Interdisciplinary Center for Advanced Manufacturing Systems

SMART MANUFACTURING ADOPTION STUDY 2025

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Smart manufacturing technologies have become increasingly important to the competitiveness of the U.S. manufacturing sector. As manufacturers continue to face workforce shortages, productivity pressures, and growing global competition, technologies such as automation, artificial intelligence (AI), additive manufacturing, big data, Sensors/Internet of Things (IoT), and predictive analytics offer significant opportunities to improve operational performance and strengthen long-term competitiveness. However, successfully implementing these technologies remains a challenge for many manufacturers, particularly small and medium-sized manufacturers (SMMs), which represent more than 95% of all U.S. manufacturing firms [1-4].

This report presents the fourth annual installment of the ICAMS Smart Manufacturing Adoption Study, a longitudinal research effort designed to monitor smart manufacturing adoption across the U.S. manufacturing sector. The study examines manufacturers' business challenges, technology value perceptions, adoption maturity, implementation barriers, and preferred resources for learning about and deploying smart manufacturing technologies. Adoption is assessed using a five-stage framework consisting of awareness, researching, evaluating, implementing, and using [5].

The 2025 findings reveal that workforce and operational efficiency challenges remain manufacturers' highest priorities, while automation continues to be the most valued and mature smart manufacturing technology. Artificial intelligence has demonstrated the fastest growth in both perceived value and adoption since the inaugural survey, although most manufacturers remain in the early stages of implementation. The study also identifies a lack of awareness, lack of business cases, and workforce skill gaps as the primary barriers to adoption and highlights the importance of peer experience and case studies in supporting technology implementation. Together, these findings provide actionable insights to help government, industry, and academia accelerate smart manufacturing adoption and strengthen the competitiveness of the U.S. manufacturing sector.

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EXECUTIVE SUMMARY

Smart manufacturing technologies continue to play an important role in helping manufacturers respond to workforce shortages, improve operational performance, and remain competitive in a rapidly evolving global marketplace. To better understand how manufacturers are adopting these technologies, the Interdisciplinary Center for Advanced Manufacturing Systems (ICAMS) conducts longitudinal research examining technology adoption trends, implementation barriers, and the factors influencing investment and adoption decisions across the U.S. manufacturing sector. The study places particular emphasis on small and medium-sized manufacturers (SMMs), which represent more than 95% of all U.S. manufacturing firms [1-4].

The 2025 ICAMS Smart Manufacturing Adoption Survey represents the fourth annual installment of this ongoing research effort and builds upon the inaugural survey conducted in 2022. The survey examines manufacturers' business challenges, perceptions of smart manufacturing technologies, adoption maturity, barriers to implementation, and preferred resources for learning about and deploying new technologies. By tracking these measures over time, the study provides insight into how manufacturer priorities and technology adoption patterns are evolving. As of the end of September 2025, the survey yielded 117 responses, including 97 fully completed surveys, representing manufacturers across 28 U.S. states.

The study evaluates adoption patterns for six smart manufacturing technologies:

- Additive Manufacturing
- Artificial Intelligence (AI)
- Automation
- Big Data
- Sensors/Internet of Things (IoT)
- Predictive Analytics

Five key findings emerged from the 2025 Smart Manufacturing Adoption Survey:

1. **Workforce and operational efficiency challenges remain manufacturers' top concerns.** Labor shortages and productivity pressures continue to constrain growth and competitiveness.
2. **Automation remains the most valued and most widely adopted technology.** Manufacturers view automation as the most effective tool for addressing workforce and operational challenges.
3. **Artificial Intelligence (AI) is gaining momentum.** Interest and adoption have increased substantially since 2022, although most manufacturers remain in the early stages of adoption.
4. **Lack of business cases and workforce skills gaps remain the primary barriers to technology adoption.** Many manufacturers continue to struggle with investment justification and workforce readiness.
5. **Manufacturers rely on practical, experience-based resources.** Peer experience and case studies remain the most influential resources for learning about and adopting new technologies.

The survey findings provide the foundation for a set of recommendations directed toward government, industry, and academia. These recommendations are intended to address identified challenges and promote broader adoption of smart manufacturing technologies:

- **Government** efforts should focus on workforce development, business case development, and peer-learning initiatives to accelerate smart manufacturing adoption, particularly among small and medium-sized manufacturers.
- **Industry** should expand peer-to-peer knowledge sharing, implementation support, and workforce training to help manufacturers move from technology awareness to deployment.
- **Academia** should strengthen industry partnerships and emphasize applied research, workforce development, and practical implementation guidance that addresses real-world manufacturing challenges.

Collectively, the findings suggest that manufacturers increasingly recognize the value of smart manufacturing technologies; however, broader adoption will depend on addressing workforce skill gaps, strengthening business cases, and expanding access to practical implementation knowledge.

OBJECTIVE

The Interdisciplinary Center for Advanced Manufacturing Systems (ICAMS) launched the Smart Manufacturing Adoption Study in 2022 to better understand the state of smart manufacturing adoption among U.S. manufacturers and provide data-driven insights to support industry, government, and academic decision-making. At the time, limited empirical data existed on the maturity of key smart manufacturing technologies, creating a need for a longitudinal study to track adoption trends and measure progress across the U.S. manufacturing sector.

The primary objective of this study is to assess the current state of smart manufacturing adoption among U.S. manufacturers and identify the factors influencing technology implementation. Specifically, the study evaluates manufacturers' business challenges, perceptions of the value of technology, adoption maturity, implementation barriers, and preferred resources for learning about, evaluating, and deploying new technologies. The analysis focuses on six key smart manufacturing technologies: additive manufacturing, artificial intelligence (AI), automation, big data, sensors/Internet of Things (IoT), and predictive analytics.

By tracking these measures annually, the study provides a longitudinal benchmark for monitoring adoption trends and identifying changes in manufacturer priorities over time. The findings provide actionable insights that can inform policy development, industry initiatives, workforce development efforts, and future academic research. Ultimately, the study supports ICAMS' broader mission of accelerating smart manufacturing adoption, strengthening the competitiveness of U.S. manufacturers, and advancing the nation's manufacturing capabilities, particularly among small and medium-sized manufacturers (SMMs), which represent more than 95% of all U.S. manufacturing firms.

METHODOLOGY

The ICAMS Smart Manufacturing Adoption Study was developed using a mixed-methods approach. The research effort began in 2021 with the development of a semi-structured interview guide to explore manufacturers' experiences, perceptions, and challenges with smart manufacturing technologies. In-depth qualitative interviews were conducted with manufacturers representing a range of company sizes and industry sectors. Insights from these interviews were used to identify key themes and inform the development of the survey instrument.

The qualitative findings served as the foundation for a quantitative annual survey designed to assess smart manufacturing adoption among U.S. manufacturers. The survey was reviewed and approved by Auburn University's Institutional Review Board (IRB) and is administered annually using the Qualtrics survey platform. The first survey was launched in 2021, with the inaugural annual report published in 2022. Since then, the survey has been administered annually to establish a longitudinal benchmark for tracking technology adoption trends across the U.S. manufacturing sector.

The 2025 survey represents the fourth annual data collection effort within this ongoing research program. The survey examines manufacturers' business challenges, perceptions of the value of technology, adoption maturity, implementation barriers, and preferred resources for learning about, evaluating, and implementing smart manufacturing technologies. To support year-over-year comparisons, the core survey constructs and measures have been maintained across survey administrations, with minor refinements as needed to improve clarity and reflect evolving technology trends. Data collection for the 2025 survey began in May 2025 and concluded in September.

Survey participants were required to represent manufacturing organizations and possess sufficient knowledge of their organizations' operations, technology investments, or strategic initiatives to answer questions about smart manufacturing adoption. To increase survey reach and participation, survey invitations were distributed through a network of industry associations, manufacturing organizations, professional networks, and partner organizations that support U.S. manufacturers. The 2025 survey was promoted to the membership of several organizations, including the Society of Manufacturing Engineers (SME), The Digital Manufacturing and Cybersecurity Institute (MxD), and IPC International, Inc., a global electronics industry association and standards organization. As of September 25, 2025, the survey yielded 117 responses, including 97 fully completed surveys, representing manufacturers across 28 U.S. states.

Technology adoption maturity was assessed using the five-stage framework developed by Everett Rogers [5], which defines adoption as a progression through awareness, researching, evaluating, implementing, and using. This framework provides a consistent approach for assessing adoption maturity across the six technologies examined in this study: additive manufacturing, artificial intelligence (AI), automation, big data, sensors/Internet of Things (IoT), and predictive analytics.

The resulting dataset provides one of the few longitudinal benchmarks available for assessing smart manufacturing adoption trends, implementation barriers, technology priorities, and resource utilization among U.S. manufacturers. The data also enables year-over-year comparisons that reveal how manufacturers' priorities, perceptions of technology, and adoption patterns have evolved since the inaugural survey.

RESULTS

Overview

The following analyses are based on data collected through the 4th annual ICAMS Smart Manufacturing Adoption Survey, conducted in 2025 and building on the inaugural survey reported in 2022. The results highlight the key challenges manufacturers face and identify the technologies respondents believe will provide the greatest value in addressing them. By tracking responses over four consecutive years, the survey provides insight into evolving industry priorities and the changing landscape of smart manufacturing implementation.

The results provide insight into manufacturers' progress in adopting six key smart manufacturing technologies by identifying where organizations fall within the five-stage adoption framework: awareness, research, evaluation, implementation, and use. Additionally, the analysis identifies the primary barriers to technology adoption, including a lack of awareness, insufficient business cases, limited capital, high implementation costs, a lack of peer experience, resource constraints, workforce shortages, and workforce skill gaps. To further investigate potential differences in adoption patterns and barriers, the results are disaggregated by order mix and company size, enabling comparisons across distinct manufacturing environments and organizational characteristics.

As of September 25, 2025, the survey yielded 117 responses, with 97 completing it in full. The number of responses included in each analysis varies by question and is identified by the sample size (n) reported in each figure caption.

Demographics

Survey respondents were asked to identify the U.S. state where their manufacturing facility is located. Figure 1 illustrates the geographic distribution of survey respondents by state. Respondents represented manufacturing facilities located in 28 U.S. states, providing broad geographic coverage across the Midwest, South, Northeast, and West. (Figure 1: States of Respondents)

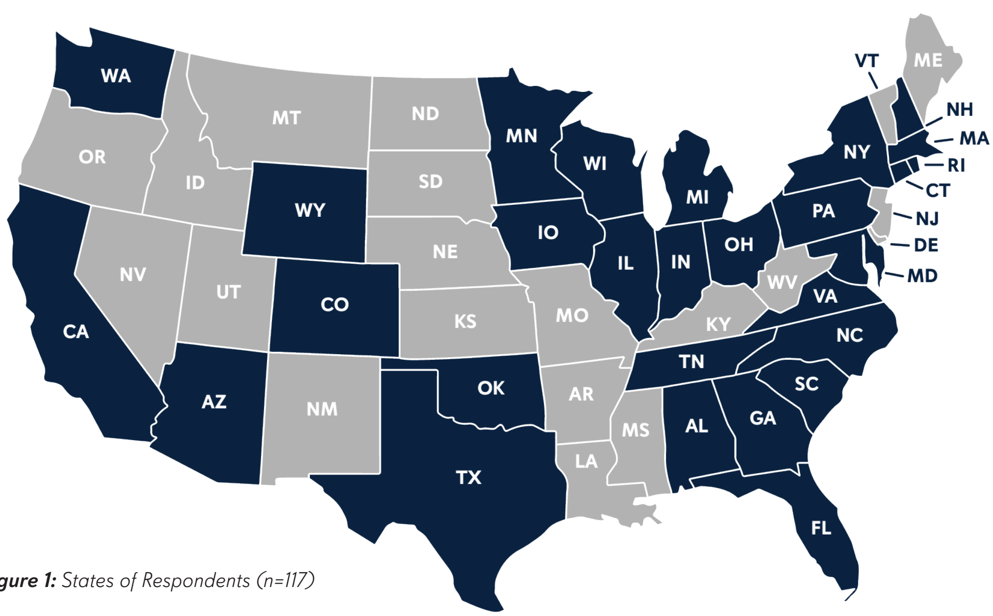


Figure 1: *States of Respondents (n=117)*

The survey sample included organizations from a broad range of industries, including aerospace, automotive, consumer goods, defense, energy, medical, and transportation. Because respondents were allowed to identify multiple industry affiliations, the cumulative percentage across categories exceeds 100%. (Figure 2: Industry Breakdown)

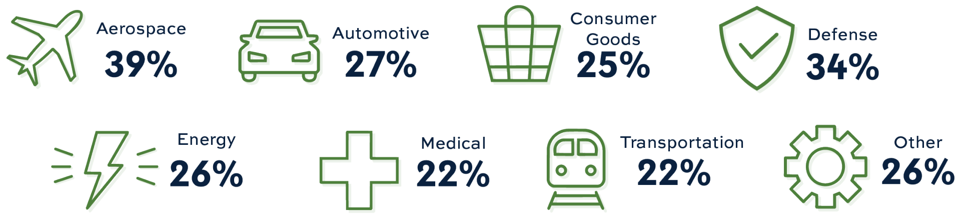


Figure 2: *Industry Breakdown (n=117)*

To characterize the sample, SMMs were defined as manufacturers with fewer than 500 employees and annual revenue below $100 million [1]. Based on these criteria, nearly two-thirds of respondents (62%) qualified as SMMs. The respondent population was largely composed of small manufacturers, with 81% reporting fewer than 500 employees. Annual revenue figures also closely aligned with the SMM definition, with 62% of respondents reporting revenue below the established $100 million threshold. These results suggest that the survey captured the perspectives of a substantial number of manufacturers who fit the study's target SMM population, while also including larger organizations for comparison. (Figure 3: Number of Employees at Respondent's Location and Figure 4: Company Revenue)

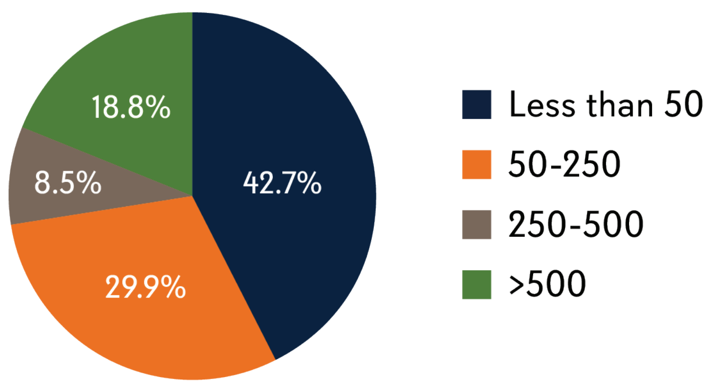


Figure 3: *Number of Employees at Respondent's Location (n=117)*

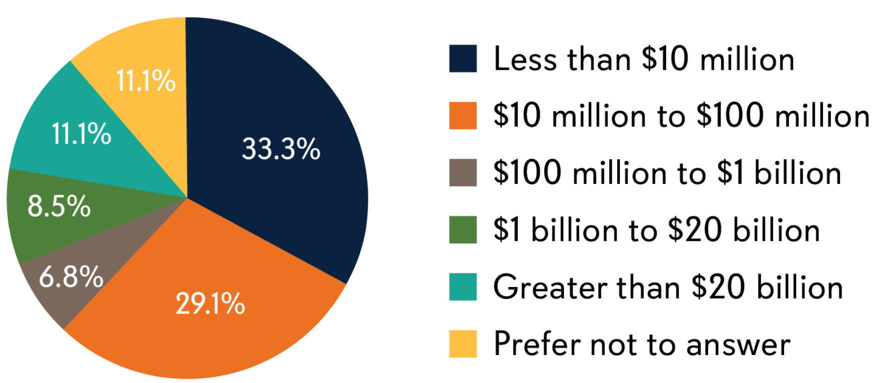


Figure 4: *Company Revenue (n=117)*

Top Challenges

To identify the most pressing organizational concerns, respondents were asked to select the three greatest challenges facing their businesses. The survey included eight response categories: access to capital, capital improvements, competitive pressure, operational efficiency, revenue/profits, sales/marketing, workforce- engineering, and workforce- operations. Workforce challenges were separated into engineering-focused positions, which typically require a college degree or specialized technical training, and operational positions responsible for running equipment and supporting production activities on the factory floor. The results are presented in Table 1. (Table 1: Top Business Challenges)

Workforce- operations, operational efficiency, and revenue/profits emerged as the three most significant challenges manufacturers are facing. Workforce- operations was identified as a top-three challenge by 60% of respondents, making it the most frequently cited concern. Operational efficiency followed closely, with 55% of respondents ranking it among their top three challenges. The prominence of workforce- operations is further reflected in the fact that nearly half of the respondents (45%) identified it as one of their top two challenges. These findings suggest that recruiting, retaining, and developing personnel for production and shop-floor operations remain critical concerns for manufacturers and continue to impact overall organizational performance.

Table 1: *Top Business Challenges (n=117)*

2025	Access to Capital	Capital Improvements	Competitive Pressure	Operational Efficiency	Revenue/ Profits	Sales/ Marketing	Workforce- Engineering	Workforce- Operations
#1	9%	5%	15%	18%	9%	11%	8%	25%
#2	0%	9%	7%	17%	18%	11%	19%	20%
#3	7%	11%	15%	20%	14%	12%	8%	15%

NOTE: In this table and those that follow, conditional formatting was used to highlight the top two responses per row.

Figure 5 illustrates the evolution of manufacturers' top business challenges from 2022 through 2025. **Workforce- operations remained the most frequently cited challenge throughout the study period**, with approximately 60% of respondents consistently ranking it among their top three concerns. Although the percentage of respondents ranking it among their top three concerns declined slightly from 62% to 59% over the four years. Workforce- operations also received the largest share of first-place rankings each year, demonstrating that workforce shortages and retention challenges on the factory floor remain manufacturers' most pressing concern. (Figure 5: Top Business Challenges Year-Over-Year)

Operational efficiency also remained a leading challenge across all four years, although its prevalence declined modestly over time, falling from 64% in 2022 to 55% in 2025. Despite this decline, more than half of respondents continue to identify operational efficiency as a top-three challenge, highlighting the ongoing need to improve productivity, reduce waste, and optimize operations.

