Cloud-enabled manufacturing

Operations and IT leaders turn ambition into advantage

In collaboration with

IBM | aws

How IBM can help

IBM can help manufacturers leverage hybrid cloud, AI, and automation to achieve new levels of business agility. We help you set your direction based on a time-tested Industry 4.0 reference architecture and industry standards, achieve scale by consistently deploying advanced shop-floor technologies on an open platform, and unleash optimum value by selecting manufacturing process use cases to address immediate needs. For more information, visit ibm.com/industries/manufacturing

How AWS can help

AWS helps leading manufacturers transform their operations with the most advanced set of cloud solutions, including machine learning, IoT, robotics, and analytics. AWS allows you to focus your resources on optimizing production, creating new smart products, and improving operational efficiencies across the value chain, not on the infrastructure to make it happen. For more information, visit aws.amazon.com/manufacturing/

Key takeaways

Advanced digital technologies underpinned by cloud can power manufacturing transformation.

- Nearly half (48%) of surveyed manufacturers indicate they can harness more value from cloud.

  Companies need to pivot from a focus on cost savings for isolated cloud use cases to an end-to-end, outcome-driven cloud strategy.

- Innovative manufacturers are leveraging cloud to build a foundation for digital dexterity.

  A subgroup of top performers have implemented a data-driven culture 1.7 times more than their closest peer group, positioning them to embrace emerging technologies that drive operational transformation.

- Cloud-enabled digital technologies such as AI and IoT catalyze reinvention.

  Leading manufacturers are modernizing both how they work and the tech tools they use while investing in the digital skills of their workforce to elevate performance and production.

Capturing cloud's potential

As the Industry 4.0 era evolves, manufacturing organizations have been steadily embracing cloud computing, with most reporting significant implementation progress in 2022.[1]

But recent insights from the IBM Institute for Business Value (IBM IBV) and Amazon Web Services (AWS) suggest that many manufacturing organizations may not be optimizing the value—and opportunity—of cloud as the cornerstone for digital transformation. In our global survey of manufacturers, only half (52%) of their IT executives say their organizations are harnessing cloud's benefits.

What is holding them back? Three reasons stand out in our research:

- A surprisingly low number of manufacturing workloads have been migrated to the cloud, hindering advanced operational initiatives where cloud can be a key enabler.
- Some manufacturers lack integrated technology strategies that include cloud, AI, IoT, and application modernization for manufacturing activities.
- Some respondents have focused strictly on cost savings versus additional business outcomes, such as improving performance and increasing value across core manufacturing operations.

The lesson for manufacturers? Merely adopting cloud for simple lift-and-shift workloads or standalone use cases is not enough. A more outcome-driven approach can help them realize benefits such as boosting productivity, quality, machine availability, and sustainability, as well as accelerating engineering efforts and product lifecycle management.

Organizations are tackling the next phase of complex technology-powered initiatives—including supply chain orchestration, quality analysis and resolution, materials and production optimization, and predictive monitoring of assets. And they are learning that these require integration of data, security, and exponential technologies, with the cloud as the foundation to make innovation possible—and powerful. In fact, our research has shown that combining cloud computing with these other levers of business transformation can generate 13 times greater benefits than cloud alone.[2]

Without a more strategic, value-driven approach to cloud, digital transformation in manufacturing becomes more challenging. To explore how manufacturing organizations can unleash more value from cloud and the advanced technologies it enables, we analyzed survey responses from both manufacturing and IT executives at more than 1,100 manufacturing companies worldwide to assess their organizations' digital technology maturity and data maturity. Respondents work in automotive, electronics, downstream oil and gas, chemicals, metals, and industrial machinery (see "Study approach and methodology" on page 32). Our analysis resulted in four archetypes (see Figure 1):

- **Constrained Operators:** behind their peers in both digital technology and data management
- **Digital Enthusiasts:** committed to digital transformation but lagging in their data practices
- **Data-focused Deciders:** invested in data management but lacking technology enablement
- **Transformational Optimizers:** leveraging data and technology to drive success.

FIGURE 1

Manufacturers' maturity in leveraging data and digital technologies is defining how they unlock cloud's deeper value.

Source: IBM Institute for Business Value

We then pinpointed five traits that distinguish Transformational Optimizers, positioning them to outperform the other groups in key performance metrics and achieve cloud-driven benefits:

- A modern cloud platform
- A robust data foundation
- Digital technology integration
- New ways of working
- Business outcomes linked to cloud.

This report dives deeper into each of these attributes, describing the archetypes' efforts in each area to support their operational priorities. An action guide offers a three-step plan for moving forward based on a manufacturer's maturity in digital technologies and data management.

Why have only half of manufacturing organizations harvested business outcomes from cloud?

3 in 4 of application/ system workloads for manufacturing-related operations have not been migrated to cloud

3 in 4 of organizations have not established integrated technology strategies across cloud, AI, and application modernization for manufacturing activities

3 in 5 manufacturing and IT leaders say their organizations do not focus on business outcomes of technology initiatives

IT Q. What percentage of your applications/systems workloads have been migrated from the data center(s) to your cloud estate? IT Q. Describe your organization's technology strategies for the following activities. Manufacturing Q and IT Q. To what extent do you agree with the following statements: IT and manufacturing focus on the business outcomes of technology initiatives; percentages show responses of 4 and 5 on a 5-point scale where 1=strongly disagree and 5=strongly agree.

