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Accelerate Industrial Transformation

How manufacturers prepare shop floors for a future with AI

June 2024

Why read this paper?

Factories and plants are evolving, with manufacturers adopting new technologies and paradigms to help them utilize their data better and secure their operations. The adoption of advanced shopfloor technologies including software containerization, centralized device management, and industrial data operations has ushered new operating paradigms for scalability, automation, and serviceability for numerous organizations. This transformation improves the way businesses extract insights from their production environment, make real-time decisions, and boost operational efficiency. AI integration is the foreseeable next paradigm shift, promising to add even greater operational efficiency and automated decision-making on factory floors; however, many companies remain unsure how to prepare for this shift.

This paper presents insights on how manufacturers are modernizing their operations to prepare for a future in which AI plays a key role on the shop floor. It outlines the building blocks to using AI on the shop floor and intends to present learnings that will serve as a guide to best practices in preparing factories for a future with AI.

Read this paper to understand what is behind the following six key findings:

1. **Scalable, automated, and serviceable factories are the future**
   - A majority of survey participants (72%) highlight scalability, alongside automation and serviceability, as crucial factors for the future of manufacturing.
   - These paradigms ensure that factories can efficiently expand with demand, operate with minimal manual decision making, and maintain high uptime through easy troubleshooting and maintenance.
2. **Cybersecurity and data management are top of mind right now**
   - Security vulnerabilities and data management complexities present pressing challenges, with 58% of respondents viewing cybersecurity as a severe issue.
   - This concern is steering current technological priorities toward enhancing network security and ensuring the integrity and availability of data for decision-making.

3. **Device management is critical for security and data handling**
   - With 68% of participants acknowledging the importance of device security, device management emerges as a pivotal practice.
   - It addresses security threats and manages data flow, underlining the evolving scope of device management beyond mere updates and device health monitoring.

4. **Containerized workloads are coming to the shop floor**
   - The adoption of containerized software on the shop floor is rising, with 85% of survey respondents already utilizing this technology.
   - This shift towards containerization at the edge signifies a move to improve operational efficiency, system stability, and security.

5. **Industrial data operations push the limits of operational technology data management**
   - Integrating information technology (IT) and operational technology (OT) systems through industrial data operations is gaining traction, with 52% of respondents deeming it as very or extremely important.
   - This approach aims to streamline data flow, enhance quality, and provide value, indicating a burgeoning investment in technologies that facilitate seamless IT/OT integration.

6. **Respondents are investing in underlying data architecture for AI**
   - Manufacturers are prioritizing adjustments to their data architecture to accommodate AI, focusing on AI-based predictive maintenance and the emergence of generative AI.
   - This investment reflects an understanding of the need to address technical complexities and skill challenges to harness AI's full potential in future manufacturing operations.

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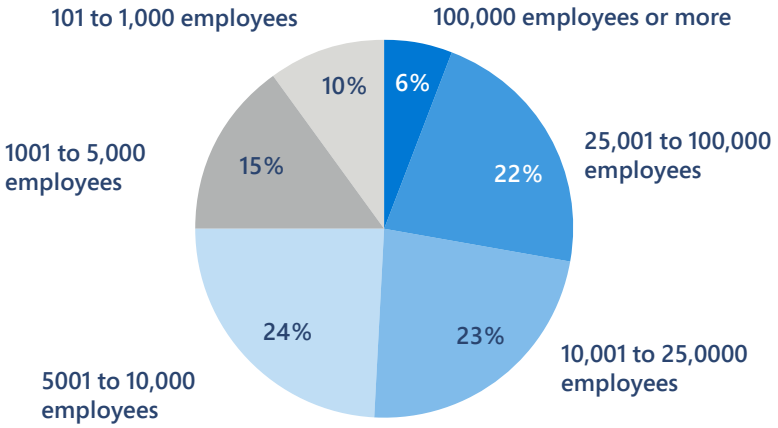
Methodology

Microsoft developed this document in close collaboration with IoT Analytics, a boutique market research company focusing on IoT, AI, the cloud, edge technology, and Industry 4.0.

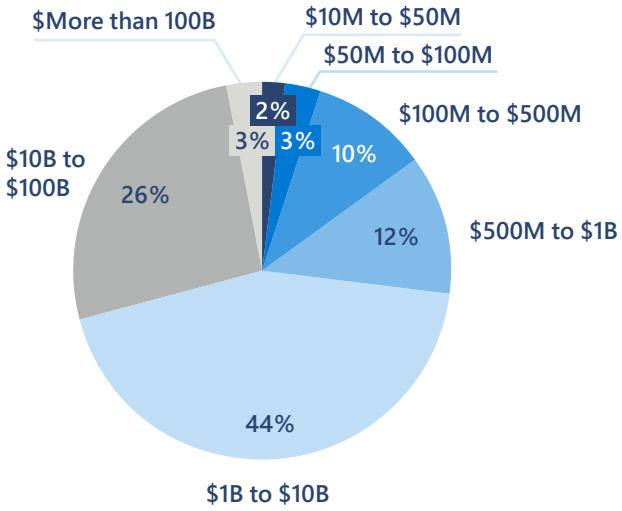
The centerpiece of this research is a survey conducted between February and April 2024, with a total of 500 respondents working in manufacturing worldwide. The respondents are key stakeholders in their employers' smart manufacturing strategies. They represent a variety of manufacturing segments, from both discrete manufacturing (e.g., automotive) and process manufacturing (e.g., chemicals), and are equally distributed across North America (33 %), Europe (33 %), and Asia-Pacific (33%). The size of their organizations varied in size: 75 % of respondents worked at companies with more than 5,000 employees, 15 % with 1,000–5,000 employees, and 10 % with less than 1,000 employees.

Overview of N=500 participants

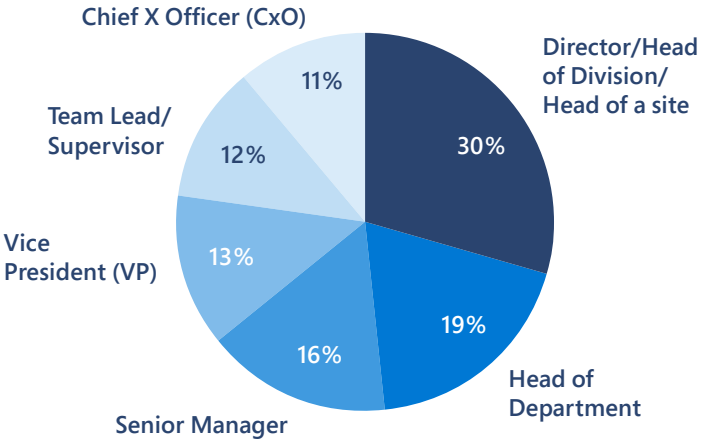
How many employees does your current employer have?



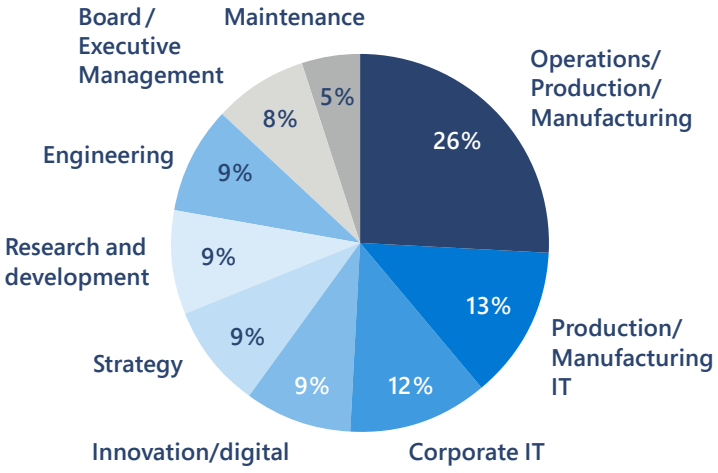
How much revenue has your employer roughly generated in the last calendar year?



What is your level of seniority within the organization?



What department are you primarily working in at your organization?



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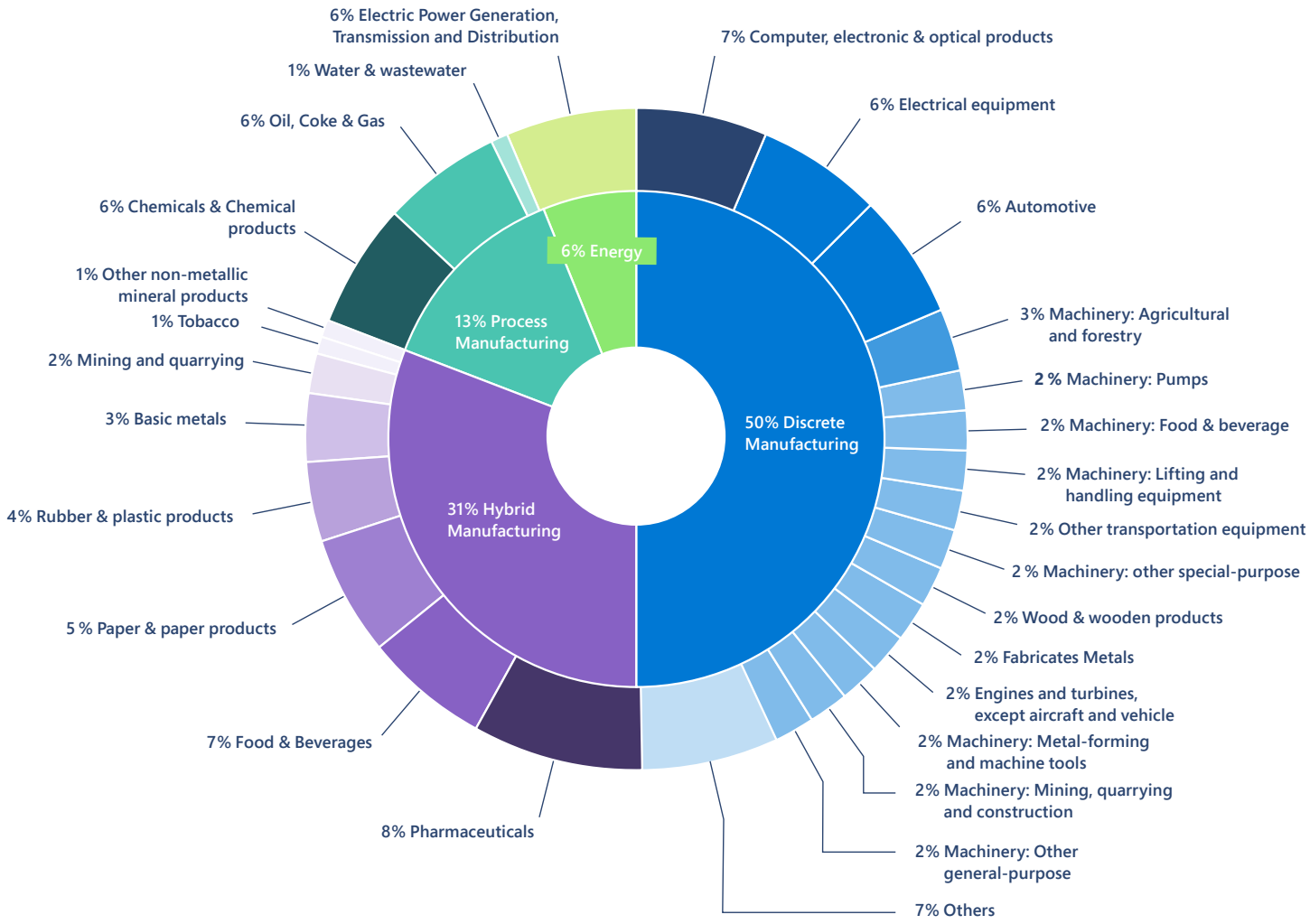
Which is the primary industry focus of your employer (ISIC classification)?



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1 Introduction

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Key paradigms of the factory of the future

Manufacturers are embracing automation to enhance scalability and maintenance despite security and data management challenges. They are transitioning towards more automated factories that are designed not only for flexibility to scale seamlessly in response to fluctuating demand but also to enable ease of maintenance and support to ensure the serviceability of individual hardware and software components. As manufacturers embark on a path to making this vision a reality, challenges such as mitigating security risks and managing data effectively are becoming more apparent.

Exhibit 1: Imagining the factory of the future:
Six key paradigms that matter to manufacturers

Status quo	Future paradigm	Importance	What it will mean
Many manual processes	Scalable	★★★★★	Expand as demand grows, replicate across sites
Unique and restricted local setup	Automated	★★★★★	Autonomous processes with little human interaction
System/machine service dependent on few individuals	Serviceable	★★★★★	Ease of maintenance, troubleshooting, support
Limited access	Accessible	★★★★★	Providing intuitive / low-code interfaces and tools to use workflows and applications
Rigid and monolithic systems	Modular / Flexible	★★★★½	Separate, self-contained units
Proprietary and isolated systems	Interoperable	★★★★½	Seamless communication between tech components

Three paradigms stand out as important to the factory of the future. When asked to indicate which paradigms will either be very or extremely important within the next 3 to 5 years, a super majority of survey respondents indicated the following three paradigms:

1. **Scalable (72 %).** Scalable factories are designed for seamless expansion as market demand increases and scaling down as market demand decreases. Scalability also applies across sites: operational methods and procedures that work in one factory are easily adapted in other factories. This ensures that production can grow efficiently without significant reinvestment.

