Automation Alley®

Technology In Industry 2019 Report

Industry 4.0: From Vision to Implementation

"The more we think about how to harness the technology revolution, the more we will examine ourselves and the underlying social models that these technologies embody and enable, and the more we will have an opportunity to shape the revolution in a manner that improves the state of the world."

- *Klaus Schwab, Founder and Executive Chairman, World Economic Forum*

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Foreword

What are the possibilities of The Fourth Industrial Revolution? We are only beginning to scratch the surface of what is imaginable through Industry 4.0. Today, in factories across the globe, products fitted with sensors are interconnected and sharing information, machines can learn to optimize processes and fix themselves before they fail and robots are working collaboratively alongside human workers.

By 2025, Industry 4.0 is expected to generate close to $1 trillion in economic value. Through Industry 4.0, large manufacturers are becoming more streamlined, efficient, agile and are seeing improved production outputs and increased sales. However, to unlock the true potential of this revolution, all businesses along the supply chain must adapt and implement a digital mindset.

As Michigan's Industry 4.0 knowledge center, Automation Alley's mission is to help manufacturers of all sizes understand the rapid technological changes associated with digitalization so that our state—and our nation—remain globally competitive. This 2019 report, "From Vision to Implementation," is a guide to help your company assess its current position and get you on a path to long-term success: one led by a new business model that's driven by information to spark innovation.

In 2017, our report gauged your readiness for Industry 4.0, in 2018 we gave you the tools to harness its power and in 2019 we are calling you into action.

Just as the way we work is changing, so to is the way we must think about our education system. While Industry 4.0 will eliminate many blue-collar jobs, "new-collar" jobs are emerging. Through this collaborative report, Automation Alley is empowering industry and academia to work together to upskill our current workforce to meet new technological demands while ensuring our children are prepared for the jobs of the future.

Tom Kelly
Executive Director & CEO
Automation Alley

About This Report

Imagine Industry 4.0 as a human body, where artificial intelligence and machine learning are the brain, Big Data and IoT connectivity are the central nervous system and robotics are the muscle. Together, these smart technologies are creating intelligent networks along the entire supply chain, opening the floodgates to innovation and creating upheavals to our industries and our society.

Automation Alley's 2019 Technology in Industry Report is a response to the overwhelming need for knowledge and direction related to Industry 4.0. It's a data-driven guide to smart technology implementation, featuring use cases, emerging trends, challenges, opportunities and action items for industry, designed to help business, educators and policy makers keep pace with the velocity and magnitude of change related to Industry 4.0.

The report also features a study of three key segments spanning four generations of Southeast Michigan's Industry 4.0 talent pipeline.

Our unique approach to the creation of this report includes a collaborative team of academic and corporate partners, who center their research around the eight core technologies of Industry 4.0: The Internet of Things, Big Data, cloud computing, cybersecurity, robotics, artificial intelligence, additive manufacturing and advanced materials and modeling, simulation, visualization and immersion.

New to this year's report is the Velocity Index, a powerful tool designed to help companies assess the maturity of Industry 4.0 technologies and their projected rate of development within various industries. Through simple charts, the Velocity Index provides a snapshot of each technology sector's potential for return on investment, providing corporate executives with an independent opinion of Industry 4.0's potential to impact their bottom lines.

Separately, the eight technologies of Industry 4.0 are creating waves across all industries, but, when integrated together, they are transformative. As Michigan's Industry 4.0 knowledge center, Automation Alley's goal with this report is to help you leverage the intersections of Industry 4.0 technologies, systems and people to gain a considerable competitive advantage.

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Ford Motor Company | Dow Chemical Company | Altair | Ghafari Associates, LLC
Michigan Economic Development Corporation

Key Findings

Understand

Understanding Industry 4.0 concepts and to what degree your company plans to implement Industry 4.0 technologies is the fundamental first step that all organizations should have accomplished at this point. However, our data suggest many organizations have not achieved this yet.

Plan

Companies must develop a solid action plan of what their objectives, expected benefits and return on investment measures are related to Industry 4.0 technology implementation.

Train

Despite the technological disruption caused by Industry 4.0, humans will remain the central core component of healthy organizations and societies. Successful Industry 4.0 adoption is dependent on creating a culture of change adoption and constant innovation. Organizations are at risk for underappreciating and underinvesting in this crucial area. Educators and industry leaders should join forces to review current curriculum methods and develop a plan to strengthen the creativity and innovation skills of the talent pipeline.

Implement

Companies need to understand that Industry 4.0 is an entire ecosystem that goes beyond hardware and software. Companies cannot plan to implement Industry 4.0 for one product or one department. Implementation must be approached holistically and must integrate with pieces of the supply chain and customer base to truly be impactful.

Partner

The capital and deep technical expertise for understanding, planning, executing and continually re-evaluating Industry 4.0 are much greater than most small and medium-sized businesses can invest in individually. Partnerships, alliances, joint ventures and public-private cooperation will all need to be explored to make Industry 4.0 accessible to these companies.

Emerging Trends & Traits Shaping the Industry 4.0 Talent Pipeline

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The Fourth Industrial Revolution, known as Industry 4.0, is having a dramatic technical and cultural impact as it disrupts socio-technical ecosystems in the state of Michigan and around the world. Industry 4.0 is the result of the convergence of digital, biological and physical technologies.

Attracting, retaining and cultivating human talent is the key to success in the 21st Century, but the demand for talent is outpacing supply. The current education system is struggling to produce quantities of graduates with Industry 4.0 skills. The lack of qualified talent, across all spectrums of work, is impacting the entire technical and manufacturing workforce from the shop floor to the C-suite. Calls for stepping up workforce reskilling efforts have become ever more urgent as Industry 4.0 skills have become critical components of labor markets. (Schwab, 2016)

In Automation Alley's 2018 Technology in Industry Report, we reported that the disruptions of Industry 4.0 technologies, combined with demographic and generational changes, are creating new challenges the likes of which industrialized nations have never known or experienced. We gave an example of the disruption as cited by a World Economic Forum report which states that 65% of students in primary education today will work in jobs that currently do not exist. (World Economic Forum, 2016) If this is indeed the case, then the region that develops a talent pipeline and retains that talent will be a strong contender for global Industry 4.0 leadership and competitive advantage.

Manufacturing technology is no longer focused solely on automating manual labor, it is also now automating cognition at a phenomenal pace. Research suggests that, during the 1940s, knowledge was doubling about every 25 years. Today, estimates by the Skillman Foundation report that human knowledge is estimated to be doubling every 13 months, and, with further technological advancements, is expected to double at the astounding rate of every 12 hours in the foreseeable future. (Allen, 2019)

If the Midwest manufacturing region is to keep pace and maintain a global leadership position, it must transform and continuously develop human labor. Some argue that if the core OEMs (General Motors, Ford Motor Company and FCA) do not transform into tech companies, as opposed to automobile manufacturing companies, they'll become Tier 1 suppliers to the likes of Amazon, Google and Apple. (Livengood, 2019) Furthermore, the small and medium-sized firms, which are the lifeblood of the Tier 2 and Tier 3 supply chain, face even greater challenges to recruit, develop and retain human talent, because they have to do so with far less resources than an OEM or Tier 1 company.

Objectives of this Research

This research seeks to build on Automation Alley's 2018 Technology in Industry Report to identify emerging trends, pinpoint challenges and opportunities and gain data-driven insights into the forces shaping the talent pipeline in the American Midwest. Research objectives include:

1. Building on the research findings from the 2018 Technology in Industry Report to provide a deeper and more comprehensive understanding of the talent pipeline in the Midwest.
2. Accessing and evaluating three key segments of the talent pipeline: 1) next-generation leaders, 2) undergraduate engineering students and 3) skilled trade apprentices.
3. Defining the fundamental DNA composition of the talent pipeline in terms of the professional competencies, motivational factors and behavioral styles of the three groups.
4. Producing data-driven insights that industry and education collaborators can use to modify and strengthen the talent pipeline in the Midwest.
5. Develop new knowledge to help us understand and better develop strategies to attract, develop and retain top Industry 4.0 talent in the Midwest and the greater United States.

Overview of the Talent Landscape

Today, a new set of working skills are required. To address the needs of human talent, which is critical to developing and retaining an Industry 4.0-ready workforce, industry and educators must go beyond simply reskilling and upskilling initiatives. What organizations must focus on are career strategies, talent mobility and re-engineering ecosystems and networks to facilitate both individual and organizational reinvention. (Bersin, et al., 2017)

Robotics and automation should not cause society to fear the loss of human worth, for the human is still the central core component of prospering organizations and healthy societies.

Some of that fear is caused by outdated corporate approaches and institutions that were shaped by earlier stages of the digital age. They are now creaky and unfit for the new Industry 4.0 age. (Richards, 2018) Today, technology is moving forward at an accelerated pace and many routine forms of work tasks of the past (factory and office) are becoming extinct.

The transition in tasks holds true for both blue-collar and white-collar jobs. For example, a recent study conducted by the Ralph C. Wilson, Jr. Foundation reports that 30% of the middle skilled labor pool will be displaced by automation by 2030 in Southeast Michigan. (Brachman, 2018) Similar changes are being felt by white-collar workers. In early 2019, as part of its plan to cut $2.5 billion in costs, GM shed 2,300 white-collar employees and 1,500 contractors with an additional 4,000 layoffs that followed in February 2019. (Meloni, 2019)

> **Robotics and automation should not cause society to fear the loss of human worth, for the human is still the central core component of prospering organizations and healthy societies.**

The same is true in education, which is extremely resistant to change due to inflexible structures and a heavy reliance on tradition. The level of disruption becomes evident by the fact that, in 2016, 131 universities and colleges in the U.S. went out of business or merged with others. (Busta, 2019) With undergraduate enrollments declining and new educational options available, educators (both faculty and administrators) must accept the fact that the traditional education models and methods are obsolete and broken. The Automation Alley Industry 4.0 Consortium is an example of self-organization by faculty to address such concerns. (Pistrui and Kleinke, 2019)

Emerging Trends

Figure 1 presents an overview of the emerging trends and traits shaping the workforce environment. Four themes can be identified as central forces in the Industry 4.0 work environment:

1. Workforce Must Embrace Frequent and Constant Change

Frequent change can be a central cause of stress and conflict in the workforce. To make matters worse, Industry 4.0 is expected to significantly increase the pace of change. Companies need to be aware of the implications of disruption to their workforce.

One tactic to employ in this environment is for organizations to create their own positive disruption. By creating adaptive spaces (both physically and virtually) that encourage the free flow of ideas, greater organizational agility can be fostered. (Arena, 2018) This model calls for the freedom to self-organize entrepreneurial pockets in parallel to existing operational systems. The adaptive space then serves as both a buffer and intermediary to bring the two dimensions together.

2. Flexible Adaptive Teams Must Collaborate with Other Teams

Organizations that leverage the Industry 4.0 environment effectively will have to de-scale the traditional hierarchies and fiefdoms that are currently prevalent. Team agility, an entrepreneurial mindset and the ability to persist through failure are fundamental to creating and sustaining networks of interrelated teams.

3. Companies Must Create Cultures of Inclusion & Internal/External Transparency

A culture of inclusion is key to effectively employing adaptive teams. For the "teams of teams" approach to effectively function in the disruption of Industry 4.0, the organization must possess a shared consciousness. Establishing and maintaining shared consciousness demands the adoption of extreme transparency throughout both the internal teams and external stakeholders. (McChrystal et al., 2015) This requires breaking down traditional hierarchies, implementing agile methodologies in the face of disruption due to emerging technologies and the changing nature of work tasks.

> **People must be perpetual learners (often in real-time) and think in new and dynamic ways.**

4. People Must Be Life-long Learners & Dynamic Thinkers

The fourth, and perhaps most critical, theme is that people must be perpetual learners (often in real-time) and think in new and dynamic ways. Dynamic thinking requires empathy, collaboration, experimentalism and a focus on solving problems and creating value for other humans. (Pistrui and Kleinke, 2018) Organizations that focus on human need, technological feasibility and business viability will be best positioned to leverage and prosper in an Industry 4.0 environment.

Figure 1: *Emerging Trends and Traits Shaping the Industry 4.0 Workforce*

Past Trends	Present Trends	Emerging Trends
Structured hierarchies	Networks of teams	Empowered agility
Static career	Dynamic longevity	Recreation and repurpose
Recruiting talent	Cognitive technologies	Matching talent to culture
Selection and retention	Employee journeys	Well-being and inclusion
Performance appraisals	Continuous feedback	Cultures of performance
Managerial hierarchies	Leading in rapid change	Dynamic thinking models
Digitizing platforms	Building digital organizations	Changing nature of work
Key performance indicators	People-centric analytics	Recalculating performance
Diversity through delegation	Diversity through process	Value creation via diversity
On balance sheet employees	Insourcing outside expertise	Open talent economy

Sources: McChrystal et al., 2015; Deloitte, 2017-18; Arena, 2018 ; Pistrui and Kleinke, 2018; Pistrui, 2018.

Industry Analysis

Positive Disruption: Redefining Workplace Culture and Building New Business Models

Bosch, a German-based global engineering leader, is an example of an organization that is in the process of transforming its business model and culture. Traditionally known as an auto parts, appliance and power tools manufacture, today the company is redefining itself as an Internet of Things (IoT) company, supplying technology and services. (The Economist, 2017) This represents a dramatic overhaul of the company's traditional business model.

To accomplish the overhaul, Bosch is focused on developing an agile mindset while fostering continuous learning that aims to meet the learner at the point of need through vehicles such as BoschTube (think personalized YouTube channel used to deliver specific knowledge to solve problems on demand, 24-7). (de Arriba and Phadke, 2019)

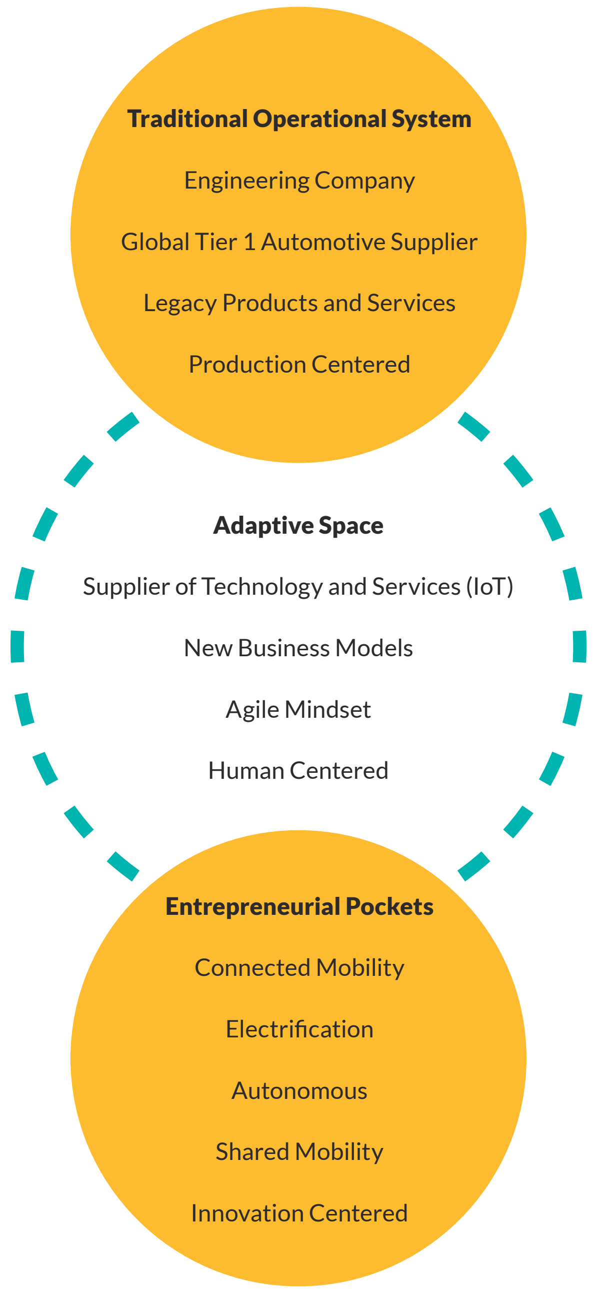
The core of Bosch's transformation is centered around people and culture, as illustrated in Figure 2. Bosch is embracing the diversity found in the four active generations in the workforce to foster innovation and build new business models. They are aspiring to create a culture where employees' ideas are welcomed and encouraged (bosch.com/careers, 2019).

To attract top talent, Bosch presents four entry opportunities or phases that include:

- **Pupils:** High school internships leading to apprenticeship or employment.
- **Students:** A college internship or working student talent relationship program.
- **Graduates:** A graduate program focused on subjects students are passionate about.
- **Professionals:** Promoting quality of life with worktime models and continuous learning.

Bosch is an example of a large global company with thousands of employees and vast resources at its disposal. How does this compare and contrast to small and medium-sized businesses, which we define as enterprises with less than 500 people?

***Figure 2:** Redefining Culture & Business Models*



Sources: The Economist, 2017; Arena, 2018; de Arriba and Phadke, 2019; Bosch, bosch.com/internet-of-things/

Implications for Small and Medium-Sized Enterprises

Small and medium-sized enterprises (SMEs) play a leading role in the Midwest and around the world. Privately controlled, often owned by families, SMEs tend to be conservative when it comes to business risk. Typically, the demands of the day-to-day business will prevent these firms from having a longer-term focus. Many wrestle with ownership turnover as less than one-third of SMEs survive the transition from the first to the second generation of family ownership.

So, what is the impact of Industry 4.0 on SMEs? Research in Germany (often considered the birthplace of Industry 4.0) shows that SMEs greatly lag large corporations in the early adoption of Industry 4.0 technologies. (Schröder, 2016) Most SMEs view large investments in new technologies with caution and trepidation. However, failure to integrate the cyber, physical and human systems in a timely manner will rapidly render SMEs obsolete and drive them out of business.

If SMEs are to remain competitive in a global marketplace, they need to implement Industry 4.0 technologies broadly and effectively. (Kota and Mahoney, 2018) SMEs can also employ positive disruption techniques. Given that they are smaller, and often more entrepreneurial and agile than Tier 1s, SMEs may in fact be in a better position to respond and capitalize on Industry 4.0 disruptions, if they can make wise investments with limited resources. Figure 3 provides an assessment and implementation framework SMEs can use to formalize the processes of identifying and accessing opportunities associated with Industry 4.0 forces.

What is important to consider for SMEs is that their customers, large and small, are all being forced to address Industry 4.0 technologies. Consequently, all organizations should have a sense of urgency and engage in conversation, expand knowledge, as well as collaboratively prototype and undertake calculated Industry 4.0 experiments.

At the center of this process will be the people involved. SMEs can be more vulnerable when it comes to navigating generational leadership succession. This is because often they have family members and business partners who may have different skill levels and motivations. Often, those seeking employment gravitate towards larger organizations for the perceived stability and benefits, when in reality the best opportunities for work-life balance and upward mobility are often with SMEs.

***Figure 3:** SME Industry 4.0 Implementation Framework*

- Create an Industry 4.0 taskforce that includes a diverse cross section of people (multiple generations) and subject matter expertise.
- Engage and partner with your customer, and your customer's customer (engage the marketplace).
- Educate yourself and seek advice from vendors, educators, trade groups and governmental agencies.
- Define and understand your options: a) do nothing and hope for the best, b) explore and experiment, c) go all in, d) gradually ramp-down and cash out, or e) exit the business.
- Experiment and place calculated bets employing outcome-based measures (don't be afraid to fail).
- Invest in your talent pipeline and leverage new generations who will be more technically savvy and bring fresh perspectives.
- Take advantage of state and federal programs that support the development and implementation of Industry 4.0 initiatives.

Sources: Pistrui and Kleinke, 2019; Kota and Mahoney, 2018; Schröder, 2016; Kurfuss, 2014.

Opportunities & Challenges

Socio-cultural Transformation in the Era of Industry 4.0

Socio-cultural transformation is a challenge confronting industry due to each generation's radically different views on work-life balance, the loss of knowledge through Baby Boomer retirement and a global shortage of qualified talent. Figure 4 provides and overview of generational trait strengths and challenges.

Generation X now holds 51% of management and leadership positions. With an average of 20 years of workplace experience, they are primed to quickly assume nearly all top executive roles. (Neal and Wellins, 2018) Not far behind are the Millennials, who represent the largest segment of the working population.

Gen Zers are now joining the workforce in entry level positions. They are a generation with their own unique attributes that include being very inclusive in nature and are found to rally around causes. They believe profoundly in the efficacy of dialogue to solve conflicts and improve the world. Gen Zers make decisions and relate to institutions in highly analytical and pragmatic ways. (Francis and Hoefel, 2018) Their world is rooted in mobility and multiple realities. In 2017, O'Boyle, et al. reported that many Gen Zers expressed concern that technology is weakening their ability to maintain strong interpersonal relationships and develop people skills. This is a shortcoming that organizations should be aware of as they enter the workforce.

Framework for Multi-gen Industry 4.0 Workforce Development

To successfully navigate the Industry 4.0 environment (and beyond), organizations will often need to integrate four different generations into their workforce. This will be no easy task given the generational differences and general shortage of qualified talent. Below is a general framework that organizations can use to guide their efforts. This is a complex undertaking, so this framework represents only a starting point from which to build:

- Foster open dialog and set expectations upfront concerning policies, procedures, pathways and organizational culture.
- Celebrate generational diversity and make it an open topic of discussion in group settings and in team assignments.
- Use data-driven tools, techniques and methods to identify (individual, team and organizational) strengths and developmental needs.
- Create an environment of inclusion and make collaboration and mentoring core components for feedback and professional development.
- Balance human interaction including face-to-face communication and collaboration with screen time and working remotely. (Pistrui and Kleinke, 2019)

***Figure 4:** Generational Trait Strengths and Challenges*

Baby Boomers 1946-1964	**Generation X** 1965-1980	**Millennials/Gen Y** 1981-1996	**Generation Z** 1997-2012
			
Strengths	**Strengths**	**Strengths**	**Strengths**
Work-centric/career driven	Results and efficiency focus	Excellent technical skills	True digital natives
Independent and self-reliant	Metrics and data driven	Can-do attitude	Radically inclusive
High level of competitiveness	Conventional leadership style	Excellent multi-taskers	Mobilizes around causes
Challenges	**Challenges**	**Challenges**	**Challenges**
Support hierarchical thinking	Forgotten generation	Lacking professional loyalty	Requires constant feedback
Believe in face time at office	Works to live vs. live to work	Quickly bored and frustrated	Little delineation between work and home
Aggressive & confrontational	Lack of process focus/skills	Enjoys working remotely	Can be focus challenged

Sources: Patel, 2017; DeMers, 2017; Rezvani & Monahan, 2017; Francis & Hoefel, 2018; Pistrui & Kleinke, 2019; Pew Research, 2019.

Southeast Michigan Snapshot

Talent Pipeline DNA: Professional Competencies, Motivational Factors & Behavioral Styles

Research conducted by University of Detroit Mercy in partnership with Oakland and Macomb Community Colleges, Walsh College and TTI Success Insights investigated three key segments of the talent pipeline in Southeast Michigan:

1. **Next-Gen Leaders (NGLs):** Engineers from OEMs and Tier 1 suppliers who have a Master's degree and are emerging leaders in their organizations. This group is comprised primarily of Gen Xers and Millennials.
2. **Next-Gen Engineers (NGEs):** Undergraduate engineering students who are in their freshmen and junior years. This group represents Gen Zers.
3. **Next-Gen Skilled Trades (NGSTs):** Individuals enrolled in two-year skilled trades programs such as robotics, cybersecurity and welding. They represent a cross section of generations, but are primarily Millennials and Gen Zers.

Methodology

To collect data, our academic team partnered with TTI Success Insights, a 30-year-old Arizona-based firm that serves clients in 90 countries and 40 languages. The firm is the global leader in providing research-based validated compliant assessment and coaching tools that enable organizations to meet their talent management needs. Their client base includes Fortune 500 companies, government agencies and educational institutions around the world.

For data collection, TTI's TriMetrix® DNA assessment suite was used. TriMetrix® DNA assessments are used by organizations for professional development and social science research. The TTI TriMetrix® DNA assessment suite is designed to increase the understanding of an individual's talents in three distinct areas: competencies, motivators and behavioral styles. Understanding strengths and weaknesses in each of the three areas will lead to personal and professional development and a higher level of personal satisfaction.

For this report, the TTI TriMetrix® DNA assessment was administered online between the fall of 2017 and the winter of 2019, with 473 individuals participating in the study, 66 NGLs, 182 NGEs and 225 NGSTs. The sample is comprised of 349 (74%) males and 124 (26%) females.

Females play an important role in the talent pipeline representing 29% of the NGST and 26% of NGE. However, when it comes to NGLs, females trail off to 17%. There is cause for concern that perhaps either in perception, or reality, there are fewer opportunities for females to advance into management positions. This is an area worthy of further investigation and analysis beyond the scope of this report.

The TTI mean is a sample of all the individuals who have taken the TriMetrix® DNA assessment suite. This is a national sample across all job sectors and allows for comparison.

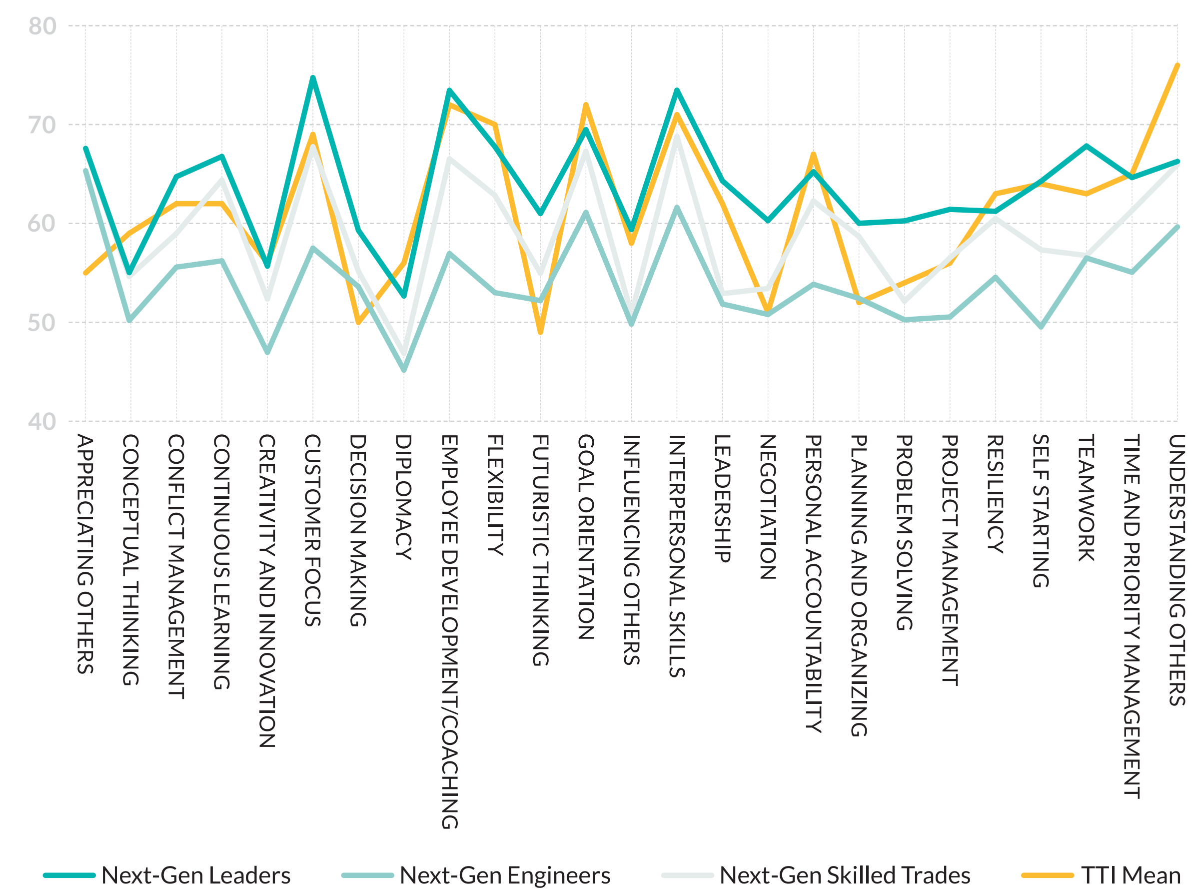
Professional Competencies

Based on responses to a series of questions, this section of the report presents an overview of the development of 25 professional competencies that contribute to superior performance in many types of jobs. For many jobs, professional competencies, often referred to as "soft" skills, are as important as technical skills in producing superior performance. Professional competencies are transferable to a variety of professions, whereas technical skills are usually job-specific.

Figure 5 presents a comparative visual overview of the 25 professional competencies of each segment of the talent pipeline as compared to the TTI mean, a sample of all the individuals who have taken this survey across all job sectors. As expected, the Next-Gen Leaders exhibit the greatest level of professional competency development. They also have the greatest level of experience and highest level of education. They have very well-developed interpersonal skills combined with a strong customer focus.

Next-Gen Engineers are young and in their formative years and their level of professional competency development reflects this. They are found to be goal oriented and demonstrate some level of interpersonal skills. The Next-Gen Skilled Trades people comprise four different generations and thus represent a more eclectic and diverse set of individuals. They demonstrate strong interpersonal skills and show appreciation for others.

***Figure 5:** Southeast Michigan Professional Competencies vs TTI Mean*



Next-Gen Leaders

Figure 6 provides a deeper look into the professional competencies associated with each segment of the talent pipeline. The Next-Gen Leaders were found to be well positioned to lead their organizations into the future. This group, which is comprised of a mix of Gen Xers and Millennials, is customer centric and demonstrates the ability to help others develop and grow. As one might expect, they have well developed communication skills and possess the ability to interact and relate with others.

Turning to the three least developed skills, it is eye opening to learn that this group, the future leaders, score low on creativity and innovation. Being able to effectively create new approaches, designs, processes, technologies and systems will be imperative for companies to navigate the disruption associated with Industry 4.0. The same can be said for conceptual thinking. Electrification and autonomous vehicle development (not to mention new business models) requires analyzing hypothetical abstract concepts and formulating connections and new insights.