Revenue and profitability concerns exhibited greater variability than many of the other business challenges examined. After declining from 40% in 2022 to 34% in 2023 and 33% in 2024, the percentage of respondents ranking revenue/profits among their top three challenges increased to 41% in 2025, surpassing the level observed in the inaugural 2022 survey.

Competitive pressure increased steadily from 29% in 2022 to 36% in 2025, indicating growing concerns about market competition. **Workforce- engineering challenges also increased overall during the study period**, rising from 29% in 2022 to 34% in 2025. However, concern peaked at 41% in 2023, remained elevated at 40% in 2024, and then declined in 2025. Despite this recent decrease, workforce- engineering continues to be a more prominent challenge than it was at the beginning of the study period. **Sales and marketing challenges increased modestly** from 31% in 2022 to 34% in 2025.

The most substantial decline occurred in access to capital, which decreased from 29% in 2022 to 16% in 2025, suggesting that financing constraints have become less problematic relative to other business challenges.

Collectively, these findings indicate that while **workforce and operational issues remain the dominant concerns** for manufacturers, **competitive and workforce-related pressures have become increasingly important** over the four-year study period.

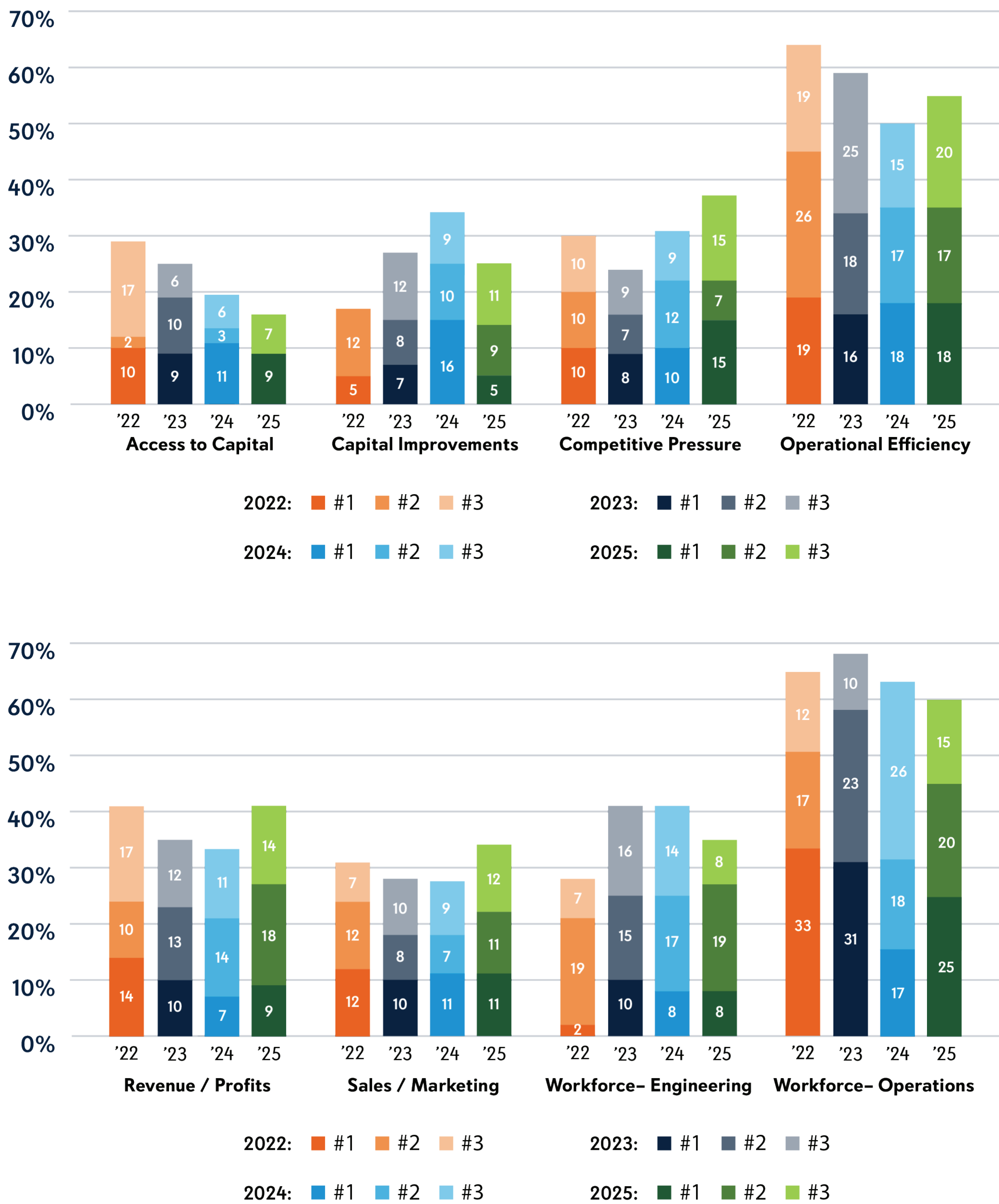


***Figure 5:** Top Business Challenges Year-Over-Year (n=117)*

After identifying their top business challenges, respondents were asked whether the circumstances contributing to those challenges were improving, remaining the same, or worsening. In 2025, 19% of respondents indicated that conditions were improving, 47% reported that conditions remained unchanged, and 34% believed conditions were worsening. (Figure 6: Circumstances Driving Top 3 Challenges)

While the percentage of respondents reporting improvement remains relatively modest, the overall results suggest a more stable operating environment than was observed in the inaugural 2022 survey. In 2022, nearly half of respondents (48%) reported that their circumstances were worsening, compared to 34% in 2025. At the same time, the proportion of respondents reporting stable conditions increased from 26% in 2022 to 47% in 2025. These findings suggest that manufacturers have moved away from the heightened uncertainty experienced in 2022 toward a more consistent business environment.

However, the fact that one-third of respondents continue to report worsening conditions indicates that significant challenges remain. Ideally, a greater proportion of respondents would report improving circumstances; however, the results presented in the following sections help explain why progress has been limited by highlighting the barriers that continue to impede manufacturers' ability to adopt and implement new technologies.

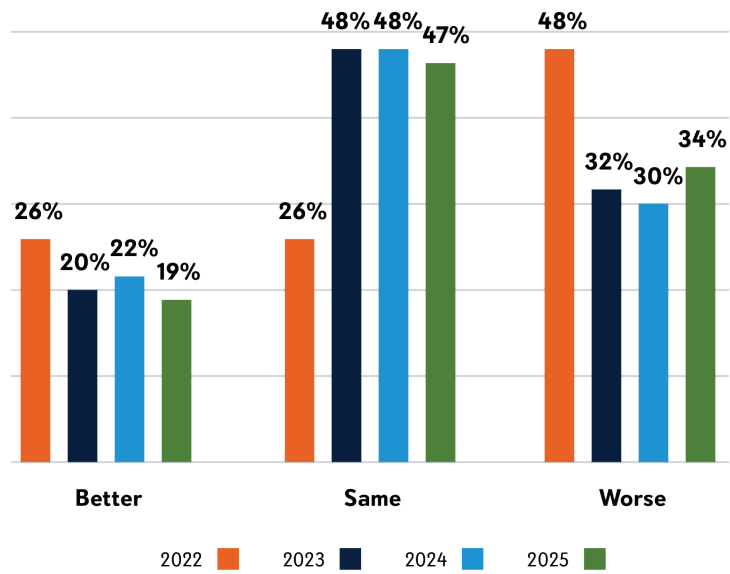


Figure 6: *Circumstances Driving Top 3 Challenges (n=117)*

Smart Manufacturing Component Value

Respondents were asked to rank the six smart manufacturing technologies according to their ability to address the business challenges identified earlier in the survey. **Automation emerged as the clear leader**, with 36% of respondents ranking it as the most important technology and an additional 16% and 12% ranking it second and third, respectively. In total, 64% of respondents ranked automation among their top three technologies, making it the most highly valued solution for addressing business challenges. These findings suggest that manufacturers view automation as a key tool for addressing persistent challenges related to workforce shortages, operational efficiency, and productivity. (Table 2: Perceived Value of Smart Manufacturing Technologies)

Artificial intelligence was the second most frequently selected top-ranked technology, with 19% of respondents identifying it as the most important technology, followed by Additive Manufacturing (15%), sensors/Internet of Things (IoT) (12%), Predictive Analytics (11%), and Big Data (6%). **While fewer respondents ranked predictive analytics and Sensors/IoT as their most important technology, they were frequently selected as second- and third-ranked technologies**, indicating that manufacturers recognize their value as complementary capabilities within broader smart manufacturing initiatives.

Overall, the findings suggest that manufacturers place the greatest value on technologies that directly improve operational performance and address workforce-related challenges, while data-driven technologies are increasingly viewed as important supporting capabilities.

***Table 2:** Perceived Value of Smart Manufacturing Technologies (n=114)*

2025	Additive Manufacturing	Artificial Intelligence	Automation	Big Data	Sensors/IoT	Predictive Analytics
#1	15%	19%	36%	6%	12%	11%
#2	10%	14%	16%	16%	10%	23%
#3	7%	15%	12%	9%	22%	18%

Figure 7 illustrates how manufacturers' perceptions of the value of smart manufacturing technologies evolved between 2022 and 2025. **Automation remained the most highly valued technology throughout** the study period, with 76% of respondents ranking it among their top three technologies in 2022. However, its perceived value declined to 63% in 2023, partially recovered to 72% in 2024, and settled at 64% in 2025. Despite this decline, automation remained the top-ranked technology in every survey year. (Figure 7: Perceived Value of Smart Manufacturing Technologies Year-Over-Year).

Artificial intelligence experienced the most notable growth over the four-year study period. The percentage of respondents ranking AI among their top three technologies increased from 19% in 2022 to 48% in 2025 (a staggering 29-percentage-point increase), representing the largest increase of any technology examined. The share of respondents ranking AI as their most important technology also rose substantially, increasing from 2% in 2022 to 19% in 2025. These **findings suggest growing confidence in AI's potential to address key manufacturing challenges.**

Additive manufacturing also gained importance over time. The percentage of respondents ranking it among their top three technologies increased from 21% in 2022 to 41% in 2024, then declined to 32% in 2025. Although interest moderated in the most recent survey, additive manufacturing remained more highly valued than in the inaugural survey.

Big data remained one of the least valued technologies throughout the study period. While the percentage of respondents ranking it among their top three technologies increased from 12% in 2022 to 34% in 2024, it remained at 31% in 2025. Similarly, Sensors/Internet of Things (IoT) experienced substantial fluctuations, increasing from 62% in 2022 to 67% in 2023 before declining to 43% and 44% in 2024 and 2025, respectively.

Predictive analytics demonstrated strong growth between 2022 and 2023, rising from 31% to 59% of respondents ranking it among their top three technologies. **However, its perceived value subsequently declined** to 55% in 2024 and 52% in 2025. Despite this decrease, predictive analytics remained considerably more valued in 2025 than it was in 2022.

Overall, the findings suggest a gradual shift in manufacturer priorities. While automation continues to be viewed as the most effective technology for addressing business challenges, **interest in data-driven technologies, particularly artificial intelligence, has increased substantially since the inaugural 2022 survey**, reflecting the growing role of advanced analytics and intelligent systems in manufacturing operations.

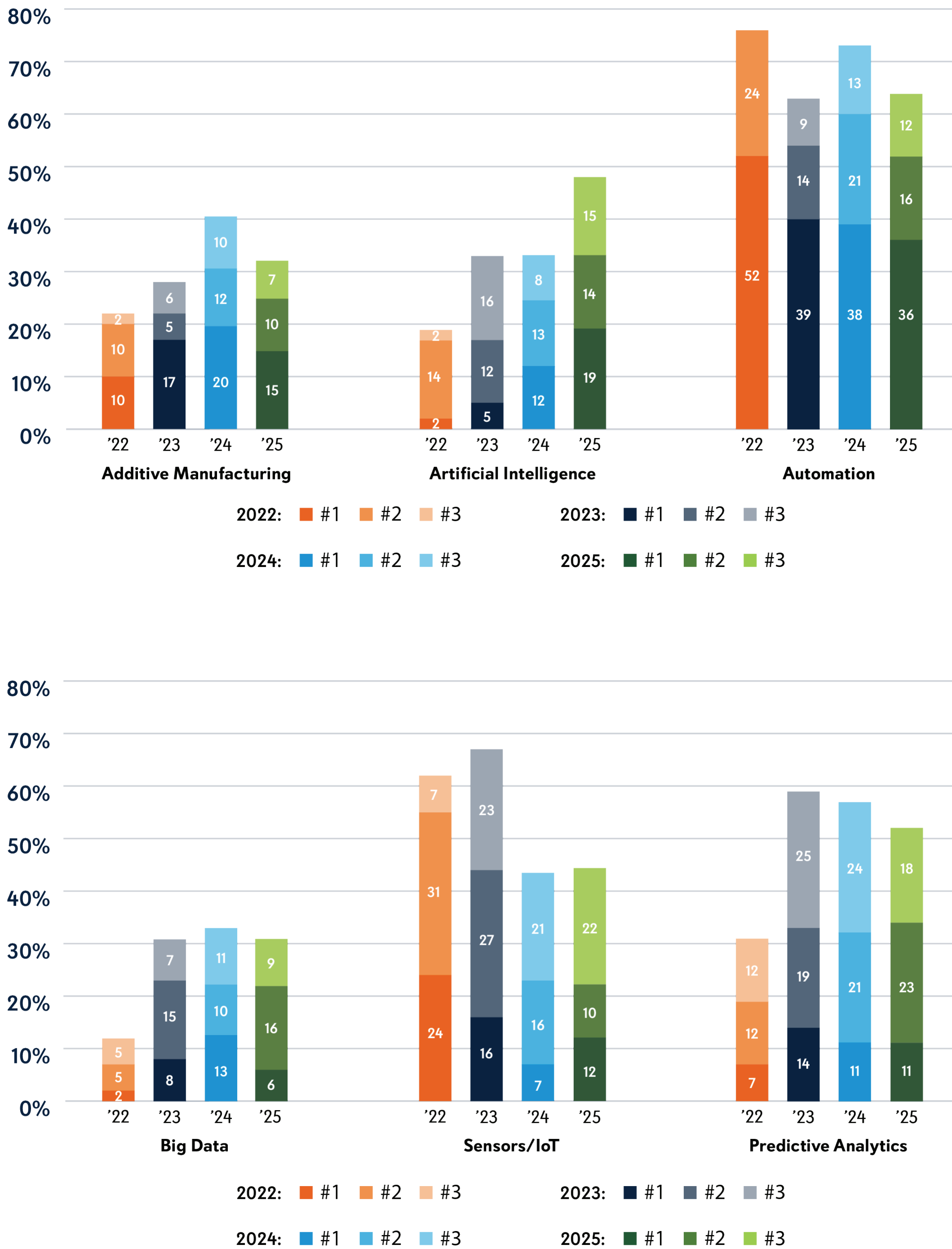


Figure 7: *Perceived Value of Smart Manufacturing Technologies Year-Over-Year (n=114)*

Smart Manufacturing Component Adoption

Participants were asked to assess their organization's stage of adoption for the six smart manufacturing technologies using a five-stage framework: awareness, research, evaluation, implementation, and use. Table 3 and Figure 8 compare the adoption maturity of these technologies. Automation and additive manufacturing emerged as the most mature technologies, with 37% of respondents reporting active use of each technology, and 59% (37% + 22%) and 52% (37% + 15%) indicating they were either implementing or using them, respectively.

In contrast, artificial intelligence remained in the early stages of adoption, with 56% of respondents reporting being in the awareness or research stages, while only 11% reported active use. Big data also exhibited relatively low adoption maturity, with 56% of respondents remaining in the awareness or researching stages and just 11% actively using the technology.

Sensors/Internet of Things and predictive analytics occupied an intermediate position, with 60% and 55% of respondents, respectively, reporting that they were evaluating, implementing, or using these technologies.

