

Why cognitive manufacturing matters in electronics

Activating the next generation of production success

IBM Institute for Business Value

Executive Report

Electronics

How IBM can help

IBM has a unique position in the marketplace, with cognitive platforms and services, industry-specific offerings and expert consulting to support electronics companies. We engage clients in identifying cognitive manufacturing entry points that move beyond cost cutting to transforming production with capabilities that include:

- Business and technology strategy consulting services to define a client's cognitive manufacturing strategy and use cases to deliver business value through technology
- Watson accelerators and services that allow quick starts to key cognitive manufacturing use cases in visual inspection and quality, maintenance and plant-level IoT
- A best-in-class platform for enterprise search for trend-spotting and deep discovery
- Consulting, design, and implementation approaches that support new interaction and business models that make cognitive manufacturing more affordable and extensible.

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Hyper-complex production meets cognitive computing

Electronics manufacturing is surrounded by continuous complexity. Executives face rising resource costs in traditionally low-cost production markets. They must address increasing customization, shorter lead times, frequently changing requirements and shrinking order sizes – all while managing a sophisticated supply network. They need to examine automation potential and maintain critical institutional knowledge. Thinner margins and increased competition threaten consistent quality, risk greater downtime and reduce desired flexibility. Investments in new equipment and automation systems are increasing the amount of data available from the shop floor, but most is not used to its full potential. Now, cognitive manufacturing is transforming production to address such complexity. These new systems address manufacturing issues, integrating cyber and physical systems for optimal output and interpreting data for value identification and realization.

Executive summary

To understand how the electronics industry is applying cognitive computing to manufacturing, the IBM Institute for Business Value surveyed 140 electronics executives around the world and across all industry subsectors. We found that a core group of early adopters has kicked off a new generation of production success with cognitive manufacturing and show greater returns on investment (ROI) with increased productivity. Our analysis answers some important questions.

Who is ready for cognitive manufacturing? Those who have a good understanding of advanced analytics and the Industrial Internet of Things (IIoT) are prepared to embrace cognitive manufacturing more quickly than others.

What defines cognitive manufacturing maturity? Our study found three stages of cognitive manufacturing maturity. We call those organizations in the earliest stage Observers, followed by Starters and Actives, respectively. These groups differ on two key characteristics: the presence of an overall strategy for cognitive manufacturing, and degree of strategic execution of multiple projects that enable higher project success and significantly fewer failed projects. Strategy is the crucial enabler of higher maturity.

How do manufacturers get beyond the obstacles and barriers to increase cognitive manufacturing maturity? The obstacles encountered by our respondents are tied to organizational maturity. Overcoming them is fundamental to increase cognitive manufacturing success.

In this report, we'll first describe cognitive computing and how it gives rise to cognitive manufacturing. Then, we'll review specific study findings and recommend actions for electronics executives.



34% of surveyed electronics manufacturers were most advanced in cognitive manufacturing and consistently delivered high ROI projects



57% of respondents were not satisfied with their ability to rapidly reconfigure production lines



More than 70% of respondents had Industrial Internet of Things efforts underway, a first step in cognitive manufacturing

The current state of electronics manufacturing: Complex

It's been said that we are at the rise of a second machine age. While the first machine age drove industrialization, this one uses digitization and the ability of machines to access and put those digital assets to work. It makes machines, and the humans who work with them, smarter. The birth of "cyber-physical" systems combined advanced manufacturing technologies and advanced computing technologies to work together seamlessly. These new systems can exchange information, improve uptime and provide support to each other and their users.

This new approach to manufacturing is mission-critical for electronics as seismic shifts occur on multiple fronts. Consider these trends:

- Multiple electronics manufacturing locales are encountering aging workers and worker shortages
- Most economies are seeing a rise in worker wages and difficulty in filling what once were highly desirable manufacturing jobs
- Billions of sensors collect data from machines, but electronics organizations often cannot access it – let alone make sense of it – for manufacturing purposes
- Users want more functionality and personalization in the electronics produced.
- The downside cost of failure to deliver key metrics is increasing, placing a higher premium on quality, flexibility and throughput (see Figure 1).

