# Cognitive Manufacturing:

## An Overview and Four Applications that are Transforming Manufacturing Today

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# Introduction

Manufacturing is undergoing a dramatic transformation as companies instrument their factory equipment with network-connected sensors and employ sophisticated data analytics to better understand and optimize production. The techniques offer new opportunities to improve key business performance metrics, derive new value from manufacturing data, improve product quality, and enhance the way information and knowledge are managed in an organization.

Manufacturers have always been keen to improve the business of production, but as companies employ these new data-driven techniques they are faced with a new challenge: how to find and respond to actionable insights in their manufacturing information. Conventional computing can't scale with the large influx of data or the complexity of the analytics, which limits the data's applicability and benefits.

Cognitive manufacturing—also known as smart manufacturing or Industry 4.0—offers new opportunities to harness manufacturing data so companies can realize their modernization objectives. Cognitive manufacturing uses cognitive computing techniques along with Industrial IoT (IIoT) applications and advanced analytics to evaluate data in real time from multiple systems, equipment, and processes. It then automates or guides manufacturing accordingly. Companies that use cognitive manufacturing technologies can discover previously unknown issues or problems in their manufacturing processes to improve the life cycle of a product, from design through manufacturing to after-market support.

This paper explains the importance of cognitive manufacturing while highlighting four fundamental manufacturing applications: asset performance management, process and quality improvement, resource optimization, and supply chain optimization. The paper also describes a technical architecture for cognitive manufacturing and suggests steps companies can take to begin developing strategies for implementation.

# Cognitive Manufacturing: What It Is and Why It Matters

Cognitive manufacturing leverages cognitive computing, the Industrial IoT, and advanced analytics to digitize, understand and optimize manufacturing processes in ways that were not previously possible.

Cognitive manufacturing is powerful because it combines sensor-based information with machine learning and other artificial intelligence capabilities to find patterns in structured and unstructured data from plant, enterprise and industry systems. It pulls relevant information together in real time and applies analytics to yield unprecedented levels of understanding and insights about the manufacturing process. It automates responses based on its findings and delivers actionable information as well as continuously updated knowledge to decision makers in the manufacturing setting.

These sophisticated capabilities are possible today because technologies facilitating the IoT and data analytics engines are mature and can be implemented at scale, thanks to pervasive connectivity and reduced costs for chipsets, sensors, cloud computing, and storage. The capabilities are also necessary if companies expect to take advantage of the skyrocketing volumes of data their IoT applications are generating, from the data collected by sensors to unstructured data contained in text files, correspondence, videos, audio and other sources.

Cognitive technologies can find meaning in this data in ways that, until now, only the human brain could comprehend. This level of understanding will be considered essential for success in the modern manufacturing era as heightened competitiveness and cost sensitivities demand new levels of agility, responsiveness and innovation from manufacturers.

Cognitive technologies look deeply into a manufacturing process and business environment to derive information that has tangible value for a manufacturer.

# Key Issues Cognitive Technologies Address for Manufacturers

Manufacturers can use cognitive technologies to solve fundamental business challenges, find new value in their manufacturing data, improve quality and enhance knowledge management in their organizations.

**Solving business challenges:** Cognitive manufacturing helps organizations improve fundamental business metrics, such as productivity, product reliability, quality, safety and yield, while reducing downtime and lowering costs. Applications can be easy to use and generate immediate benefits. For example, a field technician sent to repair a machine can simply submit symptoms into a cognitive engine that will then analyze the symptoms and suggest a set of repair options ranked in order of probability of success. The approach improves the first-time fix rate, which improves productivity and reduces costs.

**Creating new value from manufacturing data:** Cognitive technologies look deeply into a manufacturing process and business environment to derive information that has tangible value for a manufacturer. The process considers new data sources as well as unstructured data and applies advanced analytical models to find significant relationships that weren't revealed in the data before.

By using cognitive technologies, predictive maintenance activities—previously reliant on historical data—can be enriched with information found in technician logs, maintenance records, emails and other sources. Product inspections can be performed by cognitive visual inspection systems that learn from pictures of manufactured products to identify defects and determine if the defects are tied to quality issues. Companies that use these types of techniques can improve plant operations and performance and reduce costs as well.

**Improving product quality:** Successful manufacturers are always striving to build the best-quality products. In a recent survey of electronics manufacturers, for example, IBM found that two-thirds (66%) of company executives consider minimizing defects and achieving a higher rate of accuracy in production to be key performance indicators for their facilities.

Cognitive manufacturing enables companies to put a laser-like focus on quality throughout the life cycle of a product's development—from design through manufacturing and even after distribution when companies must ensure product quality through warranty and support programs. The approach improves yield, reduces overall warranty costs, and helps ensure customer satisfaction for the lifetime of a product.

