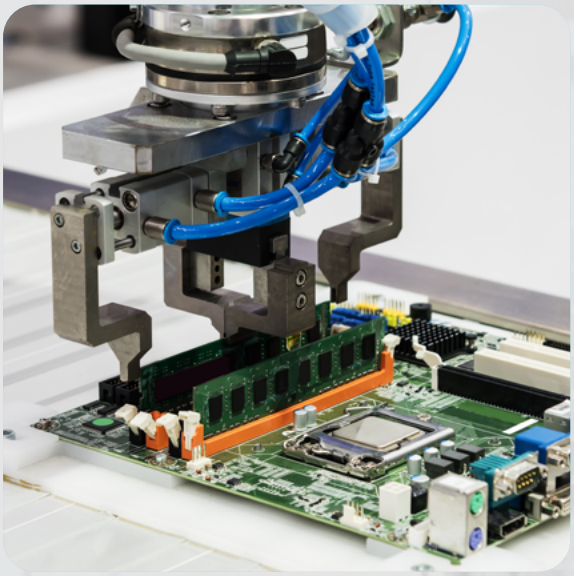
Capgemini | Microsoft

The Road to Intelligent Manufacturing

Leveraging a Platform Approach



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Intelligent manufacturing is essential to thrive in the digital era

The value of intelligent manufacturing is clear. No matter where you are in your digital transformation journey, the results are compelling: those who successfully implement intelligent initiatives realize 17 – 20% efficiency gains.[1]

Opportunity notwithstanding, intelligent manufacturing is largely driven by necessity. Product cycles are getting shorter. Pressure is increasing to improve efficiency and sustainability. The industry is experiencing a decline in the skilled workforce—leaving as many as 2.4 million vacant jobs through 2028 and costing the industry $454 billion.[2] These are significant roadblocks to staying competitive, making intelligent manufacturing essential to thrive.

Intelligent manufacturing is an approach fueled by connectivity, automation, and cloud-scale data management and analytics. Beyond technology, intelligent manufacturing includes even more expansive concepts: connected ecosystems. Innovative business strategies. Agile operating models. Productive, connected employees. These are all essential pieces of a more connected, intelligent organization.

At Microsoft and Capgemini, we've helped discrete and process manufacturers across every industry implement intelligent manufacturing initiatives—from basic connectivity to complex, autonomous systems. Drawing on our experience, we'll use this paper to discuss the key technical and business considerations that will propel you forward on your intelligent manufacturing journey.

Intelligent manufacturing systems:

- **Adapt to the evolution of products and technology without disrupting operations**
- **Support a connected ecosystem, from supplier to customer, to meet market and customer demands**
- **Improve performance and efficiency by anticipating and correcting process deviations**
- **Generate insights that can be used to improve future iterations of products and processes**

80% of manufacturers will need to extensively restructure in order to put data at the center of their processes.[3]

Intelligent manufacturing requires a new approach to business and technology

The transformation to intelligent manufacturing is a journey that every manufacturer is capable of. However, getting there requires embracing a data-driven approach to operations, processes, and technology.

From a business perspective, intelligent manufacturing means making data a core business function. This requires changes to processes and culture. Faster, more collaborative workstreams between IT and OT teams are necessary to drive agile development and leverage data-driven insights. Because of these new working relationships, as well as the rise of data-driven and autonomous operations, bringing employees along through the journey and developing their skillsets is key.

In terms of technology, intelligent manufacturing requires supporting data-driven operations with an agile approach to innovation. Unfortunately, current systems aren't open or designed for data-intensive operations and agile evolutions, making innovation costly and time consuming. And while manufacturing execution systems (MES) still form the backbone of operations, intelligent manufacturing means being able to augment and adapt these systems—adding the power of the cloud and intelligent applications to mature operations. Point solutions are one option, but they're often rigid and create data siloes that prevent manufacturers from unlocking the insights hidden in the data.

Between both business processes and technology, a successful transformation depends on a consistent and holistic approach to data—including everything from how you manage data to how you distribute insights to employees. Only with a consistent approach to data can you scale efficiently, enable agile innovation, and ultimately realize the end-state of intelligent manufacturing.

Place data at the heart of your business

Achieving data-driven operations doesn't happen all at once. It's a process that unfolds throughout the transformation to intelligent manufacturing. Because there are so many critical aspects of data-driven operations, from governance to compliance, it's helpful to break them down in order to better understand what it means to put data at the heart of your business.

