SMART MANUFACTURING ADOPTION STUDY 2023

Interdisciplinary Center for
Advanced Manufacturing Systems

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Over the past two years, the mainstream press painted a picture that digital manufacturing, Industry 4.0 (I-4.0), and Smart Manufacturing were at their tipping point, reaching their fullest potential. However, the press is beginning to realize that there are significant barriers for the manufacturing industry to overcome in the coming years before a tipping point is reached [1]. Small- and Medium-sized Manufacturers (SMMs) that comprise over 95% of the U.S. industrial base are lagging in adoption compared to Original Equipment Manufacturers (OEM) and large first-tier counterparts.

The objective of this study is to uncover and analyze the current state of technology adoption by U.S. manufacturers, particularly SMMs, and to identify the motivators and barriers that must be addressed to accelerate adoption. This report is the second of a five-year longitudinal study that provides insights into the year-over-year progress of smart manufacturing technology adoption. An annual survey is conducted to generate the results in this report.

The results of this study reveal current business challenges, motivators, and barriers to adopting smart manufacturing technologies such as 3D printing, artificial intelligence (AI), automation, big data, sensors/Internet of Things (IoT), and predictive analytics. The adoption stages used in this study are awareness, researching, evaluating, implementing, and using. SMMs can use the results of this study to compare their adoption progress to their peers. These insights will also inform the Department of Defense (DoD) on the actual state of industrial base readiness for digital manufacturing.

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EXECUTIVE SUMMARY

The purpose of the Interdisciplinary Center for Advanced Manufacturing Systems (ICAMS) longitudinal research program is to provide insights that will accelerate the depth and breadth of smart manufacturing adoption to improve U.S. manufacturing competitiveness. ICAMS targets its efforts toward the Small- and Medium-sized Manufacturers (SMMs) that comprise over 95% of U.S. manufacturers [2].

To accelerate adoption, we must first gain insight into the current state of adoption and the progress U.S. manufacturers have made in technology adoption. This report is the second annual smart manufacturing adoption study that tracks and quantifies the progress of technology adoption of the U.S. industrial base. This report uncovers valuable insights about SMM motivations and barriers to adopting each smart technology.

The six smart manufacturing technologies at the core of this research are:

- 3D Printing
- Artificial Intelligence (AI)
- Automation
- Big Data
- Sensors/Internet of Things (IoT)
- Predictive Analytics

The taxonomy used to assess the technology adoption levels follows the work of Dr. Everett Rogers [3]. The five stages of the technology adoption process are awareness, researching, evaluating, implementing, and using.

The results of this research reveal the top business challenges manufacturers are facing, the value manufacturers place on each of the six technologies listed above, and the current stage of adoption for each of the technologies. A year-over-year comparison is provided to track the progress of technology adoption by the U.S. industrial base.

The top two business challenges remain the same from the 2022 study; operational efficiency and operations workforce are the most significant challenges that manufacturers are facing in 2023. The percentage of companies that view their circumstances as worsening has dropped by nearly 16-percentage points; this statistic is encouraging news for the U.S. manufacturing industry- circumstances are improving.

Manufacturers continue to place a high value on sensors/IoT, automation, and predictive analytics. Interest in predictive analytics, big data, and artificial intelligence is growing significantly.

The most widely adopted smart technologies are 3D printing, automation, and sensors/IoT. Approximately 50% of survey respondents are in the implementing and using phases for these technologies. On the other hand, the technology in its greatest infancy is artificial intelligence, with over 60% of respondents being in the awareness and researching adoption stages.

The survey results also disclose the most significant barriers to adopting each smart manufacturing technology and provide insight into which resources manufacturers use to learn about, decide on, and implement smart technologies.

Two of the most common barriers to adopting smart technologies are a lack of awareness and a lack of business cases. Manufacturers seek out business articles, case studies, and peer experience when evaluating the technologies. SMMs place exceptionally high value on case studies and peer experience, meaning considerable effort should focus on developing these two resources.

The analysis resulted in three key findings that, if addressed, would help accelerate the adoption of smart manufacturing technologies:

1. There has been significant growth in adoption of predictive analytics over the previous year. The perceived value of predictive analytics has risen significantly.

2. Later stage adoption barriers present new and more complicated challenges. Manufacturers rely on peer experience and vendors which cannot be generated quickly.
3. Workforce challenges are only getting worse. Manufacturing as a whole is in dire need of experienced and skilled workers.

The ICAMS team developed recommendations for government, industry, and academia after a review and analysis of the survey results.

- Government recommendations include creating a robust and ambitious smart manufacturing technology adoption plan, including leveraging investments like the U.S. Department of Commerce's (DoC) Technology Hubs to focus on and accelerate technology adoption [4].
- Industry plays a prominent role in other companies adopting smart manufacturing technologies. Their willingness to share their success stories through case studies and peer experience is invaluable. Large manufacturers should assist their lower-tier suppliers in technology adoption to reap benefits across the supply chain and boost SMM technology adoption.
- Academia serves as a trusted and neutral third party that can study the availability and applicability of technology resources. Once the gaps are identified, research efforts can be directed toward identifying and publishing success stories and developing low-cost technology solution alternatives for SMMs.

OBJECTIVE

Until this research, there has not been a comprehensive study of smart manufacturing adoption paths and rates. Such information is crucial to identifying the status and state of industry in the technology adoption process. The insights from this research can be used to accelerate the depth and breadth of adoption and accurately measure adoption progress.

This report is year two of a longitudinal study designed to collect information on smart manufacturing adoption annually for five years, focusing on Small- and Medium-sized Manufacturers (SMMs). This distinction is essential in understanding the current state and status of the manufacturing industrial base in the U.S. For the last ten years, reporting on the adoption of smart manufacturing technologies has focused on large manufacturers with the resources and talent available to take on digitalization initiatives. This level of resources and support does not exist for SMMs [5],[6].

The design of the qualitative and quantitative instruments will remain relatively consistent to help better gauge year-over-year advancements in the adoption process. The outcomes of this effort include:

- Greater ability to accelerate smart manufacturing adoption by U.S. manufacturers;
- Quantitative evidence of the success of acceleration efforts and where to adjust; and
- Data-driven recommendations for government funding and programs.

METHODOLOGY

This initiative began with the desire to understand the true state of technology adoption in the U.S. A quantitative survey instrument was designed and launched in 2021, resulting in the first annual report in 2022. This report is year two of a five-year study to track the progress of technology adoption.

Auburn University conducted the quantitative survey after approval by its Institutional Review Board. Qualtrics was the survey platform used, and this year's annual survey was launched in January 2023. The following organizations helped attract participants by publicizing the effort to their members.

America Makes
IPC International, Inc. (world-wide electronics association and standards body)
Manufacturing x Digital Institute (MxD the Digital Manufacturing Institute)
National Defense Industrial Association (NDIA)
Society of Manufacturing Engineers (SME)

As of March 17, 2023, there were 146 partially completed survey responses and 95 fully completed. The number of responses, (n), is indicated in the caption of each visualization in the Results section.

Based on the quantitative findings, the ICAMS team developed an interview guide to gather qualitative insights on the effectiveness of various adoption practices. The team then conducted four interviews, three in person and one by phone.

RESULTS

Overview

This research study began in 2021 with high-level interviews, asking manufacturers about the challenges they faced with adopting smart manufacturing technologies and their perception of Smart Manufacturing/Industry 4.0. A longitudinal survey was created and launched from these interviews, resulting in the first annual report being published in mid-2022. The annual survey was relaunched in early 2023, resulting in this report- the 2nd annual ICAMS Smart Manufacturing Adoption Study.

The survey results provided insights into the audience's perceived value of six smart manufacturing technologies, the participants' adoption phase, and their most significant barriers. The survey also captures the resources the subjects will most likely turn to when learning about, deciding on, or implementing these technologies.

The survey findings provide information to help understand how to accelerate the depth and breadth of adoption for these six technologies. Coupling that information with a recommended prioritization of the six technologies provides a roadmap that can help inform government programs and funding. This yearly survey provides quantitative evidence of how far the U.S. industrial base has progressed in adopting these technologies and the success of those government efforts.

Several organizations assisted in this research by asking their constituents to participate in this survey. The aggregate of those responses is contained in this report.

Demographics

The population of survey respondents spanned 36 U.S. states. The survey's reach was a desirable improvement from last year's 16 states. (See Figure 1: States of Respondents)

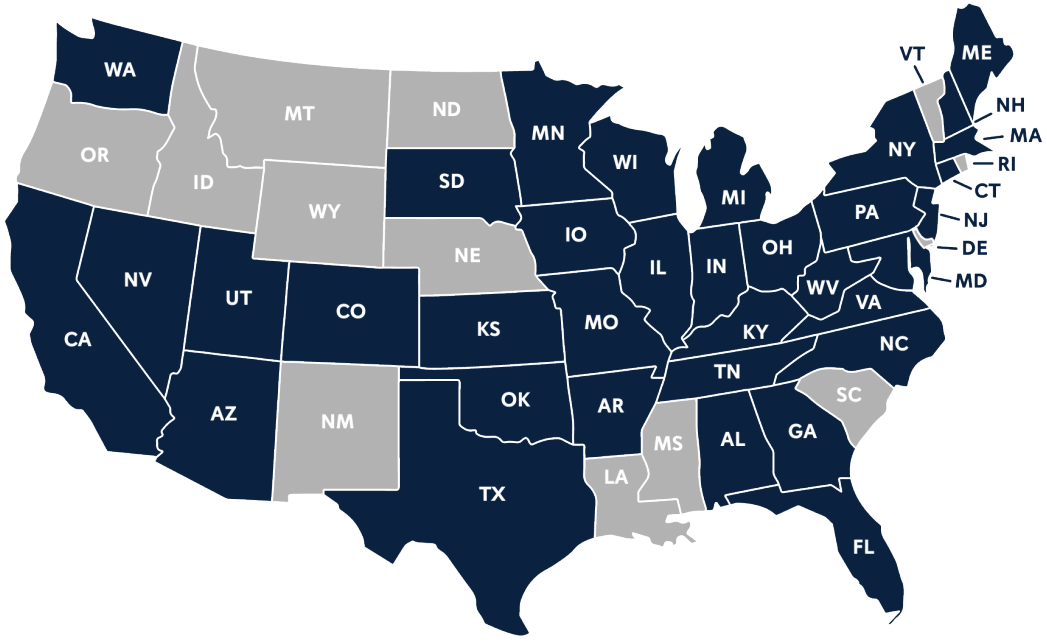


Figure 1: *States of Respondents (n=146)*

Respondents represented a cross-section of industries: aerospace, automotive, consumer goods, defense, energy, medical, transportation, and other. Many respondents serve more than one industry, resulting in a summation of categories greater than 100%. (See Figure 2: Industry Breakdown)

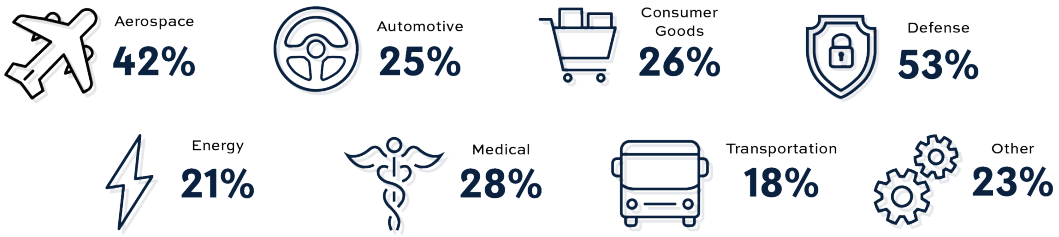


Figure 2: *Industry Breakdown (n=146)*

For this study, an SMM is defined as having under 500 employees and an annual revenue of under $100 million. SMMs represented a majority of the survey respondents, with 39% of respondents having less than 50 employees, 27% having between 50 and 250 employees, and 10% having between 250 and 500 employees. Of the respondents, 67% have an annual revenue of under $100 million. (See Figure 3: Number of Employees at Respondent's Location and Figure 4: Company Revenue)

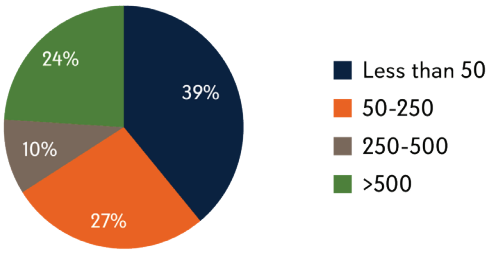


Figure 3: *Number of Employees at Respondent's Location (n=146)*

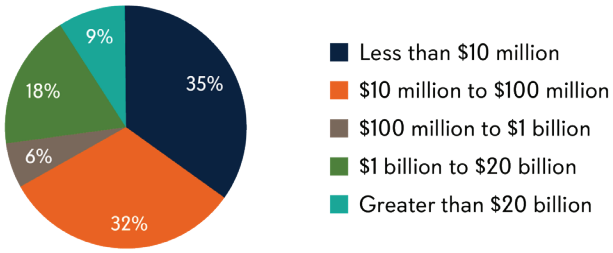


Figure 4: *Company Revenue (n=94)*

Top Challenges

Participants were asked, "What are the top three challenges your business faces?" and provided six options from which to choose. (See Table 1: Top Business Challenges)

The top three challenges businesses are facing are (1) workforce- operations, (2) operational efficiency, and (3) workforce-engineering. Workforce was divided into engineering-focused roles that typically require a degree and roles operating equipment on the factory or shop floor. **Workforce- operations and operational efficiency are the clear leading challenges, with nearly 60% of the respondents indicating them as top three challenges.** An overwhelming 31% of respondents noted workforce- operations as the #1 challenge. These results are comparable to last year's top three of (1) operational efficiency, (2) workforce- operations, and (3) revenue/profits. (See Figure 5: Top Business Challenges Year-Over-Year)

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

2023	Access to Capitol	Capital Improvements	Competitive Pressure	Operational Effeciency	Revenue/ Profits	Sales/ Marketing	Workforce-Engineering	Workforce-Operations
#1	9%	7%	8%	16%	10%	10%	10%	31%
#2	10%	8%	7%	18%	13%	8%	15%	23%
#3	6%	12%	9%	25%	12%	10%	16%	10%

Table 1: *Top Business Challenges (n=146)*

Deloitte and the Manufacturing Institute project that 2.1 million manufacturing jobs will be unfilled by 2030 [7]. Therefore, workforce- operations is likely an issue that will continue through the next decade. Filling these jobs with the next generation, Gen Z, will be crucial to the viability of the U.S. manufacturing industry [8].