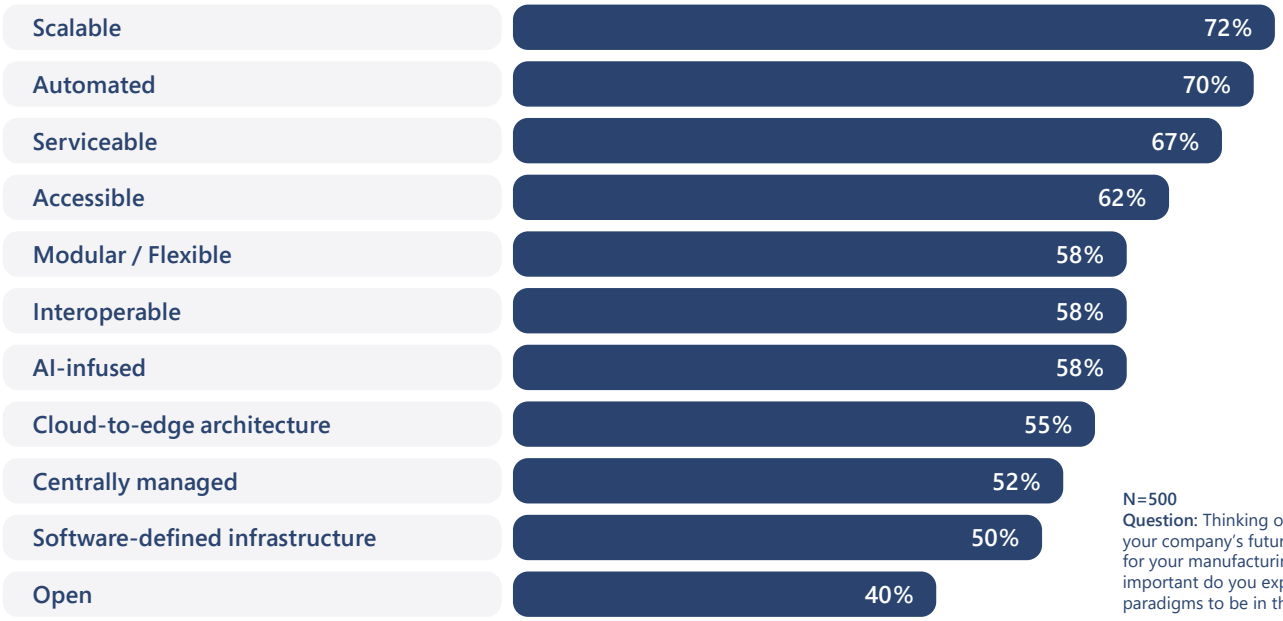
2. **Automated (70 %).** Automation processes in factories aim to augment, and in some cases replace, manual processes and labor to increase overall efficiency, improve quality, and reduce costs.

3. **Serviceable (67 %).** Serviceability means easy maintenance and quick troubleshooting of the factory assets, IT and OT systems, and the factory itself to minimize downtime. It emphasizes the importance of fast and effective problem resolution.

Exhibit 2: Key paradigms of future factories

Scalability is the lead paradigm for the factory of the future

Share of respondents who believe that the respective paradigm will be "very" or "extremely" important within the next 3 to 5 years



N=500
Question: Thinking of the development of your company's future technology stack for your manufacturing operations. How important do you expect the following paradigms to be in the next 3 to 5 years?

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Voices from the industry:

Scalability across plants is not easy.

A director at a US-based automotive OEM who oversees optimizing manufacturing operations across sites:
"The most challenging aspect for us, in regard to the adoption of technologies, is the standardization between multiple plants, countries and regions."

The CIO of a German automotive OEM:
"I think that Bosch is one of the most advanced companies. They managed to replicate success from one production site to multiple others. They already have edge AI at scale on many of their shop floors- leveraging a central data lake in a hybrid cloud setup."

Automation is key for operational visibility and performance.

A senior manufacturing IT manager at a UK-based food and beverage manufacturing company:
"With automation on the shop floor, and especially our MES system to streamline workflows across the value stream, we can capture information about anomalies in machinery performance and aggregate this to generate analytics for continuous improvement."

The head of production at an India-based fabricated metals manufacturing company:
"Shopfloor Automation is necessary to gain more visibility in operations. We can only have real-time data tracking with automation."

Skill gaps are making serviceability crucial in setting up factories.

The maintenance director at a South Korea-based engine manufacturer:
"Technology development nowadays is so fast that my team cannot always keep up."

When manufacturers say they prioritize the serviceability of their assets, they mean that they ensure machines keep on running, even during skill shortages. According to the Germany-based machinery manufacturer association VDMA, 80 % of machinery manufacturing companies reported serious or noticeable bottlenecks due to skill shortages, making a strong case for designing future factory setups with serviceability in mind.

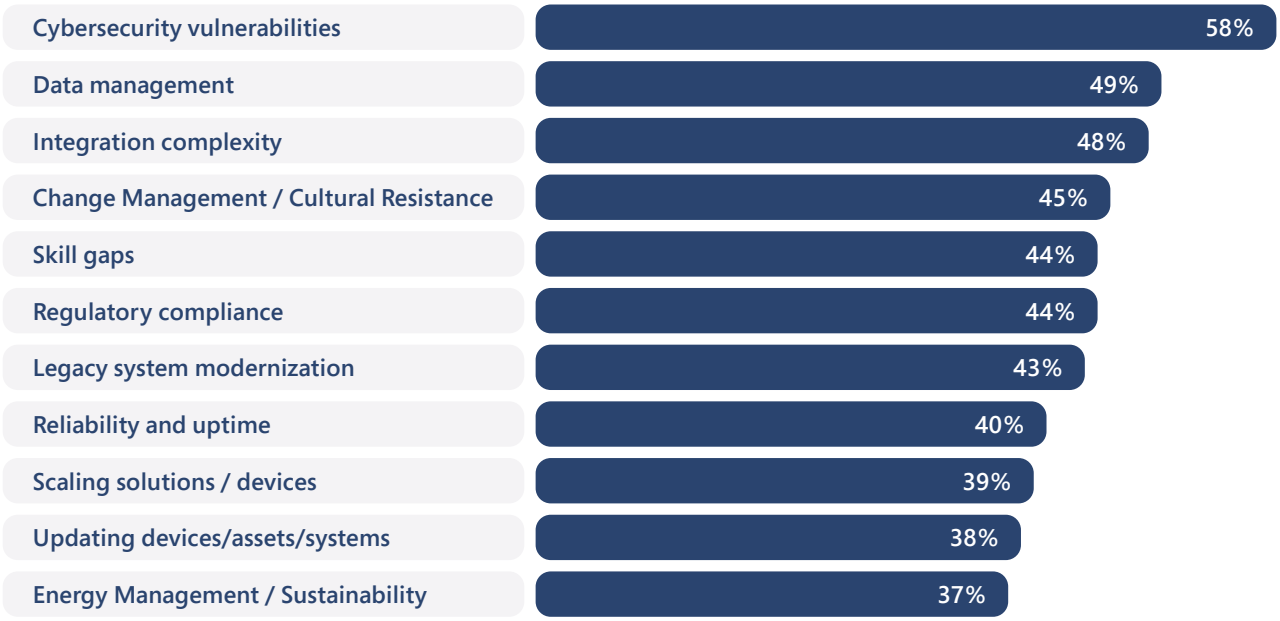
Key challenges to realizing the factory of the future

Cybersecurity vulnerabilities, data management, and skill gaps are the top three challenges that manufacturers face as they transition toward the factory of the future. Over half of the respondents indicated that cybersecurity vulnerabilities were severe or major challenges.

Meanwhile, 49 % of respondents rated data management as a key challenge, followed closely by integration complexity.

Exhibit 3: Key challenges to get to the factory of the future
Cybersecurity vulnerabilities tops the list of key challenges right now, as well as data management and integration complexity

Share of respondents who point to each challenge as Severe or Major



N=500
Question: How severe are the following challenges for organizations in your industry at the moment?

Voices from the industry:

Security is a top challenge, driven by strict industry standards.

A senior automation manager at a Germany-based pharmaceutical manufacturer:
"The pharmaceutical industry has to keep up with CFR Part 11 requirements, which are strong in terms of cybersecurity. New digital solutions offer great help, but the industry itself is very conservative in adopting them because security is a major concern. Another example is that we are not yet allowed to update our devices on the shopfloor over the air. We still have to do offline updates."

The chief operations officer at a US-based machinery manufacturer and the chief digital transformation officer at a US-based automotive OEM:
"Security is becoming our organization #1 priority. For that we use Virtual Private Cloud with our global Hyperscalers, not standard Public Cloud offerings for added security. Think of it as an extended virtual dedicated cloud data center. It is very important to mention that our industry has a heavy focus on cyber security. It will remain our #1 priority until at least 2025. Complying with regulations is a major challenge as well."

OT data management is more complex than IT data management.

The operations director at an Italy-based water and wastewater company:
"Organizations often have a wide range of devices and systems that generate a lot of industrial data, such as machines and sensor readings. This becomes complex very quickly."

Integrating technology across multiple sites is complex.

A maintenance director at a South Korea-based engine:
"Across our multiple production sites. There are different levels of skills and resources. Our main concern is about the integration and orchestration of different solutions. We need to face up different projects with different technologies in different regions."

Top technology priorities for realizing the factory of the future

On the road to becoming more scalable, automated, and serviceable, key technology priorities of manufacturers include:

1. **Security** – Securing the factory, including network, application, and OT security as well as access management
   - **Network security:** Examples include firewalls, intrusion detection systems, and virtual private networks.
   - **Application security:** Antivirus software, secure coding practices, and application security testing tools can address this.
   - **OT security:** Examples include network segmentation, access control, and anomaly detection systems.
   - **Identify and access management:** Examples include multi-factor authentication, single sign-on systems, and user access review and privilege auditing tools

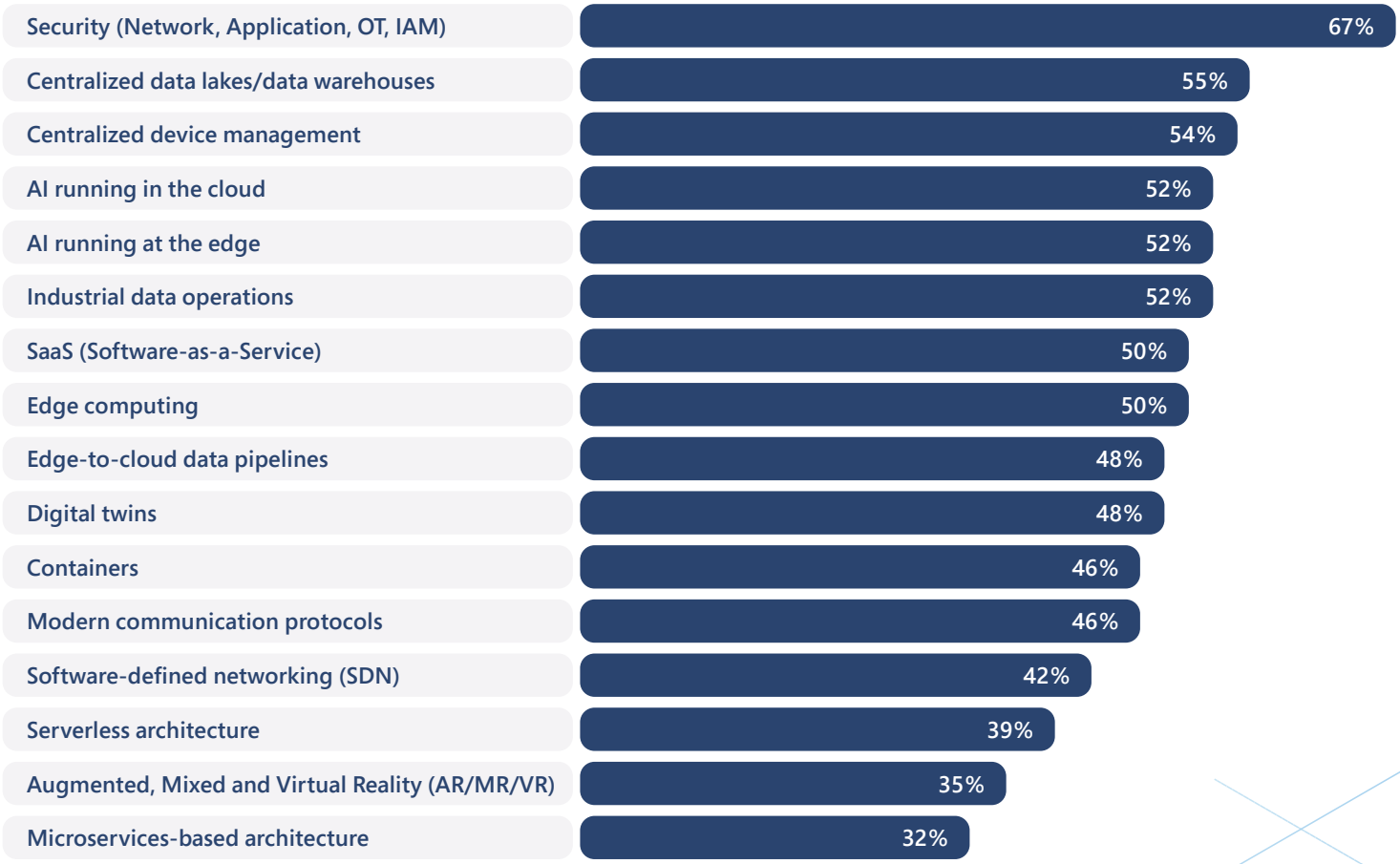
2. **Centralized data lakes/data warehouses** – Storing and managing large volumes of diverse data from various sources for advanced analytics and decision-making
   - Examples include cloud-based platforms that enable real-time data analysis, trend prediction, and comprehensive data integration.