Data governance: Intelligent manufacturing requires strong data governance. This means developing policies, standards, and best practices to ensure you're collecting high quality data that can be used across the organization. You'll need to implement policies to mandate documenting connectivity processes and training employees around security and privacy. This is how you'll establish best practices that will be essential down the line, like leveraging open data models so you can scale beyond initial use cases. Many manufacturers establish a governing body to enforce these standards across the company, ensuring transparency and accountability.

Data modeling: Intelligent manufacturing requires establishing not just physical connectivity but also logical connectivity. Open data models create a path to effortless scale and integration down the line. An intelligent manufacturing approach leverages edge gateways with open standards like OPC UA to establish a single, open data model for existing infrastructure and new applications and assets. This facilitates the integration of disparate IT and OT systems and alleviates the need to completely retrofit all your legacy equipment. In most cases, connecting existing machines and processes significantly reduces the cost of implementation.

Data standardization: Standardization on the edge creates a structure for data streams to come together in the cloud, even if telemetry data is coming from machines managed by legacy systems using different protocols. This enables manufacturers to adhere to global data and platform standards while still innovating locally. Data standardization should extend beyond just internal operations, paving the way for an end-to-end, connected ecosystem. Working with suppliers that enforce the same open standards ensures secure and scalable connectivity.

Data contextualization: Connectivity alone isn't enough to unlock value from data. If you want to identify why something is failing or what's causing inefficiency, you need to understand the complex network of dependencies that occur between all parts of the system. For example, perhaps you notice that one of two pumps in a chemical process isn't performing as it should. By creating a contextual model and comparing historical measurements of the upstream and downstream process as it relates to each pump, you can gain more visibility into what's impacting pump performance.

Data security and compliance: Intelligent manufacturing depends on security from sensors to the cloud. Partnering with a leading cloud provider helps you stay ahead of evolving threats, as they can deploy threat mitigations at a moment's notice. In combination with edge gateways, the cloud is critical to maintaining security as businesses embark on intelligent manufacturing initiatives.

The cloud also helps keep up with changing regulations and compliance requirements. For example, manufacturers can more easily meet GDPR requirements if they leverage cloud services to automatically build a unified catalogue of sensitive data types, rather than leaving data siloed in on-premises, legacy IT systems. Compliance processes established in the early phase of your project significantly reduce the time it takes to meet these regulatory requirements.

Building an intelligent operations platform facilitates agile, incremental, and iterative innovation—the key to achieving data-driven operations and intelligent manufacturing.

An intelligent, end-to-end platform fuels data-driven operations

Building an intelligent operations platform facilitates agile, incremental, and iterative innovation—the key to achieving data-driven operations and intelligent manufacturing. A platform approach begins with connecting your machines at the edge and to a flexible cloud platform. Then data modeling, analytics, and services are implemented in stages alongside your existing systems—infusing intelligence throughout your operations. In the end, you'll have built a true intelligent operations platform that powers intelligent manufacturing initiatives across your entire business.

An intelligent platform exists alongside your existing systems rather than replacing them, meaning implementation won't disrupt operations. And thanks to a platform's open data models and standards, new applications that improve productivity on one production line can easily be transposed onto multiple sites. All these applications and systems feed into one another—so the more data you collect and services you add, the stronger the platform becomes.

An intelligent, end-to-end platform…

1 Minimizes disruptions and complements your existing systems

An intelligent platform augments and enhances existing systems—meaning you don't have to worry about too much change at one time. As the platform is implemented in phases, it allows manufacturers to improve, rather than replace, their existing MES, ERP, PLM, and other control systems. This also enables agile learning and experimentation; new initiatives and data-driven processes can be tested without getting in the way of current operations.

2 Enables secure, repeatable, and end-to-end connectivity

An intelligent platform leverages standardized protocols and open data models in the cloud and on the edge to establish connectivity throughout your entire business. Secure and efficient communication layers exist between all brownfield and greenfield machines, sensors, assets, applications, and control systems. It also gives manufacturers a system by which they can enforce global data standards when needed and meet evolving compliance requirements.