Workforce- engineering emerged as a top three challenge in 2023, but it staggers behind the leading challenges, with 41% of the respondents indicating workforce- engineering as a top three challenge. An increase from 28% in 2022 to 41% in 2023 could signal that workforce- engineering is an emerging problem. The increased need for engineers is discussed further in the following subsection (Challenges: Workforce) and will need to be examined in future studies.

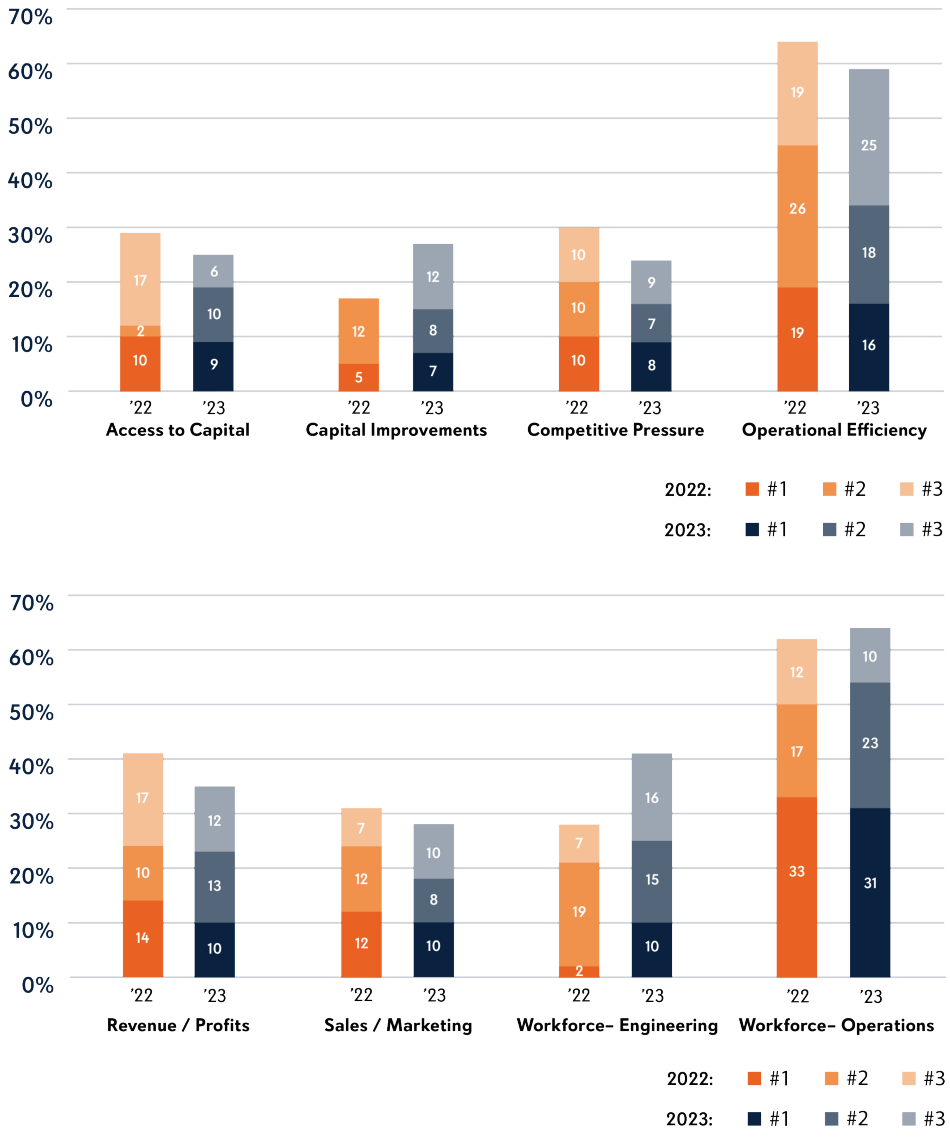
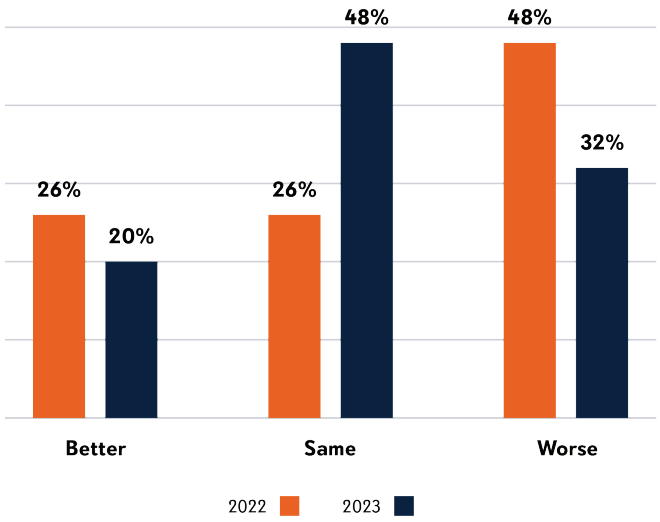


Figure 5: *Top Business Challenges Year-Over-Year (n=146)*

Though not in the top three challenges, **capital improvements is also surfacing as a challenge, with 27% of respondents listing capital improvements as a top three issue,** an increase from just 17% in the 2022 study. Like workforce- engineering, capital improvements could be an emerging issue that needs to be monitored.
When asked about the circumstances driving their top three challenges, 20% of respondents said their circumstances are

improving (a slight decrease from 26% in 2022), 48% noted their circumstances are remaining the same (an increase from 26% in 2022), and 32% indicated circumstances worsening (a significant decline from 48% in 2022). This finding should encourage manufacturers- **circumstances driving business challenges are trending positively.** There is a considerable drop in manufacturers that view their circumstances as worsening, which is a highly desirable outcome. (See Figure 6: Circumstances Driving Top 3 Challenges)

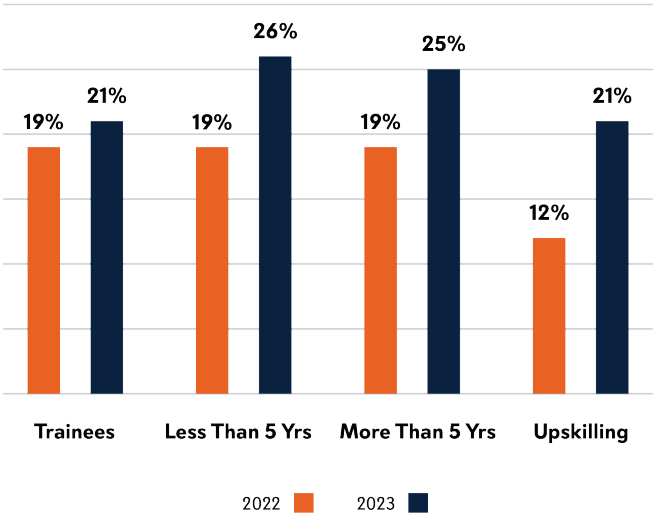
Figure 6: *Circumstances Driving Top 3 Challenges (n=146)*



Challenges: Workforce

Workforce- operations is a top three issue for 64% of respondents, and therefore, workforce issues were investigated further. Those who indicated workforce as a top three challenge (56 respondents) were asked to specify the level of workforce experience and skills they are seeking. Trainees (21%), less than five years (26%), more than five years (25%), and upskilling of the current workforce (21%) were all chosen as workforce experience needs. All levels of experience saw an increase in need from last year, which likely indicates that the need for employees is a growing issue. The relatively even distribution of needed experience and skills may suggest that an operations workforce is needed throughout organizations, not just at an entry-level. (See Figure 7: Workforce Experience Needed)

Figure 7: *Workforce Experience Needed (n=146)*



In fact, experienced workers are needed the most, regardless of years of experience (less than or more than five years). The

need for workers is likely due to the number of current or anticipated unfilled jobs. Manufacturers are less concerned with hiring trainees and upskilling their current workforce. They desire to hire workers with existing knowledge and skills. This manifests in escalating wages as experienced workers move to the highest-wage companies, causing a "bidding war" for their services. As a result, some companies have come to the realization that they must hire and train workers. This is shown by the growing interest in upskilling the existing workforce, with 12% of the respondents indicating this need in 2022 and 21% in 2023.

Respondents were asked to select their workforce needs from the following options: engineering, Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) operators, machine operators, planning, quality control, and supply chain. **The most sought-after workforce roles were engineers and machine operators. Engineering skills are rising in demand, with 21% in 2022 to 34% of respondents indicating a need for engineers in 2023.** The demand for machine operators is also growing, with 25% of respondents indicating a need for machine operators in 2023, up from 19% in 2022. All other workforce skill needs experienced little to no change year-over-year. (See Figure 8: Workforce Skills Needed)

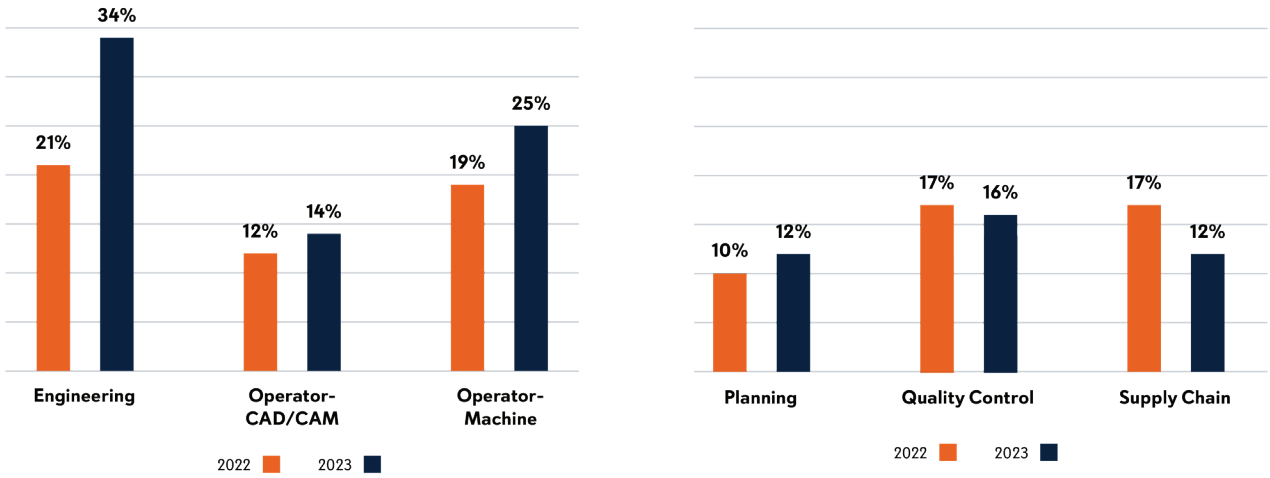


Figure 8: *Workforce Skills Needed (n=146)*

Smart Manufacturing Component Value

When ranking smart manufacturing technologies by their importance in addressing business challenges, automation was a clear leader, with 40% of respondents marking it as the #1 perceived technology solution. The other technologies paled in comparison, being ranked significantly lower by respondents: 3D printing (17%), artificial intelligence (5%), big data (8%), sensors/IoT (16%), and predictive analytics (14%).

With regard to the technologies that were ranked as the top three technology solutions, there are three leaders: (1) sensors/IoT, (2) automation, and (3) predictive analytics. Sensors/IoT was ranked in the top three business solutions by over 67% of the respondents. However, sensors/IoT was mainly ranked as a #2 or #3 solution- unlike automation, which was mostly ranked as a #1 solution, meaning automation is more top of mind as a potential business solution. Like sensors/IoT, predictive analytics was mostly ranked as a #2 or #3 solution, being ranked as a top three business solution by 59% of respondents.

Automation is perceived as a top three technology solution by 63% of respondents. Predictive analytics followed close behind, being ranked by 59% of respondents as a top three business solution. The top three technologies, sensors/IoT, automation, and predictive analytics, were ranked ahead of all other technologies by a wide margin. Interestingly, 3D printing was ranked as the #1 business solution by 17% of respondents (falling second to automation), but it was only ranked by 28% of respondents as a top three business solution. There is likely a perception that there is a niche market for using 3D printing as a technology solution, whereas the other technologies have more widespread applications. This could also mean there is a misconception of the uses and benefits of 3D printing. (See Table 2: Perceived Value of Smart Manufacturing Technologies)

2023	3D Printing	Artificial Intelligence	Automation	Big Data	Sensors/IoT	Predictive Analytics
#1	17%	5%	40%	8%	16%	14%
#2	5%	12%	14%	15%	28%	19%
#3	6%	16%	9%	7%	23%	26%

Table 2: *Perceived Value of Smart Manufacturing Technologies (n=95)*

The 2023 top three technology solutions remained consistent with last year's top three: sensors/IoT, automation, and predictive analytics. Also consistent with the previous year, many participants ranked automation as the #1 business solution (52%). There was a drop from 76% to 63% in the percentage of respondents that noted automation as a top three business solution; this likely means manufacturers are becoming more aware of the benefits of other technology solutions, yet they keep automation as a desired solution. (See Figure 9: Perceived Value of Smart Manufacturing Technologies Year-Over-Year)

Predictive analytics increased as a top three solution by a notable 28-percentage points from 2022, demonstrating the increased awareness of the benefits of predictive analytics. With the rise of artificial intelligence and the introduction of ChatGPT, we expect to see artificial intelligence climb in the coming years [9]. Artificial intelligence has increased 14-percentage points in its perceived value since 2022; big data is also climbing the ladder, with a 19-percentage point increase.