3. **Centralized device management** – Managing and controlling all connected devices from a central location.
   - Examples include software platforms that allow for remote updates, device monitoring, real-time diagnostics, and inventory management.

Exhibit 4: Technology priorities right now

Cybersecurity vulnerabilities tops the list of key technologies right now, as well as centralized device management and AI in the cloud / at the edge

Share of respondents who believe that the respective technology will be "very" or "extremely" important within the next 3 to 5 years



N=500
Question: How important do you regard each of the following technologies for the manufacturing operations of companies in your industry in the next 3-5 years?

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Lessons from leading manufacturers

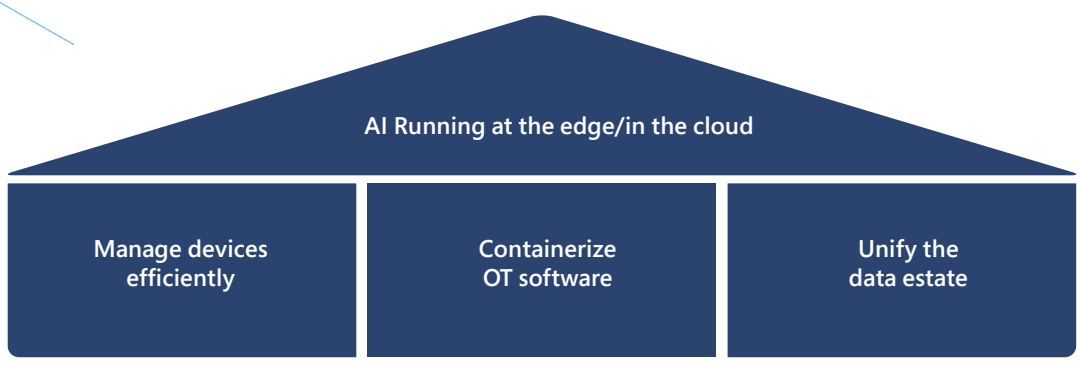
Integration of AI on the shop floor is increasing, with top-down initiatives gradually elevating its priority. Recognizing AI's future ubiquity, companies are working to overcome the aforementioned challenges and investing in scalable, future-proof technology that will position them to adapt to AI and its potential.

Companies that are recognizing the future ubiquity of AI and preparing their factories do at least three things well:

1. **Manage devices efficiently with centralized device management.** This involves managing industrial devices, including provisioning, certificate management, health and security monitoring, and updating, from a single, central location.

2. **Containerize OT software**. Containerizing software workloads allows new or updated applications to contain all the necessary elements to run at the edge or in the cloud consistently, no matter where they are installed.

3. **Unify the data estate with industrial data operations.** This involves standardized data integration in a place where everyone can access it. Industrial data ops are key technologies that manage and improve data flow, quality, and value within an industrial context.



Voices from the industry:

AI is driving the containerization of OT software workloads.

A head of production at a French-based chemical manufacturer:
"I do think that AI is the important part of the discussion which will lead to using more containerized software."

Efficient device management is key for a future with AI.

An operations team lead at an Australia-based mining company:
"From my experience in the mining industries, companies make the most out of AI because they have efficient device management. Good device management processes enable real-time monitoring of machines, workers, equipment, and underground material to improve mining site safety and productivity."

Unifying the data estate increases the chances of successful AI implementation.

The head of production planning and quality control at a South Korea-based electrical equipment manufacturer:
"In my industry, companies with a strategic approach to digital transformation have significantly higher success rate for AI adoption. A strategic approach to digital transformation involves feeding AI applications from a common data layer. This can provide vast improvement to manufacturing processes with AI use cases like AI-based predictive maintenance."

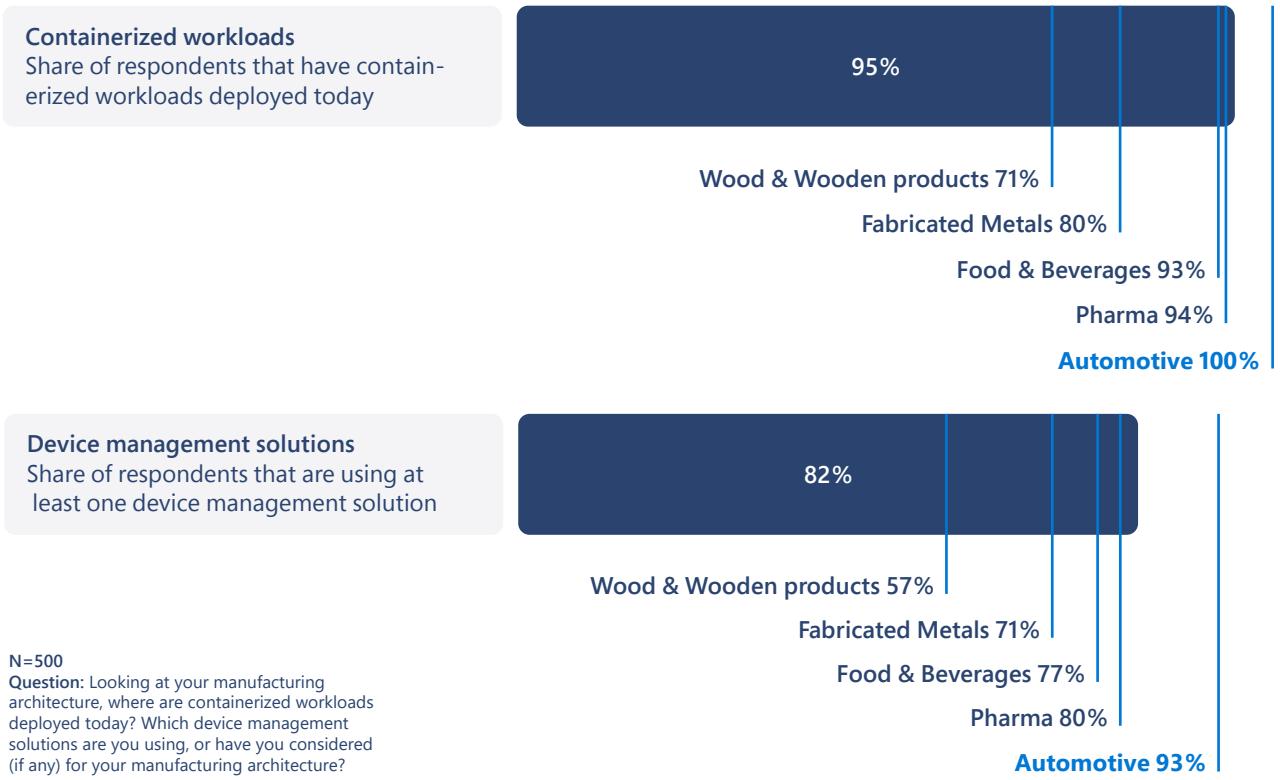
Spotlight on leading industries in digital transformation

Automotive manufacturers are further ahead in the adoption of innovative technologies, such as containerized workloads and device management solutions, to improve their operations. 100% of respondents from automotive manufacturers and suppliers indicated their employers have containerized workloads deployed today and 93% of them indicated that their employers use at least one device management solution.

Exhibit 5: Forerunners of digital transformation

Survey respondents tagged automotive companies as the forerunners of digital transformation

Comparation of the progress of automotive manufacturers on the adoption of containerized workloads and device management solutions



N=500
Question: Looking at your manufacturing architecture, where are containerized workloads deployed today? Which device management solutions are you using, or have you considered (if any) for your manufacturing architecture?

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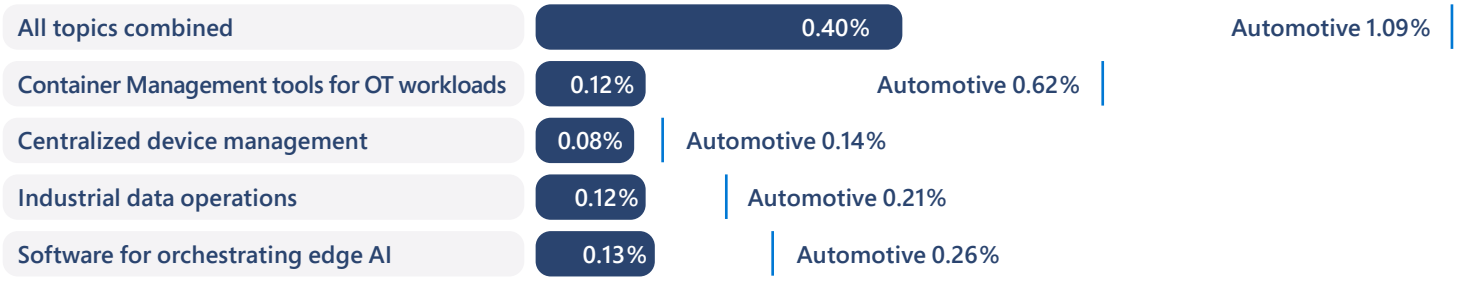
Automotive manufacturers also have the largest budgets dedicated to accelerating industrial transformation. Out of all industry verticals surveyed, respondents working in the automotive industry expressed having the largest budgets (as a share of their companies' revenue) for container management tools for OT workloads, centralized device management, industrial data operations, and software for orchestrating edge AI.

Exhibit 6: Overall vs. Automotive: Average share of each topic on the company revenue

Automotive manufacturers also lead with the biggest budgets dedicated to accelerating industrial transformation

Comparation of the progress of automotive manufacturers on the adoption of containerized workloads and device management solutions



N=500
Question: Approximately how large are your organization's 2024 budgets for the following topics?

Voices from the industry:

BMW, Tesla, and Hyundai are seen as examples of leading shopfloor technology adopters in the automotive industry.

A corporate IT director at a Singapore-based lifting and handling equipment manufacturer:
"BMW is very much ahead in the adoption of containerization, they have reduced their operational expenses by approx. 50 %, I believe which is very appreciable, and digitally they have achieved a very big milestone."

A manufacturing director at a US-based manufacturer of electronics and optical products:
"Tesla has achieved large-scale battery production increases, leveraging AI to help detect issues and quality in manufacturing. They have achieved a very big milestone."

A senior production manager at a Japanese power company:
"With the help of centralized device management, they were able to remotely monitor equipment health, energy consumption, and performance of their manufacturing plant."

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Building the factory of the future

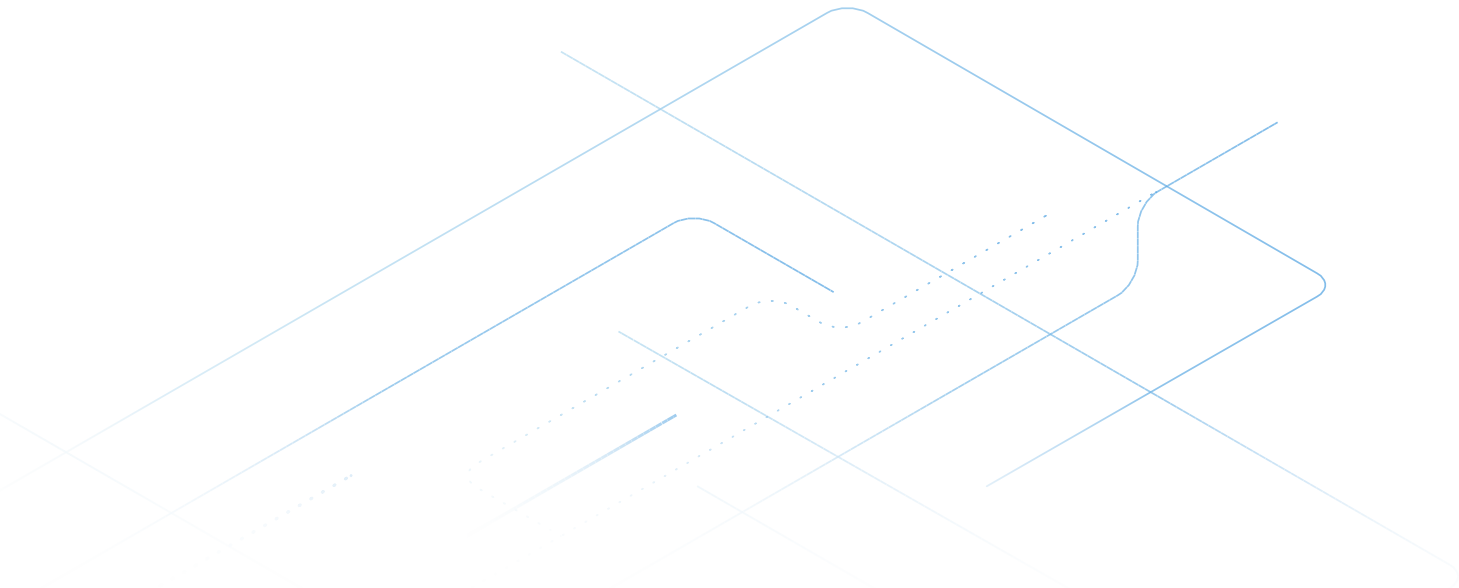
The factory of the future is scalable, automated, and serviceable. To realize these three paradigms—and to prepare for AI on the factory floor—companies must overcome cybersecurity vulnerabilities and data management complexities. Top technology priorities to address these challenges, as identified by the respondents, include:

- Security, including network, application, and operational security, as well as access management
- Centralized data lakes and data warehouses to store and manage large volumes of diverse data
- AI running at the edge, close to the data source, or in the cloud

Looking at lessons from manufacturers that are at the forefront of modernizing and preparing their factories for the future, three actions stand out as building blocks:

1. Efficient device management
2. Containerize OT software
3. Unify the data estate through the adoption of industrial data ops

The next few chapters will delve into these building blocks individually, culminating with a look at how companies are investing in and adopting these blocks to realize the factory of the future.



