentralized planning processes. Autonomous manufacturing units, coupling robotics and highly skilled workers, will adapt to continuous customer-driven changes in product, enabling a single production line to create different product types without reengineering the production process. This autonomous capability is critical as manufacturers increasingly face a world of "batch-of-one" orders. Logistics will have to decide whether to ship spare parts or position 3D printers at the locations where they are needed.

As machines and objects become smart and communicative, production units will become more active, autonomous, and self-organizing. Objects and machines will be able to decide together which tools will be used and where parts should move for the next production step. Machines will report their condition and work status back to a manufacturer's ERP system. Plant managers will get a real-time view of production through these systems – and will then be able to react quickly if problems occur and adjust production plans to optimize order fulfillment.



Industry 4.0 will help manufacturers connect systems, networks, and machines to enable smart factories, smart logistics, smart energy grids, and smart cities.

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All of this communication will produce massive amounts of data. With 50 to 100 sensors per machine and 500 manufacturing steps (or more), there can be terabytes of data that must be stored, combined with other data sources, and analyzed.

When coupled with enterprise production data, this data from the shop floor will enable completely new kinds of optimization and business ideas. These could enable efficient production of highly customized items for single customers, the monitoring of energy consumption, and maximized utilization of machines and resources. Companies will be able to identify operational risks earlier and solve potential problems before they occur.

Via cloud technology, companies can also share data with the businesses that produced their machines and help them develop better products and services. Detailed data from the production and delivery processes can help them identify affected products and customers more precisely, thereby reducing the number of customers they must notify. Repairs can be done remotely by downloading software patches or triggering action on a device via a remote connection.

REAL-TIME, VALUE-ADDING NETWORKS

When it comes to collaboration between companies, technology has historically created rigid processes by triggering sequential workflows. Inspired by social networks, the depth and breadth of collaboration between companies will change considerably in coming years. More business processes will be linked, and the interaction between companies will evolve from supply chains into value networks that can rapidly restructure partnerships to address batch-of-one requests.

Manufacturers will optimize the entire business network by sharing and analyzing data. Digitalization and pervasive connectivity will enable real-time analysis of all business activities. Cost structures can be simulated to support decision making. Market changes can be anticipated and business ideas implemented more quickly. This will lead to much higher value for all network members and an increase in outsourcing and project-based work.

Such improvements require business-critical data from partners – including information on capacity, planning data, and product costs. A secure and efficient exchange between partners, in turn, requires a reliable infrastructure and

Organizations with a well-defined, enterprise-wide, high-performance analytics strategy have a 68% greater ability to use Big Data.

Source: SAP Performance Benchmarking

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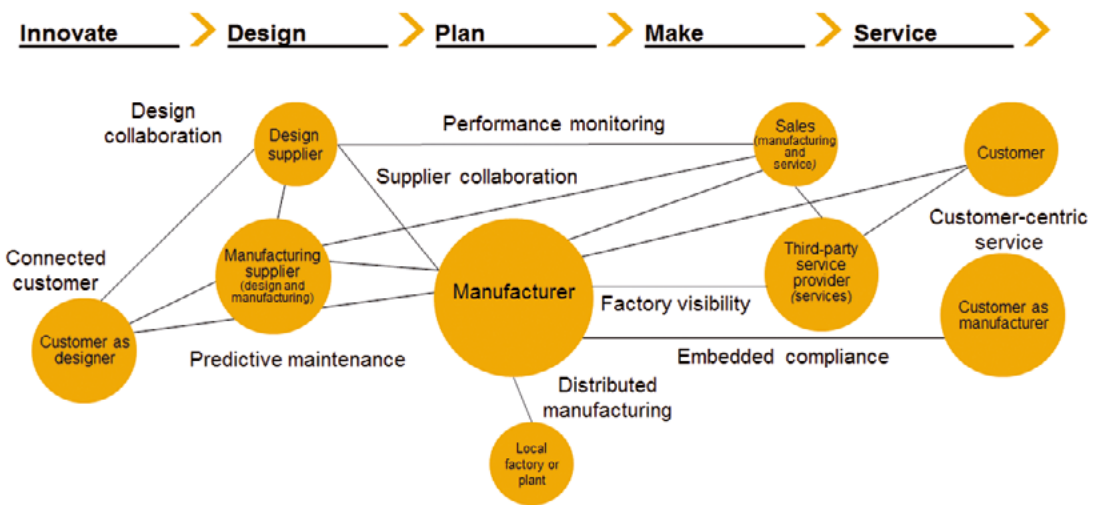
systems that enable trust building. Methods like privacy preserving and multiparty computing can help companies run optimizing algorithms on encrypted data without disclosing their critical data. Using "sticky" policies, firms can attach metainformation about standards and guidelines about data usage. Such methods and concepts are still in research but should become more efficient and usable in the future.