Electronics manufacturing, long considered the most complex in the world, will continue to evolve to meet worldwide demand. Meanwhile, the industry must maintain a very global supply chain, full of bespoke and mission-critical parts, sourced from around the world. Plants will still need to coordinate in real time, sharing forecasts, expertise and outcomes. Regulatory pressure, affecting products and the production process itself, is forecast to increase and become more localized.

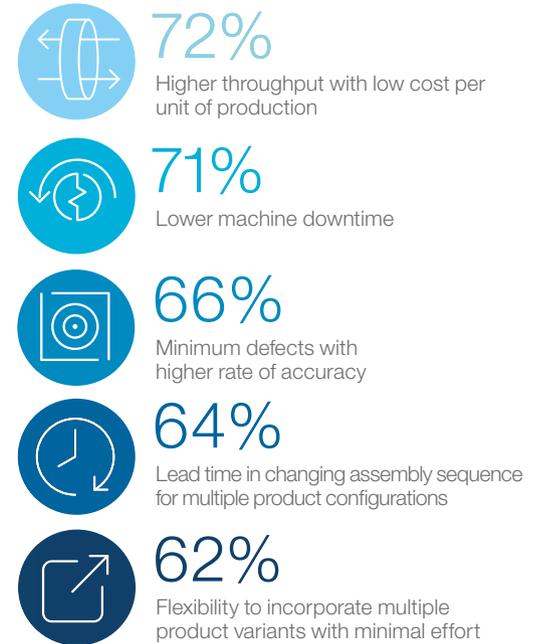
To address the rising complexity, many electronics manufacturers turned increasingly to technology, primarily analytics and robotics automation. However, those solutions only go so far in the second machine age. What's really needed is a new way to think about the problem, an approach that unites data and harnesses its value to transform production.

That approach is cognitive manufacturing.

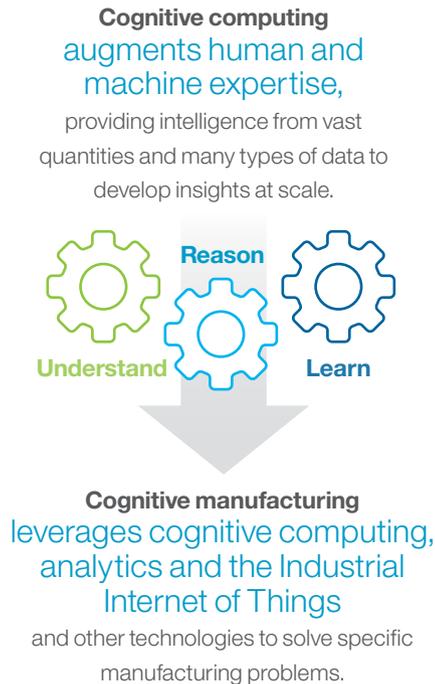
Figure 1

Critical manufacturing key performance indicators (KPIs)

How important are these performance indicators for your production plant?



Source: Percent of respondents who said this KPI was important or very important. n=140.

Figure 2*From cognitive computing to cognitive manufacturing**Source: IBM Institute for Business Value analysis.*

The next generation of electronics manufacturing

Cognitive computing creates a “human and machine” partnership to understand, reason and learn (see Figure 2). It helps make sense of the massive amounts of data manufacturing creates. Yet, it goes further – making it easier to find the answers to complex operational questions, delivering disruption while it drives increased innovation. It can amplify the benefits of analytics and automation with greater flexibility and speed.

The digitization of production is the main reason cognitive computing can change manufacturing. To deliver the world’s demand for small and large electronics, production was managed for decades on spreadsheets, in native applications and in the heads of engineers, production leaders and technicians who kept machines humming along. As more digitized data became available, cognitive systems could access and combine it for insight generation. As sensors and measurement systems started streaming data, the desire to use it to make better decisions came to light.