Overall, the findings suggest that automation and additive manufacturing have reached the highest levels of adoption maturity, whereas artificial intelligence and big data remain in earlier stages of adoption for many manufacturers. (Table 3: Smart Manufacturing Technology Adoption and Figure 8: Smart Manufacturing Technology Adoption)

Table 3: *Smart Manufacturing Technology Adoption (n=110)*

2025	Additive Manufacturing	Artificial Intelligence	Automation	Big Data	Sensors/IoT	Predictive Analytics
Using	37%	11%	37%	11%	17%	10%
Implementing	15%	15%	22%	15%	19%	18%
Evaluating	10%	19%	16%	19%	24%	27%
Researching	15%	34%	11%	21%	19%	20%
Awareness	22%	22%	14%	35%	21%	25%

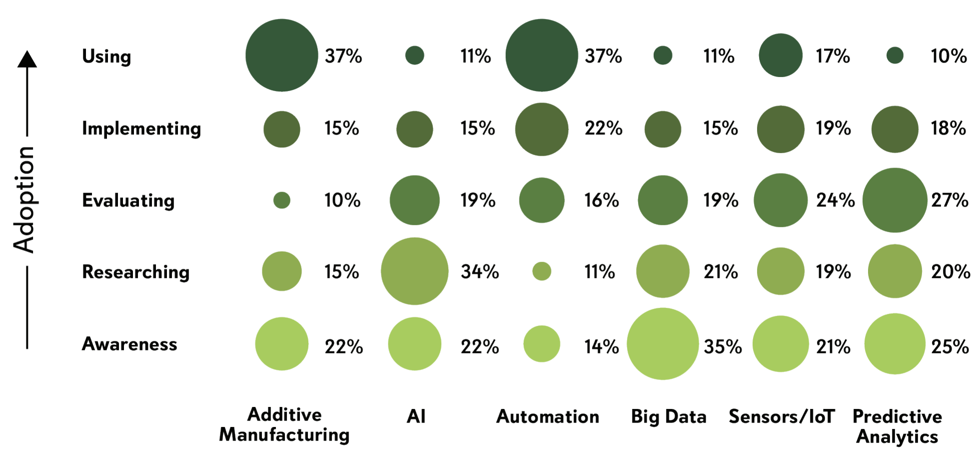


Figure 8: *Smart Manufacturing Technology Adoption (n=110)*

Adoption: Additive Manufacturing

Additive manufacturing adoption continued to mature between 2022 and 2025. The percentage of respondents in the awareness stage declined from 42% to 22% (a 20-percentage-point drop), while the share of organizations researching, implementing, or using the technology increased. The using category grew from 26% in 2022 to 37% in 2025 (an 11-percentage-point increase), making it the largest adoption stage for additive manufacturing in the most recent survey. Additionally, more than half of respondents (52%) reported either implementing or using additive manufacturing in 2025, compared to 38% in 2022. These findings suggest continued progression from awareness toward implementation and sustained use of additive manufacturing technologies. (Figure 9: Additive Manufacturing Adoption Year-Over-Year)

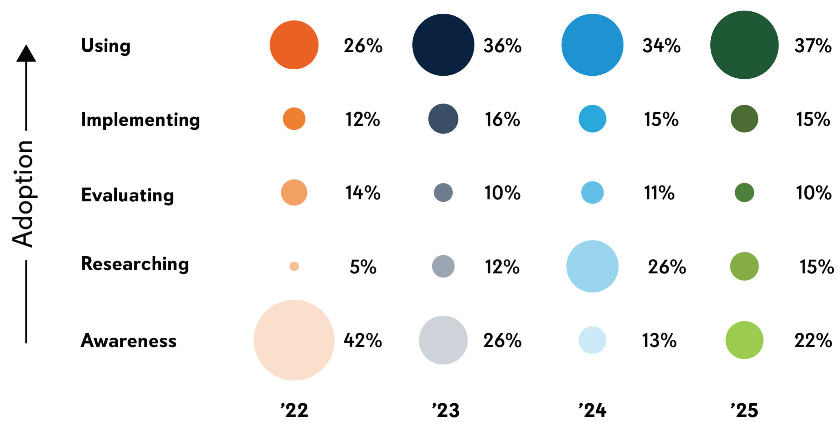


Figure 9: *Additive Manufacturing Adoption Year-Over-Year (n=110)*

Adoption: Artificial Intelligence

Artificial intelligence (AI) exhibited one of the most pronounced shifts in adoption maturity among the technologies examined. The percentage of respondents in the awareness stage declined from 47% in 2022 to 22% in 2025 (a 25-point-percentage drop), indicating that fewer manufacturers are unfamiliar with the technology. Over the same period, the proportion of respondents in the research stage increased from 26% to 34%, while the share actively using AI increased more than fivefold, from 2% to 11%. Adoption also progressed in the implementing stage, rising from 9% in 2022 to 15% in 2025. Despite these gains, a majority of respondents (56%) remained in the awareness or researching stages in 2025, suggesting that AI adoption is still in the early phases of maturity for many manufacturers. (Figure 10: Artificial Intelligence Adoption Year-Over-Year)

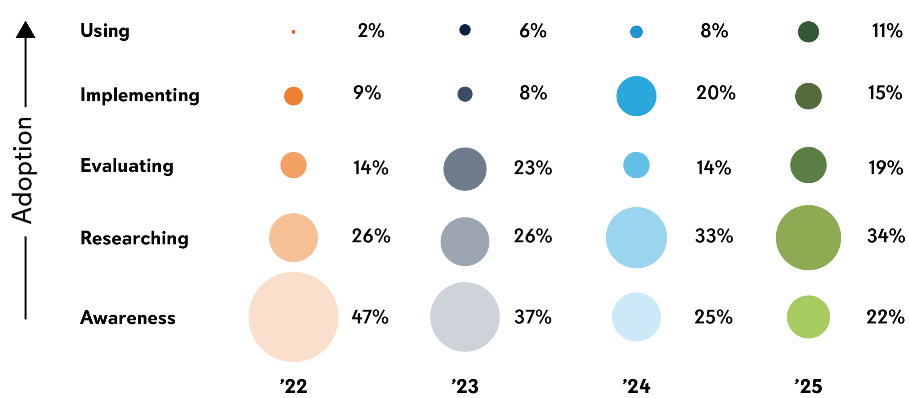


Figure 10: *Artificial Intelligence Adoption Year-Over-Year (n=110)*

Adoption: Automation

Automation demonstrated consistently high levels of adoption throughout the study period. The percentage of respondents actively using automation increased from 30% in 2022 to 37% in 2024 and remained at 37% in 2025. Similarly, the proportion of respondents implementing automation increased slightly from 21% in 2022 to 22% in 2025. Over the same period, the percentage of respondents in the research stage declined from 21% to 11%, suggesting that many organizations have progressed beyond the exploratory phase of adoption. In 2025, 59% of respondents reported either implementing or using automation technologies, compared to 51% in 2022. Meanwhile, the share of respondents in the awareness stage remained relatively low, ranging from 8% to 14% across the four survey years. These findings indicate that automation is one of the most established smart manufacturing technologies, with a majority of manufacturers having moved beyond awareness, research, and evaluation into implementation and sustained use. (Figure 11: Automation Adoption Year-Over-Year)

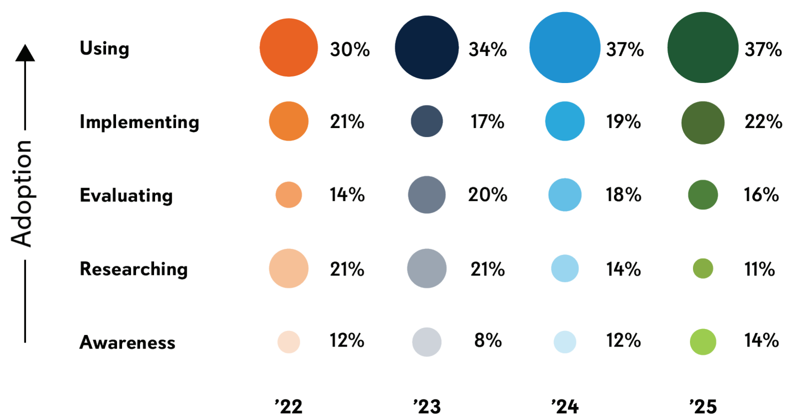


Figure 11: *Automation Adoption Year-Over-Year (n=110)*

Adoption: Big Data

Big data adoption has progressed more slowly than other smart manufacturing technologies and remains concentrated in the earlier stages of the adoption lifecycle. Big data adoption exhibited a mixed pattern over the four-year study period. The percentage of respondents in the awareness stage declined from 35% in 2022 to 19% in 2024, indicating growing familiarity with the technology; however, awareness increased back to 35% in 2025. Similarly, the share of respondents in the researching stage increased from 16% in 2022 to 30% in 2024 before declining to 21% in 2025. The percentage of respondents implementing big data technologies grew from 16% in 2022 to 28% in 2024 but fell to 15% in 2025. Despite these fluctuations, the use of big data increased modestly from 9% in 2022 to 11% in 2025. (Figure 12: Big Data Adoption Year-Over-Year)

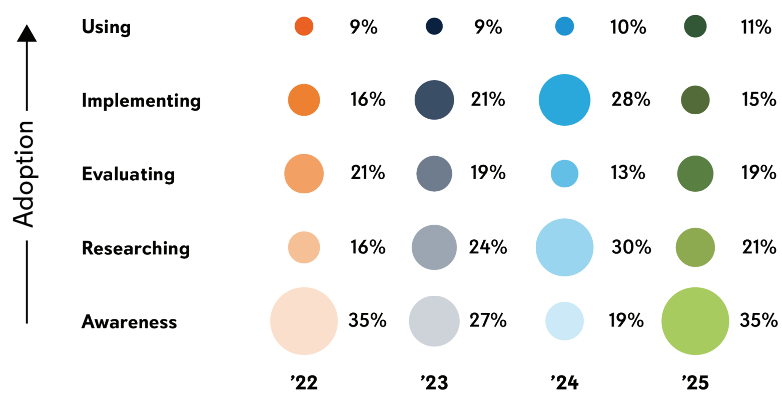


Figure 12: *Big Data Adoption Year-Over-Year (n=110)*

Adoption: Sensors/IoT

Unlike automation and additive manufacturing, **Sensors/Internet of Things (IoT) exhibited a shift toward earlier adoption stages** between 2022 and 2025. The percentage of respondents in the awareness and researching stages increased from 25% in 2022 to 40% in 2025, while the proportion implementing or using the technology declined from 56% to 36%. Because the survey captures different respondents each year, these changes likely reflect differences in the composition of the respondent sample rather than a broad retreat from Sensors/IoT adoption. Nevertheless, the results indicate that Sensors/IoT remains one of the more mature technologies examined, with a majority of respondents (60%) still reporting that they are evaluating, implementing, or actively using the technology in 2025. (Figure 13: Sensors/IoT Adoption Year-Over-Year)

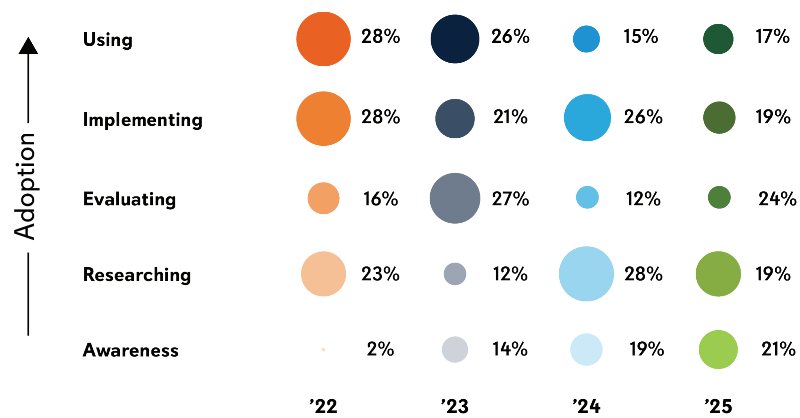


Figure 13: *Sensors/IoT Adoption Year-Over-Year (n=110)*

Adoption: Predictive Analytics

Predictive analytics adoption remained relatively stable between 2022 and 2025. In 2025, 55% of respondents reported evaluating, implementing, or using predictive analytics, compared to 49% in 2022. Active use remained relatively low, decreasing only modestly from 12% to 10% over the study period, while approximately 45% of respondents remained in the awareness or researching stages. These findings suggest that predictive analytics has achieved moderate adoption maturity but continues to lag behind more established technologies such as automation and additive manufacturing. (Figure 14: Predictive Analytics Adoption Year-Over-Year)

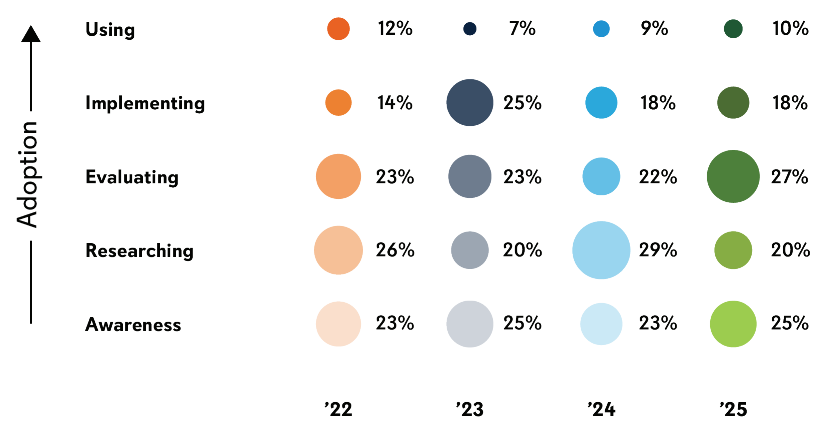


Figure 14: *Predictive Analytics Adoption Year-Over-Year (n=110)*

Smart Manufacturing Adoption Barriers

Respondents were asked to identify the three most significant barriers preventing the adoption of each of the six smart manufacturing technologies. The barriers evaluated included lack of awareness, lack of business cases, lack of capital, high costs, lack of peer experience, limited resources, workforce shortages, and workforce skill gaps. Table 4 presents results from a weighted-average approach, assigning greater weight to barriers ranked higher by respondents. This method provides a more comprehensive assessment of the relative importance of each barrier by accounting for both the frequency with which a barrier was selected and its perceived significance. (Table 4: Adoption Barriers by Technology)

Table 4: *Adoption Barriers by Technology*

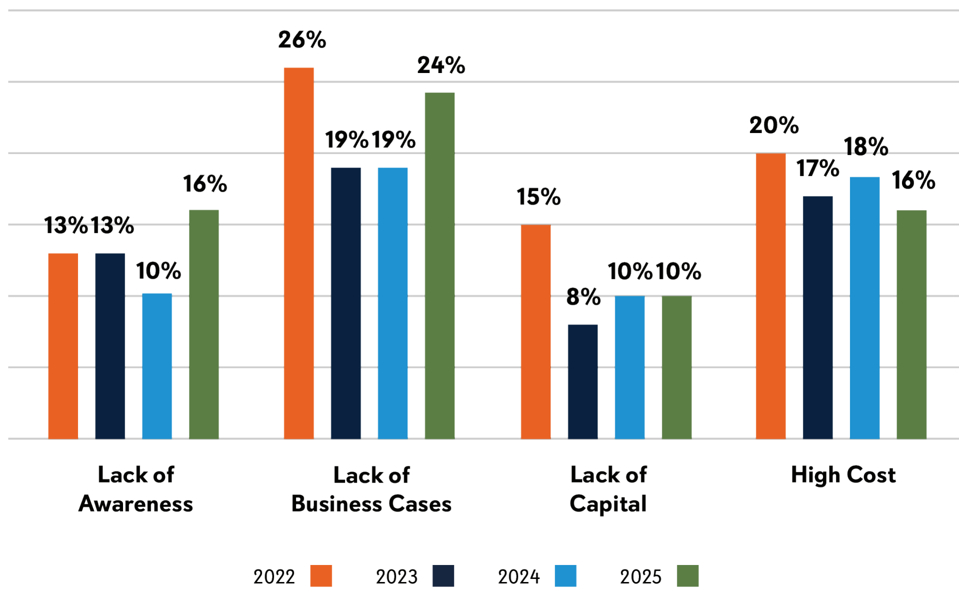
	Lack of				Lack of				
2025	Awareness	Business Cases	Capital	High Cost	Peer Experience	Resources	Workforce	Workforce Skill Set	Number of Respondents
Additive Manufacturing	16%	24%	10%	16%	10%	5%	10%	10%	107
Artificial Intelligence	22%	20%	6%	8%	10%	9%	8%	17%	103
Automation	10%	14%	16%	21%	6%	7%	12%	14%	102
Big Data	19%	22%	6%	11%	7%	12%	10%	14%	101
Sensors/IoT	18%	20%	9%	12%	7%	10%	10%	14%	101
Predictive Analytics	21%	21%	6%	10%	8%	9%	9%	16%	100

Across the six technologies examined, **a lack of business cases and a lack of awareness emerged as the most frequently cited barriers to adoption.** A lack of business cases was identified by approximately one-fifth of respondents for most technologies and represented the leading barrier for additive manufacturing (24%), big data (22%), and sensors/IoT (20%). Similarly, lack of awareness remained a significant obstacle, particularly for artificial intelligence (22%), predictive analytics (21%), big data (19%), and sensors/IoT (18%). **Workforce-related challenges also persisted across all technologies,** with workforce skill gaps ranging from 10% to 17% and workforce shortages ranging from 8% to 12%.

In contrast, automation **adoption was more commonly constrained by high costs** (21%) and capital requirements (16%), reflecting its relatively advanced stage of adoption. Collectively, these findings suggest that organizational knowledge, demonstrated business value, and workforce capabilities remain the primary factors limiting broader adoption of smart manufacturing.

