CONEXUS INDIANA

IUPUI KELLEY SCHOOL OF BUSINESS

A Glimpse into Indiana's Factory of the Future:

Companies Scale-up Industry 4.0 Technology Investments to Enhance Efficiency and Optimize Productivity

2022 Industry 4.0 Technology Adoption Report

Introduction

The importance of Indiana's advanced manufacturing and logistics industries (AML) should come as no surprise. The advanced manufacturing industry alone employs 520,000 Hoosiers and contributes more than 26% of the state's gross product, accounting for $100 billion of Indiana's economy in 2019. With more than 9,300 companies, manufacturing accounts for approximately 1 in 5 private jobs in Indiana.[1] Indiana's logistics sector serves the manufacturing base and moves more than $650 billion in goods each year. Logistics is an impactful industry in its own right, enabling Indiana to claim the "Crossroads of America" moniker.

AML drives Indiana's economy, providing Hoosiers with career-spanning opportunities that offer upward mobility. The state is a major part of the global economy; innovating, making and moving products that save and transform lives. It's not hyperbole to say that the world depends on contributions from Indiana's AML companies to keep a robust global economy in motion. The good news is that Indiana has successfully navigated the first three industrial revolutions and is progressing well into the fourth, known as Industry 4.0. Capturing the full benefit of Industry 4.0 is now the target for many organizations.

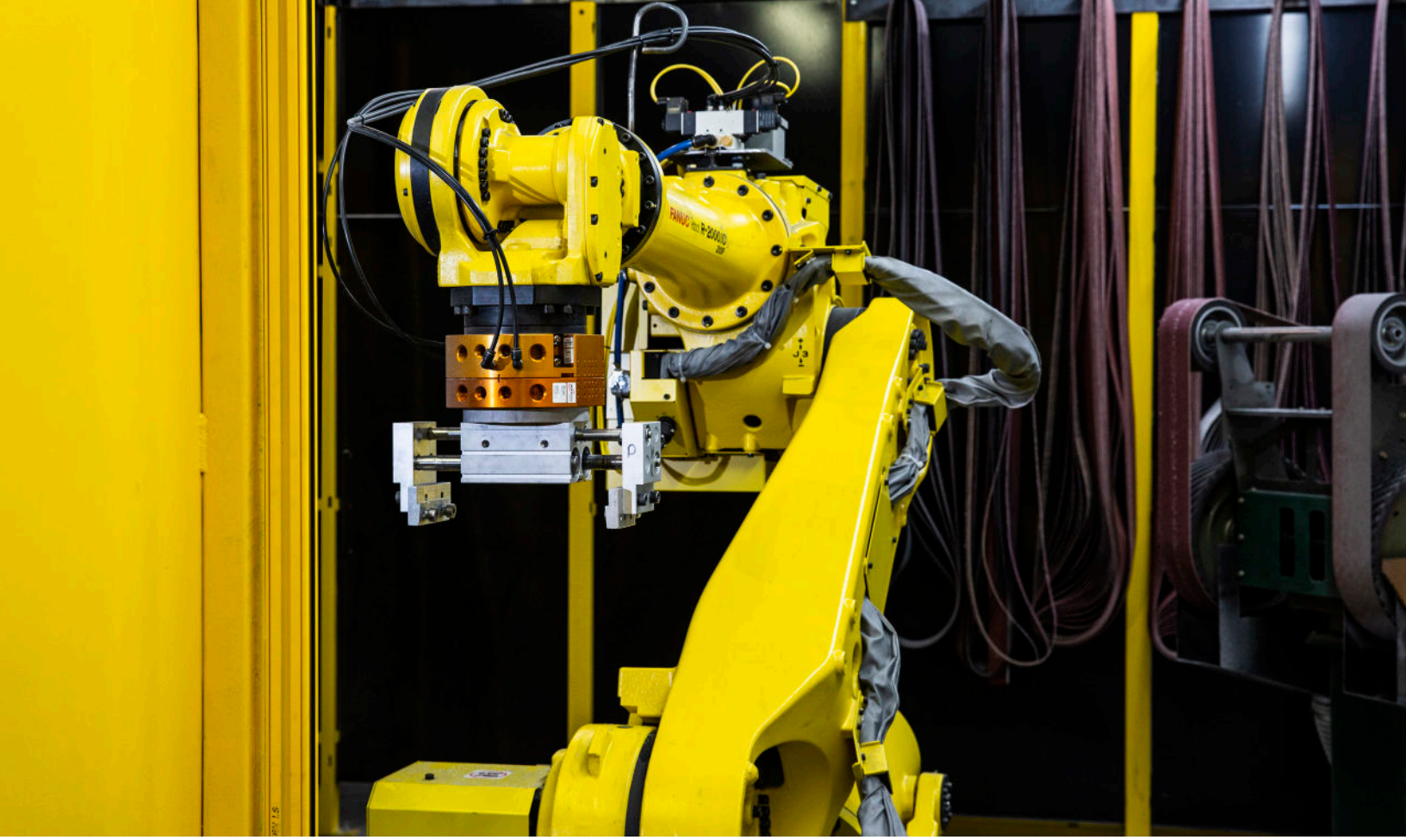
Marked by the use of smart technologies and data-driven insights to increase competitiveness, productivity and profitability, Industry 4.0 awareness is well established in 2022. A growing number of companies are strategically deploying technologies, and even companies early in their journey are designating leaders or project teams to research and prepare for what is next. Only a handful of companies anticipate no foreseeable technology adoption.

Industry 4.0: The Intersection of Manufacturing and Digital Transformation

Tracing the impact of the industrial revolutions that preceded it demonstrates the urgency to invest in Industry 4.0 technologies. Beginning in the late 1780s, the first industrial revolution brought water and steam power to production. The success of those technologies and the discovery of electricity drove Industry 2.0 and the development of sophisticated machines to improve mass production. The early stages of automation, the Internet and computers defined Industry 3.0. Those eras enabled Indiana's AML sectors to continuously reinvent themselves, forming the basis of today's digital transformation known as the Fourth Industrial Revolution (Industry 4.0).

Industry 4.0 is sometimes referred to as Smart Manufacturing. It further integrates digital technologies such as the Internet of Things (IoT), cloud computing and analytics, and artificial intelligence (AI) and machine learning (ML) into company-wide operations and manufacturing processes. Outcomes of Smart Manufacturing are increased production and flexibility/agility, real-time visibility into equipment performance and responsiveness to customer demand. Smart Manufacturing also leverages data to a significant degree for predictive maintenance, self-optimization of process improvements and increased production efficiencies. In short, companies aligned with Industry 4.0 are highly connected, digitized, agile and more autonomous than those entrenched in Industry 3.0.

[1] "The State of Indiana's Advanced Manufacturing Workforce," Conexus Indiana, 2022 Indiana, 2022. (https://www.conexusindiana.com/2022/07/state-of-indianas-advanced-manufacturing-workforce/). Accessed 7/20/2022.



Batesville Products Inc. (BPI), Lawrenceburg, Indiana

In this third installment of an annual study into Industry 4.0 technology adoption, Conexus Indiana again partnered with Indiana University's Kelley School of Business Center for Excellence in Manufacturing. As with previous studies, this year's report shows Indiana's progress along the technology adoption curve and provides insights into several digital interventions supporting adoption statewide, including Indiana's Manufacturing Readiness Grants program, Energy INsights and AnalytiXIN.

Indiana's manufacturing intensity, coupled with its significant focus on increasing the pace of technology adoption, puts the state as a whole on a path toward being a Factory of the Future[2]– one where ongoing efforts are surfacing notable trends in additive manufacturing, machine vision, cobots, cybersecurity and analytics. Companies moving forward with widespread adoption appear to develop a competitive edge through increased efficiency, agility and productivity. Sustaining this trajectory over the next five years will have automation and humans working side-by-side in collaborative fashion with companies striving to attract a highly skilled workforce marked by systems-thinking, troubleshooting and programming mindsets. This progress is occurring even during a confluence of inflation, labor shortages, the COVID-19 pandemic and supply chain disruptions. The march toward this digital manufacturing revolution by Indiana companies is not despite these challenges; it's a way to cope and put them in the rearview mirror.

[2] "The Factory of the Future." Daniel Küpper, Kristian Kuhlmann, Sebastian Köcher, Thomas Dauner, and Peter Burggraaff. Boston Consulting Group, December 6, 2016. (https://www.bcg.com/publications/2016/leaning-manufacturing-operations-factory-of-future). Accessed 8/8/2022.

2022 Key Findings

1. Indiana manufacturers are prioritizing Industry 4.0 technology adoption despite rising costs, labor shortages and supply chain disruptions.

- Implementations and pilot projects of Industry 4.0 technologies increased year-over-year by 35%.
- One in 3 companies now perceive Industry 4.0 as a positive investment for growth.
- Only 4% of companies reported no foreseeable adoption of these technologies, a 69% decrease year-over-year.

2. More companies are dedicating resources by allocating capital and appointing leaders or teams to advance their Industry 4.0 agendas.

- The number of companies with both budgets for technology adoption and strategic roadmaps rose by 13% year-over-year.
- One in 2 companies reported having a dedicated Industry 4.0 team or leader, and of those companies, 95% said their Industry 4.0 leader or team is empowered, accountable and resourced.

3. Companies are implementing technologies that offer manufacturing flexibility, quality improvements, product innovation and a collaborative mix between labor and automation.

- Among Indiana's Industry 4.0 technology adopters (those that have implemented one or more technologies), additive manufacturing (39%), cybersecurity (29%), machine vision (29%), advanced modeling (27%), big data and analytics (26%) and cobots (25%) are the most frequently deployed.

4. Indiana's Factory of the Future will be connected, efficient, agile and secure.

- Cobots, cybersecurity, sensor technologies and Internet of Things (IoT) are expected to be adopted by nearly half of manufacturing and logistics companies in the next five years.
- This mix of technologies showcases a growing desire for production flexibility (cobots), protection from cyber threats and data leaks (cybersecurity) and cost reduction (sensor technologies and IoT) through predictive maintenance, overall equipment effectiveness (OEE) and other Key Performance Indicators (KPIs).

5. ‘Budget restrictions’ remains the top obstacle for progress during the Fourth Industrial Revolution.

- For the third year in a row, nearly 3 in 4 (71%) companies reported budget restrictions as either a primary or secondary obstacle hindering Industry 4.0 tech adoption.
- Despite the budget challenge, companies recognize the benefits of Industry 4.0 and are moving forward with a wide array of technology projects, sometimes driven by a technology adoption roadmap.

6. Rather than eliminating jobs, automation is reorienting the workforce away from monotonous, routine tasks that can be limiting factors for production and toward opportunities for systems-thinking, troubleshooting and programming.

- As in the prior years’ studies, the top motivators for automation remain efficiency and lowering costs (86%), improving quality (78%) and increased production speed (68%).
- Labor-related motivations focus on minimizing monotonous/repetitive human tasks (61%) and shifting the workforce to higher-value functions (52%) rather than eliminating positions or reducing payroll (12%).

7. Companies are leaning on Industry 4.0 technologies to drive efficiency and optimize productivity.

- Efficiency (cost reduction) soared up the list of primary strategic business objectives, increasing by 49% year-over-year, and optimizing productivity remained a top objective (58%).
- As more than 70,000 jobs remain unfilled, Indiana’s manufacturers are leveraging technology to digitize operations and processes (53%) and implement production automation (47%) to increase capacity while reducing operating costs.

Study Methodology and Demographics

Conexus Indiana gathered input from nearly 200 manufacturers. The sample had notable consistency with prior years in terms of demographics and sector mix of survey respondents. Participants in the 2022 survey were from a wide cross-section of Indiana's manufacturing ecosystem, touching nearly 2 dozen sectors as highlighted in **Figure 1**.

Small, medium and large enterprises—based on both revenue and employment—all were well-represented. More than three-quarters were from mature organizations with operational track records of 25 years or greater. Many of those businesses are small-to-medium enterprises (SME), which represent the highest number of Indiana's manufacturers. Hence, 60% of respondents reported revenues of $0-$49 million and 46% reported 0-99 employees (**Figures 2, 3 and 4**).

The most represented sectors include automotive, fabricated metal products, industrial equipment and aerospace and defense. Tool and die makers, construction and transportation were added as new categories in 2022 to better represent the diversity of Indiana's manufacturing economy; they made up a combined 30% of the survey population, with almost half of those identifying as tool and die makers. Nearly 1 in 10 respondents identified as providers of precision metal parts, tools and jigs used in the production of other products. This reflects Indiana's rich history as a supplier of component parts and subassemblies to many other manufacturers.