2 Manage devices efficiently

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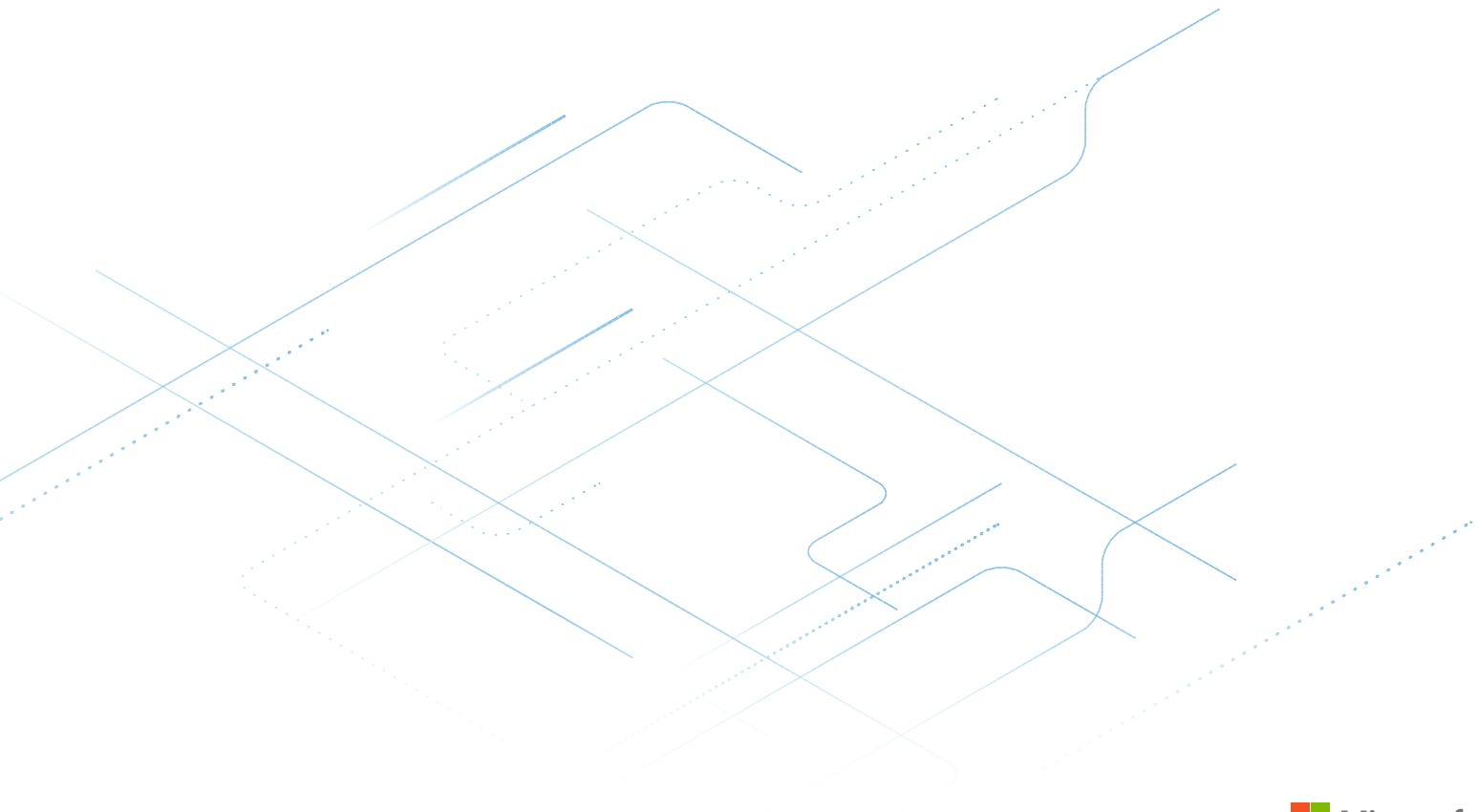
Characteristics and benefits of effective device management

Device management is crucial for maintaining the integrity and efficiency of operations within a factory setting. By ensuring devices are secure and function optimally, device management systems play a key role in the overall productivity of a manufacturing environment. Key functions include maintaining device security to protect against unauthorized access and potential threats, managing software updates to ensure devices operate with the latest functionalities and security patches, and monitoring device performance to prevent downtime. Effective management of these elements is essential for the smooth operation of factory processes, enabling better control and visibility across the manufacturing floor. This not only enhances operational reliability but also supports scalability and adaptability in an ever-evolving industrial landscape.



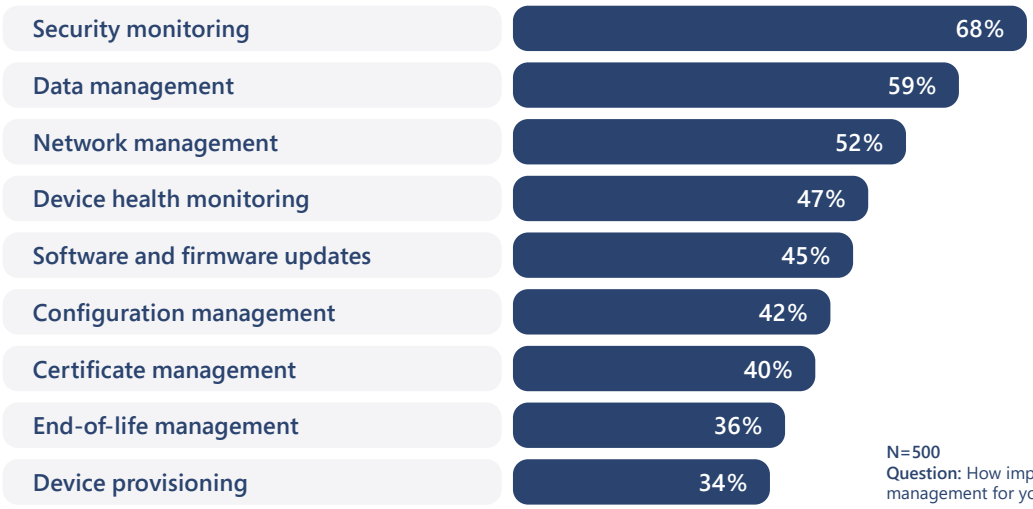
Crucial aspects of device management in addressing key challenges

Device management helps ensure security and better data management. 68 % of survey respondents noted that the security monitoring aspect of device management was very or extremely important to their organization. Data management is the second most important aspect of device management, with 59 % of respondents mentioning it. Some respondents added that centralized device management helps them consolidate data streams, enabling unified access and analysis and thereby breaking down data silos.

Exhibit 7: Key device management challenges

Device management is about properly ensuring security, breaking down data silos, and ensuring devices health.

Share of respondents who point to the respective aspect as "very" or "extremely" important for devices management in manufacturing operations



N=500
Question: How important are the following aspects of device management for your devices/assets used in manufacturing operations?

Voices from the industry:

Device management is critical for security.

A head of R&D at a Germany-based power distribution company:
"Centralized device management should always pay attention to the fact that security is paramount."

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How manufacturers perform device management

Device management mostly occurs during runtime. 74% of respondents shared that their organizations can perform device management during runtime, meaning they control, monitor, and update devices dynamically while they are active and running. Meanwhile, 26% of respondents marked that their organizations can only perform device management when creating a static device image, which is a snapshot of a device's firmware, software, and settings in one package. By relying only on static device images, updates are made to the firmware, software, or settings within an image, and the image is then loaded onto a device—updates are not performed dynamically while the device is active and running.

Device updates are often performed on-premises. 73% of respondents noted that their organizations used on-premises device management to update at least some shopfloor assets. Meanwhile, 52% update at least some assets via cloud device management, and 16% use USBs or disks directly to update assets. Cloud device management is an approach that increase visibility and decrease complexity, leading to more efficient and streamlined operations. Centralized device management reduces downtime and enhances overall productivity by ensuring timely updates and consistent performance across devices.

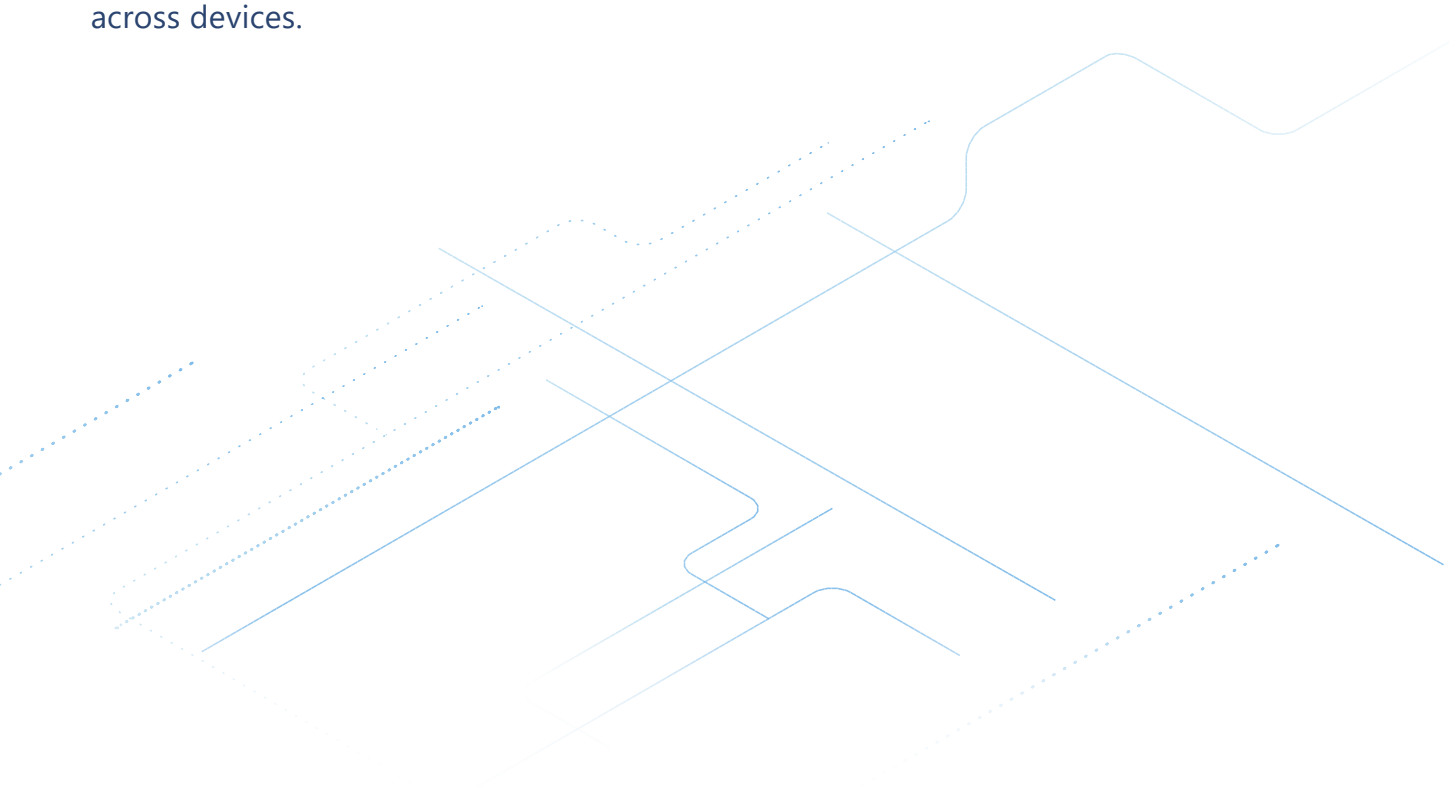
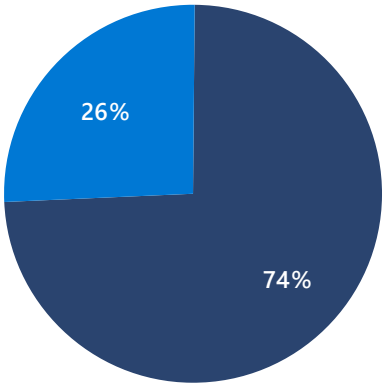


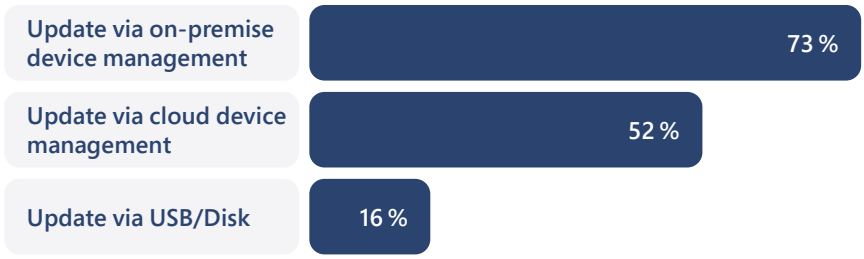
Exhibit 8: Most common device management methods

Most organizations adopt runtime device management

Share of organizations that manage most devices on the shopfloor in the respective way



Share of organizations that update most devices on the shopfloor in the respective way



- We can perform device management at runtime
- We can perform device management only when creating a static device image

N=500
Question: How do you manage the majority of your devices on the shop floor / How do you update the majority of your devices on the shop floor?