A second prerequisite for real-time, value-added networks is the creation of places where companies can connect, share, and communicate with each other (see Figure 2.) Many companies already use marketplaces to collaborate with their supply chains. These marketplaces and other business networks will cover an increasing number of business activities going forward. The marketplaces will enable dynamic relationships for engineered services and direct materials supported by new contractual terms and fast onboarding.

Challenges exist, but as production becomes more localized and individualized, online networks will help manufacturers anticipate production stops, find new suppliers on the fly, and manage changes in market conditions and customer behavior more effectively. Connectedness will be core to enterprise success.

Connecting Industries Across People, Factories, Machines, and Products
Figure 2



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ENHANCED WORK ENVIRONMENTS

As forthcoming cyber-physical systems further automate machine-related work, will factories of the future be as empty of humans as offices are now empty of paper?

While manufacturers must have the flexibility to respond quickly to increasingly rapid fluctuations in demand, constantly laying off employees and rehiring them can be costly. Leading companies will gain competitive advantages by replacing rigid work patterns with flexible workforce deployment.

As machines become smarter, production lines can be enriched and humanized. As simple manual tasks disappear and customized production becomes the norm, workers can be assigned as needed to coordinate automated production processes and intervene when machines call for action. They will have new demands in managing complexity, problem solving, and self-organization. This might involve, for example, robots helping with manual work or augmented reality that provides the right information at the right time.

Looking at augmented reality, context-sensitive glasses and 3D visualization can help workers fulfill their tasks without long training sessions. Technicians can get visual instructions and historical data from machines during maintenance and repair. Engineers can easily access large amounts of data on their mobile devices and identify machine weaknesses on the spot. These and other technologies will also enable an aging expert workforce to collaborate closely with a younger tech-savvy generation.

In each of these scenarios, technology provides flexibility. Workers will be assigned where help is needed. This will place higher demands on them in terms of managing complexity, problem solving, and self-organization. The nature of work will change.

Companies have 19.7% higher adherence to production plans when customer delivery dates are integrated with material availability and real-time manufacturing conditions.

Source: SAP Performance Benchmarking

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TECHNOLOGICAL FOUNDATION
Two technologies support these five areas of opportunity: 1) cyber-physical systems that help to merge the real world with the digital world and 2) business software that integrates data for use along the product lifecycle.

Cyber-physical systems include all kinds of items, devices, and machinery that become smart and interactive through embedded software and connectivity. Using sensors and actors, they measure and control the physical world to improve top floor–shop floor integration.

Cyber-physical systems collect, store, and analyze sensor data through local business logic. They combine business logic with local and global communication capabilities to provide and use data and services. Eventually, machines will become autonomous service providers, evolving into coworkers on the shop floor.

Business software integrates information from all levels – including processes, product lifecycles, and resources – and orchestrates the processes. Integration of cyber-physical systems and business software will be required to deliver on the promise of Industry 4.0. We will see the convergence of information technology and operational technology.

Companies that track and analyze key performance indicators for standardized asset management at all of their facilities have 29% lower service and maintenance costs than companies that do not.

Source: SAP Performance Benchmarking

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Communication Brings Process Intelligence

THE PROMISE OF CYBER-PHYSICAL TECHNOLOGY

Cyber-physical systems – intelligent connectivity and communication between machines – will be one of the foundational and most powerful technological developments within Industry 4.0. The foundation of cyber-physical systems will be machine-to-machine (M2M) communication, which enables network-connected devices to exchange information and initiate actions without requiring intervention by or assistance from people.

Machines "talk" to each other in a language of their own, known as "telemetry." Telemetry helps remote machines and sensors collect and send data to a central point for analysis and action by humans, computers, or other machines. Machines have been moving in this direction for years, with internal computer processors and software telling them what to do based upon defined parameters and conditions.