Traits that transform manufacturing

Trait #1

A modern cloud platform

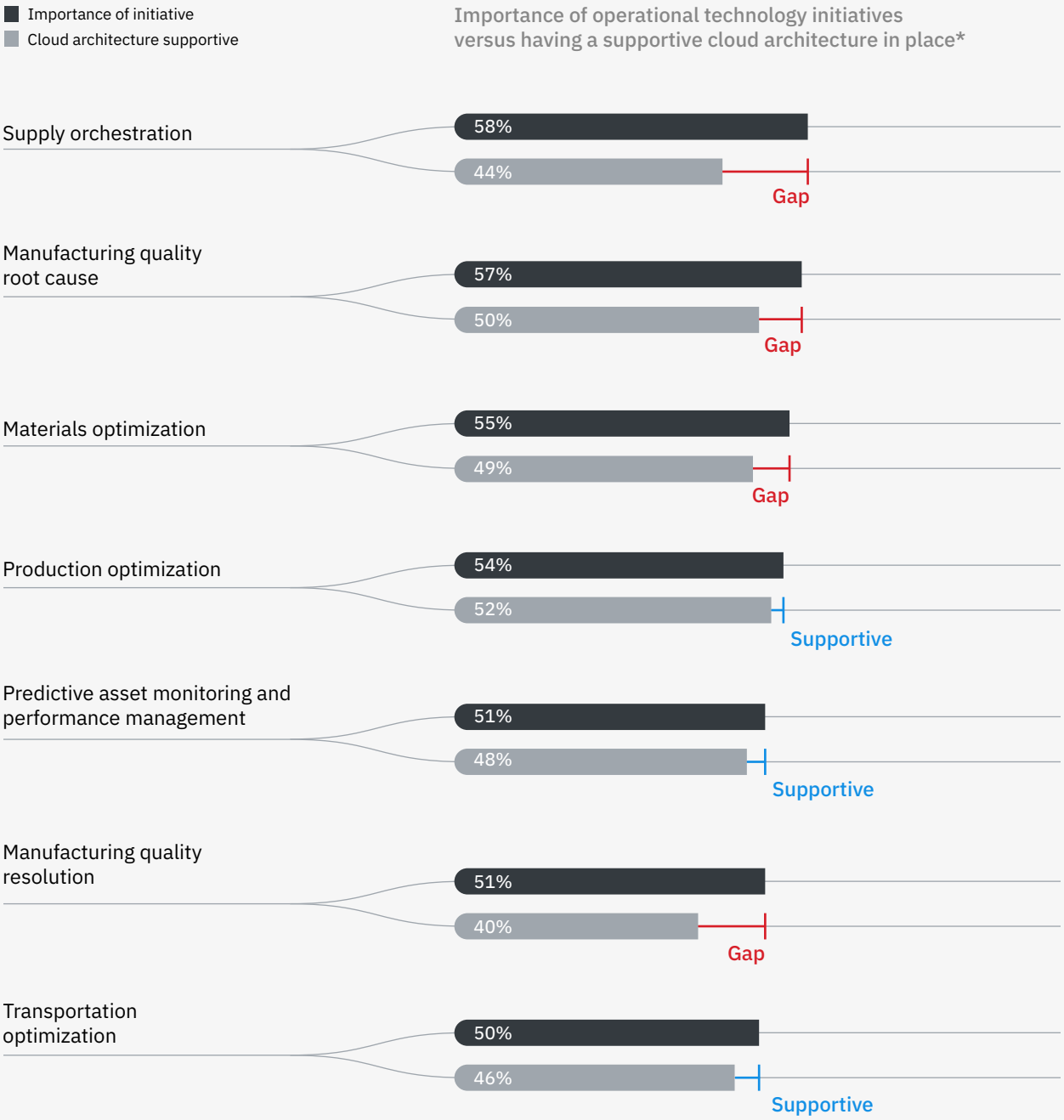
Digital transformation is facilitated by hybrid cloud, which combines and unifies public cloud, private cloud, and on-premises environments to create a single, flexible, cost-optimal IT infrastructure that enables organizations to process data where it makes the most sense.[3] It enables real-time data collected from sensors, devices, and machines on the factory floor to be used by other factory assets, as well as shared across other components in the enterprise software stack, including ERP and other business management software.[4]

Similarly, cloud supports the required IT workloads, such as operational technology (OT)-IT integration, edge analytics, OT security, and both new and traditional applications. Data from different manufacturing operations can be centralized, allowing cross-factory insights, KPI comparison, and optimization.[5] In addition to basic cloud infrastructure advantages, more than 60% of executives in our survey say that advanced cloud capabilities such as containers, portability, and DevSecOps are an imperative for success.

But for many manufacturers, their current cloud architecture insufficiently supports most of their primary initiatives, making it difficult to orchestrate the multiple digital technologies required for implementing these priorities (see Figure 2). For instance, predictive management of assets might require the cloud, IoT, AI, and 5G. Manufacturing quality root cause needs the cloud, IoT, AI, computer vision, and edge computing. Without the cloud underpinning the other technologies, these initiatives could stall or even fail.

FIGURE 2

Executives report their cloud architecture is inadequate for some of their most important technology initiatives.



**A gap is defined as a percentage point difference of more than 5%. Manufacturing Q. How important are the following operational technology initiatives to your organization? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all important and 5=extremely important. IT Q. To what extent does your cloud architecture support your operational initiatives? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.*

Transformational Optimizers have made the most progress in implementing cloud technologies to support advanced operational initiatives (see Figure 3). Take supply orchestration for example—a critical area given that a National Association of Manufacturers survey found nearly 80% of manufacturers cited supply chain disruptions as their number-one business challenge.[6] Transformational Optimizers report their cloud architecture supports supply orchestration 1.5 times more often than peers. They are gaining real-time tracking to monitor and manage the flow of materials and track work in progress and finished goods. With this insight, they can prevent inventory issues by intervening when an issue occurs. Manufacturing executives estimate that optimized supply orchestration can yield 37% lower supply chain costs.

Likewise, Transformational Optimizers report their cloud architecture supports manufacturing quality root cause initiatives 1.4 times more often than peers. The ability to identify problems or defects in manufacturing processes and automate rectification translates to determining the cause of a problem faster and mitigating recurring issues. Executives estimate this focus can reduce the cost impact of poor quality by 57%.

Transformational Optimizers are also better positioned for predictive management of assets—a priority that executives say can increase asset availability by 52%. Using data and analytics, predictive capabilities help facilitate asset utilization and avoid costly downtime and repairs.

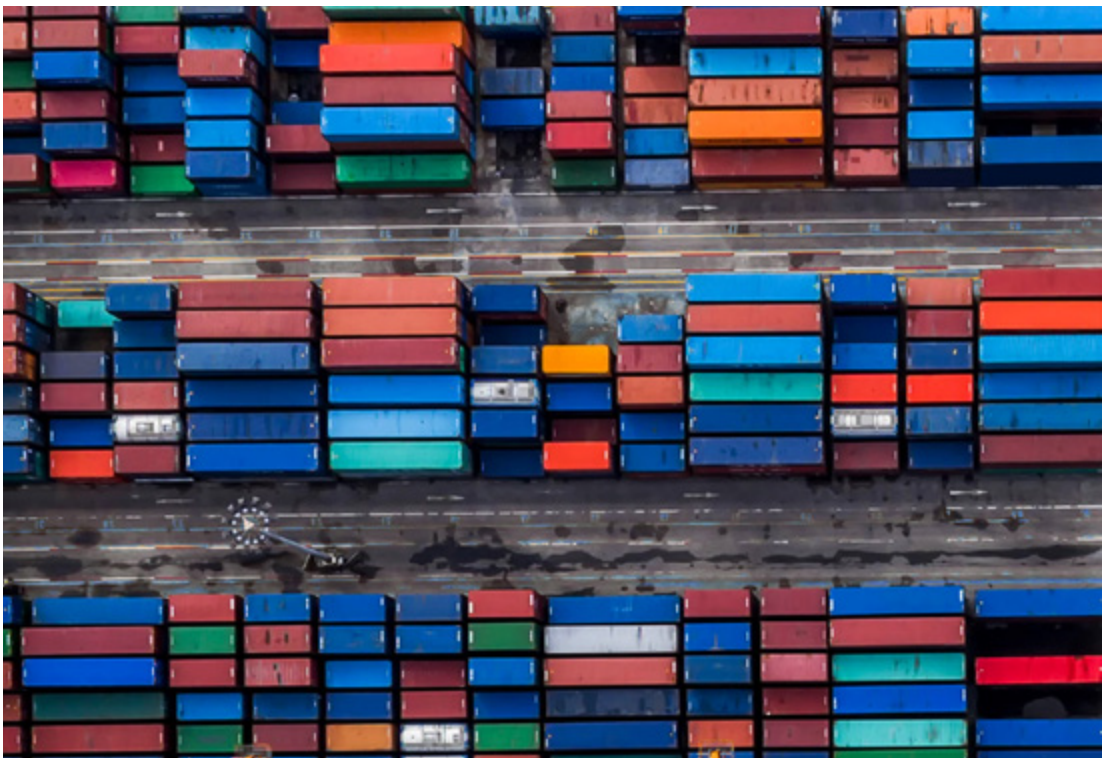


FIGURE 3

Transformational Optimizers claim a more mature cloud architecture to support operational technology initiatives.