Because cognitive computing can combine newly digitized data points, it discovers patterns and answers questions across the plant by including streaming data from equipment, locations and sensors. Cognitive manufacturing harnesses natural language and sensory-based capabilities in ways that traditional analytics, prevalent in manufacturing, could not. It amplifies investments in current production technologies, such as the IIoT, analytics, mobility, collaboration and robotics to provide tangible benefits at the plant level.

Cognitive approaches to maintenance offer potential solutions to the more than 50 percent of respondents who reported challenges related to unplanned machine downtime. Additionally, cognitive approaches can help speed time and drive flexible automation for the 40 percent of respondents who were challenged in configuring machines quickly to increase flexibility.

When asked “How successful are your manufacturing plant operations?” only two-thirds said that said they were very or quite successful. Over 40 percent reported challenges in maintaining their desired rates of production. More than half were challenged to create desired levels collaboration across their manufacturing operations. Fifty-seven percent achieved less than their desired success at rapidly reconfiguring production lines – critical to moving toward a low volume, high mix – and more profitable future.

With complexity rising in electronics, these pressures seem likely to intensify if they remain unchecked.

Identifying the cognitively capable

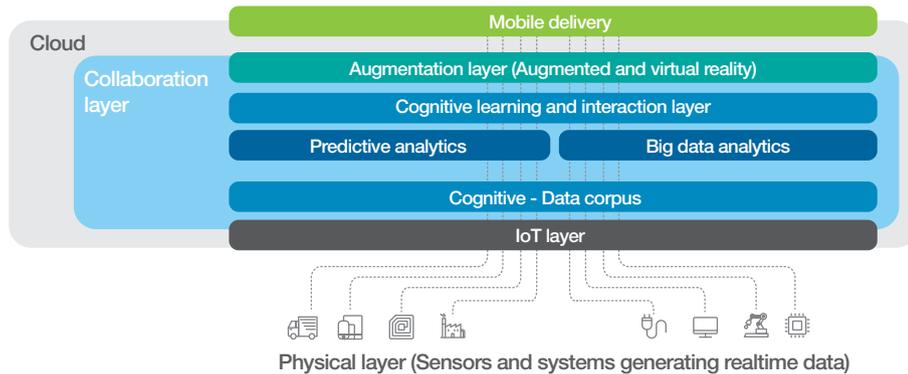
As valuable as cognitive manufacturing can be, adoption of cognitive computing is nascent: only 7 percent of study respondents are in broad rollout across the industry. While that might seem low, electronics is an early adopter of this new capability – nearly double that of other industries, with another 50 percent of respondents reporting limited rollouts and pilots. In fact, 65 percent are ready for cognitive.

To be cognitively capable, an organization needs to actively use advanced analytics. This might include predictive analytics or big data approaches. A majority of respondents were actively pursuing these areas – over three-quarters were piloting or in stages of rollout. More than 70 percent of respondents also had IIoT efforts underway.

Yet, analytics and IIoT are not the only technologies supporting automation and cognitive manufacturing transformation. Multiple technologies participate across an evolved infrastructure designed for more informed electronics production. This infrastructure is cyber-physical, meaning it combines physical and virtual layers with bi-directional flows that allow machines and humans to work together more seamlessly (see Figure 3).

Figure 3

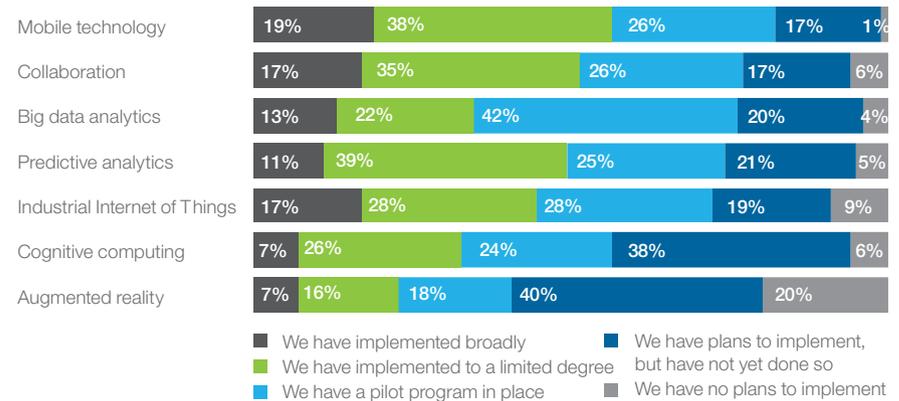
Data technology and users unite in a “cyber-physical environment” that enables cognitive manufacturing



Source: IBM Institute for Business Value analysis.