3 Powers agile innovation

A platform evolves as your business matures. You begin to build an end-to-end platform through small industrial IoT initiatives—deploying sensors, collecting data, and distributing insights for decision support. Then you can progressively add more sensors to collect an expanded range of data, deploy machine learning (ML) applications to capitalize on new use cases and opportunities, and seamlessly integrate IT and OT data systems in the cloud. These digital technologies facilitate an IT and OT convergence, so teams can collaborate to drive efficiencies and develop new processes and products.

4 Unlocks insights and optimizes operations

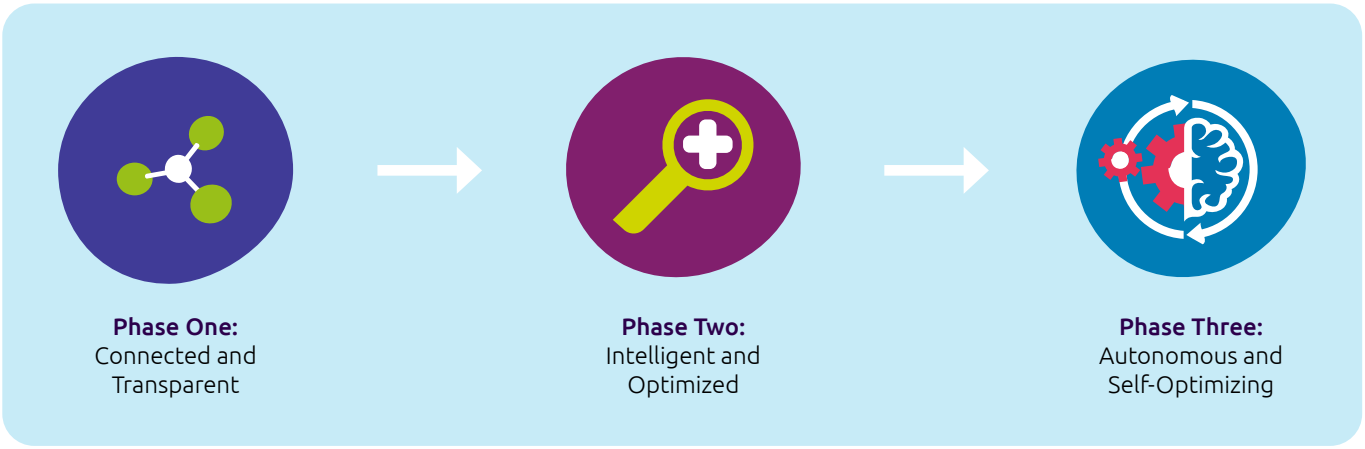
Today, an average industrial production line uses several thousand sensors. In the new digital era, manufacturers can expect to leverage more than 10 times that amount, allowing large swaths of data to be captured over extended periods of time. This plethora of data offers unprecedented visibility into the functionality of equipment and processes. These insights are used to optimize operations and empower teams to execute their jobs more efficiently and at greater scale.

5 Supports the evolution towards flexible and ultimately autonomous operations

A platform will ultimately automate and guide MES systems on its own, leveraging intelligence from across the value chain. Prescriptive technology—analytics that not only anticipate what will happen but also prescribe actions to prevent it—and algorithm-based decision-making improve operational efficiency. These self-optimizing systems adapt and evolve with new innovations.

With the right technology, implementation strategy, and roadmap, an intelligent platform enables an agile, low-risk, and easily scalable transformation towards intelligent manufacturing.

The Roadmap to Intelligent Manufacturing



The phases we've outlined here provide a basic timeline for how most manufacturers use an intelligent, end-to-end platform to transform. In each step, you'll add use cases and build on existing ones—evolving your operating model, adapting business processes, and adding to the capabilities of the platform along the way.

In our experience working with manufacturers, there are always key business and technical considerations that are imperative to move forward. We've seen what works and learned from what doesn't. In the following sections, we outline the phases of the journey, objectives for each phase, and the key business and technical considerations to drive a successful project.

Phase One: Connected and Transparent

Objectives of Phase One

Phase One is foundational—in fact, 75% of IoT projects fail because of poor planning and execution in the initial stages.[4] The strategy, data practices, and approach to change management you establish here will ensure you can scale quickly and sustain success throughout the journey.

