VIEWPOINTS ON INNOVATION

VIEWPOINTS ON

Manufacturing Innovation in a Digital World

A KALYPSO PUBLICATION

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The Manufacturing Executive's Primer on Digital Innovation

by Zachary Segundo, Alexander Tang, Michael Glessner and Joe Dury

We are on the cusp of a global digital innovation wave, with companies and consumers embracing more connectivity and finding success. As just one example - with Amazon's Dash Replenishment Service, your smart Brita water pitcher can order its own filters, and your smart GE washing machine can reorder laundry supplies.

The demand for smart products drives the need for smart manufacturing, including new ways to link consumers to a company's design thinking, manufacturing methods and overall raw material suppliers via a digital connection. This new connected world holds great promise, and it's easy for executives to translate this potential into shorter innovation cycles, less manufacturing downtime, higher product adoption rates, and a more robust bottom line.

But it's not going to be easy. The numbers regarding digital preparedness are startling.

- According to a recent study commissioned by Infosys Consulting, only **15%** of executives believe that their company has the **skills and capabilities to execute** on their digital strategy
- Just **31%** of surveyed senior business and IT executives believe they have a **systematic digital strategy** today
- And only **9%** of firms have reached the level of **digital maturity where they are truly differentiating** across all aspects of digital activity[1]

In order to combat these disappointing results, companies that decide to incorporate digital innovation as a critical piece of long-term success need a well-defined strategy. Pulling a company forward to catch the digital innovation wave is a company-wide initiative that shouldn't just be restricted to IT, marketing, or engineering to execute in isolation.

1 http://www.experienceinfosys.com/bedigital

Critical Components to the successful execution of Digital Innovation Strategy

- **Leadership** – 57% of survey respondents whose companies had a systematic digital strategy indicated that their CEO was responsible for defining the firm's digital vision and strategy. The CEO should set the strategy for the company while other executives drive the supporting strategies for each of their respective areas.[2]
- **Communication** – The shift from traditional manufacturing to manufacturing in a digital environment is very significant. Leadership must communicate how the change will affect all members of the organization, and this needs to be done on a very personal level. How will this shift affect their job security and their daily tasks? Lack of communication creates a vacuum that can quickly be filled with misinformation, creating unease and mistrust.

2 https://www.pwc.com/gx/en/advisory-services/digital-iq-survey-2015/campaign-site/digital-iq-survey-2015.pdf

- **Commitment** – Well-executed digital innovation strategies require significant investment and dedicated resources at the working level of the enterprise. In many instances, there is also a need for significant investment to partner with 3rd parties to execute in areas outside of the company's internal competencies or capacities. As with any large transformational initiative, the journey will likely require years, not months, so executives need to have a long range view of the digital innovation path and remain committed to the goal.
- **Momentum** – Digital innovation success may require a long-term commitment, but digital capabilities and the enabling technologies change rapidly, so execution must include short term goals and prototypes to provide some near-term wins that the company can celebrate and learn from. These iterations will support a long-term digital strategy that will constantly evolve as the landscape changes. Agile thinking, constant improvements, and strategic experiments are important parts of staying ahead of the curve. With digital innovation programs, executives cannot wait for all of the components to be ready before a phase goes live. As specific aspects of the digital innovation strategy come online, release them, learn from them, and build off of them.
- **Making it Stick** – Short-term wins will remain short-term if there is no effort to ensure that the change becomes a permanent part of the company. Executives should celebrate and promote the successful execution of the strategy and the innovations that result from it.

Digital innovation comes in many forms, including adoption of cloud methodologies, harnessing the power of innovation analytics, connecting consumers to the factory floor and engineering teams, or developing smart connected products. Companies that are prepared with strategy, commitment and support will ride the wave and stay ahead of it to meet the challenge.

A Look Ahead: An Interview from the Future on the Birth of Digital Manufacturing

by Christian Crews, Michael Glessner and Joe Dury

To understand what digital manufacturing really means for industrial manufacturers, and how it might evolve from where we are today, here's our peek into the future. All people, company and product names (except ours) are fictitious.

January 19, 2026

Viewpoints on Innovation (VoI) interviews Connor Smith, the Chief Digital Manufacturing Officer (CDMO) for Entity X, the U.S.'s hottest manufacturing company. Over the last ten years, he's helped Entity X go from an old-line fabrication plant serving the automotive industry in Detroit to a multi-billion-dollar company producing relevant, connected hard goods for both businesses and consumers.

VoI: As we sit here today in 2026, can you share with us what you found when you arrived at E-X ten years ago back in 2016?

CS: Well, I walked into a small but very capable fabrication plant making components for the auto industry. We had very smart and dedicated people, but were really beholden to a few big customers. We had first rate equipment, and were known for being able to hit our deadlines for delivery of new designs.

VoI: What started the shift into what E-X is now?

CS: Let's remember what it was like ten years ago. The Internet of Things (IoT) was still in its early stages. The ideas were there but the cost was still dropping. And the cloud was in its infancy. We can say that now. I think 10 years ago we would have said the cloud was pretty far along. But we had no idea how the cloud would evolve into what it is today. We had the Internet for 10 years before social media platforms came and completely redefined what the Internet meant.

So back in 2016 we could only imagine what the combination of the cloud and IOT would do for data and information storage. This evolved into a system of systems, easily connecting disparate data streams into useful information and revolutionizing innovation and production of products. Smart use of data has become the key.

Let me share an example: In 2016, simulation was firmly embedded in design, but we were at the beginning of being able to simulate people and how they interact with products – something we take for granted now. I would say now that social media has evolved into connected business, and the old platforms like Twitter and Facebook are now the bones and sinews linking together the new environment of ambient intelligence. This "internet of services" provides enormous data on how our products are used in the field, helping us make them better even after release to the market and create new products that build upon this constant learning.

The E-X CEO Jen Mayor saw these elements as the start of something that could allow the company to shift its business model a bit. Millennials were forming families and settling down, really entering the prime age of consumption. But they still valued connectedness and had an open and flexible view of privacy. When she considered the immense amount of data being generated combined with E-X's internal capabilities of fast fab, she realized we could use that data and build a smart, fast, consumer-facing business supplying relevant, connected hard goods to a new market. At the same time, we could serve our business customers with parts and sub-assemblies embedded with sensors to enable their own smart products and reap the same rewards.

Vol: And Cloud Baby was born…

CS: For these Millennials, we wanted our first product to serve their most pressing need. Their babies didn't have Facebook pages; they weren't connected or online. If they were in day care you'd have to get a caregiver to tell you how their day was. That was clearly unacceptable for Millennial parents! Cloud Baby was a piece of hardware that started as a simple tracker to connect parents to critical information about their kids - heart rate, body temperature, diaper condition, etc. We expanded to include a streaming camera, control over the environment, and Wi-Fi communication with a nearby care-giver or spouse. We could deliver updates over the air and dramatically change the device's functions and capabilities, and parents could choose what services they wanted. From there we expanded into a whole line of connected cloud goods for Millennial parents.