Slightly more 'start-up' manufacturers participated in this year's survey. While only 3% of participants in the 2020 and 2021 studies were companies in operation for less than 5 years, that number tripled to 9% in 2022. Correspondingly, the number of companies in the 6- to 25-year category decreased from 23% in 2021 to 13% in 2022.

Figure 1 **Industry Sector Mix**

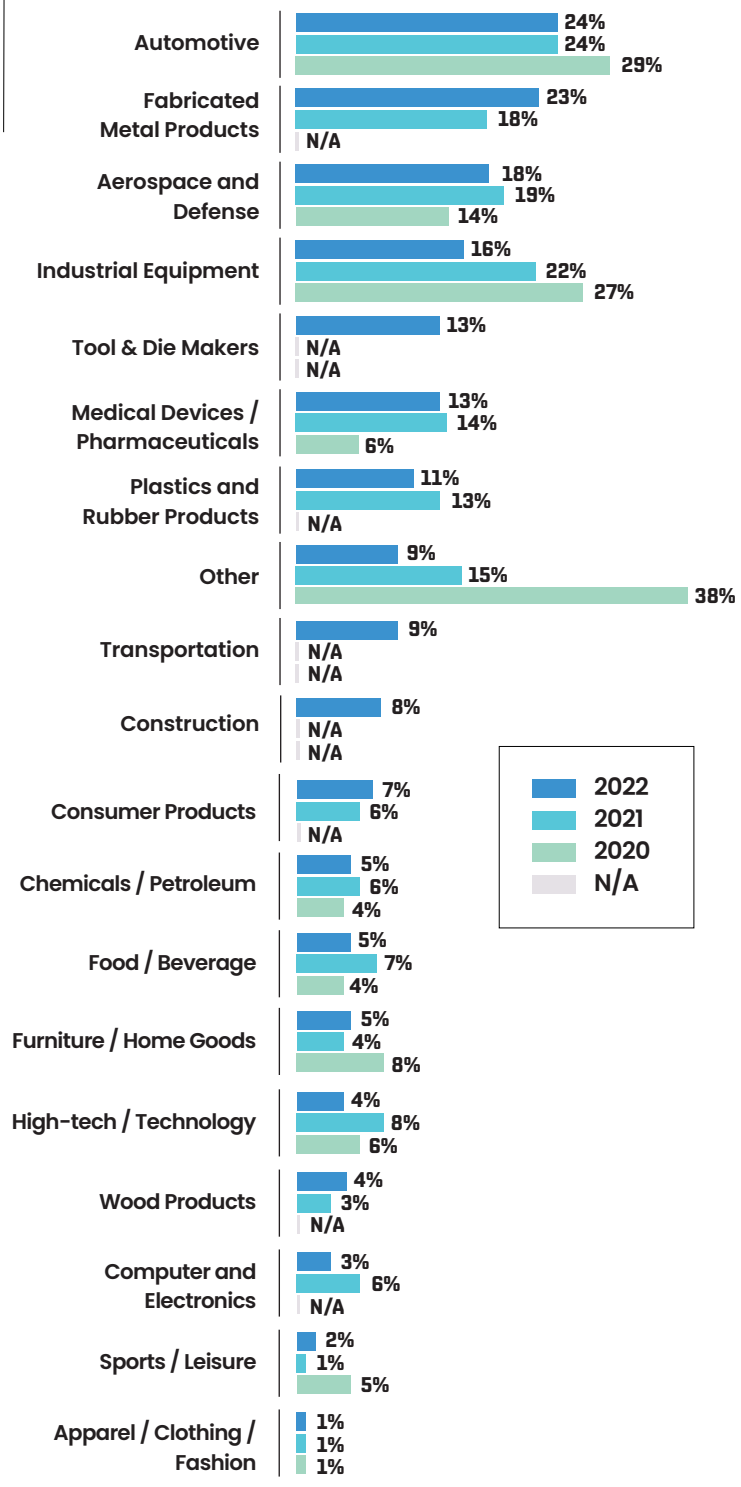


Figure 2 **Size by Revenue**

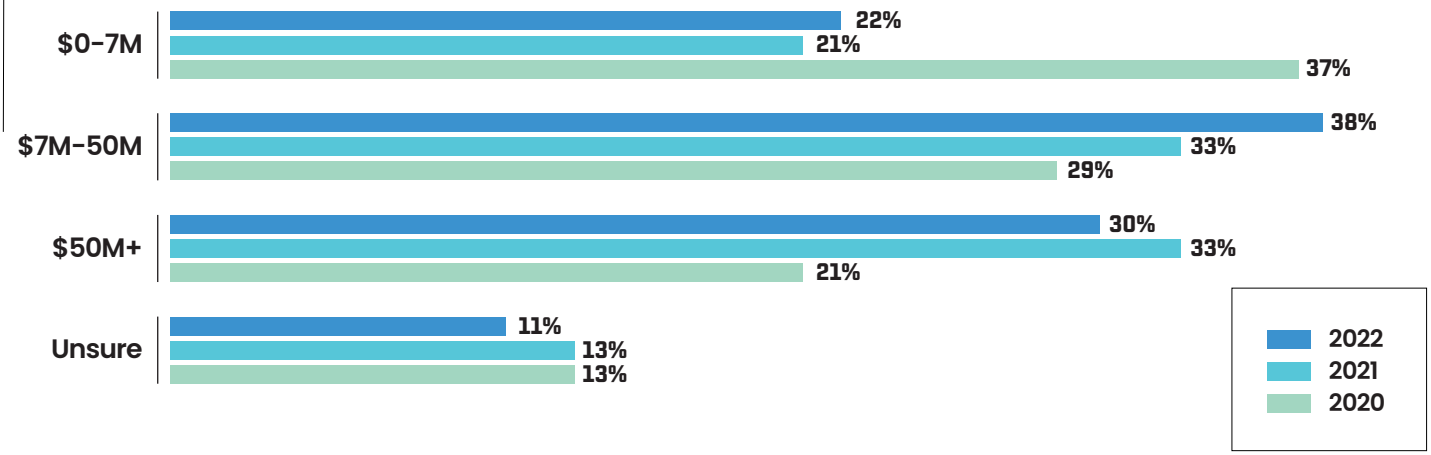


Figure 3 **Size by Employees**

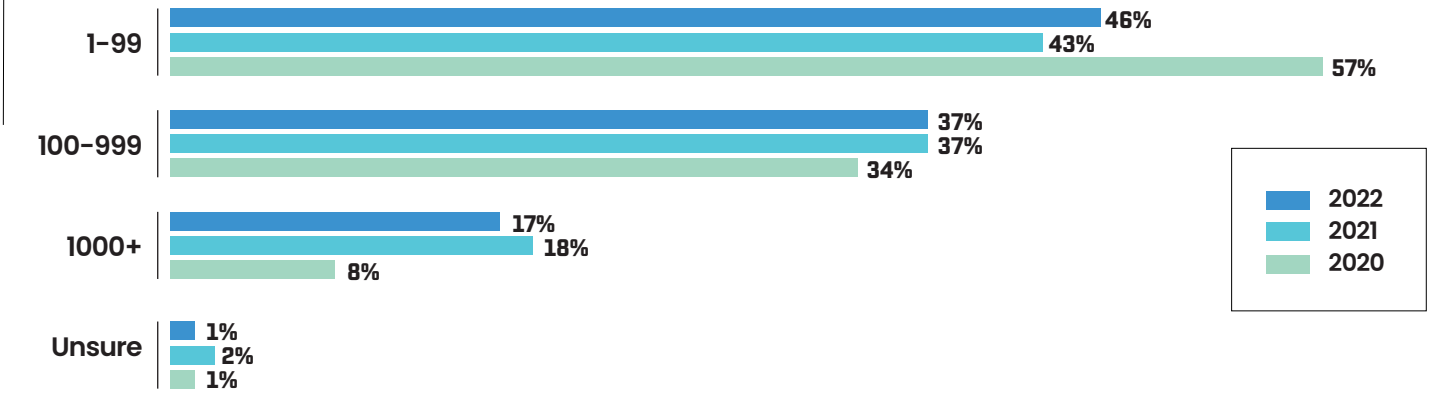
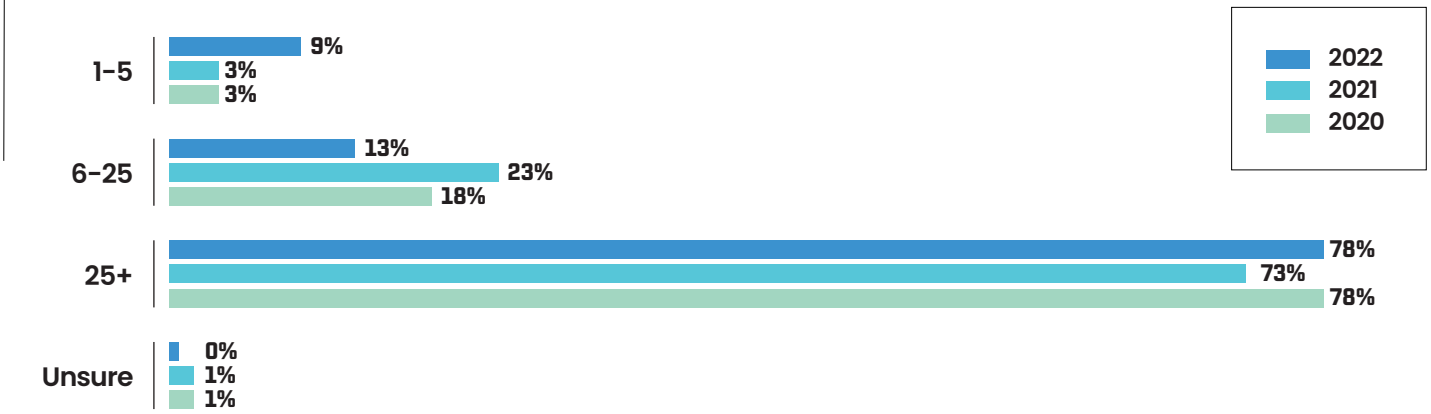


Figure 4 **Company Age**



Technology Adoption Budgets, Roadmaps and Leadership See Uptick Despite Macro-Economic Pressures

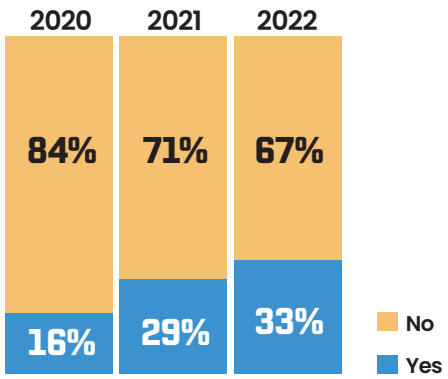
Despite a turbulent business environment in the past couple years, marked by inflation, labor shortages, the pandemic and supply chain disruptions, Indiana companies have steadily marched forward in the Fourth Industrial Revolution. The 2022 data shows continuing growth in the number of Hoosier companies budgeting for technology investments, developing strategic roadmaps to guide decision-making and assigning leaders or teams to execute projects.

Budgets and Revenue Allocation

One-third of respondents (33%) reported having a technology adoption budget—up from 29% in 2021. (Figure 5). And it's clear that more manufacturers recognize the need to leverage technology to scale-up capabilities in 2022 with 47% of companies earmarking 1-5% of annual revenue toward their technology adoption budget.

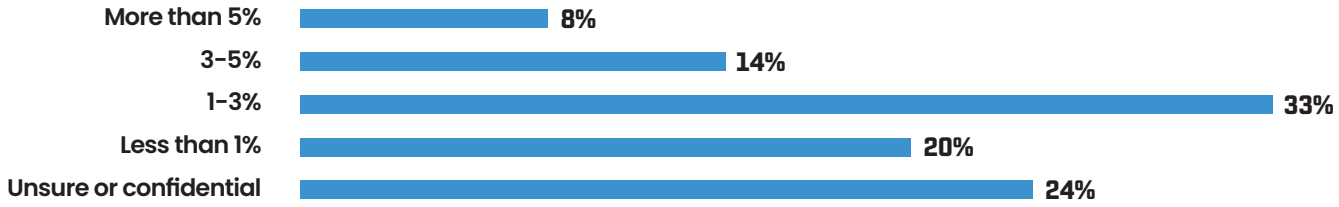
Another 8% reported an even more aggressive approach to adoption, allocating more than 5% to their Industry 4.0 strategy.

Figure 5 **Companies with a Tech Adoption Budget**



As technologies mature, it will be interesting to track revenue allocation in the coming years for the more aggressive manufacturers (i.e., those that budget more than 5% of revenues) versus today's typical 1-5% expenditure category to see if the pace of Industry 4.0 investments remains constant or accelerates (Figure 6).