The purpose of Phase One is to establish a data-driven culture throughout your business, so employees and teams are prepared for and engaged in the transformation. By equipping employees with the visibility and insights they need to make data-driven decisions, you'll help critical stakeholders like machine operators, maintenance technicians, and factory managers understand the value of investing both time and effort into data initiatives. The data-focused culture you build here will be the foundation for success down the line.

Key considerations for Phase One

1. Select the right use case

Success begins with a clearly defined use case. We've found it's helpful to choose a use case that will prove value quickly and scale efficiently. The best option is to pick something relatively easy to implement that also aligns with your larger business strategy. Initiatives that only solve for a single pain point won't always scale. At the same time, projects that take a one-size-fits-all approach and don't account for local pain points often fail.

Common starting points for an intelligent platform typically focus on improving the reliability of critical equipment, overall equipment effectiveness (OEE), and quality. At the beginning, this could mean monitoring a small set of machines or simply connecting a production line for more visibility. As you implement this initial use case, this is where your data-driven approach will come to life. Strong data governance policies and open data models are critical as you connect machines and equipment, ensuring your use case can scale and the services you develop are transferable.

With simple analytics and dashboards, employees will have a clear view of what's happening, so they can adjust processes or parameters to drive efficiencies. In fact, a well-designed OEE dashboard often enables a 1 – 3% gain in overall efficiency. As this is where many intelligent initiatives stall out, it's important to showcase these results to stakeholders. We recommend defining your use case performance metrics up front in order to track and present the before and after results. Starting small and getting results quickly is a great way to keep stakeholders engaged and the funding flowing.

2. Scale iteratively

With an intelligent platform, you can take an agile, incremental approach to scaling. By identifying key success factors from the initial use cases—and learning from any mistakes you make in the first go around—you can scale to

75% of IoT projects fail because of poor planning in the initial stages.[4]

One manufacturer saw a **15%** increase in machine utilization on their connected production lines compared to their other locations.[5]

more sites without disrupting operations. In the beginning, you'll only scale your simple initiative to other production lines and facilities, but these iterative practices will be useful throughout the journey. At the end of each sprint, it's important to confer with stakeholders to evaluate and iterate on the results. This will help stakeholders see the power of the solution and keep the process moving.

3. Begin developing employee competencies

Intelligent operations are an investment in people, not just technology. It's important to begin developing skillsets early on and bring people along the journey with you. Involving employees in sprints, proofs of concept (PoCs), and minimum viable products (MVPs) is a great strategy. You might consider facilitating workshops or designing role-specific trainings to develop competencies. Teaching employees how to use dashboards and applications not only drives operational efficiency but also engages them in the digital transformation process and expands their skillsets.

Engaged employees can become the strongest champions to drive adoption and support across the organization. Value their input. If an employee says something isn't working properly, ask more questions. It's important to work alongside them to implement the solutions that will impact their jobs.

Example of a platform approach to Phase One

Recently, we helped a manufacturer in the oil and gas space implement an intelligent platform. They started by gathering data to determine the root causes of stops, alerts, and losses for their machines. They began by connecting a variety of equipment on their production line, including machine tools, furnaces, and cranes, as well as their existing MES, to track factors such as temperature, vibration, and voltages. This gave their engineers the ability to see when certain machines exceeded the optimal parameters and adjust production as needed.

After the first five months of deployment, the manufacturer saw a 15% increase in machine utilization on their connected production lines compared to their other locations.[5] By demonstrating the success of the first plant to stakeholders, they then planned to scale the infrastructure to other locations and plants.

With platform architecture that leveraged open data standards, the manufacturer scaled to eight plants and connected 440 machines—many being heterogenous systems—in just 12 months. In the end, the initiative gave nearly 50 users real-time status updates, provided analysis of historical data and visual metrics dashboards, and prevented 26,000 hours of downtime in one year.

Outcomes of Phase One

At the end of Phase One, employees are still busy making day-to-day decisions and judgment calls but are now armed with accurate and reliable data to make decisions and drive optimizations. For example, if you've set out to minimize production disruptions from machine downtime, employees will be able to see machine status and make educated decisions as to when to schedule maintenance.

In terms of scale, the platform in place enables you to take an agile approach, so you can work incrementally by conducting sprints to test initial hypotheses and solve problems. And while the main outcomes of Phase One are establishing a data-driven culture and setting the stage for transformation, the transparency and visibility you establish will still yield significant results.