Percent that say their cloud architecture supports these operational technology initiatives

IT Q. To what extent does your cloud architecture support your operational initiatives? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Case studies

Volkswagen transforms manufacturing and logistics[7]

To transform its automotive manufacturing and logistics processes, the Volkswagen Group built the Volkswagen Industrial Cloud on AWS, which uses AWS IoT services to connect data from machines, plants, and systems across more than 120 factory sites. The Volkswagen Industrial Cloud aims to yield a 30% increase in productivity, 30% decrease in factory costs, and save over $1 billion in supply chain costs. The Group is also using AWS to expand beyond manufacturing into ride-sharing services, connected vehicles, and immersive, virtual car-shopping experiences to shape the future of mobility.

IBM Systems Manufacturing scales AI value by combining hybrid cloud with edge computing[8]

Rather than build an isolated AI solution, IBM Systems Manufacturing combined hybrid cloud with edge computing to scale the value of AI across the global manufacturing enterprise. It deployed a first-of-its-kind AI visual inspection system on assembly lines in plants in Canada, Hungary, Mexico, and the US.

The solution leverages cloud and edge computing to eliminate bandwidth and latency issues that arise from running AI inferencing in a data center. The AI models are deployed to edge devices where image data is processed, enabling the company to detect anomalies and act on them in real time.

AI models and edge devices are managed from a central location through the cloud, an automated process that reduces software maintenance costs by 20%. Compared to a human inspector, AI automation reduced inspection times from 10 minutes to one minute in one use case.

Trait #2

A robust data foundation

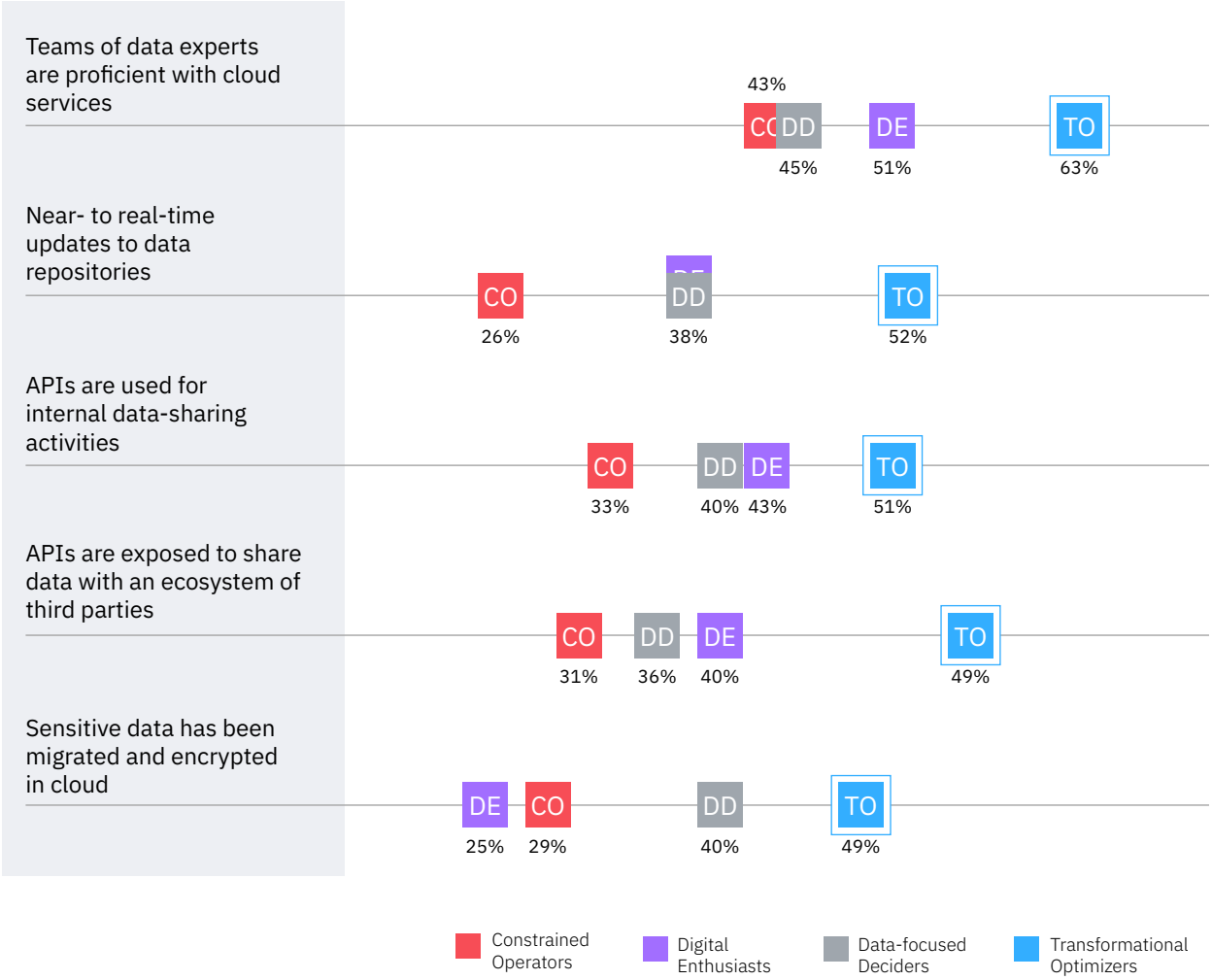
Manufacturers have more than enough data to fuel far-reaching operational changes, but approximately 90% of that data stagnates in isolated systems.[9] Cloud computing flips the script, enabling manufacturers to cultivate a culture where high-quality data is democratized and employees are skilled in digital technologies. Data from equipment, processes, and systems feeds deeper insights that drive continuous process improvement.

Transformational Optimizers demonstrate the greatest data maturity, having implemented a data-driven culture 1.7 times more than their closest peer—Data-focused Deciders—and 2.9 times more than Constrained Operators. These leaders are leveraging the cloud and other technologies to strengthen data management practices (see Figure 4). For example, nearly two-thirds (63%) of Transformational Optimizers have teams of data experts who are skilled in cloud services, and they have near real-time capabilities to update data repositories. This helps ensure that employees can tap into the most current data for insights that power improved factory operations.

FIGURE 4

Cloud underpins strong data management practices to sharpen factory operations.

Percent that are implementing these data management practices



IT Q. To what extent does your manufacturing organization use the following data management practices? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Case study

Panasonic Connect conquers complexity with shop-floor analytics[10]

To support chip manufacturers adapting to new semiconductor packaging trends, Panasonic Connect has infused advanced analytics into two process control solutions that have emerged as the company's first smart-factory offerings.

The first solution created an advanced plasma dicer—a specialized tool for more precise cutting and processing of semiconductor wafers—by fully automating the "recipe" generation, which determines the optimal combination of decisions on variables that affect the process. This solution reduced the development cycle time by as much as 30%.