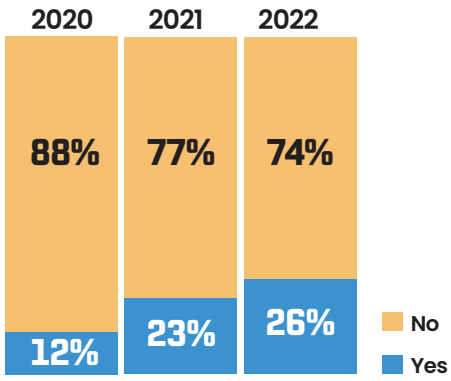
Figure 6 **Revenue Allocation to Tech Adoption Budget**



Strategic Roadmaps

The number of Indiana manufacturers that have developed a strategic roadmap for technology adoption increased year-over-year yet again. Twenty-six percent of companies now have a documented vision for how technology can address identified pain points and align synergies between departments (Figure 7). Most of these companies (53%; Figure 8) are developing their roadmap in-house, suggesting that technology adoption is often an important part of broader strategic planning rather than an isolated exercise which might otherwise be outsourced. In 2022, slightly more companies leveraged resources from a parent or affiliate company. One possibility behind this movement (14% in 2022; 3% in 2021) is larger companies are more likely than their smaller counterparts to have budgets, roadmaps and dedicated personnel for Industry 4.0 technology adoption. Thus, larger companies may be encouraging their supply chain partners to 'do something Industry 4.0-related,' or corporate level champions might be similarly messaging their smaller divisions to act aggressively. Approximately the same percentage of companies as last year (22%) leveraged a third party to help develop their Industry 4.0 roadmap, which suggests that these companies continue to gain value from their partnerships with academic institutions or external consultants.

Figure 7 Companies with a Strategic Roadmap



Adopting technologies without a strategic roadmap (Figure 7) remains pervasive (74%). Of that group, half (50%) are still using an ad-hoc, case-by-case approach as new opportunities and appropriate use cases arise (Figure 9). Another quarter (24%) are integrating adjacent functions, possibly to align company-wide goals like customer service, product quality or efficiency. However, the biggest net-change in 2022 is for the category "we are not adopting Industry 4.0 technologies." That category fell from 22% in 2021 to only 9% in 2022. This year's results indicate that companies making no plans are truly in a dwindling minority.

Figure 8 Strategic Roadmap Development

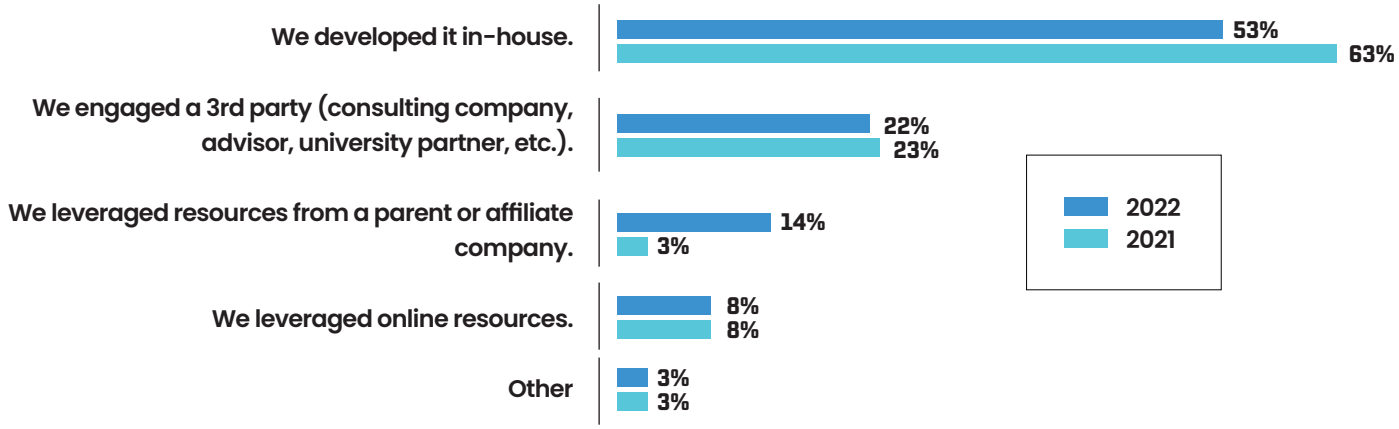
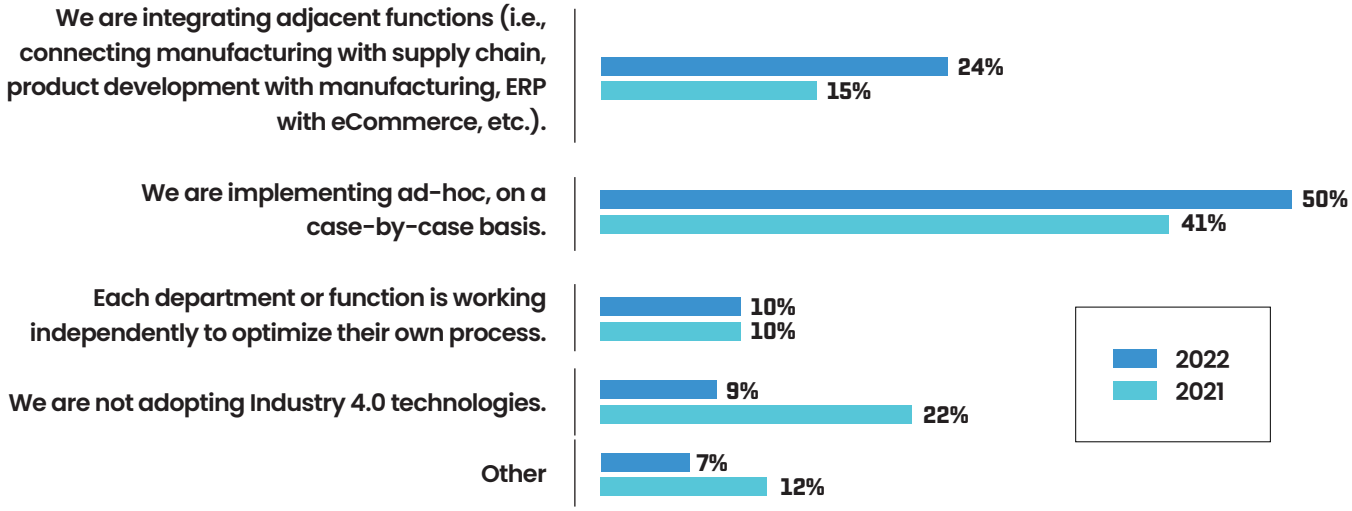


Figure 9 **Technology Adoption Approach Without a Roadmap**

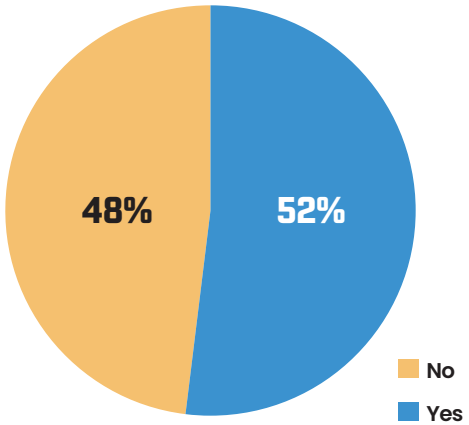


Technology Adoption Leadership

This year's survey asked for the first time whether Indiana manufacturers have a designated Industry 4.0 leader or team responsible for executing overall strategy (**Figure 10**). A majority (52%) reported that they do, and surprisingly, 95% of those respondents said their Industry 4.0 leader or team is empowered, accountable and has resources available. Companies seem to recognize and appreciate that to be successful in the Fourth Industrial Revolution, an individual or team needs to be put in charge with substantial resources. Only a decade ago, positions with "Innovation" or "Technology Adoption" in the job title often lacked authority to perform their responsibilities effectively or enact meaningful organizational change. Times are clearly changing for the better in this regard.

Manufacturers also clearly realize that effective execution of a technology adoption project goes beyond oversight from executive management and stretches into manufacturing operations and engineering services. When companies with a designated leader or team were asked to identify the department in which their individual or team works, 39% indicated executive management, but slightly more (44%) said manufacturing or engineering services. While an experienced leader will always be needed to rally the workforce around a unified vision, empowering the workforce (especially those of younger generations on the shop floor) to recommend possible technology solutions/ use cases and participate in decisions about technology vendors or automation providers further increases the likelihood of successful implementation.

Figure 10 **Companies with a Dedicated Industry 4.0 Leader or Team**



Industry 4.0 Now Seen and Understood as a Positive Investment for Growth

Last year's study showed that Hoosier companies were well on their way into the Fourth Industrial Revolution. This year, it's clear the trend is accelerating. Companies' perceptions of Industry 4.0 technology adoption point in one direction: Industry 4.0 is a positive investment for growth—increasing by 41% year-over-year (**Figure 11**).

The level of interest in Industry 4.0 technology adoption also increased: 58% of companies in 2022 have successfully implemented or piloted an Industry 4.0 technology—up from 43% in 2021 and 21% in 2020. The number of companies that indicated no foreseeable adoption of Industry 4.0 technology has virtually collapsed to just 4% (down from 31% in 2020 and 13% last year; **Figure 12**).

Still, more than one-third (37%) of manufacturers continue to research and plan for what's next—perhaps preparing for their first pilot project or developing a strategic roadmap (**Figure 12**). And not one survey respondent reports apprehension about job losses resulting from technology, even considering the COVID-19 pandemic, supply chain disruptions and rising costs (**Figure 11**). In fact, it's more likely that companies view Industry 4.0 as a mitigation strategy for some of those challenges.

Figure 11 **Company Perceptions of Industry 4.0**

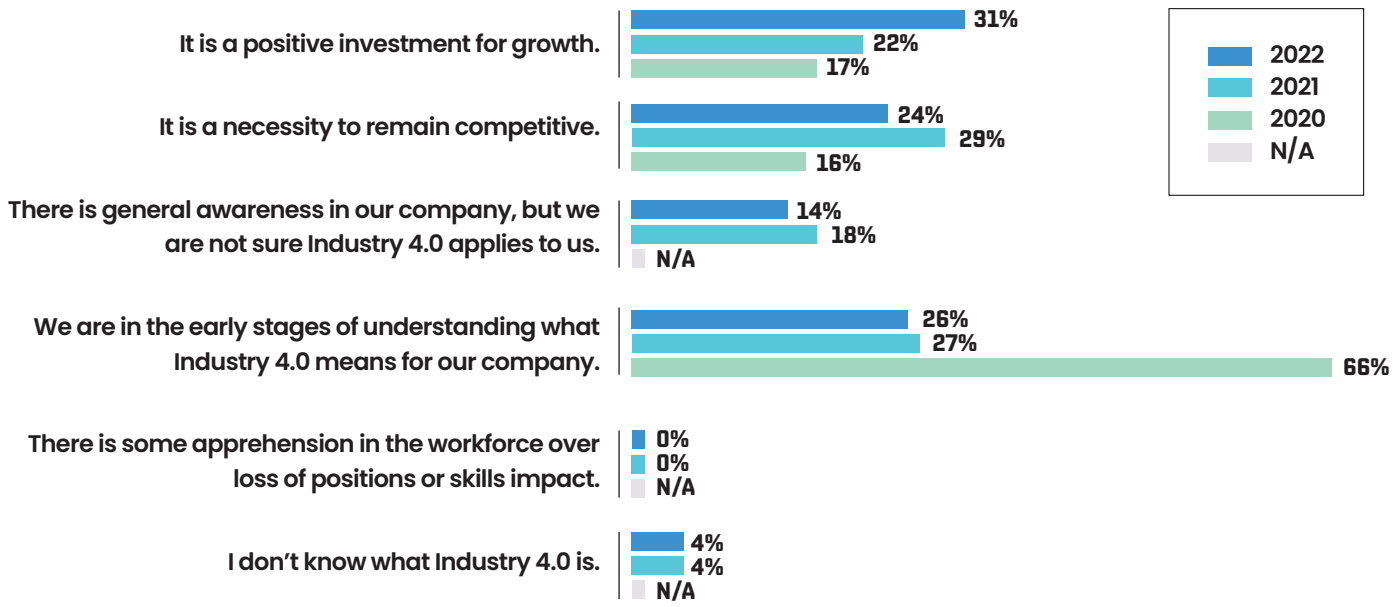
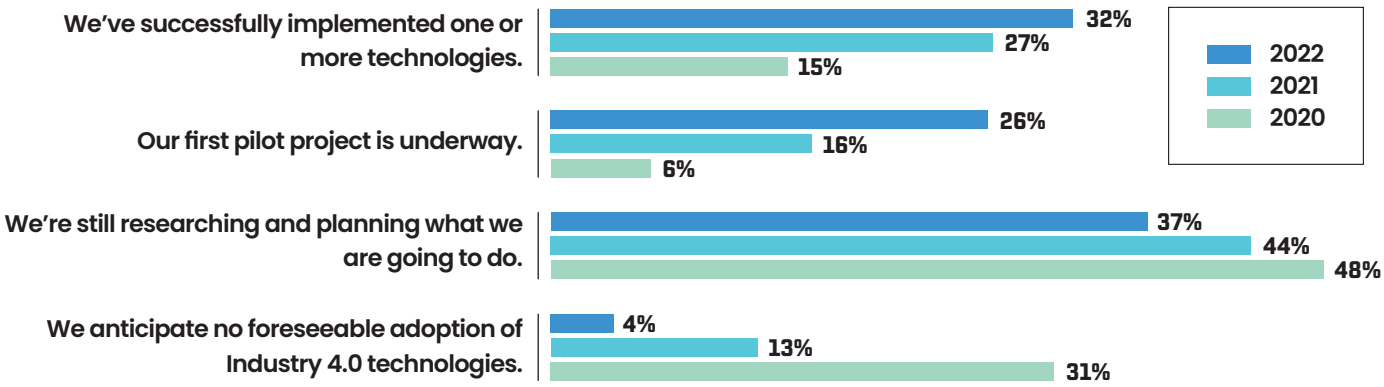