**Enhancing knowledge management:** Cognitive manufacturing is all about exploiting data from diverse sources—not only equipment sensors, but also logs, manuals, employee biometric monitors or the environment. The approach incorporates these types of sources and data into the analytical process to create a knowledgeable system that is continuously learning. It is able to make insightful operational recommendations based on a comprehensive understanding of manufacturing conditions.

# Four Compelling Applications for Cognitive Manufacturing

Four cognitive manufacturing applications are providing compelling benefits to manufacturers. The applications, featured here, include asset performance management, process and quality improvement, resource optimization and supply chain optimization.

**Asset Performance Management—** *Improving reliability and performance of equipment and assets through better visibility, predictability and operations*

Manufacturers can employ cognitive asset performance management (APM) systems to improve the reliability and performance of their plant equipment while reducing costs.

Cognitive APM is used to sense, diagnose, and communicate performance issues to reduce unnecessary downtime. It incorporates techniques used for traditional predictive maintenance—which are largely based on historical data—as well as holistic techniques that determine overall equipment effectiveness (OEE) of a component as part of a larger manufacturing function in the facility.

Cognitive APM goes beyond these practices. It not only anticipates a potential failure, it looks into information from relevant user manuals or technicians' logs to understand how teams have fixed similar issues before. It uses this information to recommend specific actions or solutions to remedy the impending problem.

The benefits can be significant: In one application, an automotive manufacturer employed cognitive technologies to predict machine failures and provide early warning of equipment issues so teams can perform predictive maintenance before the equipment fails. The application has reduced the plant's downtime by 34%. In another automotive application of cognitive technologies, a manufacturer has reduced plant and equipment maintenance costs by about 10%.

Cognitive manufacturing enables companies to put a laser-like focus on quality throughout the life cycle of a product's development—from design through production and warranty support.

## Process and Quality Improvement—*Optimizing yield and productivity of manufacturing operations, from design through warranty support*

Quality is not strictly the condition of an end product: It is a representation of the entire manufacturing process and the range of variables that influence the product's development throughout the manufacturing life cycle. Manufacturers can use cognitive manufacturing tools to closely monitor and understand the many operational attributes that influence product quality to ensure that all products shipped to market meet their companies' quality requirements. The benefits include improved productivity and yield from design through production and warranty support.

Manufacturers across the industrial sector have used cognitive process and quality improvement techniques. The benefits include significantly increased revenues due to higher quality manufactured products; savings from lower repair and warranty costs; reduced quality control labor costs; as well as increased system uptime. The benefits can be substantial: A European automobile manufacturer, for example, achieved a 25% improvement in productivity by using predictive models to identify specific parts of a production line that needed adjustment. In another application, an electronics manufacturer projects that use of cognitive technologies will lower its quality control labor costs by 5 to 20%.

The cognitive approach is effective because it uses analytics, algorithms, automated visual inspections and machine learning to identify potential quality problems earlier and more definitively than conventional techniques such as statistical process control (SPC) or manual inspections. Cognitive technologies can find subtle problems that might normally go undetected to deliver detailed, accurate and timely insights, including real-time alerts.

Cognitive technologies can also help manufacturers monitor and interpret the condition of products after distribution to the market. The approach can monitor variations in product wear and replacement rates and consider warranty terms and recall notices, among other unstructured data sources. It can use this information to identify early warning signals of accelerated wear and replacement for a part, with minimal false alarms.

## Resource Optimization—*Improving safety of workers and optimizing energy efficiency and facility productivity while reducing costs*

Cognitive technologies offer manufacturers vital opportunities to make the best use of their resources. Key use cases include ensuring worker safety and health, optimizing energy efficiency of manufacturing processes and facilities, and improving factory floor scheduling.