Vol: But how? A lot of companies had good ideas like that. How did you guys come up with those ideas, and how did you know which would work?

CS: We had a strong focus on innovation, and paid attention to the data as it poured in. We realized that as more things became connected to the cloud, that the impact on product ideation, design, and manufacturing would be enormous. You have to remember that in 2016, our feedback on products came from warranty cards and people complaining to customer service or through Twitter! When the product left our factory, manufacturing was done and in many cases the entire enterprise thought the same. With cloud-enabled connectivity, manufacturing's involvement with the product continues at a very fundamental level. Suddenly we had data on where our products were used, how they were used, how often and for what. So manufacturing continued to learn how to improve the product long after it shipped. We could institute design changes for quality adjustments or cost reductions if use in the field was different than expected, and we could apply these learnings to the new products coming down the line. We could even push software updates out to our deployed products to quickly solve problems in the field.

William Gibson, the Science Fiction novelist, has a famous quote that the street finds its own uses for things. And having a connected device showed us that. On the consumer side, our customers were using our devices for all sorts of things we hadn't thought of. People were using Cloud Baby as bicycle security devices! We turned those uses into new app updates available in the cloud, or entirely new products we could simulate. Since it was on-demand, we were only paying for a few days of simulation time for initial testing of each new product idea. Then we'd 3D print to test a physical version and send data straight to the factory floor from the 3D print file. Any problem with how it was used in the field was instantly communicated back to the development team and design changes were almost instantaneous.

Vol: E-X's track record on new products is remarkable, can you share any insights about why this is?

CS: When I joined in 2016, we initially had all this data and no way to make sense of it. Bringing in the capacity to analyze the data and turn it into actionable intelligence was the first step. And we soon realized that fast fab meant we didn't have to do a year of analysis; we could put some prototypes out there, get the data on how they were being used, and quickly adapt. It meant a little more work done on the front end in digital modeling before the physical prototype. Also, we were sharing our work real-time with suppliers, so we were getting predictive costing and updates from suppliers based on assembly line data and performance in the field. Sometimes they would see and correct a failing part at the factory before we even contacted them! So we soon saw the benefits of a truly connected supply chain all the way down to the production environment. All of this helped – and continues to help – continuously improve our products.

Vol: But you still had to have the capability to do it in a way that was cost effective, something a lot of companies struggle with.

CS: When I started in manufacturing, we had in-house product lifecycle management (PLM) systems that smoothed the process of getting a new product out the door. PLM enabled all the product information to stay together from the time the product was designed to when it left the building. But we needed a lot more. Company policy and government regulations required traceability back to source for all parts and ingredients, along with carbon footprint or other sustainability information. And now we had PLM extending out to the product's life in the marketplace – on the shelf at the retailer, in the online fulfillment center, and during shipment to the customer. There was data around the entire life of the product while it was in use, including service updates and information on end-of-life recycling. This is fine if the products were staying fairly static, but with the added requirement to constantly update existing products in the field and churn out entirely new ones, PLM needed to integrate into a larger innovation platform covering a broader scope of data.

Vol: What did that mean at the plant level? Your traditional factory had to change as well, right?

CS: Yes, there's no doubt we benefited from taking advantage of the new digital factory. We started with democratizing the data. A networked data model, rather than a hierarchical model, meant the use of the data was not confined to one application or structure. Users could design the structure "fit to purpose." This meant all parts of the organization had access to all the data we had, from internal design and production data to external feedback from the marketplace. They found many creative and valuable new uses for that data, too – more than we could have thought possible!

It wasn't magic – there was a lot of work done to create standards to manage the transition as we matured and progressed through our plan. There was a lot of organizational change management. But some of that was removing processes and standards, not adding them. Content was reused, which reduced all the documentation involved, such as work instructions, training, and technical specifications. This eased the transition and made things less complex for the workforce to adopt the new way of working.

From there we could use the digital factory not just to optimize our products, but to optimize the plant itself. Again we allowed the data and information to tell us the way. We could simulate everything from environmental aspects like humidity to how a design change could impact production schedules and costs, or the impact of switching to a new supplier for a key part. Since the data was networked and unstructured, we could use data models and predictive analytics to find answers to complex production problems that had many contributing factors, creating seemingly random defects.

With today's new era of digital manufacturing, we have an innovation platform; a system of systems supported in the cloud. We are now at a place where the product influences how it is built as it is built. That's pretty amazing. PLM systems now have to integrate across a wide range of other systems, and store and track product data in a much wider sea of information.

Vol: How did your plant workers at the traditional fab plant embrace this new world?

CS: There were certainly some organizational change management issues and these had to happen. All of a sudden the products were talking to them as they were being manufactured. Cloud-based PLM was flexible, but did require some training of the workforce both in manufacturing and engineering as well. We invested in hybrid systems that we could customize to fit our needs when necessary. The intelligence of today's products is getting truly amazing – they tell us when they are built incorrectly or something isn't working right. Testing is no longer a separate activity; instead it is baked into the product itself. The synergy we see between operations and engineering has been amazing and it started by staying focused on the product and the data it was giving us about the use in the market.

Vol: I hear it's all fun and games there now...

CS: You are referring to our gamification platform. For our baby and parenting products, we used the motivation and structure of video games, something Millennials knew very well, to help them learn about and use the products to the fullest. We used the same thing for training and work on the line at the plant.

Today, we have dashboards tracking all of our production, from idea generation through to product shipping. It allows for self-directed work teams, and encourages collaboration across functions. The work can be fluid, allowing people to come together around problems and organize through capabilities. Our product designers don't really "work" anymore; they come in and play a game together. You own your score, so it's up to you to optimize and own the processes that contribute to the score. Artificial Intelligence always wins, of course.

Vol: Yes, you were one of the first to have algorithms take a leadership role.

CS: It's not appropriate for everything, but there are places where artificial intelligence can do a great job. Some of our employees have had to get used to working on projects run by AI's. It frees our people up to deal with the exceptions and the problems, or to dream up new solutions for our customers.

VoI: Any last thoughts?

CS: This is the way the world is now. There is no part of the market that is safe from being a part of connected businesses. Even our B2B products are feeling it, as we supply our sub-assemblies to companies going through the same thing with the same needs in terms of connectivity, speed to market, and ongoing real-time changes on the factory floor. The traditional coal face isn't the front lines of where work gets done anymore: today the front lines are a digitally connected block of silicon enabling data that's changing every second.

Digital manufacturing is here. Get all your data into the cloud, use a cloud-based innovation platform that connects your PLM with best in class systems to handle the process from ideation to end-of-life, customize where you need to and invest in organizational change management for your people. This will give the organization a learning method to supply products that really meet the customers' needs and wants!