Figure 12 **Level of Interest in Industry 4.0 Tech Adoption**

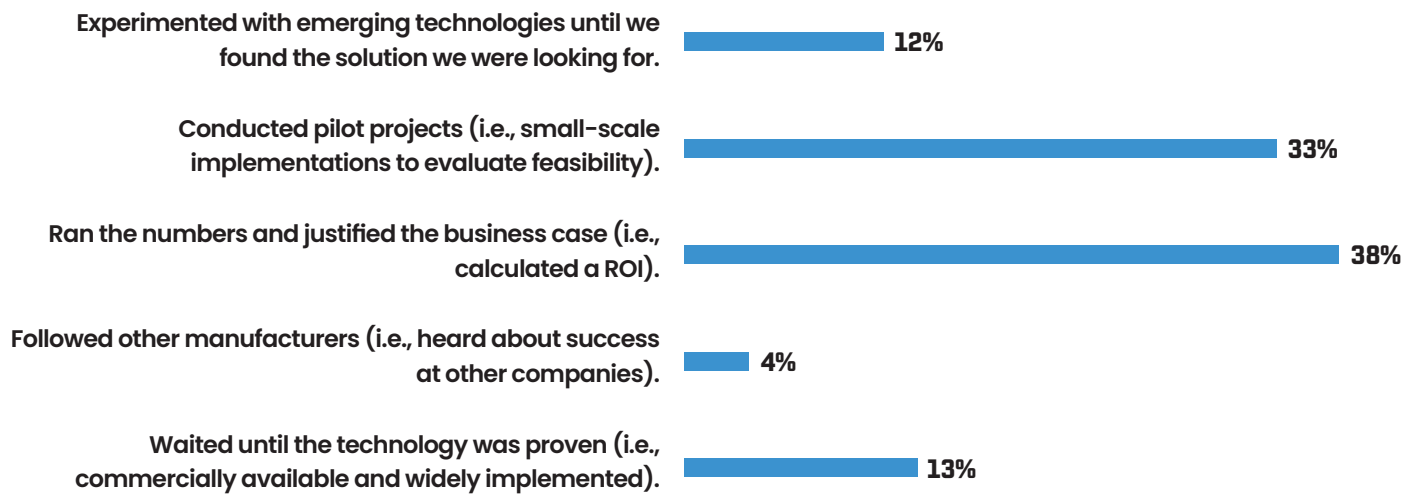


Moving Forward with a Technology Adoption Project

Of the manufacturers that have launched a pilot project (26%) or implemented one or more technologies (32%; **Figure 12**), most are following "tried and true" business methods—calculating a return on investment (ROI) and justifying the business case. It's important for manufacturers to perform an ROI analysis on potential Industry 4.0 projects given a multitude of options, and calculating the ROI likely helps a company select the best technology solution for a given use case (i.e., cobot vs. robot).

Without implementation experience offering a hindsight perspective, it is often hard for companies to determine which technology deployments are likely to achieve promised benefits and which might underdeliver. Hence, one-third (33%) of respondents have chosen to conduct a pilot project to evaluate feasibility, whereas 12% of Indiana companies experimented with emerging technologies before determining a viable solution (**Figure 13**). This raises the question of whether those pursuing more cautious approaches may have encountered past difficulties implementing advanced technologies during Industry 2.0 or 3.0.

Figure 13 **How Companies Decide to Move Forward with an Industry 4.0 Tech Adoption Project**



Technologies that Lead and Lag

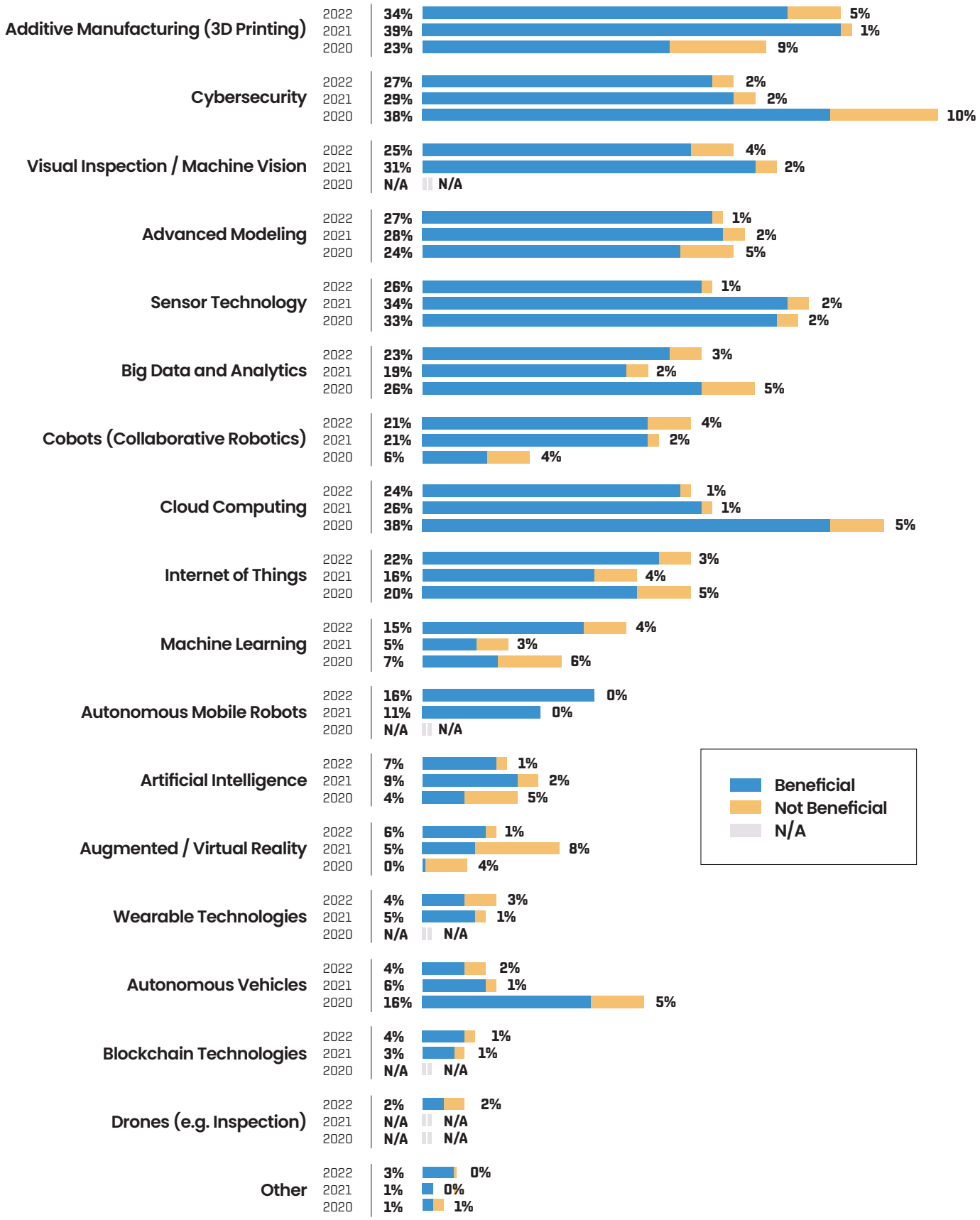
A handful of Industry 4.0 technologies have established traction at Hoosier manufacturers, including additive manufacturing, cybersecurity, machine vision, advanced modeling, big data and analytics and cobots (**Figure 14**). The technology mix squarely centers on improving manufacturing flexibility, quality and processes, optimizing the mix between human labor and automation, data-driven insights, reducing the threat of possible cyber-attacks and bolstering cyber compliance. While not all these leading technologies saw an outright increase from last year, they continue to remain at the top of the list and stand out as prime candidates for Indiana's digital Factories of the Future.

But not all commonly adopted technologies are universally perceived as beneficial when implementations are evaluated in hindsight. Those identified most often as beneficial include additive manufacturing, cybersecurity, advanced modeling, sensor technology and machine vision (**Figure 14**). One possible reason for the positive experiences with these 5 technologies is that they are relatively mature with well-defined use cases. Companies likely have overcome many of the adoption hurdles (also noted in last year's report) that can range from cost, talent and complexity of integration to the business case and vendor selection. Emerging technologies, which are less mature, at times fumble through a period of trial and error, where challenges must be overcome and value is proven.

It takes persistence in a period of trial and error to improve the outlook of a technology deployment. The changes over time for augmented/virtual reality (AR/VR) is an example. In 2020, all AR/VR implementations were perceived as 'not beneficial', and in 2021, implementations continued to be perceived unfavorably (62%). But this year, the tide has turned for AR/VR: Only 13% of implementations were perceived as not beneficial. While this could signal an improvement in company satisfaction, the path toward widespread AR/VR adoption is still not a smooth one. The number of AR/VR projects has slowed noticeably, with total implementations declining by 46% year-over-year (13% in 2021 versus 7% in 2022).

ADDMAN, Westfield, Indiana

Figure 14 **Implementation Rates of Industry 4.0 Technologies**



Technologies that Lead: Cobots

The percentage of companies implementing cobots continues to increase year-over-year while the number of companies characterizing them as beneficial remains steady (**Figure A**). Some of the additional implementations are yet to be perceived as beneficial, as it often takes experience for a manufacturer to focus deployments on the tasks or functions most likely to succeed. Machine tending and component assembly are well suited for cobots, especially when simplicity and flexibility are required (**Figure B**); but highly complex, heavy payload or high-speed applications with extended runtimes are best reserved for industrial robots.

Figure A Cobots (Collaborative Robotics)

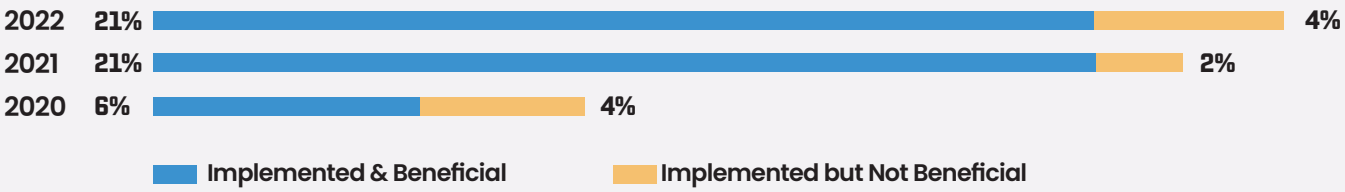
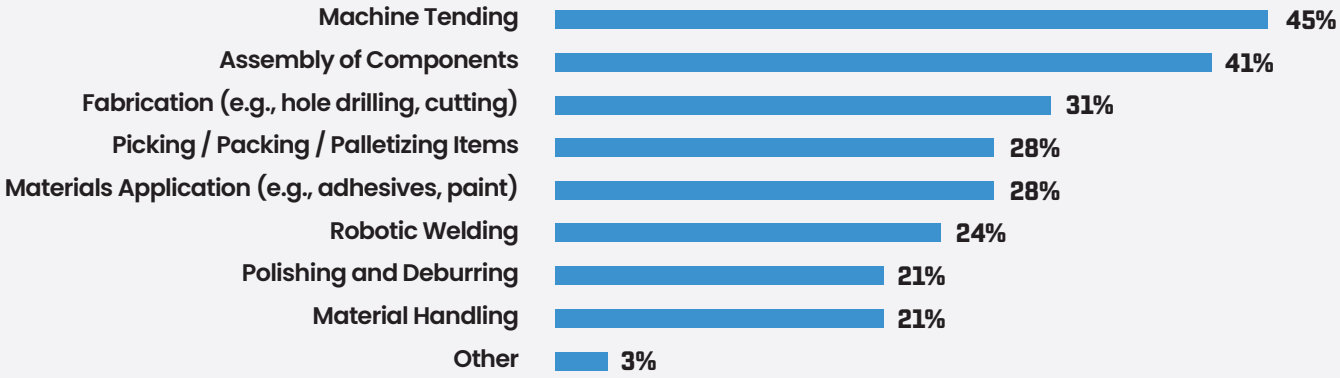


Figure B Cobot Use Cases



Technologies on the Rise: Big Data and Analytics

Last year's report showed that many companies were collecting data but not capturing its full value. Responses from this year's survey moderately improved with the big data and analytics implementation rate rising a modest 5% (21% in 2021 to 26% in 2022; **Figure C**).