Adoption Barriers: Additive Manufacturing

Lack of business cases remained the leading barrier to additive manufacturing adoption throughout the study period. In 2025, respondents most frequently cited lack of business cases (24%), lack of awareness (16%), and high cost (16%) as barriers to adoption. Compared to 2022, capital constraints and high cost became less significant (both dropping approximately 5 percentage points), while lack of peer experience, workforce shortages, and awareness-related challenges increased modestly (all by approximately 4 percentage points). These findings suggest that organizational justification and cost considerations remain the primary obstacles to the adoption of additive manufacturing. (Figure 15: Adoption Barriers for Additive Manufacturing)



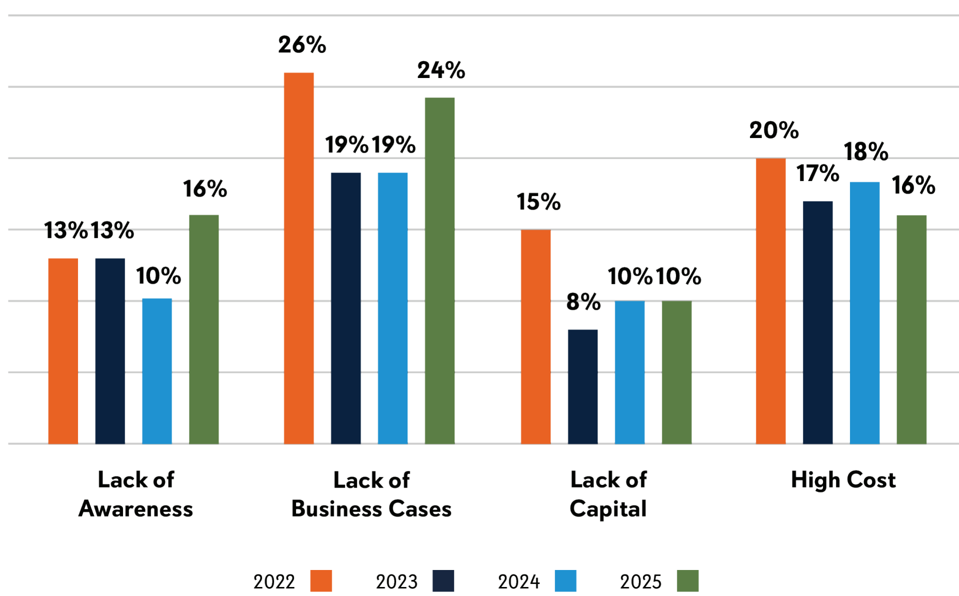
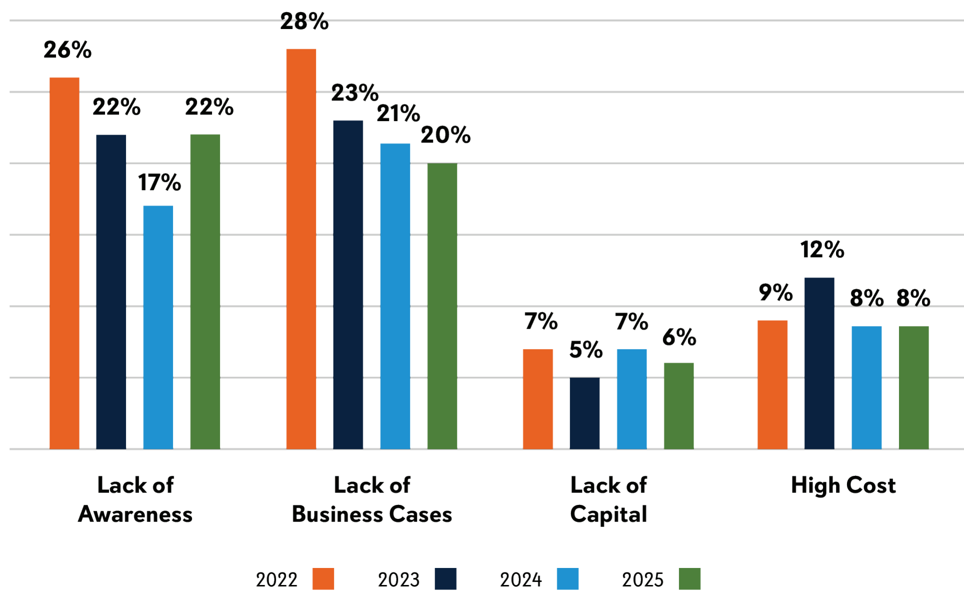


Figure 15: *Adoption Barriers for Additive Manufacturing (n=107)*

Adoption Barriers: Artificial Intelligence

Lack of awareness and lack of business cases remained the primary barriers to artificial intelligence adoption, although both declined between 2022 and 2025. In 2025, respondents most frequently cited lack of awareness (22%), lack of business cases (20%), and workforce skill gaps (17%) as barriers to adoption. Compared with earlier survey years, the lack of peer experience, workforce skill gaps, and resource constraints became more prominent (each increasing by approximately 4 percentage points), suggesting that organizational readiness and technical expertise are increasingly important factors influencing AI adoption. (Figure 16: Adoption Barriers for Artificial Intelligence)



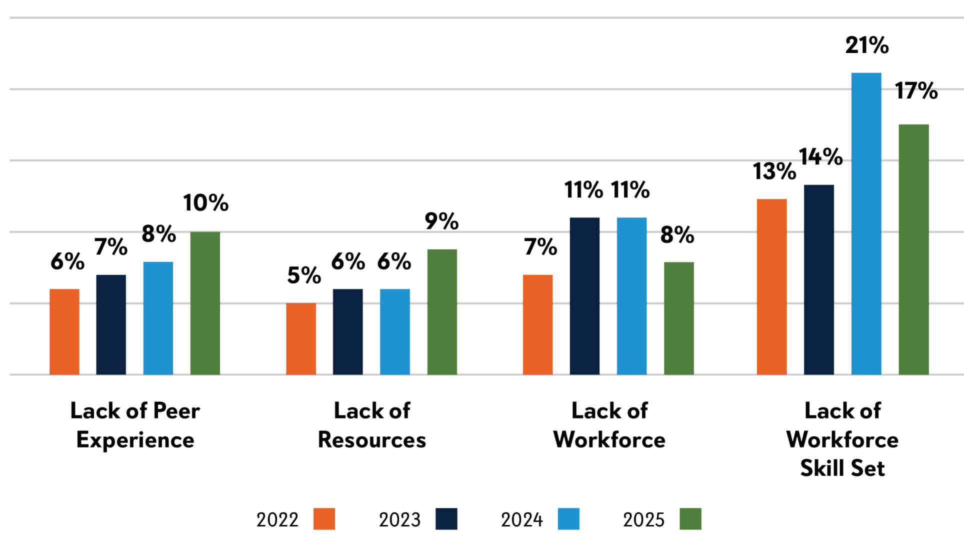


Figure 16: *Adoption Barriers for Artificial Intelligence (n=103)*

Adoption Barriers: Automation

High cost remained the predominant barrier to automation adoption throughout the study period, followed by workforce skill gaps, capital requirements, and workforce shortages. In 2025, respondents most frequently cited high cost (21%), capital requirements (16%), lack of business cases (14%), and workforce skill gaps (14%). Compared to technologies such as artificial intelligence and big data, awareness-related barriers were less prominent, suggesting that automation has reached a more mature stage of adoption and is increasingly constrained by cost and workforce challenges rather than understanding or perceived value. (Figure 17: Adoption Barriers for Automation)

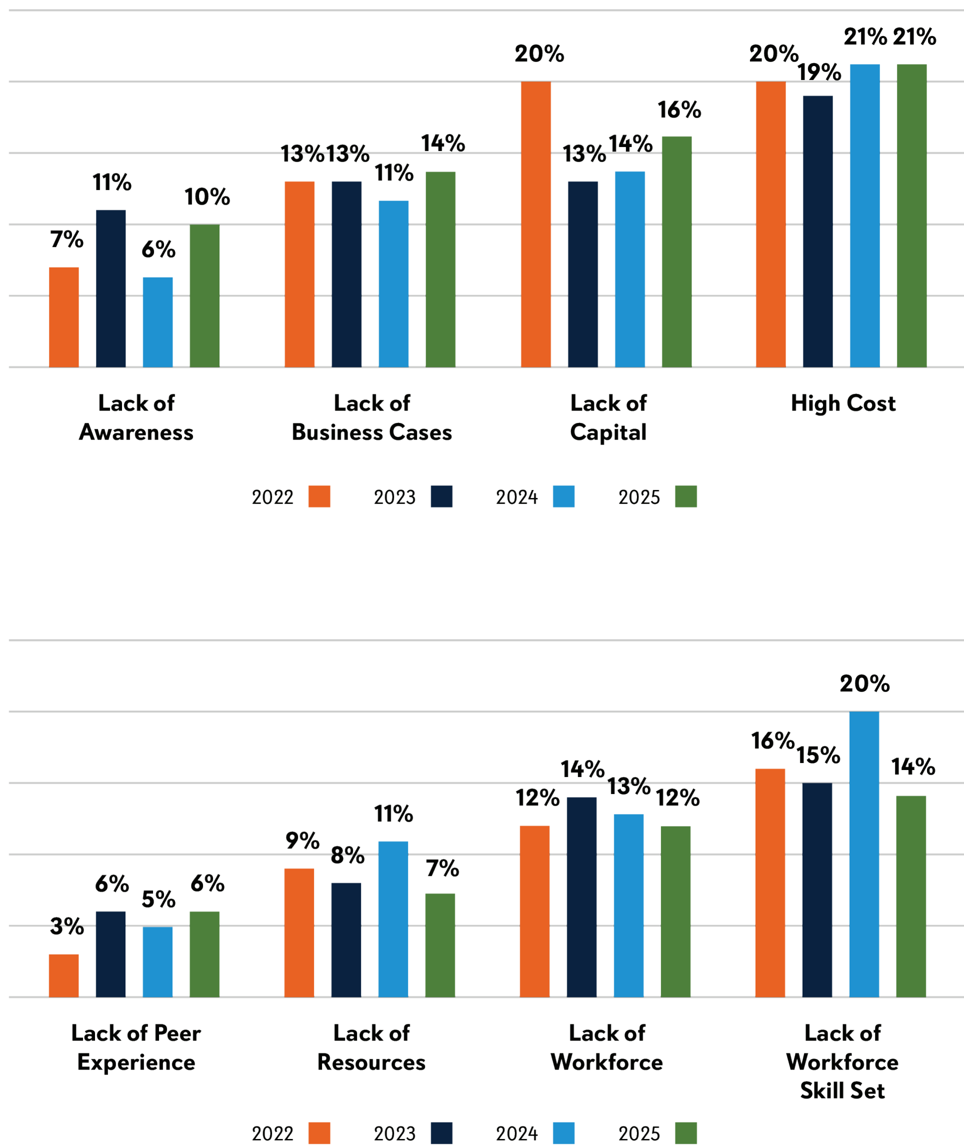


Figure 17: *Adoption Barriers for Automation (n=102)*

Adoption Barriers: Big Data

Lack of awareness and lack of business cases remained the most significant barriers to big data adoption throughout the study period. In 2025, respondents most frequently cited lack of business cases (22%), lack of awareness (19%), and workforce skill gaps (14%). Over the 2022-2025 study period, awareness-related barriers declined (by 6 percentage points), while resource-related challenges became more prominent (increasing by 8 percentage points). These findings suggest that although manufacturers have become more familiar with big data technologies, demonstrating business value and developing the necessary organizational capabilities remain significant barriers to adoption. (Figure 18: Adoption Barriers for Big Data)

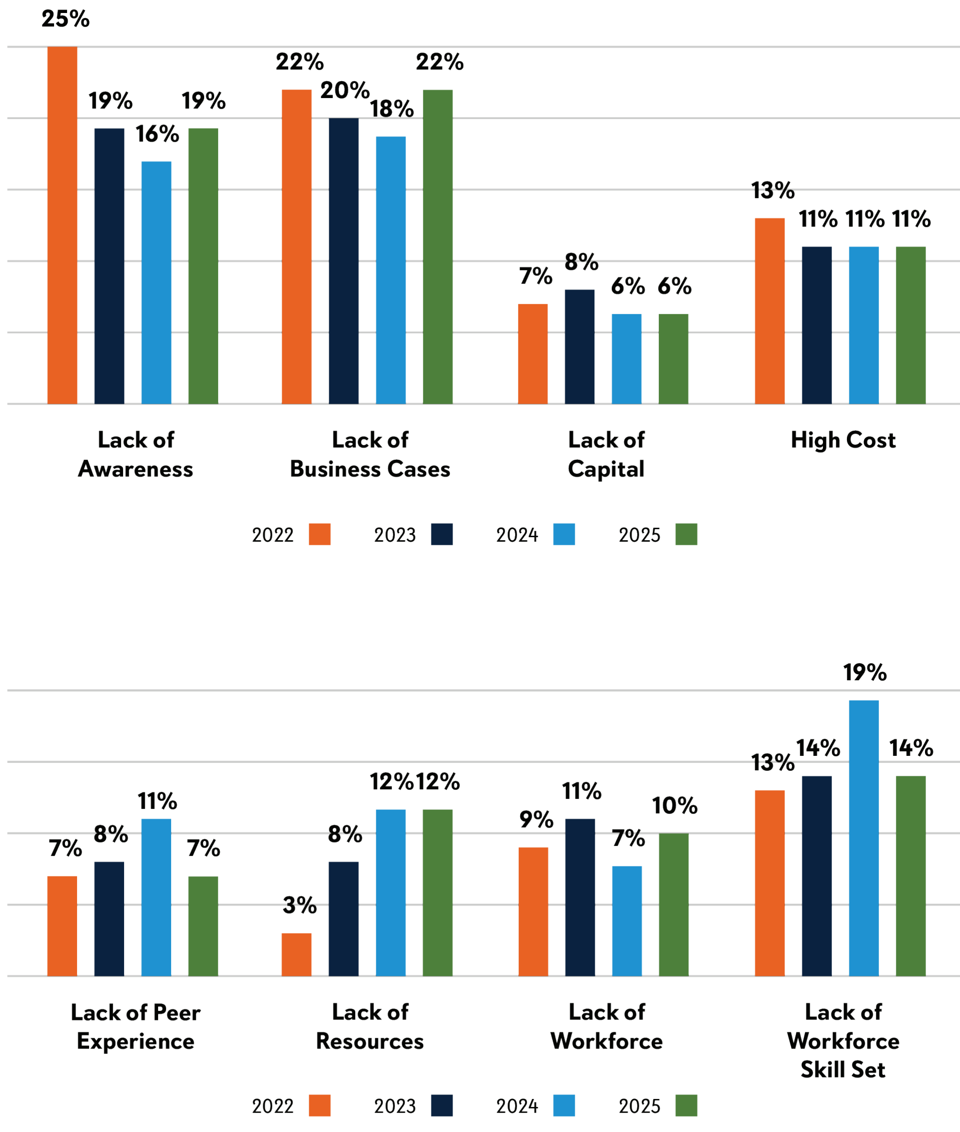
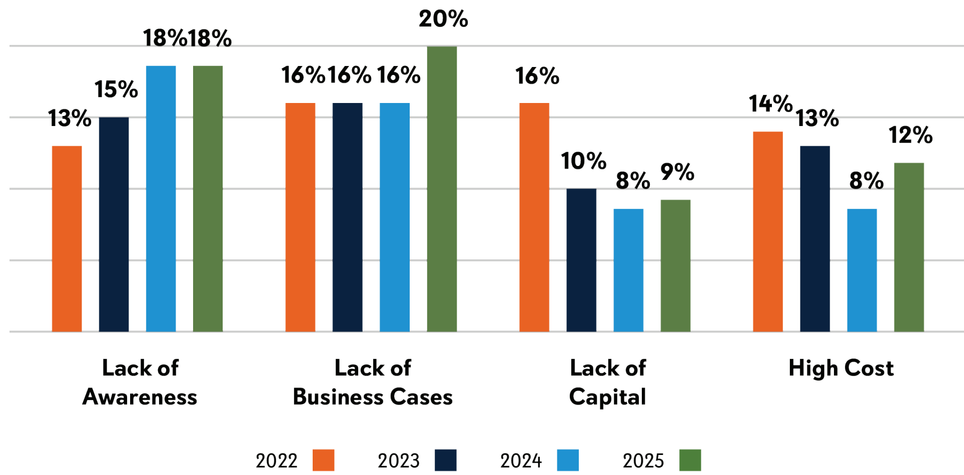


Figure 18: *Adoption Barriers for Big Data (n=101)*

Adoption Barriers: Sensors/IoT

Lack of business cases (20%), lack of awareness (18%), and workforce skill gaps (14%) were the most frequently cited barriers to Sensors/Internet of Things (IoT) adoption in 2025. Since the inaugural 2022 survey, awareness-, resource-, and business case-related barriers increased (all by 5 percentage points), while capital constraints and workforce skill gaps declined by over 7 percentage points. These findings suggest that sensors/IoT adoption is increasingly constrained by organizational knowledge and workforce capabilities rather than by financial considerations alone. (Figure 19: Adoption Barriers for Sensors/IoT)



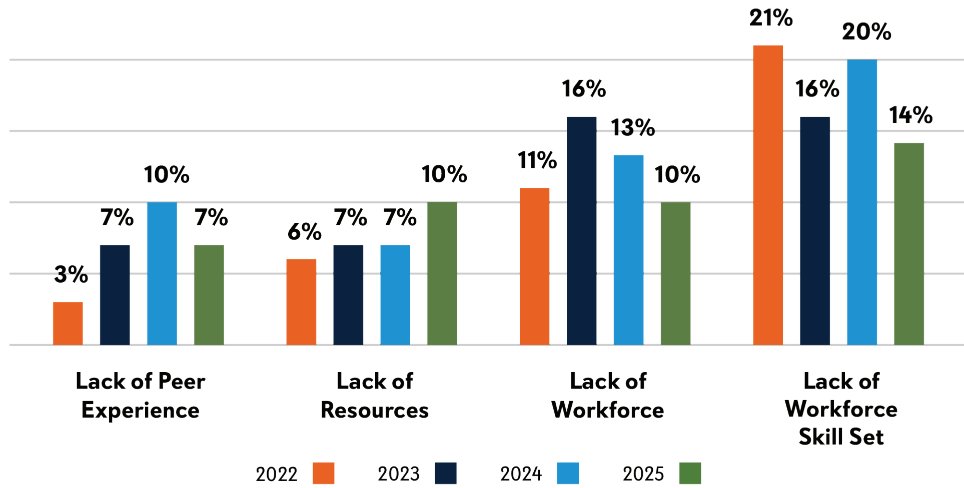


Figure 19: *Adoption Barriers for Sensors/IoT (n=101)*

Adoption Barriers: Predictive Analytics

Lack of awareness (21%), lack of business cases (21%), and workforce skill gaps (16%) were the primary barriers to predictive analytics adoption in 2025. Over the study period, awareness- and business case-related barriers declined (by 5 and 7 percentage points, respectively), while resource limitations became more prominent (increasing by 6 percentage points). These findings suggest that manufacturers increasingly recognize the value of predictive analytics but continue to face workforce capability and organizational readiness challenges that impede adoption. (Figure 20: Adoption Barriers for Predictive Analytics)