Two Ways IoT is Disrupting (and Helping) the Manufacturing Process

by Cameron Beattie, Zachary Segundo and Austin Locke

The internet of things, also known as (IoT), is an emerging technology that has the potential to disrupt the manufacturing industry. It's about allowing a device with a switch to connect to the internet. For example, a thermostat in your house that is controlled by your phone or a sensor on a CNC machine connecting it to the factory. According to Gartner, approximately 3.9 billion things were connected in 2014 and it is expected to rise to 25 billion by 2020, equating to a 35% annual growth rate.

Factories that are connected to the internet are far more productive and efficient than those that are not. IoT helps manufacturers drive down costs, eliminate inefficiencies, manage workforce skills/gaps and develop new areas to generate business, yet only 10% of industrial operations use IoT, leaving a tremendous growth opportunity for IoT in manufacturing.

In A Look Ahead: An Interview from the Future on the Birth of Digital Manufacturing, we imagine what the near future can be for a manufacturing company building on a core strategy that relies on IoT, business intelligence (BI), and cloud-based applications. But how can this strategy usher in a new digital age of innovation?

How is IoT Disrupting the Manufacturing Process?

There are endless possibilities on how IoT can be used in both discrete and process manufacturing. Two primary areas are Machine to Machine Communication and Product Development Processes.

Machine to Machine Communication

Manufacturing floors produce huge amounts of valuable data that can be used for many purposes, but companies must capture it to put the data to work.

Machine to Machine Communication is a term used to describe technology that allows networked devices to exchange information directly to each other, and it is set to disrupt the manufacturing industry. For example, rather than staff maintaining and monitoring machines on the factory floor, sensors can monitor the equipment and the factory's performance.

Machine to Machine Communication can:

- Reduce unnecessary downtime due to unwarranted maintenance or unexpected repairs
- Increase ability to maintain a precise inventory of spare parts
- Enable machines to share analytics about factory performance and easily identify bottlenecks on the line, respond to conditions to lessen their effect and identify maintenance issues in real time
- Facilitate the transfer of data from a mobile device to another machine to manage how the machine interacts with its environment

- Support remote operation centers, permitting factories to be set up all around the world, managed from a central location, and monitored in real time
- Decrease the number of quality incidents and reduce waste due to more tightly controlled production monitoring

The enablement of IoT through Machine to Machine interaction triggers manufacturing efficiencies and quality performance that previously were unattainable, enables real bottom line changes, and leads to higher net income, driving future innovation or company reinvestment.

Machine to Machine Communication Example: GE's Durathon Battery Factory

GE's factory uses 10,000 sensors on the assembly line to report the status of each component in real time which can be viewed via iPad or phone.

Benefits include:

- Real time information on what is actually happening on the factory floor in machines and products
- Rapid decision making when this information is shared within the organization
- Waste reduction; i.e. identifying and removing defective products while on the line
- Continuous data sharing between machines to automatically adjust production speed, eliminating human intervention
- Early failure identification, minimizing line stoppage and emergency repairs

Product Development Process

The IoT drastically changes product development processes. Instead of guessing what a consumer needs, the IoT provides a foundation of information that allows manufacturers to tailor products specifically to a consumer, extending the manufacturing process well beyond the factory floor. Product sensors can relay information back to a manufacturer, informing them of what features are being used, when, where, and how. This insight and real time feedback of how a product is being used blurs the line between product development, manufacturing and product use, and opens up entirely new product applications and markets.

In the previously referenced Interview from the Future on the Birth of Digital Manufacturing, an example is given of a leading digital manufacturer using product data from consumers to recognize that a connected baby monitor was also being used as a bicycle security device. The business then "turned those uses into new app updates available in the cloud, or entirely new products we could simulate." There are also several real-world examples of the IoT impacting product development.

Product Development Process Examples

1. Coca-Cola's Freestyle vending machine monitors where, when, and how their product is being consumed by connected vending machines

2. Bosch created Health Buddy, a device that monitors vital signs and records patient inputs. Instead of being confined to a hospital room, a patient can live in the comfort of his or her home while medical staff remotely monitors their condition

3. HP created a printer that automatically orders ink when the printer reaches a certain threshold of pages printed. If used widely, HP could analyze data to determine production schedules of ink demand

4. In response to a formerly unknown quality issue, Tesla sent a software update to their vehicles that automatically adjusted the car's suspension in rough road conditions

In these examples, products are connected devices, providing valuable information to designers that can be used to improve the customer experience or help solve a product development issue. This connectivity allows companies to analyze the data received from the product and tailor it and/or develop the next generation of the product, update it with new features, and adjust to new demands being placed on the product.

The overall result of these product development process changes are an increase in revenue from new products. Shorter design and innovation cycle times, successful target marketing, elimination of extraneous marketing expenses, accurate production forecasting, and lower inventory costs, are all direct benefits of well executed digital innovation efforts.

Building your Business Case for the Industrial Internet of Things

by Jordan Reynolds

You've seen demonstrations, read whitepapers, lived and breathed the hype, and now you're overwhelmed with a sense of urgency and wondering how to even get started with the Industrial Internet of Things (IIoT). You're right to feel perplexed. For all the alluring promises, there remains a troubling lack of testimonials, leading practices, or general consensus on where and how to approach these opportunities.

Industrial business leaders should take a structured three-part approach to evaluating their IIoT investments. These methods will ensure your organization picks the right investments, fully understands their true potential and can defend them from the scrutiny they're certain to be subjected to.

Explore the Art of the Possible

Evaluating investment areas like the Industrial Internet of Things is often a balancing act between recognizing current business needs and envisioning new possibilities. To complicate the matter, IoT technologies and standards are in flux. Obsolescence, new developments and redefinition create uncertainty about the right entry point and a reliable path forward.

It is these ambiguities that underpin the phrase "the art of the possible." Just as an artist bears the burden of reconciling something new with something desired, progressive business leaders are called to explore and pursue important new opportunities in line with their organization's strategic objectives.

To identify and evaluate new opportunities, we recommend starting with an approach organized around asking and answering key questions to stimulate critical thinking, draw out ideas and identify underlying presumptions. Industrial firms should consider a formal **opportunity assessment initiative** to answer these questions, and map the resulting decisions to enabling capabilities.

Start first by identifying immediate needs. While the questions to be answered vary across organization and industry, start with the basics.

- How do we define digital within the context of our own industry?
- How are digital capabilities changing our industry?
- How are our customer expectations evolving within a connected world?
- Where do we want to play, and how should we stand against our competitors?
- What do we need to do differently and what will it take to succeed?

Compare your answers to these questions to an evaluation of the possibilities. "What can we do now that we couldn't do before, given advancements in digital technology and changing user behavior?"