Data-driven insights for factories, which are inherently data-rich environments, is a fundamental element of Industry 4.0. From machines and products to energy consumption and workers, these data sources can be unlocked to drive decision-making at all levels. But implementing a robust information and operational technology infrastructure to store and analyze such information is not always easy–it's not uncommon for just one shopfloor machine to produce many gigabytes of data annually. Accordingly, only 9% of manufacturers reported sharing and using data company-wide, integrating it with their supply chain partners or performing a deep value-chain analysis (**Figure D**). Conversely, a plurality of manufacturers (48%) identify their use of data as 'minimal' or 'beginning to impact decision-making more and more.'

Figure C Big Data and Analytics

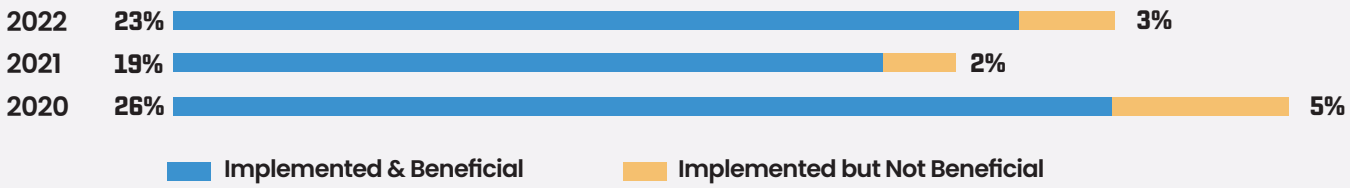


Figure D Use of Data for Analytics and Decision Making

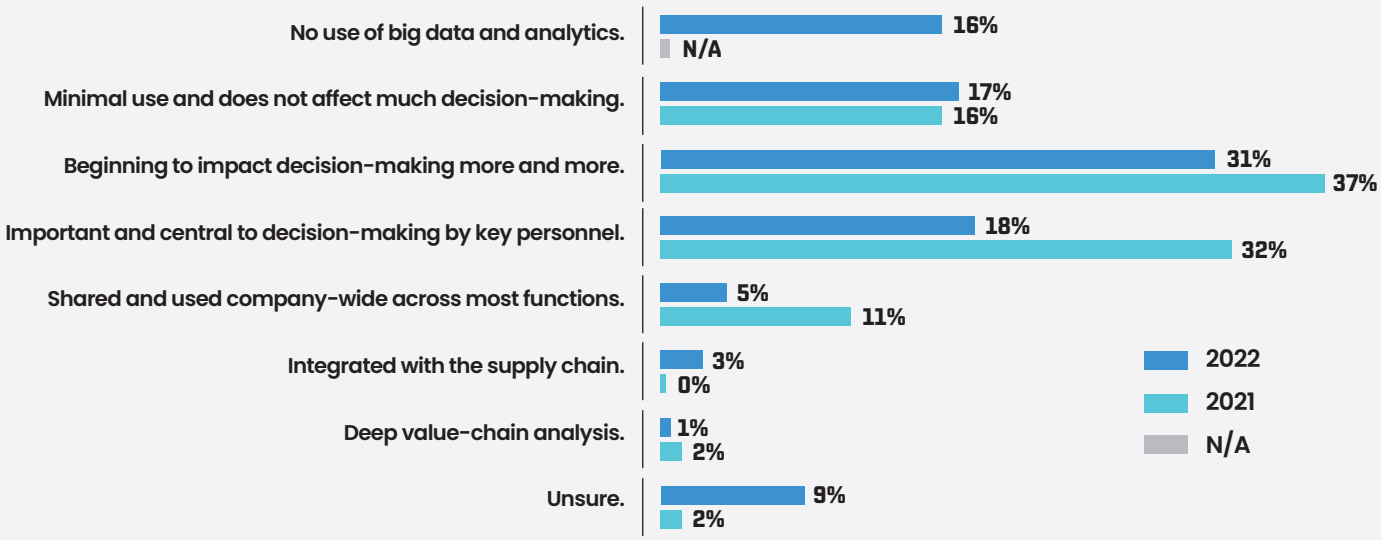
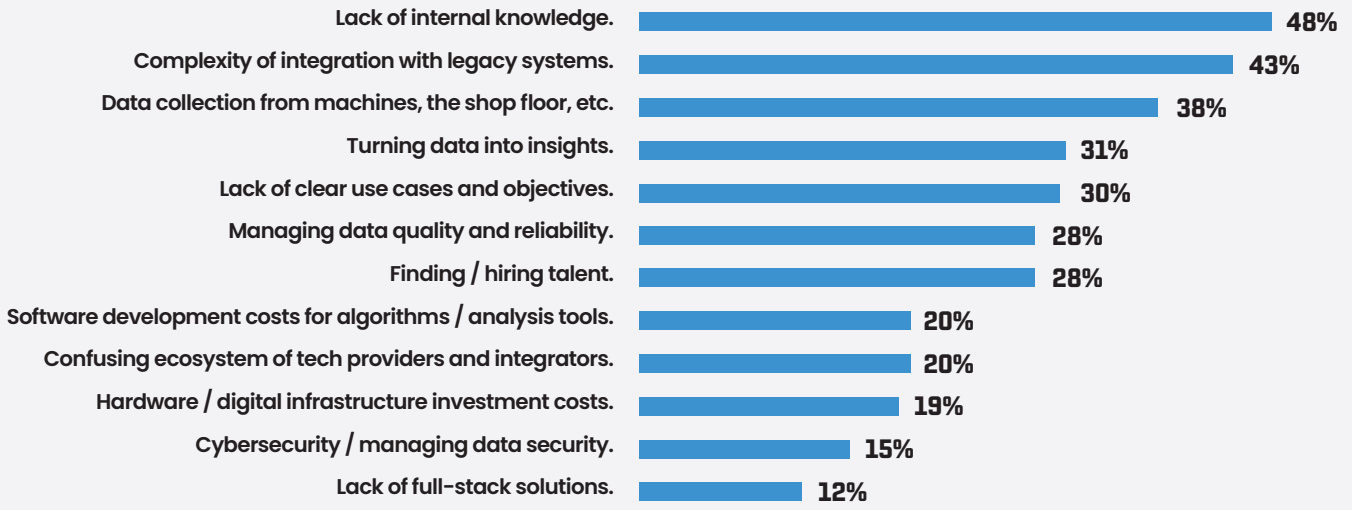


Figure E Big Data and Analytics Barriers

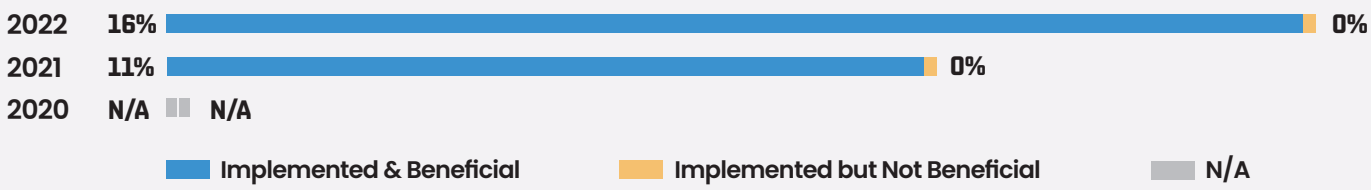


Moving from simply collecting data to transforming and analyzing that information with visualization tools and algorithms is a big step, particularly for small- and mid-sized companies. Thus, in 2022, companies were asked to identify their biggest barriers to big data and analytics adoption (**Figure E**). The top four barriers were lack of internal knowledge (48%), complexity of integration with legacy systems (43%), data collection from machines (38%) and turning that data into insights (31%). At the other end of the spectrum, it is also worth noting that digital infrastructure investment costs (19%), cybersecurity (15%) as well as lack of full-stack solutions (12%) are generally not seen as hurdles.

Also Among Technologies on the Rise: Autonomous Mobile Robots

Autonomous mobile robots (AMRs) are also making a noticeable move up the adoption curve, with 16% of survey respondents reporting a beneficial implementation (**Figure F**), a 45% increase year-over-year. None of the adopters reported a struggle with obtaining value from their deployments.

Figure F Autonomous Mobile Robots

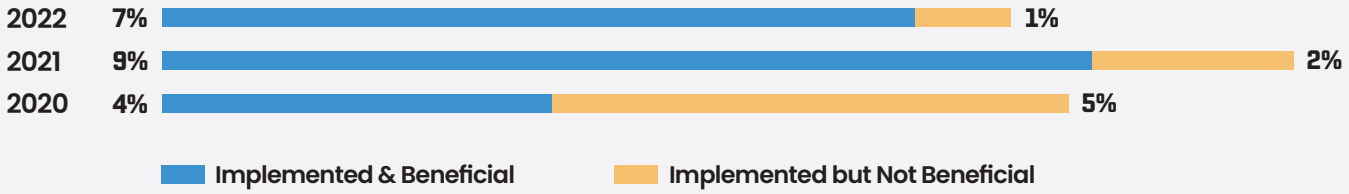


Like cobots, it's possible AMRs are being implemented to augment a tight labor supply rather than to reduce headcount. They address tasks that companies are challenged to cover with labor, and in many cases, are collaborative systems designed to work efficiently alongside humans. Because AMRs provide automated material/part transport, the workforce can be redeployed on the shop floor for maintenance, programming and other knowledge-based tasks. It's likely that AMRs will continue to see an uptick in implementations as acquisition costs decline and hurdles for programming and integration subside.

Artificial Intelligence Continues to Lag

Although total implementations slightly declined in 2022, satisfaction with artificial intelligence (AI) adoption remained roughly on par with the prior year (**Figure G**). In short, AI remains an emerging Industry 4.0 technology that currently is not eliminating many positions or gaining traction. Last year's report noted that sophisticated digital infrastructure and specialized talent are needed to deploy AI, and little has changed in 2022. On the other hand, machine learning (ML) implementations are steadily growing—from 8% in 2021 to 19% in 2022 (**Figure 14**). This is a positive signal for eventual AI adoption as ML is often a precursor to more sophisticated systems.

Figure G Artificial Intelligence



Looking Ahead: Technologies on the Horizon

We asked survey respondents to look ahead and identify Industry 4.0 technologies most anticipated within the next 5 years (**Figure 15**). Nearly half of respondents cited cobots, cybersecurity, sensors and Internet of Things (IoT). This is notable because just 2 years ago only 25% of companies anticipated near-term adoption of those same technologies.

While all technologies, including blockchain, are expected to see at least some level of implementation within 5 years, the technologies nearest the top seem to offer the most tangible and direct impacts on flexibility, connectivity, security and efficiency. Cobots improve production flexibility, cybersecurity protects against threats and data leaks and sensors and IoT can drive efficiency and cost reductions through predictive maintenance and overall equipment effectiveness. Further down the list are the technologies that enhance a company's competitive edge under conditions of change and uncertainty (i.e., supply chain challenges, cost of raw materials and worker shortages).