The key components that make this possible already exist:

- Sensors that monitor machine performance, condition, and status
- Radio-frequency identification
- Wireless network connectivity
- High-performance computing software for interpreting data, making recommendations, or automatically taking action

Smart machines with these components are used in many common day-to-day applications – from remote monitoring of vending machine stock levels and automated control of home appliances to smart meters that optimize home energy use and automotive controls that optimize engine performance.

CYBER-PHYSICAL TECHNOLOGY AND THE FUTURE OF MANUFACTURING

The real value of cyber-physical technology is the integration and contextualization of data that connected devices bring to help manage and control a business process. M2M-enabled systems can link enterprise design, manufacturing, logistics, and service processes with events from the real world to enhance operational visibility, traceability, and accountability. It is a catalyst for more intelligent and automated operations and enables new business models for enterprises of all sizes.

M2M communication is, by design, a system of real-time connectivity and feedback that can collect and distribute valuable information throughout processes to an established network of people, partners, and customers. The speed of communication through this integrated network enables faster and more efficient reaction to changes in the operational conditions of production assets and compresses the cycle time for order delivery.

M2M communication can greatly enhance the work environment. Both machines and operators work more effectively throughout all stages of the manufacturing process. Manufacturers can be more efficient, responsive, and agile in meeting new market needs. A broad range of industries is increasingly deploying M2M-enabled business processes – from discrete and process manufacturing to service-oriented businesses such as transportation and logistics.

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BRINGING TANGIBLE VALUE THROUGH CYBER-PHYSICAL TECHNOLOGIES

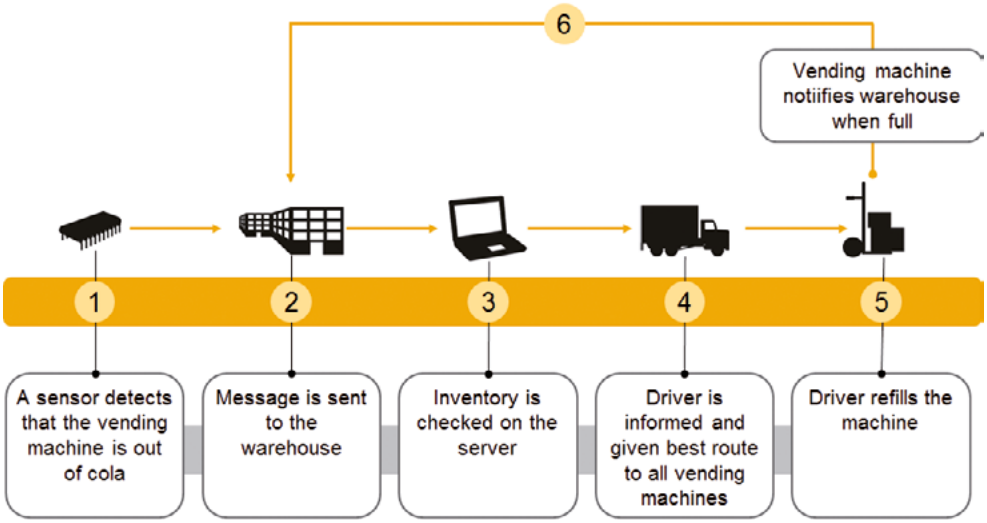
Some M2M applications are very sophisticated and extend across many processes with broad networked communications. Others are far simpler. All enhance efficiency and value. Let's look at a very simple example: a soft drink vending machine.

A basic challenge in managing a vending machine is the lack of insight into its inventory level or operating status without being physically in front of the machine. A driver on an inventory replenishment visit may find the machine is empty of all or the most popular products or that the unit is broken. In either case, the owner has lost days of revenue. The inventory transportation cost and time may have been completely wasted.

Figure 3 shows a "smart" vending machine that senses that it is running low on a specific soda. It sends an alert to the warehouse, inventory availability is validated, and a delivery work order is triggered automatically. Once the soft drink is delivered and the vending machine restocked, the machine closes the loop by notifying the warehouse that "all is well."

With this smart machine, owners can run their vending business more accurately and efficiently on replenishment and service. They will maximize their revenue and can even create new business models by offering real-time price changes on the machine wirelessly based on demand, loyalty, and promotions – a far more efficient and cost-effective process than discovery by physical inspection and, most importantly, the customer is satisfied.