Strategy for Success: These findings provide an excellent opportunity for educators and industry leaders to review, refine and reform educational practices to address these deficiencies both in the schools and respective companies. These findings suggest that topics such as design thinking, creativity, social science and systems engineering should be integrated into all levels of education.

Next-Gen Engineers

Next-Gen Engineers, comprised of Gen Zers who are all undergraduate engineering students, represent the next generation of engineering talent. Figure 6 shows this group has their own set of unique strengths. The top two professional competencies they have developed at this stage in their lives seem to align with their generational tendency to be radically inclusive. This includes identifying with and caring about others. They exhibit the abilities of building rapport and relate well to different kinds of people. It is not a surprise that this group is goal orientated, given the intensity and rigor associated with earning an engineering degree. There is some cause for concern when reviewing the least developed professional competencies in the Next-Gen Engineering segment. They lack the ability to demonstrate self-initiative. Today's work environment with rapid change and disruption demands an opportunity-seeking mentality and self-drive. This is also a point of potential conflict between Gen Zers and Gen Xers.

Just as the Next-Gen Leaders segment scored low on creativity and innovation, the Next-Gen Engineers do as well. The fact that both groups score so poorly in this area should be a wakeup call for both educators and industry leaders.

Strategy for Success: These findings suggest that educators and industry leaders should join forces to review current curriculum methods and develop an action plan to strengthen the creativity and innovation skills in both students and faculty.

Next-Gen Skilled Trades

Next-Gen Skilled Trades people demonstrated strong development of three primary professional competencies. First, they exhibit solid interpersonal skills associated with effectively communicating, building rapport and relating to a diverse group of people. Second, they were found to have developed a customer focus with the skills to anticipate and meet customers' needs, wants and expectations. Third, Next-Gen Skilled Trades people were found

Figure 6: Competency Strengths and Weaknesses of Southeast Michigan Talent Pipeline vs TTI Mean

Next Generation Leaders (NGL)

	Competency	Average	TTI Mean
Top 3	Customer Focus:	75	63
	Employee Development:	73	72
	Interpersonal Skills:	74	67
Bottom 3	Creativity & Innovation:	56	56
	Conceptual Thinking:	55	59
	Diplomacy:	53	56

Next Generation Engineers (NGE)

	Competency	Average	TTI Mean
Top 3	Appreciating Others:	65	55
	Interpersonal Skills:	62	71
	Goal Orientation:	61	72
Bottom 3	Self-Starting:	50	64
	Creativity & Innovation:	47	56
	Diplomacy:	45	56

Next Generation Skilled Trades (NGST)

	Competency	Average	TTI Mean
Top 3	Interpersonal Skills:	69	71
	Customer Focus:	68	69
	Appreciating Others:	68	72
Bottom 3	Problem Solving:	52	54
	Influencing Others:	51	58
	Diplomacy:	47	56

Two or more standard deviations above the mean

One standard deviation above the mean

One standard deviation below the mean

NGL n = 66, NGE n = 182, NGST n = 225

to be appreciating of others, having the ability to identify with and care about others. These findings reflect that this segment of the talent pipeline is often working and attending school part time. They represent a cross section of generations and socio-economic strata.

In terms of least developed professional competencies, three items emerged. The Next-Gen Skilled Trades group lack problem solving skills associated with defining, analyzing and diagnosing key components of a problem to formulate a solution. Although they have strong interpersonal skills, they have underdeveloped abilities to influence others. Personally, they are weak at affecting other's actions, decisions, opinions or thinking. Lastly, is their lack of diplomacy as they struggle with the ability to effectively and tactfully handle difficult or sensitive issues.

Strategy for Success: These insights suggest that Community Colleges have both the need and opportunity to review, recalibrate and redirect programs to improve Industry 4.0 skillsets. As skilled trades continue to transform around Industry 4.0 technologies, the workforce will most certainly need better problem-solving competencies. Further, as skilled trades become more collaborative in nature (think robotics, the Internet of Things (IoT), cloud computing and Big Data intersections) the workforce will be confronted with a different set of human interaction. New types of working relationships will require the ability to influence others with diplomacy, especially across and between generations.

Professional Competencies Below the National Mean

There are five professional competencies that the Southeast Michigan data set scores below the TTI mean. Three noteworthy themes emerge out of the data (see Figure 7). 1) They score below the mean as it relates to understanding the uniqueness and contributions of others. 2) They score lower on conceptual thinking. Conceptual thinking relates to identifying patterns and formulating connections and concepts. 3) They score lower on personal accountability.

These findings suggest that our emerging talent pipeline is more rigid, light on sensitivity (empathy) and less focused than the TTI mean. These are important distinctions in an Industry 4.0 environment.

These findings provide some valuable insights and direction into what educators, industry and policy makers should begin to address. For example, how can our educational system begin to develop measurable ways and methods to improve the conceptual thinking skills in their graduates? As the workforce proceeds through generational leadership succession, how can both industry and educators help people empathize and embrace the uniqueness and contributions of others? This is vital to strengthening the talent pipeline.

Strategy for Success: These finding suggest that instilling a broader goal orientation and personal and professional development must become core components of strengthening the quality of the workforce. With these new-found insights, educators, industry leaders and government officials should review existing workforce development programs and initiatives to determine if these deficiencies are being addressed and begin immediately to formulate strategies and secure funding to address these core Industry 4.0 skill deficiencies.

Behavioral Styles

For this report, we utilized DISC, a behavior assessment tool based on the theory of psychologist William Moulton Marston. DISC centers on four different behavioral traits: Dominance, Influence, Steadiness and Compliance. There are no best styles and all people exhibit some level of intensity of all four components.

Understanding behavioral styles can help in gaining the commitment and cooperation of others, resolve and prevent conflict, build effective teams and enhance awareness and personal performance. People exhibit both natural behavioral styles (the ones we wake up with in the morning) and adapted behavioral styles (the ones related to our environment, level of stress and job requirements). Figure 7 presents an overview of each segment's behavioral styles.

One common theme is that all three groups lack a sense of urgency to take immediate action. Both the engineering and skilled trades segments are resistant to frequent change, including rapidly shifting between tasks. Another surprising finding is that Next-Gen Leaders scored low in analysis. This seems counter-intuitive given the nature of their work.

***Figure 7:** Behavioral Strengths and Weaknesses of Southeast Michigan Talent Pipeline vs TTI Mean*

Next Generation Leaders (NGL)

	Average	TTI Mean
Top 3		
Competitive:	59	49
Customer-Oriented:	59	64
Persistent:	59	61
Bottom 3		
Organized Workplace:	53	51
Urgency:	54	43
Analysis:	55	53

Next Generation Engineers (NGE)

	Average	TTI Mean
Top 3		
Persistent:	67	61
Consistent:	66	61
Following Policy:	64	60
Bottom 3		
Urgency:	41	43
Frequent Change:	48	52
Versatile:	48	54

Next Generation Skilled Trades (NGST)

	Average	TTI Mean
Top 3		
Consistent:	68	61
Persistent:	68	61
Following Policy:	66	60
Bottom 3		
Urgency:	37	43
Competitive:	46	49
Frequent Change:	46	52

One standard deviation above the mean

One standard deviation below the mean

NGL n = 66, NGE n = 182, NGST n = 225

Motivational Factors

Motivators are the driving forces or the "why" of what we do. Understanding motivators provides insights into what drives people's actions in personal and professional settings. Primary motivators can be referred to as the aspects of life for which one is passionate and perceived as important, or the thoughts that provide one with purpose and direction in life. This report defines 12 motivational factors (see Figure 8).

Next-Gen Leaders

Figure 9 (see pg. 26) provides a comparative overview of the motivational factors shaping the talent pipeline in Southeast Michigan. The Next-Gen Leaders are found to be commanding but not very collaborative. They are driven by status, recognition and control over others. They are not motivated to play a supporting role if given a choice.

Next-Gen Engineers

As one might expect, the Next-Gen Engineers, who are undergraduate engineering students, are driven by the functionality and objectivity of their surroundings. They are in a rigorous, structured and demanding environment so this driving force is critical to achieving their degree. This group is also receptive to new thoughts and ideas but are driven only by practical results. They are driven to assist others for a specific purpose, not just for the sake of being helpful or supportive. It is also not surprising that Next-Gen Engineers do not score higher in resourcefulness. This is a result of being in an academic environment that has yet to adopt new methods that fall outside a defined system for learning.

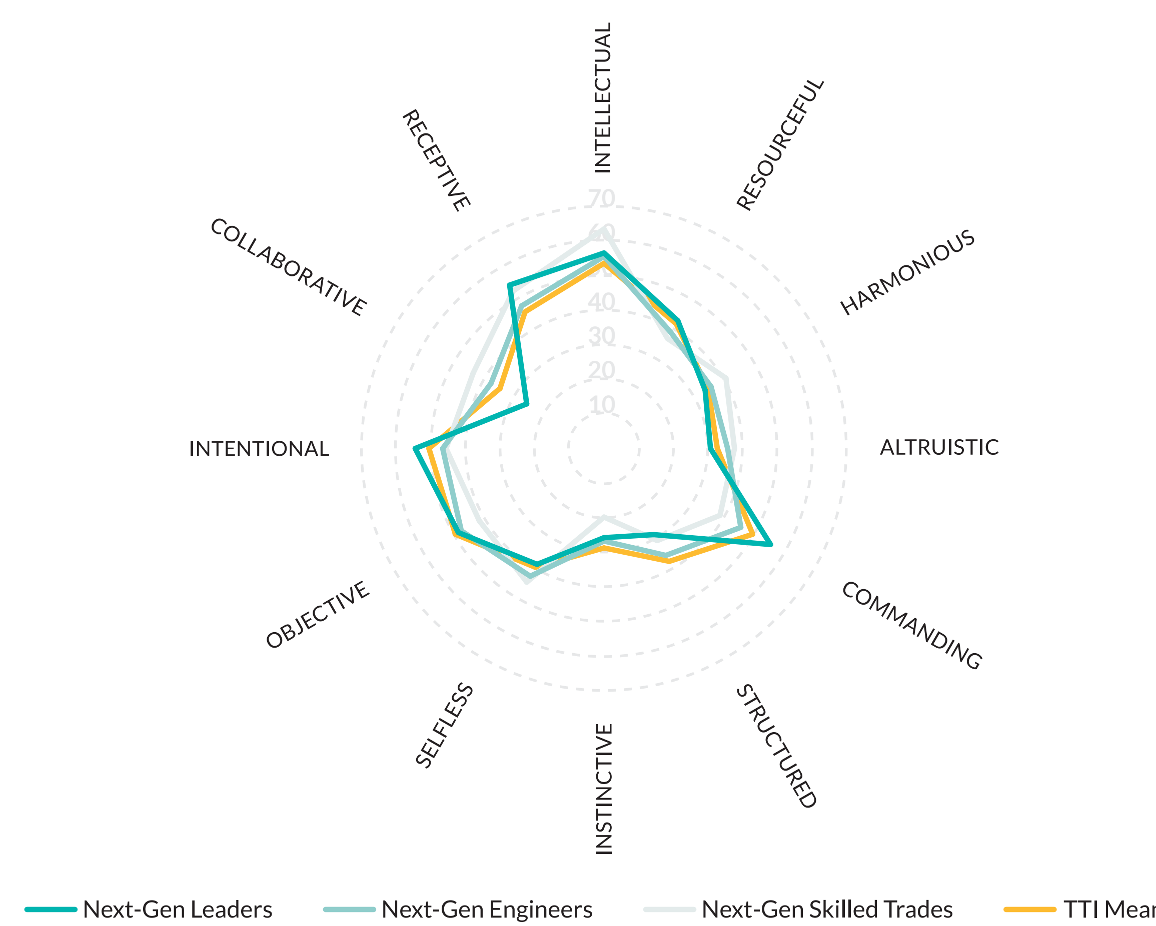
Next-Gen Skilled Trades

The Next-Gen Skilled Trades group has some surprising and insightful motivators. First, they were found to be intellectually driven by opportunities to learn and acquire knowledge and had the highest level of motivational intensity. This may be due to the fact that they may be working fulltime while pursuing their education. Counter to this, Next-Gen Skilled Trades people were also found to be much less instinctive, whereby they can utilize past experiences and intuition. As students, they are seeking new knowledge and skills that can be used to improve their everyday lives and those of their families. Another interesting insight from this group is that they are not driven to achieve practical results through maximizing both efficiency and returns for their investments of time. This suggests that this group may be searching for opportunities that are not clear or well defined.

Motivational Factor Common Threads

Patterns emerge between the three groups when looking closely at motivational factors. All three segments are driven by an intellectual quest. They are motivated by opportunities to

***Figure 8:** Southeast Michigan Motivational Factors vs TTI Mean*



learn and acquire knowledge. This is encouraging as the integration of Industry 4.0 technologies demand intellectual curiosity and engagement. The Industry 4.0 disruption and rapidly changing environment requires continuous learning and new skills.

Another commonality is that both the Next-Gen Engineers and the Next-Gen Skilled Trades groups are receptive to new ideas, methods and opportunities that fall outside a defined system. This would seem logical as both groups are in school. The same logic holds true for the Next-Gen Leaders who are driven by status, recognition and control over personal freedom. Conflict could arise between Next-Gen Leaders, who have a drive to command and control, and the Next-Gen Engineers and Next-Gen Skilled Trades people who are motivated to pursue new ideas, methods and opportunities.

Another common thread is that all three segments have indifferent traditional approaches, proven methods and a defined system. Perhaps this is the result of the Industry 4.0 environment where change is constant, and people are being forced to adopt new methods and adapt to a changing work environment. This may also reflect generational differences where certain groups want to "do it their way."

Figure 9: *Motivational Strengths and Weaknesses of Southeast Michigan Talent Pipeline vs TTI Mean*

Next Generation Leaders (NGL)	Average	TTI Mean
Top 3		
Intellectual:	57	54
Commanding:	56	50
Intentional:	55	51
Bottom 3		
Collaborative:	26	35
Instinctive:	26	29
Structured:	29	38

Next Generation Engineers (NGE)	Average	TTI Mean
Top 3		
Intellectual:	56	54
Receptive:	58	46
Objective:	47	50
Bottom 3		
Instinctive:	27	29
Structured:	36	38
Altruistic:	37	33

Next Generation Skilled Trades (NGST)	Average	TTI Mean
Top 3		
Intellectual:	64	54
Receptive:	53	46
Intentional:	46	51
Bottom 3		
Instinctive:	20	29
Structured:	31	46
Resourceful:	37	42

One standard deviation above the mean

One standard deviation below the mean

NGL n = 66, NGE n = 182, NGST n = 225

Conclusions

- Team agility, an entrepreneurial mindset and the ability to persist through failure are fundamental to creating and sustaining networks of interrelated teams that are key to Industry 4.0 implementation.
- The Industry 4.0 talent pipeline needs to produce workers that are perpetual learners (often in real-time) that have the ability to think in new and dynamic ways.
- Organizations that focus on human need, technological feasibility and business viability will be best positioned to leverage and prosper in an Industry 4.0 environment.
- Small and medium-sized enterprises greatly lag large corporations in early adoption of Industry 4.0 technologies. (Schröder, 2016) Most view large investments in new technologies with caution and trepidation. However, failure to integrate the cyber, physical and human systems in a timely manner will rapidly render obsolete the enterprise unwilling or unable to adapt to Industry 4.0.
- To successfully navigate the Industry 4.0 environment (and beyond), organizations will need to integrate four different generations in their workforce.
- Next-generation engineers (currently in the higher education system) are trending low in the category of resourcefulness. This is a result of an academic system that has yet to fully appreciate, embrace and adapt to the rate of Industry 4.0 technology change.

Action Items

- Small and medium-sized businesses should not wait for change to trickle down to them. Instead, they need to control their own positive disruption by creating adaptive spaces (both physically and virtually) that encourage the free flow of ideas.
- To fully leverage the Industry 4.0 environment, enterprises will have to de-scale the traditional hierarchies of siloed organizations and implement agile methodologies to drive change by taking advantage of emerging technologies and the changing nature of work tasks.
- Findings suggest that topics such as design thinking, creativity, social science and systems engineering should be integrated into all levels of education, as personal and professional development become core components of strengthening the quality of the workforce.
- In order to successfully navigate the Industry 4.0 environment (and beyond), enterprises should utilize a variety of available resources to support their workforce development including validated assessment tools, advisors, educational institutions and professional service providers.

Intel Insights

Industry 4.0: Transforming People, Processes, Technologies & Organizations

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Predictions about Industry 4.0 are everywhere. Autonomous machines will self-monitor and organize their own maintenance. Customized products will be built on highly flexible production floors that link to inventory systems, with just-in-time delivery of needed parts without human intervention.

But what does it take to get from where most companies are today to a future where these predictions are reality? Intel Corporation has been working with over 400 manufacturers and their ecosystem partners to better understand how this transition actually plays out—and they've discovered some interesting things.

The Power of Vision

First, most of the companies Intel is talking to are following the advice of pundits: Start small. They focus on point solution pilot or proof of concept projects. But even when these projects are successful these islands of excellence are often not scalable because larger integration challenges were neglected. Companies instead should be following the mantra: Think Big, Start Small. Without a vision for what Industry 4.0 tools and technologies could do for your factory, how can you know whether or not progress is being achieved?

It Takes More than Technology

Another challenge could be dubbed "If I have the technology, problem solved." For example, a predictive maintenance solution requires an understanding of the forces that impede machine performance. But it requires that the data exist and can be collected in a form useful across systems. Among the companies Intel works with, lack of information in a suitable form, sharable across organizational silos and available in a timely manner were top of mind obstacles to Industry 4.0 transformation.

Data-Driven Culture

A third hurdle to Industry 4.0 transformation is corporate culture. For some, the ROI is too unclear to be decision-ready, particularly when considering risks. While others want to try "something" just to get started and learn. Both thought patterns miss the mark. The problem lies not in how to get started, but in how to grow teams that can define the problem space, assess the options and understand how to gauge value add of any particular solution in terms of metrics that drive operational performance and business value.

Convergence & Empowerment are Essential to Industry 4.0 Transformation

Industry 4.0 success also requires a convergence of cultures. In a transformation being driven by digital technologies, operational excellence and experience (OT) must be merged with that of information technology (IT). Having one without the other results in: (1) great operational ideas that lack the digital infrastructure needed to be sustainable; or (2) advances in IT systems that fail to be deployed in the factory because their value cannot be described in metrics that reflect operating imperatives.

The solution is very simple—but hard to achieve. We must build an organizational culture where IT and OT converge. And it's not just OT and IT professionals who will need to be involved. Manufacturing expertise resides throughout the factory. While individuals at all levels see a mandate for change, they often do not feel empowered today to discover, test and deploy new ways of working with these technologies. Convergence and empowerment—two concepts that are rarely linked.

Industry 4.0 Requires Organizational Changes

The organizational silos that have supported economies of scale production may not be well-suited to Industry 4.0. The resulting siloed decision-making is often a hindrance in the rapidly changing world of Industry 4.0. A colleague who works with robot deployment noted that the U.S. is well behind Japan in the use of collaborative robotics (cobots). The main reason, he asserts, is that in Japan managers—from maintenance to first-shift supervisors to controls specialists—are empowered with both funding and decision-making autonomy. Without that, he contends, the focus of real problems gets lost in the corporate accounting shuffle.

Companies serious about Industry 4.0 transformation need to embark on a journey that will encompass their people, their processes, their operating technologies and their organization. While the first three have gotten more attention in the past couple of years, it is the latter—organization—that may be the biggest barrier to change.

The Internet of Things

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The Internet of Things (IoT) describes internet-connected devices with built-in sensors that can record, process and/or transmit data to the cloud for a variety of applications including system diagnostics, control, remote monitoring and measuring trends. IoT is essentially the nervous system that unleashes the power of cloud computing, data analytics, machine leaning and artificial intelligence (AI). The upcoming 5G launch—the latest generation of cellular mobile communications—is expected to exponentially expand the number of IoT devices, throughput and reliability. In this section, we will dive into the managerial technical investment decision making process, in light of the disruptive impact of IoT technology.

IoT is a key enabler for Industry 4.0, directly impacting:

- **Interconnection:** Communication between smart cyber-physical systems—machines, devices, sensors and people via the internet.
- **Data:** Connected devices provide real-time data, that can be monitored, analyzed or controlled potentially 24-7.
- **New Services & Analytics:** Paired with advanced analytics and machine learning, new value is created from data, including automatic monitoring and autonomous functions of industrial systems.

Current estimates of IoT applications and future predictions vary quite widely from one source to another. For example, a 2017 study of IoT predicts that there will be 25-50 billion IoT devices by 2020. (Saariko, et.al., 2017) A recent Forbes report projects IoT use will save $11 trillion annually by 2025 and corporate profits will be boosted by 21% by 2022. (Forbes Insights, 2017) A PTC report predicts a $10trillion to 15 trillion addition to GDP over two decades and over 50 billion IoT devices by the end of this decade. (PTC, 2017) While estimates vary significantly, most studies show that the global base of connected devices will grow anywhere from 15%-30% CAGR (compound annual growth rate) over the next several years. According to Cisco, by 2022, almost half of the world's 28.5 billion connected devices will be specifically dedicated to IoT applications with machine-to-machine data transfer connectivity, and while home and corporate devices will make up the bulk of this connectivity, the connected car will have the fastest growth rate (28% CAGR). (Gagliordi, 2018)

> **IoT is essentially the nervous system that unleashes the power of cloud computing, data analytics, machine leaning and artificial intelligence (AI) solutions.**

Emerging Trends

Proliferation of IoT in All Sectors

IoT is one of the fastest growing industrial trends and is being implemented in all sectors of the economy. A recent Forbes report identified the energy, finance, health care, manufacturing, retail, information technology, telecom and transportation sectors to be at least 40% dependent on IoT technologies. (Forbes Insights, 2017) Based on early adoption data, IoT has the most influence in areas of customer experience and financial applications. However, IoT will eventually affect all aspects of a business merely because product-based sensors can provide enormous insight into the enterprise from manufacturing through marketing, customer demands, product customization and customer experience.

The Rise of the IoT Ecosystem

A successful IoT system needs three main types of players:

1. **Engager:** A strategy or procedure that develops products equipped with a sensor or a network of sensors, that captures real-world events in the form of digitized data.
2. **Enabler:** A reliable network that provides wireless connectivity between the sensors and collector of data.
3. **Enhancer:** An individual or system that uses, enhances and analyzes the data to develop useful practices.

This means that IoT activity is not achieved by a single individual. It is important to build an IoT ecosystem that not only involves all aspects of the enterprise, but also includes partnerships with others who are working with customers so that high value can be offered to the customer along with improving value for the company.

Big Data Creates New Opportunities

In every industry sector, the inclusion of IoT devices results in the generation of huge quantities of data. The transition from a detached product to an IoT-connected product opens the door to understanding how customers use the product, product lifecycle tracking, service and maintenance records and more. Often, new-adapters of IoT struggle to effectively utilize the data now available to them. If the collected data can be converted to product knowledge, IoT has the potential to alter industries by rapidly improving product lines and business models and additional value creation for the customer, all leading to opportunities for increased revenue.

5G: Game-changing Technology for the Next Generation of IoT

The telecom industry is poised to break into the fifth generation, or 5G, which promises 100-times the speed of 4G LTE and will enable a new wave of ultra-efficient, internet-connected devices. That means, for instance, you might be able to download a full-length movie in a matter of seconds.

5G, with its low latency, high throughput and gigabit speeds, could take IoT to a whole new level (Automotive, 2018) and is anticipated to greatly impact the automotive and manufacturing sectors.

The Leap to 5G

What to expect:

- High throughput: 100-times or more data relative to today's 4G connectivity
- Ability to manage billions of IoT connections simultaneously
- Low latency: Latency of 1-10 m-sec vs. 4G's 100 m-sec

Early Adoption Experiences are Raising New Questions

Fast-emerging IoT technology is becoming a major disruptor and raises many questions for companies who want to adopt IoT applications but are not fully aware of its impact. Some of these questions are:

- What can be gained by connecting products directly to the internet that cannot be gained by the current slew of gadgets?
- What are the financial and logistical implications of the transition from the current state to a fully IoT-enabled state?
- Which of my competitors are further along on the path of adoption than others?
- What lessons can be learned from IoT implementations in other market segments ?

Industry Analysis

Automation Alley recently conducted a small survey of 70 manufacturing professionals to better understand the state of Michigan's manufacturing base as it relates to Industry 4.0. Respondents of the survey were mostly leaders of small and medium-sized companies. When asked how important IoT is to their industry sector, 33% of respondents indicated IoT is used in some production within their sector. However, more than 25% of individuals surveyed did not respond to this question. (Figure 1) This may be a matter of concern as they may be falling behind the market trends in their own sector, or they may not be aware of the ways in which IoT can leverage their work.

When asked about an implementation timeline, about 34% of the respondents indicated that there is no plan in their enterprise to implement any IoT solutions and over 30% of individuals surveyed did not respond to this question. About 36% of respondents plan to implement within the next year or have already implemented. (Figure 2)

One long-term outcome of the use of IoT is the opportunity to develop new revenue streams through revision of the business model, but challenges exist. When asked what the biggest challenge is within IoT, the majority of respondents felt investment cost was the main roadblock. (Figure 3) Another 22% indicated lack of training as the main reason. Other reasons with substantial respondents agreeing include lack of clear understanding on the part of senior management and a perception that IoT would not be beneficial for their business. Once again, a large percentage of individuals surveyed did not respond to this question. The response to this question clearly indicates a lack of awareness of the value of IoT. It is also clear that these enterprises may have not ventured into any systematic cost-benefit analysis around this technology.

Since the respondents were mostly from small to medium-size companies across Michigan, several trends are emerging for this population: (1) Over 50% of companies find IoT applications important to their sector, (2) The majority of the applications seem to be at a fairly early stage, (3) More awareness of IoT's impact in their own sector is necessary, including cost-benefit analysis and innovative use of technology and associated data, (4) Sector leaders need to explore ways to innovate new product or service ideas using the access to enormous amounts of data that would be generated, and (5) A large percentage of non-response is concerning. While the reason for that is not known, it could be a sign of lack of awareness.

Figure 1: *Importance of IoT in Your Industry Sector*

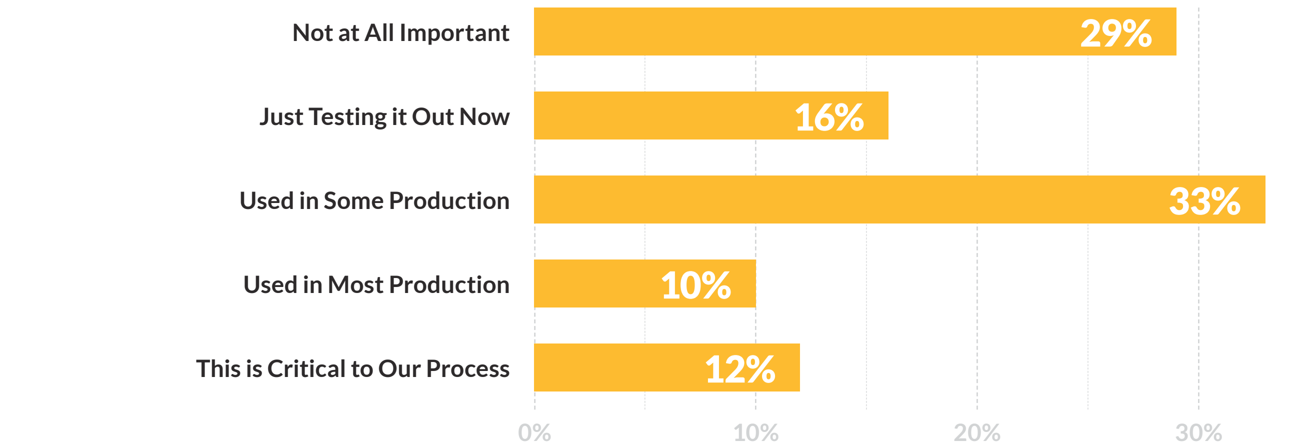


Figure 2: *Plans to Implement IoT in Your Company*

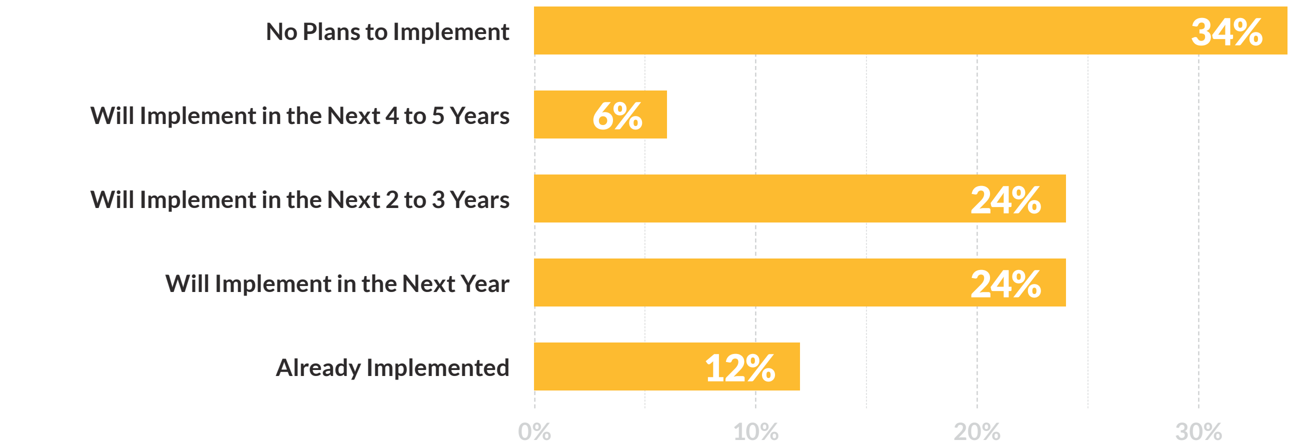
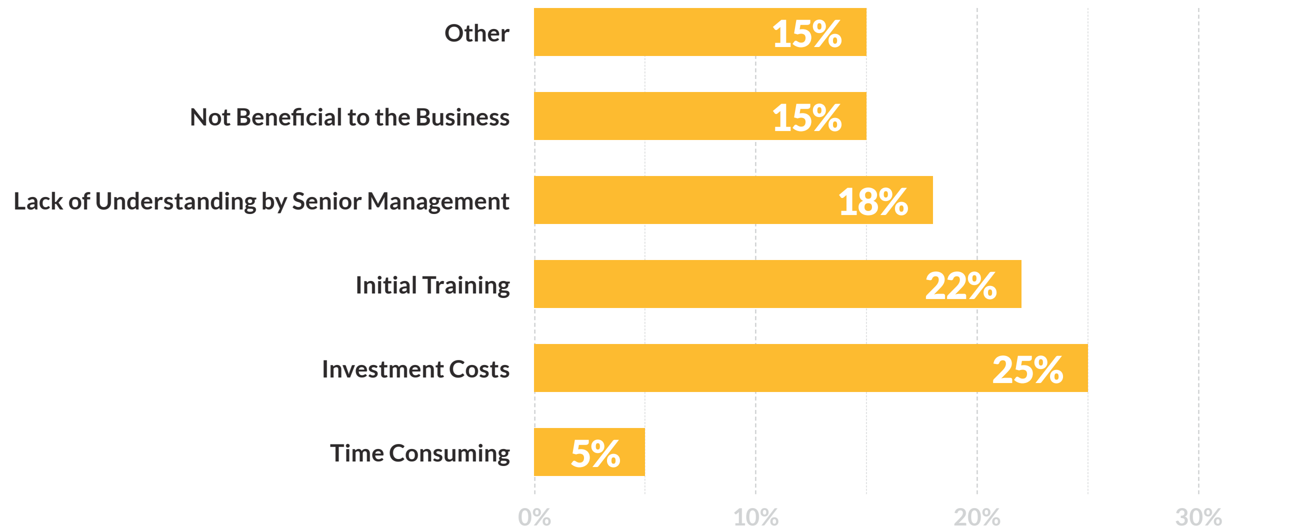


Figure 3: *Biggest Challenge of Using IoT*



Advantages & Challenges of IoT Implementation

Advantages

- IoT devices are leading to efficient tracking and monitoring of products, creating predictive maintenance and just-in-time servicing improvements.
- IoT devices and the data generated from these devices lead to numerous opportunities for improving the design and functionality of products, operational efficiencies, cutting wasteful activities and boosting profits.
- IoT devices generate huge amounts of data, which could lead to innovative service opportunities, paradigm-shifting business models and additional profit through new value creation for the enterprise and its customers.
- IoT devices lead to increased real-time visibility throughout the supply chain. OEMs have the ability to monitor suppliers for issues that may impact their operations.