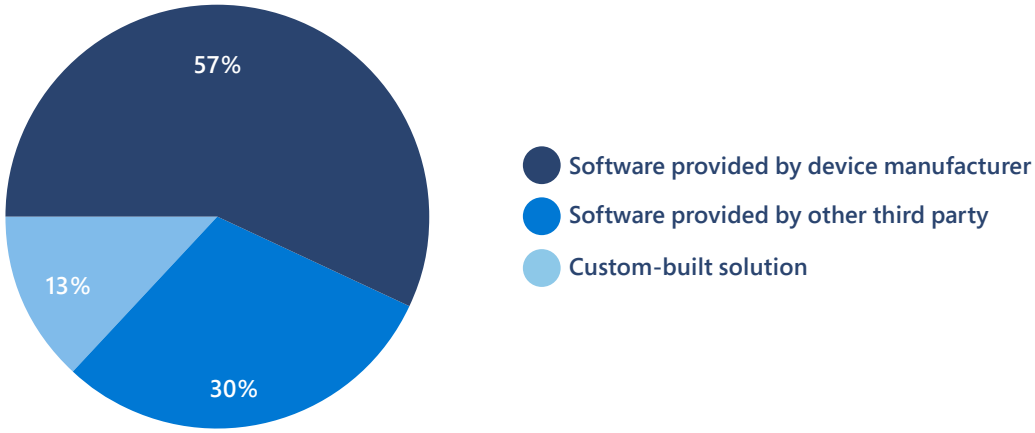
Device management software landscape

The majority of device management software in use is directly tied to key devices deployed by manufacturers. Providers of industrial automation infrastructure, such as Siemens and Rockwell, dominate this landscape, comprising 60 % of device management solutions currently in use in factories worldwide. Vendor-agnostic tools, like those provided by Microsoft, account for only 28 % of the tools reported by respondents. Additionally, custom solutions represent a significant share, with 12 % of companies opting to develop their own device management systems. There are relatively few overarching solutions provided by third parties, as most manufacturers rely on software specifically tailored to the devices they deploy.

Exhibit 9: Most common device management tools

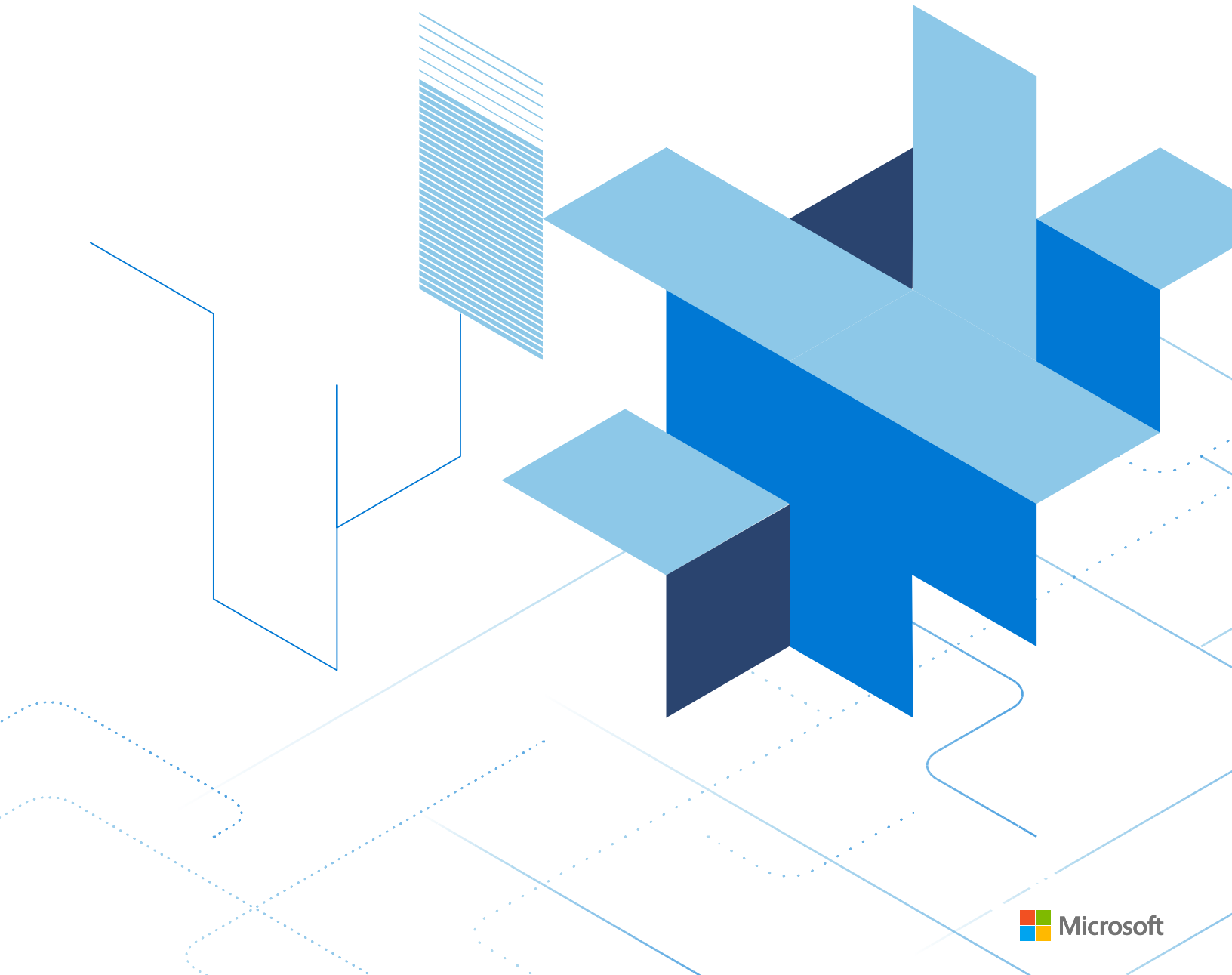
Device manufacturers dominate the device management software competitive landscape

Share of respondents that are procuring the device management solution in the respective way and mentioned vendors/tools



N=500
Question: Which device management solutions are you using, or have you considered (if any) for your manufacturing architecture?

3 Containerize OT software



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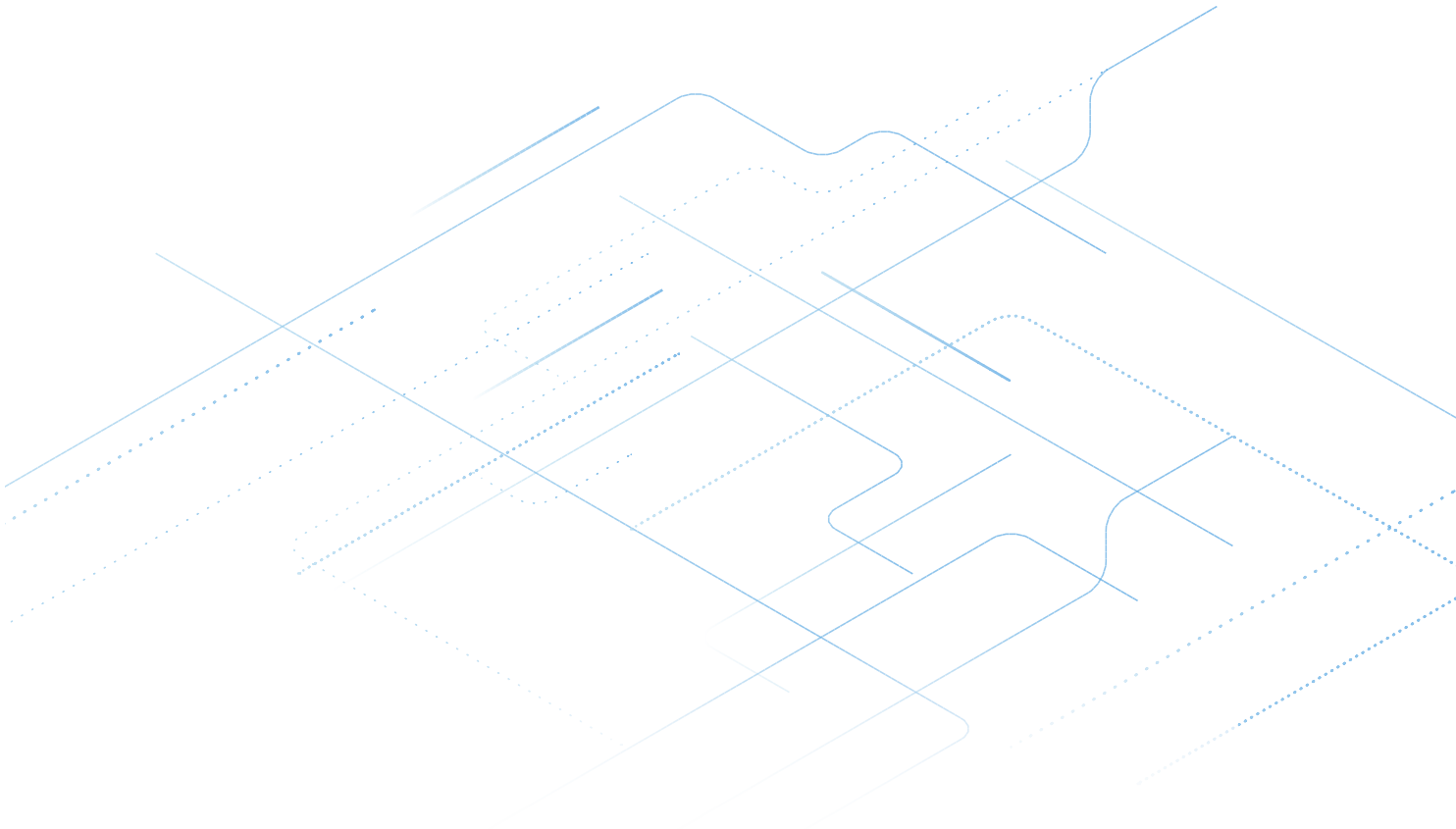
Characteristics and benefits of containerization

Containerization technology packages software with all its dependencies, ensuring consistent operation across different computing environments while improving scalability, security, and development efficiency.

Containerization of OT software matters for the AI-powered factory of the future. Software containerization has become a fundamental principle for scaling IT applications, and it is increasingly being adopted on shop floors. It enhances operational flexibility, efficiency, and security—key attributes for maintaining seamless technology deployment in scalable, serviceable, and automated factories. Moreover, containerization promotes secure, isolated environments, which is essential for safeguarding manufacturing processes against evolving threats and ensuring the adaptability of AI-powered factories.



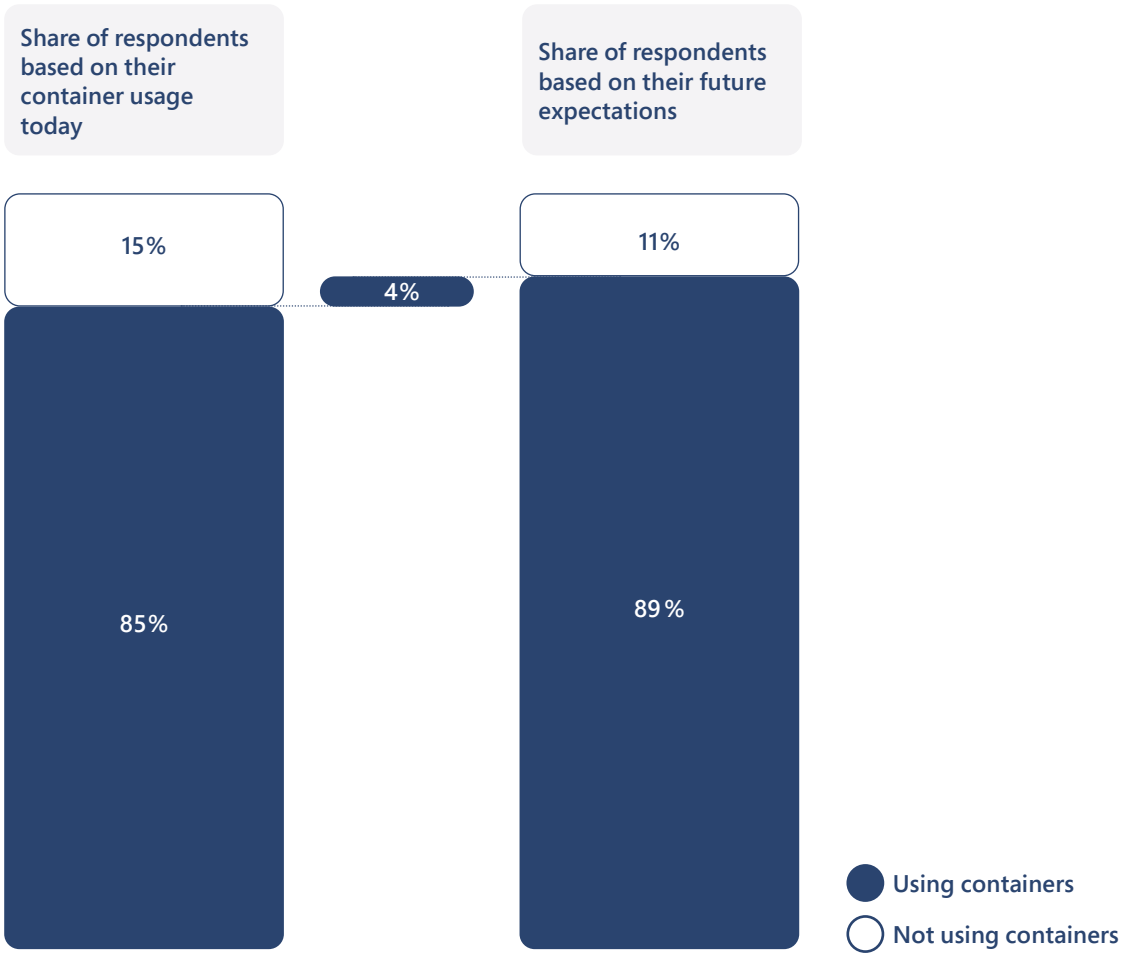
Mitigation of key challenges

Containerized software is gaining importance. 85 % of survey respondents indicated using containers across their entire operations stack (including cloud software). Meanwhile, 4 % of respondents indicated that they are not using containers today but plan to in the future.