What success looks like in Phase One

- **Select initial use case that will scale efficiently**
- **Connect small set of machines and leverage open data models**
- **Establish open frameworks and data governance for future integrations**
- **Begin developing employee skillsets**

Phase Two: Intelligent and Optimized

Objectives of Phase Two

In the second phase, sophisticated analytics and dashboards not only support decision making but also suggest actions to take. Returning to the example of reducing machine downtime—employees will still leverage dashboards for visibility into machine health, but intelligent applications will provide optimal timeframes for maintenance in order to avoid costly disruptions and minimize maintenance costs.

And as you scale and add new use cases, you'll extend datasets and enable new services. This is when the power of the platform starts to increase exponentially, allowing you to unlock more operational insights and develop complex solutions faster.

Key considerations for Phase Two

1. Build on your initial use case with advanced analytics

In Phase Two, you'll start tackling more complex problems—such as improving product quality or developing predictive and prescriptive maintenance solutions—which require more data from a wider variety of sources and finely-tuned predictive models. These layers of advanced analytics are what make a platform truly intelligent.

To start, we recommend building on the initial use case that you implemented in Phase One, whether that's reducing costs, improving OEE, or enhancing quality. Many manufacturers solve for specific pain points, like streamlining complex repair processes or reducing variable batch conditions. Advanced analytics can quickly diagnose these issues and empower manufacturers to find new solutions.

As an example of solving increasingly complex problems, we helped one dairy manufacturer leverage industrial IoT data to optimize the composition of their milk powder. The strategy was to focus on quality in order to increase revenue and reduce waste—a complex endeavor because of all the variables at play. Leveraging advanced analytics, they analyzed batch conditions to identify what variables—such as moisture and temperature—caused differences between batches and adjusted conditions to produce the same quality product across their plants. As one of the largest dairy producers in the world, the improvements they made to their batch quality translated to a significant increase in revenue and reduction in waste.

2. Hire and train dedicated resources for advanced analytics

The talent you develop in Phase Two will ensure success down the line. People are integral to everything you do, and you'll need employees who can improve the analytics, as well as those who can act on the insights you unlock. Here, we've found it's helpful to foster collaboration between data scientists and employees tasked with solving the business problem. The collaborative culture you cultivate now will pay off in dividends when it comes to implementing use cases and applications that deliver results.

As use cases become more advanced, dedicated workstreams and highly-skilled talent—such as data scientists who can build and refine ML models—will be required. Preparing data and building ML models typically requires expertise not always found in traditional manufacturing operations. We've seen manufacturers take two routes in this instance: either hire new employees or invest in trainings. Both paths are

feasible; however, if you do hire for new roles, it's important to bring current employees along and train them on how to take advantage of these intelligent solutions.

3. Reuse services as you scale to build a stronger platform

Strategically speaking, there's an importance to using repeatable processes. Leveraging the open frameworks that you established at the outset—and continue to enforce in Phase Two—you'll create an ecosystem of integrated applications and systems that enrich one another and transfer easily.

The key to making this a reality is operationalizing this approach and dedicating resources to enhancing the platform. One manufacturer we worked with created a core team to focus on application development, enforce proper data governance across the platform, and create repeatable processes for scaling. They identified where application services and templates could be reused, so that new applications could be rolled out quickly and uniformly. As a result, they were able to speed the deployment of fully integrated applications and maintain the integrity of the platform as it grew.

Example of a platform approach to Phase Two

We partnered with one aerospace company after they recognized that their non-quality parts (scrap and material that needed to be reworked) caused them significant costs. They also knew that manual quality inspections were taking far too long and delaying the production process. We helped them tackle both pain points by digitizing their quality control processes. They started small, implementing the initiative on a small set of the airplane parts they produced. Together, we designed a system of magnetic sensors and video cameras that collect inspection data along the production line.

Digitally monitoring control tests reduced their average inspection time from four hours to minutes and improved the reliability of their defect detection. The aerospace company's employees were able to access information that normally took them hours to collect in a matter of seconds. They performed analysis on quality data, identified key process parameters, predicted defects, and monitored visualizations of machine data.

The result: they were able to completely avoid CapEx for the new inspection station they implemented. Leveraging their open platform architecture, they scaled the same initiative to five additional plants and are in the process of integrating four more.