Challenges

Failure to Demonstrate Business Value: Transitioning from a traditional business model to an IoT-enhanced business is not natural for most enterprises. The final goal ought to be making profits through enabling IoT technology. Enterprises should consider proof of value and not just proof of concept, which takes a holistic look at both the technical and business feasibility. (Saarikkoet al., 2017) At the outset, leaders need to consider some of the following important questions: What will be the business model? Will you share data and/or information freely and add value to your product (i.e. compete based on quality), or will you charge for the data/information for a new revenue stream? What will you do with the data? Will you automate (replace labor) or "informate" (empower employees with faster and more accurate information)? What products and services are going to satisfy customer needs and create value for the clients and the company? Can the product create value even after it is sold? What is the return on investments and cost-benefit analysis of transitioning from a product-based to product and services-based business model? What profits will have to be sacrificed? What will be the financial gain?

> **Strategy for Success:** Determining a comprehensive return on Investment and close analysis of the financials.

Protecting the Data: With IoT applications ever increasing, large amounts of sensitive data will be generated very rapidly. Data security is perhaps the most critical concern. There are two very important aspects of the data that need to be handled up front: ownership and security. (Sfar et.al., 2018) Since there will invariably be partnerships involved, it is important to clarify who will own the data: the owner of the machine or the data gathering entity? While data security has always been a concern in business, handling enormous amounts of data in the cloud raises new levels of concern. Companies are devoting significant resources to ensure proper data security and encryption.

> **Strategy for Success:** Have clear agreements about the data ownership and a robust data protection system that is not affected by system scaling.

IoT Requires New Partnerships: All companies work with partner companies, suppliers and service providers. These partners are also engaged in IoT-enhanced services and goods, forming the IoT ecosystem. The strengths and needs of the partner entities are important since new innovations happen in the world of intersections. An innovative approach is to look at everyone's capabilities and seek opportunities to develop new strategic partnerships, new product lines and services by leveraging strengths and capabilities of partners in the IoT ecosystem.

> **Strategy for Success:** Engage the entire IOT ecosystem to form strategic partnerships.

Development of System Architecture: Think of the big picture and the entire system. What is the system architecture? Who is the service provider? What are the standards? Who are the partners? IoT technologies are evolving fast and their implementation in products and maturation of IoT technology are all happening simultaneously, which brings associated challenges. There are many vendors in the market competing for market share and nascent technologies are not standardized. For example, industrial machine sensor data is often aggregated via proprietary protocols. Therefore, it is not necessarily possible to use standard wireless networks to capture sensor traffic. Like other maturing industry sectors, there is a propensity of sensor vendors to sell end-to-end solutions based on proprietary solutions. Standardization will be demanded and necessary. Compatibility among different technologies could be an issue and there is agreement that eventually an open and uniform standard is the desired outcome. (Daugherty et. al., 2017, Sharma, 2018)

> **Strategy for Success:** Think through and plan on how the entire system will function and push for standardization.

Getting Buy-in and Participation from Your Team: Adopting IoT enhanced business practices requires the involvement of everyone within the enterprise. The upper management through the people on the shop floor all have to embrace new technology, new protocols and practices. The leaders must ensure that everyone is committed to successful implementation. It is important to encourage everyone to innovate because the mere availability of large amounts of data and connectivity will open the door to new ways of doing things. The positive attitude of everyone involved will result in innovative ways of increasing company earnings and profits.

> **Strategy for Success:** Involve others beyond the R&D department and create a culture of innovation.

Upskilling and Reskilling Your Workforce: With the advent and proliferation of IoT enabled industries, routine and repetitive jobs will be computerized and automated while new skills will be desired in the workforce of tomorrow. Data analysis, computer programming, computer networking, hardware engineering, operations and manufacturing and marketing and sales are some of the many areas where a skilled workforce will be necessary. Workers will have to be trained and hired with consideration for new tasks such as establishing the IoT enhanced operations and supporting users of industrial products and services. Other workers will need to be transitioned to new tasks, for example a heavy machine operator could serve as a remote operator of robotic devices. The enterprise will have to determine how to help the employees with IoT and data so that they are empowered. How can the data experts and non-experts benefit from an IoT-enabled business practice? What training is needed for the employees so that they get up to speed with the job at hand? (Daugherty et al., 2017)

> **Strategy for Success:** Empower and re-train your workforce to be drivers of innovation.

IoT Use Cases

Many lessons can be gleaned from companies that have successfully implemented IoT. A number of cases are summarized here, separated into four groups related to the main thrust of the cases:

1. An example of digital transformation of an automotive product line.
2. Examples where IoT systems are used to monitor systems or processes and then initiate predictive maintenance.
3. Examples where IoT devices were used to improve productivity, efficiency and profits.
4. Examples where IoT systems were used to alter the business model and develop new revenue streams.

Digital Transformation of an Automotive Product Line

General Motors' OnSTAR

For most of its 100-plus years of existence, the automobile has been a standalone un-connected machine, working only to transfer its occupants from point A to point B. However, beginning in the late 90s, General Motors launched OnStar, an onboard telematics system that connected the car both to GM's back office and the first responder's ecosystem.

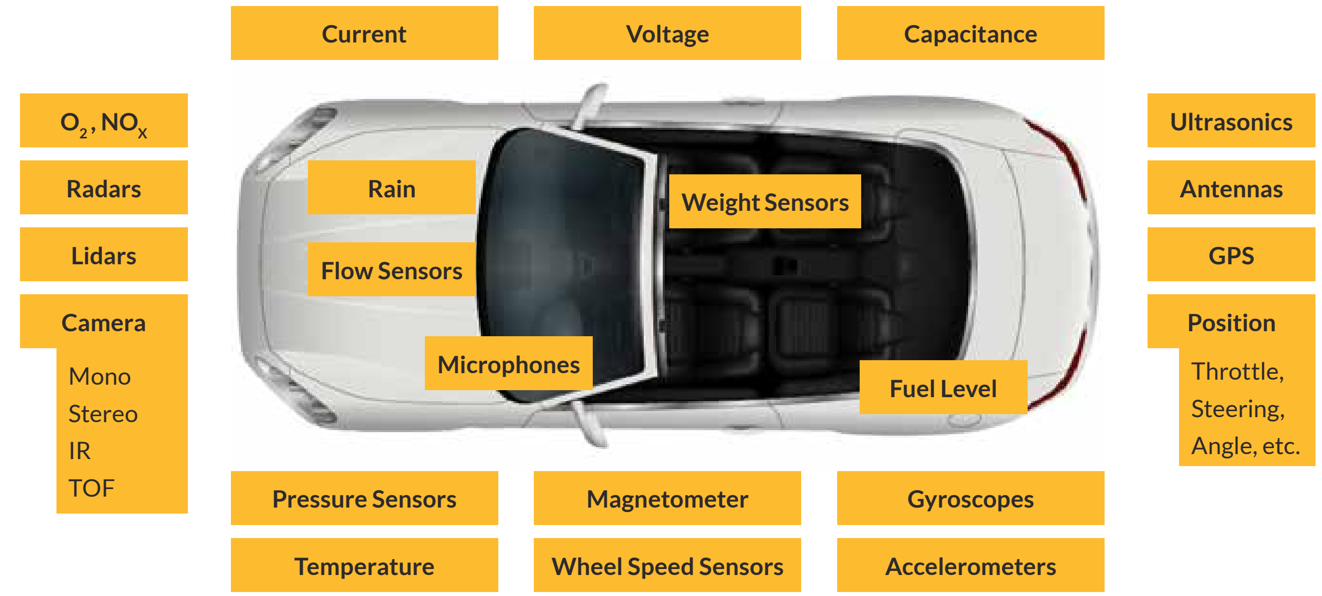
The connected car in theory enables real-time communication for a variety of use cases, such as traffic warnings, navigational re-routing, emergency calls in the event of an accident and some emerging applications such as H2C (home-to-car) actions like starting your car from home with voice commands via voice assistants such as Amazon Alexa or Google Assistant. In short, car-based connectivity is increasingly becoming mainstream.

Unlike many other IoT systems such as smart thermostats, home lighting, security or traffic cameras, the vehicle is not just a connected device but more like an IoT ecosystem with hundreds of sensors, many networked to each other, generating gigabits of data that provide many new possibilities and services for consumers. As shown in Figure 4, some of these sensors include GPS, gyroscope, accelerometer, radars, rain sensors and cameras; they are indeed the building blocks of automotive IoT. Even the driver and passenger have become "things" in this ecosystem through a new sub-system called DMS or Driver Monitoring System that generates data on a passengers' physical state, including distraction, fatigue and drowsiness.

Today's automotive IoT ecosystem can truly interact with surroundings, roads, drivers, the cloud and other vehicles. This internet-connected car with its numerous sensors generating gigabits of data is fast becoming a platform for many new mobility services. In the case of GM's OnStar, IoT technology enables:

- **Vehicle Diagnostics:** A vehicle system status update that includes data such as oil life, tire pressure, engine maintenance and other alerts is provided to the owner without needing to bring the car to the dealer. Owners can also remotely activate systems such as unlock and vehicle start remotely via smartphone.
- **E-Commerce:** This service allows the driver to get certain updates, while on the road, without having to leave the car. One example is the ability to complete a transaction such as a fuel purchase from the car's touchscreen via GM's Marketplace feature. Based on the car's GPS data and low fuel sensor, Marketplace allows local merchants to be the initial choice based on proximity and price.
- **Mobility Services:** OEMs as well as fleet operators are deploying a variety of mobility services using proprietary built-in connectivity to vehicle sensors. Here are three current examples of mobility services:
    1. Fleet management enables fleet owners to track real-time location, route guidance and better optimize efficiency and availability. This also has become a new aftermarket industry.
    2. Usage-based Insurance (UBI) allows customers to opt-in to get their driving pattern and duration of trips from insurance providers. There are several UBI services in the industry. GM has a similar service available with Progressive Insurance and Telematics Data Exchange by Verisk analytics.
    3. Car Sharing such as GM's Maven is a service that integrates a variety of data from the vehicle as well as from the external IoT ecosystem. Data such as vehicle location, availability and parking are used when a consumer makes a reservation from their mobile app.

***Figure 4:** Things (sensors) in the Vehicle IoT Ecosystem*



Source: Goswami, 2015

Monitor Systems and Process to Provide Predictive/Preventative Maintenance

GE Trains

GE Smart trains are the latest Tier 4 locomotives which have about 30 sensors to monitor the various engine parameters. The parameter data is relayed to GE transportation's global performance optimization center to be analyzed and the engine is scheduled for preventive maintenance or repairs. This effective use of IoT technology has helped GE to reduce the repair time from 3 days to 3 hours. (Shaddock, 2017)

Thyssenkrupp Elevators

Applying IoT to elevator maintenance, experts from Thyssenkrupp and Microsoft spent two years developing MAX, the industry's first real-time, cloud-based predictive maintenance solution. MAX leverages the power of Microsoft Azure, a cloud platform developed to advance IoT, to create a truly game-changing predictive maintenance service with the power to maximize elevator uptime. (Thyssenkrupp)

Shell Oil Fields

Oil company Shell is taking advantage of an IoT connectivity solution to improve the company's monitoring capabilities for its operations in Nigeria. Recently, U.S. IoT connectivity provider Ingenu and Croatian producer of industrial electronics and power electronics devices Koncar Inem delivered an IoT connectivity solution to provide digital oilfield capabilities to the Shell Nigeria pipeline facility. The digital oilfield solution provides pipeline surveillance and wellhead monitoring capabilities to remote infrastructure in the Niger Delta. (Tomás, 2017)

Leakbot Smart Water Leak Detector

LeakBot is a smart water leak detector that spots hidden leaks in the home before they become a bigger problem. With IoT technology, LeakBot can alert the home owner of any water leak via a smartphone app. (Twentyman, 2018)

Improving Productivity and Efficiency

Hershey's

Candy-maker Hershey's uses IoT sensors and Microsoft Azure algorithms for machine learning to improve production efficiencies on its Twizzlers candy line. Every 1% change in sizing for Twizzlers in a 14,000-pound holding tank resulted in a savings of $500,000. There are 22 sensors on each Twizzlers holding tank, with 60 million data points collected. (Maddox, 2017)

John Deere

John Deere is taking IoT out into the field by developing new technologies and embracing existing ones to boost the efficiency of prepping, planting, feeding and harvesting with the goal of improving per-acre crop yields. These technologies include IoT sensors, wireless communications, cloud apps and even a steering-wheel replacement that guides precision passes across arable land. (Greene, 2016)

Alitalia Airlines

GE's flight efficiency services are using IoT technologies to analyze the fuel usage data at Alitalia Airlines and find efficiencies which will reduce the fuel bill by 2% annually. The aircrafts are installed with dozens of sensors and instead of downloading data from sensors when the trip is over, flight data is tracked in real time. Sensors and actuators inside the engine are connected to the internet so data can be transmitted and viewed immediately. (Robb, 2014)

Enabling New Business Models

Rolls-Royce

Most airlines today use Rolls-Royce engines and the sensors installed in these engines will transfer data through IoT technologies to four Rolls-Royce data monitoring centers for monitoring engines health. Rolls-Royce, through its Total Care programs, essentially rents (versus selling outright) its jet engines using a model known as "power by the hour." Total Care is charged on a fixed dollar-per-flying-hour basis and, since Rolls-Royce retains ownership, the company actively manages the engine through its lifecycle to achieve maximum flying availability. (Insight, 2018)

Michelin

By leveraging the technology of IoT, Michelin Solutions—a division of Michelin that designs, develops and markets services for commercial vehicles—launched EFFIFUEL, an ecosystem that uses installed sensors in the vehicle to collect data, like fuel consumption, tire pressure, temperature, speed and location. EFFIFUEL provides a "satisfaction or your money back guarantee" by providing the fuel efficiency service risk-free to truckers and refunds them if the pre-defined targets for savings are not met. Michelin is able to take advantage of their head-start by building on the tires-as-a-service offering model to capture the larger space of drive management. (Emad, 2016)

Conclusions

- To remain competitive in the global marketplace, corporations need to adopt IoT technologies for efficiency, quality improvement and cost reduction, as well as to innovate for new value in products and services for customers.
- As companies implement new IoT solutions, they should consider the IoT ecosystem to form partnerships that will enhance new and innovative revenue streams for enterprises.
- Technological advancements and new applications are happening simultaneously with large scale adoptions of IoT. This has associated challenges such as lack of standardization of protocols, incompatibility of products and associated loss of productivity. Companies need to be aware of these and demand for more standardization.
- The emergence of IoT for tomorrow's businesses will benefit from 5G data communication technology.
- With more and more applications of IoT, the enormous amount of data generation creates new challenges of data ownership and security.
- Small and medium-size companies need to improve their awareness and knowledge of IoT.

Action Items

- As new IoT solutions are implemented, business owners must think holistically about the IoT ecosystems and form strategic partnerships to develop new business or product ideas.
- Companies should plan carefully and keep data security and ownership in mind as IoT applications are implemented.
- Policy makers should provide more information to small and medium-sized companies on the subject so that they are able to adopt IoT solutions for their enterprise.
- Government should push towards standardization of protocols of data gathering and transmission to ensure seamless device-to-device communication.
- Industry must empower and retrain people to be the drivers of innovation.

Case Study

Flooring Solutions Provider Shaw Industries Breaks Production Records with Splunk IoT

Problem

With annual sales nearing $6 billion, Shaw Industries Group, Inc. supplies flooring products and synthetic turf to residential and commercial markets around the world. To retain its competitive position, Shaw Industries wanted to implement Industrial Internet of Things (IIoT)-based, real-time factory floor analytics. According to Gabriel Gerges, Shaw's Samples division department manager, the company struggled with an overwhelming amount of data points and work order data, so much so that it was sometimes difficult to get a good understanding of issues or equipment performance. The company needed to better understand how its machines were running at any point, using real-time data.

Solution

Shaw Industries implemented Splunk Enterprise's IIoT-based, real-time factory floor analytics, allowing data from systems and industrial sensors to provide new business insights, improving production performance and spurring friendly competition among plant workers.

Implementation

Initially, Shaw Industries adopted the Splunk platform to provide visibility into a new post-consumer recycling facility. Given the ease of ingesting plant data and correlating disparate industrial data streams, additional Shaw manufacturing plants began implementing their own Splunk instances, resulting in a corporate initiative spanning 37 manufacturing facilities. Today, approximately 300 managers and engineers are trained to write Splunk searches for their machine and enterprise data. Plant managers and production managers consume Splunk dashboards for key business insights.

Outcomes

Since deploying the Splunk Enterprise IIoT solution, Shaw Industries has seen benefits including:

- Improved work order lead times
- Significantly increased sample panel production output
- Reduced energy usage at one facility, resulting in significant cost savings

"We blend IoT and business data," says Erika Swartz, a process engineer in the company's Fibers division. "The biggest value comes when you can put those sources together. I use business information to contextualize process data that previously had no context. This accelerates our time to insight and allows us to answer important questions on key business metrics. Before Splunk, our team spent a lot of time analyzing and combining reports to understand what impacted metrics. Now, we plug our data sources into Splunk and can automate analysis to understand where our opportunities are."

One group that is boosting output with the Splunk platform is the Samples division, which provides the sales force and some retail stores with hardwood floors, resilient laminate, ceramic tile and stone product samples. "At Shaw Samples, we're all about speed and servicing the customer," says Gerges. "One of the most important metrics our department uses is work order lead time — the time it takes to service a work order, from when it is created to the time it ships. Splunk has helped us drastically increase speed to drive our business."

In the past, the Samples division relied on lagging metrics to monitor production. Since the plant provided associates with a Splunk efficiency data dashboard to show real-time production, the plant has more than doubled production with focused process improvements. "Splunk is helping to change the way we do business," Gerges says.

An unexpected benefit of the factory floor dashboard is the sense of fun competition that has developed. "You might have two operators who are trying to outperform each other, and there's some good camaraderie on the floor now that you probably wouldn't have seen in the past," Gerges says.

At one of Shaw's carpet facilities, Gerges used Splunk Enterprise to analyze energy usage to help reduce energy intensity, which is a company-wide goal. "After a lot of testing, and making data-driven changes by utilizing Splunk, we reduced energy usage significantly," Gerges says.

Overall, by collecting and analyzing manufacturing and industrial sensor data in real time, Shaw has gained new visibility and insights into business-impacting issues like quality and performance.

"For us, transparency of information is important," Swartz concludes. "We have real-time information to make decisions quickly and accurately, and we are providing the same information to people across the business, so that they can make decisions, too."

Big Data

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Business leaders across the globe are wrestling with some important questions today, the most pressing of which is "what do I do with this enormous amount of data?" While Industry 4.0, and specifically the Internet of Things (IoT), enables companies to gather significantly more data than was ever previously envisioned, executives are now struggling to figure out how to best generate information and insights that are contributing to their bottom line, and whether Big Data is actually giving them a competitive advantage. It's a balancing act of evaluating the cost and benefits of adopting Big Data analytics.

There is a popular misconception that Big Data simply means more data, and more insightful and smarter data analysis. Early in its lifecycle, the term Big Data focused on the volume, velocity and the variety of data available. In more recent years, veracity and value were added. The real advantage of Big Data is a company's ability to gather data from a variety of sources and interpret information in real time to get a clearer and better understanding of their business. Big Data analytics allows companies to analyze at a much more micro level to create meaningful changes in the development of new products and services, and also to respond better to consumer issues and sentiments.

Big Data has created an information ecosystem where there is a constant flow of data, which, when analyzed and interpreted, can create meaningful insights for businesses, potentially leading to optimal solutions.

In this section, we will dive into whether Big Data is yielding value for organizations, clarify the fundamental understandings an organization must have before implementing Big Data analytics, discuss the different stages of adoption, explore emerging trends and identify challenges and advantages.

Emerging Trends

Big Data has Become Key to Decision Making

MIT Sloan Management Review recently partnered with IBM to conduct a survey of 3,000 executives across 30 industries in over 100 countries to uncover the impact of Big Data on a company's profitability and their managerial decision-making process. What emerged were insights into how companies use analytics and how they provide value. In fact, a study by Lavalle et al. (2011) found that top performing companies use analytics five times more than lower performing companies. Over 50% of the respondents said that improvement in information and analytics was a top priority in their organizations while 60% of the executives cited that they had more data than they can use effectively, citing the importance of coming up with the appropriate technology to gather, store, analyze and interpret information to make them smarter, innovative and thus competitive.

McAfee and Brynjolfsson (2012) cites a study by MIT Center for Digital Business in partnership with Mckinsey's Business Technology Office and Wharton that found companies in the top third of their industry that use data-driven decision making were, on average, 5% more productive and 6% more profitable than their competitors.

Organizations must now create a process whereby continuous data streams can be collected, stored, analyzed and interpreted in real time more efficiently and accurately. Even more important is linking processes with production to deliver optimal outcomes.

Big Data Visualization and Simulation are Driving Innovation

The use of data visualization and process simulation tools are on the rise across multiple industries. These interactive tools help managers evaluate the complex problems that they are trying to solve and visualize for themselves the value that they are personally trying to achieve, optimizing the product development process, reducing production costs and speeding up time-to-market.

Big Data visualization is also being used widely in the medical field. When patients are hooked up to a variety of machines, data is collected on their vitals. However, given the cost and complexity of storing the data, much of it is tossed away. Schonberger and Cukier (2013) cite the work of Dr. Carolyn McGrogor and her team, where they have worked with hospitals to develop a software to track real-time data on the conditions of premature babies to help them survive. The software stores, analyze and displays data on 16 different variables, including blood pressure, pulse rate, heart rate and respiration rate, to obtain a picture of not only how the patient is doing now, but how they are expected to do in the future. Using the data, Dr. McGregor's team could pre-emptively strike against the babies' deteriorating condition. Predictive analytics can save lives when presented to physicians in a way that helps them better understand trends.

Big Data Changes Human Resource Needs

The nature of Big Data has changed human resource needs within businesses and has reformatted the skill set needed for organization that want to survive and prosper. With traditional analytics, organizations simply needed professional data analysts who were essential in supporting the analytical division of the organization. Today, an analyst must have a serious knowledge of IT, must be well versed in mathematical and statistical skills, must have a solid grasp of business and economics and should have the ability to communicate effectively to different stakeholders.

Companies should invest in data engineers that can learn and apply rules to manage data regulation, governance and technology differences, thereby allowing data scientists to focus on the algorithm of insights and the context of the domain knowledge for which the insight is being used. This allows the potential for segregation of duties within the analytical team.

Big Data has forced organizations to rethink the role of IT and its relationship with business. Given the volume of data that is generated today, IT needs to invest in tools that are not only automated, robust and reliable, but that allow meaningful interactions among humans who would employ those tools, so that there is a seamless integration of the new-found analytical capabilities with the production and process environment of the organization. In short, Big Data has created an information ecosystem where there is a constant flow of data, which, when analyzed and interpreted, can create meaningful insights for businesses, potentially can leading to optimal solutions.

Industry Analysis

Understanding the Fundamental Stages of Big Data is Necessary for Successful Adoption

In order to successfully implement Big Data analytics, companies must first understand the fundamental stages of Big Data. Studies, like those mentioned previously, have shown that companies that are aware of these stages and the importance of analytics to their organization, have a better understanding of where they need to be for successful implementation. There are three identified stages of analytics within an organization: 1) Aspirational Organizations, 2) Experienced Organizations and 3) Transformed Organizations. (Lavalle et al, 2011)

1. In the **Aspirational Stage**, an organization is least prepared and holds on to traditional analytics. They are only seeking ways to improve and automate existing analytics, but at the same time are looking to cut costs. These organizations do not have the people, process or tools necessary to harness the benefits of Big Data. In this stage, a company's use of analytics in the decision-making process is rare and they use analytics to justify actions that the organization has already taken. Analytics is not used in day-to-day operations, nor is it used to create a roadmap for future strategies.
2. In the **Experienced Stage**, organizations have initiated processes to move beyond traditional analytics and are looking for ways to create a process whereby they can collect, store, analyze and interpret large amounts of data to achieve optimal outcomes. Experienced organizations use analytics to guide their decisions. These organizations use analytics to drive day-to-day operations, but not to formulate future strategies.
3. In the **Transformed Stage**, an organization has completely evolved and is using analytics in all functions to achieve optimality. These organizations are less focused on cutting costs and more focused on attaining business insights that can give them a strategic competitive advantage. Transformed organizations use analytics not only to conduct daily operations, but also to form long-term strategies. In this stage, organizations use analytics and data to guide their actions.

Companies Must Know the Difference Between Traditional vs. Big Data Analytics

When data is used to create a straightforward solution to simple problems, traditional data analytics may be sufficient. However, Big Data becomes essential when we are faced with very complex problems that require more nuanced or very complex answers. For example, if you want to know the rate of returns on your investment, and how it compares to other alternative investments, traditional data analytics may be just what you need. However, if you want to see not only the rate of return, but where your money is going, what kind of problem your investment is addressing, the competing demands for your money and how socially valuable your investment is, then Big Data analytics becomes important. Big Data analytics can often go to a micro level of personalization that traditional analytics cannot.

Big Data analytics is a management revolution. (McAfee and Brynjolfsson, 2012) With IoT and machine learning, the volume of data that is generated today is massive, making it impossible for regular computer hardware and software to analyze. In addition, the velocity, or the speed with which the data is created, is more interesting than the volume of the data. Most important, perhaps, is the variety of data that is generated today. Data that emerges from social networks (Facebook, Instagram, Twitter, etc.), email, smartphones, embedded sensors, call centers, GPS and installed video cameras—to name a few—has given businesses the capability to measure many more variables than traditional data did. Since our ability to measure things has increased exponentially, so to has our ability to manage changes and trends.

Organizations that succeed in harnessing the potentials of Big Data differ from traditional companies without the advantage of Big Data in three specific ways:

1. They utilize the flow of data instead of a stock of historical data.
2. They are increasingly relying on data scientists rather than data analysts.
3. Their core business, operations and production, are being increasingly impacted by analytics.

Automation Alley Survey

Automation Alley recently conducted a small survey among Michigan small and medium-sized manufacturers to better understand the state of Michigan's manufacturing base as it relates to Industry 4.0. When asked how important Big Data was to their sector, about 40% of respondents indicate at least some level of Big Data importance in their sector while another 22% indicated it is being tested within their sector. However, close to 40% of individuals indicated Big Data is not important in their sector, and about 30% of those surveyed did not respond to this question (Figure 1). This may be a matter of concern as they may be falling behind the market trends in their own sector, or they may not be aware of the ways in which Big Data impacts their sector.

When asked about an implementation timeline within their company, over 40% of the respondents indicated that there is no plan in their enterprise to implement. Just under 60% of respondents plan to implement within the next couple of years or have already implemented (Figure 2).

One long-term outcome of the use of Big Data is the opportunity to develop new revenue streams through revision of the business model, but challenges exist. When asked what the biggest challenge is with Big Data, the majority of respondents felt that it was not beneficial to their business (Figure 3). Another 26% indicated lack of training as the main reason. Others indicated that investment costs and a lack of clear understanding on the part of senior management were barriers to implementation. Once again, a large percentage of those surveyed (close to 45%) did not respond to this question. The responses to this question clearly indicates a lack of awareness of the value of impact of Big Data. It may also be true that these enterprises may not have ventured into any systematic cost-benefit-analysis around the impact of Big Data.

Since the respondents were mostly from small to medium-size companies across Michigan, several trends are emerging for this population: (1) About 60% of respondents have implemented or plan to implement Big Data applications in their operations within the next few years, (2) the majority of the applications seem to be at a fairly early stage, (3) more awareness of Big Data's impact in their own sectors is necessary, (5) Sector leaders need to explore ways to innovate new products or service ideas using the access to enormous amounts of data that would be generated, and (6) a large percentage of non-response is concerning. While the reason for that is unclear, it could be a sign of lack of awareness.