Exhibit 10: Containerized software current vs. future importance

Containerized software is gaining importance

Respondents' current adoption of container vs. future adoption



N=500
Question: Looking at your manufacturing architecture, where are containerized workloads deployed today? / Where do you expect containerization to be introduced next?

Reading aid:

85 % of survey respondents mentioned using containerized workloads today, while 4 % mentioned having plans for using containerized workloads in the future. This means that 89 % of survey respondents will have fully adopted containerized workloads in the future.

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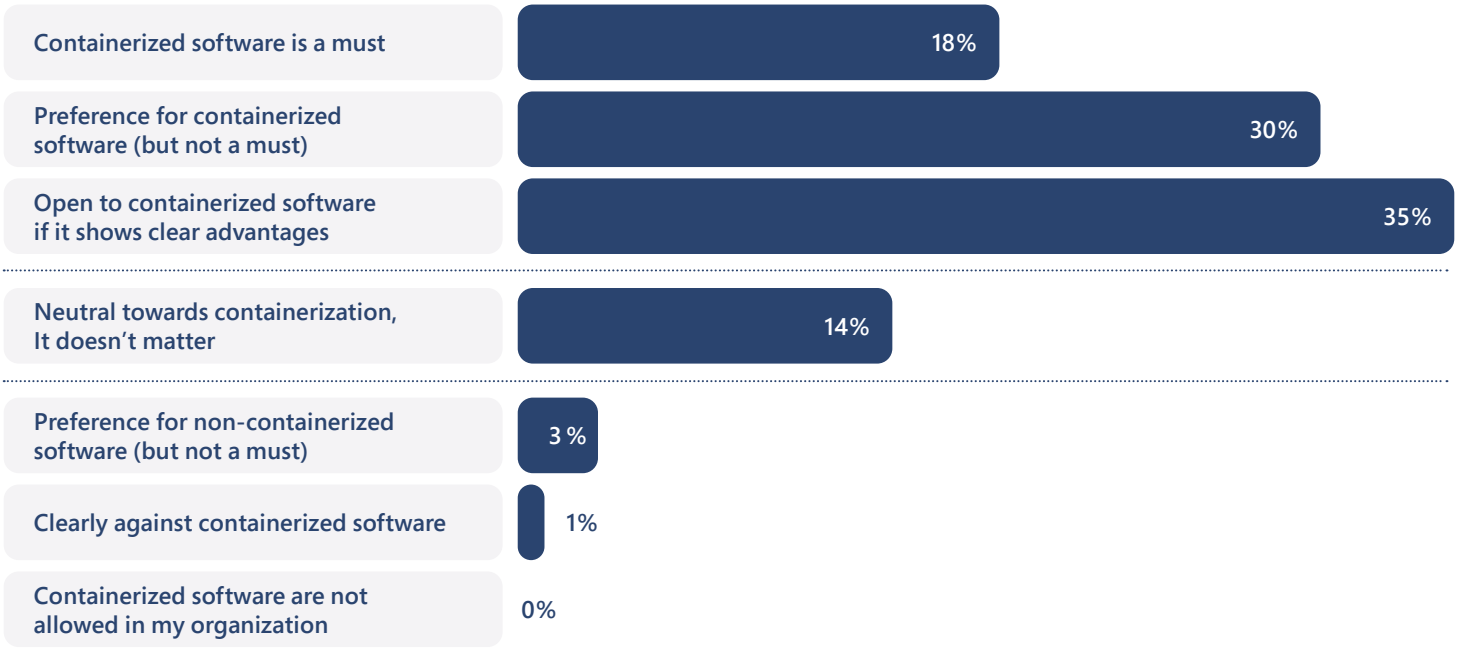
Exhibit 11: Respondents' views regarding containerization

Containerized software is becoming the norm

Share of organizations that have the following view regarding the containerization of new manufacturing software



N=500
Question: How do you think about your organization's attitude toward containerization for new manufacturing software in the next 3 years?

Microsoft

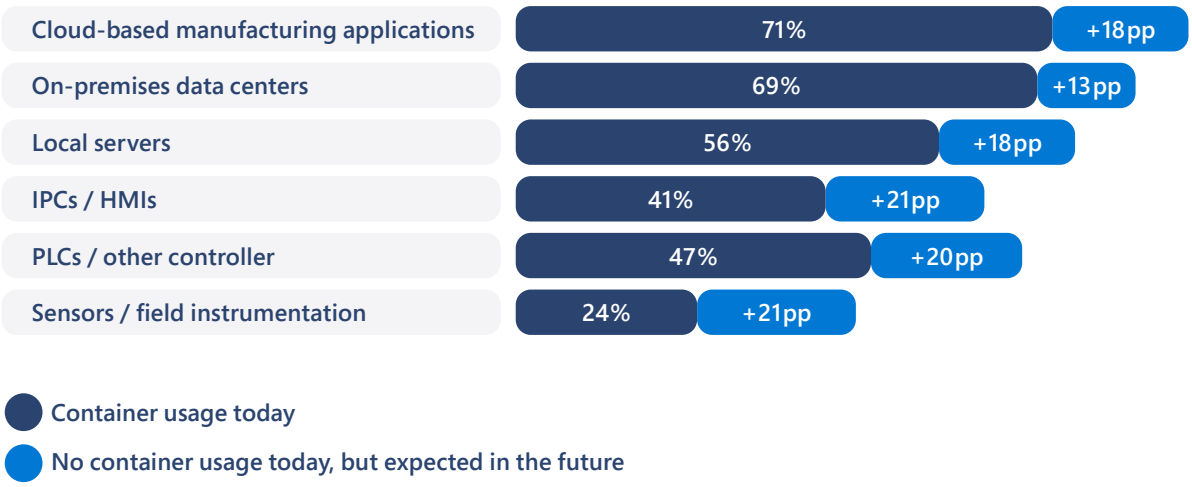
Impact on industrial edge architectures

A majority of survey respondents indicated their employers currently have some form of containerization at the edge, but many intend to extend containerization to these systems in the coming years. According to the respondents, PLCs and similar controllers have container usage today at 47 %, while containerization in IPCs/HMIs and field instrumentation are only at 41 % and 24 %, respectively. However, across these three edge device categories, approximately 1/5 of respondents expect their employers to adopt software containerization within the next 3 years

Exhibit 12: Current and future containerization adoption

Containerized software is expanding to the edge

Share of respondents based on their container usage today and future expectations



pp = percentage points

N=500
Question: Looking at your manufacturing architecture, where are containerized workloads deployed today? / Where do you expect containerization to be introduced next?

Most companies adopt containerization for network functions and IoT/ edge applications. 54 % of survey respondents mentioned that the key reason for adopting containerization is running network functions (such as firewalls or load balancing). Additionally, 46 % of respondents mentioned that they are using containers to manage IoT or edge application functions, rather than running the devices themselves."

Microsoft

Mitigation of key challenges

Containerized software mitigates key challenges to building factories of the future. Of 11 identified common challenges that factories face, 55 % of respondents indicated that containerized software could significantly or extremely mitigate reliability and uptime challenges, while 53 % indicated it could do the same for cybersecurity challenges. Updating systems, managing data, and scaling solutions were also noted as key challenges that containerized software helps mitigate, each at or just above 50 % of respondents.

Exhibit 13: Containerization benefits

Containerization helps mitigating key challenges faced on the way to develop the factory of the future

Share of respondents who believe each challenge can be "significantly" or "extremely" mitigated using containerization technology

N=500
Question: How much do you think containerization technologies deployed at the edge (IPC, Gateway, local server, PLC) can help mitigate the following challenges?

Below are a few ways that containerized software can help address these noted challenges:

1. **Enhancing system reliability and uptime.** Containerization isolates applications, which improves reliability and uptime by preventing system-wide failures. For example, if one application crashes in its container, it won't disrupt others, ensuring that essential services remain uninterrupted.

2. **Boosting security layers.** Containerization encapsulates applications, enhancing security by isolating them from one another. This means if a security breach occurs in one container, it cannot easily spread to others, akin to compartmentalizing sections of a ship to prevent it from sinking if one part is breached.

3. **Updating devices/assets/systems.** Containerization simplifies the update process by allowing individual containers to be updated independently without affecting the rest of the system. This means updates can be rolled out more frequently and with less risk of downtime or disruption. For example, a new version of an application can be deployed in a new container to a device while the old version continues to run, ensuring a seamless transition and minimizing service interruptions.

Container orchestration tool landscape

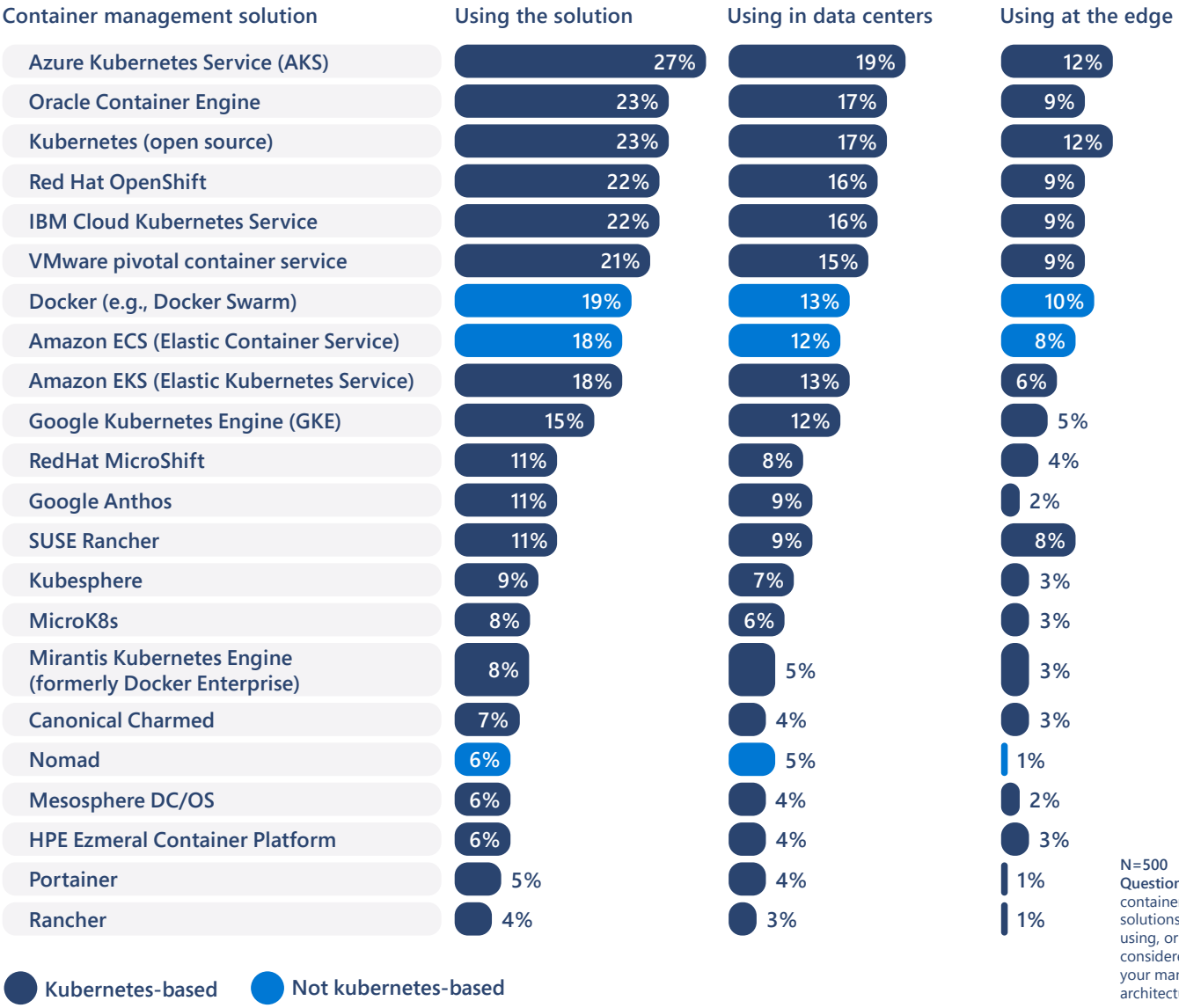
There is a strong preference for Kubernetes-based containerization in manufacturing. When asked about their containerization methods, ~80% of survey respondents marked Kubernetes-based containerization organization systems.