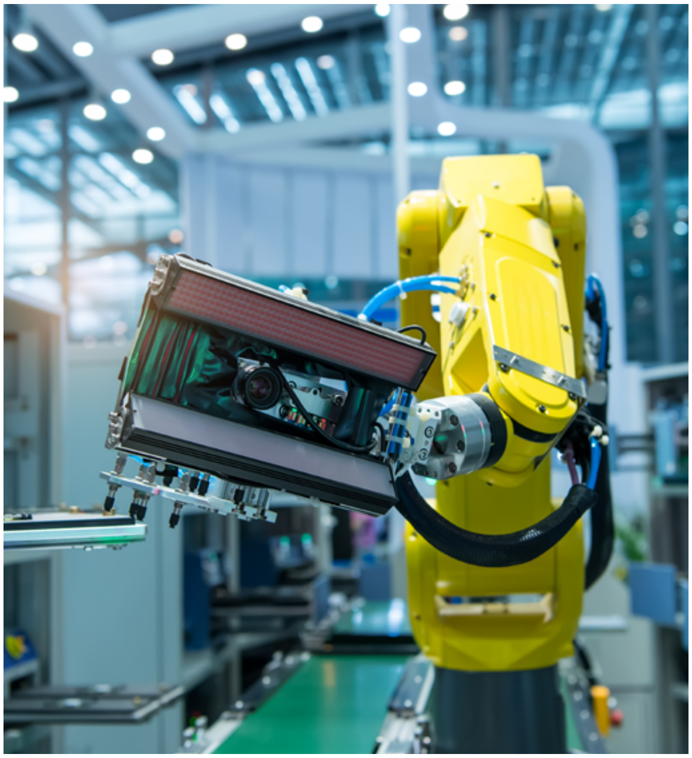
**Worker safety:** Equipping workers with sensors that help ensure their safety in the manufacturing environment is a compelling application for cognitive technologies. The wearable sensors continually monitor the workers' health and stamina and their exposure to environmental or physical hazards. Cognitive technologies integrate data from the sensors and other relevant external environmental sources to immediately

| Applications for Cognitive Manufacturing | | | | |
|---|---|---|---|---|
| | **Asset Performance Management** | **Process and Quality Improvement** | **Resource Optimization** | **Supply Chain Optimization** |
| **Business Metric** | Reduced downtime, reduced costs | Improved yield, productivity, uptime, and revenues, with reduced costs | Improved safety, reduced costs, better asset utilization | Improved on-time delivery, reduced inventory costs and fewer out-of-stock events |
| **Value** | • 34% reduction in equipment downtime for an auto manufacturer<br>• 10% decrease in equipment maintenance costs for an auto manufacturer | • 25% productivity improvement for a European auto manufacturer<br>• 5-20% reduction in quality control labor costs projected by an electronics manufacturer | • 10% improvement in hazard safety compliance for an industrial products manufacturer<br>• 10% in energy consumption savings for a cement plant<br>• 15% reduction in cycle time for a semiconductor manufacturer | • 10% reduction in global supply chain costs for an automotive OEM<br>• >20% improvement in inventory reductions for an automotive OEM and for an industrial products manufacturer |

identify problematic situations that might compromise the employees' health. The technology alerts the worker or supervisor of any issues that need an immediate response.

Improving worker safety helps ensure the health of the workforce and manage the workforce better. It also helps improve operations, facilitates compliance with safety guidelines and regulations, and demonstrates compliance. One industrial products manufacturer, which used cognitive technologies to enable worker fatigue alerts and proximity monitoring, improved its ability to detect hazardous environments and reduce worker exposure to hazards. The applications improved the company's associated safety compliance metrics by 10%.

**Energy resource optimization:** Companies can use IoT along with data analytics, machine learning and other cognitive techniques to evaluate the many complex and highly variable factors that contribute to energy consumption in their manufacturing plants. Solutions can generate detailed energy profiles of processes or buildings to identify energy inefficiencies and energy waste so companies can discover precisely how to reduce energy consumption and



costs. Improved use of energy resources not only helps companies reduce operating costs, it contributes to a company's green objectives. In one application, a cement plant used advanced machine learning algorithms to predict energy consumption behavior and optimize its process based on the predictions. The applications reduced energy consumption by 10%.

**Optimizing factory floor planning and scheduling:** Optimizing the planning and scheduling of factory floor operations is a worthwhile application for cognitive technologies because planning and scheduling efforts are often hampered by staffing or budget limitations, the inability of existing processes to handle large volumes of data, and the complexity of the manufacturing or design process, among other constraints.

Yet companies have multiple business objectives to optimize planning and scheduling, including needs to shorten time-to-market; reduce costs; and improve throughput, productivity, profits and other key performance indicators (KPIs). Companies can use cognitive techniques to perform what-if analyses of planning or scheduling options and apply the findings to adjust operations accordingly.

In one application, for example, an automotive manufacturer employed cognitive technologies to optimize the configuration of its production line to balance the workload between stations, use labor more efficiently, and increase the rate of production while also adhering to its design for manufacturing (DFM) practices. The application enabled the manufacturer to reduce operating costs and capital investments by about 10%.  In another application, an automobile manufacturer used cognitive planning tools to optimize its use of available plant capacity to bring a new model of cars into production. The application enabled the manufacturer to reduce operating costs and capital investments by about 10%. In yet another application, a semiconductor manufacturer was able to reduce cycle time by 15% by reducing equipment idle wait times, thus increasing throughput and asset utilization.