Figure 1: *Importance of Big Data in Your Industry Sector*

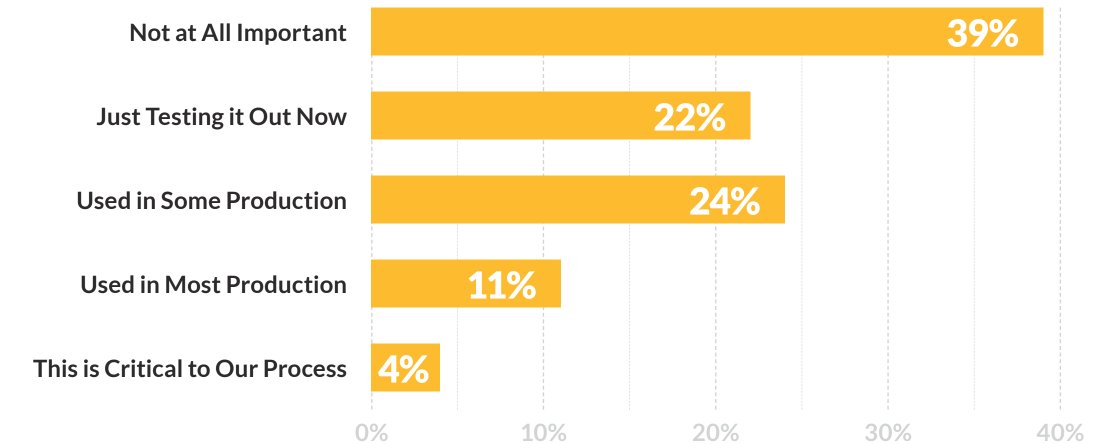


Figure 2: *Plans to Implement Big Data in Your Company*

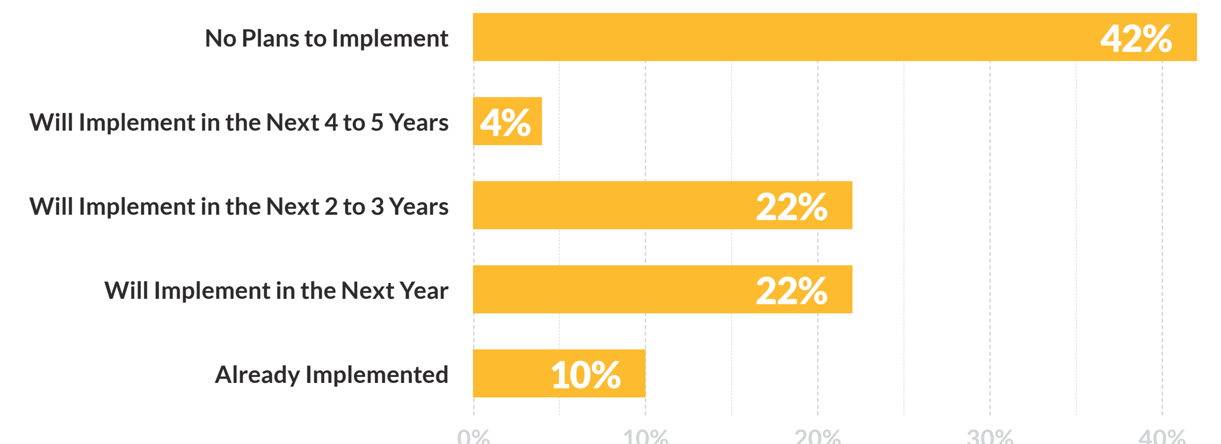
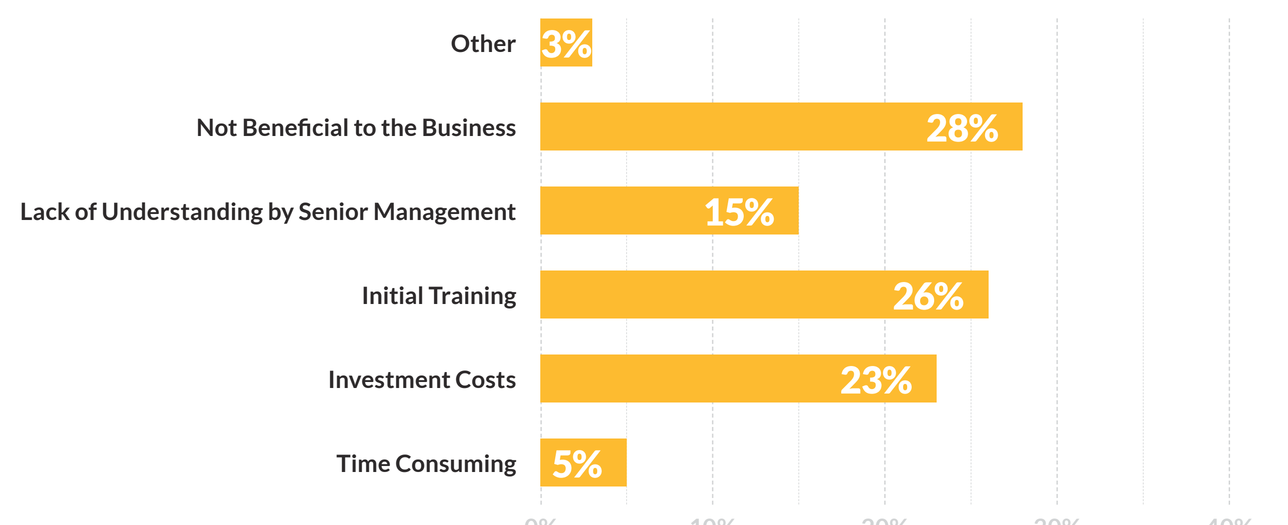


Figure 3: *Biggest Challenge of Using Big Data*



Advantages & Challenges of Big Data Implementation

Advantages

Big Data analytics are a true game-changer for business, with the potential to help companies achieve competitive advantage and reach their overall goals by helping them better understand their customers, cut costs and increase efficiency, productivity and sales. However, Big Data analytics within an organization will fail if companies do not have a plan in place for how to properly protect, manage and use the data being collected. Below are five main challenges to implementation.

Challenges

- **Big Data requires a fundamentally new way to arrive at a decision.** Executives must move from intuition to what can be inferred from available data. Once the decision is made to rely on data analytics, the questions that become critical are the source of the data, the reliability of the data and the decision makers' willingness to substitute data for intuition, especially in cases where the data is contrary to intuitions that emerged from past experiences.
- **There is a lack of understanding of how to use analytics to improve business.** Decision makers often have a lack of understanding of how data analytics can improve productivity and profitability, and how this is aligned with strategic direction.
- **Management often lacks the bandwidth to handle Big Data.** It also competes with decision makers' various other priorities within an organization.
- **Investment costs are a real issue.** New tools are required for appropriate data visualization that allows decision makers to see analytics, make decisions and implement decisions in real time. The cost of Big Data analytics also contributes to the reluctance of adopting it. There are so many alternative priorities that decision makers often have, that they find it difficult to invest in Big Data tools. This problem is compounded by the fact that most often technologies become obsolete so fast that it becomes difficult to justify an investment on a technology today that will become obsolete tomorrow.
- **Securing Big Data must be a priority.** Every business wants to collect troves of data, but once a company has collected the data, they must protect it. Information classification becomes critical with Big Data, as does data ownership. Before making the leap to Big Data implementation, companies must develop a clear understanding about what they are trying to achieve and put a security plan in place that addresses the additional risks and challenges of Big Data.

Conclusions

- Big Data analytics are having a profound impact on both productivity and profitability within organizations.
- Big Data analytics is different from traditional analytics, since its deals with a flow of data instead of a stock of historical data. This allows decision makers to make real-time decisions at a more micro level than is possible with traditional data.
- The adoption of Big Data for decision making requires a different approach than conventional data analytics. This will require a fundamental shift in corporate culture and business models, also impacting human resource allocations.
- Not surprisingly, there is serious oppositions to the adoption of Big Data analytics. Most notably, the opposition rises from three fundamental insecurities: (1) Data substitutes the intuition of decision makers. (2) Many decision makers are reluctant to make a hefty investment in Big Data because of competing priorities and the speed at which technology is changing. (3) The benefits of Big Data are not immediately clear to decision makers.
- The adoption of Big Data analytics becomes easier, and its outcome more effective, if it is aligned with the strategic direction of the organization.

Action Items

- Companies must decide if there is a value proposition to use Big Data. Once that is defined, the need for data will emerge, and it is crucial to maintain that order for Big Data analytics to be successful.
- In theory, Big Data should provide critical insights to business leaders. Organizations must decide what critical business insights it needs to reach its objectives, if that business insight is aligned to its core mission and if the data needed to gain those insights are crucial for its decision-making process.
- Many companies that are looking to adopt Big Data need to fundamentally rethink how IT supports their business. Rather than hiring traditional data analysts, data scientists and data engineers should have a more strategic role, rather than merely support, within the business.
- Before making the leap to Big Data implementation, companies should employ a security plan to protect the data being collected.

Case Study

Wind Turbine Leader Vestas Turns to PTC & Digital Data to Help Usher in the Next Generation of Sustainable Energy

Problem

Vestas has been at the forefront of wind energy for 40 years, introducing market-leading wind energy solutions that have driven down the cost of energy and taken wind energy from niche to mainstream. With more than 23,000 employees, industry-leading smart data capabilities and an unparalleled number of wind turbines in service, Vestas is driving the future of sustainable energy solutions.

Building some of the most complex and in-demand offerings in today's eco-friendly world, Vestas was looking to improve a manufacturing process that requires numerous shop floor workers to put together thousands of materials in a critical step-by-step process. With a build process that is so dynamic, their machines require very detailed work instructions that had been traditionally printed on hundreds of pages of paper. An industry visionary, Vestas also frequently adds the latest technologies into their products, meaning that initial work instructions have to be updated to meet the latest specifications and best practices each time there is an upgrade or an engineering change.

Currently, as part of the product planning team's role, workers have to visit each shop and check that every workflow has the latest information—creating a lengthy review process and unnecessary

travel costs. Adding to this, the archaic process required workers to manually sift through numerous pages of instructions that may not be relevant to their specific job function, further stifling productivity. Also, as with many organizations in the manufacturing space, some of the company's most experienced workers are nearing retirement age and possess a wealth of knowledge that needs to be captured and archived.

All in all, Vestas knew that the methods in place were not sustainable in today's ultracompetitive smart manufacturing world and decided to kick off a search to find a partner who could help them improve these workflows.

Solution

During their search for Industry 4.0 technology, it became clear that the company needed to take a digital-first approach to their manufacturing and reduce their reliance on paper-based instructions. To do so, Vestas is adopting an entirely digital turbine production process—everything from CAD design to manufacturing. The company turned to PTC's ThingWorx Operator Advisor, which equips machine operators with the relevant information they need to identify and complete tasks—including role-specific digital work order information and instructions with rich CAD drawings and videos—all in a single interface.

Implementation

Because of the pre-built, configurable building blocks provided through the ThingWorx platform, the full deployment of Operator Advisor—from conceptualization to hitting the factory floor—will take Vestas less than half of the time if the company was looking to roll out an in-house solution. The company is also hoping that with the build instructions not having to be printed out, it will help remove a large amount of the work of that the product planning team is currently doing.

Outcome

Introducing a technology that provides a multitude of workforce enhancement capabilities to a labor-intensive production ensures Vestas' manufacturing floor employees will have access to all of the information needed to complete their job, digitally and in real-time. This will help ease the impacts felt by the veteran employees retiring and combat the current volatility that the manufacturing space is facing around employee retention.

Additionally, this will have far-reaching impacts on things like safety and reductions in training times as the technology will not only provide the floor worker with the task at hand, but the best way to complete it.

Vestas and PTC's partnership will continue to pay dividends as the company plans for the next generation of smart manufacturing technologies, as only PTC provided the operational data display through digital, 3D, video and augmented reality that they were looking for. With this technology in place, Vestas believes they are set up for success in a factory of the future, with a road map of how they can easily integrate this data with other smart tools and even robots.

Furthermore, and true to its culture, Vestas is also looking to build a sustainable solution on their shop floor by minimizing its ecological footprint through Operator Advisor. The hope is that the technology will also allow the company to remove print and copy machines and countless boxes of paper from all manufacturing sites.

ptc

Case Study

Before the Floor: Laying the Groundwork for Smart Manufacturing Success with Configit

Problem

A global Fortune 500 manufacturer leads the field among its competition, but its U.S. Motors and Generators business unit wanted to do more.

This company offers an enormously wide breadth of configurable products. It was a challenge for them to maintain stocked product and nearly impossible to maintain the flow and integrity of one-off orders.

It was taking the company 10-12 months to build a product that would only be purchased once, and often, six months into the build process someone had to speak up to say, "we can't build this product." Thus began a debate between functional units. Who calls the customer? Who pays for the lost time and materials? And most importantly, how did this happen?

It happened because engineering, manufacturing and sales operated in different silos. Engineering relied on one configurator to help design products, but production relied on a different configurator, and sales relied on yet another configurator. The result was confusion, errors and fights between departments. That meant costly mistakes and an incredibly high time to market. In a global manufacturing environment delivering 1.5 million products per day, this landscape was financially and operationally unacceptable.

Solution

The business unit knew that solving this problem was necessary to move forward in the future and so they began an initiative called Smart Simplicity. The project aims to unleash the full potential of existing Industry 4.0 initiatives, but to do that, the company had to first solve the configuration challenges.

Implementation

With Configit's help, the business centralized all configuration rules into a single repository that feeds multiple ERP, PLM, sales and customer systems.

Each department came together to define all elements of a product. These elements are then standardized into a central location. With this setup, an element is authored once, defined once, and stored once, then accessed by all other systems.

For example, a feature is authored and defined once then stored in Configit Ace. Once its been created, the feature is then consumed and becomes a standardized option or choice. That option or choice can then be pushed to SAP and becomes a characteristic or value. That characteristic or value is exactly the same as what was defined and stored in the very beginning, it's simply been pushed into the appropriate system and given the appropriate nomenclature.

This pattern continues on to feed a product configurator. Now, a salesperson is creating a quote. Because the rules were established up front and have been consistent throughout each system, the salesperson is selecting options that have already been validated. It's impossible for the salesperson to quote a product that manufacturing can't build or engineering can't design.

Outcomes

The benefits are now gigantic. With a centralized repository of rules, a customer is given an accurate, real quote the first time. For this global manufacturing leader that meant that teams were able to reduce time from configuration to manufacturing from six months to four weeks. They've experienced zero order errors and realized a 45% improvement in collaboration between R&D and sales.

But the Smart Simplicity project aims to do even more. With its new configuration solution in place, the business unit can implement Digital Models. Teams will be able to look at a configured product from design to production and have visibility into the product as it's made by a Doosan machine. Everyone will be able to see the flow of products through the floor and the manufacturing team can now re-order the flow based on product configuration, allowing for the most efficient build and assembly processes possible.

Beyond this, the Smart Simplicity project plans to implement the digital twin, an initiative that was previously impossible. There were simply too many engineered-to-order products sold to effectively introduce the digital twin. But now, because all configuration data is standardized, centralized and connected, a digital twin can be created at the time of quote.

With both a digital twin and digital model in place, the global manufacturer can realize huge efficiency gains. Engineering no longer wastes time designing an impossible product, manufacturing no longer stops the assembly line because a product can't be built, and sales no longer calls the customer to say that his order has to be updated and will now be six months late.

By starting at the beginning of the product lifecycle, this manufacturing leader was able to lay the foundation for its Industry 4.0 initiatives to be as successful as possible.

Configit®

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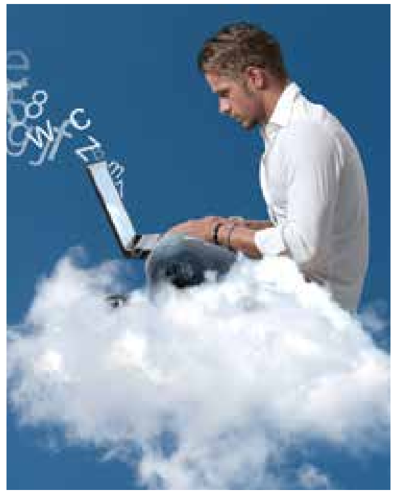
Cloud computing has traditionally been defined as the storing and accessing of data and programs over the internet instead of your computer's hard drive. Today, cloud technology in all its forms—software, platform, or infrastructure as a service is rapidly becoming essential to the needs of business. Companies are increasingly finding cost savings and improving business agility through empowering cloud computing. In 2019, most enterprises will procure cloud services from two or more vendors. (Bartoletti, 2018) Cloud computing is no longer being used just to store and process data, it is empowering small and medium -sized businesses to compete and prosper in new ways.

Cloud computing can serve as the catalyst to drive innovation and growth when it is combined in new ways with other Industry 4.0 technologies.



Emerging Trends

Cloud computing is a critical component to this complex Industry 4.0 ecosystem enabling new business and manufacturing models for greater global integration while maintaining business agility. Cloud computing is driving transformations in industry that are changing how organizations utilize, manage and deliver services, as well as how they develop products. (Clemons, et. al, 2018) The average cloud budget has spiked nearly 36% in 2018. Much of these increases are driven by small and medium-sized business. (IDG Cloud Computing Survey, 2018)

In 2019, organizations will likely focus on shifting their cloud strategies from the low-end infrastructure-as-a-service (IaaS) opportunity to extracting valuable data from their business processes. (Robinson, 2018) This includes integrating data across the enterprise with external data sets combined with applying new, innovative services such as artificial intelligence (AI), blockchain and analytics. Research points out that while many business processes have already moved to the cloud, 80% of mission-critical workloads and sensitive data are still running on-premises because of performance and regulatory requirements. (Robinson, 2018)

Based on interviews with more than 6,300 senior IT executives, Ovum's ICT, a consultancy, answers key questions concerning enterprises' needs at a national and industry level. (Illsley, 2018) Figure 1 provides a snapshot of the key trends shaping cloud computing in 2019. Three distinctive themes emerge:

1. Cloud computing is expanding across more core business applications.
2. While spending on cloud is increasing, firms are scrutinizing their investments much closer.
3. There are a variety of factors globally that are driving investment ranging from disaster recovery to security to storage.

In addition to these trends, there are some additional developments enterprises need to be aware of, as shown in Figure 2. In 2019 and beyond, industry will see companies moving away from a "one-cloud-fits-all" approach towards hybrid multi-cloud architectures based upon changing needs and advancing technologies. People are also starting to get more comfortable with open cloud technologies.

***Figure 1:** Key Global Cloud Computing Trends*

- Cloud computing is now being used for more core business applications.
- The value proposition is being more closely scrutinized by companies of all sizes.
- Cloud spending is increasing overall but differs by region and company size.
- Servers and storage remain the largest spend category in the infrastructure budget.
- North America sees backup and disaster recovery as biggest growth opportunity for cloud.
- Europe focuses on security and data protection related to cloud computing.
- Asia-Pacific looks to storage services as the top cloud service.

Sources: Illsley, 2018; Bartoletti, 2018

***Figure 2:** Emerging Developments of Cloud Computing*

- Hybrid multi-cloud architectures will replace the "one-cloud-fits-all" approach.
- Companies will increasingly embrace open cloud technology.
- Cloud skills and culture will be the key to cloud adoption.
- As cloud adoption rises, developers must put security first.
- There will be an explosion of edge computing.

Source: Pistrui, 2019

As GenXers and Millennials continue to ascend into leadership positions, industry receptiveness to cloud technology as well as their cloud skills will continue to accelerate, as will the adoption and implementation of multi-cloud architectures. The single most challenging aspect of cloud implementation will be security.

To better understand and take advantage of cloud computing, companies should strive to identify opportunities to create Industry 4.0 Intersection Innovation Typologies. (Pistrui and Kleinke, 2018) Doing so can lead to exponential collaborative innovation and growth opportunities. This is especially true with cloud computing which can serve as the catalyst to drive innovation and growth when it is combined in new ways with other Industry 4.0 technologies.

An example is presented in Figure 3, which illustrates that cloud computing can be combined with Big Data, the Internet of Things (IoT) and additive manufacturing and advanced materials to foster network innovation that can produce mass customization.

The cloud provides tremendous power in terms of computing and storage, yet, with more and more data being generated, we are still limited with the amount and speed at which data can moved between the cloud, sensors and devices. Edge computing is a process that brings the cloud's capabilities closer to the actual devices collecting the data (Figure 4). (Bellini, 2019)

To take advantage of the computational power of cloud computing while avoiding its latency issues, edge computing is emerging as an effective means to process sensor data locally for real-time use. (Kota and Mahoney, 2018) Edge computing is expected to grow in importance and empower cloud computing in new ways. Edge computing offers the dual advantage of the low latency that was formerly only offered by on-premise computing, now combined with the scale and capacity afforded by the cloud.

***Figure 3:** Industry 4.0 Intersection Innovation Typology*

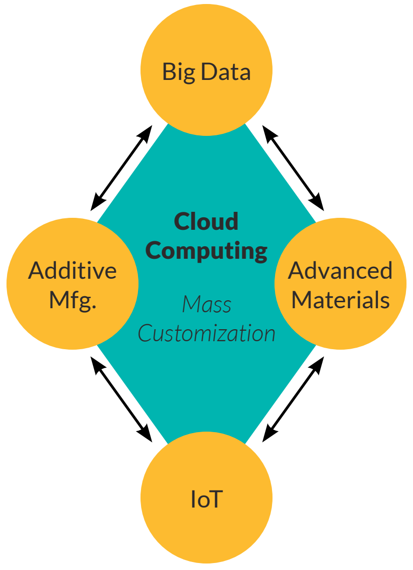
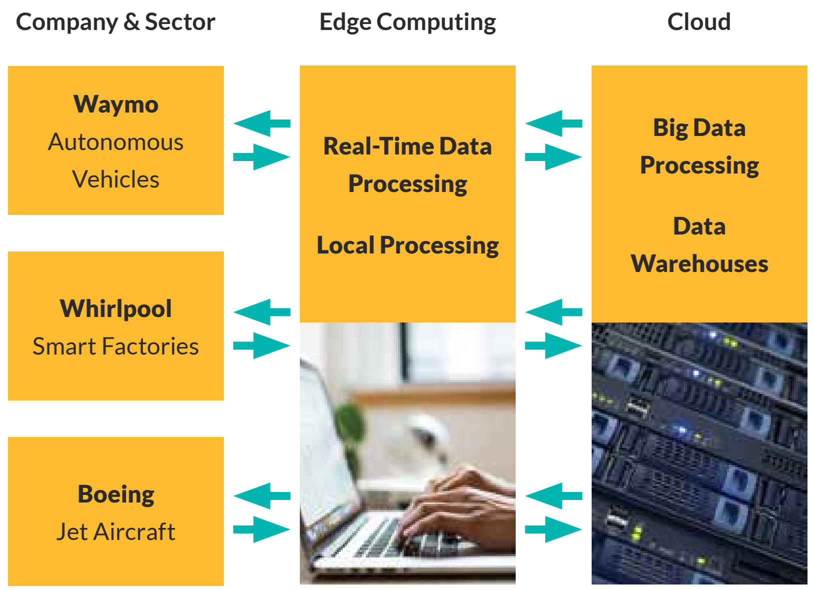


***Figure 4:** Edge Computing: Industry Use Cases and Applications*



Sources: Pistrui, 2019; Bellini, 2019; Kota and Mahoney, 2018.

Industry Analysis

As cloud becomes the basis of most innovative manufacturing IT systems, firms must gain insights to better understand the fundamentals and the challenges associated with efficient interoperability in an Industry 4.0 environment. (Pedone and Mezgar, 2018) This section will address these needs by providing insights into cloud computing service and deployment models with a series of industry snapshots.

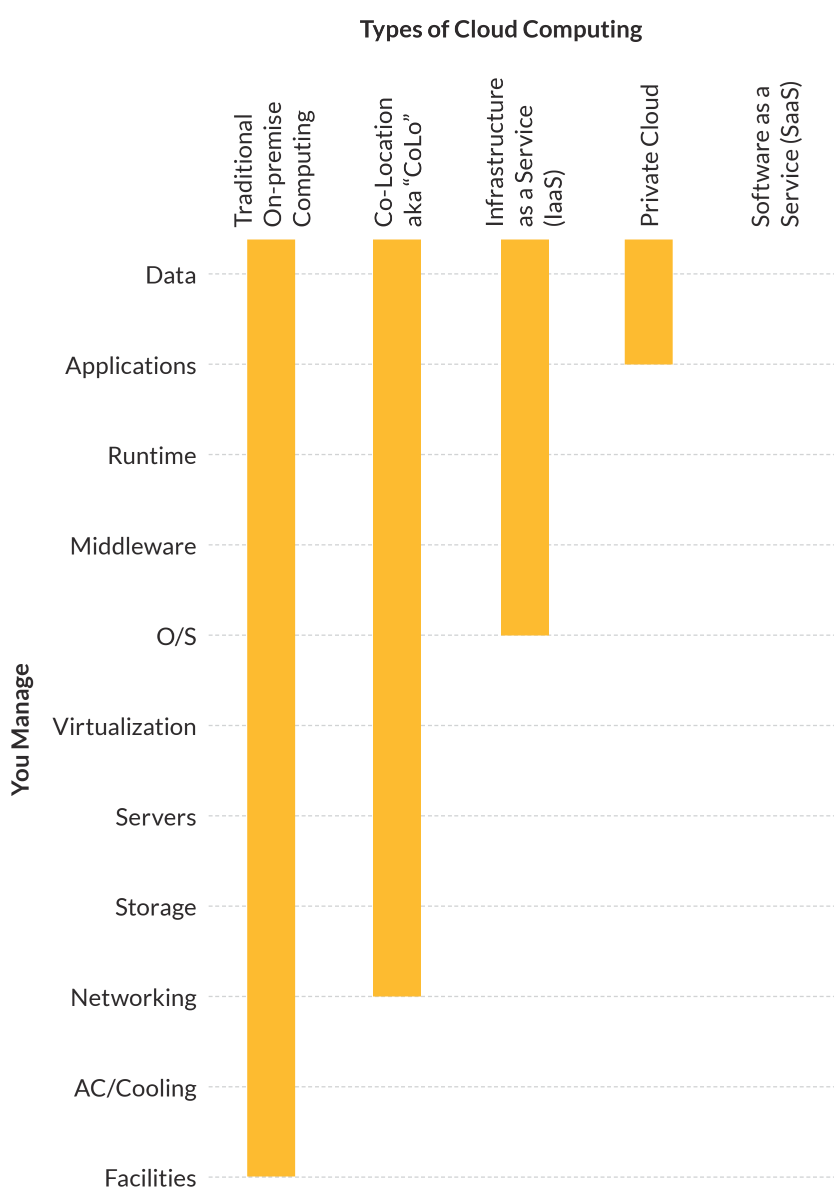
Cloud Service Models

Corporations can decide on various levels of implementation of cloud computing, ranging from full in-house, to full-service models, as shown in Figure 5.

Software as a Service (SaaS) is a method for delivering software applications over the internet, on demand and typically on a subscription basis. With SaaS, cloud providers host and manage the software application and underlying infrastructure, and handle any maintenance, like software upgrades and security patching. Users connect to the application over the internet, usually with a web browser on their phone, tablet, or personal computer. (Jain, 2018)

Beyond office productivity software (email, Office365, Google Docs, etc.) organizations are renting access to sophisticated business applications such as customer relationship management (CRM), enterprise resource planning (ERP), and document management. Organizations pay for what they need through a subscription arrangement or according to the level of use. SaaS is expected to play a central role in firms that focus on implementing Industry 4.0 technologies and techniques.

***Figure 5:** Varying Degrees of Implementation of Cloud Computing*



Sources: Courtesy of RSM

Platform as a Service (PaaS) refers to cloud computing services that supply an on-demand environment for development, testing, delivering and managing software and applications. It is designed to make it easier for developers to quickly create web and mobile applications without the worry or costs associated with setting up and managing the underlying infrastructure. (Jain, 2018)

PaaS provides a framework that can be used to build on and develop or customize cloud-based applications. PaaS lets developers create applications using built-in software components and also provides the tools for data analytics that organizations can use to mine data to discover patterns and predicted outcomes to improve forecasting, product design, investment returns and other business decisions.

Infrastructure as a Service (IaaS) is a common application of cloud computing services. In essence, with IaaS, an organization rents the IT infrastructure (servers, virtual machines, storage, networks and operating systems) from a cloud provider paying for what they need.

Implementing an IaaS strategy allows for flexibility in setup and dismantling of test and development environments, allowing teams to bring new applications to market faster.

Multiple websites can be hosted with less expense than other models. Storage, backup and recovery can be provided to help aggregate and manage costs. IaaS can also provide flexibility and the ability to respond to unpredictable demand and growing needs for storage with greater ease than on-site storage solutions.

Figure 6 summarizes the advantages and disadvantages of the three cloud computing service models.

***Figure 6:** Comparison of Cloud Computing Service Models*

Software as a Service (SaaS)	Platform as a Service (PaaS)	Infrastructure as a Service (IaaS)
End-user applications delivered as a service.	Platform to build custom applications.	Compute, storage, or other IT infrastructure as a service.
Advantages	**Advantages**	**Advantages**
Pay for only what you need on a real-time basis.	Ability to build multiple platforms including mobile.	Access to IT (staff, hardware software and services).
Mobilizes the workforce around common platform.	Support geographically distributed business models.	Provides storage, security, tools and analytics.
Gain access to sophisticated applications and tools.	Gain access to additional key analytic resources and tools.	Gain access to scalable resources and support.
Disadvantages	**Disadvantages**	**Disadvantages**
Slower speeds than client/server applications.	Some part of infrastructure is not cloud compatible.	Management of entire underlying IT infrastructure.
Limited applications and variable functions/features.	Security risk related to off-site data storage.	Legal restrictions related to out-of-country data storage.
Loss of control associated with using an outside vendor.	Potential hidden costs associated with support.	Security levels may not meet compliance requirements.

Sources: Pistrui, 2019 ; Cloudhelix, 2019 ; Gaebler, 2019; Barry, 2019.