Microsoft has a key role in the container management landscape. According to survey respondents, Azure Kubernetes Service (AKS) is the top container management solution platform rolled out by manufacturers today.

Exhibit 14: Most widely used container orchestration systems

Microsoft with a key role in the container management landscape

Share of respondents using the following specific container services



N=500
Question: Which container management solutions are you using, or have you considered (if any) for your manufacturing architecture?

Microsoft

Containers at the edge ensure low latency and uniform updates.
Container workloads processing data closer to the source—at the edge—reduce the need to transmit data for processing elsewhere. Further, by encapsulating applications and their dependencies into single containers, manufacturers can make updates or changes centrally and then uniformly deploy the containers across all edge devices, ensuring that each device runs the same version with minimal downtime.

4 Unify the data estate

Microsoft

Characteristics and benefits of Industrial data ops

Industrial data ops optimize data collection and delivery for seamless integration and real-time decision-making. Industrial data operations (data ops) are a set of practices, processes, and technologies that streamline the collection, organization, and delivery of data across an industrial environment. By managing and unifying data from various sources, data ops facilitate seamless integration of information, ensuring it is accessible and usable for decision-making purposes. This approach helps break down data silos, providing consistent and high-quality data to support analytics and improve predictive insights. While it can enhance AI applications, industrial data ops are primarily focused on delivering data in a reliable, real-time manner for optimizing industrial operations and achieving strategic goals.

Top industrial data ops features

Manufacturers realize that they need a platform that allows them to query both IT and OT data, even if the data sources are separate. 52 % of respondents ranked this industrial data ops feature as very or extremely important to companies in their respective industries. Manufacturers increasingly realize that to deliver unified insight, they need a platform that allows them to query both IT and OT data even if the data sources are separate. Modern industrial data ops plays a key role in helping organizations get OT data into such platforms.

Other important topics for industrial data ops include:

- The ability to represent processes, physical sites, and assets using digital twin modeling tools: Allows for the virtual representation and simulation of physical processes, sites, and assets, facilitating enhanced analysis and predictive maintenance
- Supporting the Web of Things (WoT): Enables seamless integration and communication between devices and the internet, promoting interoperability and real-time data exchange
- Supporting the data-modeling Digital Twin Description Language (DTDL): Ensures consistent, scalable, and interoperable models across the AI-enhanced industrial ecosystem

Exhibit 15: Key industrial data operations themes

A combined IT/OT data platform enhances operational intelligence by integrating data

Share of respondents that point to each industrial data ops theme as "very" or "extremely" important for companies in their industry

N=500
Question: How important are each of the following Industrial data operations themes for companies in your industry?

Voices from the industry:

Good data ops starts with minimizing the number of platforms and interfaces a company has

A production VP at a US-based food and beverage manufacturer:
"Minimizing number of data platforms and interfaces we have to work with is the most important topic for industrial data ops in our company."

Microsoft

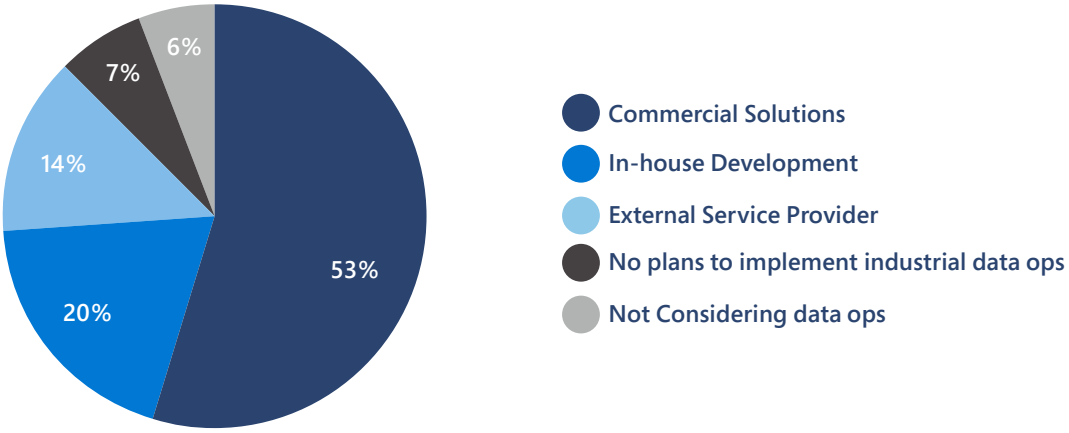
Industrial data ops landscape

Manufacturers prefer outsourcing industrial data ops to commercial solutions and service providers. Most manufacturers have adopted industrial data ops. 87 % of companies have already adopted industrial data ops technology in some form or are planning to do so. In the meantime, 53 % of respondents indicated leaning towards commercial solutions for implementing industrial data ops, while 14 % relied on external service providers. Many of the commercial solutions in the realm of industrial data ops are relatively young companies entering the industrial space, such as Litmus (established in 2015), and Sight Machine (2011). One of the explanations as to why this landscape is so fragmented is the technical complexity of industrial data ops. Technical complexity is the top challenge to industrial data ops adoption, according to 20 % of survey respondents.

Exhibit 16: Commercial solutions vendors are the most common data ops providers

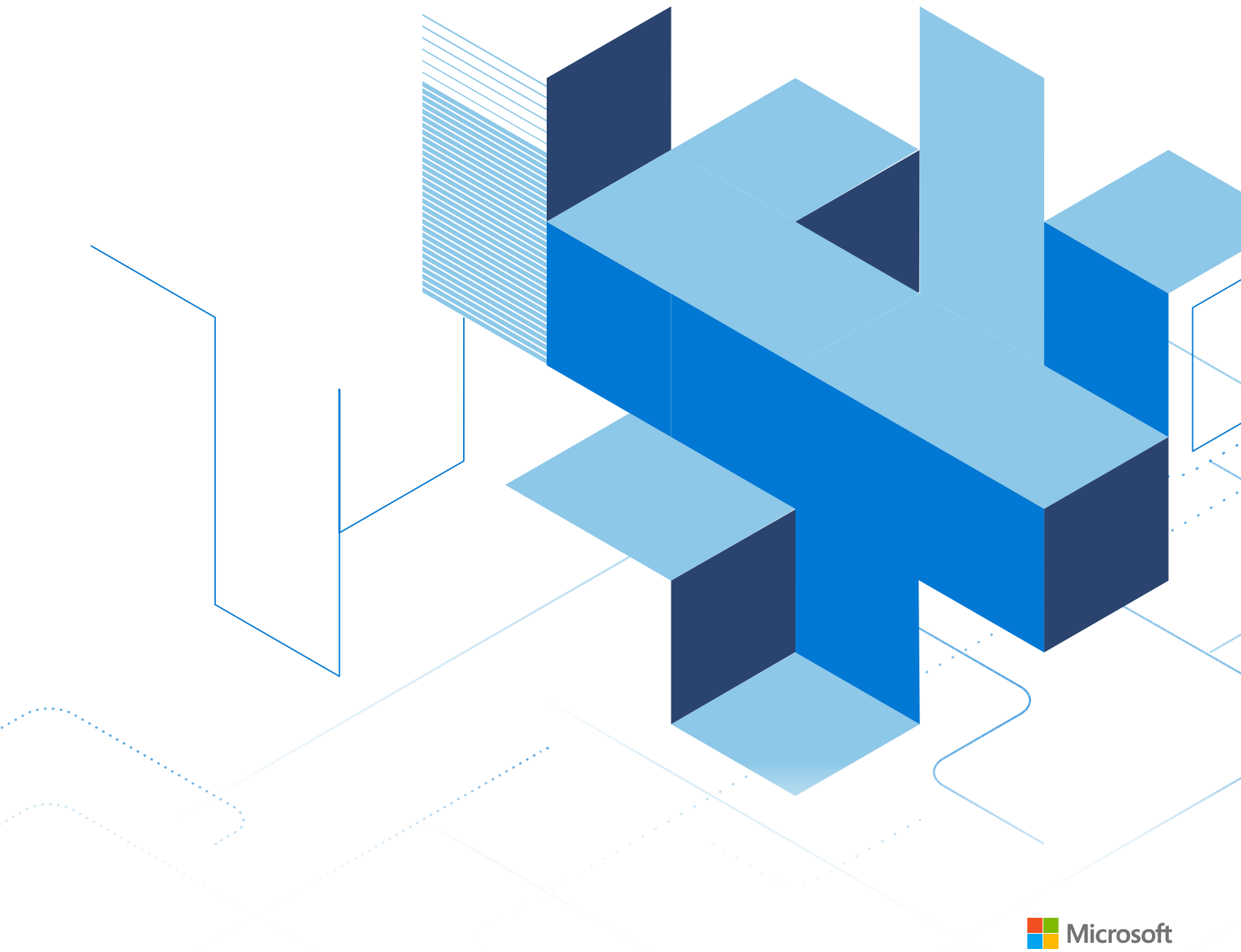
Commercial solutions vendors are the most common data ops providers

Share of respondents by way of implementing industrial data ops and mentioned vendors/tools



N=500
Question: How are you implementing or intending to implement industrial data operations in your manufacturing architecture?

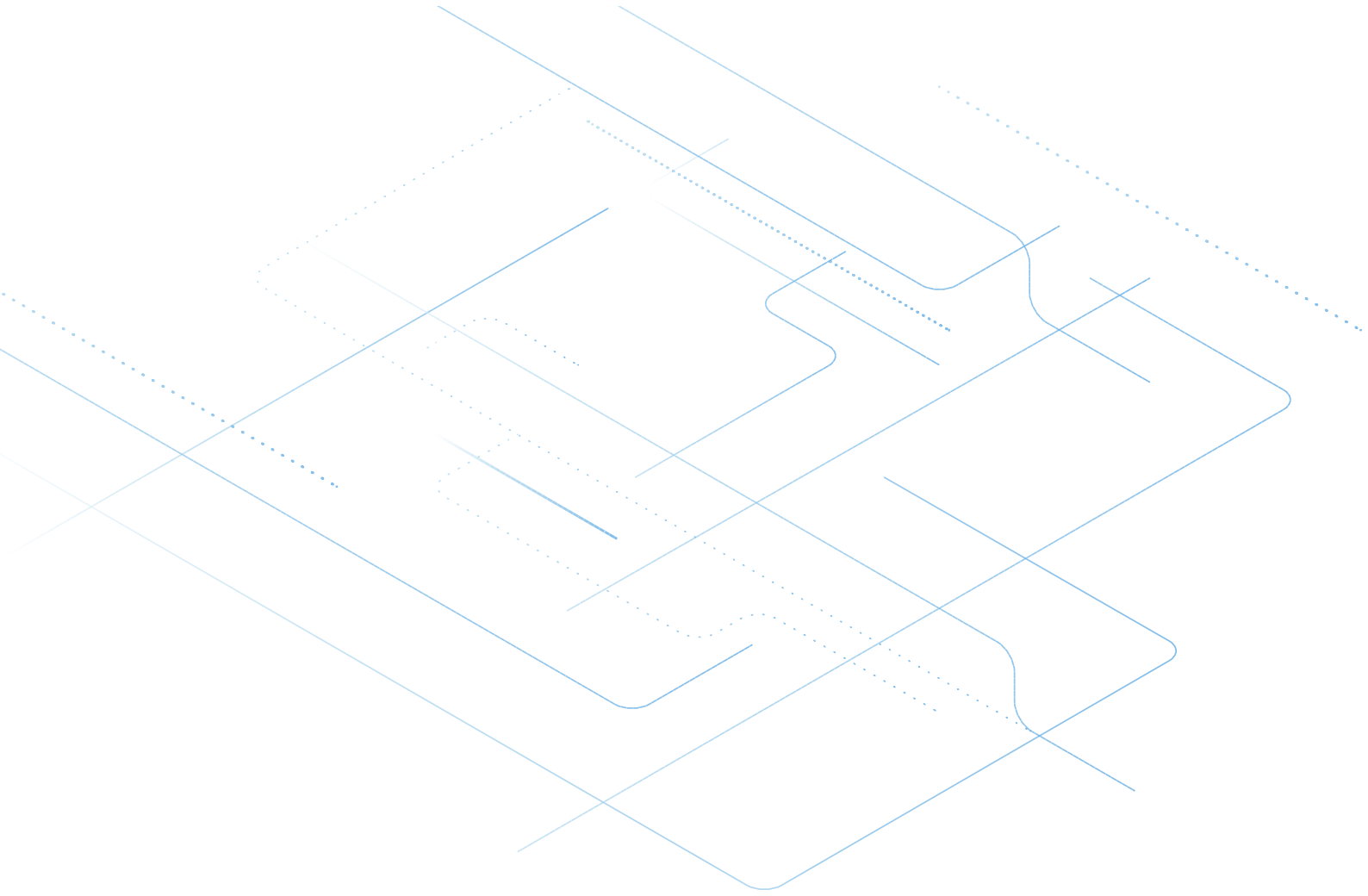
5 Bringing it all together: Future manufacturing operations with AI



Microsoft

Investments in device management, containerization, and data ops drive AI-powered future factories

Companies are making investments in the three building block technologies—centralized device management, software containerization, and industrial data operations. This chapter delves into investments and challenges. It offers a comprehensive analysis of strategic investments manufacturers are making toward creating AI-powered factories of the future, challenges slowing investment and adoption, and explores the anticipated impacts of these technologies on future manufacturing operations.