A Smart Vending Machine
Figure 3



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Here are several other examples of applications in use today that are transforming operations for manufacturers:

- **Industrial automation and monitoring**
  The convergence of M2M-driven operational technology and traditional IT business networks are enabling automated factory equipment operation, more accurate analysis of asset utilization, connected process and inventory tracking, remote machine diagnostics, and predictive maintenance service requests to keep a plant running at peak performance levels.
- **Telemetry-controlled energy**
  Smart meters and sensors can be employed throughout a factory that send power-usage statistics to centralized monitoring environments where systems can then automatically divert power to where it is needed and lower consumption levels where and when it is not. Controls like this can significantly reduce plant operating costs and support business sustainability and environmental conservation goals.
- **Aftermarket services (AMS)**
  Original equipment manufacturers are embedding M2M data-collection sensors that monitor equipment utilization and provide operational status reporting so that customers can manage in-field machinery remotely. Information can be collected from the point-of-sale configuration, through production, and for historical in-field maintenance. Combining this information with real-time operational statistics provides a complete view of the asset and makes it possible to predict maintenance requirements that maximize uptime and reduce truck rolls by resolving issues remotely.

WHAT IS REQUIRED TO ENABLE M2M SOLUTIONS?

To maximize the value of M2M technology, manufacturers must invest in a technology foundation that goes beyond just connectivity.

Using SAP HANA® to Manage Big Data and Execute Analytics

The SAP HANA® platform was specifically designed to handle the high velocity and large volumes of data that can be generated from M2M-connected assets. SAP HANA provides the processing performance and algorithms to conduct powerful real-time analysis. This analysis provides the insights manufacturers need to act on the massive amount of data generated by the network of interconnected assets in an M2M environment.

SAP HANA has been used successfully in several M2M cases to provide business insights that were previously too slow or virtually impossible to calculate. It has enabled a real-time business environment for applications such as condition-based maintenance, predictive equipment failure analysis, and automated replenishment of consumables based on real-time production status and near-term product demand forecasts.

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Bringing Cloud Deployment to M2M Systems
Our investment in cloud computing environments and the addition of the Ariba business commerce network of trading partners are key reasons why customers prefer M2M solutions from SAP. The value added from Ariba, an SAP company, coupled with flexible deployment, helps align the total cost of ownership for an enterprise with the value it gains through process and resource optimization, increased revenue, or both. Using the Ariba® Network, businesses of all sizes are already connecting to buy, sell, and manage cash more efficiently. Network participants reach remarkable operational takeouts of 60% to 80% and a 66% decrease in approval times.

Workforce Mobility
SAP mobile solutions bring the power of M2M information to the point of work, wherever that may be. Manufacturing and service organizations are far more productive when connected by smartphones, tablets, iOS, and Android devices to M2M sensor data, process workflows, and business information. Whereas the power of Big Data lies in the analytics that drive business outcomes, the power of mobility lies in speed and real-time availability.

Enhancing the User Experience with 3D Visualization
As products and processes become more complex, a simplified user experience is needed for optimal productivity and efficiency. Enhancing this experience with animated 3D visualization can provide access to large amounts of data to anticipate problems, clarify the steps in a manufacturing or service process, and help users perform tasks more quickly and with higher quality by eliminating the language barrier of written instructions.

Putting All the Applications Together
For an enterprise to get maximum value from cyber-physical communication, the architecture needs to package software and services into an application platform that is simple to use and integrates all the required components. The solution must connect to and capture information from the relevant data sources, but also perform analysis and initiate real-time actions based upon this insight. SAP is committed to delivering the generic, cross-industry functionality that manufacturers require to develop, deploy, and run cyber-physical applications.

Best-in-class manufacturers are 40% more likely to use a consistent risk-based approach to the safety of employees, equipment, and the environment across global operations than competitors.