Our research examined *seven technologies that work together with a cloud platform* to create a cognitive manufacturing environment (see Figure 4). Given the potential for these technologies, it's not surprising many electronics producers are actively placing bets on them. However, respondents have met varying degrees of success.

Figure 4
Adoption of technologies in the cognitive manufacturing stack



Source: Survey question: "To what extent has your organization implemented these technologies?" n=101.

Of the eight technologies we studied, all respondents were in the process of implementing, or had already implemented cloud computing, which is the basis for cognitive manufacturing. Eighty-three percent of respondents have at least a pilot program for *mobile technology* in place; of that group, 19 percent have implemented it broadly. Close behind is *collaboration*, with 78 percent of respondents having at least a pilot underway and 17 percent with broad implementation. *Big data analytics* rounds out the top three, with at least a pilot by 77 percent of respondents and broad implementation by 13 percent. By comparison, just 57 percent of respondents have a *cognitive computing* pilot or implementation, and only 7 percent have implemented it broadly.

Three stages of cognitive manufacturing maturity

Being cognitively capable is just the start; developing expertise with these new technologies is what can drive cognitive manufacturing value and modern production capabilities. Most electronics manufacturers are heading toward implementation on many technologies. Yet, merely implementing technology is not sufficient to deliver success.

Cognitive manufacturing maturity is tightly correlated with not only the technologies, but another variable as well. An electronics company must have a defined cognitive manufacturing strategy. Reviewing respondents in this way allowed us to develop three key cohort groups, with each representing approximately one-third of our respondents.

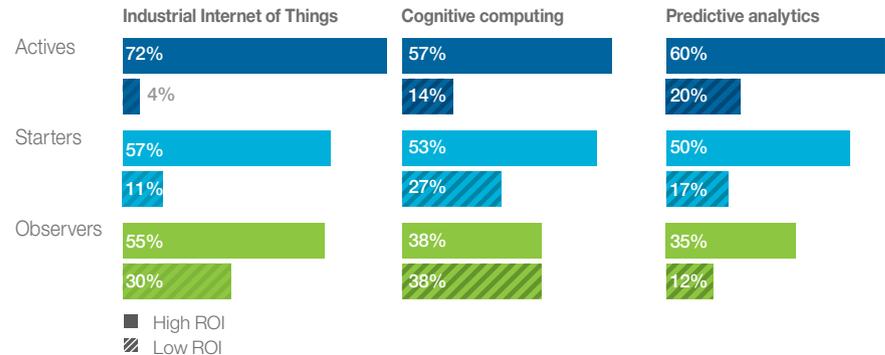
Level 1 is comprised of “Observers.” Observers told us they either are not pursuing cognitive solutions or have yet to develop a cognitive strategy. Level 2 represents “Starters,” who have a cognitive strategy, and have one or two cognitive manufacturing technology projects underway. Level 3, the “Actives,” also have a strategy, but are pursuing multiple projects in cognitive manufacturing to support it.

Companies with a strategy significantly outperformed those without one. While that may sound obvious, in this study it proved vital to successful technology projects. Those with both a strategy and implementations – Starters and Actives – achieved better ROI for each technology, noting their projects delivered “significant” or “substantial” (classified as high ROI) far more frequently than “limited” or “none” (considered low ROI in this study), and even “moderate” ROI.