Cloud Deployment Models

Cloud computing is comprised of four primary deployment models. 1) Public: accesses over a public network, 2) Private: company-owned and managed, 3) Hybrid: combination of public and private and 4) Multi-Cloud: combines multiple providers (Figure 7).

Public cloud deployment models provide pure cloud hosting based on a pay-per-user license model or subscription fees. For over a decade, public clouds have long been known to be suitable for business requirements that make it necessary to manage load spikes, host SaaS applications, utilize short-term or instant infrastructure for SaaS applications, and to develop and manage applications for high user consumption that would otherwise require a significant investment in infrastructure from the businesses. (Klein, 2011) The key benefits are that it reduces capital expenditure and operational IT costs.

Private clouds are the services and infrastructure maintained on a private network, often in an organizations on-site data center. (SpeedyCloud, 2017) Security concerns can be addressed through a virtual private network (VPN) or by the physical location within the organization's firewall system. Further, where data or applications are required to conform to various regulatory standards (e.g., SOX, HIPAA, or GLBA) may require data to be managed for privacy and regulations that govern the organization. (Connectria, 2019)

Hybrid clouds combine on-premises, private cloud and a third-party, public cloud allowing for data and applications to be shared between them. (SpeedyCloud, 2017) Three of the foremost benefits of implementing a hybrid cloud approach are cost savings, greater security and much better organizational agility. (Tran, 2019) By enabling data and applications to move between the public and private clouds, a hybrid cloud provides greater flexibility, more options and services and helps to optimize existing infrastructure, security and compliance.

Hybrid cloud solutions are often considered by organizations as a key component of a business continuity solution where critical data is replicated to a cloud solution in a different location to the primary systems. (I Seek, 2019) Hybrid cloud solutions also provide a solid platform to support innovation because concepts can be tested and prototyped without the need to make additional capital investment. Hybrid cloud solutions also allow organizations to scale on demand providing more efficiencies in a secure environment at manageable costs.

Figure 7: Advantages and Disadvantages of Cloud Deployment Models

Public

Cloud infrastructure that is located and accessed over the public network.

Advantages:	Disadvantages:
• Scalability/ Flexibility/Bursting • Cost effective • Ease of use	• Operated by third party • Unreliability • Less secure

Private

Cloud infrastructure owned and exclusively available to a single organization.

Advantages:	Disadvantages:
• Organization specific • High degree of security and control • Ability to choose your resources	• Lack of elasticity and capacity to scale • Higher cost • Requires significant engineering effort

Hybrid

Cloud infrastructure that combines public and private systems.

Advantages:	Disadvantages:
• Cost effective • Scalability/Flexibility • Balance of convenience and security	• Integration of multiple systems • Protentional complexity of systems • Regulation and compliance issues

Multi-Cloud

Cloud infrastructure that combines multiple public cloud providers.

Advantages:	Disadvantages:
• Minimizes potential downtime • Security and reliability • Most advanced and robust	• Administrative requirements • Requires engineering expertise • Can be labor intensive

Sources: Pistrui, 2019; Bertovic, 2017.

Multi-cloud computing involves two or more cloud computing service providers. While a multi-cloud deployment can refer to any implementation of multiple SaaS or PaaS cloud offerings, today, it generally refers to a mix of public IaaS environments, such as Amazon Web Services, IBM and Microsoft Azure. (Target Tech, 2019)

The primary reasons to employ a multi-cloud strategy is to minimize downtime and prevent data loss as a result of local component failures. However, this comes with a cost as the firm's IT team must have a working knowledge of multiple vendors, platforms and systems.

Implementing multi-cloud computing strategies can be particularly daunting for small and medium-size enterprises who most often have fewer resources than large firms. Implementation and security alone can pose new challenges. When the multi-cloud environment is dependent upon an assortment of manual workflow processes, it can significantly hamper successful deployment within a multi-cloud environment. (Fretty, 2018) The key to successful cloud computing is to navigate the economic, organizational and technical hurdles confronting an organization. (Sundermann, 2017)

Current State of Cloud Computing in Small and Medium-Sized Firms in Michigan

Research conducted as part of this study by Automation Alley provides some further insights related to how Michigan's small and medium-sized firms are approaching the implementation of cloud computing. In a small survey of 70 firms, 23% of respondents reported that they have already implemented some form of cloud computing, while a surprising 30% indicated they have no plans to implement cloud computing at all (Figure 8).

On the other hand, 46% plan to implement some form of cloud computing over the next 5 years and 31% reported that their staff lacked the proper training to fully leverage their cloud computing infrastructure. In terms of benefits, three areas emerged which included improved efficiency, reduced costs and improved customer satisfaction. Given the small sample size, these findings are considered directional. Additional research is called for to advance our understanding of cloud computing in small and medium-sized firms.

***Figure 8:** Michigan SME Cloud Computing Snapshot*

23% have some form of cloud computing already implemented.

46% plan to implement some form of cloud computing over the next 5 years.

30% indicated they have no plans to implement cloud computing at all.

31% reported that they lack the proper training required to leverage cloud computing.

The primary benefits firms gain from cloud computing include:

22% Improved efficiency

17% Reduced costs

11% Improves customer satisfaction

Source: Automation Alley survey, February 2019

Advantages & Challenges of Cloud Implementation

Advantages

It is certain that cloud computing is critical to boosting the potential impact and promise of Industry 4.0. It is a central component that accelerates innovation and the ability of personalized, local production and mass customization. Cloud computing, through the myriad of service combinations, provides for:

- **Cybersecurity:** with strong protections for smart factories and production systems.
- **Big Data:** by making sense of complex data, identifying new and creative products and collaborating across all sectors of the organization more efficiently.
- **Industrial Internet of Things (IIoT):** allowing for greater control and tracking of equipment for zero defaults, greater reaction times, traceability of products and predictability of production and quality levels.
- **Additive Manufacturing and Advances Materials:** to minimize scrap, aid in mass customization and rapid prototyping, and improved connectivity.
- **Mass Customization:** that address the needs of the market and customer with greater efficiency, flexibility and on-demand manufacturing.

Challenges

As enterprise cloud strategies continue to mature, IT teams will face a new set of challenges in 2019, ranging from cost governance to the management of complex, multi-mode architectures. (Linthicum, 2019) Despite the wide acceptance of cloud computing, there are currently several significant perceived challenges companies experience as they implement new IT strategies. (Lerner, 2019)

- **Data integration:** how to efficiently move data from on-premises databases into the cloud and/or how on-premises databases will share information with cloud-native databases.
- **Cost management:** although cost reduction is a common reason companies migrate to the cloud, often times cost overruns significantly higher than original estimates, the trade-off of capital vs. expense spending.
- **Hidden cost factors:** many new cloud users overlook factors such as networking, data transfer, security and storage costs.
- **Added complexity:** implementing hybrid and multi-cloud models with on-premises systems become more complex and may hamper the staffs' ability to effectively do their jobs.
- **Security concerns:** many companies struggle with the perception that the cloud is not as secure as in-house databases and systems.
- **Perception of control:** in parallel with security concerns IT departments often are challenged by the perception of losing control of data.
- **Talent shortage:** perhaps the biggest challenge is the sheer lack of qualified and certified IT professionals required to administrate and manage cloud computing systems.

Conclusions

- Cloud computing is a fundamental and important technology that is central to harnessing the power of other Industry 4.0 technologies.
- Edge computing is a rapidly emerging area that firms of all sizes and sectors need to be aware of in order to properly invest.
- Cloud computing is not a one-size-fits-all technology. Company size and sector are forces that are shaping what type of investments are made in both technology and the talent.

Action Items

- Firms of all sizes should do a thorough review of their people, polices and procedures related to cloud computing, data storage and analytics to best align, protect and leverage their platforms and data.
- Firms should communicate with their customers and vendors and strive to collaborate on cloud computing strategies to ensure maximum value for their investments.
- Firms should look at how other Industry 4.0 technologies connect with their cloud computing strategies and implement Industry 4.0 intersection innovation typologies to foster innovation, new business models and growth.

Case Study

Sweet Harvest Foods Enlists Marco for Cloud & other IT Solutions

Problem

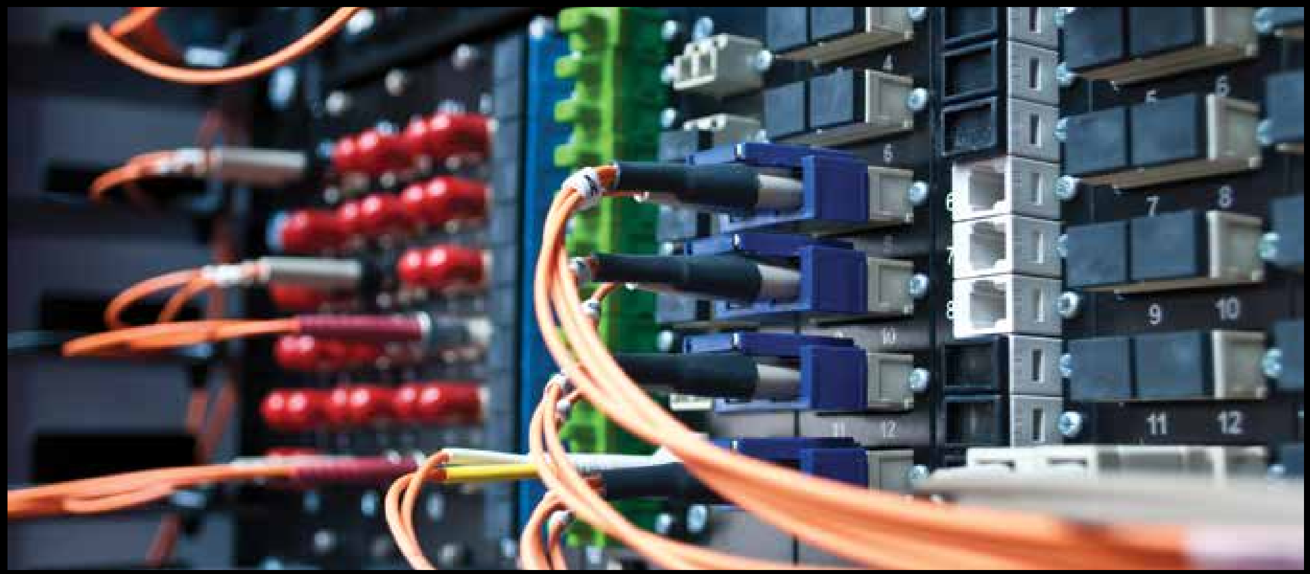
If your company had an overnight merger and suddenly grew twice its size, how would your IT department keep up? Brian Pleschourt, IT director at Sweet Harvest Foods, had to answer that question. He faced rapid growth when a larger company purchased the organization. “Instantly, we more than doubled in size, adding a California and Michigan location, combined with our two Minnesota locations,” he explained.

Sweet Harvest Foods is a worldwide leader in honey procurement and distribution. The company is one of the largest processors of 100% pure, all-natural honey with offices in Minnesota, California and Michigan. They distribute their products—honey, molasses, and agave—to food manufacturers, national retail and grocery chains and food distributors. Their approach allows for supply chain transparency, traceability and consistent quality of products.

Even before Sweet Harvest Foods’ swift expansion, Pleschourt was the lone IT staff member. “I was the only person, so I was busy. Fortunately, I partnered with Marco six months before the merger. I wasn’t aware of the merger but was planning for future growth.” With about 30 years of IT experience, Pleschourt originally needed assistance with only some Tier 2 and Tier 3 level aspects. “I needed support for things that were outside my knowledge. That’s why I went to a hybrid solution. I liked the flexible support offerings.” Marco assisted him for specific IT recommendations and provided service for the tougher problems.

Solution

Pleschourt worked hands-on with Tier 1 level IT solutions, acting as the Support Desk for Sweet Harvest Foods. After transitioning into multi-locations with multiple domains, he needed help implementing best practices. So Pleschourt added Marco’s Support Desk full-time, which now remotely services all four locations across the country.



Implementation

Marco’s expert Support Desk members assist Pleschourt and his co-workers using their various skill sets. “Having Marco as my IT department with full Support Desk allows me to know that if I need a network expert or an Microsoft Exchange expert, they are available to me.”

Marco’s Managed IT services assured Pleschourt that his growing company could adapt to the changes, mitigate risk and standardize systems. His consulting systems engineer was instrumental in the planning and implementation of new hardware, firewalls, switches and servers. Marco also added Backup as a Service (BaaS) and private cloud (IaaS), plus helped find ISPs for reliable internet. The Marco team installed teleconference rooms in a Minnesota location as well.

“Right now, all four sites have Cisco Meraki, redundant firewalls, redundant internet and redundancy in switches. We implemented each project for the migration and standardization across all platforms.” Marco and Pleschourt wanted to eliminate single point of failure with the back-ups and store data in one secure spot.

Besides Marco’s aid, Pleschourt appreciates the quality of the chosen Cisco products. He said the visibility and remote management of the firewalls, switches and access points have proven to be extremely advantageous.

Outcomes

- Reliable IT support and cloud services
- Expert strategic planning consultations
- Flexible technology options

Although some IT directors or IT staff members may feel threatened by bringing in another company, Pleschourt said he never felt hesitant to partner with Marco. “I think a company still needs an IT leader. Marco is my IT department. I’ve never felt endangered by the fact that I’ve brought Marco on board. I was drowning in work and needed a partner.”

Although the IT field can be unpredictable, and technology is always changing, Pleschourt said Marco has helped solve problems when his anxiety level rises. He explained that he has been able to reach the right people and escalate requests. “You can’t anticipate everything that is going to happen on a project; Marco excels at being very responsive to change.” He added that the implementation process, from the first contact to planning to installing, went smoothly.

Now, Marco is helping Pleschourt merge their domains into one. He plans to continue working with Marco for further projects, and of course utilize the Support Desk. Pleschourt even offers feedback to Marco through a Leadership Counsel, a group of customers who provide feedback about Marco’s products and services to enhance clients’ experience.

“I recommend Marco, and a lot of it has to do with the fact that you have a deep bench of experts. I’m very satisfied. Marco doesn’t present itself like an IT subcontractor. I feel we are true business partners. We share responsibility,” Pleschourt said. He brainstorms with Marco team members to discover the most fitting solutions to meet his needs, and that has helped Sweet Harvest Foods succeed.

Cybersecurity

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According to the World Economic Forum, cyberattacks are among the top five risks facing the world in 2019. (The Global Risks Report, 2019) As smart transportation systems gain traction on our roads and the Internet of Things (IoT) is rapidly integrated on our factory floors, OEMs across the globe—and their supply chains—are more vulnerable than ever to cyber threats.

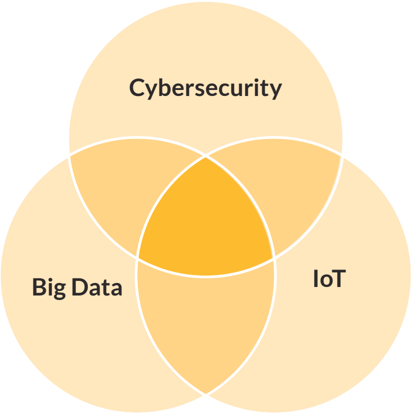
While many organizations realize the benefits of IoT integration into daily operations, there is not a clear understanding of the associated cybersecurity risks this technology brings into the manufacturing ecosystem. (Hale, 2018; Nugent, 2016) In fact, the majority of corporate cybersecurity breaches come at a significant cost, sometimes resulting in lost revenue and the long-term impact of a tarnished reputation.

As many organizations begin to implement IoT, there is a tendency to tackle cybersecurity from an Information Technology (IT) approach, resulting in a failure to address the operational technology (OT) challenges it brings. (Nicolas, 2017) According to Howell (2016), the manufacturing industry is one of the most infiltrated industries from a cybersecurity point of view.

Connected cars have networked electronic control units (ECUs), allowing data collection on consumers and their driving habits. An estimated 250 million connected cars will enter the global market by 2020. (Howell, 2016) Manufacturers are taking actions to protect the collected personal information using measures addressing privacy auditing and the utilization of centralized data centers in a singular platform. (Sharp, 2018)

The information presented in this section will focus on those vulnerabilities and associated impacts under the lens of manufacturing. This section will explore three areas: automotive cybersecurity, the Industrial Internet of Things (IIoT) and data protection in the manufacturing industry. Since all three of these topics are so closely intertwined in terms of manufacturing, this report takes all three into consideration including their overlapping nature into what is known as Industry 4.0. (Figure 1) Business leaders must focus on a hybrid approach to cybersecurity that includes people, procedures and technical measures to remain competitive.

Figure 1: *Industry 4.0 Typologies: Cybersecurity, Big Data and IIoT*



Emerging Trends

Vehicle Cybersecurity: Protecting the Computer on Wheels

In the past, there were high-profile public cases in which hackers identified vulnerabilities within a connected vehicle, raising concerns over the potential disclosure of the consumer's Personal Identifying Information (PII) or jeopardizing safety through vehicle network compromise.

The cybersecurity community has responded and currently in-vehicle network security dominates the automotive cybersecurity market. The projection for in-vehicle network security measures are expected to generate a market revenue of $236.4 million between 2018 through 2024. (Global Market Insights, 2018) The projections are a result of the current environment where the in-vehicle networking system carries a variety of information, supporting consumer experience and operational messages contributing to the normal functionality of the vehicle.

With mixed data categories traversing network communications, protecting the data and messages over the network bus is critical for privacy and operational security. Furthermore, network protocols, such as Local Interconnect Network (LIN), Controller Area Network (CAN), automotive Ethernet, FlexRay, Wi-Fi, 5G, Bluetooth and Dedicated Short-Range Communication (DSRC)

greatly increase the attack surface of the vehicle. With expanded attack surfaces, implementation of cybersecurity measures on the vehicle is paramount to provide authenticity, integrity and reliability of internally and externally transmitted data.

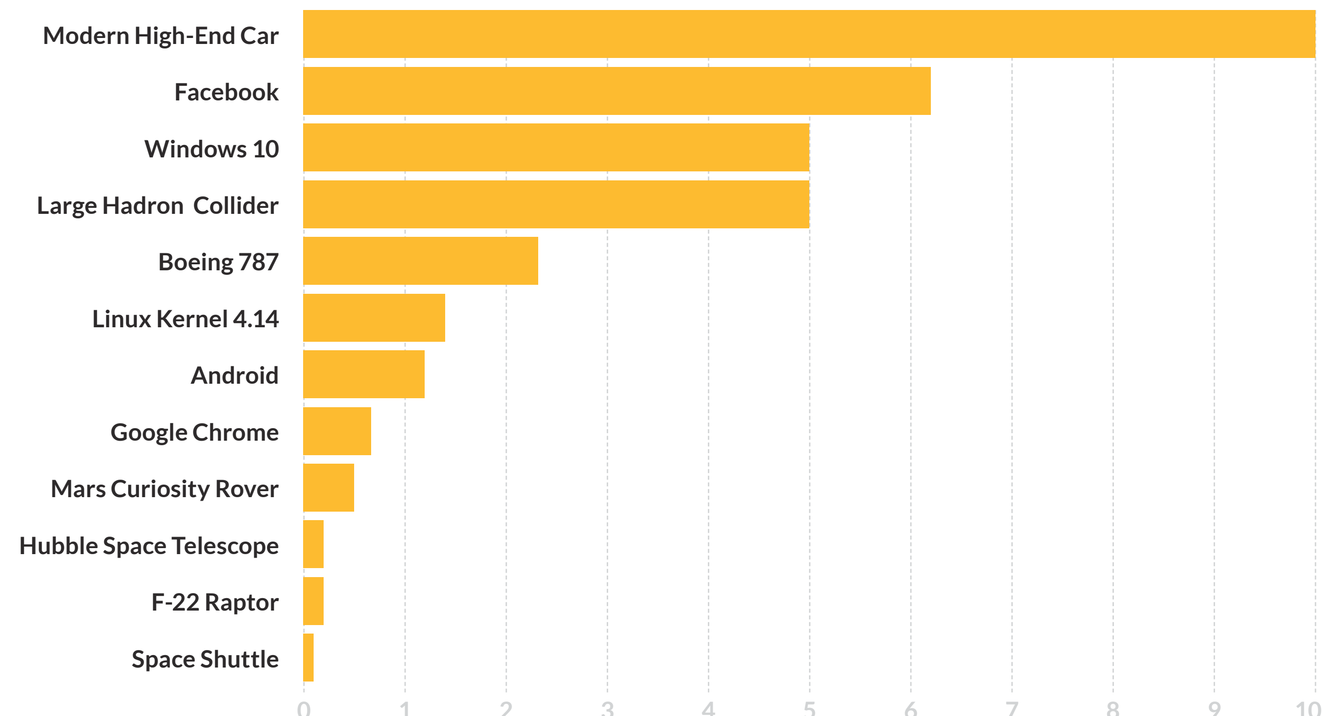
In-vehicle software systems require strong cybersecurity measures including encryption, authentication between systems, incorporating pre-implementation of threat modeling and static code analysis. With vehicle software footprints increasing, implementing strong measures will continue to be a challenge. (Boldt, 2017) Based on comparisons across several applications, the modern vehicle holds the largest number of lines of code (Figure 2). Given this information, the industry can no longer avoid implementing strong cybersecurity measures on in-vehicle software systems.

Not only is the vehicle at risk of direct compromise of its internal computing systems, the vehicle is also at risk for remote theft that does not require alterations to the vehicle. The most common of these

attacks are on the Passive Entry Passive Start (PEPS) and Remote Keyless Entry (RKE) systems. (Glocker et al, 2016; Greenburg, 2018)

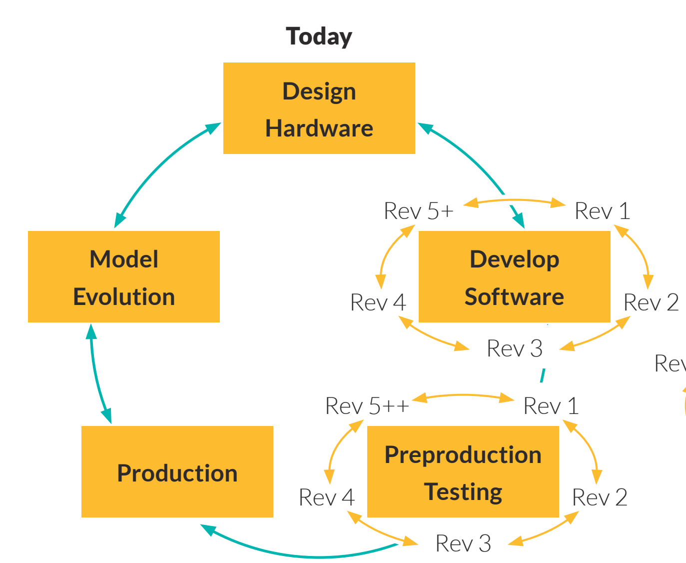
Figure 3 presents the prior state of the automotive development lifecycle where the cycle went from design of the hardware environment to the software development prior to pre-production testing. Figure 4 presents the lifecycle of the connected vehicle where the software is developed at the same time as pre-production testing followed by the production launch. What this shows is a need to increase development cycles in an effort to get to production faster. These cycles will need to include measures for cybersecurity from encryption of the messages passing through the intra-vehicle network (CAN, LIN, Auto Ethernet) as well as the data that is communicated to the remote backend systems that support over-the-air updates. Implementing this one aspect, a secured development lifecycle and methodology will mitigate a great majority of the cyber risks posed with the connected vehicle.

***Figure 2:** Lines of Code in Software Applications (in Millions)*



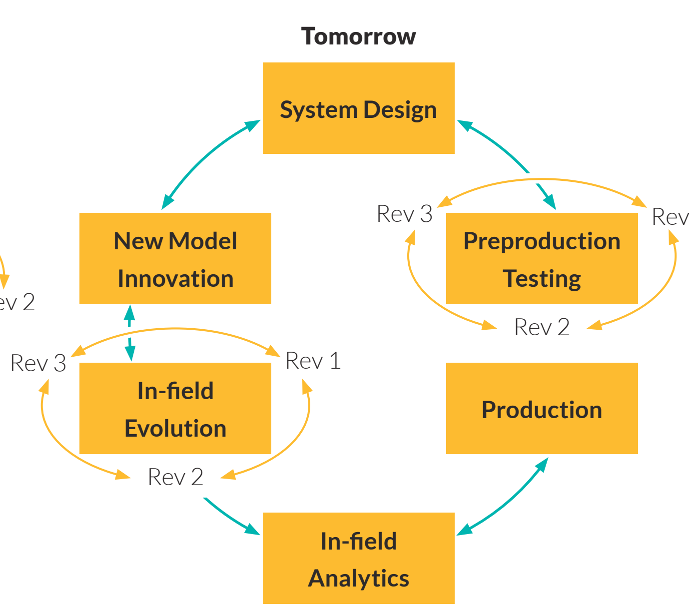
Source: NASA, IEEE, Wired, Boeing, Microsoft, Linux Foundation, Ohioh.

***Figure 3:** Automotive Development Lifecycle*



Source: Lewis, 2015

***Figure 4:** Connected Vehicle Development Lifecycle*



Source: Lewis, 2015

Manufacturing Cybersecurity: Tackling Risks in the Digital Ecosystem

Like the connect vehicle, IIoT creates more opportunities for security holes. Adding complex sensor data, industrial analytics, and smart machine functionalities in the manufacturing ecosystem enables data gathering and real-time remote management features across multiple geographical locations. (Rubio, et al, 2017)

New technologies—such as artificial intelligence, the cloud and Big Data—enable a merging of virtual and physical worlds. Organizations offer a virtual service for a physical asset, enabling training and visualization for machine maintenance. (Resnick, 2016) IIoT provides sensor data to virtual digital twins, illustrating the growing complexity of the manufacturing ecosystem and importance of accurate data for successful implementation and optimization.

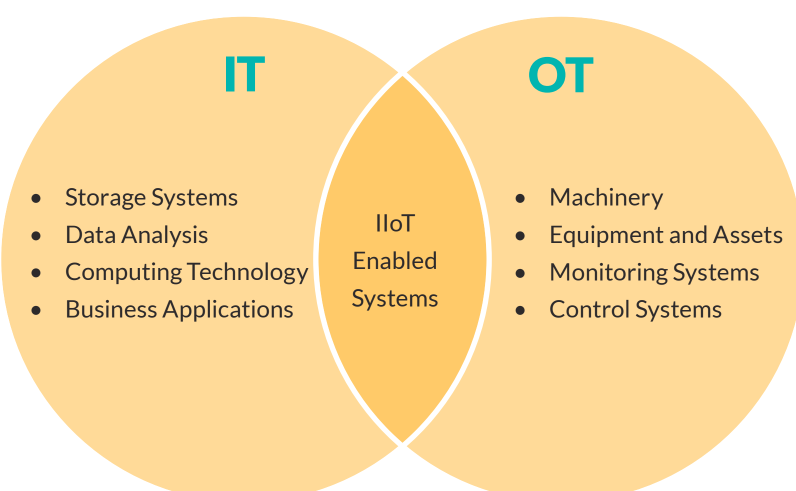
Many organizations tend to focus on these benefits IIoT promises, without realizing considerations specific to Industry 4.0 — technical complexity and the need for additional cybersecurity. IIoT will bring exceptional benefits to Industry 4.0, however, with the increased opportunity Industry 4.0 presents, there is also an increase in security risks and threats within the digital ecosystem. (Hale, 2018) Certainly, industry has been implementing networked based intelligent assets for years; however, with the addition of IIoT, the risks presented do increase the depth of complexity, integration issues and breadth of device types. (Byers, 2017)

Traditionally, information technology (IT) and operational technology (OT) have had fairly separate roles within an organization. However, IIoT is changing the operational architecture of manufacturing and is bringing these two worlds together (see Figure 5).

IIoT will bring exceptional benefits to Industry 4.0, however, with the increased opportunity Industry 4.0 presents, there is also an increase in security risks and threats within the digital ecosystem.

IIoT best-in-class implementations requires the convergence of IT and OT departments. Attackers are able to exploit the security gaps between IT and OT when these two departments have different practices and priorities. Successful IIoT implementation will require collaboration and corporation between IT and OT to minimize cyber threats within an organization.

***Figure 5:** Industry 4.0 Operational Architecture*



Source: LNS Research

Big Data Cybersecurity: Safeguarding our Right to Privacy

Big Data is not a new concept. "The total amount of data in the world is exploding with an estimated 2.5 quintillion bytes of data generated every day. Indeed, almost 90% of the data in the world was created in the last two years alone." (Liang et al., 2018) This explosion of data is in part leading to a need to provide protection. This lack of data protection can come in the form of protecting the data of customers, the organization and suppliers, including the connected vehicle.

There is a need for information security that scales with Big Data and also anticipates the demand, and possible legislation, for privacy. The protection of organizational data and customer privacy must remain a top priority, without stifling a robust ecosystem of information sharing. As such, manufacturers must move away from the idea of choosing between information sharing and information security. (Liu Quiong-mei, 2010) Organizations must determine how to implement data protection policies and programs to protect the sensitive information while moving the organization into the Industry 4.0 domain.

The microelectronics manufacturing industry has evolved as technology has progressed and changed. There is more complexity in the way devices are developed into smaller sizes while simultaneously being demanded to perform faster. This has brought in the need to implement the fundamental core concepts of Industry 4.0. (Moyne, 2018) This migration to Industry 4.0 has also brought the inclusion of Big Data infrastructures. With Big Data inclusion, there is also support for advanced data analytics. The inclusion of massive amounts of data within the operating environment has also introduced numerous risks that continue to challenge factory integration. (Moyne, 2018)

Organizations must determine how to implement data protection policies and programs to protect the sensitive information while moving the organization into the Industry 4.0 domain.

In the semiconductor industry, the collection of data from remote sensors and OEM tools is expanding. "Gathering the data and feeding it into remote analytics software to perform fleet-wide comparison presented familiar obstacles related to Intellectual Property (IP) protection." Many of the obstacles encountered with this data collection were found to be directly related to the protection of IP, the management of Big Data and implementation risks. (Suerich, 2018) The challenge then lies in the ability to protect sensitive IP from disclosure.