Source: SAP Performance Benchmarking

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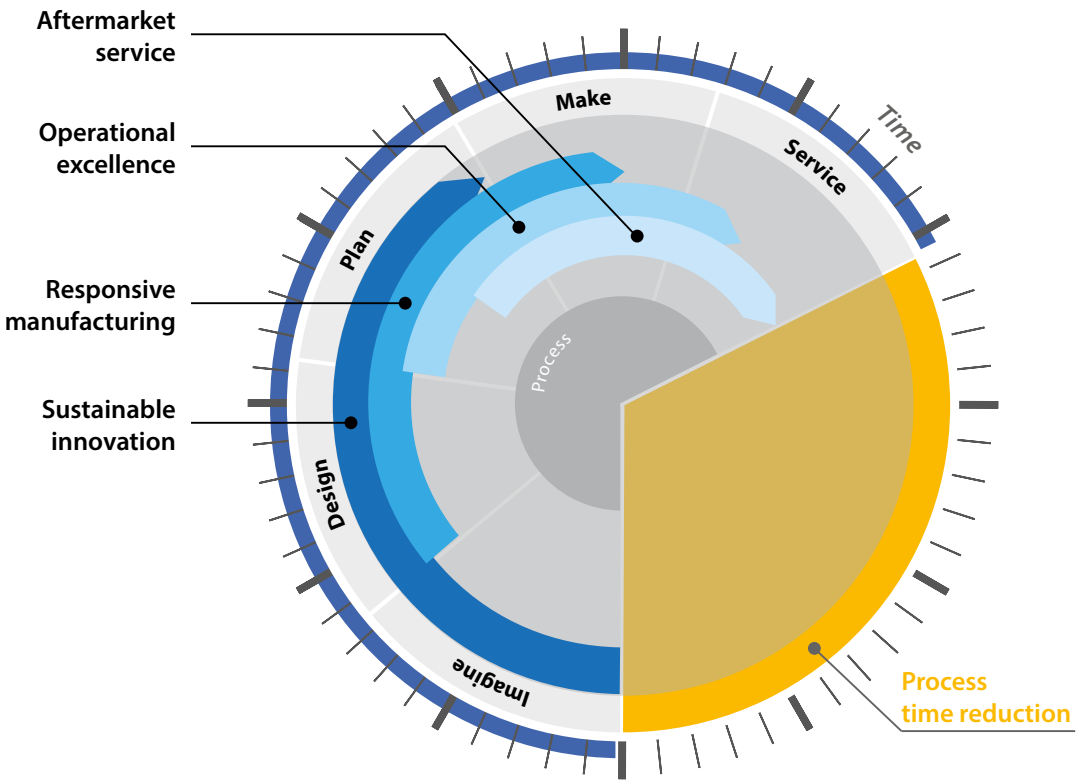
Idea to Performance: Seizing the Opportunities of Industry 4.0 Today

CREATING A HOLISTIC FRAMEWORK OF PROCESSES, IT PLATFORMS, AND SOFTWARE
To integrate the industrial value chain and product lifecycles, manufacturers must seamlessly integrate processes – from product design to supply chain management, production, aftermarket service, and training. These processes must align with the related technology platforms and solutions to create a holistic framework for Industry 4.0. SAP's efforts to address the idea-to-performance process encompass the following areas (see Figure 4):

- Sustainable innovation
- Responsive manufacturing
- Aftermarket service
- Operational excellence

Solutions that address the idea-to-performance process leverage SAP Business Suite applications as a foundation, extended by mobile, SAP HANA, and cloud capabilities. They also increasingly leverage 3D visualization and M2M connectivity.

Idea to Performance, Integrated Business Processes
Figure 4



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SUSTAINABLE INNOVATION: ACCELERATING PRODUCT AND SERVICE INTRODUCTION

As Industry 4.0 takes hold, companies must be able to rapidly innovate, launch new products, and meet evolving regulatory compliance and quality requirements. Sustainable innovation, a key part of the idea-to-performance process, emphasizes improvements for ideation, innovation, product design, and development – as well as the exchange of data with manufacturing, service, and other downstream activities.

As network connectivity increases dramatically, a massive data explosion will force manufacturers to optimize processes for new product introductions continuously, select information that provides real insight, and eliminate data and activities that add no value. Challenges that prevent these companies from reaching their full potential include organizational silos, heterogeneous IT landscapes, and product complexity.