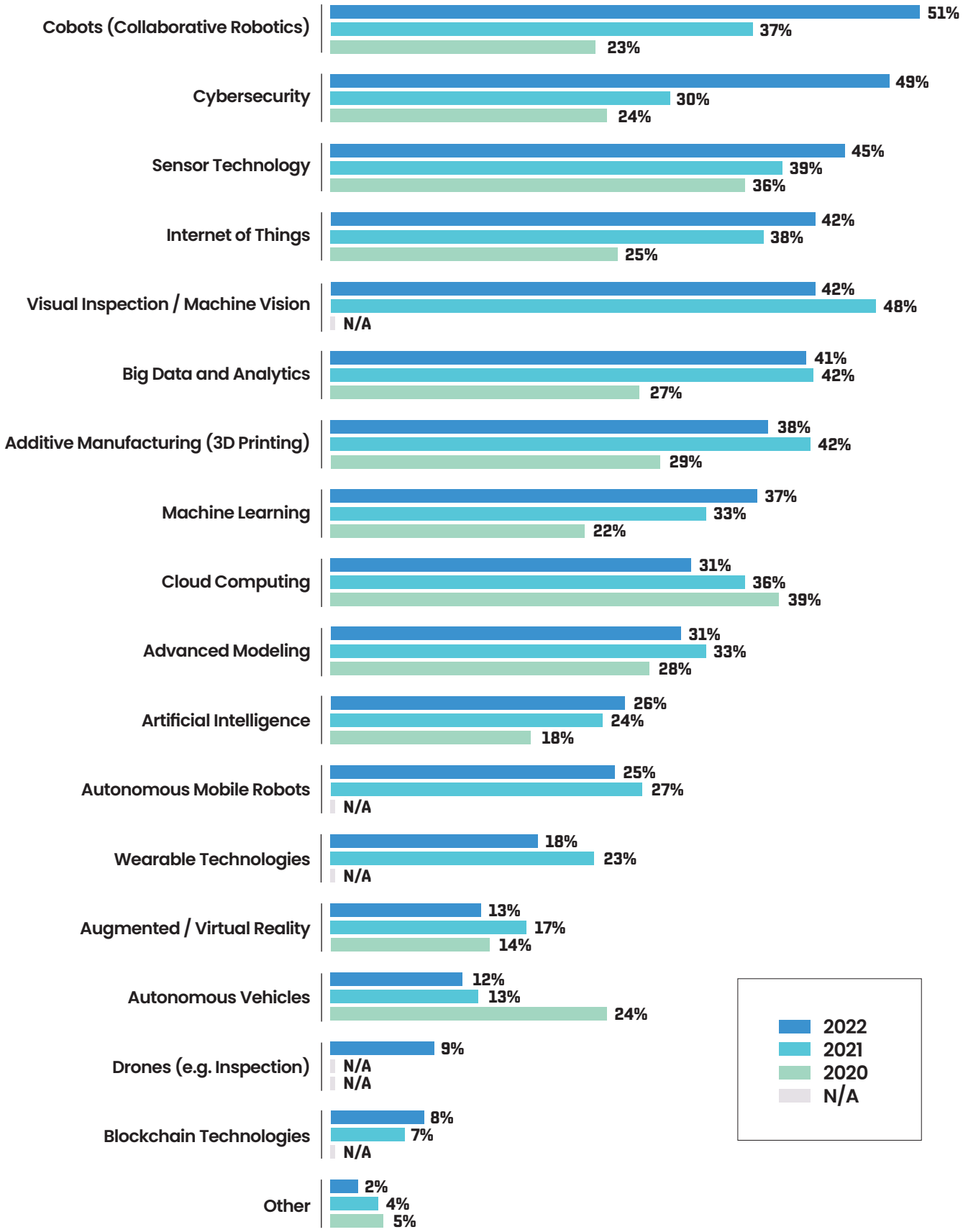
This year we asked companies about drone technology as it is increasingly useful for material handling and inventory inspection and monitoring. Almost 1 in 10 companies reported they anticipate implementing drones within the next 5 years, perhaps expecting to move, monitor and inspect products autonomously. Autonomous mobile robots (AMRs) are another example of that objective with 1 in 4 companies predicting to adopt AMRs by 2027. Only a few years ago, AMRs may have been out of reach for small- to mid-sized manufacturers, but the ease of deployment is rapidly evolving with lower requirements for installed infrastructure and facilities modifications. Companies are steadily discovering how AMR adoption can reduce both labor costs and transit times on shop floors for parts and raw materials with reduced need for human oversight.

AI adoption held steady with about 1 in 4 companies expecting to make at least some decisions autonomously with minimal human intervention in the next 5 years. Having said that, companies must make significant progress to bridge the gap between reality and expectations. While 1 in 4 companies say they expect to adopt AI, only 9% reported actual implementation. At current pace, AI implementations for functions such as forecasting, inventory control and production scheduling are likely years away from successful deployment.

Some Industry 4.0 technologies have trended downwards across 3 years of the studies, including cloud computing, wearables, augmented and virtual reality and autonomous vehicles. Reasons for downward trends likely vary between the technologies but may include: (1) lack of historical success, (2) indirect tie to shopfloor productivity, (3) identification of trusted digital integrators / tech providers and/ or (4) technology maturity level.

Metro Plastic Technologies, LLC, Noblesville, Indiana

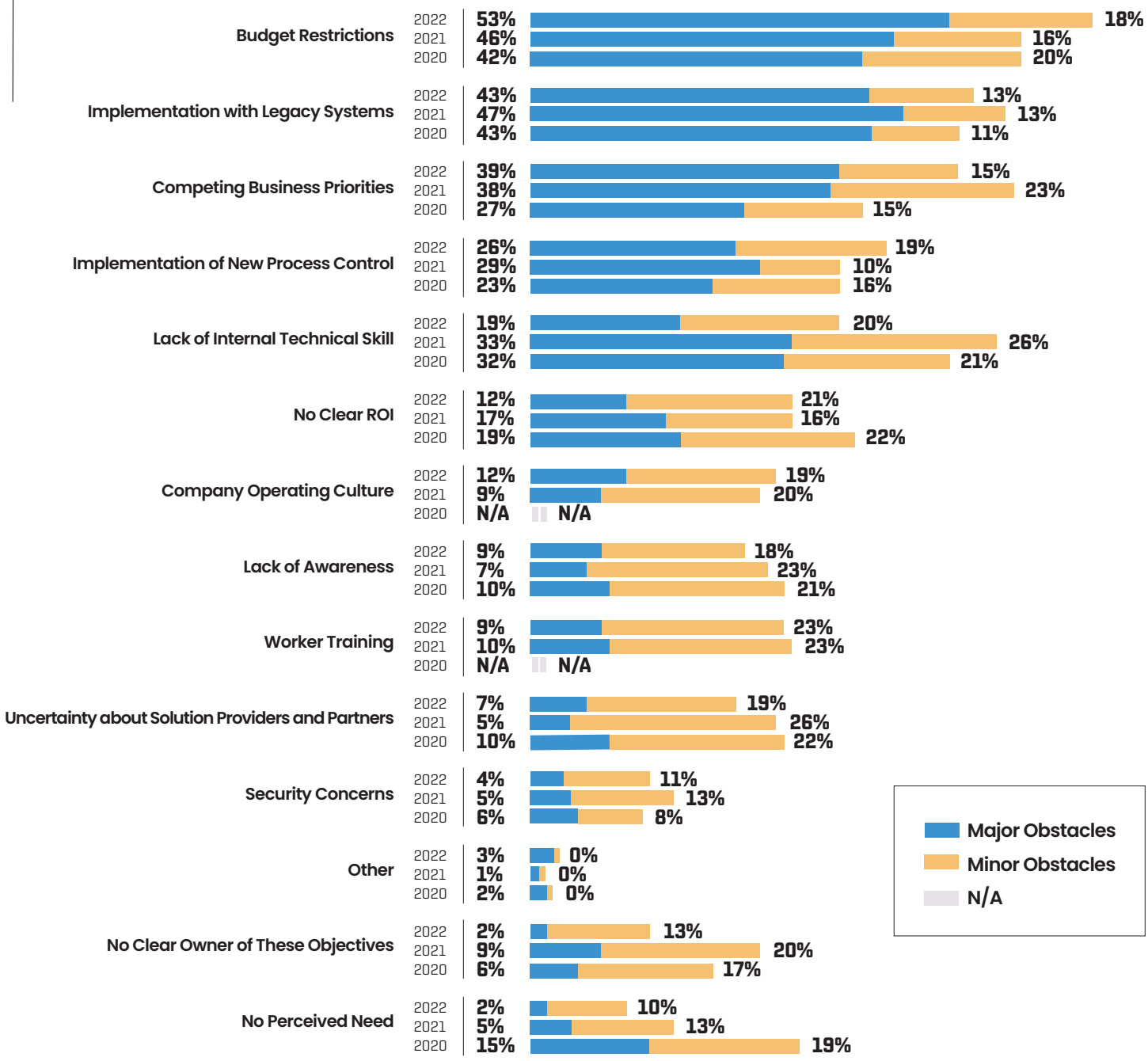
Figure 15 **Industry 4.0 Technologies Companies Expect to Implement in the Next 5 Years**



Budgets Remain the Biggest Barrier to Industry 4.0 Technology Adoption

For the third year in a row, budget restrictions remain the top obstacle for technology adoption (**Figure 16**). Limited budgets have historically inhibited growth and technological change, and it is possible that companies will begin to conserve cash and borrow less as supply chain disruptions, worker shortages and inflationary pressures persist. But companies evidently recognize the need for digital adoption despite these budget limitations.

Figure 16 Major or Minor Obstacles for Industry 4.0 Tech Adoption



The number of times 'no perceived need' was cited as either a major or minor obstacle declined for the third consecutive year. Companies also reported a substantial decrease in 'lack of internal skill' as a barrier (39% in 2022 versus 59% 2021). In part, this might be explained by rising confidence as technology adoption gathers steam and manufacturers that were initially hesitant begin to experience success and see cultural acceptance among their workforces.

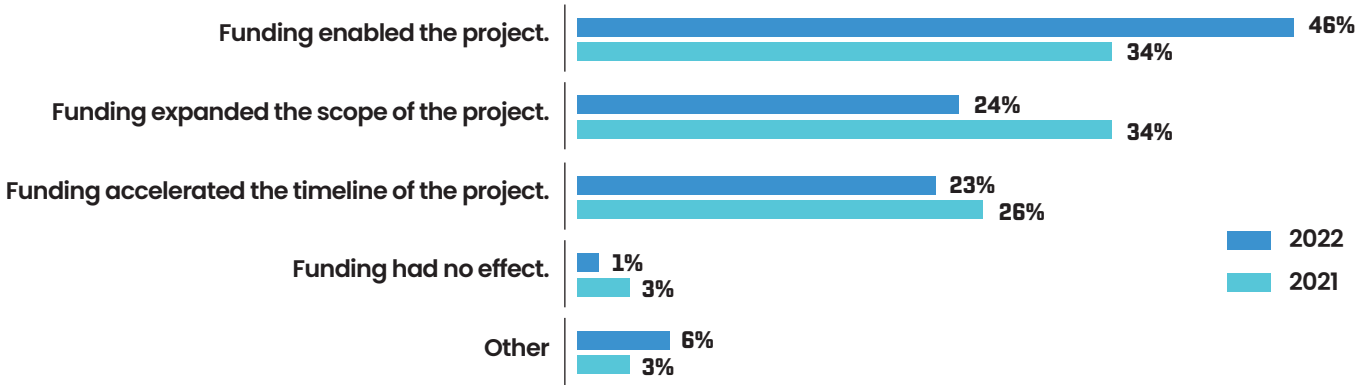
Manufacturing Readiness Grants are Helping Hoosier Companies Accelerate Their Journey to Industry 4.0

As budget restrictions remain the top obstacle, the State of Indiana has aptly expanded the Manufacturing Readiness Grants program. Indiana's Manufacturing Readiness Grants (MRG) program, championed by Governor Holcomb and the Indiana Economic Development Corporation (IEDC) in 2020, started as part of the $10 million Economic Activity Stabilization and Enhancement (EASE) program, $4 million of which was allocated to MRG, to stimulate manufacturing investment in the state. In its continuing commitment to support those efforts, an additional $20 million was added as a line item specifically for MRG in the State's 2021-23 budget.

Manufacturers now have a resource to directly alleviate budget restrictions. In fact, 46% of companies reported that grant funding enabled their project. Another 47% said it expanded the project scope or accelerated its timeline (**Figure 17**). Just 1% reported that it had no effect. Such impressive statistics reflect the degree to which the program is meeting its purpose—incentivizing tech-enabled capital investment at small- to mid-sized manufacturing firms in over 60 Indiana counties.[3]

Administered by the IEDC, Next Level Manufacturing Institute and Conexus, the MRG program has made available $17.4 million in matching grants through June 30, 2022, to support $138 million in capital investments by Indiana's manufacturers. The grants have helped Indiana manufacturers fund cobots, additive manufacturing, advanced robotics, machine vision, next-generation machines and more. Many of those matching grants are also the subject of case studies published on the Conexus website.