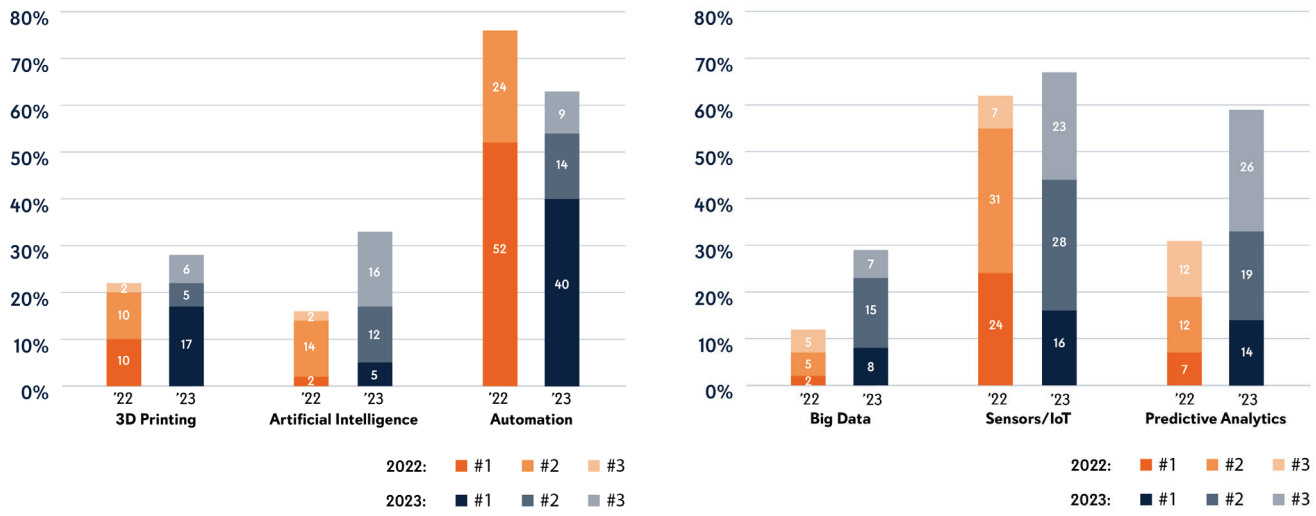


Figure 9: *Perceived Value of Smart Manufacturing Technologies Year-Over-Year (n=95)*

Smart Manufacturing Component Adoption

Participants were asked to determine where their firm is in adopting the six smart manufacturing technologies. The five stages of adoption the respondents were asked to choose from were awareness, researching, evaluating, implementing, and using. In the first stage of adoption, awareness, manufacturers become cognizant of the technology. In the researching stage, manufacturers seek further knowledge about the technology's uses, benefits, and applicability. Manufacturers then move on to the evaluating stage where they review various solutions, comparing costs and the use of resources. Manufacturers introduce the new technology during the implementation phase, utilizing in-house personnel or vendor support. Finally, manufacturers reach the stage of using where the technology is fully implemented and used in production.

The technologies that are in the completion stage of adoption, using, by the most participants, are 3D printing (36%), automation (34%), and sensors/IoT (26%). On the flip side, the technologies in the earliest stage of adoption, awareness, are artificial intelligence (37%), big data (27%), and 3D printing (26%). (See Table 3: Smart Manufacturing Technology Adoption and Figure 10: Smart Manufacturing Technology Adoption)

2023	3D Printing	Artificial Intelligence	Automation	Big Data	Sensors/IoT	Predictive Analytics
Using	36%	6%	34%	9%	26%	7%
Implementing	16%	8%	17%	21%	21%	25%
Evaluating	10%	23%	20%	19%	27%	23%
Researching	12%	26%	21%	24%	12%	20%
Awareness	26%	37%	8%	27%	14%	25%

Table 3: *Smart Manufacturing Technology Adoption (n=100)*

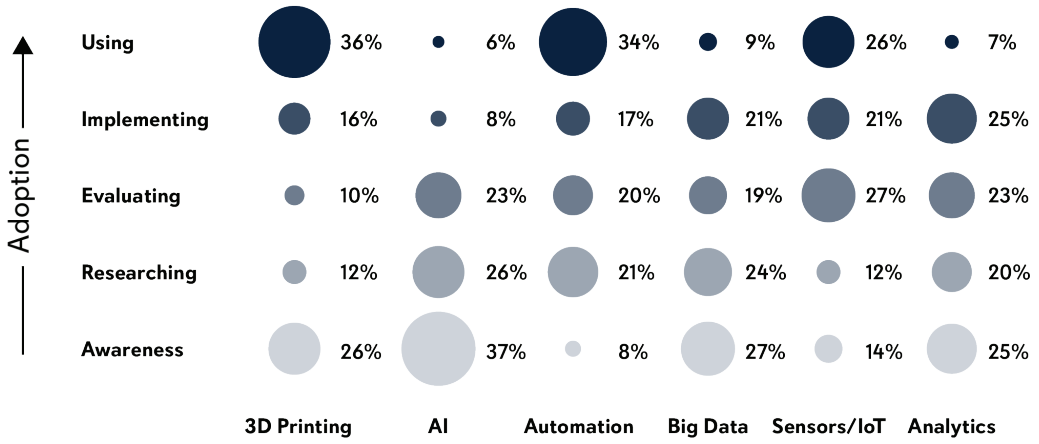


Figure 10: *Smart Manufacturing Technology Adoption (n=100)*

Adoption: 3D Printing

Over the past year, respondents have indicated an increase of 10-percentage points in the use of 3D printing, but only 28% of companies indicated 3D printing as a potential solution to their business challenges. Although the percentage of respondents using 3D printing has grown, a large group is still at the awareness stage (26%). This could be due to the wide breadth of 3D printing options, such as increased prototyping uses where product ideas are being tested in polymers, but metal parts are still not approved for use in key performance areas. (See Figure 11: 3D Printing Adoption Year-Over-Year)

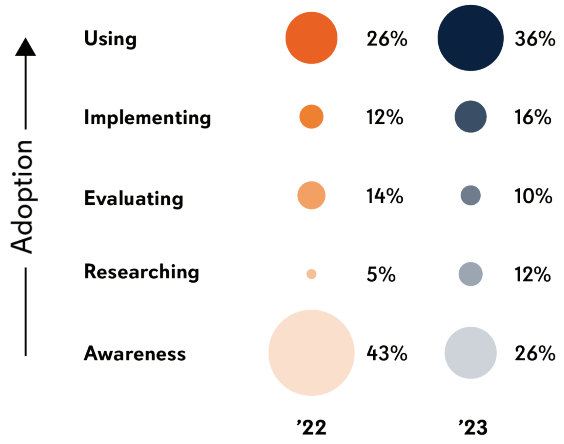


Figure 11: *3D Printing Adoption Year-Over-Year (n=100)*

Adoption: Artificial Intelligence

Artificial intelligence is the technology in the earliest stages of adoption, with 63% of respondents in the first two stages of awareness and researching. However, there was movement toward the later stages of adoption, with 6% of the audience now using it compared to just 2% in 2022. We have also seen an increase of 9-percentage points in manufacturers evaluating artificial intelligence. (See Figure 12: Artificial Intelligence Adoption Year-Over-Year)

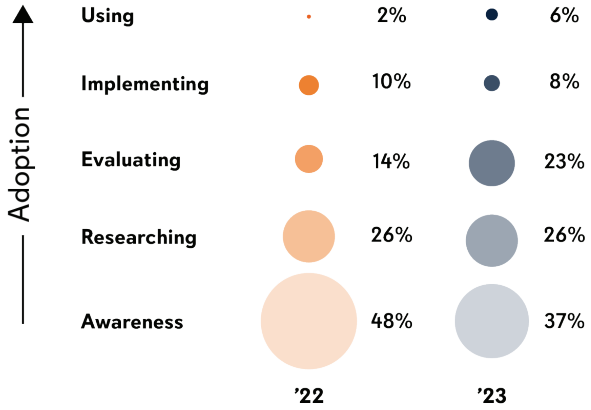


Figure 12: *Artificial Intelligence Adoption Year-Over-Year (n=100)*

Adoption: Automation

Automation has seen little change over the past year, with approximately 50% of respondents still in the implementing and using phases of adoption. However, automation is at the top of manufacturers' minds as a top business solution that can help address their business needs. Therefore, we must understand the barriers to adopting automation, which we will explore more (See Adoption Barriers: Automation). (See Figure 13: Automation Adoption Year-Over-Year)

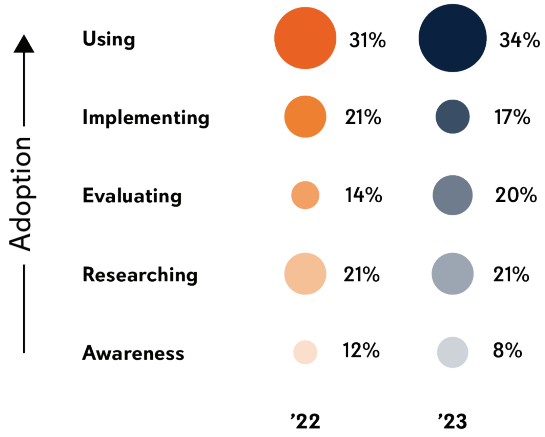


Figure 13: *Automation Adoption Year-Over-Year (n=100)*

Adoption: Big Data

Few companies use big data (9%), but approximately 20% of companies are either researching, evaluating, or implementing it. To date, the perceived benefits of big data are only recognized by 30% of respondents. Manufacturers are becoming more aware of the benefits of big data, moving from the adoption stage of awareness to research. (See Figure 14: Big Data Adoption Year-Over-Year)

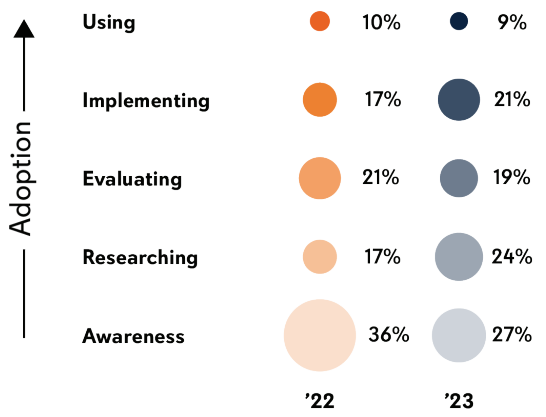


Figure 14: *Big Data Adoption Year-Over-Year (n=100)*

Adoption: Sensors/IoT

Despite the high ranking of sensors/IoT as a smart technology to help address business challenges, we have not seen an increase in its implementation or use. The data shows that the use and implementation of sensors/IoT have decreased. However, that is likely not the case; the increased sample size of the 2023 study likely provides a more accurate representation of the population's adoption of sensors/IoT. Sensors/IoT has increased 12-percentage points in awareness over the past year. However, approximately 10% of respondents have moved from researching sensors/IoT to evaluating it. (See Figure 15: Sensors/IoT Adoption Year-Over-Year)

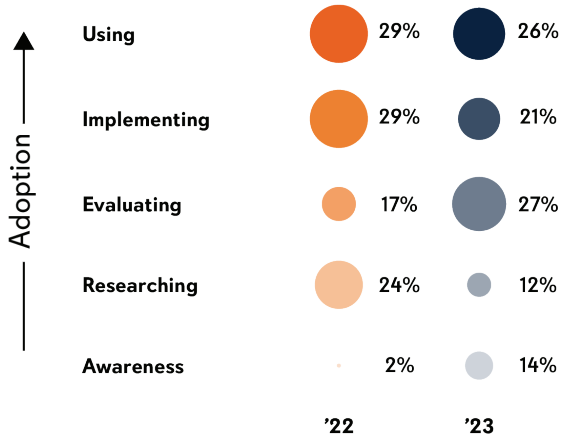


Figure 15: *Sensors/IoT Adoption Year-Over-Year (n=100)*

Adoption: Predictive Analytics

More companies are beginning to implement predictive analytics (an increase of 11-percentage points), but few currently use it (7%). The increased sample size of the 2023 study likely contributed to what appears to be a decline in the using stage of predictive analytics adoption. The percentage will likely increase in the coming years because predictive analytics was ranked as a top three technology solution by 59% of companies. (See Figure 16: Predictive Analytics Adoption Year-Over-Year)

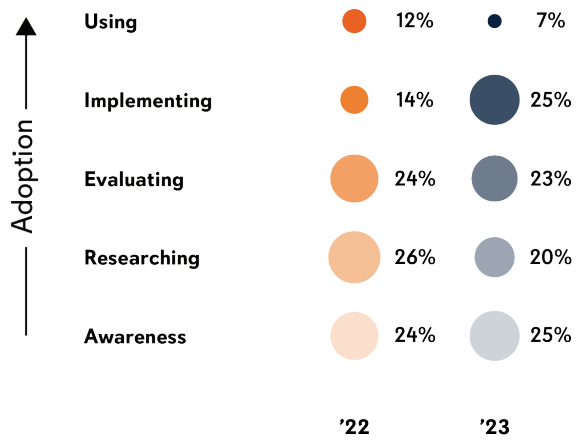


Figure 16: *Predictive Analytics Adoption Year-Over-Year (n=100)*

Smart Manufacturing Adoption Barriers

To accelerate the depth and breadth of adoption of smart manufacturing technologies, we must first identify the barriers hindering adoption so they can be addressed and overcome. Survey respondents were asked to rank the top three issues that impede their ability to better adopt each of the six smart manufacturing technologies. A weighted ranking was applied and converted into percentages of manufacturers experiencing the following barriers: lack of awareness, lack of business cases, lack of capital, high cost, lack of peer experience, lack of workforce, and lack of workforce skill set. **Lack of awareness and lack of business cases are significant barriers to adopting smart manufacturing technologies.** (See Table 4: Adoption Barriers by Technology)

	Lack of				Lack of			
2023	Awareness	Business Cases	Capital	High Cost	Peer Experience	Resources	Workforce	Workforce Skillset
3D Printing	13%	19%	8%	17%	10%	4%	13%	15%
Artificial Intelligence	22%	23%	5%	12%	7%	6%	11%	14%
Automation	11%	13%	13%	19%	6%	8%	14%	15%
Big Data	19%	20%	8%	11%	8%	8%	11%	14%
Sensors/IoT	15%	16%	10%	13%	7%	7%	16%	16%
Predictive Analytics	22%	17%	8%	11%	7%	8%	11%	16%

Table 4: *Adoption Barriers by Technology (n=100)*

Adoption Barriers: 3D Printing

Respondents noted a lack of business cases (19%) and high cost (17%) as the most significant impediments to adopting 3D printing. These results are consistent with last year's top two: lack of business cases (26%) and high cost (20%). A lack of business cases dropped from 6-percentage points, meaning a lack of business cases is becoming less of an impediment, or another impediment is becoming more dominant. In this case, the latter appears to be true, with a lack of workforce growing as an issue. The percentage of respondents that indicated lack of workforce as a barrier (13%) more than doubled from the 2022 study (6%). (See Figure 17: Adoption Barriers for 3D Printing)