As an input to your ideation activities, you may consider how other industrial firms have met their strategic goals with IIoT capabilities, including:

- Proactive decision making – e.g., Using predictive analytics and machine learning to proactively identify leading indicators of problems in production and in the field
- Blended digital & physical experiences – e.g., Deploying advanced visualization techniques to field service agents to increase the speed and accuracy of repair operations
- Enhanced situational awareness - e.g., Identifying bottlenecked systems and issues in real-time alerts that allow management teams to respond immediately
- Real-time automation - e.g., Building industrial systems that can act autonomously, and make decisions with minimal human intervention
- Digital integrations that cross over traditional boundaries – e.g., Gaining insights from customer usage to influence requirements and design features

Working backwards from the possibilities to your evaluation of immediate needs, are there any clear and notable intersections? These may be the areas where you should focus your remaining efforts.

Form a Value Hypothesis

The desired output of an effective opportunity assessment is a set of targeted value drivers ready to be strengthened through an investment justification process. We recommend a **business case** development phase to comprehensively outline, communicate and gain alignment on your ideas.

Your business case should be constructed as a set of measurable hypotheses, each with its own underlying assumptions to be validated, including quantitative and qualitative business impact. These hypotheses should address the chain of causation from technology, process and organizational changes implemented, upward to key operational targets for the business, and further on to top-tier strategic and financial goals.

Consider this example of an industrial machinery company evaluating an investment in predictive analytics capabilities:

"If we invest in a machine learning technology platform, we can use our telematics data to develop a predictive analytics capability. This will help us programmatically identify leading indicators of machine failure weeks before incidents occur, and procure replacement components early enough to reduce total asset downtime from three days to one day.

This could improve perceived quality of our products allowing us to sustain competitive advantage. It will also drive substantial financial returns. Two days of downtime reduction per asset translates to $2.5M in incremental annual cash flow. With an initial capital investment of $5 million, the investment yields $2.65M in net present value and a 35% internal rate of return (IRR) - 20 percentage points above our internal cost of capital."

Perhaps the most important components of the business case are the technological, organizational and market assumptions that you implicitly acknowledge throughout the value hypothesis. Particularly with emerging technology investments like IoT, an effective business case is one in which assumptions are diligently identified, documented and detailed with practical validation steps.

Inquire with Strategic Experiments

All too often, firms hastily move from the business case to a full capital appropriation and program implementation. While adding some incremental cost, strategic experiments geared to validate your value hypothesis are an effective way to mitigate risk and unlock previously unforeseen requirements.

A leading practice for IIoT investments is to sponsor one or more **proof of value** activities to reliably confirm the viability of your idea. Working from the hypothesis and assumptions outlined in your business case, build a plan and a focused team to examine areas of technical risk and business uncertainty.

Proof of Value activities often take the form of working product prototypes, theoretical models, consultations, subject matter research, and interviews with customers and business partners. Aside from the obvious risk mitigation benefits, they offer a stop-loss opportunity to start small and fail fast if it's determined that the idea is not viable or not ideal at the current time. They also lay much of the technical groundwork for the implementation phase that follows.

The best Proof of Value engagements also set out to identify scalability concerns that should capture attention early in the implementation.

- Can we organize our value chain such that our product or service can be manufactured and distributed at scale?
- Can we scale to the volume of data and bandwidth required to support production?
- Will the market bear the volume of products or services we forecast to secure profitability and growth?

A well-executed business case can help you make informed decisions and envision a clear picture of how an IIoT investment can generate incremental revenue and profitability. Aside from these analytical benefits, it's true value is the experience of ideation, hypothesis formation and validation that helps drive alignment and enthusiasm across your organization for an exciting new idea.

With a structured approach that incorporates leading practices, you can ensure that your business case for IIoT is the motivating experience you had hoped for, rather than the aimless misadventure you had feared.

Case Study: Predictive Analytics and Improved Product Decisions with Machine Learning

by Jordan Reynolds and Chad Markle

The Internet of Things (IoT) has exploded, creating unprecedented demand for IoT-enabled devices, services, and solutions. According to McKinsey, by 2025 more than a third of the IoT's projected annual value of $6.2 trillion will be attributed to the global manufacturing industry.

Manufacturers seeking to gain and maintain a competitive edge have been implementing smart equipment to improve operations. Operational performance improvements such as reduced downtime, improved response times, and reduced human error translate to measurable improvements on the bottom line.

Watch a video demo of this use case

As manufacturers have become increasingly connected, their connected systems, machines, sensors, and other devices are generating a wealth of new data. But this data is complex in nature, and given the sheer volume of data generated, isn't easily gathered and analyzed. It is a challenge traditional manufacturing systems are not designed for – and manufacturers are missing out on valuable insights as a result.

Machine learning technology can help, when implemented in support of an IoT strategy and validated via a strategic experiment that proves the potential value. Manufacturers should take a comprehensive approach to machine learning and analytics, integrating equipment, systems and people into a highly collaborative environment that rapidly adapts to changing operational requirements and operates on a scale much larger than simple IoT applications.

With the right strategy, industrial manufacturers can capitalize on the opportunity to generate business insights from data, capturing sustainable economic value. Here's an example of a use case, developed by ThingWorx partner Kalypso, for machine learning in industrial manufacturing. This use case is centered around wind farms, but could apply to any manufacturer with smart, connected capital equipment in the field.

> **Of all these new technologies, big data may prove to be the one with the broadest impact on the largest number of companies. There is no one-size-fits-all technology – different kinds of big data problems require different kinds of solutions, and in most cases a mixture of solutions is required.**
>
> – Chad Markle, partner and Digital Practice lead at Kalypso

Predictive Failure of Equipment in the Field

Imagine a wind farm that has implemented smart, connected turbines using the ThingWorx Platform with the goals of gaining better insight into operational performance and making improvements for better outcomes. The farm has experienced problems stemming from repeated equipment failure, including lengthy and unplanned downtime and costly unplanned maintenance – which translates to bottom line losses and unhappy customers.

Its wind turbines are all connected and the farm wants to identify patterns that signify proper operation, signs of impending failure or maintenance issues, and other operational performance indicators. These insights will help to improve decision-making, planning, and operations outcomes.

Each turbine generates millions of points of data. But the business lacks a system to properly gather and analyze it and currently monitors data manually. This is problematic for several reasons:

1. Manpower resources are insufficient to monitor and process the high volumes of incoming data
2. Employees monitoring data are not experts in the field of data science or mathematics
3. The data is complex and in new and varying formats, making it difficult to manage with any traditional analytics tools
4. Risk for error is high due to the volume, velocity, and variety of data

Without the ability to properly and effectively manage incoming data from the turbines, the business is unable to get the much-needed insights from its connected operations.