Industry Analysis

Rethinking Transportation: Robust Connectivity Ushers in New Era of Vehicle Security

When examining the Industry 4.0-influenced vehicle cybersecurity market, there is an anticipation the market will grow at a rate of over 23.5% from 2018 to 2024. (Global Market Insights, 2018)

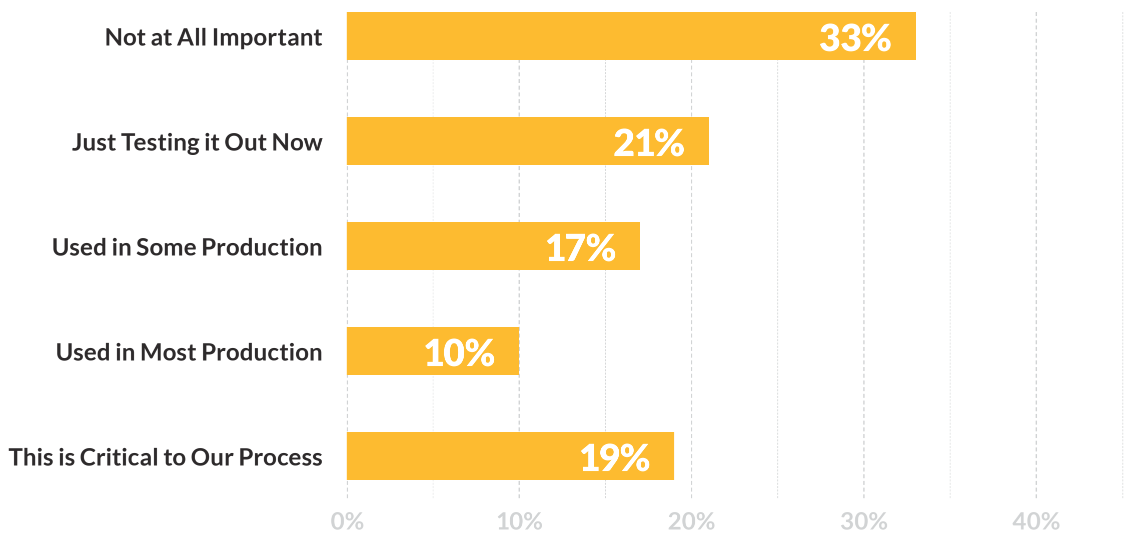
To be certain, smart transportation systems are combining information and networking capabilities to form an ecosystem of networked systems, supporting traffic regulation concepts and forcing humans to rethink transportation going forward.

The connected vehicle, in this type of highly connected ecosystem, offers the consumer telematics capabilities such as Vehicle-to-Vehicle (V2V) communications, real-time traffic information, on-board navigation systems, vehicle diagnostics, over-the-air software updates, in-car infotainment systems, including smartphone connectivity access for social media, streaming services and remote vehicle access for auto-start. With robust connectivity, companies functioning in the automotive cybersecurity market are investing heavily in research and development strategies, bringing about innovations in the automotive cybersecurity space. Regulatory and standards requirements, along with consumer demands will spark innovations in the automotive cybersecurity space.

This growth rate is most notable within the European automotive cybersecurity market. Expected growth should continue forward reaching $224 million (USD) by 2024. (Global Market Insights, 2018) Germany is the largest contributor to the European market, home to some of the world's leading automobile manufacturers that include Ford, Volkswagen, BMZ, Audi, Mercedes-Benz, Opel and Porsche.

Furthermore, with the growing need of telematics and cellular network in the automotive sector it influences a parallel growth in the automotive cybersecurity market. The next-generation of connected vehicles will make use of 5G networks to enable V2V and V2I (Vehicle-to-Infrastructure) sensors in order to support real-time navigation as well as collision avoidance which ultimately will reduce the total cost of ownership of the vehicle.

***Figure 6:** Importance of Cybersecurity in Your Industry Sector*



Retooling Factories: Cybersecurity for the Supply Chain

When hearing the term cybersecurity, most small and medium-sized manufacturers think of data breaches. Since most of these companies do not collect a significant quantity of data, they do not feel threatened. However, with the rise of ransomware, the focus of attacks has turned to business interruption.

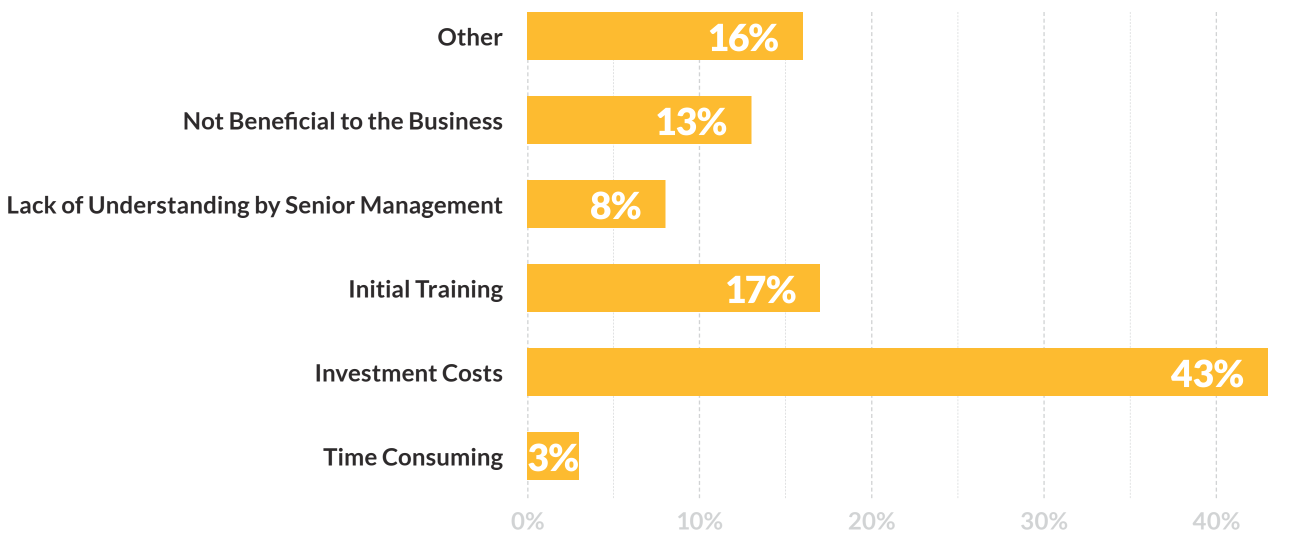
A large majority of respondents to the World Economic Forum's risk assessment survey of top global executives expected increased risks in 2019 of cyberattacks leading to theft of money and data (82%) and disruption of operations (80%). (The Global Risks Report, 2019)

Companies along the supply chain need to consider the cybersecurity posture of their customer.

> **More and more organizations are refusing to do business with those small to medium-sized organization that do not have a strong cybersecurity posture because it generates too much risk for them in the supply chain.**

But in Automation Alley's recent small survey of Michigan small and medium-sized manufacturers, 33% of individuals surveyed selected cybersecurity as "not important" (Figure 6). There can be several reasons for this unexpected finding. An organization can be using cloud computing services that address multiple cybersecurity requirements, which could indicate that the organization is putting trust into their vended solution(s) therefore deeming cybersecurity as "unimportant." It could also indicate a lack of awareness around cybersecurity and what it encompasses. Regardless, organizations need to take steps to identify all assets in a manufacturing setting to understand the threat landscape and attack vectors. As indicated in Automation Alley's 2018 Technology in Industry Report, cybersecurity needs to be addressed in the entire organization to include not only enterprise backend and business systems, but also those that run the manufacturing operations for IIoT which now include the Vehicle-to-anything concept (v2x).

***Figure 7:** Biggest Challenge of Using Cybersecurity*



It was difficult to reach an understanding of why cybersecurity is a challenge (Figure 7). Of the respondents, 48% chose not to respond. This is often the case in cybersecurity research as organization do not want to risk public knowledge of their cybersecurity posture. Those that did respond, indicate that cost is the number one challenge. However, these organization must consider the costs associated with a breach, which could not only include actual dollar losses, but also losses associated with their brand, reputation and position within their industry.

With these findings and the research presented, cybersecurity seemingly remains on the back-burner for many small to medium-sized organizations. Given that the OEMs of the auto industry as well as other large manufacturing organizations are consumers of the goods and services these smaller organizations offer, in addition to being held to many industry and federal regulations, cybersecurity will become increasingly important over the next year in terms of the supply chain.

IIoT suppliers are highly competitive in the market space, focusing on who is first to market. Suppliers and their consumers tend to embrace the benefits an IIoT solution delivers, failing to prioritize cybersecurity during the design phase in the process lifecycle. (Hale, 2016) Issues often arrive outside of the programmable logic controller (PLC) and remote terminal unit (RTU) suppliers when new suppliers enter into the IIoT space, often lacking a mature cybersecurity approach to product design. Some suppliers recommend positioning IIoT devices behind firewalls to address several cybersecurity challenges. (Hale, 2016) To facilitate a robust cybersecurity architecture, suppliers and manufacturers must understand all networked devices—IIoT or otherwise—are part of a larger digital ecosystem, requiring a layered security model to address complex threats. A focus on "first to market" may fail to address cybersecurity, leaving the consumer to address shortcomings in purchased solutions.

With each IIoT device implemented into the enterprise architecture, an increase in the security complexity occurs. Manufacturers, as well as suppliers, must anticipate an increase in risks associated with increased opportunities these solutions offer. (Hale, 2016) Additionally, there is an increase in the threat landscape with each added device. Fundamentally, the greater the complexity of an environment, the greater the potential for device misconfigurations, creating an avenue for device compromise. (Loukas, 2015)

When considering the attack surface, pivoting, secondary attacks and insider threats are examples. A pivoting attack involves targeting a non-interesting asset in order to gain access to something of greater value. More specifically, the actual target of the attack might be the IT assets vs. the OT non-interesting assets. A secondary attack involves attacking a supplier of another organization. For example, supplier A supplies microcontrollers to organization B. Organization B is attacked to gain access to supplier A's microcontroller IP. Once an attacker gains access to the initial target (organization B), the attacker employs trusted access to compromise the organization they really want to compromise (supplier A).

With all of the added complexity of devices increasing the chance of a misconfiguration (Loukas, 2015), monitoring and response plans must be included in cybersecurity postures. NIST has created a framework with five elements as shown in Figure 8: identify, protect, detect, respond and recover. In addition to threat intelligence, risk management, and a defense-in-depth (layered) security approach, ongoing cooperation between IT and OT should include a monitoring plan to identify compromises and respond when they are detected.

With the challenges of the increased inclusion of Big Data and data analytics in the manufacturing industry, the International Roadmap for Devices and Systems (IRDS) was created. In May of 2016, IEEE announced and launched this with a charter of "leading efforts to build a comprehensive, end-to-end view of the digital ecosystem, including devices, components, systems, architecture and software." (International Roadmap, 2017) The IRDS allows for the smart manufacturing of devices "ensuring that the microelectronics manufacturing infrastructure contains the necessary components to produce items at affordable costs and high volume in a safe and sustainable manner." (Moyne, 2018) There are challenges to this process from concepts such as Big Data, predictive analytics, AI, cloud-based solutions and cyber-physical systems in the risk of cyberattacks. (Moyne, 2018) These challenges can be overcome by setting up data protection policies that identify the problem and then working on a solution that encompasses industry-wide standards while adhering to regulatory pressures.

Figure 8: *Cybersecurity Framework*

Source: NIST

Cybersecurity Use Cases

Automotive Cybersecurity: Hacked Jeeps and Stolen Teslas

Two of the most significant vehicle cybersecurity events in recent years involve a 2015 incident in which two security researchers caused a 1.4 million product recall when they successfully hacked into a Jeep via Chrysler's Uconnect dashboard computers. And in 2018, a Tesla stolen via a Passive Entry/Passive Start (PEPS) replay attack appeared on YouTube. In this PEPS attack, the researcher demonstrated the signal transmissions from the vehicle and the FOB could be cloned allowing theft of the vehicle. (Greenberg, 2018) The PEPS attack took merely seconds, employing a $600 device.

Manufacturing Cybersecurity: Production Downtime and Money Lost

In 2016, one of the world's largest steel manufacturers, ThyssenKrupp AG, fell victim to a cyberattack originating from Southeast Asia in which technical trade secrets were stolen from the company's steel production and manufacturing plant design divisions. (Reuters, 2016)

In 2017, the WannaCry ransomware outbreak halted manufacturing operations at a Honda plant in Sayama, Japan for an entire day, affecting several older production line computers, causing them to shut down. (Forbes, 2017)

In 2018, a cyberattack hit a newspaper printing plant in Los Angeles, preventing it from printing and delivering Saturday editions of the Los Angeles Times and the San Diego Union-Tribune. It also interrupted distribution of the West Coast editions of the Wall Street Journal and New York Times, which share a production platform. The attack, which originated from outside the U.S., spread through the publishing group's network and re-infected systems crucial to the news production and printing process. (LA Times, 2018)

Data Protection: Regulations and Implications

The European Union's (EU) General Data Protection Regulation (GDPR) took effect in 2018 and is likely to be just the beginning of the "snowballing" of regulations that address the use of personal data. GDPR covers the personal data of any EU resident (Leeson, 2018) and has implications to manufacturers that conduct business in the EU such that "any company that has employees, suppliers or customers in Europe must comply with the regulation. Any company that processes data from Europe—say a U.S. marketing department creating personalized communications for a global product launch—will also need to comply with the regulation." (Leeson, 2018)

GDPR presents an overwhelming challenge to U.S. manufacturers. GDPR gives complete control of personal data to the individual. Given that, devices give the manufacturer insights into the consumer and their behavior, this regulation may add additional complexities to either collect or retain data. In the U.S., similar privacy regulation bills are being debated in state legislatures and have already been enacted in California in August 2018.

In addressing the various regulatory and standards requirements, the semiconductor industry has taken an approach to remove problems with the remote analysis of data acquisition. It employs a two-factored approach: 1) It identifies concerns and categorizes risk areas (Suerich, 2018) and 2) it identifies concerns involving interviewing employee stakeholders that handle day-to-day operations. These employees were involved in different discipline areas. The categorization of risk areas includes utilizing the NIST-specific guidelines for nine key security and privacy challenges. These areas of concern were applicable to the semiconductor industry when designing a system for the storage and manipulation of fabrication data using a public cloud. The areas are: 1) Governance, 2) Compliance, 3) Trust, 4) Architecture 5) Identity and Access Management, 6) Software Isolation, 7) Data Protection, 8) Availability and 9) Incident Response. (Suerich, 2018) Seurich investigated combining the "latest SEMI Equipment Data Acquisition (EDA) standards with cloud technologies and a flexible, transparent security infrastructure showing that it was possible to design a prototype solution that satisfies the above constraints." (Suerich, 2018)

Advantages & Challenges of Cybersecurity Implementation

Advantages

- Protection for your business and your customers: Ensure your data and that of all stakeholders remains private while safeguarding your products, services and technologies from potential threats.
- Increased productivity and profitability: Cyberattacks can slow your computers and even halt production. Implementing effective cybersecurity keeps your business up and running and profitable.
- Improved reputation and stronger customer trust: A solid cybersecurity strategy within your organization can inspire confidence among customers and clients. A protected company is a reliable one.
- Reduced insurance and compliance risks: A demonstrable cybersecurity program may reduce insurance premiums and lessen regulatory enforcement fines.

Challenges

- Product Design: Implementing a "Build-Security-In" approach to the design lifecycle is challenging for many manufacturers.
- Data Protection: Industry must continue to meet regulatory and industry best practices.
- Remediation of Attack Effects: Incident response and business continuity are critical to staying in business.
- Reliance on Legacy Systems: There is an extensive reliance in the manufacturing industry on legacy systems that are difficult to maintain.

Conclusions

- The connected nature of Industry 4.0 makes OEMs across the globe—and their supply chains—more vulnerable than ever before to cyber threats.
- There is not a clear understanding among manufacturers of the associated cybersecurity risks Industry 4.0 brings into the manufacturing ecosystem.
- There is a tendency to tackle cybersecurity from an Information Technology (IT) approach, resulting in a failure to address the operational technology (OT) challenges it brings.
- Industry can no longer avoid implementing strong cybersecurity measures on in-vehicle software systems.
- Organizations must determine how to implement data protection policies to protect the sensitive information while moving the organization into the Industry 4.0 domain.
- Those organizations that choose to not implement a strong cybersecurity posture will be increasingly challenged in the years to come where those organizations that have a strong cybersecurity posture will be selected as the supplier of choice.
- To facilitate a robust cybersecurity architecture, suppliers and manufacturers must understand all networked devices—IIoT or otherwise—are part of a larger digital ecosystem, requiring a layered security model to address complex threats.

Action Items

- OEMs must consider cybersecurity from connected vehicle development through implementation and should continue strengthening secured development methodologies.
- As a starting point, cybersecurity for Industry 4.0 with IIoT should incorporate many different factors for successful implementation. If options, such as USB plugins or services on an IIoT device are not required, they should be restricted to provide physical security as well.
- IT and OT should be merged for a successful cybersecurity strategy.
- People are an often-overlooked component within cybersecurity approaches. People enforce and ensure proper cybersecurity posturing, across an organization. (Hale, 2018) Leaders must focus on a hybrid approach of people, procedures and technical measures across their diverse environments for optimal success.
- Cybersecurity is not a technical issue, entirely. It's also an operational issue. If the manufacturing line shuts down, manufacturing deadlines are missed. If a security breach occurs due to theft or malice, the entire organization is impacted. The entire organization should take care to mitigate threats and risks across both the OT and IT ecosystems.
- Cybersecurity involves responding to breaches when they occur, planning beyond the prevention phase. As network perimeters dissolve, and IIoT and other devices extend access to OT networks, organizations must create and test incident response plans.
- Because of the ongoing data regulations both in the U.S. and abroad, organizations need to explore guidelines that can help to protect critical data and anticipate regulations that may restrict the use of this data.

Velocity Index™

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The Automation Alley Velocity Index is a new tool designed to provide companies with a snapshot of each Industry 4.0 technology's maturity and its projected rate of development within various industries.

With simple charts, one for each of the eight Industry 4.0 technology sectors identified in this report, the Velocity Index provides an independent, condensed metric to help business owners determine a technology's potential lifespan and return on investment.

The Velocity Index is based on the independent research of academic subject matter experts who utilized a confluence of data—published in advanced articles and peer-reviewed journals—compacted into single markers, providing corporate executive with an unbiased assessment of Industry 4.0's potential to impact their bottom lines.

How it works

There is one Velocity Index chart for each technology. Each chart includes the following four technology markets: 1) Automotive, 2) Health Care, 3) Retail Products, and 4) A fourth market of interest to that technology sector. Each chart plots the technology's maturity, return on investment and its direction and rate of change (velocity) within a particular industry.

A technology with high velocity, for example, is one that is rapidly maturing. Initially, that may seem exciting, but it may also indicate that the technology's standards, protocols, software or hardware investments could quickly become outdated by the next technology breakthrough. That doesn't mean a company shouldn't invest in the technology, it may, however, decide to purchase services rather than invest in capital equipment.

The following provides some detail of the chart layouts:

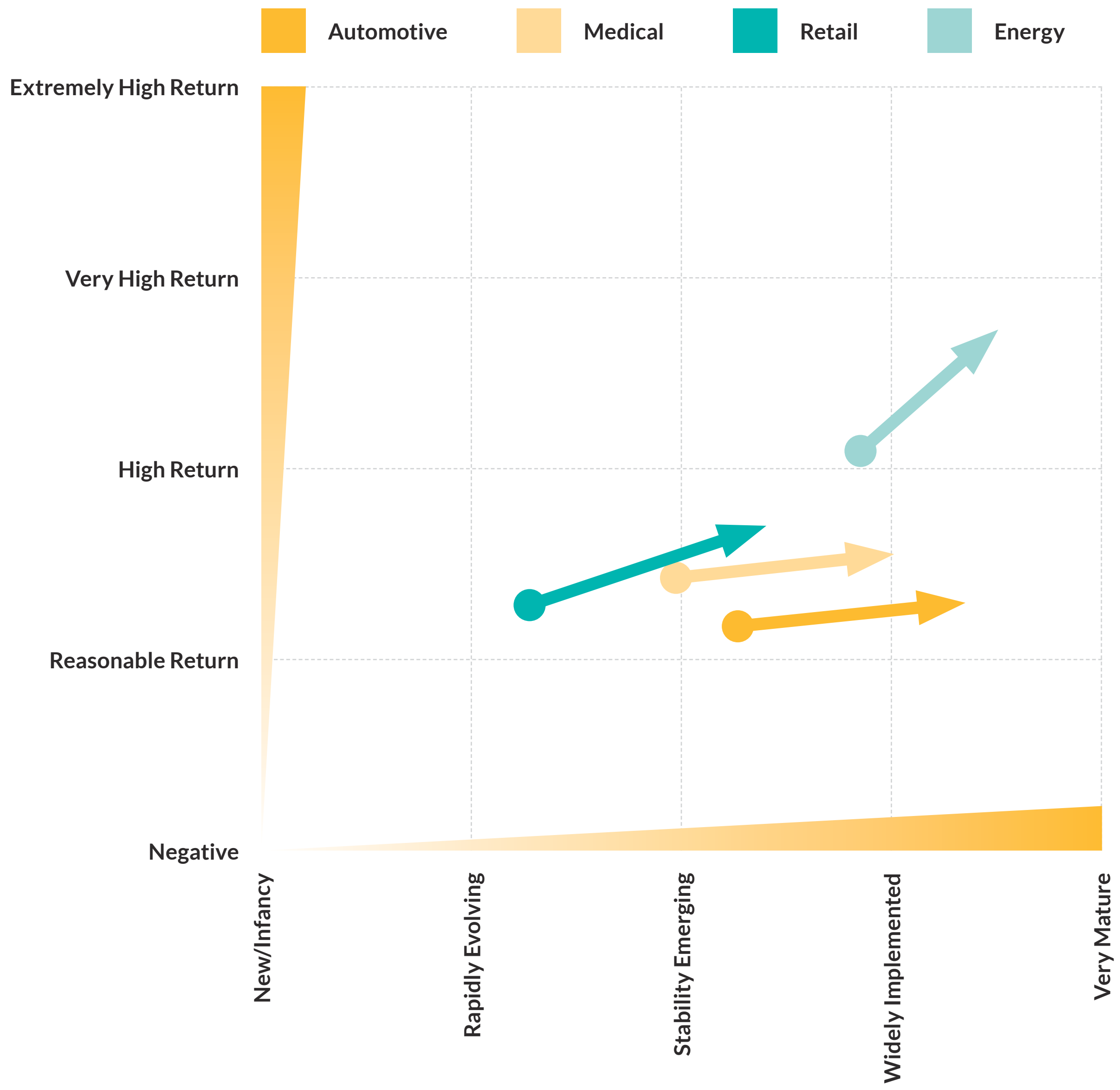
The Horizontal Axis (x axis): indicates the maturity of the technology. The scale ranges from immature to fully mature. An immature technology is one that may have been recently invented. Very few implementations are found and only the early adopters have invested. An example of an immature technology might be the use of artificial intelligence in every-day retail products. On the other end of the axis, a mature technology is one that is widely implemented and has become so pervasive that it would be unusual to find a company that has not deployed the technology. An example of a mature technology would be the use of robots for body welding operations in automotive plants.

The Vertical Axis (y axis): indicates a technology's potential for return on investment (ROI). The scale ranges from negative to extremely high returns. A technology may have a negative return on investment if the technology is a necessity for a business to simply remain competitive. An example of a negative ROI might be a company that needs to add IoT to keep up with a competitor that has launched a product line with IoT. On the upper end of the y axis, a technology may offer multiple returns on the investment. An example of a high ROI would be the implementation of technology that makes all other competitors irrelevant in the marketplace.

The Velocity Vector (arrow): indicates the rate and direction of change of a market's application of a technology. The rate of change is indicated by the length of the arrow. The four markets shown can be compared to each other, to show the relative rates at which the technology is changing. The direction of change is indicated by the orientation of the arrow. Of course, technology maturity only moves left to right across the chart, but along with the maturity change, typically, the ROI will simultaneously change.

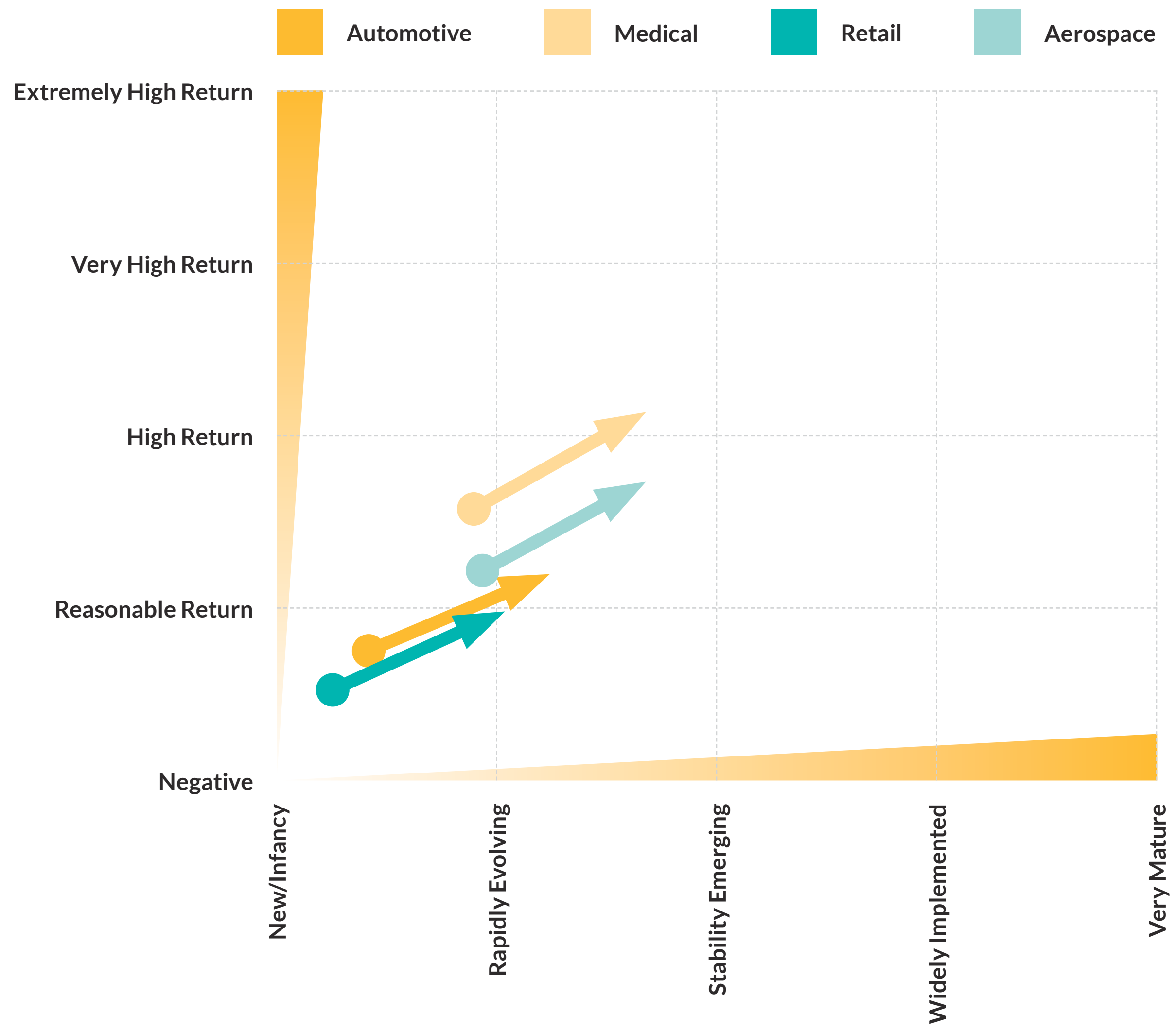
Internet of Things

IoT is approaching the level of being widely implemented, creating pressures to deploy IoT even for mature businesses, but the ROI potential is dropping. "IoT and machine-to-machine growth is creating revenue opportunities for service providers operating in mature markets, which may help to offset declining revenue trends in core business segments." (Zavazava, 2018) The return on investment scale is showing the ROI to be slightly above the reasonable returns. The markers are not higher as the cost of investment in this technology has become a concern. As reported in The Economist, in 2013, the main challenges of IoT adoption cited by executives related to understanding and perception. Today, they are more concerned with practical matters, with 29% of respondents indicating the high cost of required investment in IoT. (Twentyman, 2017)