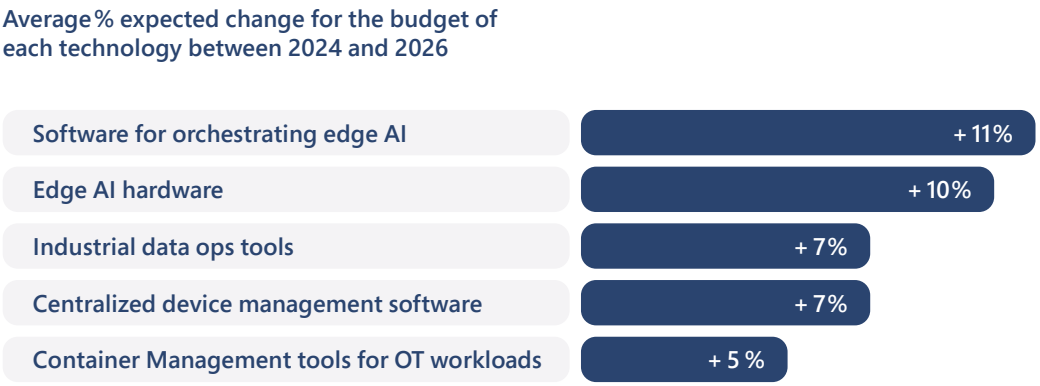
Technology investments

Manufacturers plan to invest in AI-powered factories of the future within the next two years. On average, respondents expected their organizations to increase their investments in software for orchestrating edge AI by 11%. Meanwhile, respondents expected the average investment increase for running edge AI hardware to be 10%. These planned investments signify that significant resources are being allocated to enhance automation and efficiency.

Regarding the three building blocks specifically—containerization, centralized device management, and industrial data ops—respondents expected increases of 5%, 7%, and 7%, respectively.

Exhibit 17: Investment plans for the next two years

Survey respondents are significantly planning to invest to get to the AI-infused factory of the future within the next two years



N=500
Question: How much do you expect your organization's budget for the following technologies to change between now (2024) and 2026?

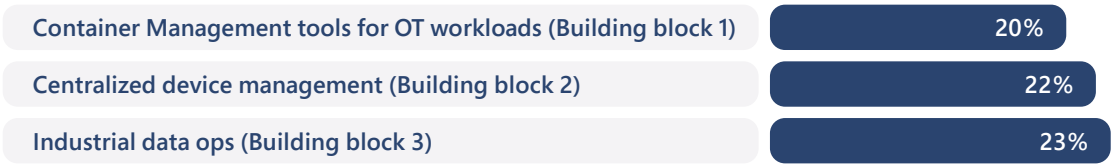
Investment amortization

Container management tools for OT workloads show the shortest amortization time. Survey respondents mentioned that the amortization of such software is 20 months on average. Out of the three building blocks, industrial data ops has the longest amortization time, with an average of 23 months. Industrial data ops is the most complex technology out of the three and is the most difficult to make a business case for, which explains this length of time. This difficulty arises from its intricate integration requirements and the substantial initial investment needed, which complicates making a compelling business case.

Exhibit 18: Amortization time

Software for orchestrating edge AI shows the shortest amortization time

Average amortization time (in months) for each of the following technologies



N=500
Question: How much do you expect your organization's budget for the following technologies to change between now (2024) and 2026?

Voices from the industry:

Technology adoption requires an ROI, but measurable ROI calculation remains a challenge.

A head of production at a Brazil-based transportation equipment manufacturer highlighted the need for upper management to have a clear view of ROI:
"I believe the most important thing to be able to roll-out these technologies is to convince upper management to invest is really be clear in the ROI."

An operations director at a US-based wood and wooden product manufacturing company remarked that calculating the ROI for them is a challenge and hinders operational advancements:
"Our industry is slow to make any changes, in almost every aspect of business operations. The ROIs are difficult for people to understand, and adopting new processes and technology is slow."convince upper management to invest is really be clear in the ROI."

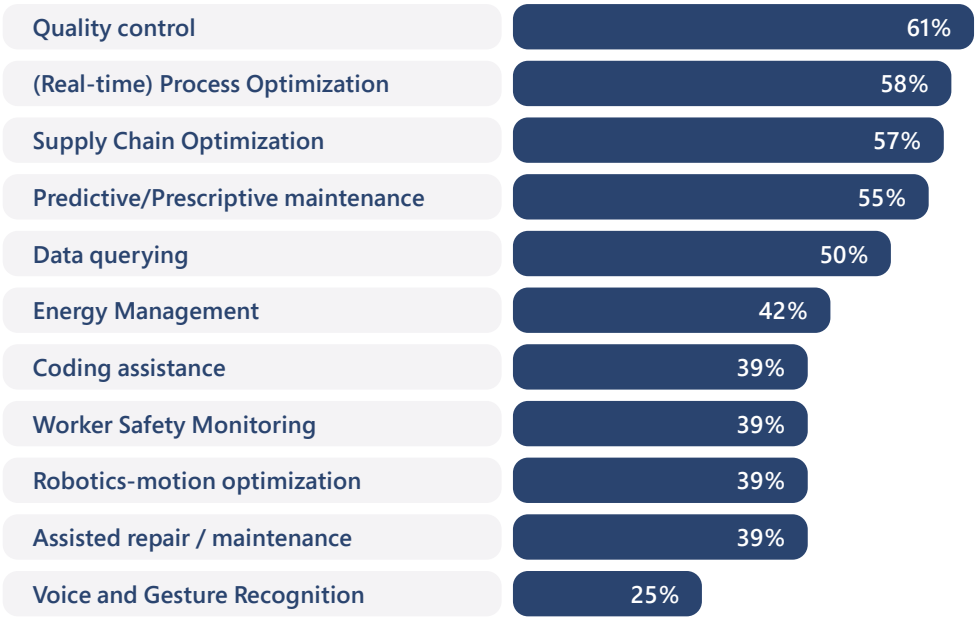
Key AI use cases enabled by investments

Quality control, process optimization and supply chain optimization are the most important AI use cases for manufacturers. In addition, use cases for generative AI appear on the rise for applications such as data querying and coding assistance. The utilization of data querying and coding support can enhance use cases such as quality control and process optimization by aiding and accelerating root cause analysis and application development.

Exhibit 19: Most important AI use-cases

Quality control, (Real-time) Process Optimization, and Supply Chain Optimization are the most important AI use-cases to manufacturers, with Generative AI coming up

Share of respondents that point to each AI use case as "very" or "extremely" important for their company



N=500
Question: How important are each of the following AI use cases for your company?

Most AI models are predominantly trained on public cloud/corporate non-cloud servers and executed on local servers. The process of training an AI model involves using large datasets to teach the model to recognize patterns and make decisions. Training typically happens on powerful servers that can handle the intensive computational load, which often includes public cloud or dedicated corporate servers that are not cloud-based. This allows for the complex computations and large-scale data handling necessary during the training phase.

Execution, or inference, of AI models, on the other hand, refers to the application of the trained model to new data to make predictions or decisions. This often occurs on local servers closer to the point of operation to reduce latency, increase the speed of response, and handle data privacy concerns more effectively. While execution can take place across various environments, including the cloud, local servers, and potentially at the far edge (like on factory shop floors or in autonomous vehicles), the move to execute AI at the far edge is progressing but is not yet a widespread practice.

Exhibit 20: Where are AI model trained?

Most AI models are predominantly trained on public cloud / corporate non-cloud servers and executed on local servers

Share of AI use case models that will be trained and executed in the respective way 2 years from now

AI Use Case	Public cloud	Corporate non-cloud servers	Local servers (within mfg. site)	IPC or similar	PLC or similar	Field instrument / IO devices / sensor / etc.
Training						
Energy Management	32%	29%	30%	8%		
Supply Chain Optimization	30%	34%	31%	4%		
Data querying	29%	37%	24%	10%		
Predictive/Prescriptive maintenance	28%	26%	41%	5%		
(Real-time) Process Optimization	26%	34%	34%	7%		
Quality control	22%	28%	44%	5%		
Coding assistance	22%	32%	34%	13%		
Voice and Gesture Recognition	21%	14%	41%	23%		
Assisted repair / maintenance	21%	30%	37%	12%		
Robotics-motion optimization	21%	35%	38%	5%		
Worker Safety Monitoring	20%	30%	40%	9%		
Execution						
Energy Management	30%	16%	34%	10%	2%	7%
Supply Chain Optimization	27%	30%	27%	6%	5%	5%
Data querying	25%	37%	20%	10%	5%	3%
Predictive/Prescriptive maintenance	27%	22%	37%	5%	5%	4%
(Real-time) Process Optimization	22%	31%	27%	10%	6%	5%
Quality control	19%	24%	42%	6%	3%	5%
Coding assistance	23%	40%	25%	8%	0%	4%
Voice and Gesture Recognition	17%	19%	40%	17%	3%	3%
Assisted repair / maintenance	11%	25%	42%	11%	7%	4%
Robotics-motion optimization	16%	22%	36%	12%	4%	10%
Worker Safety Monitoring	19%	27%	44%	6%	2%	2%

N=500
Question: Looking at all the AI use cases you marked as very or extremely important, where do you foresee the model to be predominantly trained and predominantly executed 2 years from now?

6 Conclusion: Putting the insights into action

Microsoft

10 questions to ask your organization

Manufacturers see software containerization, device management, and data ops as key for future factories. The findings in this paper confirm that manufacturers investing in software containerization, centralized device management, and industrial data operations as foundational building blocks for the factory of the future. For many, the question now is how to accelerate their efforts.

In developing their ambitions and implementation plans, manufacturers must navigate a highly dynamic environment. For the smart factory, key considerations include prioritizing the right investments, identifying and closing skill gaps, and promoting collaboration between IT and OT. For smart products, it will be crucial to gain experience with the connected technologies that enable value-added services.

To assess their current efforts and test the robustness of their planning, the following 10 questions, which are tied to the survey results, can act as a starting point:

1. **Scalability and automation:** Given that 72 % of survey participants highlighted scalability as crucial for future manufacturing, how prepared are your factories to scale operations up or down based on market demands, and what specific investments are needed to improve this capability?

2. **Cybersecurity strategy assessment.** Considering that 58 % of respondents view cybersecurity as a severe issue influencing technological priorities toward enhancing network security, what are the main cybersecurity threats to your factory, and what strategies are in place to mitigate these risks effectively?

3. **Impact of containerized software.** With 71 % of respondents utilizing containerized manufacturing software to enhance operational efficiency and system stability and many planning to extend containerization down to other OT devices, what further steps is your organization taking in this regard?

4. **Device management effectiveness.** Acknowledging that 68 % of survey respondents emphasize the importance of device security, evaluate the effectiveness of your current device management system in terms of security and data handling. What improvements are necessary?

5. **Integration of IT and OT systems.** As 52 % of respondents deem integrating IT and operational technology systems through industrial data operations very or extremely important for enhancing data flow and quality, to what extent has your company achieved this integration already or what further steps are you planning?

6. **Role of industrial data operations.** Given that a majority sees the integration of IT and OT data as a significant contributor to operational intelligence and decision-making, how do industrial data operations currently contribute to your decision-making processes, and what tools could enhance these operations?

7. **AI technology investments.** With manufacturers prioritizing adjustments to their data architecture to accommodate AI, focusing on AI-based predictive maintenance and generative AI technologies, what investments in AI and related technologies are planned for the next two years, and how do they align with your strategic goals?

8. **Skills and training gaps.** Reflecting the need for skilled personnel, as highlighted by the integration of new technologies, identify the skill gaps that exist within your workforce regarding the implementation and maintenance of AI technologies. What training programs are you considering to bridge these gaps?

9. **Evaluating technology impacts.** Considering manufacturers' focus on data and security, how do you measure the impact of new technologies on your production efficiency and product quality, and what metrics have proven most valuable?

10. **Future-proofing factory infrastructure.** With the rapid adoption of AI and containerized software reshaping the industry, how future-proof is your current factory infrastructure, and what key technologies are you lacking?

Voices from the industry:

Successful transformation relies on successful change management.

An IT director at an India-based electrical equipment manufacturing company:
"Change management is a key driver for successful implementation. Organizations have to invest in digital transformation to be competitive and grow."

A manufacturing director at an Australia-based oil and gas company:
"The major barrier is to support change management. Most of the new technologies represent a clear advantage compared with previous implementations."

The CIO at an Italy-based packaging manufacturing company:
"To start managing production using near real-time information instead of managing based on old data. We need to work on the mindset change required in some stakeholders/senior manager."

How Microsoft can support your next actions

For many manufacturers, the answers will point to the need to redesign at least some aspects of their approach to smart factory transformation. Given the highly competitive and dynamic environment, now is the time for action.

To take action with Microsoft, learn how Azure's adaptive cloud approach can help with containerization, device management, and industrial data operations to build the factory of the future:

Azure's adaptive cloud approach

Accelerating Industrial Transformation with Azure IoT Operations

Advancing hybrid cloud to adaptive cloud with Azure

IOT ANALYTICS

This report is based on research by IoT Analytics.

IoT Analytics, founded and operating out of Germany, is a leading global provider of market insights and strategic business intelligence for the IoT, AI, the cloud, edge technology, and Industry 4.0.

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