Outcomes of Phase Two

At the end of Phase Two, you'll have invested in new roles, established reusable processes, fully deployed the platform, and realized quantifiable business results. And the value won't be insignificant—for one automobile manufacturer, predicting an issue and avoiding a one-hour disruption on a single production line saves them €80,000. However, going into Phase Three, you'll see an even greater inflection point around the value that you can deliver and the exponential effects of the platform. Each new use case you add will enrich the platform, allowing you to unlock more insights, develop more complex solutions faster, and prioritize innovation.

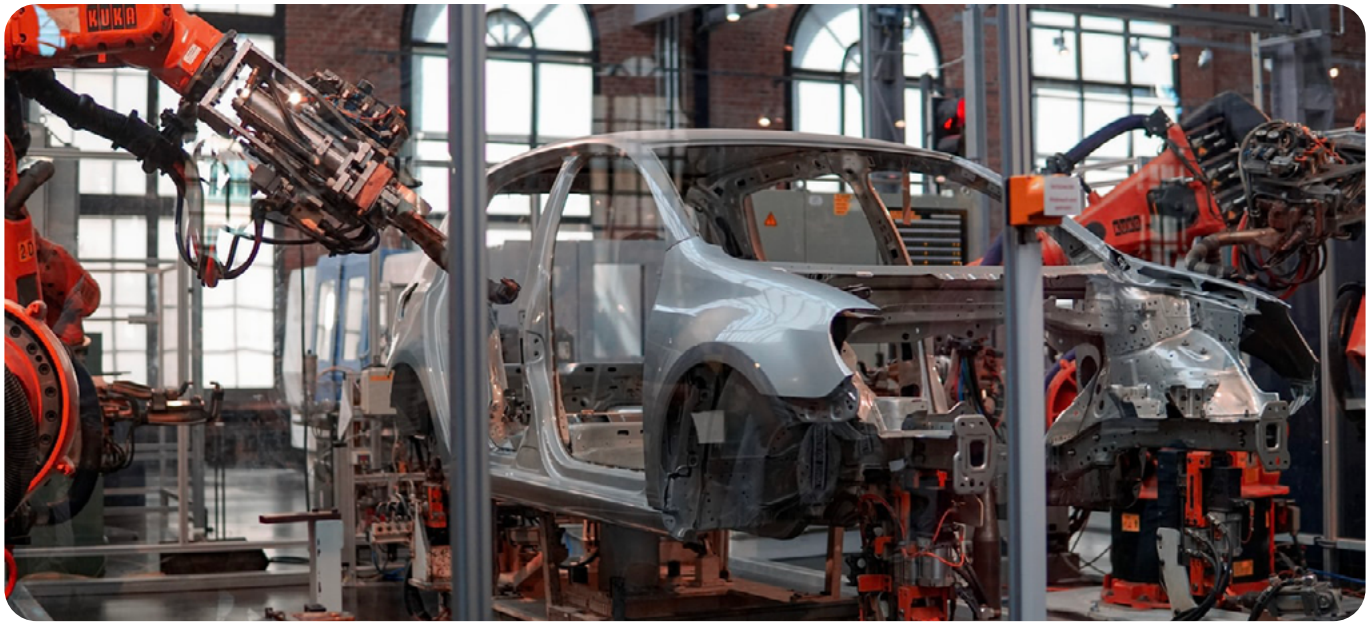
What success looks like in Phase Two

- **Rely on intelligent applications to prescribe actions**
- **Build on your initial use case with advanced analytics**
- **Implement and expand use cases**
- **Invest in employee skillsets and data teams**

Phase Three: Autonomous and Self-Optimizing

Objectives of Phase Three

In Phase Three, the goal is to delegate common and repeatable tasks to autonomous and self-optimizing systems so they can increasingly take control of day-to-day operations. Instead of just suggesting optimal times for maintenance, systems will identify the ideal timeframes, schedule the maintenance, and make any other necessary adjustments to production in order to minimize the impact on operations. With machines and systems automating routine tasks and decisions, employees will be able to focus on higher-value tasks such as implementing innovative technology and planning for the future.



Key considerations for Phase Three

1. Move towards autonomous systems and continue driving optimizations

Rather than just predicting when an issue will occur, applications now identify solutions to problems and manage their resolution. These applications enable systems that are self-correcting and self-healing. They drive operational improvements without supervision, taking subjectivity out of the loop.