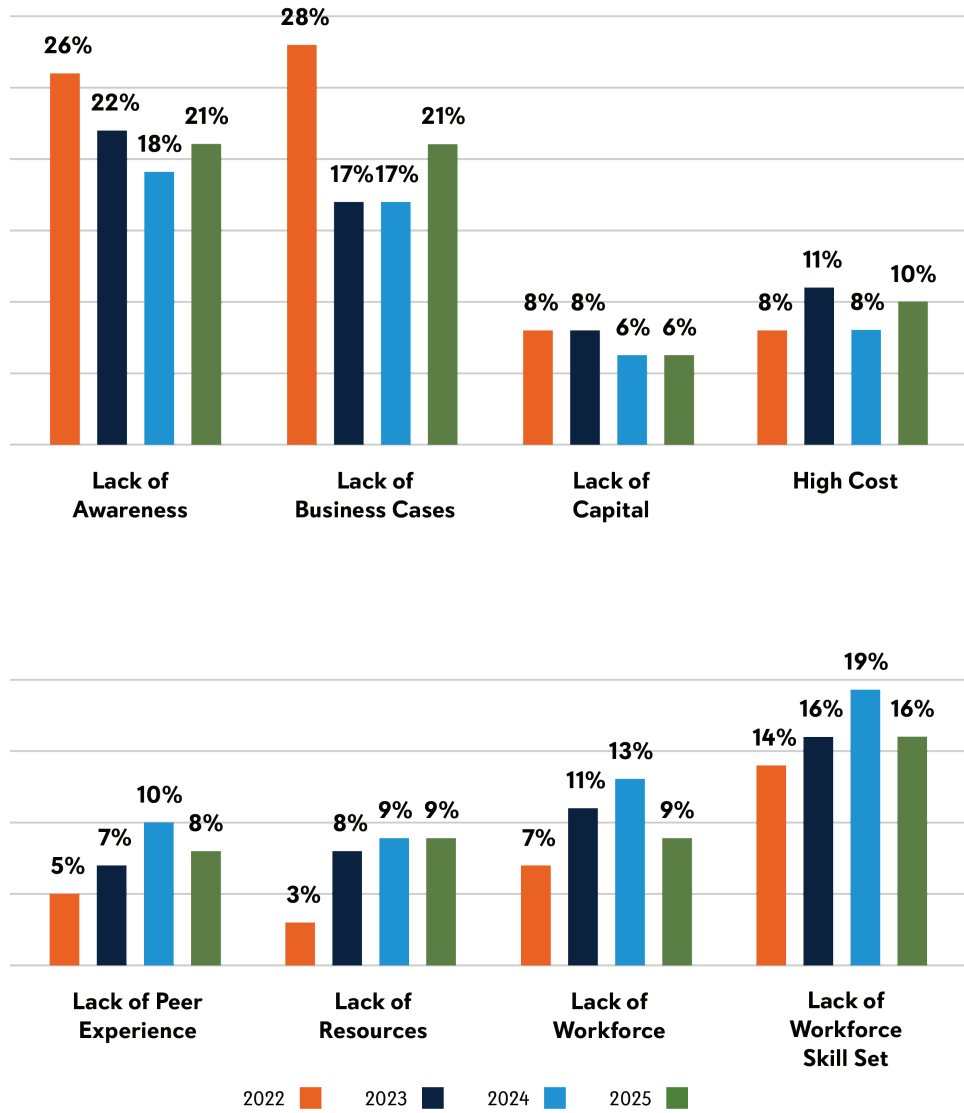


Figure 20: *Adoption Barriers for Predictive Analytics (n=100)*

Resources to Learn, Decide, and Implement

Survey respondents were asked to identify the resources they rely on when learning about, evaluating, and implementing smart manufacturing technologies. Response options included academic papers, business articles, case studies, consultants, peers, vendors, and other sources. The results indicate **that practical, experience-based resources are valued more highly than traditional information sources** throughout the technology adoption process. (Table 5: Resources to Learn, Decide, and Implement)

Table 5: *Resources to Learn (n=100), Decide (n=100), and Implement (n=97)*

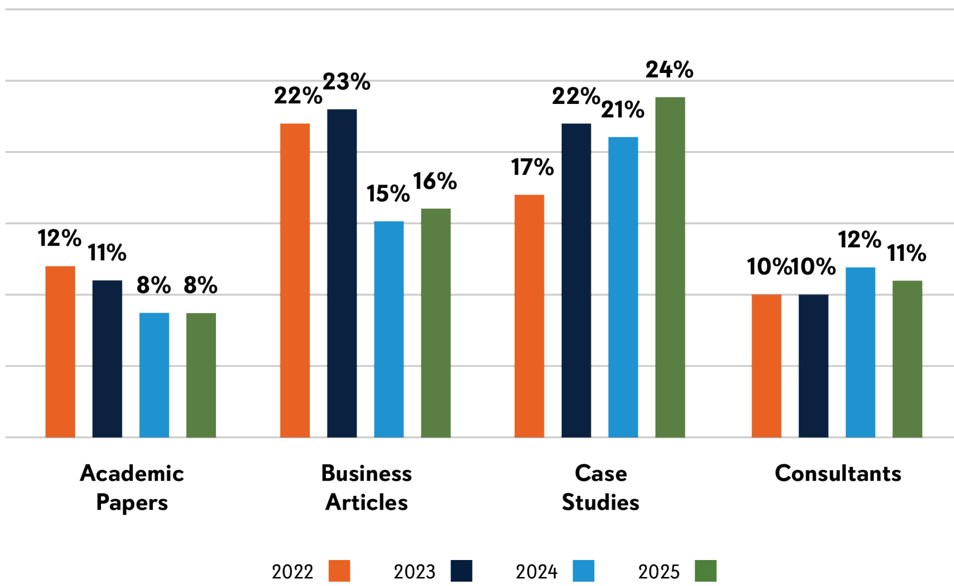
2025	Academic Papers	Business Articles	Case Studies	Consultants	Peer Experience	Vendors	Other
Learn	8%	16%	24%	11%	24%	15%	2%
Decide	7%	12%	23%	11%	26%	19%	2%
Implement	4%	9%	15%	18%	26%	24%	4%

During the learning phase, case studies and peer experience were the most frequently cited resources, each selected by 24% of respondents. When making adoption decisions, peer experience emerged as the most influential resource (26%), followed by case studies (23%) and vendors (19%). During implementation, peer experience remained the most important resource (26%), while reliance on vendors increased substantially to 24%, reflecting the critical role vendors play in technology deployment and integration.

In contrast, academic papers and business articles were consistently ranked among the least utilized resources across all three phases. These **findings suggest that manufacturers place the greatest value on practical examples and the experiences of other organizations** when evaluating and implementing new technologies.

Resources to Learn

Peer experience and case studies were the most frequently cited resources for learning about smart manufacturing technologies, accounting for 24% of responses each in 2025. Since the inaugural 2022 survey, the use of case studies increased from 17% to 24%, while reliance on academic papers and business articles declined (by 4 and 6 percentage points, respectively). These findings suggest that manufacturers increasingly prefer practical, experience-based sources of information when learning about emerging technologies. (Figure 21: Resources to Learn)



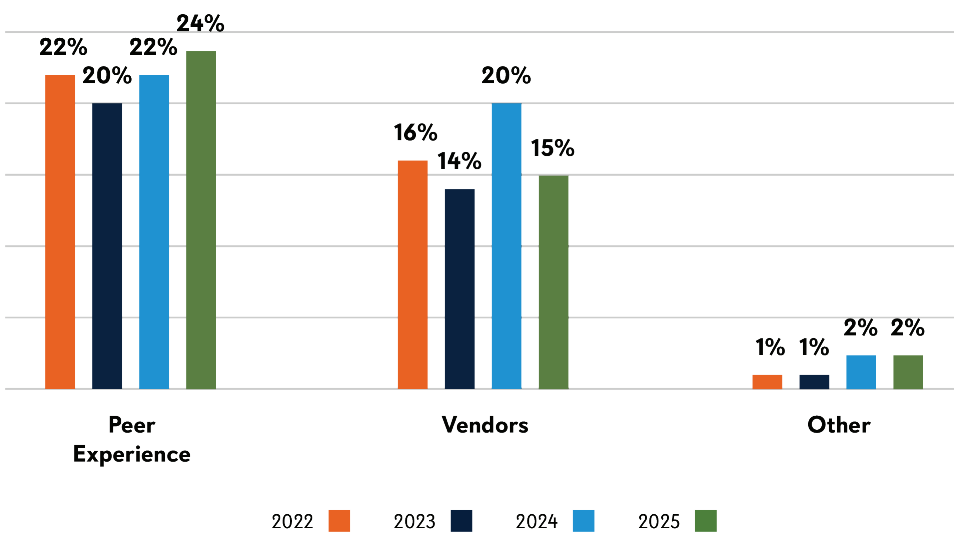


Figure 21: *Resources to Learn (n=100)*

Resources to Decide

Peer experience (26%) and case studies (23%) were the most influential resources for technology adoption decisions in 2025. Throughout this study, these resources have consistently ranked above academic papers, business articles, and consultants. This pattern indicates that manufacturers place greater value on practical insights and demonstrated implementation success when evaluating new technologies. (Figure 22: Resources to Decide)

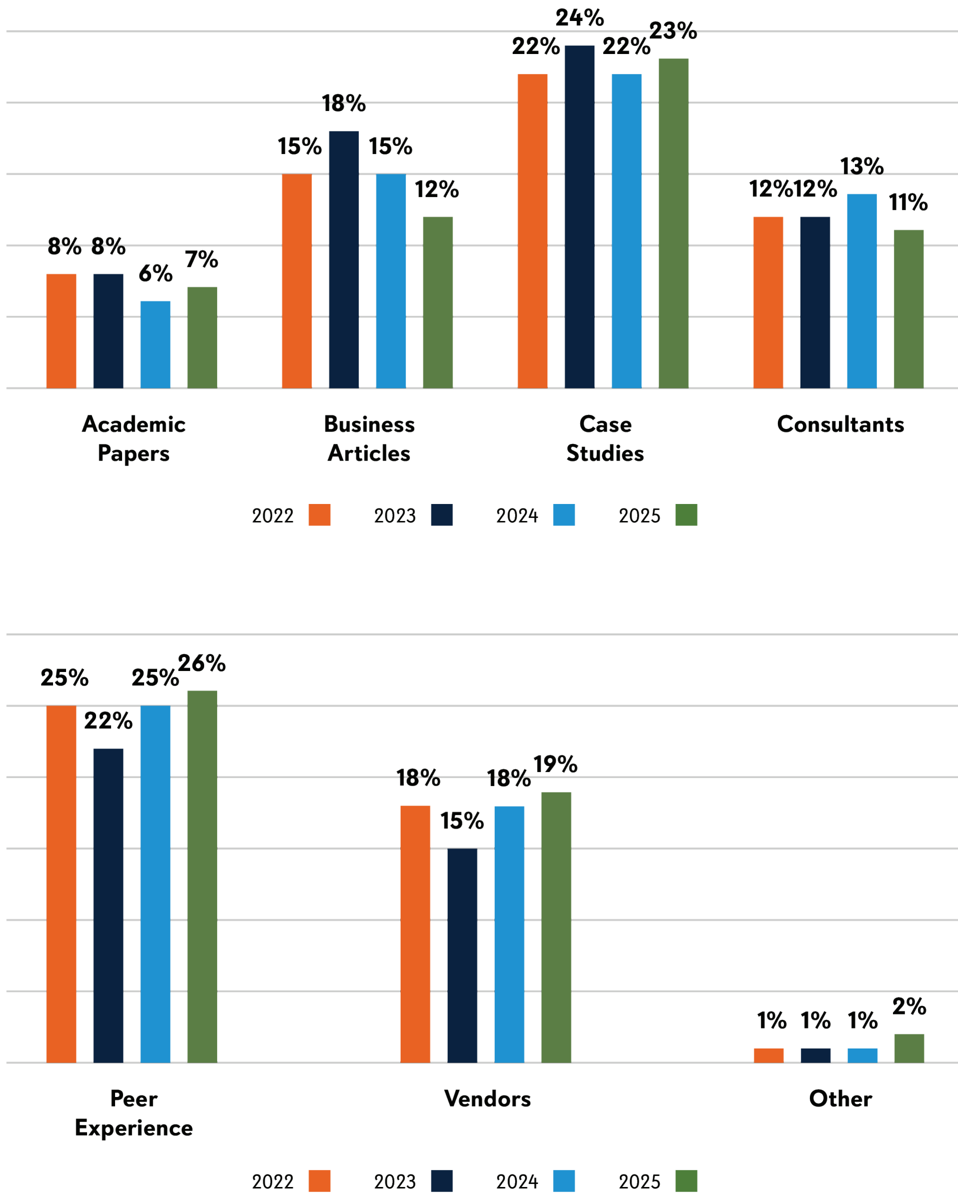


Figure 22: *Resources to Decide (n=100)*

Resources to Implement

Unlike the learning and decision-making phases, **implementation is influenced more heavily by external support and practical experience.** In 2025, peer experience (26%) was the most frequently cited resource, followed closely by vendors (24%). Consultants (18%) and case studies (15%) also played important roles, while academic papers (4%) and business articles (9%) were utilized less frequently. Since the inaugural 2022 survey, the share of respondents citing peer experience has increased from 18% to 26%, highlighting the growing importance of learning from organizations with prior implementation experience. The consistently strong reliance on vendors further suggests that manufacturers value hands-on technical expertise and implementation support when deploying new technologies. Overall, the findings indicate that successful technology implementation is driven primarily by practical guidance, industry knowledge, and external expertise rather than traditional information sources. (Figure 23: Resources to Implement)

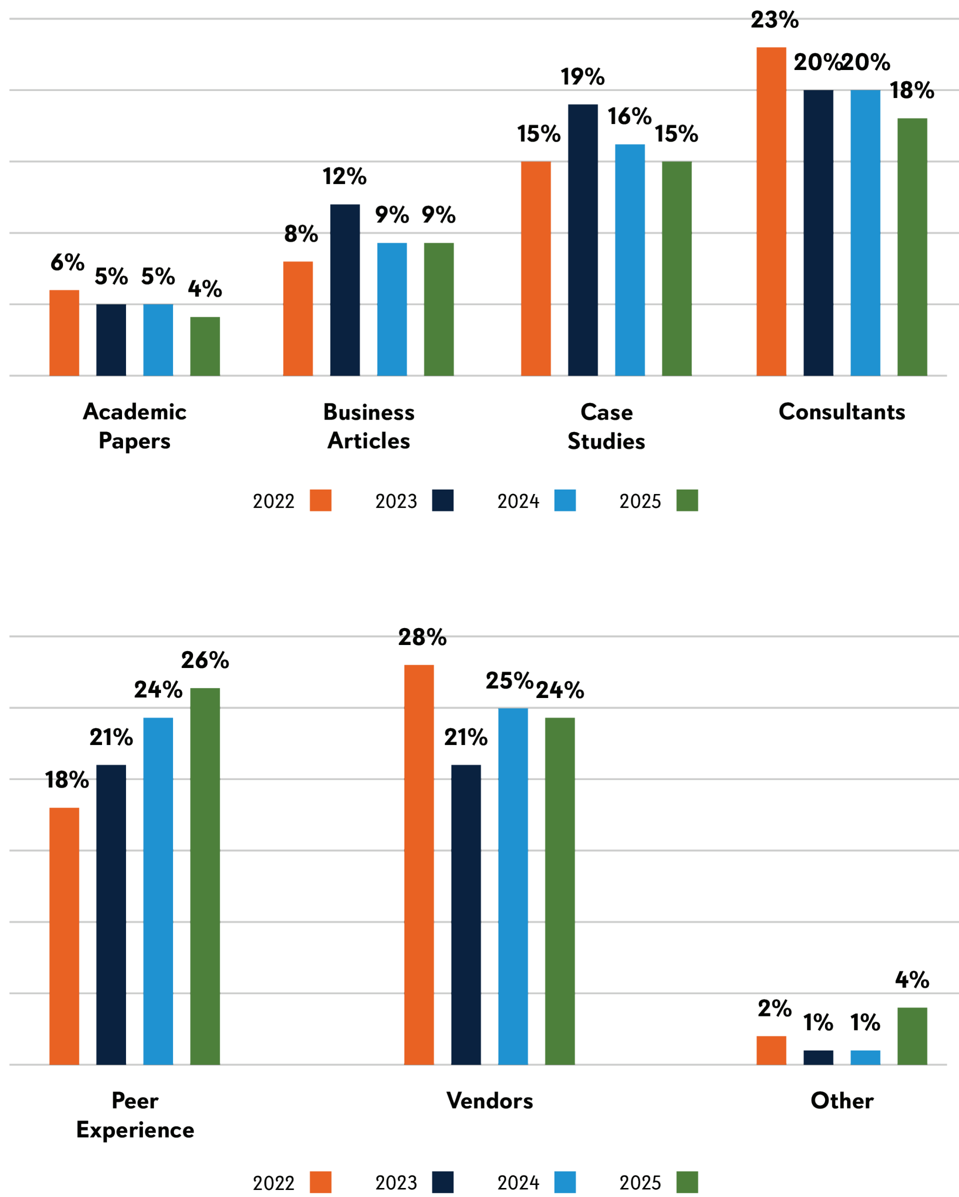


Figure 23: *Resources to Implement (n=97)*

Differences Between LV/HM and HV/LM Responses

At the beginning of the survey, respondents were asked to classify their manufacturing environment as low-volume, high-mix (LV/HM), high-volume, low-mix (HV/LM), or a combination of both. Most respondents identified as either LV/HM (51%) or a combination of LV/HM and HV/LM (38%), while only 11% reported operating in a purely HV/LM environment. Given the relatively small number of HV/LM respondents, results for this group may be less representative of the broader HV/LM manufacturing population. Segmenting the results by order mix enables a more detailed assessment of how production environments influence business challenges, perceptions of technology value, and barriers to smart manufacturing adoption. (Figure 24: Mix of Orders)

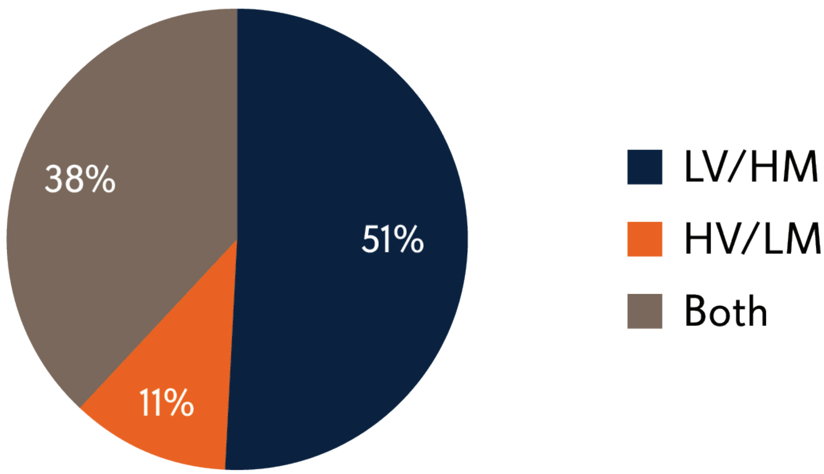


Figure 24: *Mix of Orders (n=117)*

The **business challenges identified by respondents varied by production environment.** The percentages reported below represent the proportion of respondents within each order-mix category that ranked the challenge among their top three business concerns.