A Powerful Analytics Solution

The wind farm seeks out an analytics solution that will monitor, manage, and analyze its data in order to:

- Identify performance patterns and trends
- Alert to anomalies in performance
- Predict unwanted events such as downtime or required maintenance
- Minimize human intervention and risk for error

In this example, the wind farm or the original equipment manufacturer could benefit from developing a business case for machine learning, and then validating the business hypothesis with strategic experiments and a functional prototype. Using strategic services from Kalypso and ThingWorx Analytics technology from PTC, a functioning proof of concept can be developed in a few short weeks, using the company's data. In this example, the solution provides powerful, automated analytics capabilities directly via the ThingWorx platform. Capabilities include adaptive learning technology, real-time pattern and anomaly detection, simulative and prescriptive analytics, and automated predictive analytics.

Real-time monitoring helps to minimize and avoid downtime or failures by enabling detailed monitoring of equipment condition and operating parameters such as wind conditions, vibrations, temperature and wind speed. Anomalies automatically trigger alerts and proactively initiate responses from maintenance teams or service networks as soon as a problem occurs.

Predictive analytics automatically deliver proactive information to decision makers to improve quality and performance of complex manufacturing processes and transform maintenance processes into predictive maintenance before failure occurs.

The Results

In this example, the wind farm first uses ThingWorx Analytics to analyze historic data sets numbering into millions of rows of data, to understand what's happening and what the conditions are when equipment failures have occurred. Then, ThingWorx Analytics is used for real-time usage monitoring to detect similar conditions and predictive analytics to identify when a failure is approaching.

Better insight into operational performance can be used to improve the business in a number of ways. With the Machine Learning Quick Start services from Kalypso, organizations can rapidly create value from the ThingWorx Platform and ThingWorx Analytics. In a short period of time, companies can leverage these technologies to connect historical data to a predictive analytics engine. In this example the wind farm operator can analyze and predict equipment failures, and the operations teams can better anticipate issues, schedule proactive maintenance, and avoid or minimize costly downtime.

Then, this information is used to discover new insight and optimize business processes and equipment performance.

Operations managers then use these insights to develop and implement processes or solutions that will prevent typical failure conditions from occurring. This information is also used in long-term planning. The data can also be used by the equipment manufacturer, helping R&D and product engineers understand the circumstances under which failure is likely, so they can make improvements to equipment or develop products that will minimize instances of failure in the future.

Harnessing the Power of Big Data for Digital Manufacturing

by John Hubert and Chad Markle

In our introductory article about the Birth of Digital Manufacturing, we provided a glimpse into the future – our view of what the world of digital manufacturing might look like ten years from now. In that view of a potential future, fictional CEO Connor Smith described Entity-X's remarkable transformation from a small fabrication plant to a thriving multi-billion-dollar company producing smart connected products for businesses and consumers. Key to that transformation was Entity-X's smart use of data, which fundamentally impacted all phases of the product's entire lifecycle, from ideation, to design, to manufacturing, to in-field support.

Our story is not just fiction. These changes are already happening – companies are already taking advantage of the confluence of emerging new technologies such as IoT, Cloud computing and big data to gain new insights and provide compelling new products and services. Of all these new technologies, big data may prove to be the one with the broadest impact on the largest number of companies. More than likely, your company will face not only exciting opportunities for innovation, but also terrifying threats to your business.

So, as a leader of engineering, manufacturing or operations, **what should you do?**

What is Big Data?

Big data is any data that's too big to be handled by traditional database technologies, where the bigness is measured along three primary dimensions:

1. **Volume** – The shear amount of data to be stored and processed
2. **Velocity** – The required speed of data flow, including input/output, processing, and storage
3. **Variety** – The variability (and unpredictability) of the kinds of data to be stored and processed

For example, consider the GE Durathon battery plant that collects data from more than 10,000 sensors in real time. This system has high Velocity due to the data being generated and processed at a rapid rate, high Volume due to massive amounts of data accumulating over time, and high Variety due to different sensors generating many different data formats.

Traditional database technologies simply can't handle the extremes along any of these three dimensions, so entirely new types of technologies have emerged over roughly the last 15 years, with more emerging rapidly. And there is no one-size-fits-all technology – different kinds of big data problems require different kinds of solutions, and in most cases a mixture of solutions is required. For example, maybe the battery plant has different databases for real-time control of operations vs. batch processing of analytics.

As the Volume, Velocity and Variety of data continues to explode, so does the array of big data technologies. In fact, according to a recent IDC forecast, the Big Data technology and services market will grow at a 26.4% compound annual growth rate to $41.5 billion through 2018, or about six times the growth rate of the overall IT market.

What does all of this mean to you? As you work to define and execute your big data strategies and plans, you will likely continue to be faced with a rapidly changing technology landscape, with new problems to be solved and new technologies presenting new opportunities for innovation.

Educate Yourself

Of course you've been hearing all the buzz about big data for several years now, but do you really know what it means, what kinds of problems it can solve, and what opportunities it presents to your company? Do you have a deep understanding of what your company and other companies are already doing with Big Data? These are important questions to answer, and they are moving targets, so you need to get educated and stay educated.

Establish a Cross-functional Big Data Team

You next step should be to ensure that your company is taking a holistic view of big data, and to consolidate any existing silos of big data activities and expertise. Don't limit yourself to thinking that big data is only about analytics or only for sales and marketing, and don't leave it to IT to figure out your big data strategy all by themselves. All aspects of your business will be affected, so you need a cross-functional team effort to develop and execute a comprehensive business strategy and plan regarding your data sets. This team needs to range from strategic business thinkers to PHD data scientists, and should include translators – people with expertise in both analytics and business who can bridge the communication gap between data scientists and business leaders. Beware that people with deep expertise in analytics are currently in short supply and command premium salaries.

Consider that many companies are already creating big data business units and corresponding executive leadership positions, such as Ford Motor Company's recently appointed Chief Data and Analytics Officer.

In fact, Gartner predicts that 25% of organizations will have a Chief Data Officer (CDO) by 2017, and they argue that the CDO should be a peer of the CIO, as summed up by this statement: "Data management is on the same level, organizationally, as financial management and technology management — and just as important."

Establish a Big Data Business Strategy and Plan

The first job of your cross-functional team should be to start formulating a big data strategy and plan as a key component of your company's overall strategies and plans. But don't let your current business strategies limit your thinking – you may discover new opportunities and new business models, just like Entity-X did in our story.

Your goal should be value creation through both topline and bottom line growth. For example, cost cutting measures might present themselves in the form of modified manufacturing processes, and you may realize myriad new product ideas.

Some companies have adopted a strategy of "let's gather all the data we can and then we'll figure out how to analyze it for actionable insights later." That's not a strategy. That's backwards. Technologies like Hadoop and Cloud computing make it technically and economically feasible to collect massive piles of unstructured data and then figure out how to process it later. But first you should have clear objectives, clear understanding of risks, and a much broader view of big data than just analytics.