The second solution optimized plasma cleaner machine performance through smarter, data-driven maintenance practices. The combination of reduced unnecessary maintenance, proactive parts ordering, and fewer machine outages helped decrease maintenance costs for manufacturing customers by 50%.

Data-driven maintenance practices helped decrease maintenance costs for manufacturing customers by 50%.

Trait #3

Digital technology integration

Manufacturers recognize the importance of digital technologies to their initiatives. IoT sensors monitor plant production, energy consumption, inventory, and asset maintenance. Additive manufacturing—also known as 3D printing—enables creation of bespoke parts and supports agile design changes. AI helps automate manufacturing production processes and improve quality control, while the growth of generative AI opens the door to even more advanced AI use cases (see Perspective, “Anticipating the boost from generative AI” on page 17).

These technologies, when deployed in concert, propel innovation. The cloud enables that integration. Transformational Optimizers are integrating the cloud with enabling technologies to a greater extent than peers in all areas except AI, where Data-focused Deciders are likely capitalizing on their commitment to data (see Figure 5).

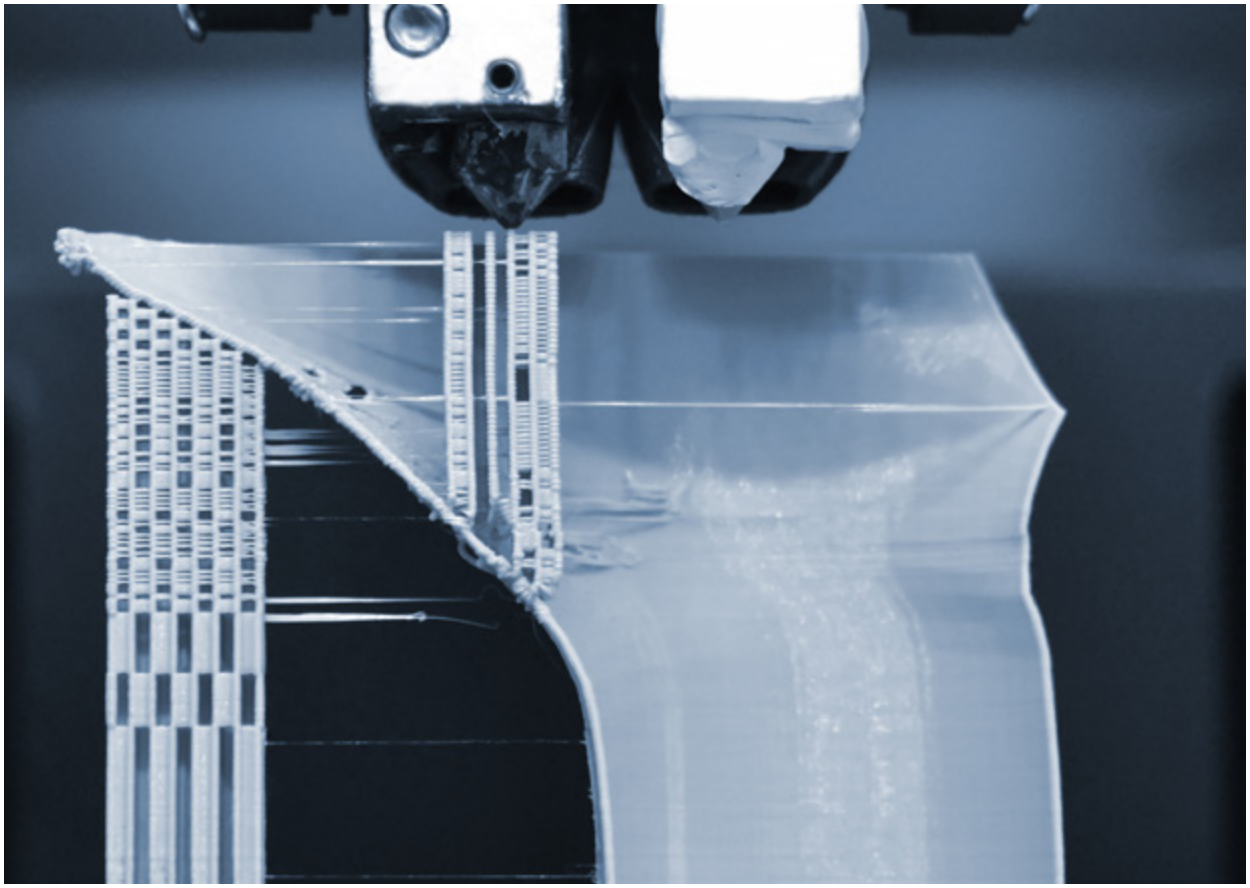


FIGURE 5

Cloud platforms enable integration of digital technologies to spur innovation.

IT Q. To what extent do your cloud platforms integrate with the following digital technologies in your manufacturing organization? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

One technology that fuses the power of IoT and both traditional and generative AI for enormous potential benefits to the manufacturing industry is digital twins. Offering a virtual representation of a system across its lifecycle and updated from real-time data, digital twins use simulation, machine learning, and reasoning to strengthen decision-making and drive efficiency, innovation, and competitiveness.[11] Transformational Optimizers are using digital twins dramatically more than their peers (see Figure 6).

FIGURE 6

Leading manufacturers use digital twins to combine real-time simulation and controls.

Use of digital twins in manufacturing operations

Manufacturing Q. To what extent has your organization used digital twins in the following areas of your manufacturing operations? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Similarly, Transformational Optimizers report heightened security readiness through the cloud (see Figure 7). They recognize that the combination of AI and the cloud is critical to defending against cyberthreats. As IT and OT become more intertwined, the OT network and connected OT devices are increasingly exposed to security risks, while remote access to OT networks by outside vendors further expands vulnerabilities. In fact, IBM X-Force® reported that manufacturing continued to be the top attacked industry in 2022.[12]

FIGURE 7

Transformational Optimizers are building cyber resilience with robust security practices.

IT Q. To what extent has your manufacturing organization adopted the following security practices? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Perspective

Anticipating the boost from generative AI in manufacturing

Our study reveals that manufacturing executives expect generative AI to improve manufacturing processes across a range of areas (see figure). Four significant pillars of impact include:

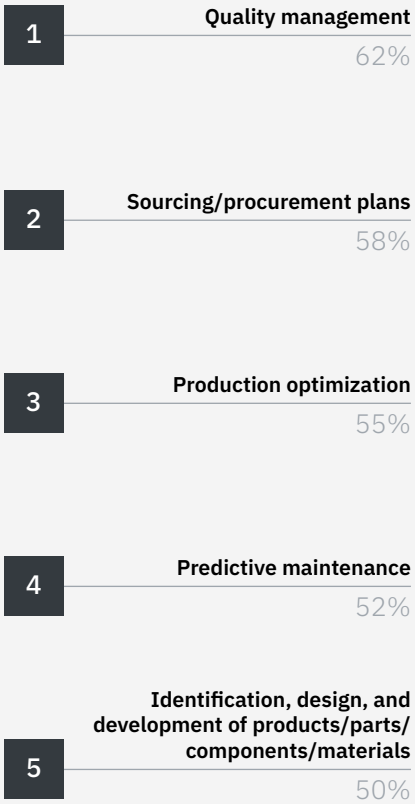
Production quality and optimization. Generative AI systems can ingest a large amount of production data and proactively detect quality issues in production. The combination of IoT and generative AI can identify real-time anomalies and optimize production accordingly, ultimately improving overall equipment effectiveness.