- **Low volume, high mix (LV/HM):** workforce- operations (63%), operational efficiency (47%), and workforce- engineering (43%)
- **High volume, low mix (HV/LM):** revenue/profits (62%) and competitive pressure & operational efficiency (54%)
- **Both (LV/HM & HV/LM):** operational efficiency (66%), workforce- operations (61%), and revenue/profits (41%)

Workforce-related challenges were most prominent among LV/HM manufacturers, with workforce- operations (63%) and workforce- engineering (43%) ranking among the top concerns. In contrast, **HV/LM manufacturers were more likely to identify revenue/profits (62%) and competitive pressure (54%) as significant challenges.** Manufacturers operating both LV/HM and HV/LM environments most frequently cited operational efficiency (66%) and workforce-operations (61%). These findings suggest that **workforce challenges are more prevalent in high-mix environments, whereas financial performance and competitive pressures are more prominent in high-volume production settings.**

Differences by Company Size

Survey responses were segmented by company size to examine differences in technology adoption patterns between SMMs and larger organizations. Respondent demographic information was used to classify companies into four size categories (recall Figure 3).

- Less than 50 employees (43%)
- 50-250 employees (30%)
- 250-500 employees (8%)
- More than 500 employees (19%)

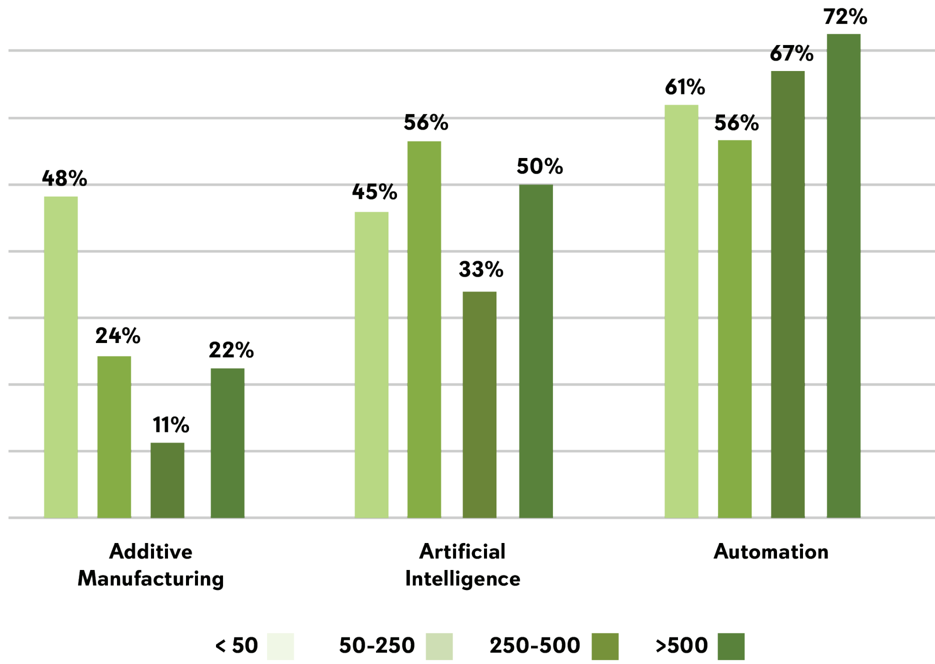
Business challenges varied across company size. The percentages reported below represent the proportion of respondents within each size category that ranked the challenge among their top three business concerns.

- Less than 50 employees: workforce- operations (58%), revenue/profits (47%), sales/marketing & workforce-engineering (40%)
- Between 50 and 250 employees: operational efficiency (64%), revenue/profits (56%), and workforce-operations (48%)
- Between 250 and 500 employees: workforce- operations (89%), operational efficiency (67%), and workforce- engineering (44%)
- More than 500 employees: operational efficiency (71%), workforce- operations (61%), and competitive pressure (42%)

Workforce-related challenges were consistently important across all size categories, with workforce- operations ranking among the top concerns for every group and reaching 89% among manufacturers with 250–500 employees. **Operational efficiency became increasingly important as company size increased,** emerging as the top challenge among manufacturers with more than 500 employees (71%).

In contrast, **revenue/profits and sales/marketing were more prominent among smaller manufacturers,** while competitive pressure was a top concern only for manufacturers with more than 500 employees. These findings suggest that **smaller manufacturers are more focused on growth and financial performance,** whereas **larger manufacturers place greater emphasis on operational performance and competitive positioning.**

The perceived value of smart manufacturing technologies also differs across company size categories. While **automation is consistently viewed as the most valuable smart manufacturing technology** regardless of company size, **larger manufacturers place substantially greater value on data-driven technologies** such as predictive analytics, artificial intelligence, and Sensors/IoT, whereas **smaller manufacturers (with less than 50 employees) exhibit a stronger interest in additive manufacturing.** (Figure 25: Perceived Value of Technologies by Company Size – Note: Totals represent the percentage of respondents within each company-size category who ranked the technology among their top three most valuable technologies.)



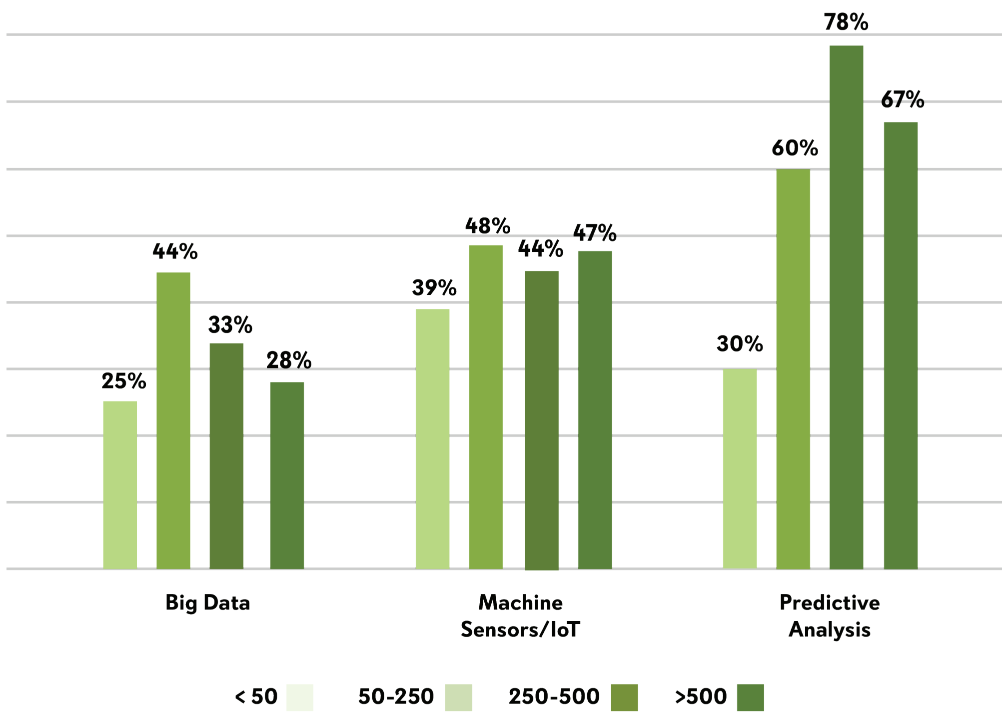


Figure 25: *Perceived Value of Technologies by Company Size (n=114)*

Top Adoption Barriers by Company Size

Table 6: Top Adoption Barriers by Company Size, presents the two most significant adoption barriers for each smart manufacturing technology, segmented by company size. By highlighting how adoption challenges vary across organizations of different sizes, the table provides insight into where targeted support, resources, and intervention strategies may be most effective in accelerating technology adoption. (Table 6: Top Adoption Barriers by Company Size)

Table 6: *Top Adoption Barriers by Company Size*

	<50	50-250	250-500	>500
Additive Manufacturing (n=107)	Lack of Business Cases (23%) High Cost (16%)	Lack of Business Cases (29%) Lack of Awareness (16%)	Lack of Business Cases (26%) High Cost (22%)	Lack of Business Cases (22%) Lack of Awareness (18%)
AI (n=103)	Lack of Business Cases (23%) Lack of Awareness (20%)	Lack of Awareness (24%) Lack of Business Cases (20%)	Lack of Awareness (25%) Lack of Business Cases (17%)	Lack of Awareness (22%) Lack of Workforce Skill Set (20%)
Automation (n=102)	High Cost (25%) Lack of Business Cases (15%)	High Cost (21%) Lack of Workforce Skill Set (17%)	High Cost & Lack of Workforce (25%)	Lack of Capital (22%) High Cost & Lack of Workforce Skill Set (15%)

	<50	50-250	250-500	>500
Big Data (n=101)	Lack of Business Cases (23%) Lack of Awareness (18%)	Lack of Business Cases (20%) Lack of Awareness (19%)	Lack of Awareness (25%) Lack of Business Cases (21%)	Lack of Business Cases (21%) Lack of Awareness (18%)
Sensors/IoT (n=101)	Lack of Business Cases (22%) Lack of Awareness (15%)	Lack of Business Cases & Lack of Awareness (22%)	Lack of Business Cases, High Cost, Lack of Resources, & Lack of Workforce Skill Set (17%)	Lack of Awareness (20%) Lack of Business Cases (19%)
Predictive Analytics (n=100)	Lack of Awareness (21%) Lack of Business Cases (20%)	Lack of Awareness & Lack of Business Cases (22%)	Lack of Awareness & Lack of Business Cases (24%)	Lack of Awareness & Lack of Business Cases (20%)

Resources Used to Learn, Decide, and Implement Smart Technologies by Company Size

Table 7: Resources Used to Learn, Decide, and Implement Smart Technologies by Company Size, identifies the two most utilized resources for learning, decision-making, and implementation activities related to smart manufacturing technologies, segmented by company size. These findings can help government, industry, and academic stakeholders tailor outreach efforts and allocate resources more effectively by aligning support mechanisms with the information sources most frequently used by manufacturers of different sizes. (Table 7: Resources Used to Learn, Decide, and Implement Smart Technologies by Company Size)

Table 7: *Resources Used to Learn, Decide, and Implement Smart Technologies by Company Size*

	<50	50-250	250-500	>500
Learn (n=100)	Peer Experience (29%) Case Studies (23%)	Case Studies (24%) Business Articles (20%)	Case Studies (34%) Peer Experience (28%)	Case Studies (24%) Peer Experience (21%)
Decide (n=100)	Peer Experience (32%) Case Studies (23%)	Case Studies (24%) Peer Experience (23%)	Case Studies (28%) Peer Experience (24%)	Peer Experience (23%) Case Studies (21%)
Implement (n=97)	Peer Experience (29%) Vendors (25%)	Consultants (26%) Peer Experience (25%)	Case Studies & Peer Experience (23%)	Vendors (27%) Peer Experience (23%)

ADVANCING SMART MANUFACTURING ACROSS THE WORLD

National strategies, public-private partnerships, and international collaboration are accelerating manufacturing innovation across the globe.

Governments around the world continue to make significant investments in smart manufacturing to strengthen industrial competitiveness, improve productivity, address workforce shortages, and enhance supply chain resilience. While national strategies differ, many countries have adopted similar approaches centered on digital transformation, public-private partnerships, workforce development, and targeted support for small and medium-sized manufacturers (SMMs). These coordinated initiatives recognize that manufacturing competitiveness increasingly depends on the successful adoption of advanced technologies such as automation, artificial intelligence (AI), additive manufacturing, data platforms, and connected manufacturing systems.

The United States has developed a robust network of organizations supporting smart manufacturing adoption through public-private collaboration. Manufacturing USA is a national network of 17 innovation institutes funded by the U.S. Departments of Defense, Energy, and Commerce. The institutes bring together government, industry, academia, and nonprofit organizations to conduct applied research, accelerate technology commercialization, and strengthen the manufacturing workforce. Several institutes focus specifically on advancing smart manufacturing, including the Digital Manufacturing Institute (MxD), Collaborative Ecosystems for Smart Manufacturing Innovation Institute (CESMII), Advanced Robotics for Manufacturing (ARM) Institute, and America Makes. Additional organizations, including the National Institute of Standards and Technology's (NIST) Manufacturing Extension Partnership (MEP) and the Interdisciplinary Center for Advanced Manufacturing Systems (ICAMS), work alongside manufacturers to deploy proven technologies and business practices that enhance competitiveness by reducing costs, improving productivity, and developing the next-generation manufacturing workforce, particularly among small and medium-sized manufacturers (SMMs).

Several countries have implemented comprehensive national strategies that coordinate manufacturing policy across multiple government agencies. Germany's Industrie 4.0 strategy continues to serve as one of the world's leading smart manufacturing initiatives and has expanded through Plattform Industrie 4.0 and Manufacturing-X, which promote digital interoperability and secure industrial data sharing. Japan has integrated manufacturing modernization into its Society 5.0 vision and National Digital Transformation (DX) Strategy led by the Ministry of Economy, Trade and Industry (METI). Similarly, China continues to advance its Made in China 2025 strategy through investments in intelligent manufacturing, industrial internet technologies, 5G-enabled manufacturing, regional smart manufacturing clusters, and globally recognized advanced manufacturing plants, called "lighthouse factories" [6].

South Korea has emerged as one of the most comprehensive examples of government-led smart manufacturing transformation. Through coordinated efforts involving the Ministry of SMEs and Startups (MSS), Ministry of Trade, Industry, and Energy (MOTIE), Ministry of Science and Information and Communication Technology (ICT) (MSIT), and the Korean Smart Manufacturing Office (KOSMO), South Korea has developed an integrated ecosystem supporting smart manufacturing adoption. Programs such as the Smart Manufacturing Innovation Initiative (SMII), Smart Manufacturing 3.0 [7], AI Transformation (AX) [8], and regional Smart Manufacturing Innovation Centers (SMICs) combine financial assistance, technical expertise, workforce development, and implementation support, particularly for small and medium-sized manufacturers (SMMs).

Other nations have similarly recognized manufacturing as a strategic national priority. The United Arab Emirates has invested heavily in industrial diversification through Operation 300bn, the UAE Industry 4.0 Program, the Industrial Technology Transformation Index (ITTI) digital maturity framework, the Make it in the Emirates campaign, and the Smart Manufacturing Incentive Program (SMIP) [9]. These initiatives seek to accelerate digital transformation while strengthening domestic manufacturing capabilities through targeted incentives and technology adoption programs. (Figure 26: Shared Elements of Leading National Strategies)

Shared Elements of Leading National Strategies

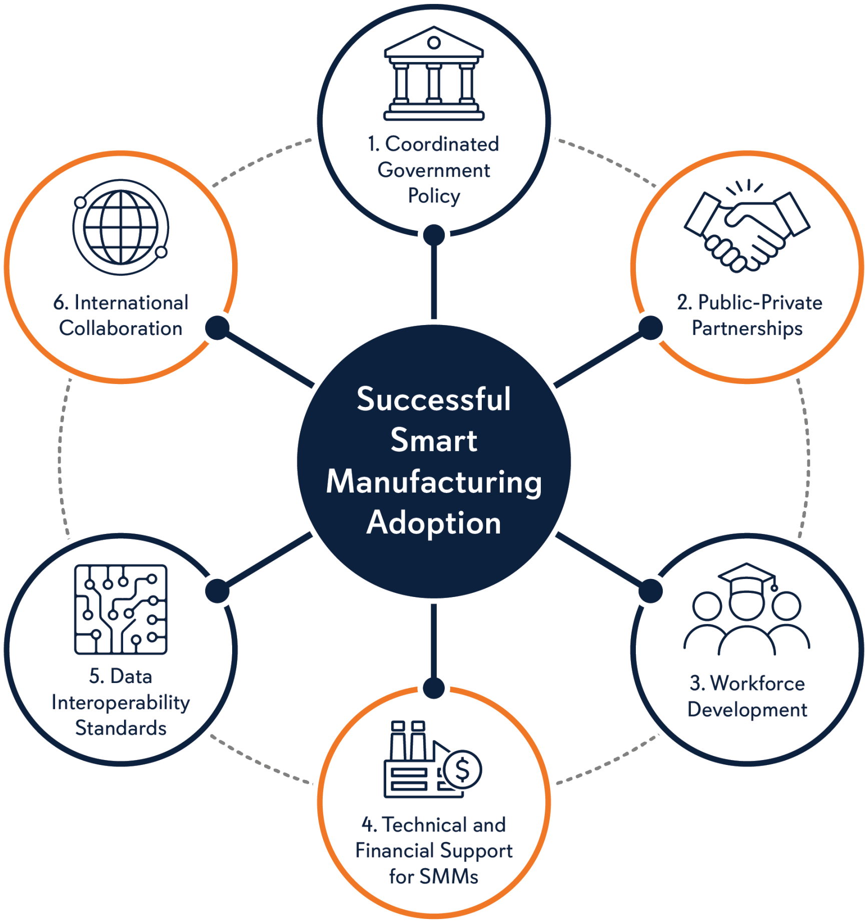


***Figure 26**: Shared Elements of Leading National Strategies*

Increasingly, smart manufacturing is also being advanced through international collaboration. (Figure 27: Countries Participating in the International Manufacturing-X Council). Organizations participating in the International Manufacturing-X Council (IMXC), including

- CESMII (United States),
- Plattform Industrie 4.0 (Germany),
- KOSMO (South Korea),
- Alliance Industrie du Futur and GIMELEC (France),
- Confindustria (Italy),
- NGen & Innovation, Science and Economic Development (Canada),
- Robot Revolution & Industrial IoT Initiative (Japan), and more, are working to establish interoperable industrial data ecosystems and promote global collaboration on manufacturing innovation.