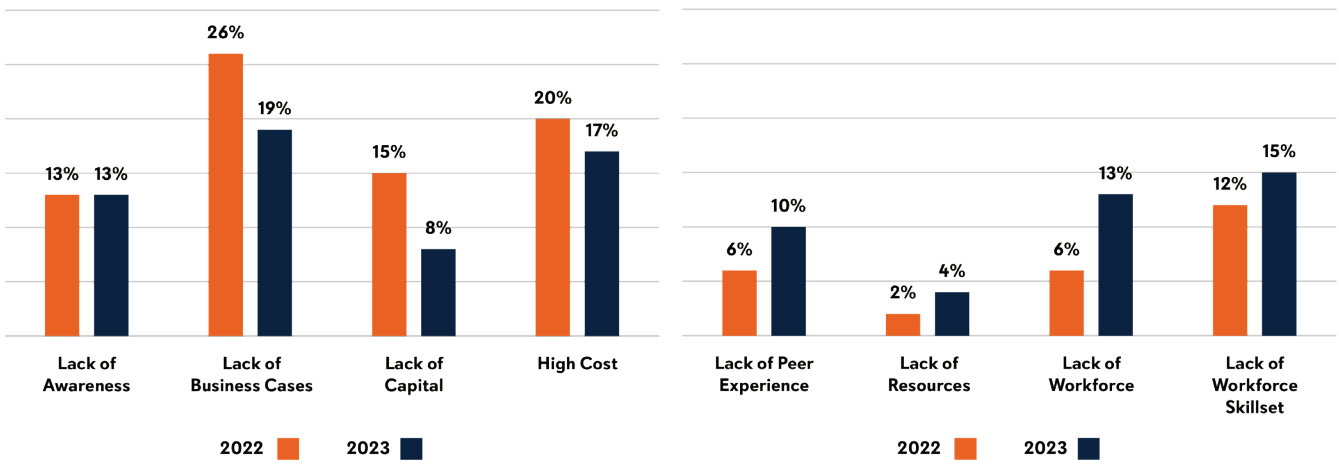


Figure 17: *Adoption Barriers for 3D Printing (n=100)*

Adoption Barriers: Artificial Intelligence

There has been little change over the past year in impediments to artificial intelligence. Lack of business cases (23%) and lack of awareness (22%) remain the most significant impediments. In 2022, the lack of business cases was 28%, and the lack of awareness was 26%. As shown earlier, manufacturers are in the earliest stages of artificial intelligence adoption. The transition of artificial intelligence from our common uses (e.g., Siri, Google, Alexa) to manufacturing applications is still in its infancy. With a substantial lack of awareness, it is unlikely that manufacturers will realize its benefits at this time. (See Figure 18: Adoption Barriers for Artificial Intelligence)

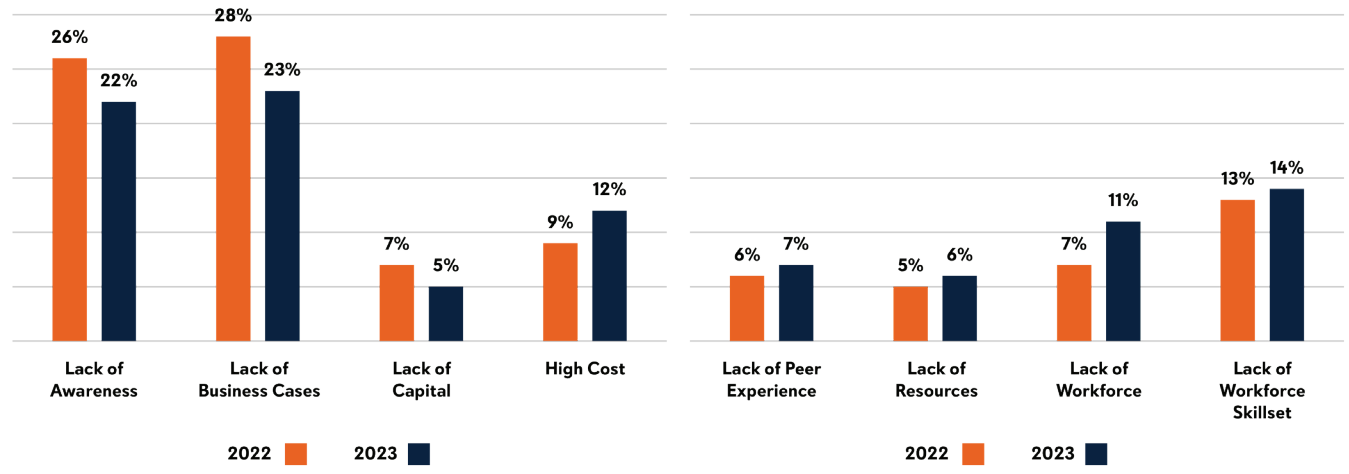


Figure 18: *Adoption Barriers for Artificial Intelligence (n=100)*

Adoption Barriers: Automation

High cost remained a top reason companies are not adopting automation, followed by a lack of the needed workforce skill set. In 2022, the most significant impediments to automation adoption were lack of capital (20%), high cost (20%), and lack of workforce skill set (16%). Lack of capital as a barrier decreased from 20% to 13%, which means the most significant barrier has changed from being unable to find capital to purchase automation to simply being too costly. Automation is perceived as highly valuable in solving business challenges, but manufacturers struggle to look past its high costs to the potential return on investment. (See Figure 19: Adoption Barriers for Automation)

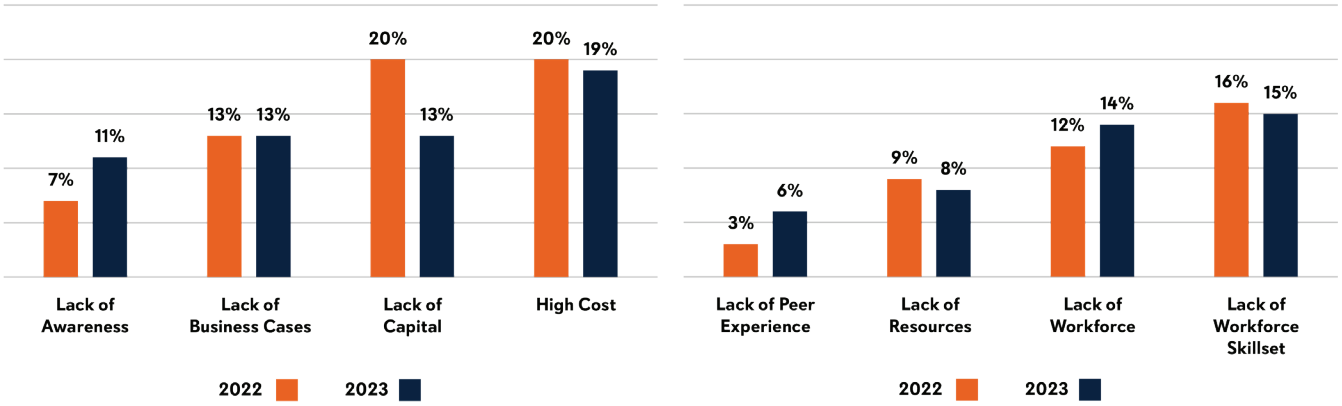


Figure 19: *Adoption Barriers for Automation (n=100)*

Adoption Barriers: Big Data

There has been very little change in the issues impeding companies from adopting big data processing, but the lack of awareness has improved significantly (a 6-percentage point decrease as a barrier). However, a lack of awareness (19%) and lack of business cases (20%) remained the highest barriers to adopting big data initiatives year-over-year. (See Figure 20: Adoption Barriers for Big Data)

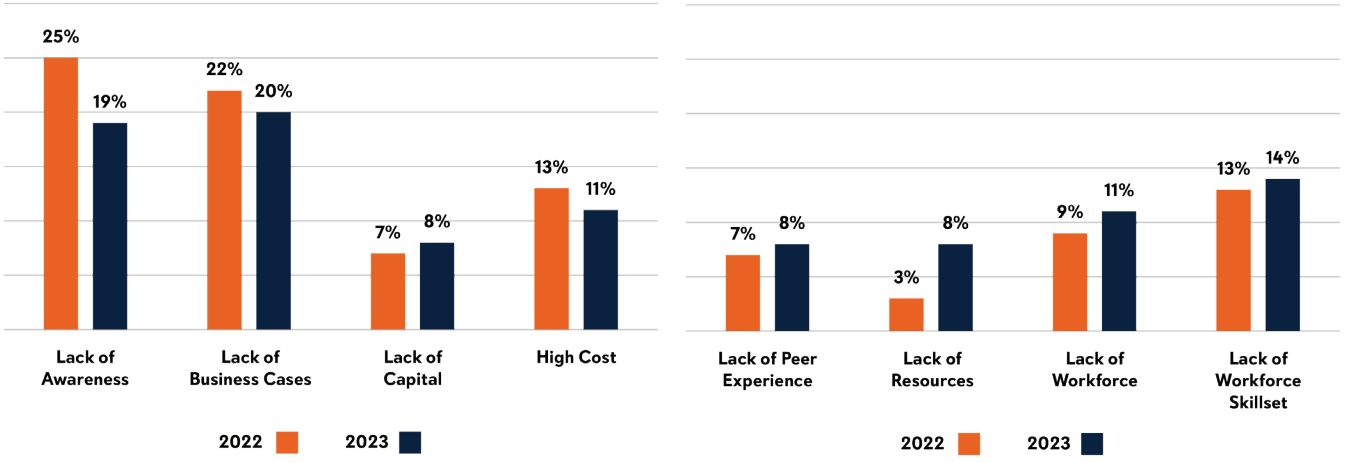


Figure 20: *Adoption Barriers for Big Data (n=100)*

Adoption Barriers: Sensors/IoT

There is no clear leader in impediments to sensors/IoT. Lack of awareness, lack of business cases, lack of workforce, and lack of workforce skill sets are all indicated as impeding the adoption of sensors/IoT (at approximately 15-16% each). With awareness being a barrier, there may be confusion around the obstacles to implementing sensors/IoT. Like 3D printing and automation, sensors/IoT saw a decrease in lack of capital as an adoption barrier. (See Figure 21: Adoption Barriers for Sensors/IoT)

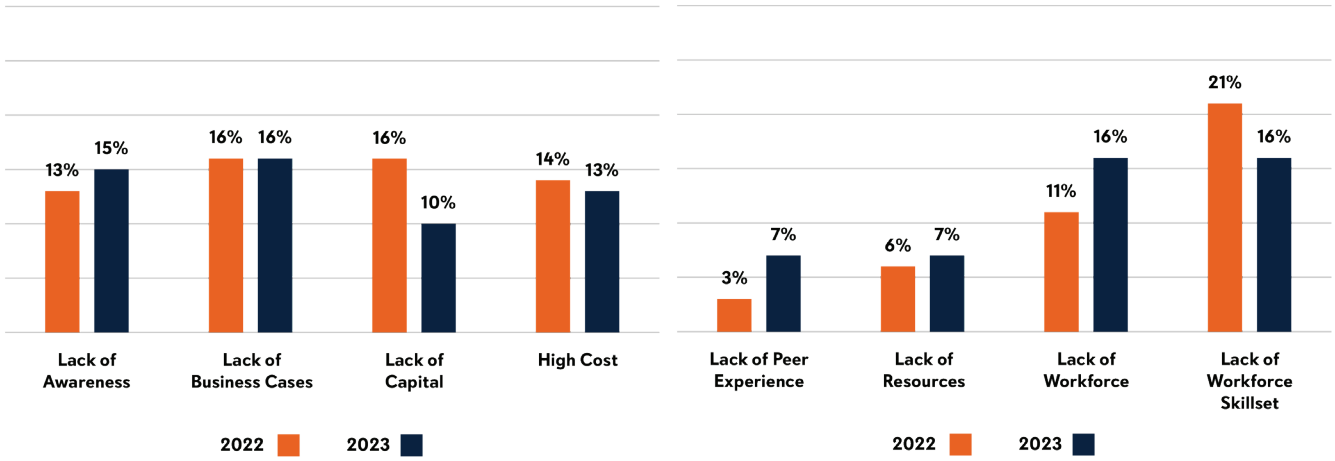


Figure 21: *Adoption Barriers for Sensors/IoT (n=100)*

Adoption Barriers: Predictive Analytics

Lack of awareness is the most significant impediment to adopting predictive analytics. Lack of awareness (22%), lack of business cases (17%), and lack of the needed workforce skill set (16%) have been consistent as the top three impediments over the past year. The availability of relevant business cases improved significantly, decreasing as a barrier by 11-percentage points, but it remained a top two barrier to adopting predictive analytics. The barriers could have been magnified with the small sample size in the 2022 study. (See Figure 22: Adoption Barriers for Predictive Analytics)

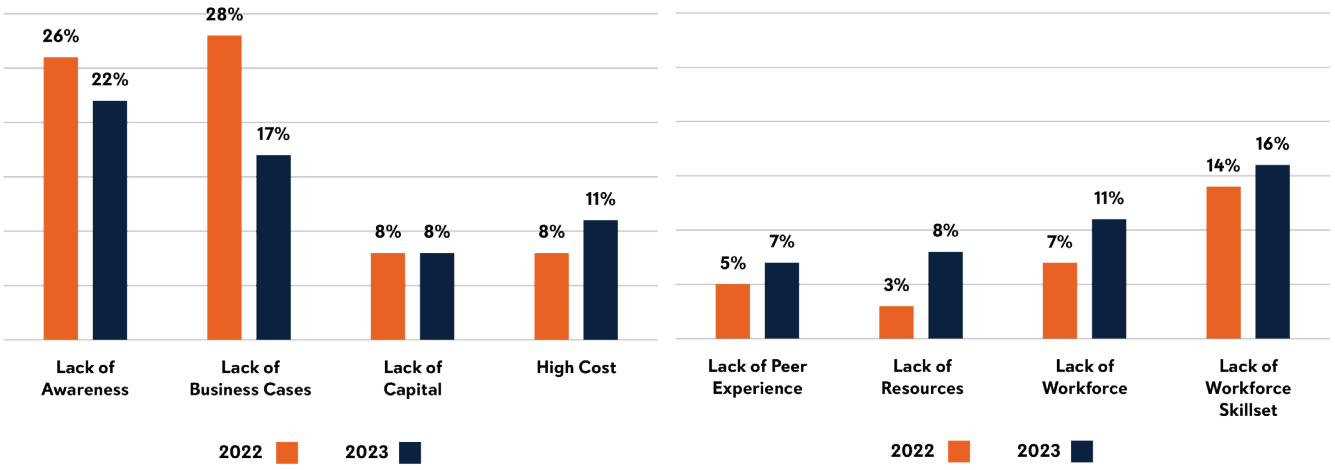


Figure 22: *Adoption Barriers for Predictive Analytics (n=100)*

See Appendix A *– Technology Adoption Value and Barriers, compares the value manufacturers place on each smart manufacturing technology with the corresponding barriers to implementing each technology.*