From IIoT projects, Actives received high ROI 18 times more than low ROI (72 percent versus 4 percent, see Figure 5), They saw high ROI from cognitive computing four times as often as low ROI (57 percent versus 14 percent). Actives also delivered three times more high than low ROI in predictive analytics projects (60 versus 20 percent). While at least 35 percent of Observers delivered high ROI in these three technology areas, they also had low ROI projects in cognitive computing (38 percent) and IIoT (30 percent).

Figure 5

The Active cohort shows more high ROI projects, with greater insulation from low ROI ones



Source: Survey question: "What level of ROI have you realized based on your application of these technologies?" n=101.

The cohorts also differed in their planned future investments in cognitive manufacturing technologies, with all three expecting to make additional cloud computing investments (see sidebar, “Comparing cohorts’ planned technology spending”). Actives indicated a willingness for continued investment in the other seven technology categories as well. Starters seem more circumspect, with fewer reported investments. Where they have committed funds, they chose collaboration and predictive analytics. Observers added mobile technologies and cognitive computing to their investment priorities.

Moving from technologies to the capabilities they enable, all three cohorts indicated a transition from establishing a platform to enabling new capabilities over a three-year horizon (see Figure 6). In fact, executives told us that 2017’s greatest priorities will be the lowest in 2020.

To enable their desired outcomes, a specific set of investments should be undertaken now. We deconstructed this by cohort group; determining that Actives have a distinct advantage: they effectively queue the technologies for greater success by adding value in each subsequent capability. Specifically, their early investments in IIoT and cloud computing, coupled with predictive and big data analytics, are expected to move them more quickly toward 2020 priorities.

Comparing cohorts’ planned technology spending

Cloud solutions investments:

- Actives – 88 percent
- Starters – 77 percent
- Observers – 59 percent

IIoT investments:

- Actives – 71 percent
- Starters – 49 percent
- Observers – 47 percent

Big data analytics investments:

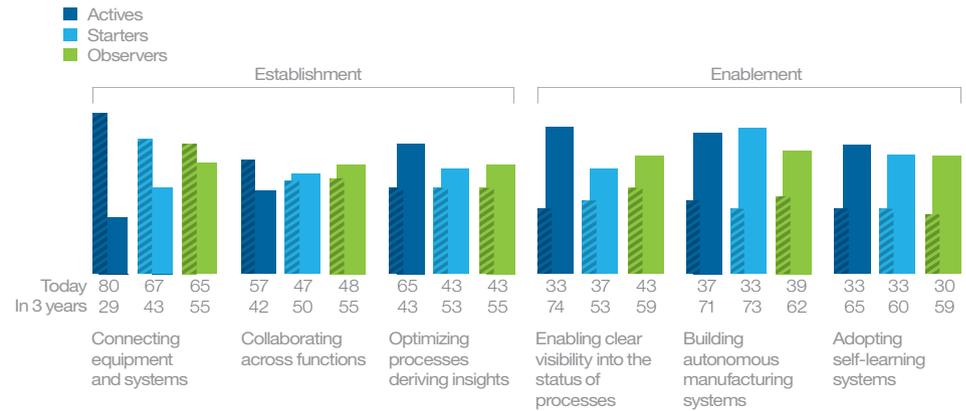
- Actives – 76 percent
- Starters – 51 percent
- Observers, 47 percent

Cognitive computing investments:

- Actives – 62 percent
- Starters – 40 percent
- Observers – 53 percent.

Figure 6

Today's investments establish the framework for advanced enablement in 2020. Actives lead today's investments, especially in connecting systems which allow the additional capabilities to work effectively.



Source: Survey question: "Which of the following steps have you taken to transition to 'smart' manufacturing (i.e., assisted by cognitive computing or artificial intelligence)? Which do you plan to take within three years? Choose all that apply for each time period." n=101.

Starts and stops: Clearing the barriers

We examined how electronics companies prepare for cognitive manufacturing, including their current and planned initiatives. The top three strategic initiatives were not about technology, but about business change (see Figure 7). Most prevalent were *business process re-engineering* and *changes in production flow and monitoring*, both reported by two-thirds of respondents, followed by *enhancement of skills development and recruiting*.