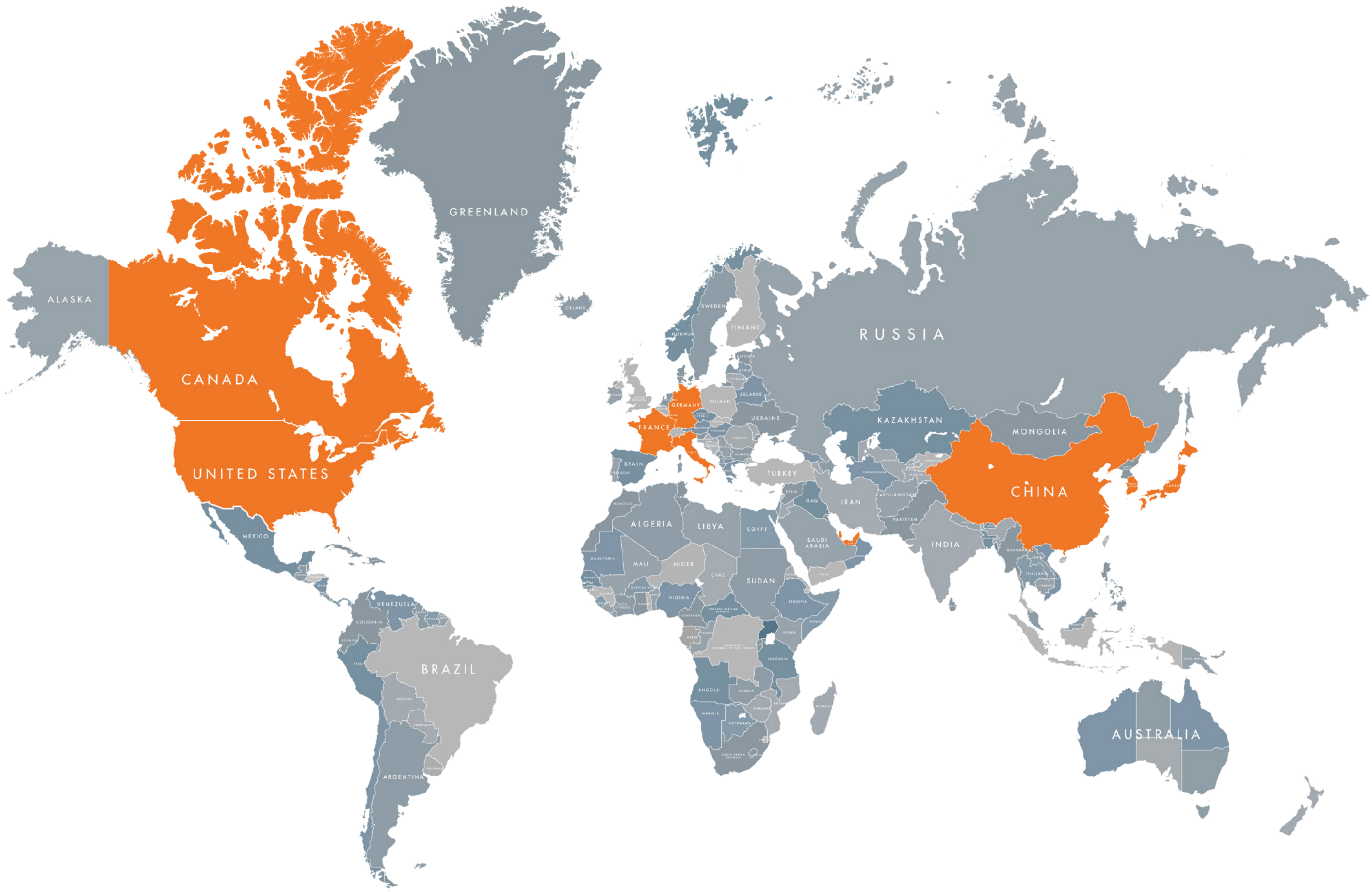


Figure 27: *Countries Participating in the International Manufacturing-X Council*

Collectively, these initiatives demonstrate that successful smart manufacturing adoption extends beyond technology investments alone. Leading manufacturing nations are combining coordinated government policy, public-private partnerships, workforce development, technical assistance, and international collaboration to accelerate technology implementation. As the findings of this study indicate, similar investments in workforce capabilities, business-case development, peer learning, and implementation support will be critical to strengthening the competitiveness of U.S. manufacturers.

ANALYSIS

The following section presents the results of the 2025 ICAMS Smart Manufacturing Adoption Survey and examines how manufacturers' priorities, technology perceptions, adoption patterns, and implementation challenges have evolved since the inaugural 2022 survey. The analysis focuses on five key findings that emerged from the data and provide insight into the current state of smart manufacturing adoption among U.S. manufacturers.

These findings highlight the business challenges facing manufacturers, the perceived value and adoption maturity of six key smart manufacturing technologies, the barriers limiting broader implementation, and the resources organizations rely upon when making technology adoption decisions. Together, the results offer a comprehensive view of the factors influencing smart manufacturing adoption and provide a foundation for recommendations to accelerate technology implementation across the U.S. manufacturing sector.

Finding #1: *Workforce and Operational Challenges Continue to Dominate.*

Workforce-related challenges and operational efficiency remain the most pressing concerns for manufacturers. Workforce-operations was consistently ranked in the top two business challenges throughout the four-year study period, reflecting ongoing difficulties in recruiting, retaining, and developing production personnel.

Operational efficiency also remained a leading concern, highlighting manufacturers' continued need to improve productivity, reduce waste, and optimize processes. Although respondents reported a more stable business environment in 2025 than in 2022, the persistence of these challenges suggests that labor shortages and productivity pressures continue to limit growth and competitiveness across the manufacturing sector.

Finding #2: *Automation Remains the Most Valued and Most Mature Smart Manufacturing Technology.*

Manufacturers continue to view automation as the technology best positioned to address their most significant business challenges. In 2025, nearly two-thirds of respondents ranked automation among their top three technologies for overcoming organizational challenges, and almost 60% reported either implementing or actively using automation technologies.

Unlike several of the other technologies examined, automation has progressed beyond the awareness and evaluation stages for most manufacturers. The combination of high perceived value and widespread adoption suggests that automation has become a foundational component of smart manufacturing strategies, particularly for addressing workforce shortages and improving operational efficiency.

Finding #3: *Artificial Intelligence Is Emerging Rapidly but Remains in the Early Stages of Adoption.*

Artificial intelligence demonstrated the greatest growth in both perceived value and adoption during the study period. Since the inaugural 2022 survey, the percentage of respondents ranking AI among their most valuable technologies increased substantially, and active use increased more than fivefold. Despite this momentum, most manufacturers remain in the awareness or researching stages of adoption, indicating that AI has not yet reached the maturity levels observed for automation or additive manufacturing. These findings suggest that manufacturers increasingly recognize AI's potential to improve decision-making, productivity, and competitiveness, but many organizations are still determining how to effectively implement and scale AI solutions within their operations.

Finding #4: *Lack of Business Cases and Workforce Skill Gaps Remain the Primary Adoption Challenges.*

Across nearly all technologies examined, manufacturers consistently identified a lack of business cases and awareness as the most significant obstacles to adoption. Many organizations continue to struggle with quantifying benefits, estimating returns on investment, and building sufficient justification for technology investments. At the same time, workforce skill gaps have become increasingly prominent, particularly for technologies such as artificial intelligence and predictive analytics. These findings suggest that adoption challenges are shifting away from financial limitations and toward organizational readiness, technical expertise, and the ability to demonstrate clear business value. As manufacturers become more familiar with smart manufacturing technologies, the need for workforce development and implementation guidance is becoming increasingly important.

Finding #5: *Manufacturers Rely on Practical Experience to Drive Adoption Decisions.*

The survey results demonstrate that manufacturers place greater trust in practical, experience-based resources than in traditional information sources when learning about, evaluating, and implementing smart manufacturing technologies. Peer experience and case studies consistently ranked as the most influential resources across all stages of the adoption process, while academic papers and business articles were used far less frequently. Vendors and consultants also played an important role, particularly during implementation. These findings suggest that manufacturers prefer evidence derived from real-world applications and proven implementation successes when assessing new technologies. As a result, peer-to-peer knowledge sharing, case studies, demonstration projects, and industry collaboration may be among the most effective mechanisms for accelerating smart manufacturing adoption.

RECOMMENDATIONS

Recommendations for Government

The U.S. government should continue expanding investments in smart manufacturing through coordinated efforts led by the Department of Commerce, Department of Defense (DoD), and the National Institute of Standards and Technology (NIST). Because a lack of awareness, a lack of business cases, and workforce skill gaps remain the primary barriers to technology adoption, federal initiatives should prioritize workforce development, implementation assistance, and the creation of industry-specific case studies and demonstration projects. These efforts should focus particularly on small and medium-sized manufacturers (SMMs), which often lack the financial and technical resources needed to successfully implement advanced manufacturing technologies [2-4].

The government should also strengthen investments in automation and artificial intelligence. Automation remains the technology that manufacturers perceive as most valuable for addressing workforce and operational challenges, while artificial intelligence has experienced the fastest growth in both perceived value and adoption. Expanding workforce training, technical assistance, and cost-sharing programs can help manufacturers move beyond the awareness and evaluation stages and accelerate technology implementation.

Finally, the U.S. Department of Commerce, Department of Defense, and NIST should strengthen collaboration with countries that have established successful smart manufacturing initiatives. Leveraging international best practices can help inform U.S. policies, funding priorities, and support programs while ensuring that U.S. manufacturers remain globally competitive in an increasingly digital manufacturing landscape.

Recommendations for Industry

Manufacturers should place greater emphasis on sharing practical implementation experiences, particularly those demonstrating measurable business outcomes. Because a lack of business cases remains one of the most significant barriers to technology adoption, manufacturers that have successfully implemented smart manufacturing technologies should share implementation strategies, return on investment, and lessons learned with their peers and supply chain partners. Increasing access to real-world examples can help reduce uncertainty and accelerate technology adoption throughout the manufacturing sector.

Industry associations should continue serving as trusted intermediaries by collecting, anonymizing, and disseminating implementation case studies, best practices, and benchmarking data. Given that peer experience and case studies remain the most influential resources for learning about and evaluating smart manufacturing technologies, industry-led knowledge sharing initiatives can play a critical role in accelerating adoption.

Lastly, manufacturers and industry associations should continue investing in workforce development by expanding training opportunities and promoting careers in advanced manufacturing. Strengthening technical skills in automation, artificial intelligence, and data-driven technologies will help address persistent workforce shortages while preparing employees to support the next generation of smart manufacturing.

Recommendations for Academia

Academia should continue supporting the manufacturing workforce by expanding educational opportunities in automation, artificial intelligence, data analytics, and other smart manufacturing technologies. Flexible credentialing programs, industry-recognized certifications, and workforce training offered during evenings, weekends, or online can help incumbent workers develop the skills needed to implement emerging technologies.

Academic institutions should also strengthen partnerships with manufacturers by conducting applied research that addresses real-world implementation challenges. Because manufacturers consistently rely on peer experience and case studies when making technology adoption decisions, universities should work with industry to develop practical case studies, demonstration projects, and implementation frameworks that translate research into actionable guidance. These efforts can help bridge the gap between research and practice while accelerating smart manufacturing adoption across the U.S. manufacturing sector.

ACKNOWLEDGMENTS

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- Society of Manufacturing Engineers (SME)
- The Digital Manufacturing and Cybersecurity Institute (MxD)
- IPC International, Inc. (worldwide electronics association and standards body)

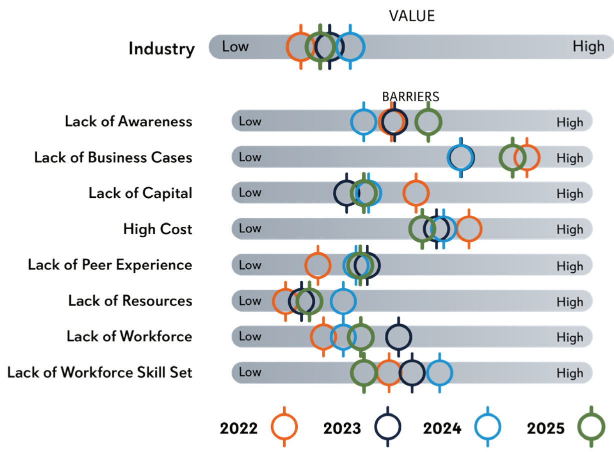
APPENDICES

APPENDIX A – Technology Adoption Value and Barriers

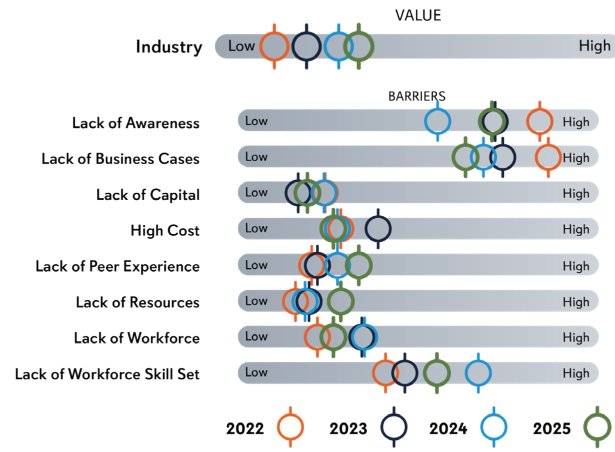
The following graphs compare the perceived value of a technology with its adoption barriers.

A higher value perception indicates that respondents viewed the technology as more effective in addressing their business challenges. Conversely, lower barrier values indicate fewer obstacles to technology adoption.

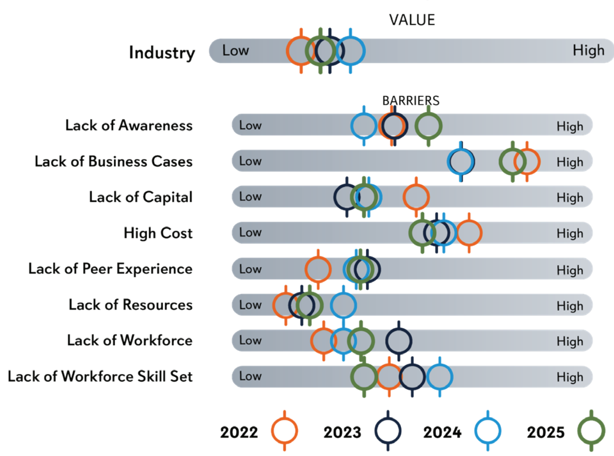
Additive Manufacturing Value and Barriers



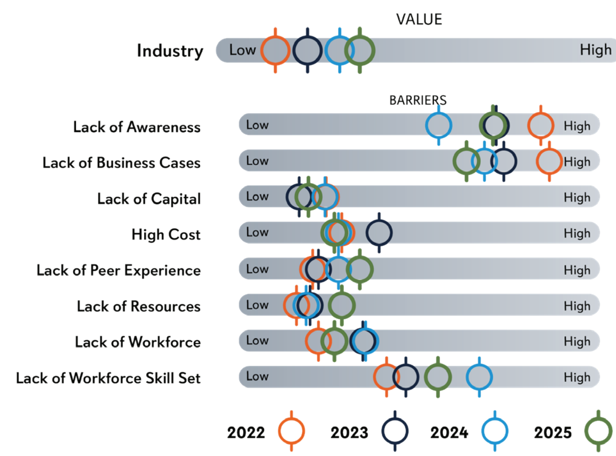
Artificial Intelligence Value and Barriers



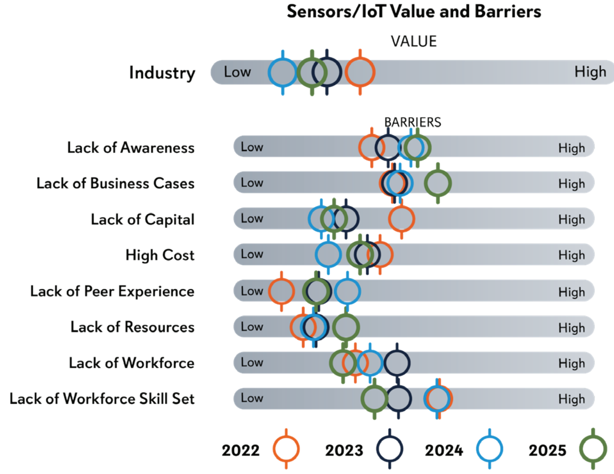
Additive Manufacturing Value and Barriers



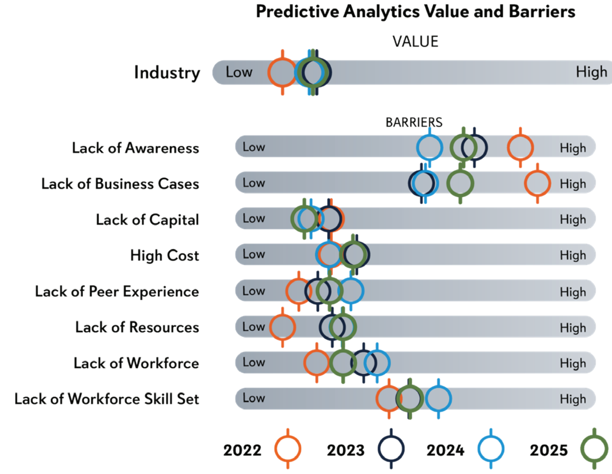
Artificial Intelligence Value and Barriers