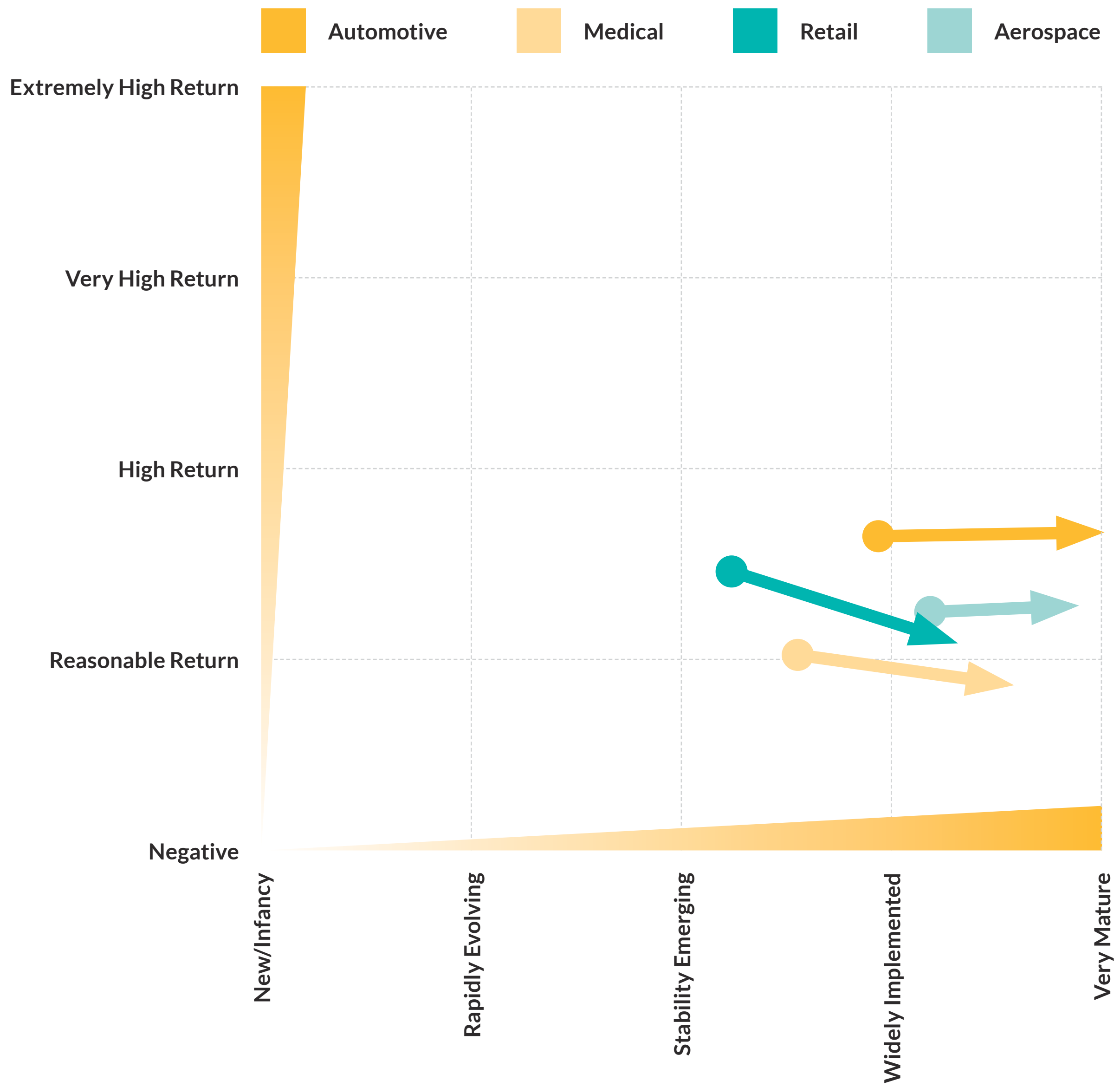
Big Data

Big Data, or perhaps better titled "the application of Big Data," may be the most promising—yet most overwhelming—of the Industry 4.0 technologies. While it holds the potential to fundamentally change the way corporate decisions are made, the way production runs are forecasted and many more promising applications, it is most bewildering in that companies struggle with the sheer volume of data, how to parse it, how to draw knowledge from it and how to extract competitive advantage. The markers are shown on the low end of the maturity axis, with vectors pointing upward as the ROI potential looks promising. Data is often referred to as "the new oil," presenting substantial revenue opportunities for business. Most industries are investing in turning the massive amount of data flowing from IoT sensors, industrial meters, connected devices, smartphones, wearables and any kind of web-based services, into actionable insights. (Zavazava, 2018) But before companies get too excited about the possibilities of Big Data, they should be aware that the immaturity of the technology can lead to some missteps as well. Google found this out the hard way as they made an erroneous assumption that the number of internet searches for flu remedies directly correlated to the number of people that are ill with the flu. They were wrong. (Salzberg, 2014)



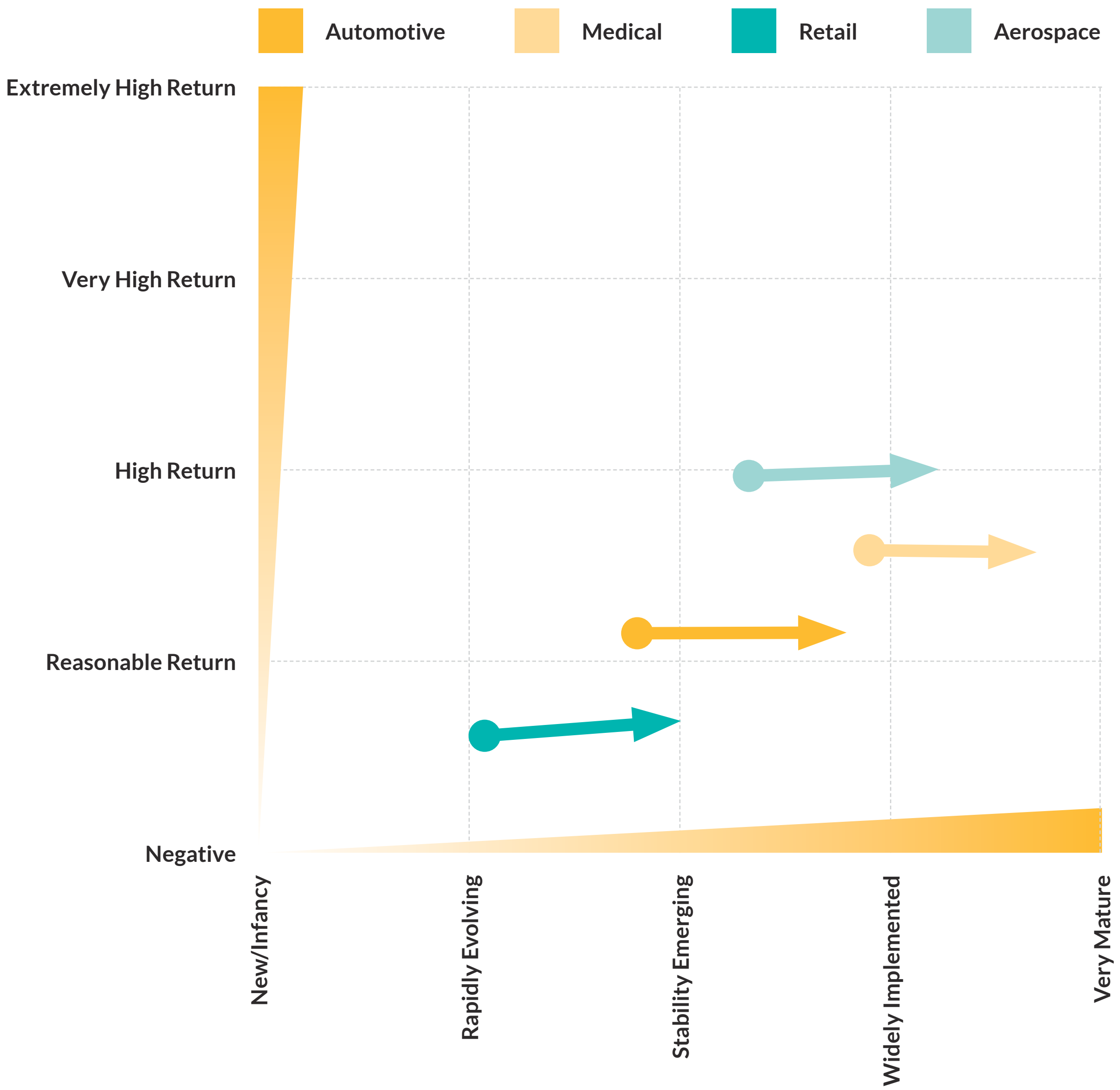
Cloud Computing

Cloud computing technology has become widely implemented and is approaching standard practice. The ROI equation comes down to the decision of internalizing computing resources or purchasing them as a service. The supply situation for cloud computing is in full competition mode with numerous competitors. Full maturity has not been reached, as there are many questions around standard practices. (Odun-Ayo, 2018) The vast majority of IT companies have already made the transition to cloud-based computing as a service. Researchers have identified strategies to avoid common mistakes that could rob the investors of ROI. Market dynamics are driving the supply side economics and will eventually bring prices down, further enhancing ROI.



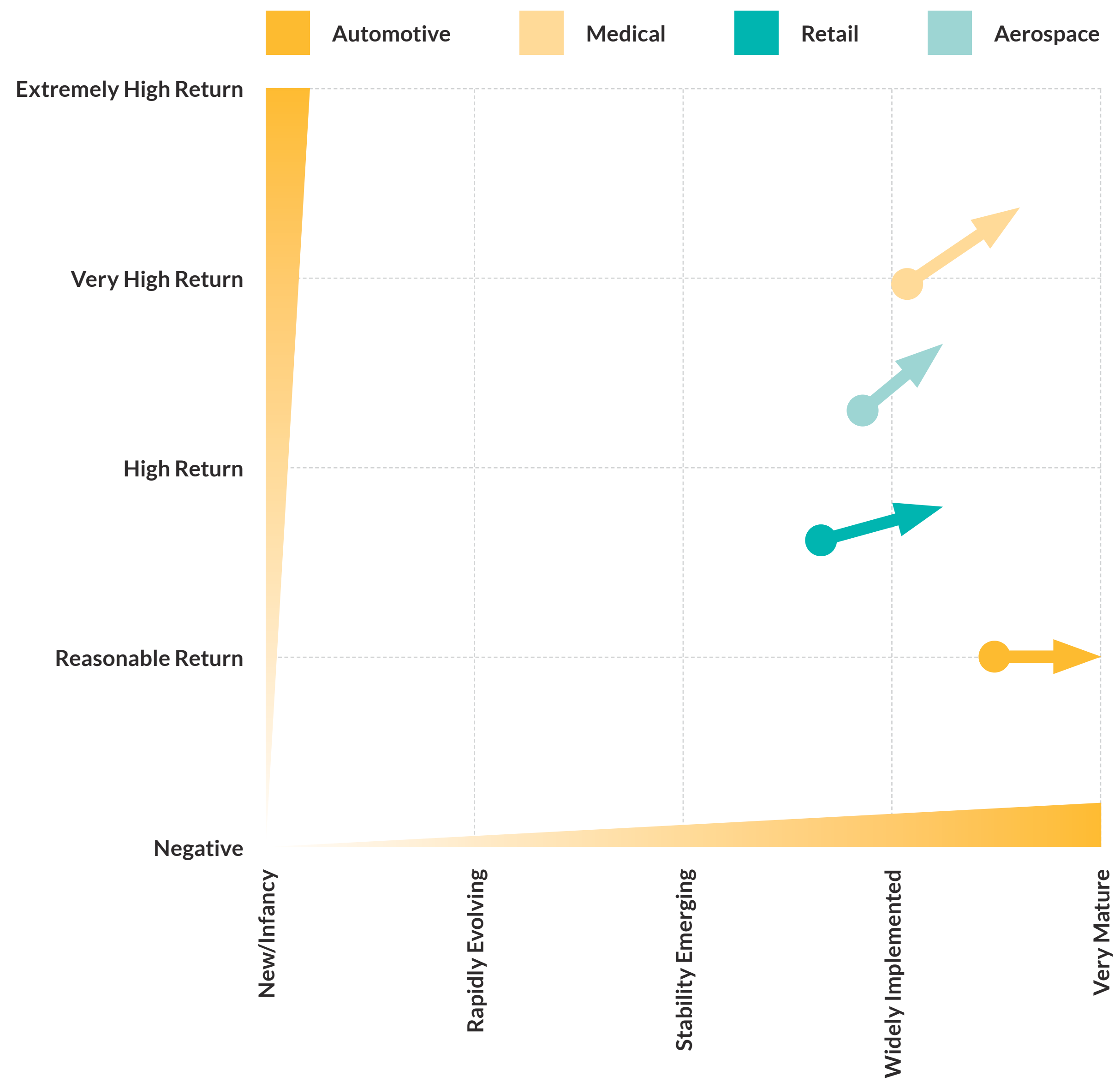
Cybersecurity

The nature and voracity of cyber threats changes every day, but the community of practice is approaching a level of maturity as indicated by the coalescence on standards and practices. It appears that the industry continues to move toward a level of uniformity by adopting voluntary, consensus-based, industry-led practices in regard to security risk assessment. (HIMSS Cybersecurity Survey, 2019) Cybersecurity is aimed at loss prevention, so it could be argued that ROI is not the best scale to use. It is included here for comparison to the other Industry 4.0 technologies.



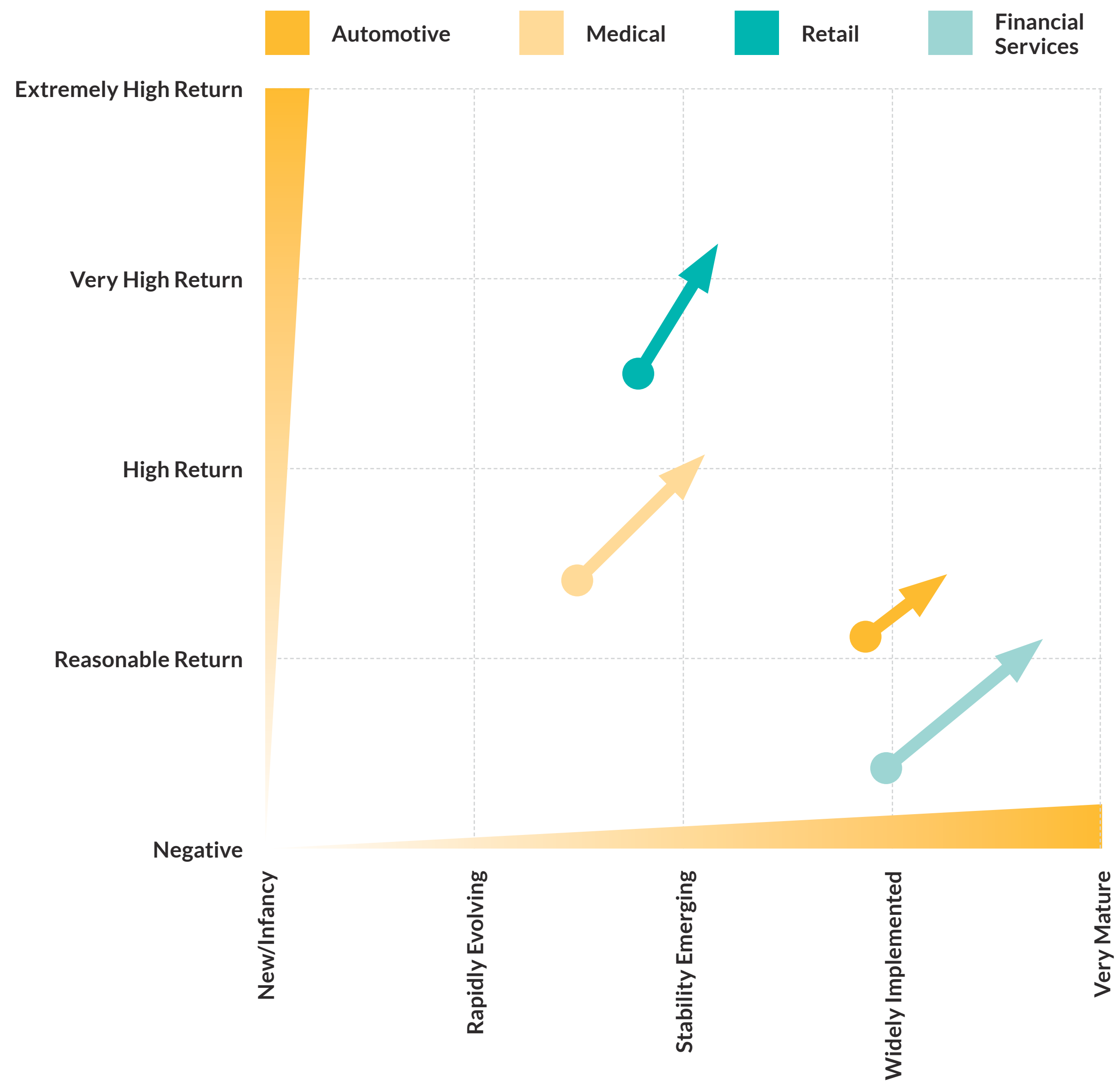
Robotics

Robotics has become ubiquitous with manufacturing and the technology has reached a state of maturity and wide implementation. The maturity of the robotics industry is indicated by the rapidly rising volume of robotics sales. In 2017, robot sales increased by 30% to 381,335 units, a new peak for the fifth year in a row. (IRF, 2018) Sales of robots will continue to increase, with a projected annual growth rate of 14% through 2020. (IFR, 2017)



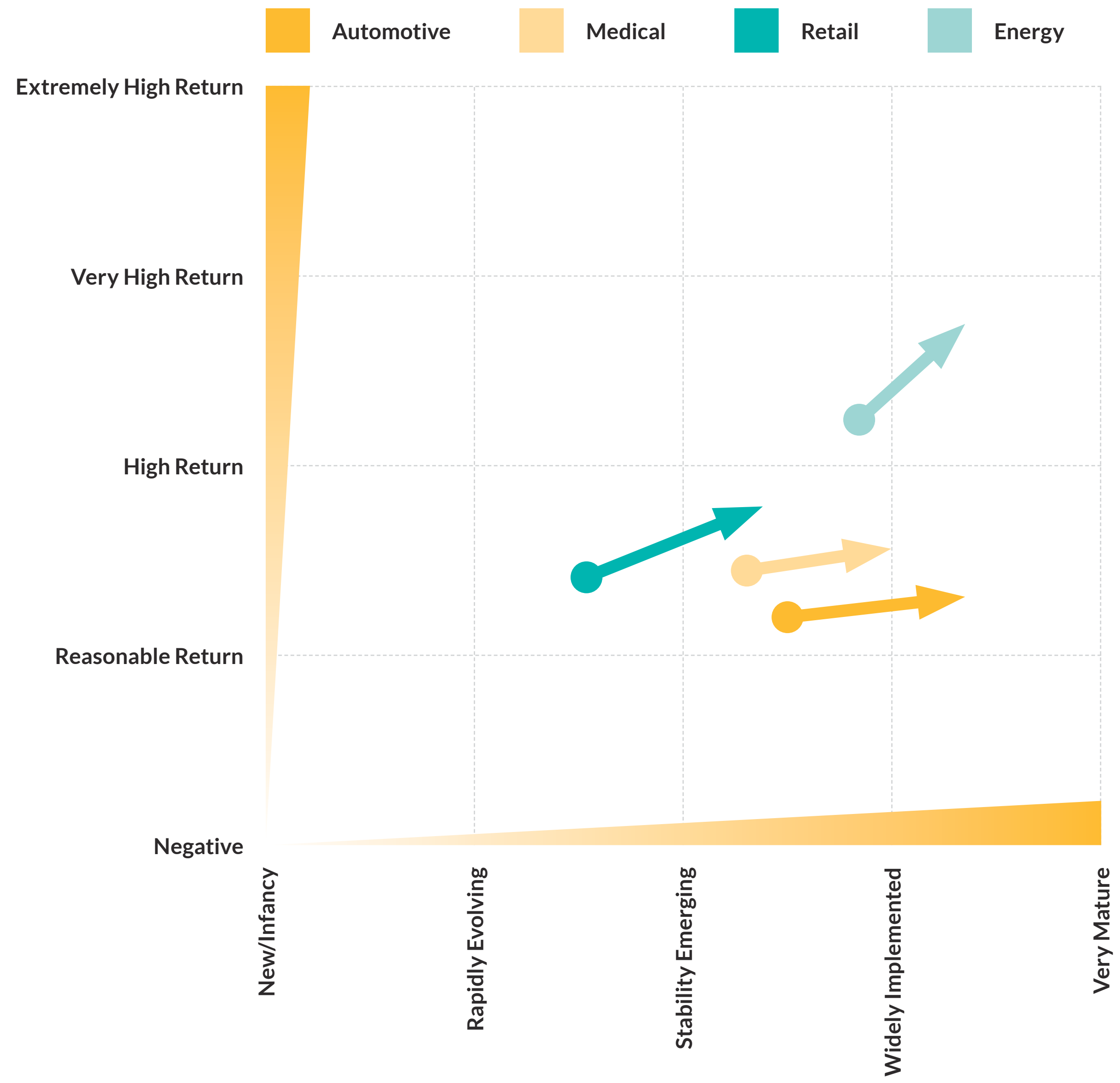
Artificial Intelligence

Artificial Intelligence (AI), when combined with other Industry 4.0 technologies like robotics and Big Data, is gaining momentum as a powerful technology solution for companies looking to enhance product development, operations, customer experience and more. Manufacturers are certainly aware of the availability of AI technology, but the technology is in the evolving stages and it is unclear whether the ROI is favorable. The majority of companies report that they have not fully determined the value proposition of AI. (Chui and Francisco, 2017) There are numerous challenges related to AI, the biggest of which is initial training, but these are indicative of the evolving state of the technology, as indicated on the Velocity Index.



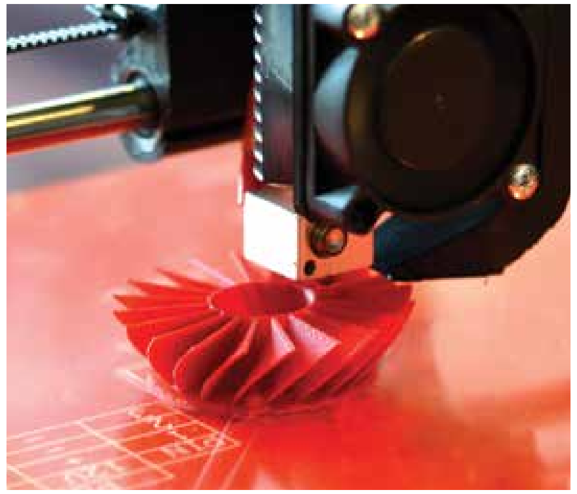
Modeling, Simulation, Visualization and Immersion

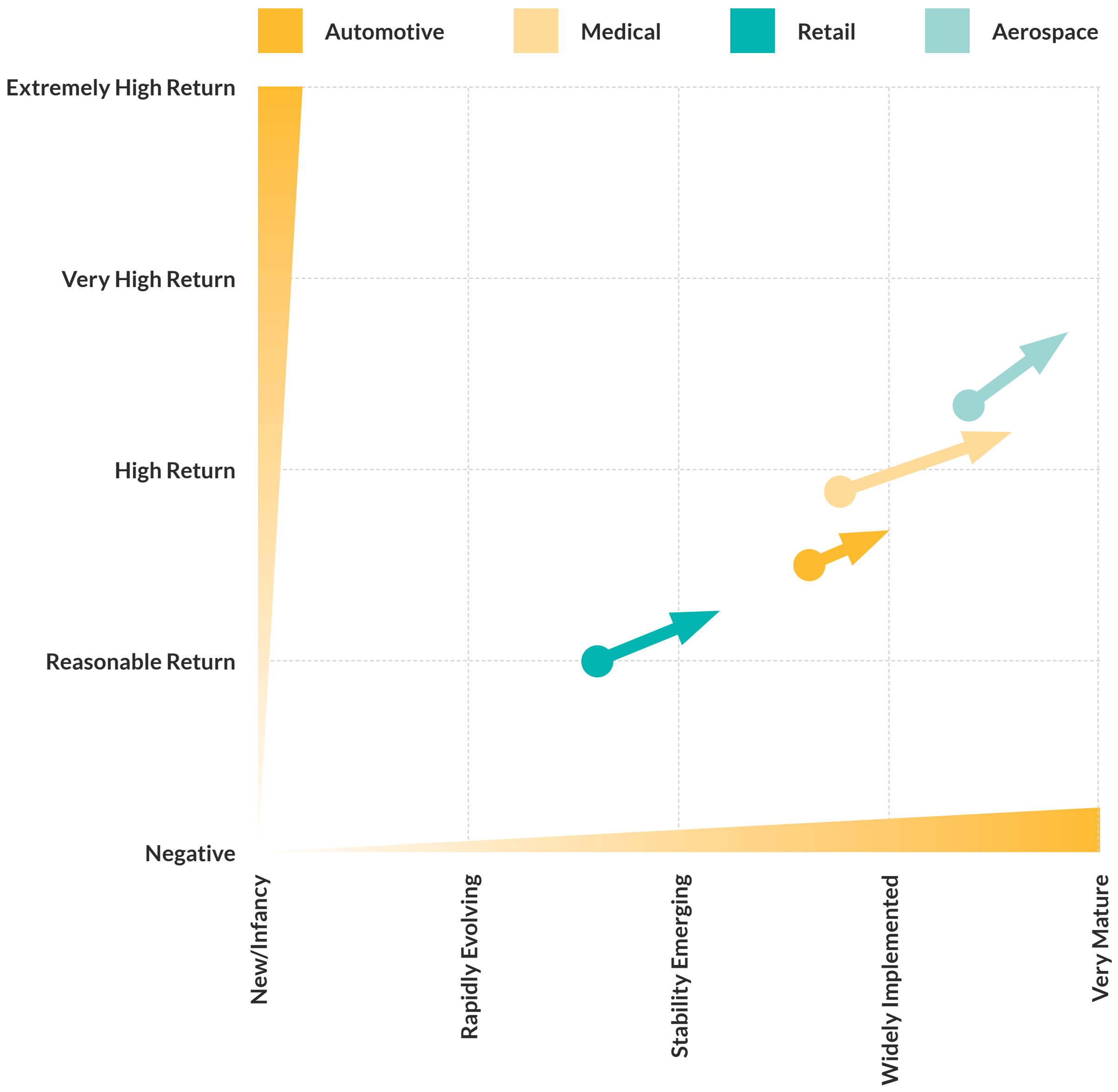
The MSVI sector is widely varied and has many applications. Tools are available for applications such as training, production workflow, logistics, material handling, product design and many more. (Kibira and McClean) This level of activity suggests the technology is fairly mature, with multiple competitors developing applications. However, it is not fully mature as MSVI has not become pervasive. NASA researchers are using MSVI to integrate the development of materials and systems, as parallel developments. This use of MSVI as the common ground tool set is an indication of the acceptance of the technology as nearing the level of a standard. The project includes development of the financial ecosystem to deliver resilient ROI. (NASA Vision 2040). Perhaps the greatest benefit and ROI from MSVI is the ability to communicate results of analysis to the spectrum of stakeholders. (Akpan, 2017)



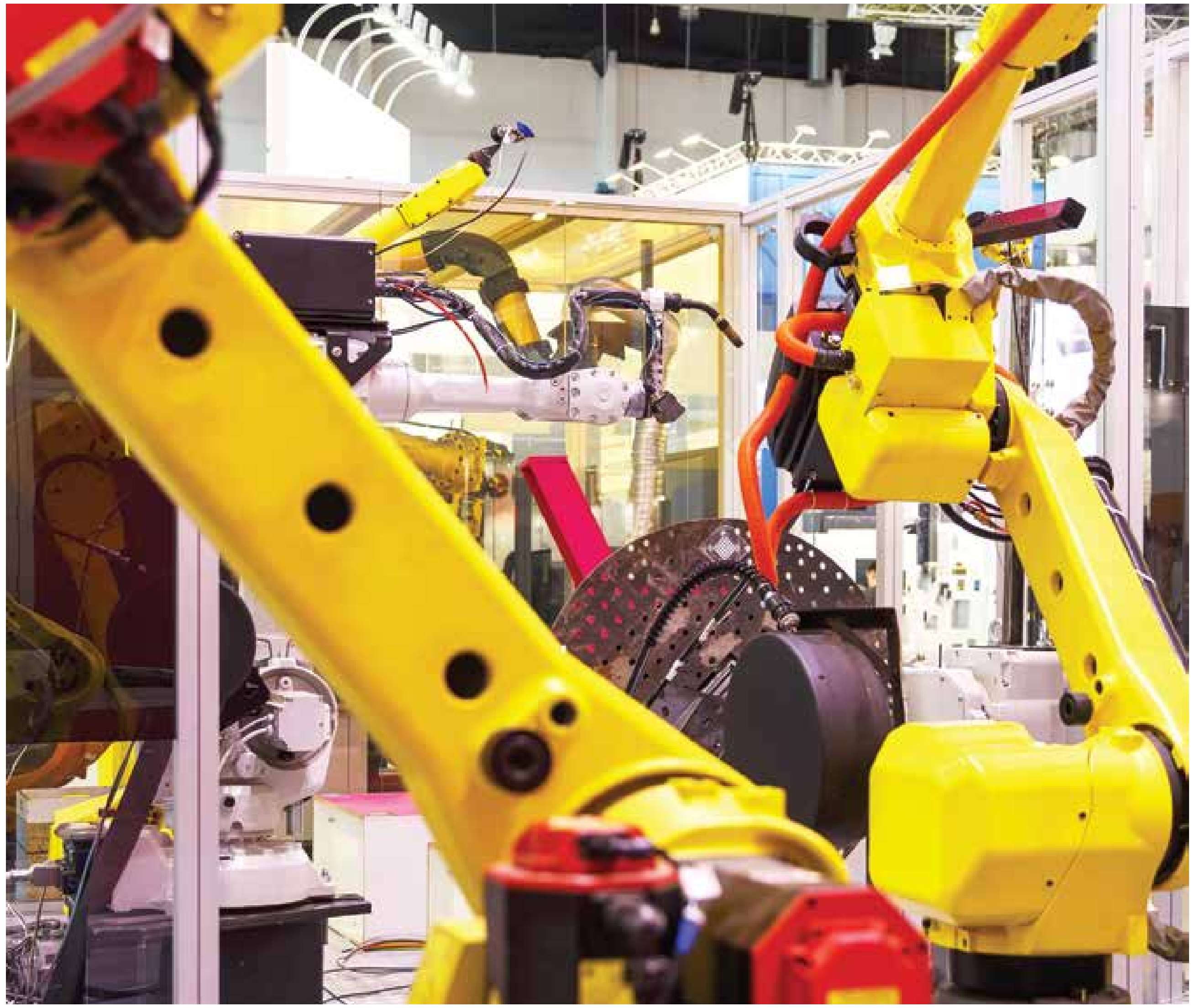
Additive Manufacturing and Advanced Materials

Additive manufacturing is emerging in various forms from desktop 3D printing to on-site construction of entire buildings. In this respect, the technology is not novel, but not fully mature. Additive manufacturing is still developing new applications in physical scale and strength of materials, but the general technology has begun to settle into stable forms. "The market for printer unit shipments will grow at a CAGR of 121.3% through 2019 and exceed $14.6 billion." (EY 3D Printing Report)





Robotics



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The proliferation of smart and connected technologies in the manufacturing industry has led to an innovation boom within the robotics sector in recent years. From collaborative robots that work safely alongside humans to the application of machine learning and artificial intelligence, Industry 4.0 is enhancing the robotic automation that revolutionized the manufacturing industry. This ever-evolving sector is poised to continue its transformation in factories across the globe.