**Supply Chain Optimization—***Improving visibility and insights to build a dynamic supply chain that accelerates innovation*

Comprehensive understanding of the supply chain is mission-critical in the manufacturing industry. Yet most organizations lack the ability to make sense of the overwhelming amount of supply chain data that is scattered across different processes, sources and systems. Further, companies don't have the network visibility to follow critical links in their global supply chain processes or the predictive capability to effectively anticipate and prevent disruptions or imbalances in their inventories.

Cognitive supply chain approaches can pull together data from a wide variety of structured and unstructured data sources so manufacturers can minimize supply chain costs, disruptions and risks. For example, when cognitive technologies were used by an automotive OEM to determine the appropriate flow of a product through the supply chain, transportation, production and storage, the company reduced its global supply chain costs by about 10%. Reduced inventories are another benefit of cognitive supply chains: To give two examples, an automotive OEM and an industrial products manufacturer each reduced their service parts and spare parts inventories, respectively, by more than 20%.

Some of the features offered by these tools include the ability to monitor component volumes and pricing details for suppliers, the financial health of each supplier, business or political conflicts, regulatory changes, adverse weather, epidemics, consumer sentiment and labor strikes. An application can send out alerts and characterize the threat or disruption, present the information in graphically rich visualization tools for decision makers, search for alternative suppliers, and recommend solutions to work around the problem. If the cognitive engine discovers a defect in equipment used in the manufacturing line, the software will immediately recommend pulling the defective part from the line and order a replacement part.

# Technology Architecture for Cognitive Manufacturing

Cognitive manufacturing uses a framework of technologies that work together to help companies transform and optimize production. The technology stack includes device, IoT platform and application layers as well as industry context specific to the applications.

**Device layer:** Devices include the sensors, gateways or programmable logic controllers (PLCs) that provide information about manufacturing assets—from engines to turbines to process equipment or robots. A participating ecosystem of partners contributes software programs and updates when devices or equipment are added, replaced or upgraded.

**IoT platform layer:** The IoT platform provides connectivity to the devices, transmits data to or from the devices, and pushes or streams information from the devices to the application layer for analysis and computation. An open platform is essential to accommodate data from all of the types of equipment monitored and to encourage collaboration from relevant vendors. The platform should be scalable and comprehensive to accommodate all the data it must receive and transmit.

**Application layer:** The application layer evaluates equipment status and operational data and uses advanced analytics, machine learning and other cognitive capabilities to predict device performance issues and provide early warnings. The application layer can find non-obvious patterns in device data and harvest insights from documents, manuals, correspondence and partners' information, including visual and audio material. Data analytics can be performed at the edge of the system to help expedite analyses and delivery of results to decision makers.

**Industry solutions layer:** The industry solutions layer adds domain expertise to the application layer. The context can include industry-specific analytical models, advanced cognitive capabilities tied to industry-specific use cases, or cognitive visual inspection technologies that are tailored to the manufacturing process.

## How to Get Started

Companies must have defined strategies to get the most value from their cognitive manufacturing implementations. A well-crafted strategy will establish the business case and long-term vision for the implementation, delineate the manufacturing processes targeted for implementation in priority order, identify technologies and skill sets needed for the project and secure executive support for the effort.

To get started,

- Identify your pain points. For example, perhaps the most costly equipment in your factory has a high rate of downtime, undermining its value in your plant. By identifying this as a need, you can craft your project to focus on increasing the component's performance and utilization.
- Find your best data resources. Some areas of your business will have better data than others. Look for those that have sufficient or extensive information and will address your specific business need, because these will yield value faster than areas of your plant that have limited data.
- Consider the impact cognitive manufacturing will have on your business processes and prepare for these while your cognitive manufacturing deployment is under way. By proceeding with each concurrently, each effort can inform the other.
- Recognize that cognitive manufacturing is an evolutionary process. Establish a timeframe to review, update and improve the strategy during the first months and reevaluate it periodically in the future.

## Cognitive Manufacturing and IBM's Role

IBM offers a suite of cognitive manufacturing solutions as part of IBM Watson IoT.

The foundation of these cognitive manufacturing solutions, IBM Watson IoT for Manufacturing, combines the power of analytics and cognitive technologies to help manufacturers improve asset performance management, plant process and product quality, resource optimization and supply chain management.

IBM Watson IoT for Manufacturing is integrated with the IBM Watson IoT platform as well as IBM's Maximo Asset Management software. The solution for cognitive supply chain optimization includes IBM's ILOG planning and scheduling tools and relevant data sources needed for supply chain management, such as weather data from The Weather Company.

For more information about IBM's Watson IoT solutions for cognitive manufacturers, visit https://www.ibm.com/internet-of-things/iot-solutions/iot-manufacturing/. To learn more about IBM's insights and solutions for the industrial market, visit http://www-935.ibm.com/industries/manufacturing/.

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