Resources to Learn, Decide, and Implement

Survey respondents were asked to choose which resources they use to learn about, decide on, and implement smart manufacturing technologies. The options included academic papers, business articles, case studies, consultants, peer experience, vendors, and other. (See Table 5: Resources to Learn, Decide, and Implement)

2023	Academic Papers	Business Articles	Case Studies	Consultants	Peer Experience	Vendors	Other
Learn	11%	23%	22%	10%	20%	14%	1%
Decide	8%	18%	24%	12%	22%	15%	1%
Implement	5%	12%	19%	20%	21%	21%	1%

Table 5: *Resources to Learn, Decide, and Implement (n=96)*

Resources to Learn

Companies that are starting investigations into technology adoption prefer to use business articles (23%), case studies (22%), and peer experience (20%) to learn about smart manufacturing. The top three resources to learn are consistent with last year's top three: business articles (22%), case studies (17%), and peer experience (22%). These results should stress the importance of the need for more mainstream articles and success stories about smart manufacturing technology adoption. Manufacturers want to see how their peers successfully adopted a technology when learning about smart manufacturing technologies. (See Figure 23: Resources to Learn)

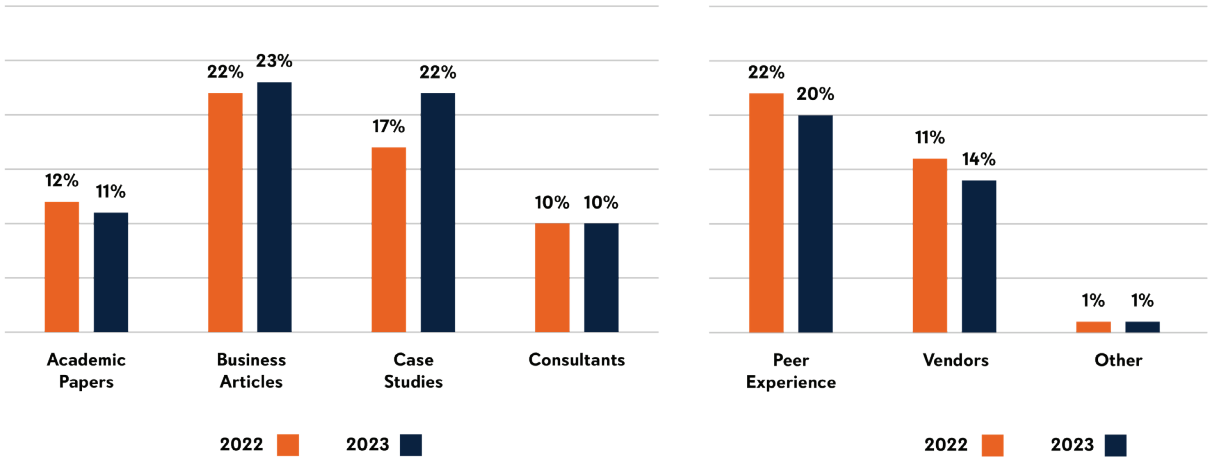


Figure 23: *Resources to Learn (n=96)*

Resources to Decide

Case studies (24%) and peer experience (22%) are leveraged by companies when deciding on the right smart manufacturing solutions. When deciding on a technology, manufacturers want to know how others succeeded and overcame barriers during their technology adoption journey. Notice the top three resources to decide on a technology are the same as those to learn about a technology: business articles, case studies, and peer experience. This reiterates the importance of releasing business articles and case studies and creating opportunities for peer-to-peer collaboration. (See Figure 24: Resources to Decide)

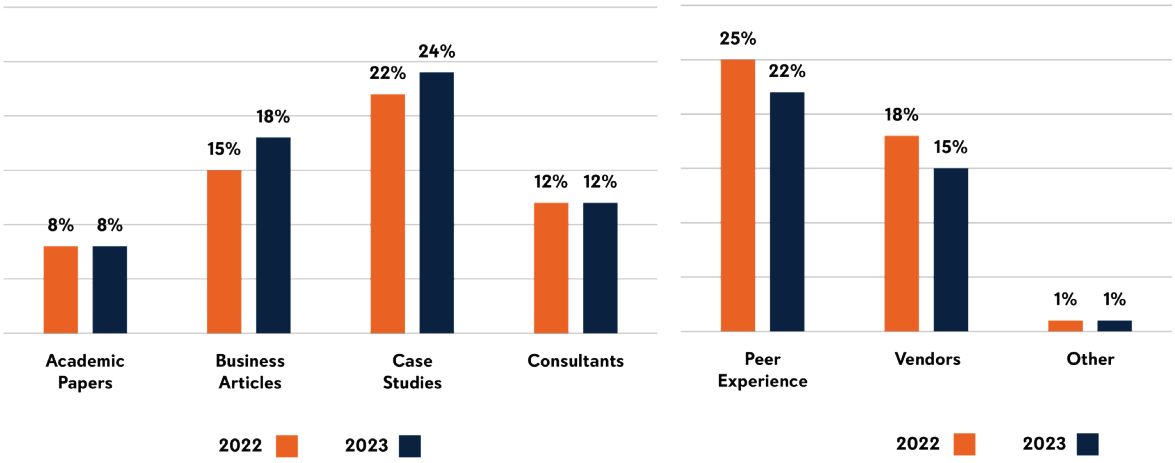


Figure 24: *Resources to Decide (n=96)*

Resources to Implement

Companies look to peers (21%), vendors (21%), and consultants (20%) when implementing smart manufacturing solutions. The top resources for technology implementation remain the same year-over-year. However, vendors saw a 7-percentage point decrease as an implementation resource since the 2022 study, meaning other resources could become more prominent. (See Figure 25: Resources to Implement)

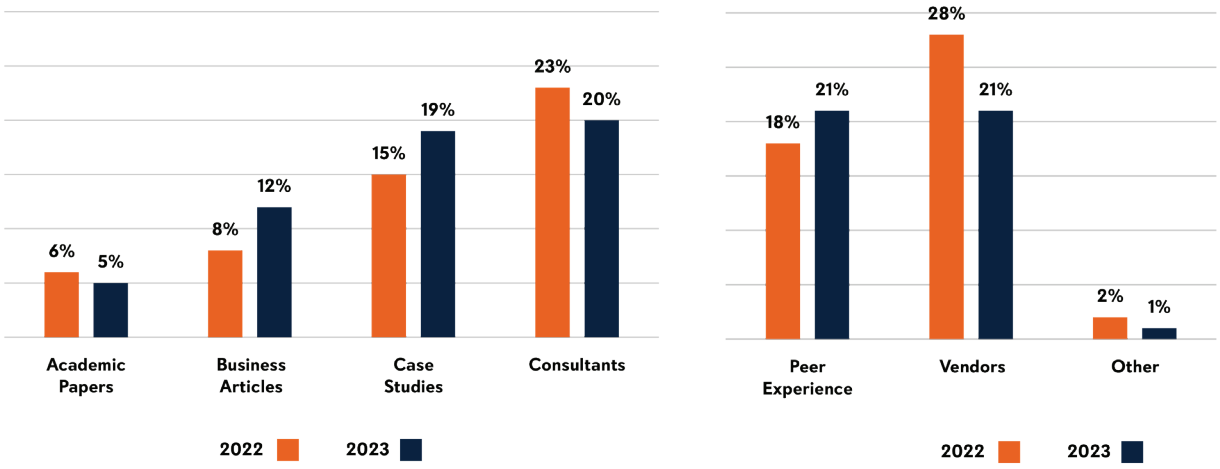


Figure 25: *Resources to Implement (n=96)*

Software Used

Respondents were asked to indicate which software packages their company uses: enterprise resource planning (ERP), scheduling, manufacturing execution system (MES), supply chain management (SCM), or supplier relationship management (SRM). Of the 94 respondents who answered this question, 82% use ERP software. This indicates the foundation for a digital transformation is likely there. However, from this survey, it is unclear whether or not the ERP systems are used effectively and for their intended purposes. It is also unclear if there is interoperability between the software packages for respondents using more than one software package. (See Figure 26: Software Used)

Scheduling software is used by 67% of the survey participants. How and if the other 33% of respondents perform scheduling functions is unclear. Scheduling is crucial to all aspects of manufacturing: procurement, production, and fulfillment. Therefore, a significant portion of manufacturers (over 30%) could benefit from introducing scheduling software.
MES software is used by only 45% of the respondents. This percentage is meager, considering 82% of companies use ERP software. Respondents using ERP and MES make up 38% of the survey population. This could indicate that manufacturers need help managing their plant floors or lack awareness of MES. Whichever the case may be, manufacturers likely need assistance in software adoption and execution.

There is significant room for growth in manufacturers adopting SCM and SRM software. With only 38% of respondents using SCM and 31% using SRM, there is likely a communication barrier between suppliers (especially lower-tier suppliers), manufacturers, and customers.

Overall, it is evident that there are ample opportunities for improvement in software adoption. All six smart technologies discussed in this report are made possible or enhanced by these software platforms. Not having or understanding these software packages could be a substantial barrier to the adoption of smart technologies.

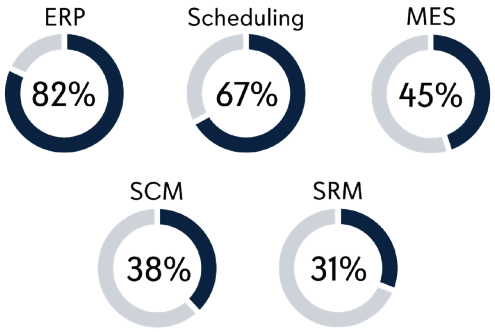


Figure 26: *Software Used (n=94)*

Differences Between LV/HM and HV/LM Responses

When reading these results, it must be remembered that most respondents (57%) chose low volume, high mix (LV/HM) as their primary production type. Fewer respondents (36%) indicated they perform both (LV/HM and HV/LM), and the smallest group (7%) represented high volume, low mix (HV/LM). (See Figure 27: Mix of Orders)

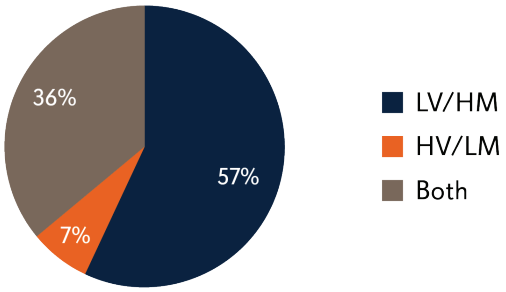


Figure 27: *Mix of Orders (n=146)*

The first difference noted is in the top business challenges. The HV/LM respondents rated workforce- operations and operational efficiency as the top challenges. These challenges were rated by 82% of the HV/LM respondents. Other challenges fell far behind; capital improvements was the next largest challenge- rated by only 45% of respondents. In the 2022 study, an overwhelming majority of respondents also rated workforce- operations as a top challenge.

Workforce- operations and operational efficiency were also rated as the top challenges by the LV/HM respondents. However, there is one striking difference; approximately 55% of LV/HM respondents rated these as top challenges, which is a significantly lower percentage than the HV/LM respondents. Last year, LV/HM production mix ranked both operational efficiency and revenue/profits as their top challenges with access to capital and workforce- operations at number two. This year, LV/HM ranked the challenges as follows: (1) operational efficiency by 55%, (2) workforce- operations by 54%, (3) workforce- engineering by 37%, and (4) access to capital by 36%.

The next difference was observed in ranking the six smart manufacturing technologies for their ability to help address business challenges. In keeping with the 2022 study, both groups ranked automation and sensors/IoT highly. In 2023, predictive analytics rose to the top three solutions with 89% of HV/LM respondents ranking it as a top three technology solution (33% ranked it number one). Automation was ranked as #1 by 44% of HV/LM respondents.

For LV/HM product mix, automation was ranked as #1 by 40% of the respondents. 3D printing was ranked as a #1 solution by 27% of respondents, but few respondents ranked it as a #2 or #3 solution. This resulted in automation, sensors/IoT, and predictive analytics being technologies that were ranked by the most participants as a #1, 2, or 3 business solutions. Though the sample size of HV/LM participants is small, it is interesting to note that no HV/LM participants ranked 3D printing as a top three business solution.

Analyzing the technology adoption stages across product mixes provided valuable insights. The technologies that are the furthest along in adoption are automation, sensors/IoT, and 3D printing for all product mix groups (HV/LM, LV/HM, and the group producing both HV/LM and LV/HM). The most prominent difference was in the adoption of automation; 67% of HV/LM participants are using automation. Meanwhile, only 27% of LV/HM respondents are using automation.

Differences by Company Size

The demographic information provided by the respondents was used to analyze the results by company size to determine if company size played a role in the findings. It is important to remember that companies with less than 50 employees comprised most of the respondents (recall Figure 3). Company size was decomposed into four categories:

- Less than 50 employees (39%)
- 50-250 employees (27%)
- 250-500 employees (10%)
- More than 500 employees (24%)

The top business challenges varied by company size. The following presents the percentage of respondents in each category that ranked the challenge as a top three issue.

- **Less than 50 employees:** workforce- operations (51%), workforce- engineering (44%), and sales/marketing (44%)
- **50-250 employees:** workforce- operations (73%), operational efficiency (70%), revenue/profits (33%), and workforce- engineering (33%)
- **250-500 employees:** operational efficiency (86%), workforce- operations (64%), and revenue/profits (43%)
- **More than 500 employees:** workforce- operations (74%), operational efficiency (69%), and workforce- engineering (54%)

The common thread here is workforce operations, with all company sizes listing it as one of their top three challenges. It is also important to note that companies with over 50 employees have two leading issues: workforce- operations and operational efficiency. Small companies are typically less capitalized and live month-to-month making payroll, which makes people (workforce- operations and engineering) and attracting new customers (sales/marketing) critical to staying in business.

When reviewing technology value perception by company size, 3D printing is mainly perceived as valuable by companies with less than 250 employees. This sparks the question of why larger manufacturers do not perceive 3D printing as valuable. On the other hand, Big Data was mainly perceived as valuable by companies with more than 250 employees. Larger companies may have larger datasets, creating a more apparent need for big data processing. Similarly, the perceived value of predictive analytics increases with company size. (See Figure 28: Perceived Value of Technologies by Company Size - Note that scoring for these categories combined the top two vote percentages.)