Sustainable innovation is the front end of a holistic process view of a product's lifecycle. With a common, integrated platform and the tools and processes to run smarter, faster, and simpler, manufacturers can become more connected, greatly improve visibility, and achieve true innovation. The availability of accurate and complete product data for the total product lifecycle and across the complete value chain enables:

- Accelerated time to market
- Increased process efficiencies
- Lower cost
- Transparent compliance
- Reduced risk

Capabilities Needed for Sustainable Innovation

To enhance visibility and achieve their sustainable innovation goals, manufacturers must break down their silos, integrate their systems, and generate clear, up-to-date information. World-class organizations manage tightly integrated end-to-end processes to achieve:

HARLEY-DAVIDSON: AN EXAMPLE OF END-TO-END DIGITAL ENGINEERING

The digitalization of products – and even whole factories – sounds visionary. But real-world uses by companies like Harley-Davidson Inc. show how we are moving closer to end-to-end digital engineering. Motorcycles from Harley-Davidson are highly emotional products – a symbol of personal freedom and the American way of life. Every single bike is custom made.

Behind this customer centricity stands a state-of-the art manufacturing process that is highly flexible and efficient. At Showcase, a new plant at its U.S. location in York, Pennsylvania, Harley-Davidson can build 1,700 bike variations on one production line and ship a customized bike approximately every 90 seconds. Real-time monitoring of the production line helps plant managers detect problems before they occur. This permits real-time decision making – what Harley-Davidson executives simply call a "phenomenal experience."

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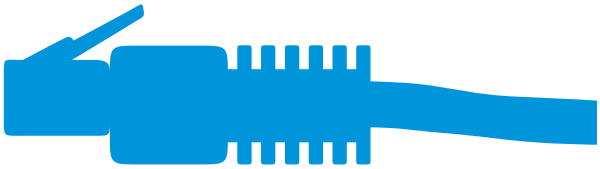
- **Continuous product innovation**
  Users must be able to view and analyze your company's product portfolio, define key performance indicators, score them in a transparent way, and include budget allocation in a project's planning stage. During execution, users must continuously update and monitor status, effort, timelines, budgets, and resource availability of projects using powerful and contextual analytics.
- **Integrated product development**
  You must be able to manage all product data related to development – including versioning, workflow approvals, change management, and 3D computer-aided design tools – in a single integrated environment. Synchronizing the engineering bill of materials and manufacturing bill of materials is an increasingly desirable trend, ensuring that your engineering and manufacturing departments use the same product data.
- **Embedded product compliance**
  By embedding compliance and sustainability requirements in the design process, you can streamline and automate product development, driving speed without risk.

Advanced Technologies for Sustainable Innovation

Technological advances are essential to a sustainable innovation platform. These include capabilities for collaboration, data management, and analytics.

Due to the size of complex product-related data and historic concerns about IP protection, solutions supporting sustainable innovation were not the first to embrace cloud technologies. Market-driven trends have seen this change over the last 18 months, as customers demand solutions that help them work collaboratively across a value chain of internal and external activities. A hybrid model is emerging with pockets of product data available in a controlled fashion. SAP offerings in this space include the SAP EHS Regulatory Content packages, the SAP EHS Regulatory Documentation OnDemand service, and the SAP Product Stewardship Network.



Machine-to-machine communication lets network-connected devices exchange information and initiate actions with no intervention by or assistance from people.

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RESPONSIVE MANUFACTURING: DRIVING CONTINUOUS IMPROVEMENT

Consumer demand for innovation, shorter product lifecycles, a scarcity of raw materials, and changing regulations are driving Industry 4.0 by connecting devices, machines, and processes. Increased margin pressures have driven companies to find ways to lower material, manufacturing, and support costs while improving the efficiency of manufacturing and delivery processes. They must also find ways to address changes in demand quickly and efficiently – before the tides shift again.

The global nature of manufacturing also introduces several challenges. Companies must be certain that all of their manufacturing locations – including those for outsourced production – can adapt rapidly to change. Responsive manufacturing – which covers the design, plan, and make portions of the idea-to-performance process – enables innovation, quick reaction to market demand signals, lower total manufacturing costs, and operations that are consistent, high quality, and socially responsible.

Capabilities Needed for Responsive Manufacturing

In a competitive environment, successful companies can coordinate flexible, responsive manufacturing within the value chain. They can readily respond to changing market conditions, enable rapid innovation and efficient execution, ensure high quality, and achieve regulatory compliance. Responsive operations require tools and capabilities that support the following types of manufacturing:

- **Discrete manufacturing**
  This includes repetitive manufacturing (mass production in which high numbers of identical units are made in a continuous flow), make-to-order manufacturing (starting when an order is received), and engineer-to-order manufacturing (building more complex and regulated projects). Responsive manufacturing supports all of these scenarios.
- **Process manufacturing**
  For this type of manufacturing, associated with formulas and manufacturing recipes, manufacturers must optimize planning and use of raw material and resources. To ensure efficient manufacturing operations, they must provide predictable output by allocating operations to

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the most effectively producing plants. Operations in process manufacturing environments are managed against defined metrics that require real-time performance visibility. Assets are managed in coordination with production for effective resource management.