As in Phase Two, it's helpful to build on the analytics you're already running. For example, perhaps you have a tried and tested prescriptive solution monitoring the consistency of chemical batches that could work autonomously. Based on data you've collected over time, the ML model that recognized that a one-degree shift in temperature improves consistency can be extended to calculate a new set point and transmit it to the MES or the control system. Once the change is implemented, the autonomous system has more accurate data to diagnose other areas for improvement.

These cycles of continuous improvement are digital feedback loops that initiate efficiency and process improvements on their own. Over time, an intelligent platform will increasingly take on more routine and operational tasks—eventually steering the MES autonomously and freeing up time for

employees and operations managers to focus on higher-value tasks.

2. Bring employees along for the journey

You've invested in data teams that will bring this to life, but you can't forget about the frontline employees in the new world of self-optimization. Because these intelligent initiatives change the way that people work, a comprehensive approach to change is essential to success. There will always be a natural resistance to disruptive technology because many perceive their jobs to be at risk. There can also be concern from employees and business leaders around implementing digital feedback loops. They often worry about leaving important decisions to computers, concerned that the ML model will make a mistake.

The truth is that these initiatives don't necessarily eliminate jobs or introduce risk, but rather help employees do their jobs more efficiently, accurately, and at a greater scale. Rather than manually inspecting machines on the factory floor, which might take hours, an operations manager can view machine status on one screen with a single glance.

In order to bring frontline employees along and continue developing their skillsets, the "learning-by-doing" approach won't be enough. In Phase Three, you'll need to put in place a systemic approach to upskilling. This will include a formal program to identify which jobs will need which new skills, and then a process to educate and train those employees.

As you do this, you'll want to maintain transparency across the different business units and walk them through changes. Distributing internal case studies is one great method. Facilitating meetings between teams to go over the results and ROI of intelligent initiatives is another possibility. Show them not only why you're doing this but also how it will affect the workplace. Many manufacturers find that if they bring their employees along in the journey, the employees find it exciting. It changes the way they work, makes their job easier, and gives them more control.

Example of Phase Three

We worked with one manufacturer of warehouse forklifts, trucks, and equipment to infuse analytics and automation throughout their products and service offerings. Leveraging an intelligent platform, they built autonomous forklifts and guided vehicles that automatically adapt to live conditions, ingest data to continually improve performance, and communicate with other machines in a "swarm" that sends the right machines to the right task at the right time. Using ML-powered simulations to train the forklifts, vehicles can quickly learn how to navigate a customer's warehouse—significantly accelerating the deployment of customized solutions.

Outcomes of Phase Three

At this point, you've built a true intelligent operations platform. Machines and systems are working autonomously, continuing to drive optimizations without human input, and taking increasing control over operations. For example, instead of operations managers spending 90% of their time running production and reacting to problems—and only 10% of their time thinking about the future—they can spend 90% of their time focused on higher-value tasks. By relying on these powerful systems, business leaders and employees can focus on driving business value: planning next generation factories, introducing new products, and implementing innovative technology.

The truth is that completely autonomous systems are still years away for most manufacturers. Even the most advanced discrete and process manufacturers leveraging autonomous applications and processes have yet to implement completely autonomous factories and facilities. But this will soon become the new normal for every manufacturer. And the journey doesn't stop there.

What success looks like in Phase Three

- **Rely increasingly on self-optimizing and autonomous systems**
- **Implement intelligent applications organically alongside employees**
- **Focus employees on high-value tasks**
- **Innovate at a rapid pace**

What comes next?

Beyond self-optimizing and autonomous systems, a platform approach also lays the groundwork for new, transformative business models. Process and discrete manufacturers can create new, outcome-based products and offer innovative "as-a-service" models.

For example, a chemical manufacturer could sell fertilizer-as-a-service instead of simply selling batches of fertilizer—delivering higher crop yields for a farmer's specific field conditions and reducing the amount of resources required. Using predictive models, the company can simulate the impact of changing environmental conditions on yield and distribute fertilizer to maximize the positive impact of those factors. Ultimately, the fertilizer company is selling an optimized and personalized service rather than a single product, creating new revenue streams and opportunities.