Sourcing and procurement. Off the factory floor, generative AI can assist with vendor discovery and evaluation, pricing, supply chain risk assessment, and contracts.

Predictive maintenance. With asset sensors continuously monitoring variables such as temperature, flow, and pressure, generative AI models can leverage the data to recognize the normal operational behavior of equipment and then identify deviations to predict and rectify equipment issues.

Product design and development. An array of alternatives for products, parts, components, and/or materials can be created by generative AI models. Using variables specified by engineers such as cost and operational criteria, generative AI algorithms can help create entirely new, innovative designs.

Operations where executives expect generative AI to have an impact



Manufacturing Q. Where do you see generative AI impacting your manufacturing operations? Percentages show responses of 4 and 5 on a 5-point scale where 1=very low and 5=very high.

Case studies

Doosan Digital Innovation protects investment in digital transformation[13]

Doosan Digital Innovation (DDI) embraced the idea that an effective, comprehensive cybersecurity program should be the foundation of digital transformation. To that end, the company identified and mapped appropriate roles and responsibilities of its staff working within the security infrastructure. DDI also consolidated its regional security operation centers (SOCs) to a unified, global SOC that delivers 24x7 monitoring and protection.

To control the operations of the global SOC, DDI updated its core security infrastructure. The team enhanced the company's proactive security incident and event management efforts, deploying technologies to oversee endpoint detection and response and delivering AI-based automation that further streamlines threat responses. As a result, the company accelerated threat reactions, cutting approximately 85% from response times.

SRAM drives innovation with next-generation manufacturing[14]

To improve the cycling experience, SRAM, a bicycle component manufacturer, has embraced the use of new materials and advanced manufacturing techniques. Working with AWS and its partner Autodesk, SRAM is leveraging generative design, which is a form of AI that uses cloud computing to speed time to design and time to market while optimizing performance.

Using generative design tools, SRAM can now generate multiple concepts at the beginning of the project and then evaluate each to choose the ones most promising to be produced using additive manufacturing (3D printing). This approach enabled them to produce a part that was twice as strong and 20% lighter in less time with fewer resources.

Trait #4

New ways of working

Transformational Optimizers have radically changed how their organizations work by:

- Investing in digital and data skills
- Training their employees in digital technologies
- Redefining the relationship between manufacturing and IT
- Establishing an operating model for their cloud operations.

They outperform their peers in each area and gain the added benefit of making traditionally mundane factories more appealing to tech workers.

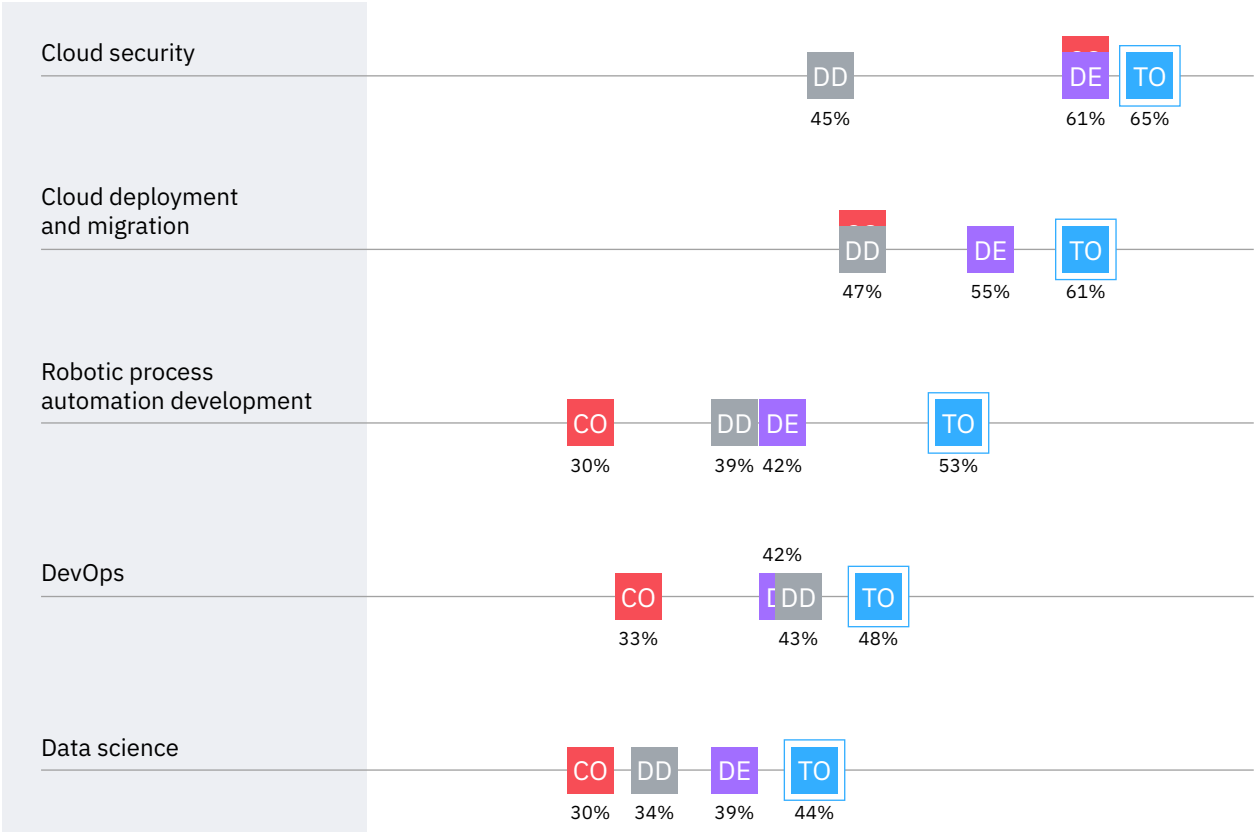
Nurturing digital and technology skills

While each archetype is actively investing in technology skills, Transformational Optimizers are ahead in all areas (see Figure 8). They sense the urgency of having employees who can put intelligent automation, data, and digital technologies to work. Three in five say they are training their employees with digital technologies and intelligent machines/devices, compared to less than half of the other archetypes.

FIGURE 8

Manufacturing organizations are investing in their workforces to close the digital skills gap.

Percent that are investing in these skills to support digital initiatives



IT Q. To what extent has your organization invested in the following skills to support digital initiatives in manufacturing? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Notably, all archetypes have significant room to improve their workforce's data science skills, which support optimization of products, simulation, and automation. Filling this need will become even more difficult as cross-industry demand for data scientists is projected to climb 36% from 2021 to 2031.[15]

Creating synergy between manufacturing and IT

Essential to implementing manufacturing's OT priorities is a shared understanding between IT and manufacturing executives. About three in five manufacturing executives from each of the four archetypes agree that they collaborate effectively with their organization's CIO/CTO. Likewise, IT leaders agree that they work effectively with the Chief Manufacturing Officer/Head of Manufacturing.