Sensors/IoT Value and Barriers



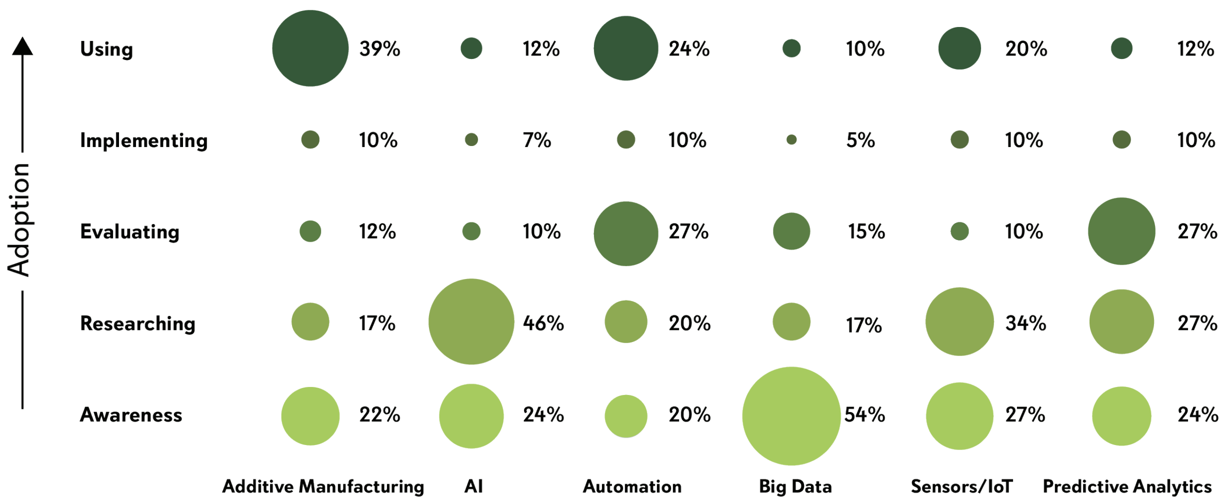
Predictive Analytics Value and Barriers



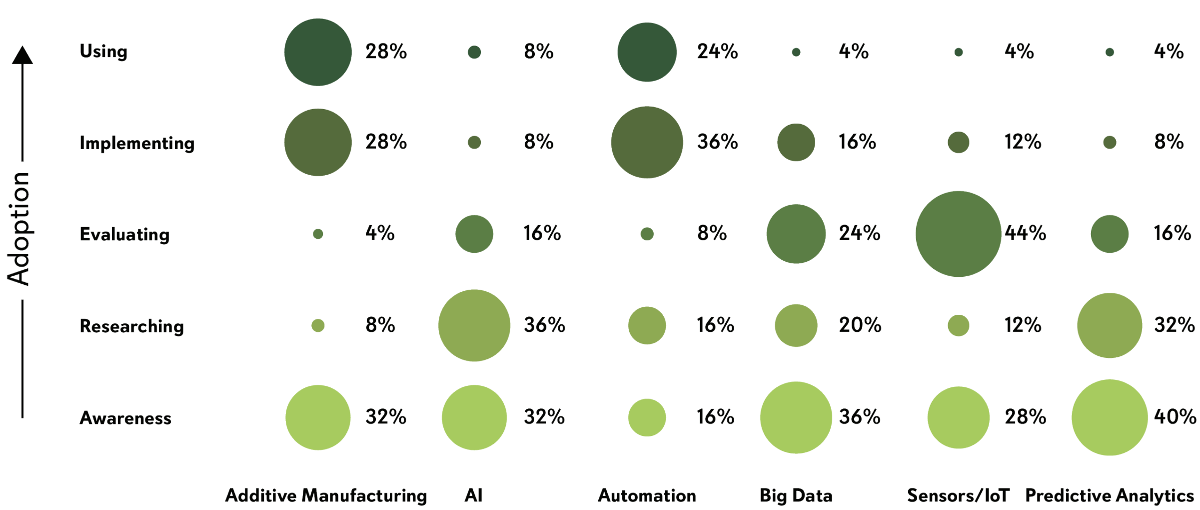
APPENDIX B – Adoption Comparison by Company Size

The following graphs are grouped by company size. The charts compare the adoption stages of the six smart manufacturing technologies by company size. Manufacturers can determine their adoption level of each technology and then use these graphs to compare their adoption progress with companies of similar size.

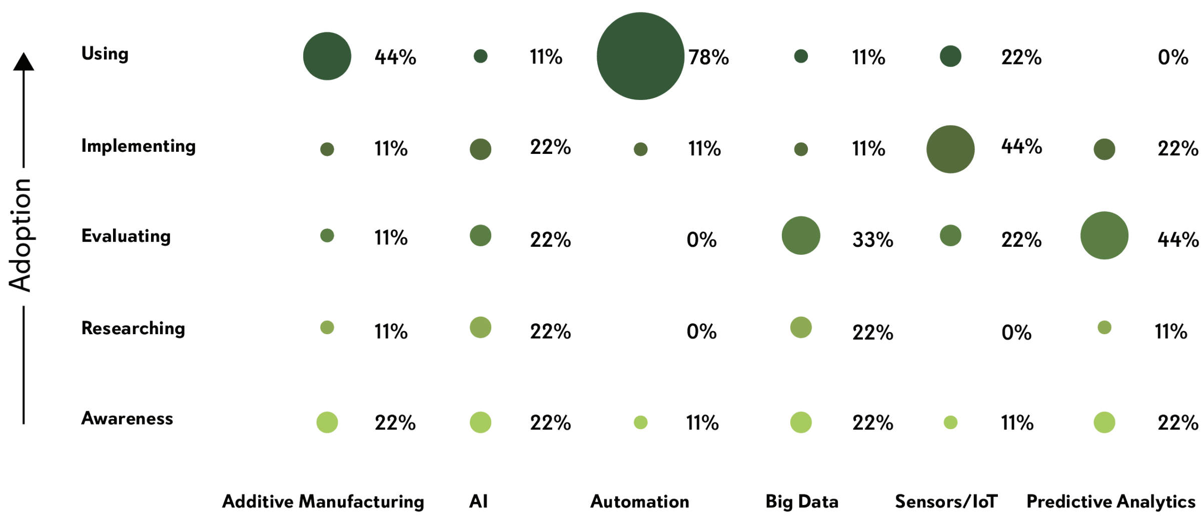
<50 Employees, Technology Adoption



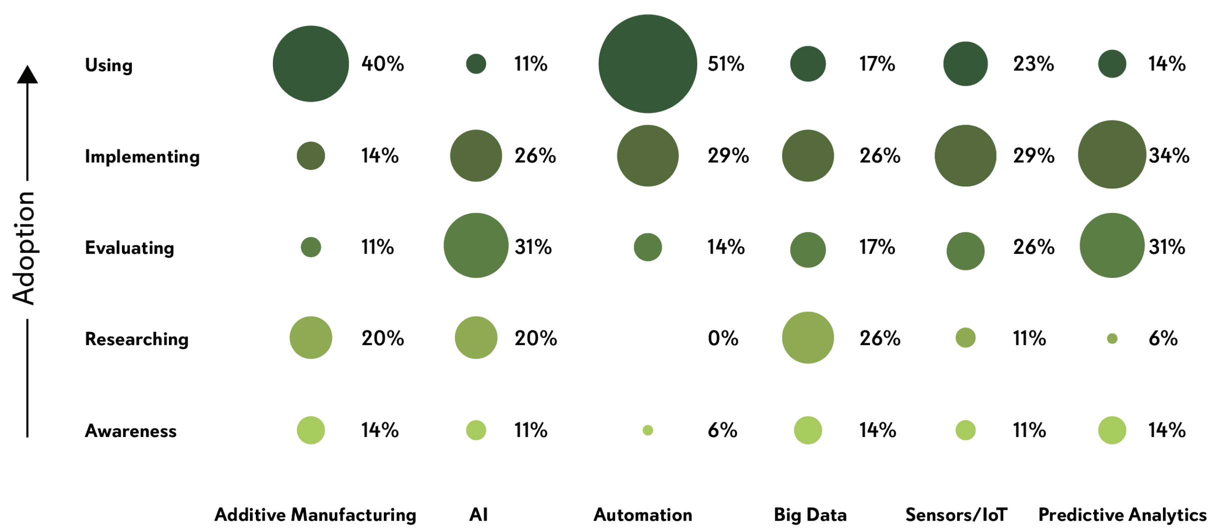
50-250 Employees, Technology Adoption



250-500 Employees, Technology Adoption



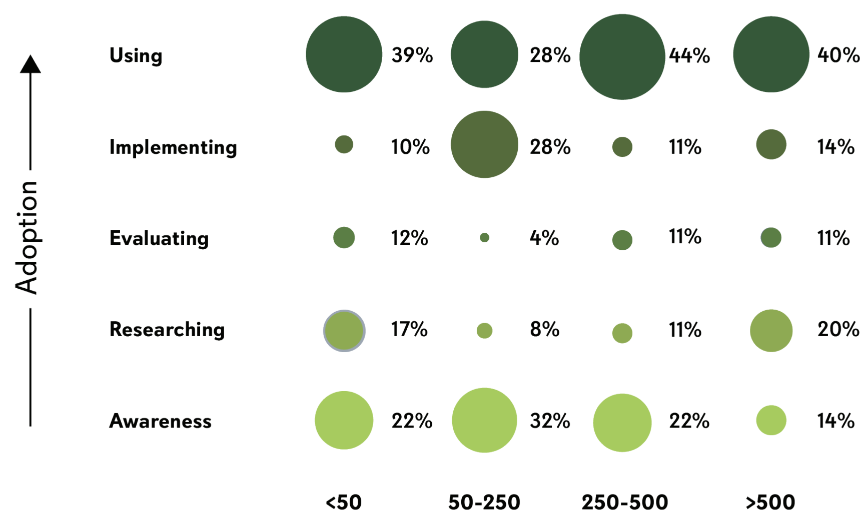
>500 Employees, Technology Adoption



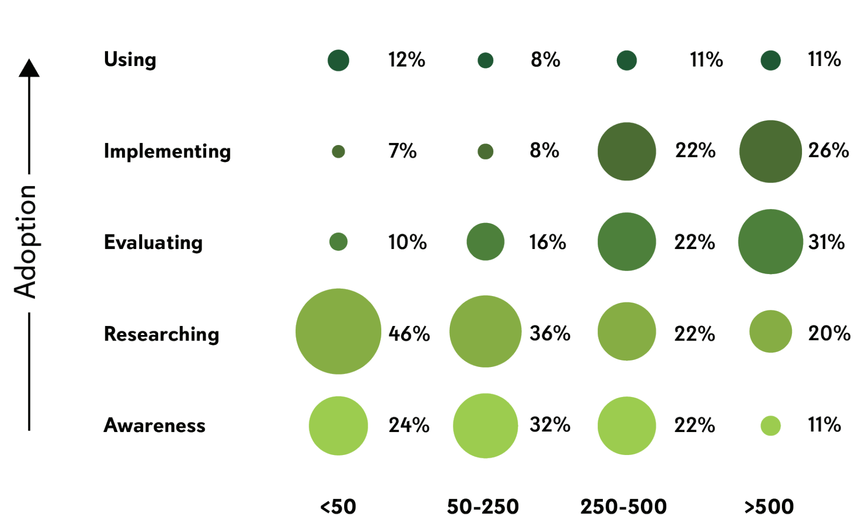
APPENDIX C – Adoption Comparison by Technology

The following graphs are grouped by technology. The charts compare the adoption stages of the six smart manufacturing technologies by each technology. This allows us to discern whether small and medium-sized manufacturers are behind in their technology adoption compared to companies of larger size.

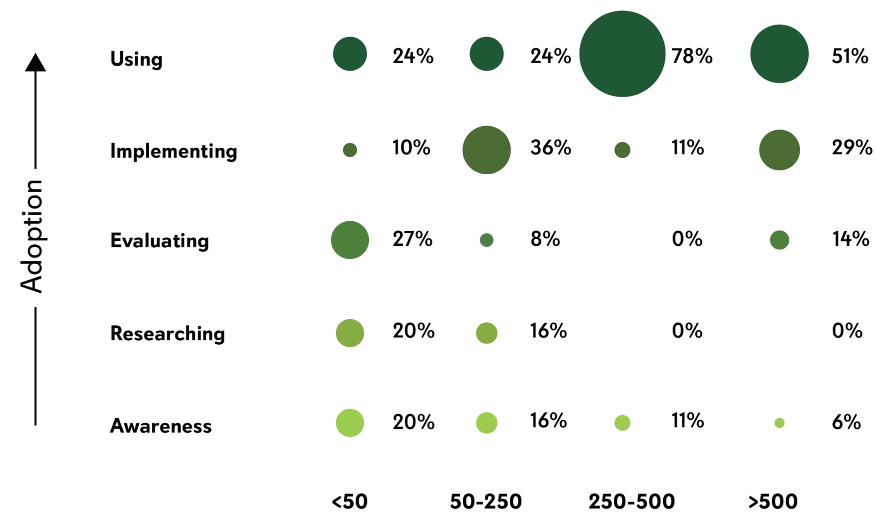
Additive Manufacturing Adoption by Company Size



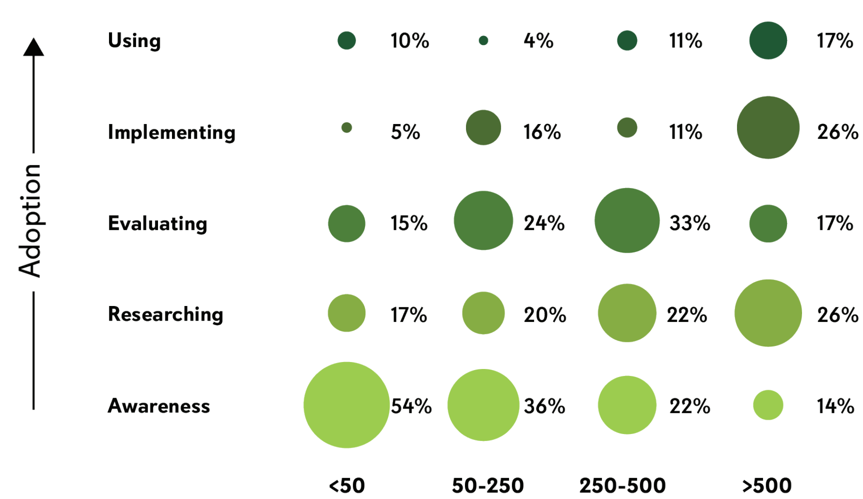
Artificial Intelligence Adoption by Company Size



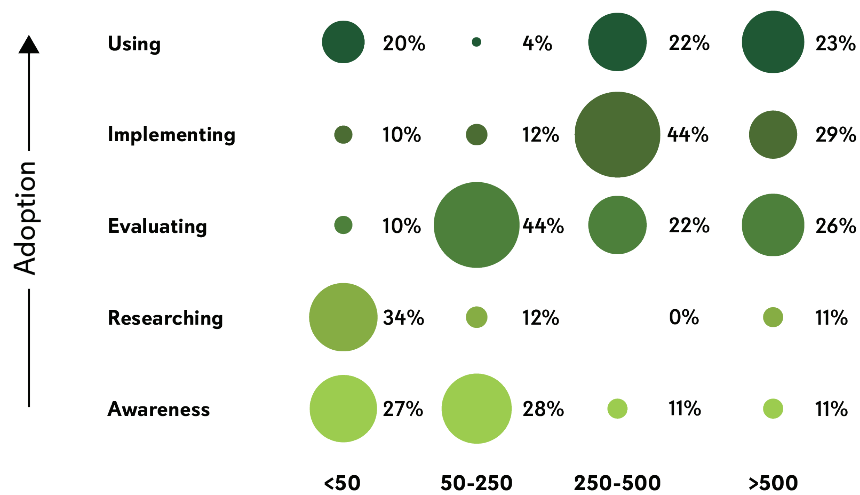
Automation Adoption by Company Size



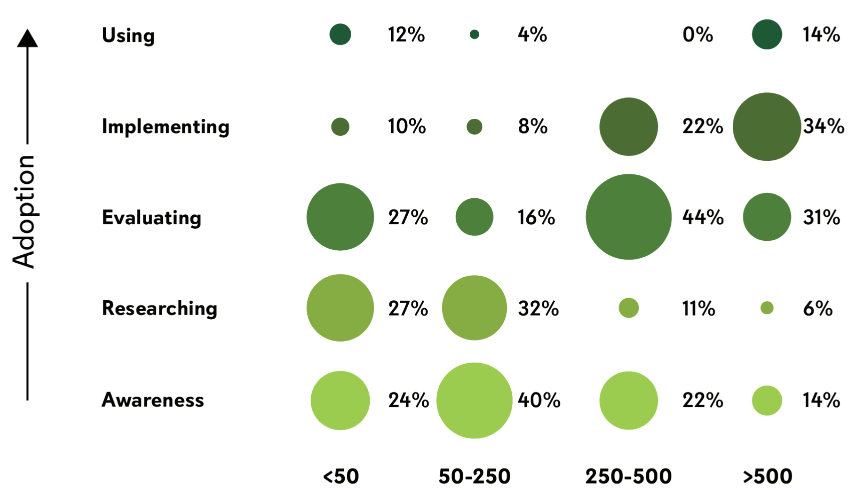
Big Data Adoption by Company Size



Sensors/IoT Adoption by Company Size



Predictive Analytics Adoption by Company Size



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