Figure 17 **Impact of Indiana's Manufacturing Readiness Grants Program on Tech Adoption**



[3] "Manufacturing Readiness Grants Program 2022 Impact Report," Conexus Indiana, 2022 Indiana, 2022. (https://www.conexusindiana.com/wp-content/uploads/2022/09/MRG-Impact-Report-9.8.22.pdf). Accessed 7/20/2022.

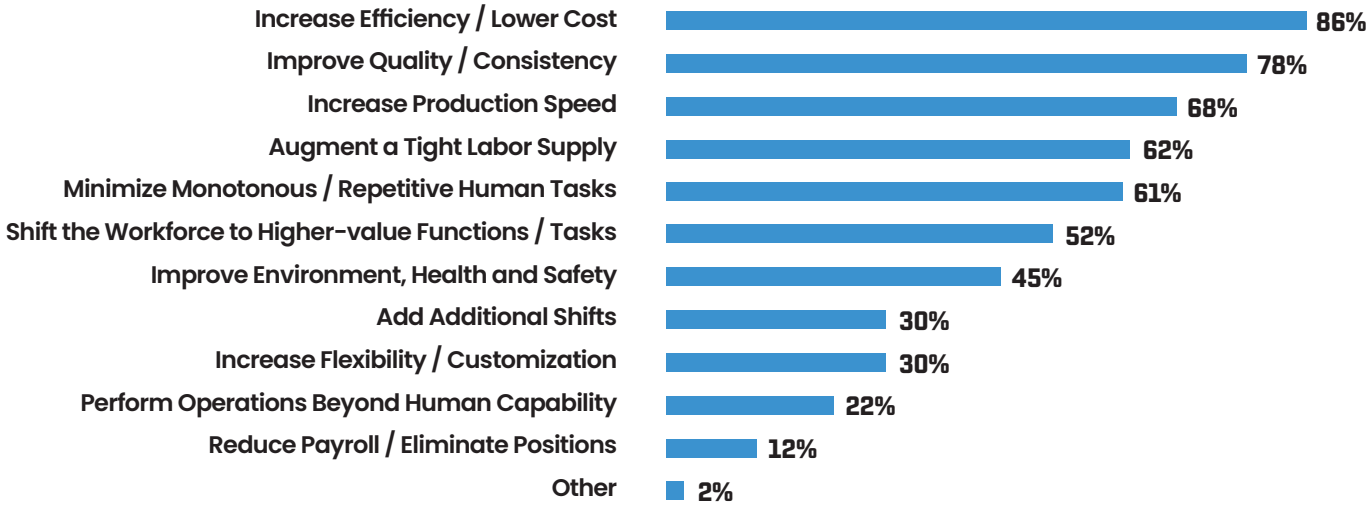
Automation and Workforce Implications: Fears vs. Reality

Recent conventional wisdom predicted that Industry 4.0 automation would displace many shopfloor workers. In fact, "The Science Survey" suggested in December 2021 that the mere mention of automation could unleash images of a "robot apocalypse" and the fear that jobs might be replaced by more productive and cost-effective robots.[4] The editorial cited a study by Massachusetts Institute of Technology (MIT) professor Daron Acemoglu showing that each robot added to the manufacturing workplace would replace 3.3 U.S. jobs—perhaps as many as 2 million by 2025.[5]

Fortunately, that doesn't reflect the experience of Indiana's AML companies and their workforces. Rather, automation is driving a reorientation of the workforce away from monotonous, routine tasks—to systems-thinking, troubleshooting and programming. The workforce of the future will include robot maintenance technicians, CNC programmers, manufacturing systems engineers and software engineers/coders. The 2022 data supports this hypothesis. Companies are not aiming to eliminate positions or reduce payroll (12%) but are instead planning to minimize monotonous/repetitive human tasks (61%) and to shift the workforce to higher-value functions/tasks (52%) (**Figure 18**).

As Industry 4.0 technology investments grow and pilot projects expand into full-scale implementations (**Figure 11**), automation will catalyze changes in incumbent worker re-training and upskilling as manufacturing companies increasingly become tech-enabled workplaces.

Figure 18 **Motivations for Implementing Automation**



[4] "The Rise of Automation Within the Workforce and What to Do About It." Ramkarran, Karishma. The Science Survey, December 2, 2021. (https://thesciencesurvey.com/editorial/2021/12/02/-the-rise-of-automation-within-the-workforce-and-what-to-do-about-it). Accessed 7/24/22.

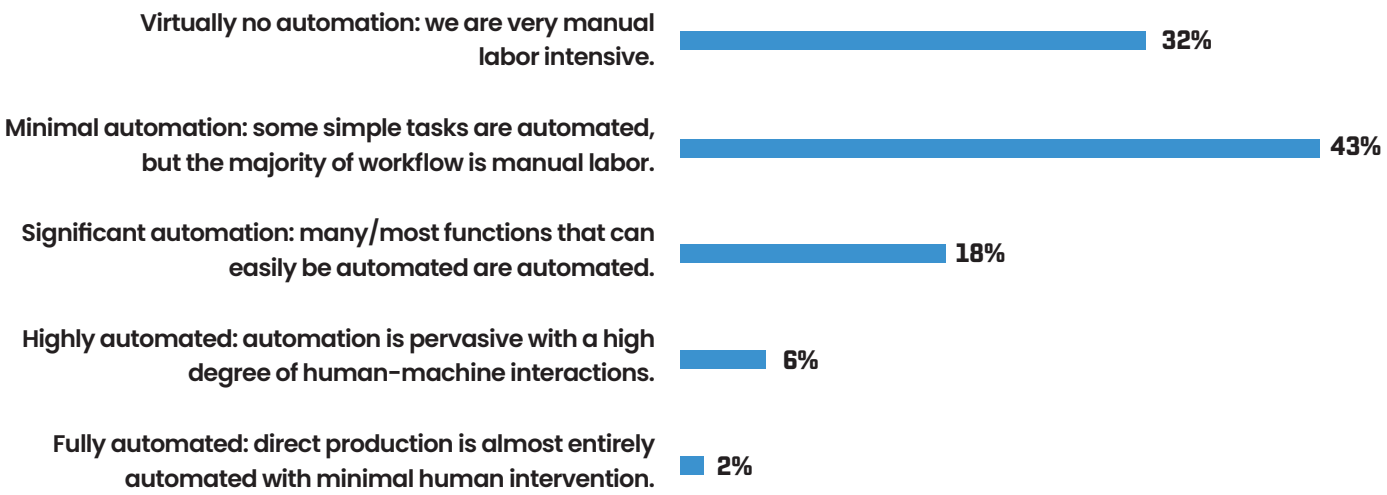
[5] "How Many Jobs Do Robots Really Replace?" Peter Dizikes, MIT News Office, May 4, 2020.

In the Fourth Industrial Revolution, technology will become pervasive in manufacturing operations, and even entry-level positions may require some level of competence in data science and computer programming/coding. However, it is difficult to estimate how much technology expertise will be needed in-house versus what will be outsourced to digital integrators and automation providers.

While top motivations for implementing automation remain efficiency/lowering costs (86%), improving quality (78%) and production speed (68%; **Figure 18**), the human component of automation will remain in sharp focus. Every machine requires some level of human interaction, whether it is to program industrial robotics or to troubleshoot an automated system. Companies should not underestimate the investment in reskilling their existing workforce to ensure the success of their automation projects. To empower employees in Industry 4.0 (i.e., shift workforce to higher-value functions, 52%), technology project investments must be two-fold: procurement of automation equipment and software and workforce training and upskilling. And it is the latter that should be strongly emphasized in a successful project plan.

Figure 19 demonstrates that a great deal of workforce realignment and reskilling is yet to take place at Indiana manufacturers, adding tension to the question about how companies plan to make these big workforce adjustments. Most companies perceive their level of robotic automation as either 'virtually none' or 'minimal' (75%). Therefore, in the next 5 years, companies must be intentional about developing their strategic roadmaps, specifically accounting for workforce investment and training plans in addition to justifying the capital investments for new technologies.

Figure 19 **Level of Robotic Automation**

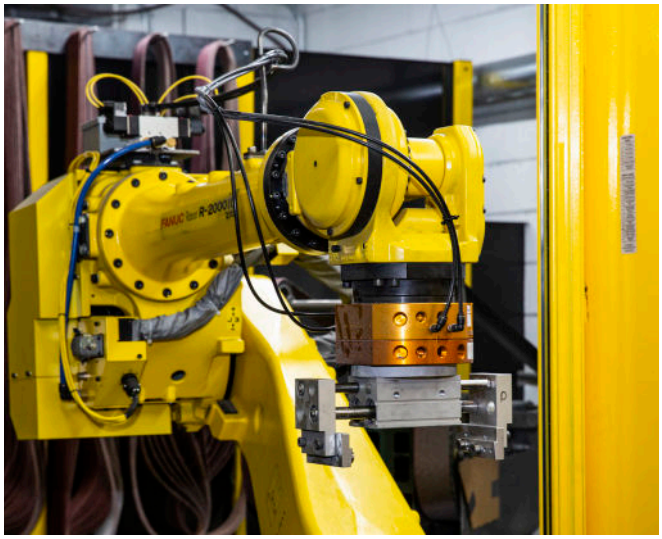


Reducing Manufacturing Costs–Not Workforce–Drives the Business Case for Industry 4.0

The business case for Industry 4.0 in the prior 2 years had been about quality, speed and cost. But this year, cost reduction soared up the list of primary strategic business objectives due to inflationary conditions (41% in 2021 to 61% in 2022). Initially, companies did not know whether inflation was transient or permanent, but it is now apparent that inflation will persist for months to come. A payroll reduction is almost certainly not an option for many companies due to tight labor markets with thousands of unfilled positions. Consequently, companies are more and more in a tenuous position with respect to continual customer price hikes, so leaning on technology adoption and Industry 4.0 will almost certainly be part of a robust cost-reduction strategy.

Crucially, enhancing productivity (70%) remained at the top of the list (**Figure 20**). In the 2021 Indiana GPS Report by the Brookings Institution,[6] ramping up technology/IT investments was identified as an opportunity for Indiana to regain its productivity advantage in the advanced industries. While underinvestment in technology has contributed to a productivity decline over the last decade, a renewed focus on digital adoption can undoubtedly turn the tide. Anecdotally, Conexus Indiana case studies show how technology investments at small- to mid-sized enterprises have improved product quality and customer service as well as enabled onshoring and expansion into new markets. And all these business outcomes lead to revenue, job and wage growth.

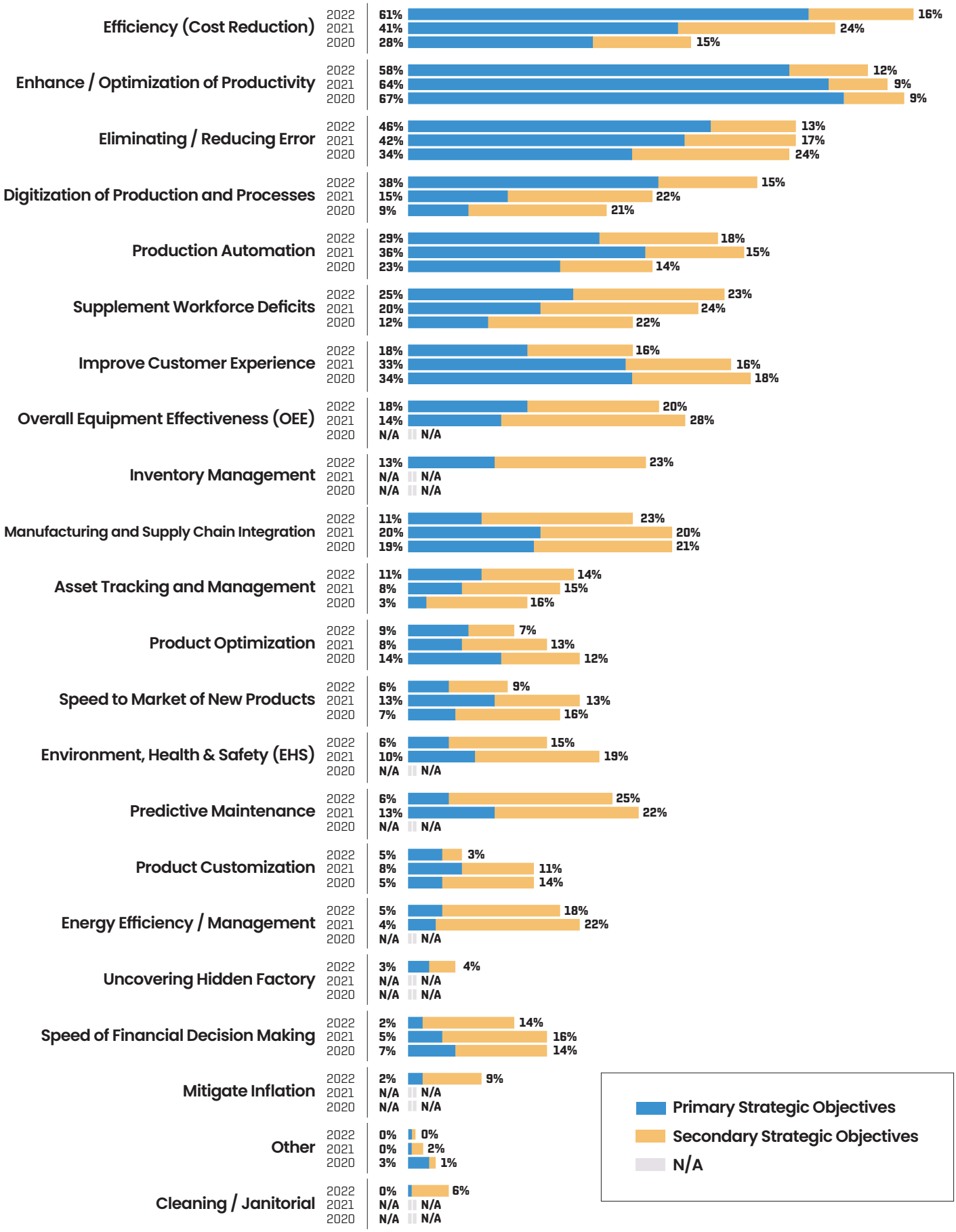
Last year's report stressed how some of the more forward-thinking Industry 4.0 concepts, such as mass customization, digitization, speed-to-market of new products and increased responsiveness to customers, were not yet a high priority at Indiana manufacturers. However, with the cost of raw materials at record highs and an inability to reduce operating costs by cutting positions, companies' priorities may well have begun to shift. Digitization of production and processes as a primary strategic objective more than doubled, with an increase from 15% in 2021 to 38% in 2022 (**Figure 20**). Digitization has the potential to significantly reduce manufacturing costs with deliberate management of data from products, machines and workers. Companies may also perceive sensor technologies and IoT as key investments to reduce operating costs and those are expected to ramp up significantly in the next 5 years (**Figure 15**).