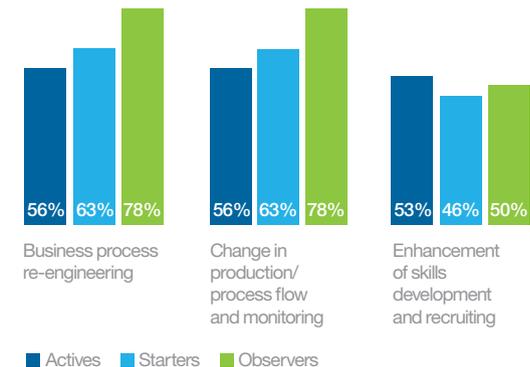
Business process re-engineering is not simply reconfiguring production lines, but includes teaching manufacturing people to rely less on spreadsheets, reports and gut feel. The evolution toward data-driven decisions is not easy in a culture that has typically depended upon “knowing” the answers and making incremental changes to obtain very small gains. Yet, that is where cognitive manufacturing brings the most value.

By providing evidence-based traceability in the reasons-to-decision process, manufacturing executives and professionals don’t just gain answers, they receive knowledge and insight. This transition to thinking “with the machine” instead of “for the machine” drives the initiative to enhance skills and recruit “new types of thinkers.” As human and machine must increasingly work together in highly complex manufacturing, this ability to work collaboratively is new.

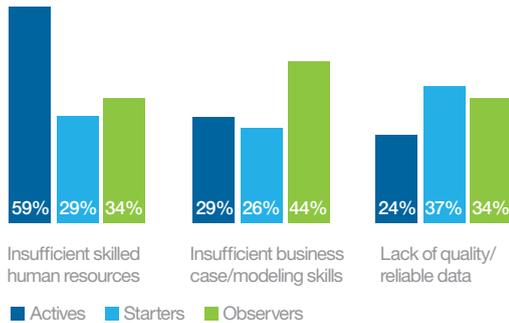
Our research found that Starters and Actives understand that processes should be redesigned simultaneously with cognitive manufacturing projects, not before. The rationale for this is simple: the information and patterns generated as a result of smarter systems can change process decisions. When changes are made in advance of being able to see how these cognitive and analytics insights impact people, processes and production, it often leads to reworking the processes.

Figure 7

Respondents noted critical strategic initiatives to implement cognitive manufacturing



Source: Survey question: “Which of the following strategic initiatives is required in your organization to implement cognitive manufacturing? Select the top three.” n=101.

Figure 8*Barriers to implementing disruptive innovations*

Source: Survey question: “What are the top barriers to implementing disruptive innovations in your organization? Rank the top three.”
n=101.

Obstacles for each cohort to overcome

We also asked about the barriers companies expect to encounter. Even those moving toward activating the next generation of production success face implementation barriers. Each cohort struggled most with barriers that tie to its own maturity level (see Figure 8).

Actives. The top barrier named by Actives was insufficient skilled human resources (59 percent). As an organization shifts toward augmenting manufacturing intelligence, it often finds that its resource mix needs to change in favor of more data scientists and people whose toolkit includes both technology and physical instruments. Being able to ask the system for help earlier is necessary. Many workers aren’t yet comfortable with the capability to review multiple options or access potentially decades of global organizational insight.

Companies that rely on “putting bodies on the line” – with little to none of the skills needed to cope with a human-and-machine partnership – risk failure. This points to a key need for Actives, who must now partner more tightly with human resources and employee education teams to address these types of training needs.

Starters. Lack of quality/reliable data was the biggest barrier for Starters (cited by 37 percent). A data quality assessment and potential remediations are often among the first steps in an analytics and cognitive project. Data quality is a common hurdle for companies starting toward IIoT and digitized operations.

To that end, Starters are beginning to work in this critical area. It has three key dimensions:

- Creation of digitized data that can be consumed by cognitive systems for use and collaboration
- Prioritization and selection of the data where it makes sense, how it generates insight and how people are exposed to it
- Creation of data governance policies that affect who has access to what and when across the largely global and often partner-driven manufacturing networks that drive modern electronics manufacturing.