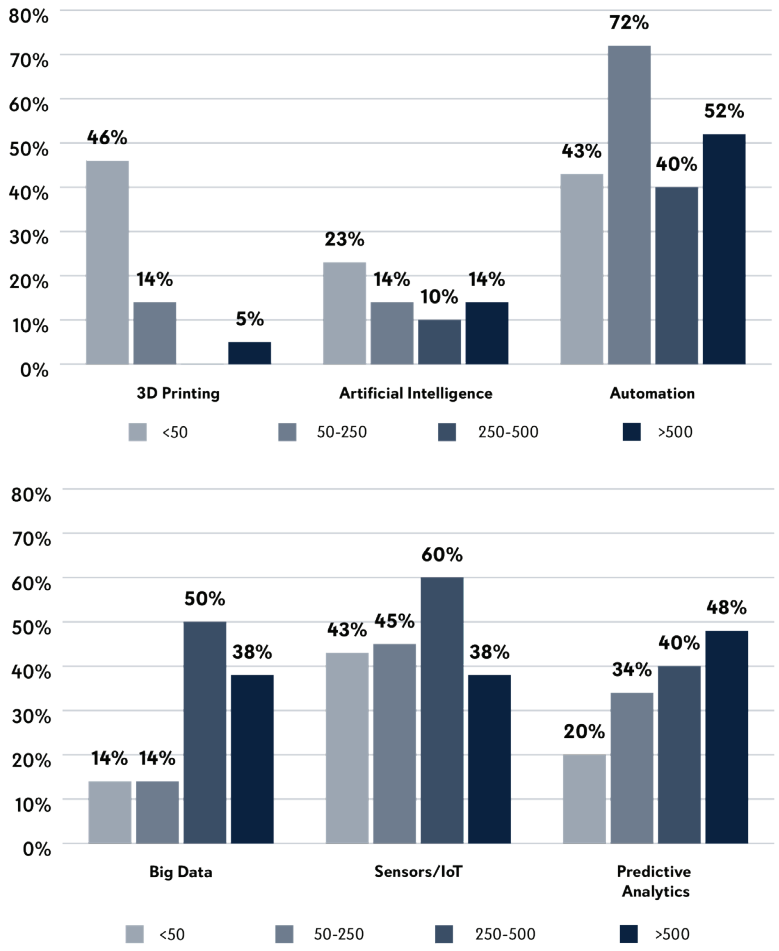


Figure 28: *Perceived Value of Technologies by Company Size (n=95)*

See Appendix B *– Adoption Comparison by Company Size, compares technology adoption stages by company size (grouped by technology). As anticipated, for most technologies, adoption stages are further along the larger the company is.*

See Appendix C *– Adoption Comparison by Technology, compares technology adoption stages by technology (grouped by company size). Manufacturing companies can use these charts to compare their technology adoption stage to their peers of similar company size.*

Top Adoption Barriers by Company Size

Table 6: Top Adoption Barriers by Company Size, lists the top two adoption barriers for each technology by company size. This table can be used to identify and address technology adoption barriers for companies of various sizes.

	3D Printing	AI	Automation
<50	High Cost (18%) Lack of Business Cases (17%)	Lack of Business Cases (25%) Lack of Awareness (21%)	High Cost (21%) Lack of Workforce Skill Set (16%)
50-250	Lack of Business Cases (21%) High Cost (17%)	Lack of Business Cases (24%) Lack of Awareness (23%)	High Cost, Lack of Workforce, & Lack of Workforce Skill Set (18%)
250-500	Lack of Business Cases (23%) Lack of Awareness & High Cost (20%)	Lack of Awareness (27%) Lack of Business Cases (20%)	Lack of Capital (23%) High Cost (20%)
>500	Lack of Business Cases (21%) Lack of Awareness & Lack of Workforce Skill Set (17%)	Lack of Awareness (22%) Lack of Business Cases (19%)	Lack of Business Cases (14%) High Cost (17%)

	Big Data	Sensors/IoT	Predictive Analytics
<50	Lack of Business Cases (24%) Lack of Awareness (21%)	Lack of Business Cases (19%) Lack of Awareness (14%)	Lack of Business Cases (22%) Lack of Awareness (18%)
50-250	Lack of Awareness & Lack of Business Cases (18%)	Lack of Workforce Skill Set (20%) Lack of Awareness (14%)	Lack of Awareness (23%) Lack of Business Cases & Lack of Workforce Skill Set (15%)
250-500	Lack of Business Cases & Can't Find Resources (20%)	Lack of Business Cases (23%) Lack of Awareness (17%)	Lack of Awareness (23%) Can't Find Resources & Lack of Workforce Skillset (17%)
>500	Lack of Awareness (21%) Lack of Workforce Skill Set (19%)	Not Enough Workforce (22%) Lack of Workforce Skillset (17%)	Lack of Awareness (27%) Lack of Workforce Skill Set (22%)

Table 6: *Top Adoption Barriers by Company Size (n=100)*

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, lists the top two resources used to learn, decide, and implement smart manufacturing technologies by company size. This table can be used by government, industry, and academia to increase the availability of the resources that are manufacturers of varying company sizes are using.

	Learn	Decide	Implement
<50	Business Articles (22%) Case Studies (20%)	Business Case (22%) Awareness (20%)	Case Studies (20%) Peer Experiance (19%)
50-250	Peer Experience (21%) Business Articles & Case Studies (20%)	Peer Experience (23%) Case Studies (21%)	Peer Experience (24%) Vendors (23%)
250-500	Peer Experience & Vendors (21%)	Consultants & Peer Experience (21%)	Consultants & Vendors (23%)
>500	Business Articles (22%) Case Studies, Consultants, & Peer Experience (17%)	Case Studies (21%) Business Articles (18%)	Consultants (21%) Case Studies & Peer Experience (17%)

Table 7: *Resources Used to Learn, Decide, and Implement Smart Technologies by Company Size (n=96)*

ADOPTION JUGGERNAUT

Calumet Electronics, a 55-year-old medium-sized printed circuit board (PCB) manufacturer in Michigan's upper peninsula, has a workforce that is curious, driven, and highly successful in accelerating the depth and breadth of innovation adoption. The company's agile processes and firm-wide engagement in identifying and embracing new technologies have earned it the title of "adoption juggernaut" by the ICAMS team.

At the core of Calumet's success is its employees. Observing them in action was reminiscent of watching a young startup company where everyone has a high level of passion for a shared mission. Despite the participants ranging from operators to senior management and new employees to seasoned veterans, the collaboration was energetic but respectful of each other's opinions.

Calumet tracks all operations issues and needs through Confluence, a corporate wiki that helps employees prioritize issues and match them with potential solutions. Through this process, several smart manufacturing technologies are already in use, including big data, automation, and 3D printing. Others, like artificial intelligence, are on the radar.

Ideas for solutions come from various sources, driven by an intense curiosity to explore different technologies and how they might apply to the company's needs. While employees leverage some traditional sources of information, like trade associations and shows, they often turn to atypical industry sources like Reddit and YouTube for inspiration. Here, they have found videos and channels highlighting hacks and experiments the Calumet team can turn into operational solutions.

Calumet's engineering team listens to ideas from any employee, matches them against the needs recorded in Confluence and assesses how well they address the operation's needs. The decision to move forward is usually based on what will deliver the "biggest bang for the buck." That decision considers the engineering team's hunches along with financial and operational data, accepting some risk in exchange for a greater reward. Not all ideas pan out, and the company is willing to cut its losses and move on quickly.

One example of this coming together is a new automation solution that the employees recently implemented. The old process for moving PCBs to carts for transportation was slow and manually intensive, resulting in quality issues. After researching various options, including paying a vendor for a custom solution, the engineering team decided it could accomplish this on its own for a lot less money and in less time. Fortunately, the team leader had experience in robotics and was able to buy most of the components needed. The team used an in-house 3D printer to make the fixtures and further reduce costs. After assembling and testing the new robotics, Calumet installed the solution and realized significant improvements in speed and quality while reducing manual labor.

Calumet has been so successful in driving adoption that it upended one of our quantitative survey findings. In our survey, most companies reported that vendors or equipment suppliers are often key sources of information and support. While Calumet has sometimes found that to be true, it also has been in the position of educating vendors on equipment capabilities. This stems from the company's drive to use advanced equipment features that other customers haven't yet discovered.

Some lessons from Calumet's success, such as using a central repository of operational issues and potential technologies to prioritize, develop, and track viable solutions, can be repeated easily. Likewise, companies can replicate expanding avenues for innovations and ideas to non-traditional sources.

Where Calumet really shines, and the most challenging element for other companies to copy, is the inventiveness and collaboration of its team. Driven by a combination of leadership that is open to ideas, employees who are passionate about their work, and a culture that accepts some losses but celebrates wins with gusto, Calumet is truly an adoption juggernaut.

ICAMS Demonstration Facility located in Auburn, AL

ANALYSIS

Overview

The findings of this study reveal the current and year-over-year changes in adoption stages of six smart manufacturing technologies. The data also provides further insights into why some adoption stages are further along than others by identifying common business challenges and barriers to adoption. The analysis of the data resulted in three key findings that are expounded below.

Finding #1: **Significant growth in adoption of predictive analytics over previous year.**

The perceived value of predictive analytics jumped considerably, with a 28-percentage point increase over 2022 findings. While the percentage of those evaluating the technology remained nearly the same (24% in 2022 and 23% in 2023), there was an 11-percentage point increase in companies that are implementing predictive analytics. Therefore, we expect to see a rise in manufacturers using predictive analytics in coming years as manufacturers advance from the implementing to the using stage of adoption.

Examining changes in adoption barriers provides clues to some of the reasons why. There was a significant decline from the 2022 study in the lack of awareness and business cases as barriers, which indicates companies are advancing to later adoption stages. However, there was an increase in barriers that impact later adoption stages. The lack of resources and workforce increased 5- and 4-percentage points respectively. This would indicate that companies are trying to move forward but are now running into new obstacles.

When comparing adoption of predictive analytics by company size, adoption stages progressed further as company size increased. One group in particular, 250-500 employees, had a high percentage of respondents in the implementation phase (50%) and zero respondents in the research phase. This is likely in part due to this group comprising only 10% of the responses. However, it is valuable to note that this group is struggling to find resources and the workforce skills to complete the implementation of predictive analytics.

Finding #2: **Later stage adoption barriers present new and more complicated challenges.**

Companies in the later adoption stages of evaluating and implementing rely on peer experience and vendors. While early-stage barriers, like educational materials and case studies, can be quickly generated, peer experience and vendor insights cannot.

The value of peer experience can only be realized when companies have adopted the technologies and when those companies are willing to share the experience. Since early adoption of any technology is often considered a competitive advantage, the information is typically not shared, making peer experience an extremely valuable resource that is hard to come by.

Vendors, on the other hand, are usually anxious to provide information to accelerate adoption as it results in greater sales. The challenge is that many new technologies rely on a small number of vendors with limited experience, especially industry-centric insights. In one case, a subject reported that they are educating the vendors on features and capabilities that the vendor's other customers do not use or have not discovered. Many of these vendors are focused on technology implementation on a company-to-company basis, which does not allow for the thorough capture and documentation of the implementation process and its resulting benefits.

Finding #3: **Workforce challenges are only getting worse.**

Last year's report identified that insufficient workforce and the lack of advanced workforce skillsets were key barriers to adoption of all technologies. The results for this year worsened for nearly all smart manufacturing technologies, with the lack of workforce again considered a greater impediment than workforce skill sets. Some of the workforce challenge is exacerbated as companies move into the later stages of technology adoption when labor becomes a greater issue.

One of the greatest needs for additional workforce is in 3D printing, with a 7-percentage point increase over last year's responses and a 3-percentage point increase in the lack of skill sets. Similarly, predictive analytics barriers saw a 5-percentage point increase in the lack of workforce availability but just a 2-percentage point increase in the need for new workforce skill sets. While these numbers are similar, they represent a more significant hurdle for those seeking to leverage 3D printing as that technology is the most widely adopted.

The speed at which the country's manufacturers are adopting 3D printing (an increase of 10-percentage points in one year of those using the technology) will continue to consume the already limited workforce. Companies seeking to catch up to competitors or create new offerings with 3D

printing will increasingly struggle unless they are able to offer far more attractive compensation or there is suddenly an influx of new workforce.

RECOMMENDATIONS

Government

This study provides the government with a blueprint of the support that could best accelerate nationwide adoption of each smart manufacturing technology. This presents an opportunity to leverage national organizations, like the Manufacturing Extension Partnership (MEP) or recently announced DoC Technology Hubs, to provide the resources needed to lower adoption barriers for each technology.

Education materials, case studies and other adoption resources along with the communications and deployment programs should be developed at the national level and distributed to the other organizations. That will help ensure greater efficiency and efficacy.

Industry

As revealed in this study, case studies and peer experience are valuable resources that manufacturers use throughout their technology adoption processes. With peer experience being crucial to learning, deciding, and implementing technologies, industry should encourage and increase opportunities for manufacturer collaboration. This will help constituents better understand what the technologies are and how they can be implemented.

Large manufacturers have the opportunity to make a large impact on technology adoption with their extensive supply chains. They can and should assist their lower-tier suppliers in technology adoption to reap benefits across the supply chain and boost SMM technology adoption.

Industry associations should aggregate and disseminate information about government-led smart manufacturing programs and act as advocates for new programs and funding. This will increase the availability and applicability of resources for manufactures of all sizes to access.

Academia

Academia serves a unique role in the adoption of smart manufacturing technologies as a trusted and neutral third party. Academics can identify the technology resources that are currently available for industry and identify gaps that need to be filled. Part of this effort should be writing, publishing, and disseminating case studies that showcase technology adoption success stories. These stories should paint a picture of how barriers were overcome in each adoption stage: awareness, researching, evaluating, implementing, and using.

Academia can also assist industry in developing low-cost technology solution alternatives for SMMs who typically do not have the same level of capital or workforce to invest in new technology development and implementation as large manufacturers. This also includes researching ways to automate the interface between systems, therefore eliminating the requirement to have a skilled worker acting as a non-value-added entity simply transferring data from one system format to another.

Government, Industry, and Academia

As suggested in the 2022 study, government, industry, and academic can combine their efforts to develop a roadmap of smart manufacturing technologies and an effective sequence in which they should be adopted for success. This should include metrics that help a company measure its progress against the roadmap.