Where Transformational Optimizers differentiate themselves is the effectiveness of their manufacturing executives' relationships with their Chief Information Security Officers (CISOs) and their IT executives' relationships with manufacturing maintenance managers. They report effective collaboration with CISOs and maintenance managers far more than peers. The CISO partnership is essential to provide control over technology and devices and help ensure a safe OT environment. Transformational Optimizers recognize that manufacturing transformation is a team effort that requires synchronization across key activities; it cannot be successful at just a leader level.

Establishing cloud operating models

Transformational Optimizers embrace modernization of their operating models to empower new ways of working. As the bedrock for data-driven operations, cloud creates the opportunity for cultural change where teams are entrusted with decisions and collaborate more effectively (see Figure 9). For example, small teams assume responsibility for end-to-end operational tasks. Cross-functional collaboration supports infrastructure development and autonomous decision-making about how best to deliver business outcomes.

FIGURE 9

Cloud enables a culture of empowerment and collaboration.

Percent that are applying these practices to cloud operations

IT Q. To what extent are the following practices applied to your cloud operations? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Case studies

Georgia-Pacific optimizes manufacturing production[16]

For Georgia-Pacific, a wood products, pulp, and paper company, getting valuable manufacturing insights was a challenge because the organization relied on disparate sources to collect and analyze data on material quality, moisture content, temperature, machine calibration, and other features. The company chose to create a new analytics solution based in the AWS Cloud.

Georgia-Pacific established a central data lake and streams real-time structured and unstructured data from manufacturing equipment to it for analysis. The solution enabled the company to optimize key manufacturing processes in many of its facilities, helping to increase profits by millions, predict equipment failure 60-90 days in advance to reduce downtime, run more production lines in a predictable manner, and produce highest-quality products at the fastest possible rates.

Rittal leverages a managed edge appliance for industrial analytics[17]

For manufacturers, operational data is often trapped in traditional OT architectures. Rittal GmbH & Co., a manufacturer of electrical and IT enclosures, is resolving the issue by adopting German Edge Cloud's ONCITE, an open, industrial edge appliance powered by AI-based analytics and hybrid cloud. Deployed in the plant at the network edge to avoid latency, ONCITE includes a set of production optimization tools such as smart manufacturing operations management, a manufacturing execution system, an industrial IoT framework, and visual inspection.

Rittal uses ONSITE to manage 250 networked production machines that generate up to 18 terabytes of data each day. After combining real-time IoT data from factory stations with product information from the ERP system, ONCITE analyzes the data in near-real time. As a result, managers can quickly visualize the status of production and gain insights into how to improve.

Trait #5

Business outcomes linked to cloud

To experience cloud's deeper benefits as an enabler of exponential technologies, manufacturing leaders must purposefully pursue its value. That means building a business case with clear outcomes and adopting ongoing, disciplined cloud financial management, also known as FinOps. FinOps provides visibility into how and where cloud services are needed and being used, what they cost, and what business benefits they deliver.

Transformational Optimizers demonstrate the importance of bringing the finance function to the table (see Figure 10). They understand finance can facilitate three critical tasks:

- Creating a coherent financial justification for cloud investments
- Becoming a system of record for tracking cloud needs, usage, and cost
- Connecting cloud investments to quantifiable business outcomes.

Transformational Optimizers leverage real-time data to enable process measurement and reporting that yields insight into cloud benefits. With this knowledge of cloud costs and usage, organizations can better account for their cloud spending, helping avoid a legacy of "cloud waste"—or overspending on cloud—that plagues many organizations.[18]

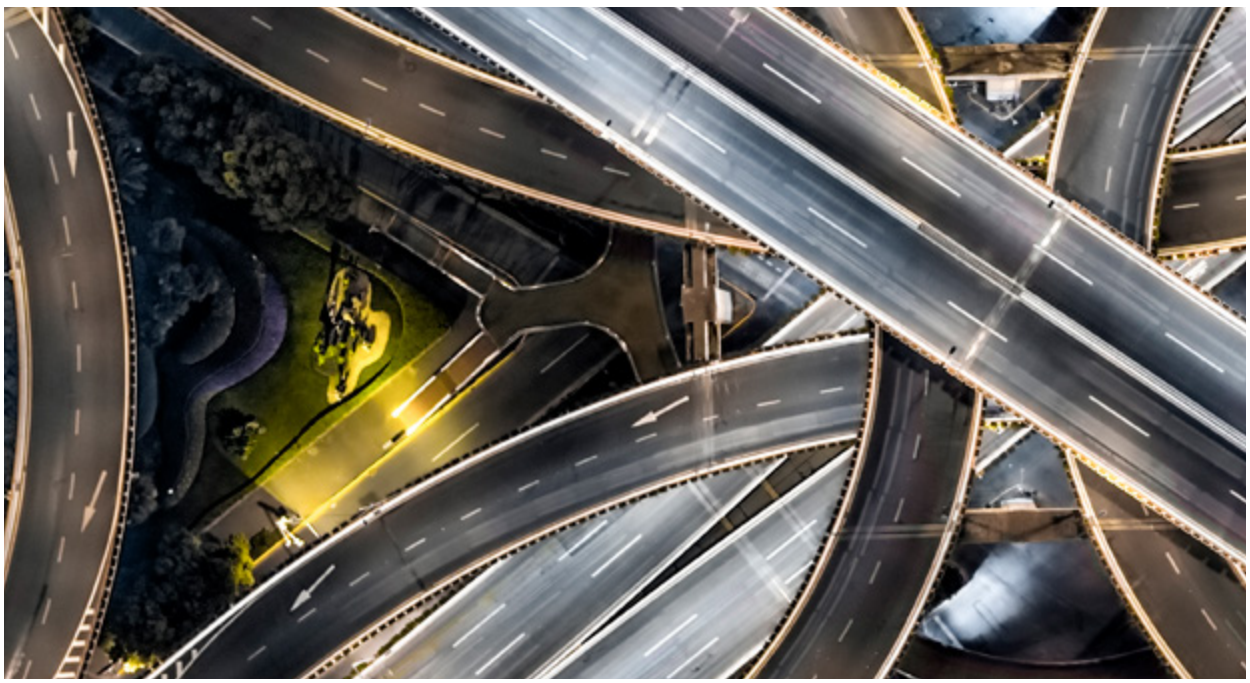


FIGURE 10

Manufacturing leaders quantify the value of cloud by collaborating with the finance function.

IT Q. To what extent has your organization implemented the following to support cloud investments in manufacturing? Percentages show responses of 4 and 5 on a 5-point scale where 1=not at all and 5=to a very large extent.

Case study

Toyota creates a smarter, more digital factory[19]

At Toyota Indiana, the company is preparing its East plant for continuous-run operations where minimizing downtime and having zero defects is critical. To enable the next-gen maintenance worker, the company has consolidated multiple IT tools supporting equipment maintenance into a common platform. It implemented a cloud-based enterprise asset management system that contextualizes and integrates a programmable logic controller (PLC), sensor, and existing manufacturing data such as work orders, and uses AI to gain better insights. The solution allows a team member to see the health of the equipment and its components, monitor for abnormal activities, and use predictive solutions to shift maintenance work from reactive to proactive.