Observers. Business case and strategy go hand-in-glove; this might go a long way to explaining why Observers are less mature. Observers – who have not yet pursued a strategy – said they struggled most with insufficient business case/modeling skills (cited by 44 percent).

The inability to model the business case for cognitive manufacturing often draws from the uncertainty of the potential results from new technologies. There are challenges in defining exactly where benefits accrue as new patterns are uncovered and business processes change. Simply put, it's a case of not knowing what you don't know.

Recommendations: Activate your cognitive manufacturing competency

Begin with strategy

Our research clearly shows the benefits of cognitive manufacturing and getting started is an imperative. A well-documented cognitive manufacturing strategy will include:

- Strategic imperatives and key drivers
- Long-term vision
- Business case
- Competitive advantage
- Targeted business and manufacturing processes
- Technology baseline and desired future state
- Analytics and automation skills assessment
- Talent management and human resources
- Executive sponsorship.

While Starters and Actives have already developed their strategies, it's important to note that cognitive computing – and by inference, cognitive manufacturing – are both in a state of nearly continuous evolution. Establish a cadence to review, update and improve the strategy over the next two to four months, and re-evaluate it periodically in the future.

Next, develop detailed use cases

As part of our work with clients, we recommend a template for use case detail that allows consistent and thorough documentation of elements (see Figure 9). This enables multiple stakeholders to discuss the approach effectively. A template can expose where value is both created and lost in the current process, providing details about the core components that drive the use case.

Figure 9

This sample shows the data and detail necessary to specify a cognitive use case.

Use case descriptions:				
Stakeholders:				<i>Illustrative</i>
Value drivers/ detractors	Core processes	Desired insights	Desired outcomes	Data inputs
Address common value drivers <ul style="list-style-type: none"> • Cost, quality, flexibility, throughput • Current constraints 	Examine areas and work breakdown for: <ul style="list-style-type: none"> • Maintenance • Energy management • Postponement operations • Critical parts management • Line reconfiguration 	Insights might include: <ul style="list-style-type: none"> • Operator productivity • Component to finished goods quality • Equipment utilization • Order fulfillment speed • Planning and scheduling accuracy • Reconfiguration speed 	Describe measures: <ul style="list-style-type: none"> • Increase operator productivity by x% • Identify defective components prior to runtime • Reduce machine downtime by y% • Increase repair and maintenance speed by z% 	Address: <ul style="list-style-type: none"> • Source • Quality • Usability • Governance • Security
Metric targets			Prioritization details	
Specific influenced metrics and improvement targets tied to business case			Overall use case scoring and normalization	

Source: IBM cognitive use case template.

Four initial high-value use cases

Cognitive maintenance: Enables a machine supervisor to assess process or machine performance and receive immediate answers, preventing unplanned downtime. Using deep search and discovery, it uncovers critical patterns that improve predictive maintenance.

Cognitive repair: Allows machine technicians to access years of historical detail including performance, quality and repairs, plus manuals and bulletins in context. Technicians can become smarter and faster with each repair.

Critical parts management: Prevents shortages with context-driven supplier/ecosystem detail, weather and transportation information, and company expertise via shared digital resolution rooms. This keeps lines up and running and increases business agility.

Visual inspection: Evaluates five key defect types during in-line processes and communicates with systems that process and classify them with “go/no go” flags for monitoring and verification. It removes defective parts and devices before they get into the marketplace.

The template should highlight the desired insights and outcomes in measurable and meaningful ways, tied to KPI improvement and overall knowledge capture. Focus on the data needed and the quality of that data. If the data is not available or is not in a usable state, the use case should address potential approaches to make it so. Last, use cases should be prioritized based on their value to the organization, and their dependencies on, or incremental value to, related use cases (see sidebar, “Four initial high-value use cases”).

Actives: Specific recommendations

Validate your investment returns and technology portfolio. Verify which technologies and capabilities are needed for your cognitive manufacturing portfolio. Assess ROI on investments, and the ability to expand and scale across technologies. Progress toward process visibility, optimization and integrated cognitive systems.