Pay Special Attention to Privacy, Security, and Data Ownership

Before you decide what data to collect and why, you need to have a clear understanding of and well-reasoned policies for the critical issues of privacy, security and data ownership. These topics should be outlined in your business strategy. They are big topics, but we can offer a few key recommendations:

1. **Do the Right Thing** – Obviously you have to comply with all applicable laws and regulations, but that's not enough to eliminate risks. The laws are still evolving, and customer trust is not easily gained or kept. So go above and beyond what's required, and be judicious in your choices about what data to collect and why.

Be completely open with your customers and treat them how you know they want to be treated – the golden rule.

2. **Provide Clear Value to Customers** – Don't just collect information that is self-serving. Make sure it has obvious value to your customers too. For example, Entity-X's Cloud Baby product collected a lot of private and potentially sensitive data about the baby, but that data, as a result of added services and insights, was valuable to the customer too.

3. **Consider How to Monetize the Data** – Who owns the data that you collect – you or your customers? If you have consent from your customers to share their data, it could open up new opportunities. For example, imagine how valuable the Cloud Baby data could be for medical research, especially if correlated with health data provided by each baby's pediatrician. Imagine if heart rate, breathing and video images of sleeping patterns could be used to help predict and prevent SIDS (Sudden Infant Death Syndrome, the sudden death of babies during sleep with no warning signs or clear reason).

4. **Understand the Technical and Human Challenges** – In our story about Entity-X, we talked about the huge value of democratizing the data – allowing everyone in the organization to see and make use of data. But what if some of that data is sensitive? Because big data tends to be unstructured, it can be technically difficult to provide granular security (to allow only certain people to see certain kinds of data). And more importantly, human factors tend to be the biggest challenges for enforcing privacy and security.

Fix Your Small Data Problems First

Don't make the mistake of rushing to do what's new and cool at the expense of excellence in the fundamentals such as PLM, ERP, MES and CRM. All of your big data knowledge and insights will be useless if you can't translate them into actions. And your newfound big data insights will actually increase the demands on your traditional business systems, not reduce them. Consider what CEO Connor Smith said: "…with the added requirement to constantly update existing products in the field and churn out entirely new ones, PLM needed to integrate into a larger innovation platform covering a broader scope of data," and "Now we had PLM extending out to the product's life in the marketplace…"

Don't Underestimate the Technology

If you think of big data technology as "Hadoop and analytics," then your view is too narrow. There are many different classes of big data problems that require different kinds of technology solutions. For example, imagine if the Cloud Baby product had a web application called Babybook that allowed parents to create video/photo albums, track baby's health statistics, and interact with their pediatrician to ensure baby's health. And imagine that millions of parents are using this application at once. That's not the domain of Hadoop, which is better suited for batch processing and analytics than real time operations. This would be the domain of some kind of NoSQL database, of which there are many choices. And the list of big data technology choices is exploding. The research firm IDC forecasts that the market for big data technology and services will grow at 21.7% CAGR, or about six times the growth rate of the overall information technology market. So you will need to do your homework and stay on your toes.

The wide array of technology choices may seem daunting. Here are some suggestions to help you get started:

1. **Start Small.** Look for early wins that you can showcase and promote within the organization

2. **Use strategy to guide your technology objectives.** Ensure senior executives in charge of important initiatives are engaged. Avoid unbridled technology quests.

3. Get some help at first. Consider hiring some outside expertise to help you get started, and build your internal expertise over time. The supply of experienced data scientists and practitioners is scarce.

4. **Think carefully about what to build vs. buy.** Right now you might have to build a lot yourself, but that is changing rapidly, which could actually be an advantage to later adopters who buy instead of build.

5. **Use the Clou**d. Don't even think about doing all of this on premise. In the cloud, the security is better, the economics are better, and it's much faster and easier to get started and to experiment. Consider packaged services that include both infrastructure and software in a PaaS or SaaS model, such as Amazon's AWS IoT.

Think Big, but Start Small and Start Now!

All of the steps mentioned above will take time to accomplish and will be ongoing. These steps are important – you need a business strategy and plan to guide your efforts, and you need to avoid letting big data efforts drain resources away from critical small data efforts. But don't let that stop you from starting now. Start small with a new product idea, just like Entity-X did with Cloud Baby. Research, experiment, prototype. And most of all, innovate!

The Factory of the Future: A Day in the Life of a Plant Manager in 2020

by Michael Glessner and Nick Ward

Smart factories, enabled by augmented reality, predictive analytics, and the digital twin, may not be as futuristic as you think. Need inspiration to get started? Here's our vision of the factory of the future, and the people and processes that will be impacted.

7:40 AM

William pulls his white pickup truck into the parking lot. Bill, as he's known in the plant, is the Director of DevOps at Stuart Sprockets, a major component manufacturer, and he is running a few minutes late. After starting his career with Stuart as a maintenance technician, Bill worked his way up through the ranks, and was promoted to Plant Manager five years ago. Two years later, as part of a firm wide reorganization, he became Director of DevOps and gained responsibility for the design of all products produced in the plant. Since that time, Bill has earned the reputation of a visionary when it comes to implementing digital technology in a manufacturing environment.

Bill hurriedly scans his phone, passes through the turnstiles, and enters the factory. He slides on his smart safety glasses and begins to walk the aisles of the plant on the way to his desk. He switches on the Manager Vision heads-up display and scans the shop floor. Information fills his field of vision—current shop status, current period performance, past period performance, trends, anomalies, non-operational equipment, and more. Seeing Machining Center #3 shaded in yellow, indicating an anomaly in the machine's operation, he adjusts his route to pass the station. Bill then greets Joel, the operator in the work cell, and asks about the anomaly.

"Hi Boss," Joel replies. "It's actually a design change that came in from product engineering last night. The customer altered the way they want to mount our product at the last minute, so engineering released a new version of the 3D model. There was an immediate alert sent to us at the production line, and a new CNC (computer numeric control) program was generated automatically from the new 3D model to reflect the changes. We are now producing the part with the new design."

"Well done!" Bill exclaims. As he walks away, he shudders to think of how a late design change would have been handled a few years ago before the concept of a digital twin used 3D data to link design and manufacturing. "In the days of paper drawings," he thinks, "I would have had to spend an afternoon dealing with the issues of getting the CNC program updated, scrapped parts, and an unhappy customer!"

9:00 AM

Bill decides to step in to the daily maintenance 'stand-up' meeting for a few minutes. He likes to spend some time each day understanding how the team members at Stuart accomplish their daily work. Bill listens to Christine, the Maintenance Manager, list the planned work to be done during the upcoming lunch break. As he listens in, he reflects on how much the maintenance technician job has changed in the past few years.

For years, Stuart had collected massive amounts of data on the components of each machine they operated. As the data sets grew over time, they became more valuable as inputs for predictive analytics based on machine learning algorithms. Now, the team can accurately predict machine component failures for many of their common processing machines before they happen. This alerts maintenance teams in advance, and allows them to schedule the replacement of components without affecting production. Maintenance spends less time fixing breakdowns and more time on preventative maintenance, significantly reducing machine downtime.