These entities should also create and promote educational programs that are targeted at the specific skills sets that are needed by industry. For example, this study revealed a need for engineers and machine operators. Educational programs geared to specific skill sets are more likely to appeal to workers than are broad, time-consuming programs. Government, industry, and academia can also join forces to incentivize workers to participate in educational programs through scholarships and certificates recognizing the mastery of a skill.

ACKNOWLEDGMENTS

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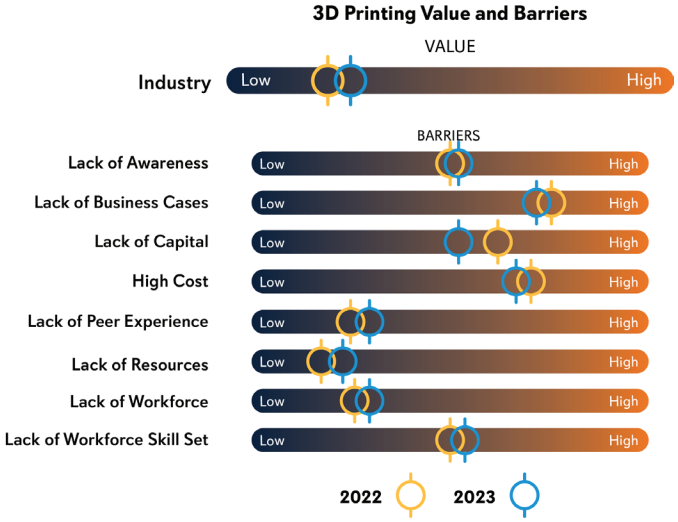
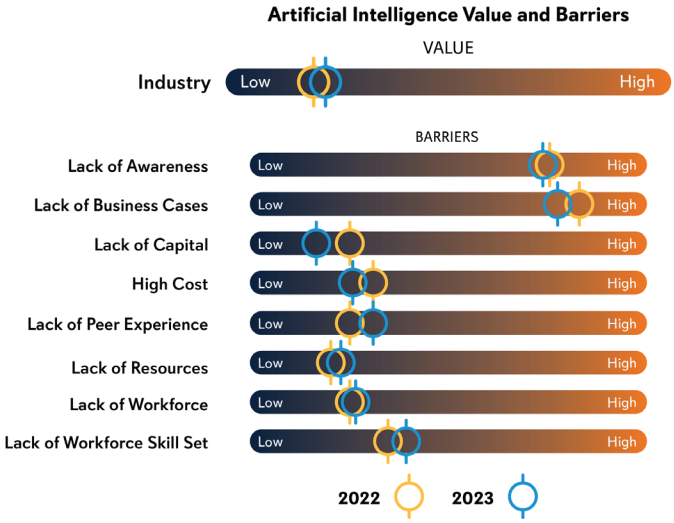
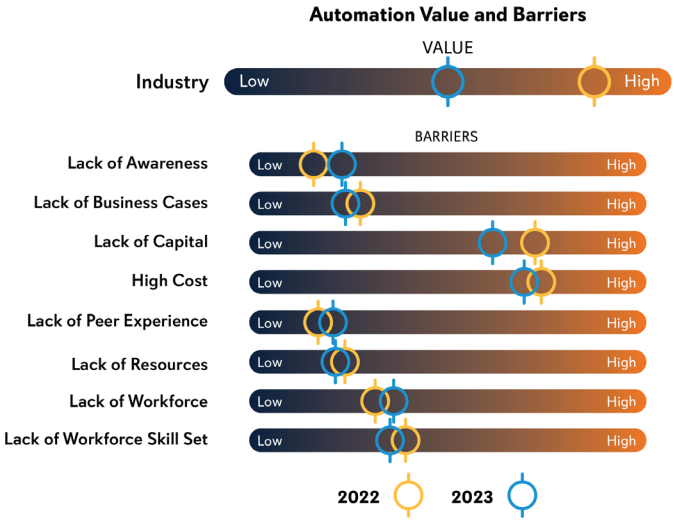
- America Makes
- IPC International, Inc. (world-wide electronics association and standards body)
- Manufacturing x Digital Institute (MxD the Digital Manufacturing Institute)
- National Defense Industrial Association (NDIA)
- Society of Manufacturing Engineers (SME)

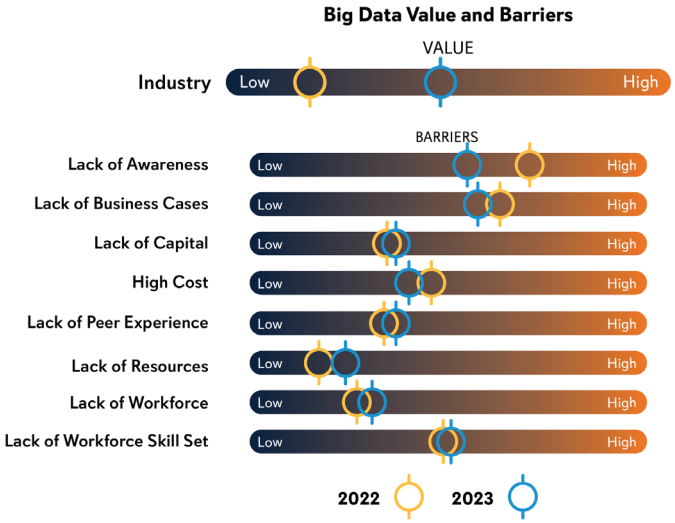
APPENDIX A – Technology Adoption Value and Barriers

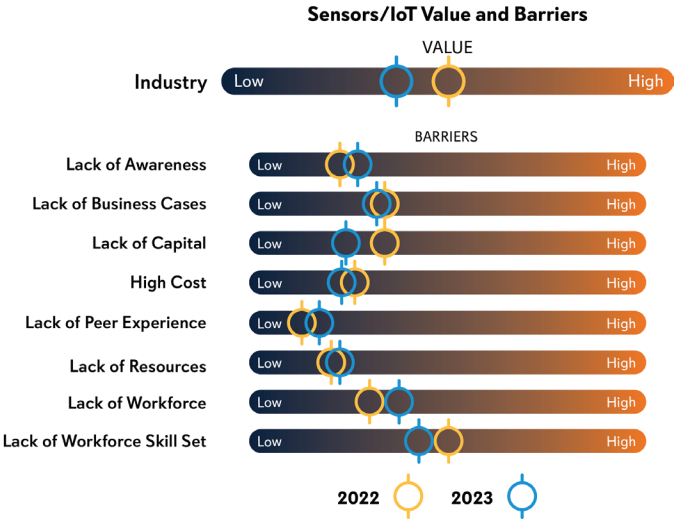
The following graphs compare the perceived value of a technology with its adoption barriers. A high value means manufacturers believe the technology could solve their business challenges. On the other hand, low barriers are favorable, meaning there are few impediments to adopting the technology. Smart manufacturing adoption aims to increase the perceived value and decrease the barriers to adoption.

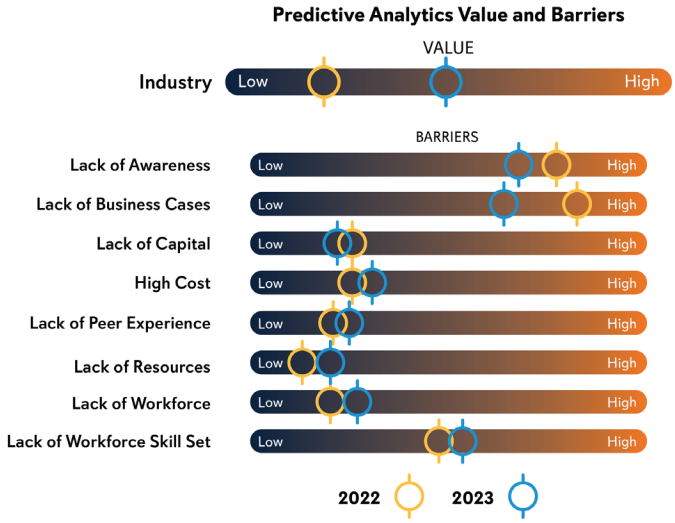






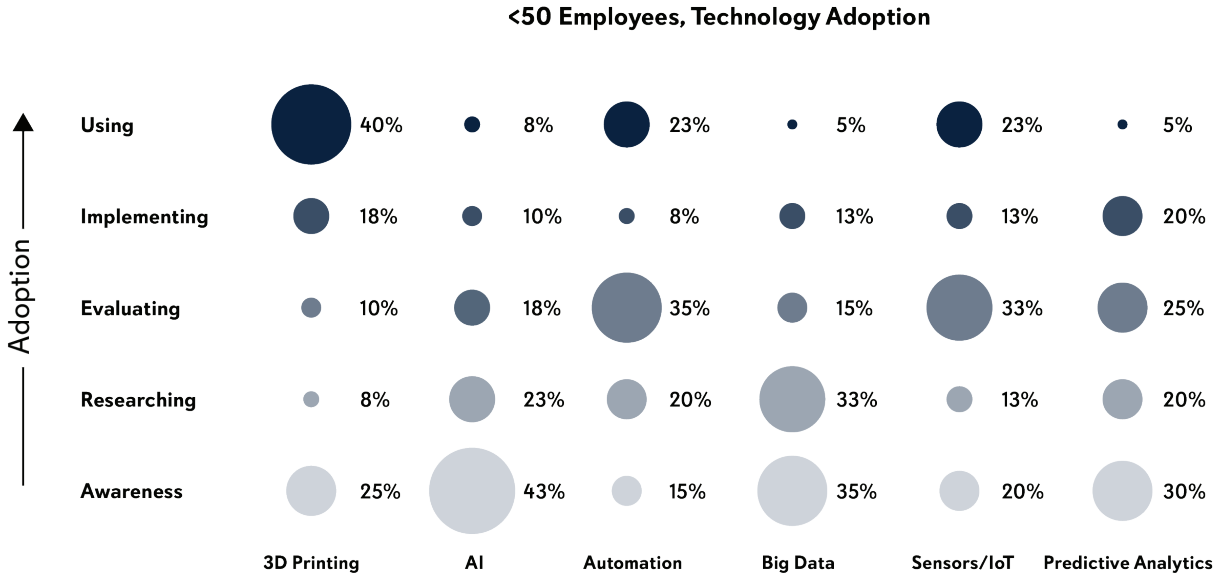

Big Data Value and Barriers
VALUE
Industry
Low
High
BARRIERS
Lack of Awareness
Lack of Business Cases
Lack of Capital
High Cost
Lack of Peer Experience
Lack of Resources
Lack of Workforce
Lack of Workforce Skill Set
2022
2023

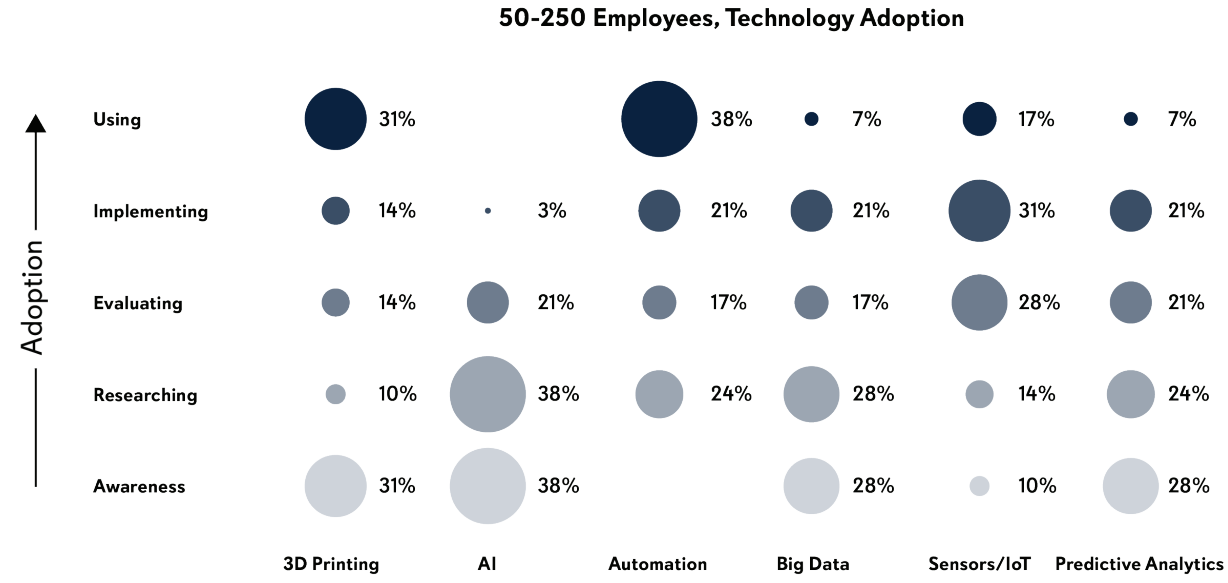

Sensors/IoT Value and Barriers
VALUE
Industry
Low
High
BARRIERS
Lack of Awareness
Lack of Business Cases
Lack of Capital
High Cost
Lack of Peer Experience
Lack of Resources
Lack of Workforce
Lack of Workforce Skill Set
2022
2023

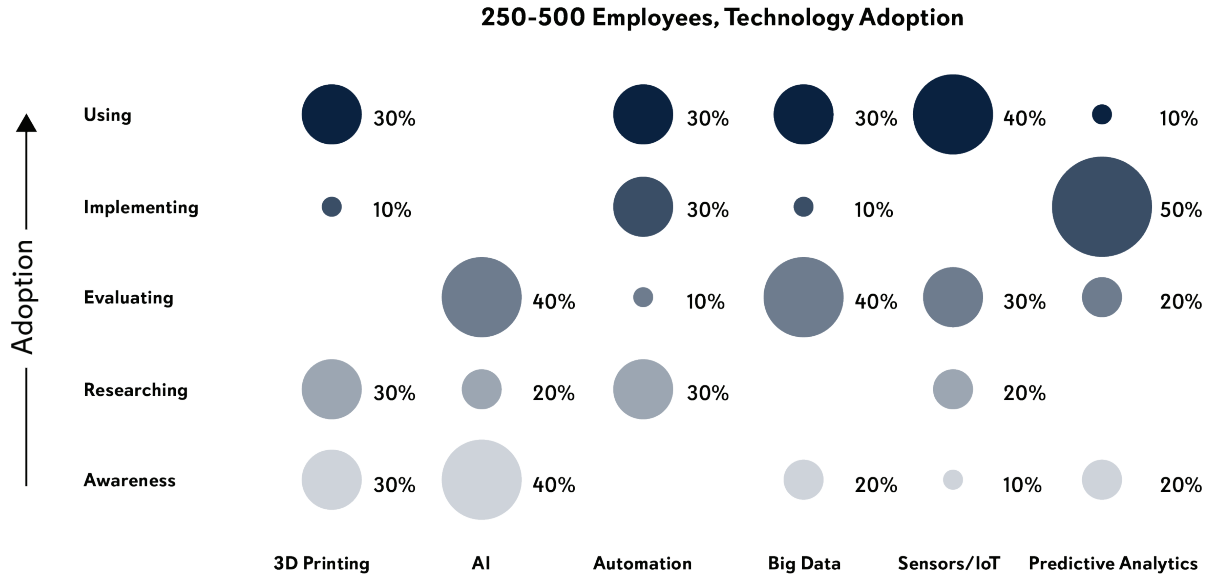

Predictive Analytics Value and Barriers
VALUE
Industry
Low
High
BARRIERS
Lack of Awareness
Lack of Business Cases
Lack of Capital
High Cost
Lack of Peer Experience
Lack of Resources
Lack of Workforce
Lack of Workforce Skill Set
2022
2023