Lock up talent early – while you’re ahead. Address your concerns about talent aggressively before others catch up; focus on skills assessments and re-education/training. Examine key processes and resources to capture mission critical knowledge. Maintain investments in collaboration and mobility to promote strong teams.

Combine analytics, automation and cognitive. Expand the use of cognitive computing into additional areas of manufacturing to generate more insights and deliver better intelligence across systems. Combine analytics, automation and cognitive to deliver autonomous manufacturing and self-learning systems. Pursue deeper integrations along the manufacturing value chain, including supply chains and quality early warning systems.

Starters: Specific recommendations

Examine current and planned investments. Determine the right queuing of technologies to support ROI and technology progression toward scale, especially IoT and cognitive computing. Assess how your approach provides specific competitive differentiation in areas like higher quality or greater flexibility – where is the strategic value?

Address data quality and governance. Focus on a digital-first approach internally and with partners that creates high-quality data for better insight generation and learning performance in cognitive computing systems. Address information readiness by working with data and analytics experts to appropriately specify all data sources, usability, governance and security.

Go beyond the technologies to specific use cases. Develop deeper understanding of the analytics and cognitive benefits to the business through use case visioning and workshops. Actively use them to build structure and roadmaps. Focus use cases on IIoT and collaboration to make the most of current investments.

Observers: Specific recommendations

Strategy first. Engage data and technology experts and manufacturing stakeholders to develop a cognitive manufacturing strategy. Examine if business process redesign is mission critical or a distraction to immediate to short term success. Consider external help to build business case and modeling while developing internal capabilities.

Enhance your cognitive capabilities. Use your strategy to increase overall cognitive manufacturing technology success and deter an ad hoc project mentality. Focus on/expand cognitive capable investments – predictive analytics, big data analytics and IIoT – to prevent falling too far behind competitors. Examine opportunities for collaboration as a means to get more digitized data to support overall cognitive strategies.

Focus on maintenance and quality of “gateway” use cases. Develop deeper understanding of the analytics and cognitive benefits to the business through use case visioning and workshops. Actively use them to build structure and roadmaps. If you have not focused on predictive or cognitive maintenance, these well-established projects can deliver solid results as an entry point. High-quality cognitive use cases, for example, those incorporating visual inspection, can be easily extended with predictive measures in subsequent phases.

For more information

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

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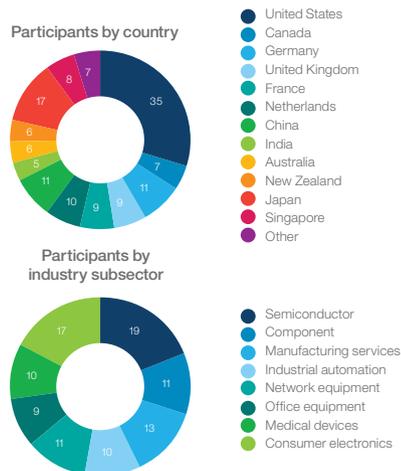
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IBM Institute for Business Value

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

Study approach and methodology

We examined two key streams of data for the 2016 IBM Institute for Business Value Cognitive Computing Study. We surveyed 141 executives from around the globe and across all industry subsectors via 40 face-to-face interviews and 101 telephone interviews from May through August 2016.



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Related IBV publications

Pureswaran, Veena, Scott Burnett and Bruce Anderson. "The Business of Things: Designing successful business models in the cognitive Internet of Things." IBM Institute for Business Value. December 2015. www.ibm.biz/businessofthings

Pureswaran, Veena and Dr. Robin Lougee. "The Economy of Things: Extracting new value from the Internet of Things." IBM Institute for Business Value. June 2015. www.ibm.biz/economyofthings

Ezry, Raphael, Dr. Michael Haydock, Bruce Tyler and Rebecca Shockley. "Analytics: Dawn of the cognitive era - How early adopters have raised the bar for data-driven insights." October 2016. <http://www.ibm.com/services/us/gbs/thoughtleadership/2016analytics/>

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