11:15 AM

Bill sits down for lunch with the product engineering team. They seem to be in a particularly good mood, which had been a common theme over the past year. However, it was not always that way. Bill remembers just three or four years ago as he was developing the pitch for the digital twin project to the Board; when product engineering was his strongest opposition.

The digital twin has been a somewhat dramatic change for product engineering. In the past, PDFs of signed paper drawings were the master record of product design information, but the digital twin made the 3D model the master. This initially upset many product engineers, who were resistant to change and could not foresee all the downstream benefits. However, now that they have adapted to the new way of working, the morale is better than ever. The tedious and administrative work required to create, print, gain approval, scan, and archive a paper drawing is now eliminated and engineers focus their time on more critical design work. And, the greater searchability of the product lifecycle management (PLM) system makes it much faster for an engineer to access any information or model required for reference.

Bill is about to ask one of the engineers about the last-minute design change from the previous night when he is interrupted by a call on his cell phone. It's Linda, his General Manager of Quality Assurance, a frequent bearer of bad news. He steps away from the lively table, greets her, and cautiously asks why she was calling.

"Bill, I just want to inform you of a regulatory change in Canada," Linda starts. "A grease, spec number SG19274, that we use on several products has been banned in all of Canada, effective next month."

Bill starts to worry; 20% of Stuart's sales are in Canada, and he has bad memories of regulatory changes like this one.
He remembers quality engineers having to go through reams of paper drawings and stand-alone databases searching for spec numbers to discover the full extent of use of an oil that was banned in California six years ago. However, what Linda says next calms him significantly.

"We have run an attribute search of the Bills of Material of all of the products we are scheduled to produce as well as all existing products in inventory, and have identified only two products intended for Canada that use this grease. We will request that engineering make design changes to these products to opt for alternative grease. Inventory impact is minimal since the one product in inventory can be sold elsewhere. We will also make sure that there is a design rule that states that this grease may not be used in any Canadian destination products in the future."

"Nice work Linda," Bill replies. "This could have been a lot worse. Good use of the new digital twin system capabilities." He gives a sigh of relief and returns to his lunch table.

2:30 PM

Bill has his monthly call scheduled with the CEO in 30 minutes, and is feeling a little nervous, so he steps out of his office and scans the factory floor from his second floor balcony. He watches one of his operators as she sets up one of the machines for a productivity improvement trial that Bill had heard about. As he watches her set up the trial jig, he thinks about how the job of operator has changed over the last five years.

The removal of paperwork and manual entry, the connection of data, and the automation of manual tasks takes away the menial work of operating a machine. Operators now have time to serve as factory entrepreneurs, working to develop and implement ideas that optimize the performance of their work cells. With a wealth of data now at their fingertips, the operators spend most their time problem solving, gathering insights, and conducting experiments in a digital environment. They have even started efforts to gamify their work, and instill a form of healthy competition between the different work cells.

The unlocked potential of the operators to drive improvements of their own processes has already paid dividends. Bill is pleased to see the safety, quality, productivity, and cost improvements at the plant, all from ideas that initiated on the shop floor. Feeling a lot better, Bill steps back into his office to do some final preparation for his call with the CEO.

3:00 PM

The phone rings and as expected, it's the CEO Roger Stuart III. "How are you Bill?" he bellows. "I'm excited to talk about some of the results I'm seeing from your plant. Profit margin on products from your operation is up 8% this year alone. It looks like some of this data wizardry you pushed us to invest in is actually paying off!"

For the next hour, Bill and Roger talk. It seems that Roger is now fully bought-in to the digital vision that Bill has pursued for the past three years. Significant improvements in manufacturing cost driven by reductions in labor and scrap, as well as increases in productivity, are impressive to Roger. He is also a supporter of the organization's focus and morale improvements driven by reduction in menial administrative work and increase in time spent on value-added tasks. Roger also mentions his delight with the business' improved sales win rate, enabled by using data to focus only on the leads with the highest potential to result in success. For the first time, Roger seems truly committed to investing in digital technology company-wide, and he's looking to Bill for advice. When the call is over, Bill can't remember a time he felt more satisfied with his work.

5:20 PM

Bill responds to his last email of the day, gets up, and leaves his office. The plant will continue producing at a steady rate into the evening. He passes a pair of maintenance technicians, preventatively changing out the gear box in one of the machines, wishes them a good night, and heads out to his truck. Now heading home, Bill thinks of how digital investments, made back in early 2017, are paying off and helping the entire plant and management team succeed.

Positioning for Success with Industry 4.0

by Joe Dury, Michael Glessner and Nate Buyon

Industry 4.0, widely considered to be the 4th Industrial Revolution, is the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things (IoT), cloud computing, and creating smart factories featuring autonomous controls. Industry 4.0 has the potential to affect every aspect of manufacturing business. The rate and pace of change are staggering, but the companies who succeed will be those that commit to learning from those who are seeing results with Industry 4.0.

Industry 4.0 will change the competitive landscape across any industry that has a manufacturing component in the supply chain. Aspects of business that were previously insulated from one another will blend together. Companies must quickly adapt to internal and external pressure to innovate with new products, so traditionally discrete business units will need to come together to meet market demands. For example, the line between development and manufacturing will blur due to an even faster rate of technology adoption and the need to constantly tune the customer experience. Companies that do not change and adapt will find it increasingly difficult to sustain any sort of competitive advantage.

The Google/Alphabet story is a perfect example of investing in change, highlighting how companies can play in multiple industries. They generate most of their profits through advertisements, but also have highly touted endeavors into automated cars, enterprise cloud storage, mobile operating systems, robotics technologies, and a plethora of productivity and media software products. It's increasingly difficult to define their industry. Their list of competitors is extensive, but they are clearly successful. Alphabet has about $73 billion in cash, while Ford's market cap was about $47 billion at the end of October.

This math tells us that no industry is safe from disruption. In this case, a twenty-year-old company has over $20 billion more in cash than the market value of a 113-year-old company.

Success in the New Era

Before we talk about the future, let's look back to how companies have learned from each other in times of change. Facebook learned from early social media and messaging platforms like Myspace and AOL instant messenger. Although it took some time, Detroit's Big 3 auto companies - Ford, GM, and Chrysler (now FCA) - learned from their Japanese rivals in the 1980s and reformed in the 1990s. Then there's the story of Zara, which is now the world's largest fashion retailer by essentially copying department stores and high-end retailers. Zara is successful by innovating in the areas where department stores and high-end retailers have historically been complacent; getting new products to market quickly while simultaneously competing in price and style.