- **Outsourced manufacturing**
  Companies that outsource all or part of their manufacturing operations must manage their manufacturing networks successfully. This requires robust collaboration capabilities.

Advanced Technologies for Responsive Manufacturing

Planning decisions in manufacturing are often based on periodic material requirements planning runs and outdated information, with the inability to replan quickly if conditions change. Problems in material flow can remain undetected or are detected too late. With material requirements planning on SAP HANA, companies can run up to 50% faster. They gain business insight that has not been possible before, which helps them identify actual and potential issues more quickly. They can match demand and supply more efficiently to provide improved service to the customers.

AFTERMARKET SERVICE: DELIGHTING EMPOWERED CUSTOMERS

With customers more empowered than ever, continually exceeding their expectations can be difficult – from delivering service over multiple channels to building loyalty through proactive interaction. Today's customers expect great service, no matter where or how they interact with your company.

Best-run customer service organizations take steps to solve customer issues smartly and quickly, streamline service operations, increase service profitability, and make sense of Big Data. They arm service reps with an interactive, 360-degree view of customers, using data gathered from social media and the enterprise. With real-time collaboration tools, their reps can consistently deliver great service.

Companies that are leading in aftermarket service and using Industry 4.0 technologies have a distinct competitive edge. They impress their customers and build loyalty by solving problems as soon as possible. They have made their service processes efficient and effective by making the most of scarce resources. And they have transformed their service organizations from cost centers into profit-and-loss organizations.

SAP gives customer-service organizations the platform, support, and information they need to provide superior customer service while driving down costs.

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Capabilities Needed for Aftermarket Service
SAP gives customer-service organizations the platform, support, and information they need to provide superior customer service while driving down costs. A complete solution portfolio for aftermarket service consists of the following elements:

- **Multichannel customer service**
  Agent-assisted customer service helps agents resolve customer issues quickly. E-service capabilities enable self-service activities. Social customer service uses social media as a new communication channel.
- **Comprehensive service management**
  Field service management requires solutions for scheduling and assigning qualified resources and providing mobile access to the information they need to complete on-site services. Complaints, returns, and depot repair management is used to streamline and automate these processes. IT service management supports service processes by creating an IT infrastructure library.
- **Contract management and billing**
  Package and solution business helps you create predefined, consistent packages that contain products and complementary services. Tools for managing service contracts help you verify contracts and service-level agreements. Service controlling and accounting support includes solutions to help you bill services accurately and on time, track service revenue, gain insight into accurate cost information, and minimize invoicing delays.

Advanced Technologies for Aftermarket Service
New ways of working that were not possible just a few years ago can take your service organization to the next level of performance. They are made possible by technology innovations that have broken down barriers of time, distance, and communications that once blocked collaboration and results.

To perform high-quality service on-site and resolve issues on the first visit, field-service technicians need mobile apps that provide all the information they need independent of where they are. With the SAP CRM Service Manager mobile app, companies can equip their technicians with the latest mobile technology and boost efficiency in their field-service processes. It can help you successfully complete more jobs in a given time and reduce billing cycles.

Service analytics help companies monitor, control, and optimize their service business so that it becomes a relevant contributor to revenue and profitability. The SAP CRM Analytics rapid-deployment solution and SAP Predictive Analysis software give you the tools for analyzing service-related information and predicting future trends and issues. This support can help you make decisions that improve customer satisfaction and retention.

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OPERATIONAL EXCELLENCE: DRIVING CONTINUOUS IMPROVEMENT

Industry 4.0 intensifies the pressure to improve operational performance. Optimizing production assets, reducing costs, and preventing production interruptions are key to maximizing efficiency and gaining a sustainable competitive edge. The challenge is how to drive continuous improvement in the "big-ticket" areas that contribute to operational excellence – such as safety, asset reliability, and energy use.

Of course, smooth-running operations with continuous improvements require clear management standards and systems that define how work should be done. The other key ingredient is disciplined execution of those standards and systems – carrying out work processes the right way every time. Process breakdowns, missed hand-offs, and other management system failures are all too common in a typical business environment of fragmented processes and information silos.