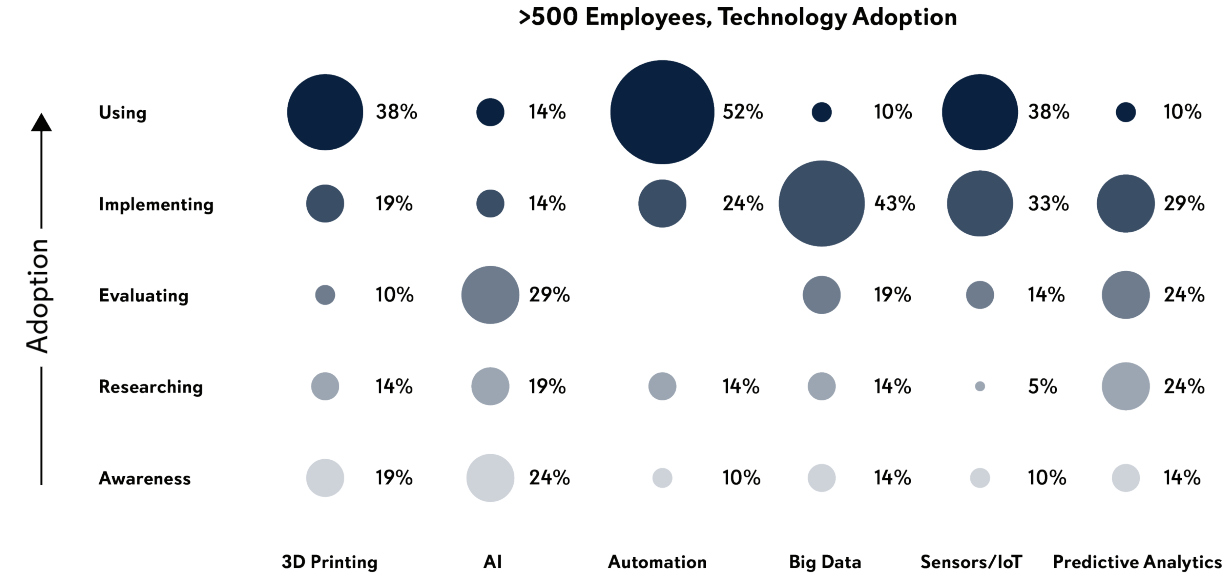
APPENDIX B – Adoption Comparison by Company Size

The following graphs are grouped by technology. The graphs compare the adoption stages of the six smart manufacturing technologies by company size.



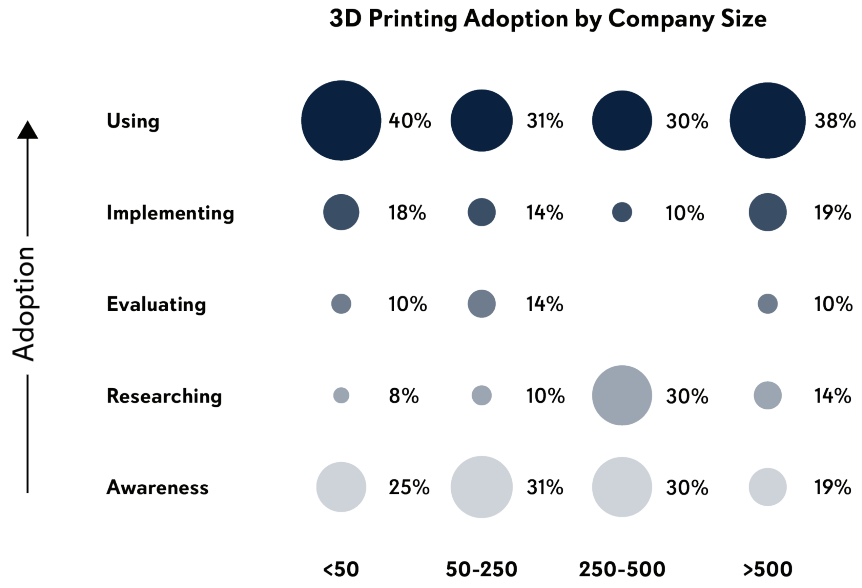


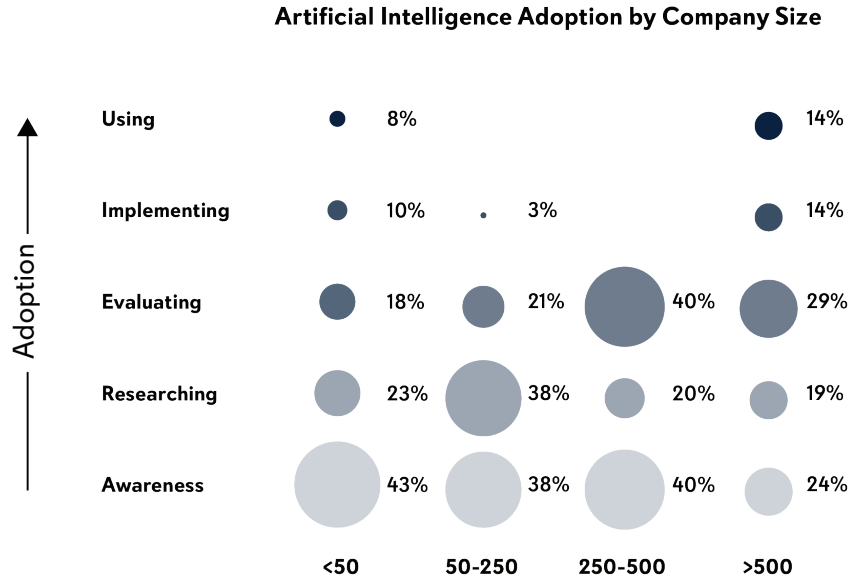

250-500 Employees, Technology Adoption
Adoption
Using
Implementing
Evaluating
Researching
Awareness
30%
10%
40%
30%
30%
30%
30%
10%
40%
20%
30%
20%
40%
30%
10%
40%
20%
50%
20%
10%
20%
3D Printing
AI
Automation
Big Data
Sensors/IoT
Predictive Analytics

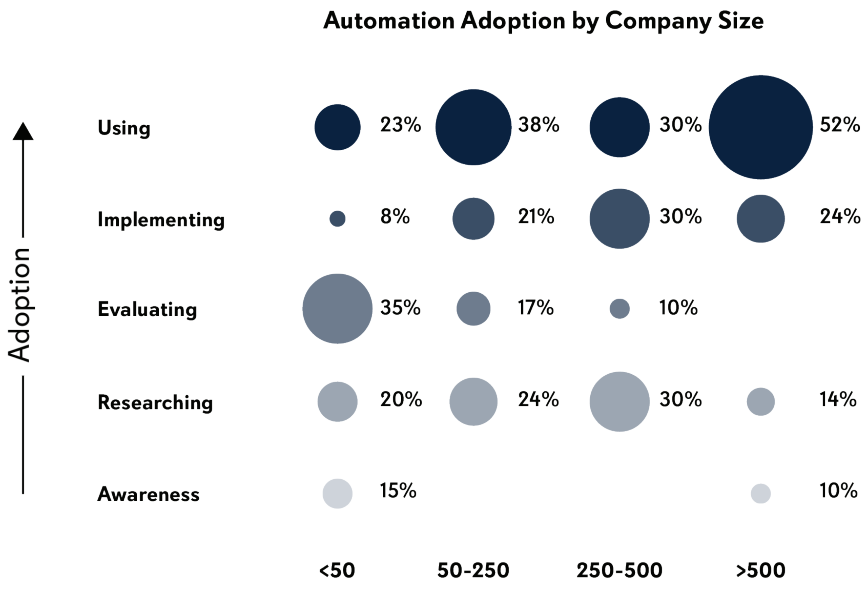

>500 Employees, Technology Adoption
Adoption
Using
Implementing
Evaluating
Researching
Awareness
38%
19%
10%
14%
19%
14%
14%
29%
19%
24%
52%
24%
14%
10%
10%
43%
19%
14%
14%
38%
33%
14%
5%
10%
10%
29%
24%
24%
14%
3D Printing
AI
Automation
Big Data
Sensors/IoT
Predictive Analytics

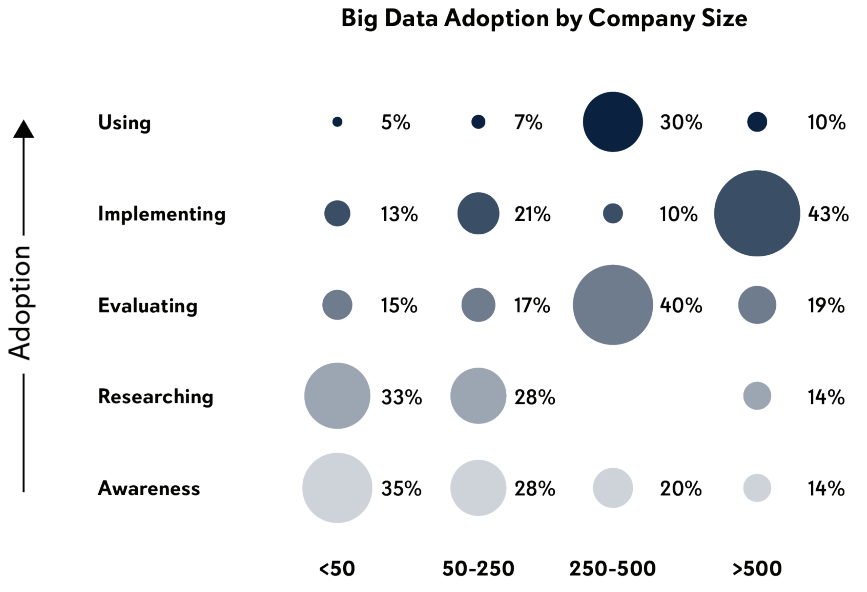
APPENDIX C – Adoption Comparison by Technology

The following graphs are grouped by company size. The graphs compare the adoption stages of the six smart manufacturing technologies by each technology. Manufacturers can use these graphs to compare their technology adoption with those of similar company size.

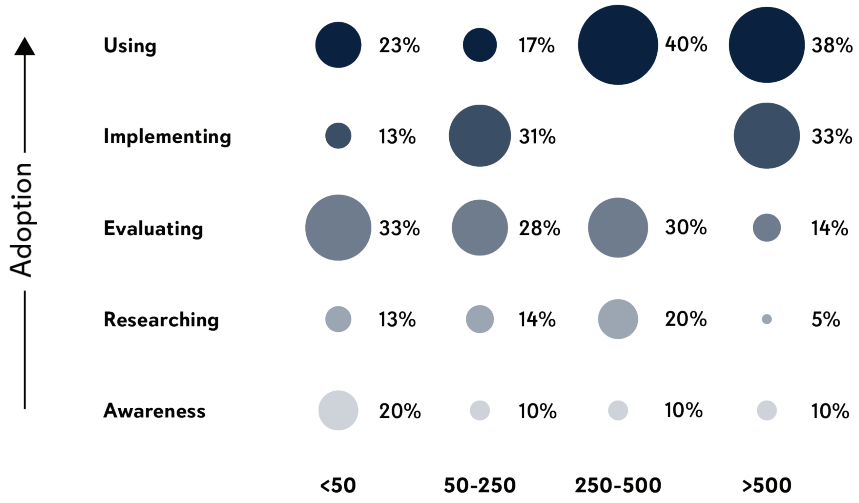




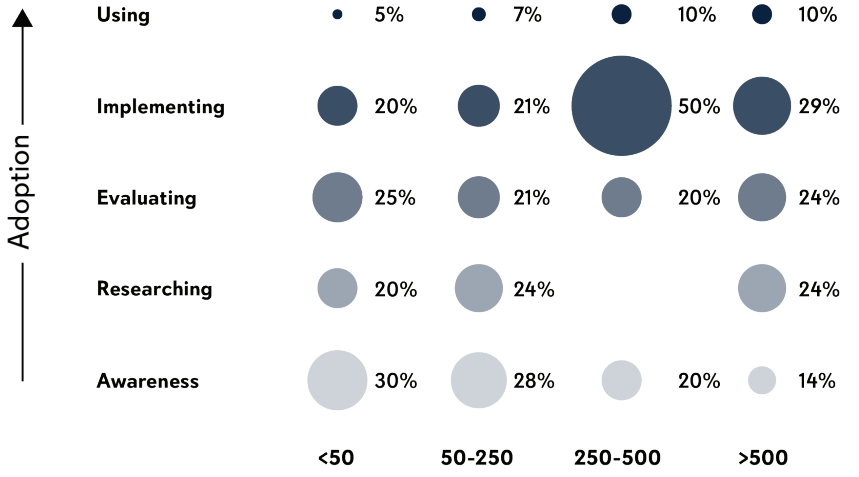

Automation Adoption by Company Size
Adoption
Using
Implementing
Evaluating
Researching
Awareness
23%
38%
30%
52%
8%
21%
30%
24%
35%
17%
10%
20%
24%
30%
14%
15%
10%
<50
50-250
250-500
>500


Big Data Adoption by Company Size
Adoption
Using
Implementing
Evaluating
Researching
Awareness
5%
7%
30%
10%
13%
21%
10%
43%
15%
17%
40%
19%
33%
28%
14%
35%
28%
20%
14%
<50
50-250
250-500
>500

Sensors/IoT Adoption by Company Size



Predictive Analytics Adoption by Company Size



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