Conclusion

Together, Microsoft and Capgemini are making this transformation possible for all businesses—no matter where they are in the intelligent manufacturing journey. With an intelligent operations platform, manufacturers can extend their traditional MES with agile, flexible, and scalable data management and analytics capabilities. Microsoft and Capgemini have decades of experience driving innovation and helping manufacturers achieve more. We're dedicated to the open standards, end-to-end security, compliance requirements, open data models, and seamless integrations that define a true intelligent operations platform.

Learn more about how Microsoft and Capgemini can help you make intelligent manufacturing a reality today.

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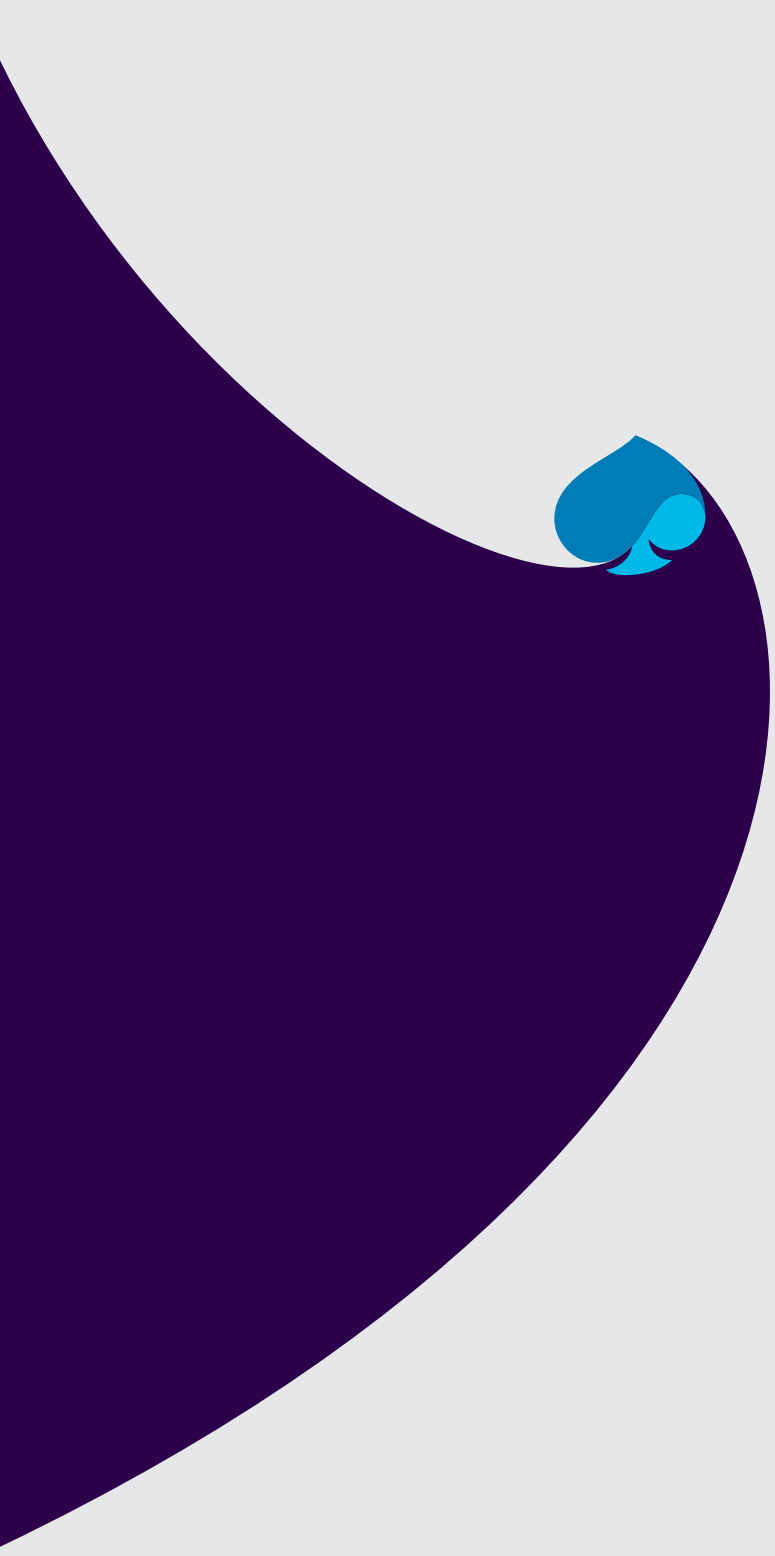

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