A cloud-based enterprise asset management system plus AI-powered analytics helps shift maintenance work from reactive to proactive.

Action guide

To help manufacturers move forward in their journey with cloud and advanced technologies and harness deeper value, we've put together a three-step plan.

01

Assess yourself

Next steps depend on your maturity in digital technologies and data. Your well-considered answers to the following questions help determine your current state and the organizational archetype with which you most closely align.

Digital maturity

- Do you align cloud technologies to deliver business outcomes in manufacturing operations?
- Do you invest in machine learning/AI skills to support digital initiatives in manufacturing?
- Do you view digital technologies such as IoT, robotic process automation, additive manufacturing, AI, and computer vision as critical in advancing manufacturing objectives?
- Have you integrated cloud services with digital technologies in your manufacturing organization?

Data maturity

- Do you actively invest in data-driven architecture?
- Do you encourage your teams to experiment with available data?
- What is your maturity level in using a data mesh or data fabric?
- Do you invest in database (manage, store, access data) skills to support digital initiatives in manufacturing?

02

Draft a blueprint

Regardless of your starting point, you should address three core priorities to help boost cloud benefits.

Charter a formal scope that defines the purpose and goals of your cloud-driven transformation efforts.

- Include the use cases to implement, noting that some are easier than others (for example, engineering shift to cloud is easier, overall equipment effectiveness [OEE] optimization is harder, supply chain orchestration is most difficult).
- Create an integrated technology strategy to support multiple use cases.
- Define the architectural requirements and decisions and operational design of cloud solutions with total cost of ownership, return on investment, and business outcomes. Several business case tools exist to help accelerate the migration to cloud.
- Organize data into an "information architecture" that aligns with the various levels of manufacturing systems.

Design and build internal workflows and processes around FinOps.

- Establish an organizational home for FinOps capabilities with executive buy-in.
- Develop governance through a responsibility assignment matrix with resources from finance, IT, engineering, and business.
- Define KPIs to measure FinOps success.
- Identify cloud cost management tools to help monitor, measure, and control cloud spend, budgeting, forecasting, and chargebacks. This allows you to reflect variable costing, agile scenario planning, and incentives for common cloud objectives.

Provide visibility into cloud benefits based on data by enabling process measurement and reporting.

- Determine cloud cost allocation.
- Build a data repository of cloud costs and usage.
- Maintain a cloud budget.

03

Optimize your efforts

The unique structure of each organization dictates many possibilities. We've constructed an impact-focused guide for each of the four archetypes; even the leading operators can get better.

Transformational Optimizers

- Capitalize on the cloud environment to continuously improve business outcomes and increase competitive advantage.
- Finalize the adoption of cloud applications to achieve full steady state.
- Automate discovery, linking, semantic enrichment, and understanding of business-ready data.
- Leverage the robust data foundation to support high-priority initiatives, such as supply chain, materials optimization, and product quality.
- Implement capabilities to govern the lifecycle of AI models to identify and eliminate drift and bias.
- Pursue the manufacturing quality resolution (cloud, IoT, AI) initiative. A manufacturing quality system should automatically enforce the use of approved materials. With deviations, reports are automatically generated, and traceability is in place. Closed-loop corrective and preventive action tracking systems integrated with the quality system enable the identification and resolution of quality issues.
- Invest in the transportation optimization (cloud, IoT, AI, robots) operational initiative. Transportation management systems link with ERPs, monitor freight and fleet status and movements, and track carbon emissions.
- Continuously challenge the "status quo" to drive innovation. Leverage process mining tools to identify improvement opportunities. Encourage experimentation across all teams.
- Add data and digital technology skills.
- Implement an organization model and enabling technologies to scale up initiatives across the enterprise.

03 Optimize your efforts

Data-focused Deciders

- Deploy advanced operational initiatives that require integration of data, security, and exponential technologies in the cloud.
- Accelerate adoption of a cloud foundation to expedite achievement of business outcomes.
- Implement a data lakehouse as a unified repository to support analytical and AI workloads.
- Adopt AI/analytics and automation technologies to support plant operators' decision-making in complex manufacturing processes.
- Focus on supply orchestration (cloud, IoT, AI, edge). Data integration is required for supply-and-demand visibility and planning. Control towers connect with IoT sensors, AI analytics, ERP, transportation management systems, and warehouse management systems.
- Use AI and automation technologies to redefine how work is done, aiming to optimize productivity.
- Add data, digital technology, cloud security, and cloud deployment skills.
- Leverage AI to predict and optimize business performance with proactive actions.

Digital Enthusiasts

- Use a cloud environment as the foundational enabler to achieve business outcomes.
- Leverage a cloud foundation to continue adoption of cloud technologies, aiming to achieve steady state in the near term.
- Establish a standardized data architecture, data commonality, and governance to engender trust in data.
- Deploy a data foundation at the enterprise and industrial edge, including data fabric to contextualize data from multiple sources and harness data as an asset.
- Process real-time data to calculate KPIs and other leading indicators to anticipate and prevent problems.
- Implement initiatives to drive OEE improvement.
- Focus on supply chain orchestration.
- Empower front-line workers with the information they need to make better informed decisions.
- Add data, digital technology, and cloud deployment skills.
- Refine the operating model to include small teams to manage end-to-end cloud operations.
- Collect data to calculate and track KPIs that quantify business outcomes.

Constrained Operators

- Define and implement a cloud strategy to facilitate achievement of desirable business outcomes.
- Establish a cloud foundation to enable deployment of digital technologies from the industrial edge to public cloud.
- Establish a standardized data architecture, data commonality, and governance to engender trust in data.
- Establish IoT capabilities to capture real-time data from OT/factories for enterprise applications.
- Integrate data, security, and exponential technologies to accelerate digital transformation.
- Automate security, privacy, and usage policies enforcement to reduce cyber risks to supervisory control and data acquisition (SCADA) and industrial control systems.
- Enhance employee understanding of intelligent machines.
- Add data and digital technology skills.
- Define metrics and KPIs, baseline current operations, and define targets to achieve the desirable outcomes enabled by technologies deployed in the cloud.

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Leading the global automotive and manufacturing organization, Wendy is responsible for supporting the world's largest automotive original equipment manufacturers (OEMs), suppliers, and cross-segment manufacturing companies to accelerate their digital transformation journeys while maximizing value creation. Wendy spent more than 20 years in the automotive industry in leadership roles across both OEMs and tier 1 suppliers. Her experience spans sales, product strategy and business development, engineering, purchasing, and quality. Wendy has been recognized as a Software-Defined Vehicle Innovator Leader by *MotorTrend* (2023), as one of the top 100 Leading Women in the North America Auto Industry (2020), and a Rising Star–OEM and Supplier (2016) by *Automotive News*.

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Scot manages AWS's manufacturing industry marketing efforts. He has over 25 years of experience in manufacturing operations with companies such as Cisco and Rockwell Automation. He focuses on marketing to industrial customers on their digital transformation journey and bridging the gap between IT and operations.