Batesville Products Inc. (BPI), Lawrenceburg, Indiana

[6] "State of Renewal: Charting a New Course for Indiana's Economic Growth and Inclusion." Brookings Institution, February 2021, Indiana. (https://indianagpsproject.com/wp-content/uploads/2021/02/2021.02.10_BrookingsMetro_Indiana-State-of-renewal-sm.pdf). Last accessed October 18, 2021.

Figure 20 **Primary & Secondary Strategic Objectives of Industry 4.0**



Recommendations

For Manufacturers

Develop an Industry 4.0 Strategic Roadmap

Manufacturers that intentionally incorporate technology adoption into their strategic planning process, and execute accordingly, yield more progress than those that do not. In this third year of study, the preceding statement is more than a hypothesis; it's clear in the data. When narrowed to only companies that have developed a roadmap, 81% report either piloting a project or successful implementation of one or more Industry 4.0 technologies. While the benefit of a roadmap may be intuitive, only 26% of the survey respondents have a roadmap in 2022. Not enough Indiana manufacturers are taking the time to develop a plan to keep stakeholders on track and accountable. And broad participation in the roadmap's development can pay cultural dividends within the workforce by fostering acceptance, enabling opportunity and allowing employees to see firsthand how the company is investing in its own future. Crucially, the process can open communication channels for team members to ideate effective solutions, including shared learnings from past projects. Case study examples of these benefits can be found in the following links (refer to 'key learnings' sections):

- **DeKalb Molded Plastics**
- **Batesville Products Inc.**
- **Indiana Furniture**

Take Advantage of Statewide Programs

In 2021, Conexus committed to growing awareness of and participation in the Manufacturing Readiness Grants program. As of Q3, 2022, $17.4 million in grant funding has been awarded to 212 companies in 60 counties, prompting projects with combined budgets of $138.9 million. Over 500 applications have been received, representing almost 5.5% of Indiana's manufacturing base. The ongoing program continues to support modernization and transformation at small- to mid-sized firms (average of 114 employees) with long histories of participation in Indiana's manufacturing economy (average of 37 years in operation).

Beyond the direct assistance of MRG, case studies on selected grant recipients, such as the examples cited, are available and provide tremendous insights on technology adoption best practices. More than 24 grant recipients have participated in **case studies.** Individually, they serve as examples for others to emulate, and collectively they form a virtual tour of Indiana's Factory of the Future–the most manufacturing intense state in the U.S.

For Policy Makers / Industry Support Organizations

Consider Expansion of the Manufacturing Readiness Grants Program

An MRG Program Impact Report was released on September 8, 2022 (see footnote 3), and the key findings were based on 169 de-identified applications and 75 anonymous survey responses from MRG recipients across Indiana. The program is clearly succeeding and yielding positive results for both the recipients and Indiana's economy. There have been clear gains in productivity, too, as many grant recipients anticipate on average adding 5 new positions, increasing wages by $196k and securing additional revenue of $2.5 million per project. More specifically, an Indiana Economic Development Corporation model estimated a 26% internal rate of return to the state for the program as a whole.

To add more fuel to these statewide productivity gains, the state might consider expanding the program to support investments from larger companies (>500 employees), logistics and other manufacturing-adjacent sectors, manufacturing entrepreneurs and proprietary technology/tech-enabled product manufacturers (i.e., hardtech companies).

Establish an Entrepreneurship Steering Committee & Position Indiana to Lead the U.S. in Hardtech Startup Creation

Given its manufacturing intensity, Indiana is uniquely positioned to lead the U.S. in hardtech (product innovation with manufacturing and technology/software components). From this strategic advantage, Conexus Indiana, Elevate Ventures and the Indiana Economic Development Corporation (co-chair) formed a consortium of like-minded organizations including AgriNovus, HG Ventures, TechPoint, IU Ventures and 16 Tech Community Corporation with several outcomes in mind:

- Increase connectedness between Indiana's key ecosystem assets (i.e., venture capital, industry support organizations, mentor networks, shared working spaces, innovation districts, accelerator programs, etc.).
- Identify opportunities for strategic events and collaboration with industry support organizations and their representatives.
- Strengthen communication channels from the subject matter experts/mentors to the hardtech entrepreneurs/startups.
- Improve local connectedness for hardtech peers (i.e., develop a robust Indiana hardtech network).

To achieve these outcomes, consortium partners should (1) assemble regularly in a working group format to support entrepreneurs where there is momentum and strengthen local connectedness, dynamism and the success narrative amongst ecosystem representatives and (2) convene hardtech entrepreneurs for networking and insights at local host locations with entrepreneurs in different stages of development. More frequent hardtech events will establish a more connected ecosystem and help push Indiana's ecosystem from 'Emerging' to a 'Top 30' ecosystem contender. It is local connectedness that fuels startup creation and revenue growth, according to a recently published report by San-Francisco-based Startup Genome.[7]

[7] "The Global Startup Ecosystem Report GSER 2022," Startup Genome, 2022 San Francisco, 2022. (https://startupgenome.com/report/gser2022). Accessed 8/29/2022.

Engage and Cultivate Indiana's AML Tech Ecosystem and Benchmark Intensity Against Other Manufacturing States

An important element of executing a technology adoption project is working with the right technology integrator or automation solution provider.

This has consistently been a shared learning from the Manufacturing Readiness Grants case studies. Even national or global technology brands use a network of certified vendors that sell their hardware and software solutions, often providing project management, integration support and training to ensure successful deployment. Companies of all sizes tend to rely heavily on this outside expertise, especially the small- to mid-sized manufacturers. For these reasons, Conexus intends to undertake new research to better understand Indiana's AML tech ecosystem and its intensity in relation to other states. The research will explore the landscape of systems integrators, software providers and technology vendors that sell solutions into manufacturing and logistics companies as well as those that assist with implementation and/or integration. The findings will help Conexus integrate the 'AML tech ecosystem' into its networked community of manufacturing and logistics companies and also determine how to better engage both networks. Given the rapidly growing number of technology adoption projects, and new incentives like the Manufacturing Readiness Grants program, both the technology adopters and technology providers require cultivation for continued progress toward Industry 4.0.

Grow Awareness of Recently Launched Digital Adoption Programs

Last year's study identified that many Hoosier companies are collecting data (68% in 2021), but few are using and sharing the data company-wide (11% in 2021; 5% in 2022), and almost no companies are using the data for deep value-chain analysis. A recommendation from that study was to encourage the launch of a new program to bolster digital infrastructure as well as the effective use of manufacturing data through big data analytics, AI/ML and other emerging technologies. Since, 2 new digital interventions of relevance have been initiated by ecosystem partners.

- **Energy INsights** was launched in March 2022 by Energy Systems Network (ESN) and the Emerging Manufacturing Collaboration Center (EMC2). The first-of-its-kind statewide program, developed in collaboration with the Indiana Economic Development Corporation (IEDC) and Amazon Web Services (AWS), will use AI and data science to reduce energy costs and improve sustainability for Indiana manufacturers. The program is designed to engage with at least 100 manufacturing companies across Indiana to integrate an Industry 4.0 solution powered by AWS that can gather data from legacy factory equipment and energy management systems to optimize energy efficiency.

- **AnalytiXIN** launched a project in summer 2022 with Purdue University, Indiana University and the University of Notre Dame to collect and analyze data gathered from manufacturing testbeds in their respective universities as well as data from manufacturers. The data will be used to develop energy analytics applications and a publicly available data lake for the broader manufacturing, research and education communities. The AnalytiXIN project will build upon the deployment of Energy INsights and other use cases from manufacturers to provide additional expertise and a forum of collaboration among manufacturers.

Conexus Indiana will continue to engage its networked community of manufacturing and logistics companies with the goal of ensuring that the community takes full advantage of the benefits offered by Energy INsights, AnalytiXIN and other digital adoption opportunities.

For Educators

Expand Opportunities for Indiana Secondary Schools to Prepare Students for Careers in High-tech Manufacturing

Modeled after the Manufacturing Readiness Grants (MRG) program, Conexus Indiana worked with the Governor's Workforce Cabinet to launch a $500,000 Education Readiness Grants (ERG) program. The program supports Indiana high schools as they prepare students for high-tech career opportunities in manufacturing by providing awards of up to $100,000 to purchase equipment that would give students experience with the types of smart technologies MRG recipients are adopting. The program aims to strengthen partnerships between industry and local schools and prepare more students to succeed in an Industry 4.0 economy.

Demand for this program far exceeded initial funding. In total, 36 applications were received with a total request of $2.7 million to support intended technology investments of $5.9 million with potential impact on 2,500+ students throughout Indiana. Beyond the initial $500,000 awards there remains at least an unmet need of $2.2 million at deserving schools in just the first round of applications. Conexus Indiana continues to seek additional program funding to fulfil this demand.

About Conexus Indiana

Conexus Indiana, a nonprofit membership-based organization, accelerates, promotes and grows Indiana's advanced manufacturing and logistics sectors by collaborating with industry, education and public-sector leaders to optimize Indiana's competitive advantage as a global leader in making and moving products. Founded in 2007 by industry leaders as part of the Central Indiana Corporate Partnership (CICP), Conexus Indiana develops education and training programs, educates the public and public sector about the importance of the industry to Indiana's health and vitality, supports business development and technology integration strategies, and delivers on talent attraction strategies to support Indiana AML and improve opportunities for Hoosiers.

Since its inception, Conexus Indiana has launched and delivered industry-driven curricula, career awareness, and work-based learning opportunities to nearly 10,000 Hoosier high school students, equipping them with the skills to begin a manufacturing or logistics career upon graduation or to pursue further education. In recent years, Conexus Indiana expanded its talent development programs to post-secondary students and unemployed and underemployed Hoosiers. These programs support the AML's growing need for tech-conversant, problem-solving and collaborative talent. These talent development programs, in addition to Conexus Indiana's Industry 4.0 research and thought-leadership platforms and the organization's growing networked community of experts, are foundational to Indiana's successful transition to Industry 4.0 and sustained business growth.

About Indiana University Kelley School of Business Center for Excellence in Manufacturing

Manufacturers are caught in an ongoing revolution that requires them to consistently invest in their facilities, staff and automation to keep up with competitors. As soon as they progress forward, the bar moves again.

The IU Kelley School Center for Excellence in Manufacturing tracks this revolution and monitors trends to provide business leaders insight into this ever-changing industry. Our center finds and illuminates the most effective trends for companies while helping our students develop the skills that managers need.

An increasing number of undergraduate and MBA students who study supply chain management are pursuing careers in manufacturing. We help them develop the understanding, vision, and flexibility necessary to enter this industry and lead these companies into the future.