Companies that successfully execute operational excellence initiatives have much to gain. A systematic improvement approach enabled by a unified information technology platform results in safer, more reliable operations with increased productivity and agility. Risk and costs are reduced, regulatory compliance is improved, and you can better focus on growing your business with confidence.

Capabilities Needed for Operational Excellence

Effectively implementing a culture of operational excellence requires the right combination of people, processes, and enabling technology. SAP has worked side by side with market leaders in the manufacturing, energy, and resource industries for more than 40 years to deliver solutions that meet this goal. We have seen that high-performing organizations drive improvement with best-in-class capabilities in the areas that are tightly integrated with core business operations:

- **Asset visibility and performance**
  You can optimize your asset management strategy by monitoring key performance indicators related to equipment and system health – such as reductions in unplanned downtime, increased utilization, and lower operating costs.
- **Asset operations and maintenance**
  Assuring uptime, ensuring safety, mitigating risks, and reducing maintenance costs help reduce downtime, improve your return on assets, and eliminate wasted time and resources.
- **Environment, health, and safety management**
  Proactive operational risk management can help to ensure safe operations and prevent the risk of operational failures, incidents, and unplanned downtime.
- **Energy and environmental resource management**
  Optimized energy spend and improved environmental performance can enhance profitability.
- **Quality management and compliance**
  Enterprise-wide, closed-loop processes for quality management can prevent deviations, enable continuous process improvement, and sustain quality control and compliance. They can also help you drive down operating costs, improve product quality, and meet customer and stakeholder expectations.

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Advanced Capabilities for Operational Excellence
Operational excellence requires processes and collaboration that span organizational and geographic boundaries, enabled by the right technology infrastructure. Integrated business software solutions from SAP in the areas of asset management; environment, health, and safety; quality; and energy work together to connect and automate formerly disjointed work processes. They provide real-time visibility into information that helps you quickly identify exceptions and trends and make better, faster decisions to improve operations.

Production and maintenance operations are where the rubber meets the road – where products are made, equipment is kept in service, and upsets are dealt with. Execution excellence requires that everyone, from the shop floor to the top floor, have access to the right information. Mobile apps such as SAP EHS Safety Issue, SAP Work Manager, SAP Rounds Manager, and SAP ERP Quality Issue can help your employees handle critical tasks and make smart decisions in real time. Their work gets done correctly and safely – the first time.

There is a 17% higher return on assets where asset management systems are fully integrated, with inventory management, MRO, purchasing, engineering, and finance.

Source: SAP Performance Benchmarking

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Conclusion

YOUR PATH TO INDUSTRY 4.0
Industry 4.0 is a confluence of new pressures, opportunities, and technologies. It will restructure production – redefining not only manufacturing processes but also redefining what a product is. It will change global competitiveness – for companies, industries, and (as production becomes local) nations – with increased colocation of design, manufacturing, and servicing.

Of course, this transformation will not be linear or predictable. It involves innovation on many dimensions simultaneously. For full delivery of new scenarios, we will need standards that enable trusted exchange of data, enhanced education programs generating a mathematics- and science-savvy workforce, and structured government incentives. This will require unique government, university, and private enterprise partnerships – such as acatech, The National Academy of Science and Engineering, in Germany and the Advanced Manufacturing National Program Office in the United States.

But make no mistake – Industry 4.0 is taking off and will accelerate. The successful companies of the future are creating new products and services today. They are transforming their businesses with new processes that fulfill the idea-to-performance approach. They are upgrading their technology infrastructure – with Big Data, mobile, cloud, analytics, and applications – to gain the future flexibility they will need to thrive.

We recommend the following to position yourself and generate value for your business. It is a summary of a methodology developed by our value engineering and value architecture teams:

- **Create ideas for new business scenarios**
  Design thinking workshops that help drive innovation momentum
- **Decide which topics are most strategic**
  Evaluate your ideas according to dimensions such as value generation or consumption of resources and environmental expectations
- **Build a road map**
  Develop an appropriate sequence of activities that help you build new processes on top of more fundamental components and services

LEARN MORE
To learn more about the idea-to-performance process and how it can help your company, visit www54.sap.com/solution/lob/r-and-d/software/idea-performance/index.html.

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