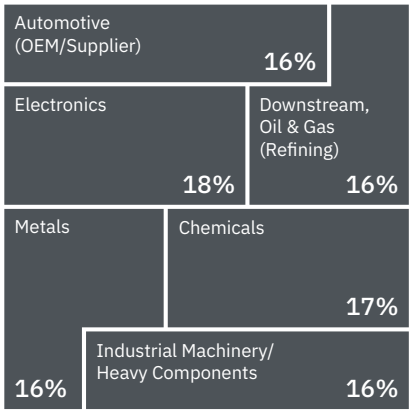
Study methodology and approach

In cooperation with Oxford Economics, the IBM Institute for Business Value and AWS surveyed 1,171 manufacturing companies in 21 countries from June to July 2023. Two surveys were conducted with each company as part of this effort.

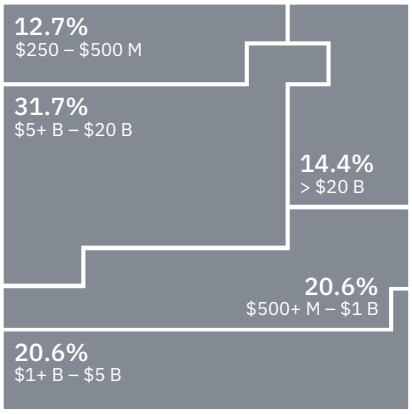
- IT leadership: executives significantly involved in defining or implementing cloud computing strategies for the manufacturing area. We collected responses from Chief Information Officers, Chief Technology Officers, and heads of IT.
- Manufacturing leadership: executives significantly involved in defining or implementing their manufacturing organization's technologies. We collected responses from Chief Manufacturing Officers or equivalent, Vice Presidents/ Directors of Manufacturing/Production, and Plant Managers.

These executives come from different industries and organizations of diverse sizes. All data is self-reported.

Industries



Enterprise size (annual revenues)



Note: Due to rounding, percentages total slightly below 100%

In terms of data analysis, we clustered organizations surveyed based on their capabilities in two dimensions:

- Digital maturity: alignment of cloud to deliver business outcomes in manufacturing operations, investment in machine learning/AI skills to support digital initiatives in manufacturing, importance of digital in advancing manufacturing objectives (computer vision), and integration of cloud platforms with digital technologies in manufacturing organization (computer vision).
- Data maturity: data-driven architecture, data mesh or data fabric, and database (manage, store, access data) skills investment to support digital initiatives in manufacturing.

This yielded four distinct archetypes:

- Transformational Optimizers stand out in their capabilities across the two dimensions.
- Digital Enthusiasts place a relative focus on advancing their digital agenda and have extended capabilities in digital and data, albeit far less than the Transformational Optimizers.
- Data-focused Deciders are far along with data capabilities but have not made enough progress on digital.
- Constrained Operators lag behind the other archetypes in digital and data.

By comparing the performance and practices of the archetypes, we were able to identify the activities that distinguish each group. These findings help ascertain the pillars of progress needed for each archetype.

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About AWS

For over 15 years, Amazon Web Services has been the world's most comprehensive and broadly adopted cloud offering. Today, we serve millions of customers, from the fastest-growing startups to the largest enterprises, across a myriad of industries in practically every corner of the globe. We've had the opportunity to help these customers grow their businesses through digital transformation efforts enabled by the cloud. In doing so, we have worked closely with the C-suite, providing a unique vantage point to see the diverse ways executives approach digital transformation—the distinct thought processes across C-suite roles, their attitudes and priorities, obstacles to progress, and best practices that have resulted in the most success.

About Research Insights

Research Insights are fact-based strategic insights for business executives on critical public- and private-sector issues. They are based on findings from analysis of our own primary research studies. For more information, contact the IBM Institute for Business Value at iibv@us.ibm.com.

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Manufacturing 4.0

Manufacturing 4.0: From data to decisions. IBM Institute for Business Value. May 2022. https://ibm.co/manufacturing-4-0

Notes and sources

1 Favilla, José, Spencer Lin, and Marcelo Sávio. *Manufacturing 4.0: From data to decisions.* IBM Institute for Business Value. May 2022. https://ibm.co/manufacturing-4-0

2 Payraudeau, Jean-Stéphane, Anthony Marshall, and Jacob Dencik. *Unlock the business value of hybrid cloud: How the Virtual Enterprise drives revenue growth and innovation.* IBM Institute for Business Value. July 2021. https://ibm.co/hybrid-cloud-business-value

3 "What is Hybrid Cloud?" IBM website. Accessed November 10, 2023. https://www.ibm.com/topics/hybrid-cloud

4 "What is Industry 4.0?" IBM website. Accessed August 22, 2023. https://www.ibm.com/topics/industry-4-0

5 "Industry 4.0 architecture for manufacturing." IBM website. Accessed August 22, 2023. https://www.ibm.com/cloud/architecture/architectures/industry-40/

6 *2022 3rd Quarter Manufacturers' Outlook Survey.* National Association of Manufacturers. Accessed August 31, 2023. https://www.nam.org/2022-3rd-quarter-manufacturers-outlook-survey/

7 "Volkswagen Group." AWS website. Accessed August 7. 2023. https://aws.amazon.com/solutions/case-studies/innovators/volkswagen-group/

8 Ouyang, Christene. "Edge computing and hybrid cloud: scaling AI within manufacturing." *IBM Blog.* August 3, 2021. https://www.ibm.com/blog/maximizing-enterprise-value-ai-edge-computing/

9 Weber, Austin. "The Big Data Dilemma." *Assembly Magazine.* August 24, 2021. https://www.assemblymag.com/articles/96570-the-bigdata-dilemma

10 "Helping semiconductor engineers conquer complexity with shop-floor analytics." IBM website. October 2022. https://www.ibm.com/case-studies/panasonic-connect

11 "What is a digital twin?" IBM website. Accessed August 23, 2023. https://www.ibm.com/topics/what-is-a-digital-twin

12 *X-Force Threat Intelligence Index 2023.* IBM Security. February 2023. https://www.ibm.com/reports/threat-intelligence

13 "New cyberthreats demand new approaches." IBM website. October 2022. https://www.ibm.com/case-studies/doosan-digital-innovation

14 "SRAM transforms cycling with Autodesk on AWS, delivering components that are 20 percent lighter and 2x stronger." AWS website. Accessed November 9, 2023. https://aws.amazon.com/partners/success/autodesk-sram/

15 *Occupational Outlook Handbook.* US Bureau of Labor Statistics. Accessed August 31, 2023. https://www.bls.gov/ooh/math/data-scientists.htm

16 "Georgia-Pacific Optimizes Processes, Saves Millions of Dollars Yearly Using AWS." AWS website. Accessed November 10, 2023. https://aws.amazon.com/solutions/case-studies/georgia-pacific/

17 Kremer, Bernd and Andreas Zerfas. "Data is the engine: Powering a smart manufacturing edge appliance." *IBM Blog.* May 18, 2021. https://www.ibm.com/blog/smart-manufacturing-edge-appliance-with-ai-and-cloud/

18 *Flexera 2023 State of the Cloud*. Flexera. Accessed March 14, 2023. https://info.flexera.com/CM-REPORT-State-of-the-Cloud

19 "Manufacturing operations management with IBM Maximo Application Suite." IBM website. Accessed July 28, 2023. https://www.ibm.com/products/maximo/manufacturing

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