For the past few years, much of the Industry 4.0 hype in the business press has focused on big data and finding ways to analyze and mine this data for strategic insights. Today, the insights that come from smart, connected products and the IoT are beginning to yield strong results. But while smart, connected products have come a long way from their Radio-Frequency Identification (RFID) ancestors for consumers and discrete factories, the far more disruptive opportunity is around both the manufacturing and service of these products, allowing them to enable more robust processes and more fulfilling customer experiences.

The high tech and semiconductor industries are leaders in this brave new world.These companies create high fidelity digital prototypes, mitigating the risk of physical and mechanical defects late in the production cycle, and creating products that can be rapidly updated in the end user's world. This digital development process aligns the data and information from design and simulation, contained in the virtual digital space, with the data and information required for the production of the physical products. The approach has some clear advantages, including spending less time and resources on physical prototyping, and less money on warranty and replacement costs. Additional benefits include reducing development cycle time, enabling a way to upgrade products, promoting a more effective value chain and inventory management process, and enabling faster time-to-market and feedback loops that react to user preferences. A simple example (that we all take for granted) now is how our smartphones are updated daily with application fixes and operating system upgrades without even leaving our living rooms or nightstands.

Other companies have adopted the concept of a digital twin to enable even smarter factories, allowing manufacturing improvements with virtual factory replication. This approach can predict when a part or production line is going to fail. The digital twin helps companies anticipate issues before they happen and address them before they impact revenue, often with minimal human intervention.

Getting Started on the Industry 4.0 Journey

A wait and see approach is no longer valid. To advance your organization in Industry 4.0, the most important step is an honest assessment of capabilities. Industries will collide, so companies must look across industry boundaries to baseline their capabilities in smart, connected manufacturing. Industrial manufacturers who are not at least experimenting with smart, connected products or digital development methods and tools are already lagging. Even if things seem fine as they are, capability gaps will only widen as bottom and top lines shrink and the threat of commoditization grows. Industry 4.0 has already proven that with greater automation comes fewer defects, lower labor costs, and better cash flow management.

This is going to be a journey, and it's all about learning how to innovate in the digital world of Industry 4.0. Start by looking for leading examples, assessing current capabilities, and getting help from a trusted advisor with deep industry knowledge and broad digital experience. Be prepared to learn fast, fail fast and adjust, as you look for opportunities to quickly gain competitive advantage while proving long-term business value.

Practical Starting Points for Industry 4.0
A Plan for the First Steps in a Successful Smart Connected Manufacturing Journey

by Nick Ward, Joe Dury, Michael Glessner and Nate Buyon

Industry 4.0, widely considered the 4th Industrial Revolution, is the current trend of automation and data exchange in manufacturing technologies to create smart factories featuring autonomous controls. It combines cyber-physical systems, the Internet of things (IoT) and cloud computing, and has the potential to affect every aspect of manufacturing business. The pace of change is staggering, but companies that commit to learning from others can succeed.

Our first article, Positioning for Success with Industry 4.0, focused on learning from others outside of one's own industry to get started with Industry 4.0. Here, we discuss how to create commitment and buy-in while addressing fundamental changes to collaboration and culture, as you work to advance Industry 4.0 within your organization.

Creating Commitment and Executive Support

As discussed in our first article, companies must first do an honest assessment of current capabilities and understand where you stand relative to competition. The next step is to gain executive support. Senior leadership buy-in requires a strategic vison that demonstrates how you'll evolve from where you are today to where you want to be in the future, and articulates the imperative to begin the change journey now. The best plans have a short-term focus with a long-term vision. Regardless of what that plan looks like, there needs to be a strong commitment to allocate capital for new technologies along with required talent to implement and refine the solutions.

To build the vision and plan, prove out the value by developing concrete use cases with a strong link to business value.

For example, a common use case is using Industry 4.0 to maximize the value of existing data by leveraging investments in Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP). Leaders in the space connect disparate data sources into a flowing structure of data for every product. A true bill of information connects design requirements and details how a product fulfills these needs through models, simulations, processing and field data. Also, linking manufacturing data to the product record can enable insightful visualizations and processing optimizations.

Linked data structures enable managers and operators of smart factories to 'see' operations in an entirely different manner. Blending the physical world with superimposed digital characteristics or dimensions provides managers with actionable, real-time insights to improve product quality, productivity, and profitability.

This journey can typically be achieved using existing PLM and ERP systems (with some improved datasets), leading to a high return on investment. These initial returns or "quick wins" can be used to build consensus within the organization and gain executive support for digital manufacturing, setting the stage for future initiatives to further enable Industry 4.0.

Considerations for Collaboration and Culture Change

The shift to a digitally connected manufacturing organization will cause the company's value chain to condense and become more connected. Divisions and departments that have historically operated in silos will need to become interconnected. Collaboration is essential to the success of developing smart, connected products leveraging a digital manufacturing process. Product development must be tightly connected to customer experience, procurement, and operations teams. R&D and engineering groups must work closely with marketing and IT to create a unified vision and roadmap for the future. Collaboration and focused communication will be necessary to successfully navigate this change.

The work of individuals within a smart connected manufacturing value chain and upgraded factory will look and feel very different. Individuals will see their duties shift, and will need to collaborate with their colleagues across the organization more frequently. For example, individuals in product engineering and manufacturing operations groups will be in frequent communication with each other to optimize the product design and manufacturing processes. These new communication channels will be enabled by technology and interconnected information systems, but will require a concurrent cultural change to fully realize their potential.

As with any significant cultural change, digital leaders should expect to see pockets of resistance across the organization. Embracing Industry 4.0 will be a big change and will require dedicated and proactive change management to overcome opposition. A shift in organizational structure may be needed to align to the changes. In the HBR article "How Smart Connected Products are Transforming Companies," the authors introduced the term DevOp to describe combining the functions of product development and operations to foster collaboration and coordination. The flexibility to reposition key influencers to the places in the DevOp organization where they can add the most value, will also be critical to the success of Industry 4.0.

Understanding the Digital Imperative

Embracing the shift to Industry 4.0 is a substantial opportunity for companies to seize a competitive advantage. Investing in innovation is a key for sustainable long-term growth. However, the window of opportunity is closing.

The pace at which companies adopt Industry 4.0 will be highly dependent on how fast managers and executive leaders embrace the challenge and leverage the technologies that are available today. Lagging firms may find themselves fighting for their survival or swallowed by more advanced players. The journey to integrate digital manufacturing technologies into existing processes will take time, but it is critical to take these initial steps now.

If you do not have the capability to make these changes or need guidance along the way, seek out trusted advisors with industry knowledge, experience, and an appreciation for what is possible for your business. Speed is essential—learn, fail, and make adjustments quickly.

You will want the history books to show how your company identified, reacted, and thrived during these disruptive times. Winston Churchill said, "History will be kind to me for I intend to write it." Industry 4.0 concepts offer the next opportunity for the savvy manager to create history.

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