In its 2018 report "Readiness for the Future of Production," the World Economic Forum said artificial intelligence and the robotic development of machines that can substitute for humans—increasingly in tasks associated with thinking, multitasking and fine motor skills—will be a key emerging trend within the Industry 4.0 ecosystem. (World Economic Forum, 2018) However, there are many things that robots, at least at this point in time, cannot do well that keep humans in the manufacturing process.

Emerging Trends

Collaborative Robots

While robots are good at performing repetitive tasks, without additional sophisticated systems, they do not react or adapt to changing manufacturing conditions such as defective parts, parts not being staged correctly, or other varying conditions in the same way as humans. Because of these existing limitations, there is presently a need for manufacturers to utilize both robots and humans in the manufacturing environment.

Robots essentially are used in manufacturing to perform work that is not suitable for humans, such as hot, cold, dangerous or noisy environments. They solve ergonomic issues by performing repetitive tasks that may otherwise result in human injury. Robots also are better suited for dangerous tasks, such as pouring molten metal or loading and unloading stamping presses. In addition, robots can perform better than human workers when it comes to speed, power and precision.

While traditional robots are placed in a cell, separated from workers by hard barrier guarding to protect the worker from the robot, collaborative robots, also known as cobots, allow the worker and robot to coexist without a hard barrier and are designed to allow the robots and workers to perform tasks collaboratively. (IFR, 2018)

Cobots can work safely alongside humans and are often far cheaper than their industrial counterparts. As cobots become more capable in tough industrial settings, they will see greater adoption by manufacturers with strict ROI requirements. (RIA, 2018) Figure 1 illustrates the differences between traditional manufacturing robots and cobots.

Within the cobots industry, there are various ranges of potential collaboration:

- Sharing a workspace but working independently
- Performing sequential movements between the worker and robot
- The worker and robot working on the same part
- The robot responding to real-time movement of the worker (IFR, 2018)

***Figure 1:** The Cobot Difference*

VS

- Large, fixed equipment
- Typically requires safety cage
- High-volume, high-speed production
- Complex integration and programming
- Difficult to change/redeploy
- High development costs

- Small and flexible
- Similar speed as human
- Fast set-up
- Easy to use
- Safe alongside workers
- Low upfront costs and fast ROI

Source: Universal Robots, 2019

Collaborative Robot Applications

Due to the force and speed limiting capabilities of robots, there are inherent limitations in their payload, which lends itself to utilizing cobots in specific applications. Initially, cobots were used in situations where it would pick up an object and place it in a specified location and orientation. (RIA, 2018) These applications have evolved to include:

- Sorting parts
- Packing and palletizing boxes
- Inspecting parts
- Monitoring machines
- Performing basic assembly operations
- Welding (RIA, 2018)

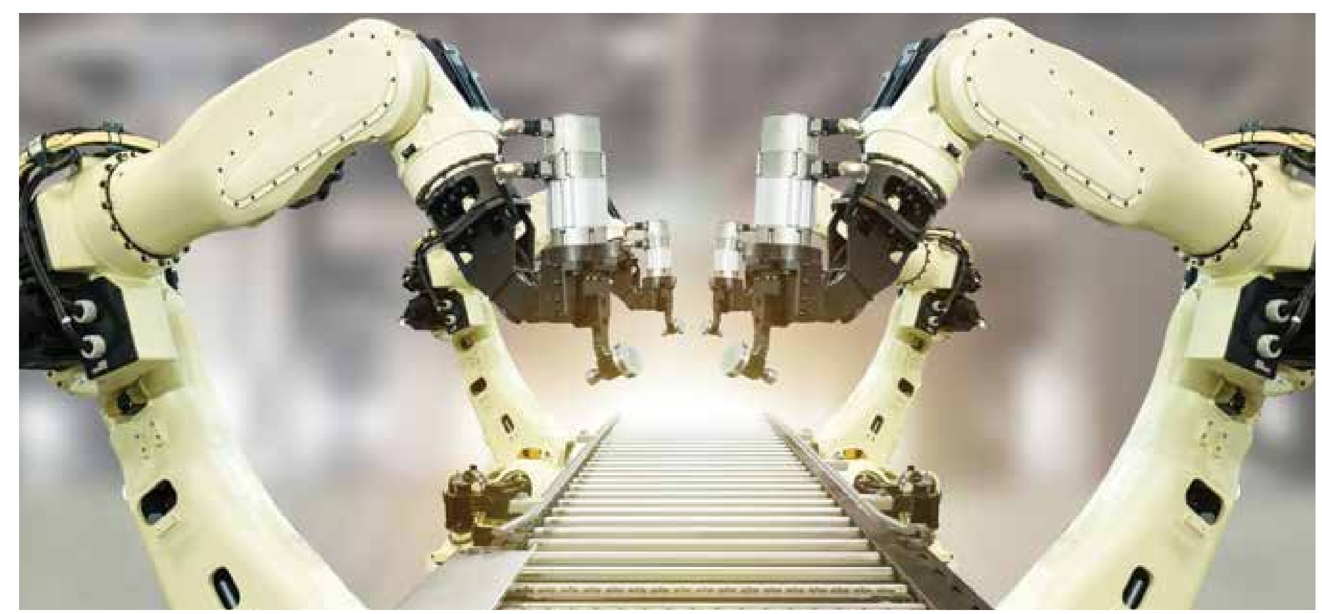
As this technology advances and as end user and systems integrators become more familiar with effective ways to implement cobots, the possibilities of how to effectively implement these machines into the manufacturing environment will continue to grow.

Cobots may also provide an avenue for companies to avoid penalties imposed on businesses which replace humans with automation. "Politicians have already proposed robot taxes to cover these eventualities. Fostering harmonious working relationships between humans and machines could be a trend which will set people's minds at ease in 2019." (Forbes, 2019)

Wearable Robotics

Wearable robotics are on the verge of exponential market growth as new technologies aimed at transforming human capabilities enter the marketplace. In particular, the market for exoskeleton robots, a unique form of professional service robot, is expected to explode in value in the next few years, reaching $2.8 billion in value by 2023 and growing at an astounding 45.2% compound annual growth rate (CAGR). (Markets and Markets, ND)

These robots, which provide essential support for human motion and enhance human strength, are being utilized in a wide range of applications, including the health care sector for rehabilitation services, military deployment to fight fatigue and injury for soldiers in combat and ergonomic support for laborers in industry who perform repetitive or stressful work. (RIA, 2019)



Delivery Bots

Companies including Segway, Google and Amazon are turning to robots to carry out delivery operations—often times the most expensive stage of the delivery process where many small, individually packaged products must be precisely targeted to reach their final destinations on time and intact. (Forbes, 2019)

From groceries to retail, online sales will continue to soar in 2019 as companies test robotic delivery device technology. In fact, the number of packages needing to be delivered every year could rise to more than 25 billion in the U.S. over the next ten years. (McKinsey, 2016)

Robotics, IoT & Smart Sensors

The Internet of Things (IoT) will continue to greatly impact industrial robotics in 2019. Increasingly, manufacturers are adding sensors into their operations, connecting multiple systems to boost efficiency and gain access to enormous amounts of data for supply chain monitoring and predictive maintenance. In 2019, technological advances in smart sensors—sensors with built-in artificial intelligence—will reduce the need for information to be sent to the cloud or centralized servers for processing, before it can be acted on. (Forbes, 2019)

Artificial Intelligence in Robotics

Artificial intelligence (AI) is set to disrupt practically every industry imaginable, and industrial robotics is no different. Continuous advancements in computing power is opening the door to entirely new AI possibilities within the robotics sector, such as advancements in specific areas of AI like machine learning.

Currently, AI and machine learning are being applied in limited ways and enhancing the capabilities of industrial robotic systems. AI can replace the need for human beings in hazardous work environments. We have yet to reach the full potential of robotics and machine learning, but current applications are promising. (RIA, 2018) Figure 2 shows the impact of AI and machine learning on the robotic processes.

Figure 2: *The Impact of AI & Machine Learning on Robotic Processes*

There are four areas of robotic processes that AI and machine learning are impacting to make current applications more efficient and profitable. The scope of AI in robotics includes:

Vision	Grasping
AI is helping robots detect items they've never seen before and recognize objects with far greater detail.	Robots are also grasping items they've never seen before with AI and machine learning, helping them determine the best position and orientation to grasp an object.

Motion Control	Data
Machine learning helps robots with dynamic interaction and obstacle avoidance to maintain productivity.	AI and machine learning both help robots understand physical and logistical data patterns to be proactive and act accordingly.

Source: RIA, 2018

Industry Analysis

Jobs

There is a general fear that robotics and automation will lead to a decrease in overall employment for workers. On the surface, this seems logical, as it can be argued that the tasks being performed by a human worker can be performed by a robot, thereby eliminating the need for that worker. However, new types of jobs will be created in factories of the future. Automation might not cause mass unemployment, but it may well require workers to make disruptive transitions to new industries, requiring new skills and occupations. (Bessen, 2019) Some industries will grow while others decline. This raises a distinct policy challenge: how to support workers making transitions to new industries, new occupations with new skills, sometimes in new regions. (Bessen, 2019)

Companies that can understand the impact of digitization will succeed. In a recent small survey performed by Automation Alley of small and medium-sized Michigan manufacturers, almost half of companies surveyed indicated they are utilizing robotics and more than half felt that robotics is important to their production processes.
For example, the use of cobots in manufacturing environments have contributed to saving operators time, allowing employees to meet increased production demand with the current allocated resources and allowing them to address more value-added tasks. (Towers-Clark, 2018)

This increase in productivity leads to increased demand, resulting in job creation. It also allows companies in high-cost countries to be able to compete with low-cost countries and bring work back to the high-cost countries. (IFR, 2017) The argument can then be made that companies that do not utilize robot technology would lose their competitiveness, resulting in job losses.

> **Within the robotics industry, cobot sales have the biggest potential for growth.**

Sales

Sales of robots continues to increase, with a projected annual growth rate of 14% through 2020. (IFR, 2017) Within the robotics industry, cobot sales have the biggest potential for growth. They currently account for only 3% of all robot sales, but are expected to grow to 34% by 2025. (Towers-Clark, 2018)

Small and medium-sized enterprises (SMEs) are the largest potential users of cobots, as they are beginning to understand the advantages and disadvantages of this technology. (RIA, 2018) Cobots, due to their lower cost and ease of programming, compared to traditional robots, have provided SMEs with the opportunity to implement automation and remain competitive. The SMEs in the Automation Alley survey indicated that the biggest challenge for companies in implementing robotics is the investment costs, which provides a good argument to invest in the cost-effective technology. These companies did see the value of robotics, as they felt that the benefit of implementing robotic solutions would be in eventual cost reductions and increases in efficiencies.

The growth trajectory for cobots has not been a guarantee for some companies, as evidenced by the failures of Rethink Robotics, Mayfield Robotics and Jibo. (Schmelzer, 2018) This may actually be an indication of the cobot market becoming more mature, as venture capitalists determined that the robots produced by these companies did not serve enough need. (Schmelzer, 2018) They are not blindly supporting robotics companies and are directing their funds to companies that have stronger products for their applications. One example of a successful company is Universal Robots, as they have reached selling their 25,000th cobot. (Towers-Clark, 2018) This indicates that there is a need for cobots and companies are investing in the appropriate technology for their applications.

Use Cases

Automotive OEMs Embrace the Cobot

General Motors has added to their robotics portfolio by incorporating cobots into their manufacturing operations. These cobots are used in a variety of applications, such as quality inspection, jobs requiring a consistent application of force, working with hot and odorous material and holding parts while a human operator makes adjustments. (RIA, 2018) This last example represents the ideal definition of cobots, where there are no fencing barriers between the cobot and operators, allowing them to work side by side. This lack of a need for fencing has increased the number of operations in a smaller footprint. (RIA, 2018)

Toyota Makes the Exoskeleton Mandatory Personal Protective Equipment

In an exoskeleton industry first, Toyota recently made the Levitate AIRFRAME exoskeleton required equipment for welding workers. "We identified risks of working overhead as a primary factor and contributor to injuries, so we tried to find ways to eliminate those risks, and the exoskeleton fit the bill quite well," said Marc Duplessis, health and safety manager at Toyota's Woodstock, Ontario plant. Toyota has made the AIRFRAME mandatory personal protective equipment just like a pair of safety glasses, closed-toe shoes or earplugs. The exoskeleton, considered a type of wearable robot, protects the muscular-skeletal system of the upper body such as the shoulders, neck and back. This is a significant milestone not just for Levitate but for the entire exoskeleton industry. (Exoskeleton Report, 2019)

Delivery Bots in Action

Autonomous deliver bots are going from experimentation to implementation in 2019. Segway's Loomo robot carries out the delivery of internal mail in workplace settings such as office blocks and shop floors, Google's Nuro takes to the streets to deliver fresh groceries as well as hot food, thanks to its separate heated and chilled cargo bays and Amazon is now testing the delivery of parcels via airborne drone delivery. (Forbes, 2019)

Advantages & Challenges of Robotics Implementation

Advantages

- **Safety:** Robots can perform the most dangerous tasks on the factory floor, keeping their human counterparts safe.
- **Performance:** The power, speed and precision of robots leads to increased productivity.
- **Cost:** The cost of robots is decreasing, particularly within the cobot market, making this advanced technology more accessible to SMEs.
- **Programming:** Cobots do not require complex code to program, rather, they are "taught" to perform movement, making programming easier.
- **Flexibility:** Cobots can be easily redeployed in various areas of the manufacturing environment and this can be done on a weekly or even daily basis.

Challenges

- **Barriers to adoption:** According to the MHI Annual Industry Report (2018), the most significant barriers to adoption are:
  - Lack of clear business case to justify the investment
  - Lack of access to capital to make investments
- **Cobot technology is still in its infancy:** Cobots are a relatively new technology, and with any new technology, implementation becomes a challenge due to hesitations about its effectiveness and lack of understanding of how to implement within the manufacturing environment. Due to the need for safety, cobots have reduced speed and payload capabilities. Although cobots are easier to program than traditional robots, they still require specially trained personnel to manage their operations and maintenance.
- **Cybersecurity:** As robots continue to connect to other systems within the manufacturing process through IoT technology, data gathered in the cloud is increasingly at risk of cyber threats.

Conclusions

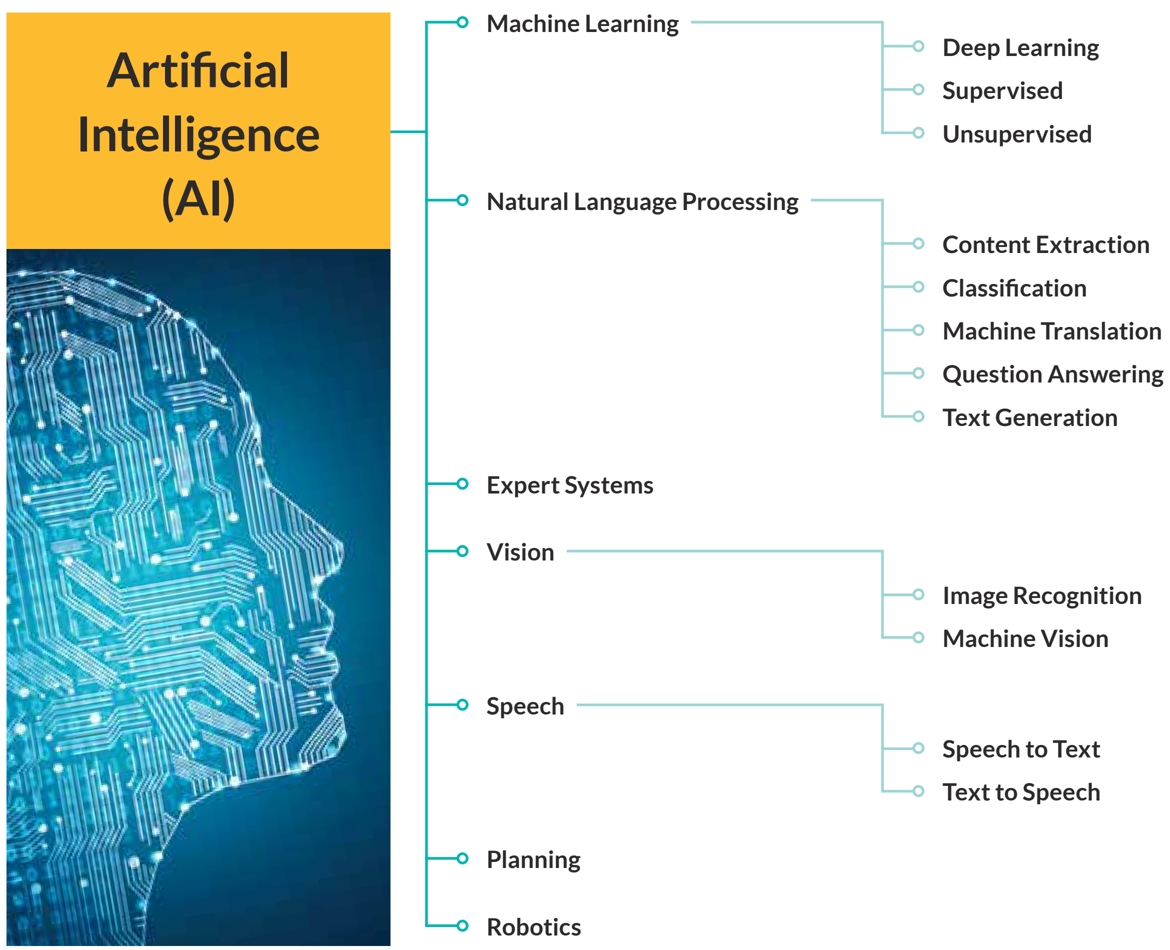
- Collaborative robots are a cost-effective, relatively easily integrated solution for manufacturers to implement automation technologies, compared to traditional robots.
- The utilization of collaborative robots can improve efficiency, reduce downtime and improve employee well-being.
- Delivery bots are becoming more mainstream in production processes as technology advances.
- Smart technologies like AI and IoT will continue to greatly impact industrial robotics, however, companies should be mindful of increased cybersecurity issues as more data is gathered and stored in the cloud.
- Robots address tasks that are ill-suited for human workers, allowing workers to address higher-level tasks, with the benefit of maintaining and creating jobs, due to improved efficiencies.
- Automation might not cause mass unemployment, but it may well require workers to make disruptive transitions to new industries, requiring new skills and occupations.

Action Items

- Manufacturers should explore how robotics can take advantage of the other Industry 4.0 technologies in their operations (IoT, AI, cloud, Big Data, etc.).
- Leadership should proactively consider and test advances in robotics such as cobots, wearable robotics and AI to improve efficiency and worker well-being.
- Manufacturers should design workflows to capitalize on the strengths of humans and robots, to allow them to work collaboratively.
- There is a shortage of qualified robotics technicians. Companies should consider upskilling and reskilling workers to take advantage of advancements in robotics solutions.

Artificial Intelligence

Figure 1: Major AI Fields and Technologies



Source: Neota Logic

Of all the Industry 4.0 technologies, artificial intelligence (AI) is being touted as the solution with the greatest promise for business. AI, defined as computer models that replicate intelligent behavior, is poised to unleash the next wave of digital disruption (McKinsey, 2017) bringing a competitive advantage that industry leaders cannot ignore. The value of AI is not to be found in AI models, but in our capabilities to harness them. Today, typical industry objects are being converted into intelligent objects that can sense, act, adapt and behave within an environment, and industry leaders will need to make conscious choices about how, when and where to deploy them.

Technology and Features

AI plays an important role in Intelligent Manufacturing Systems (IMS) by providing learning, reasoning and acting. To install IMS on the factory floor, existing operations, machinery and sensors are converted into intelligent objects, making traditional manufacturing smarter with the ability to self-correct without human intervention.

AI's maximum value within the manufacturing space will depend on the industry's ability to harness new capabilities, many of which have seen dramatic growth in recent years. Figure 1 shows the major fields and technologies within AI.

- **Machine Learning** involves the development of computer systems that can extract hidden patterns from raw data. Machine learning is classified into three major categories, namely supervised, unsupervised and deep learning.
- **Supervised Learning** involves an algorithm that builds a model from a set of training data that contains both the training observations/ examples and the labels.
- **Unsupervised Learning** involves an algorithm that builds a model from a set of training data that contains only the observations/ examples where the labels are unknown.
- **Deep Learning** enables computers to build complex concepts out of simple concepts using several layers.
- **Natural Language Processing** involves writing programs to process and analyze large amounts of natural language data.
- **Expert Systems** build computer systems that emulate the decision-making capabilities of human experts.
- **Computer Vision** deals with how computer systems can understand digital images or videos.
- **Computer Speech Recognition** deals with how computer systems can recognize and understand spoken languages.

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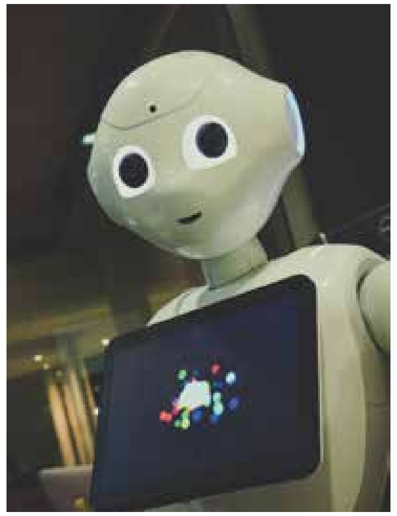


Emerging Trends

Rapid Growth of AI Investment

According to McKinsey Global Institute's 2017 report on AI, tech giants including Google and Baidu spent roughly $20 billion to $30 billion on AI in 2016, with 90% spent on R&D and deployment, and 10% on AI acquisitions. AI is also growing rapidly in the startup ecosystem, accounting for a combined total of $6 billion to $9 billion with machine learning receiving the largest share of both internal and external investment. (McKinsey, 2017) Most investments are being made in the technology, automotive and financial service sectors.

The Rise of Predictive Manufacturing Systems

Predictive Manufacturing Systems (PMS) are intelligent manufacturing systems that provide several abilities such as self-awareness, self-predicting, self-maintaining and self-learning in production, processes and machines. PMS combines different technologies and techniques namely statistics, data mining, modeling and AI methods to convert data into information in order to discover uncertainty and make predictions about manufacturing systems. (Nikolic et al., 2018)

A conceptual framework of a PMS consists of a platform, predictive analytics and visualization tools. The data is generated by the monitored assets. The platform is selected based on several factors such as computation speed and investment cost. Predictive analytics is used to extract and predict future outcomes and trends. PMS benefits include cost reduction, operation efficiency and product quality improvement.

Deep Learning Skills in High Demand

In 2018, LinkedIn reported that six out of 15 top emerging jobs were related in some way to AI. (Forbes, 2018) In particular, jobs calling for knowledge of deep learning are growing at the fastest rate, according to data gathered from job recruitment site Monster.com. (Irish Times, 2019) Deep learning is a class of machine learning techniques that exploit many layers of non-linear information processing for supervised or unsupervised feature extraction and transformation, and for pattern analysis and classification. (Deng and Yu, 2014)

Both deep learning and traditional machine learning are used to model the relationship between input and output. Deep learning has distinguishing attributes over traditional machine learning in terms of feature learning, model construction and model training. It combines feature learning and model construction in one model by selecting different kernels or tuning parameters. (Wang et al., 2018) With deep learning, manufacturing is transformed into highly optimized smart facilities. Some benefits include reducing operating costs, keeping up with changing consumer demand, improving productivity and reducing downtime, gaining better visibility and extracting more value from operations for global competitiveness. (Wang et al., 2018) Figure 2 illustrates the difference between machine learning and deep learning.

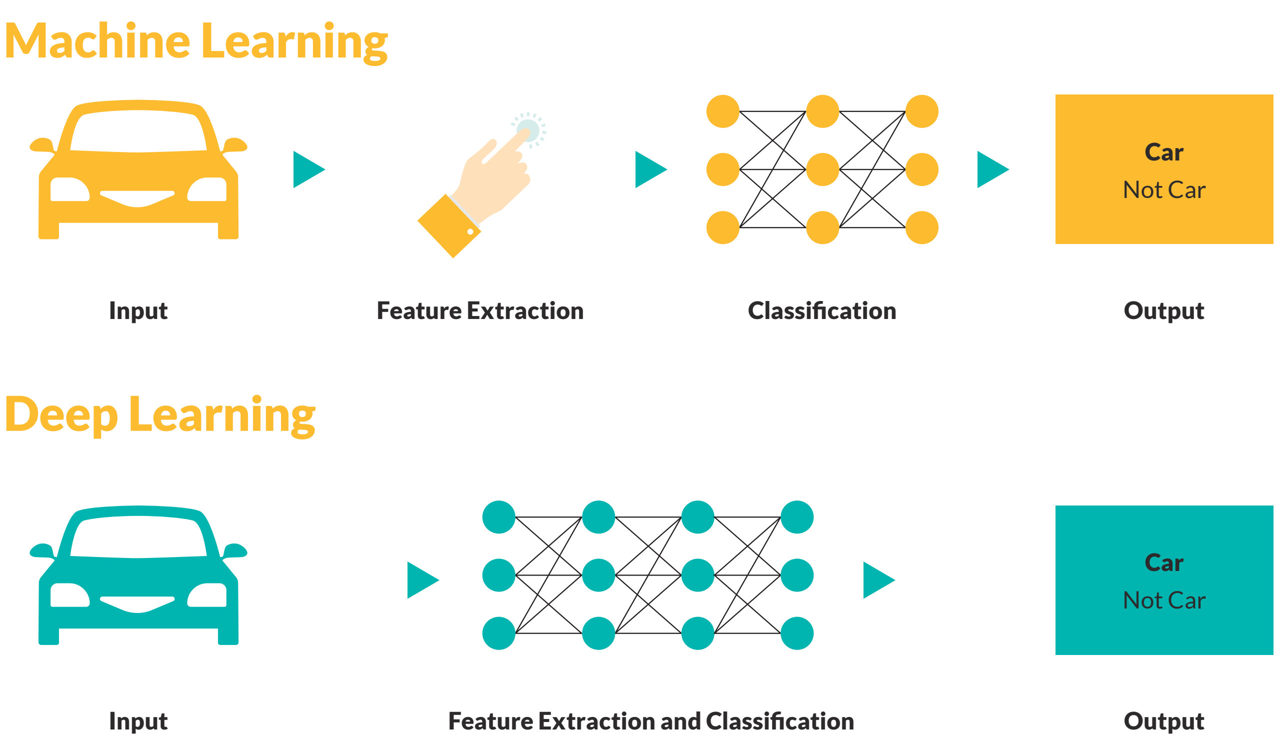
Chips Speed Up AI Execution

In 2019, chip manufacturers such as Intel, NVIDIA, AMD, ARM and Qualcomm will develop specialized chips that speed up the execution of AI-enabled applications. These chips will be optimized for specific use cases and scenarios related to computer vision, natural language processing and speech recognition. Next-generation applications from the health care and automobile industries will rely on these chips for delivering intelligence to end-users. (Forbes, 2018)

IoT and AI Converge

While data is the raw product of IoT, AI is the technology helping businesses make sense of it all. Today, with improved processing power, manufacturers are turning to AI to leverage their data. In 2019, IoT is all set to become the biggest driver of AI in the enterprise. Industrial IoT combined with AI will perform outlier detection, root cause analysis and predictive maintenance of equipment for manufacturers. (Forbes, 2018)

***Figure 2:** Machine Learning vs. Deep Learning*



Source: verhaert.com

Industry Analysis

A survey conducted by Vanson Bourne in July 2017 displays the current or expected barriers of using AI as seen by 260 respondents. Lack of IT infrastructure (40%) and lack of talent (34%) were the most significant barriers according to respondents of the survey.

Another recent survey, conducted by the McKinsey Global Institute, showed that AI adoption outside of the technology sector is still at an early, often experimental stage. Only 20% of 3,000 executives across 10 countries and 14 sectors said they currently use any AI-related technology at scale or in a core part of their businesses. Many companies say they are uncertain of the business case or return on investment. A review of more than 160 use cases showed that AI was employed commercially in only 12% of cases. (Chui and Francisco, 2017)

In Automation Alley's recent small survey of Michigan-based small and medium-sized manufacturing professionals, only 2% of the companies are currently using AI while 10% are planning to implement it in the next year and 48% have no plans to implement AI. (Figure 3)

Figure 4 shows what respondents believe to be the most important benefit of using AI: Increase efficiency and cost reduction. Figure 5 shows the biggest challenges of using AI based on Automation Alley's survey results. Most respondents felt that investment costs are a barrier while the majority feel it is not beneficial to their business. These findings suggest that Michigan SMEs may not yet realize the true value of this technology.

Figure 3: When Does Your Company Plan to Implement AI?

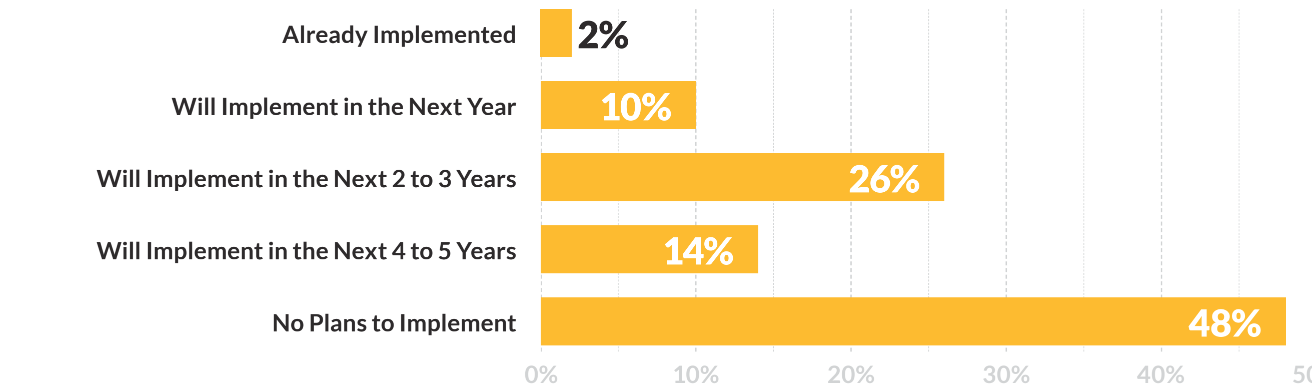


Figure 4: The Most Important Benefit of Using AI

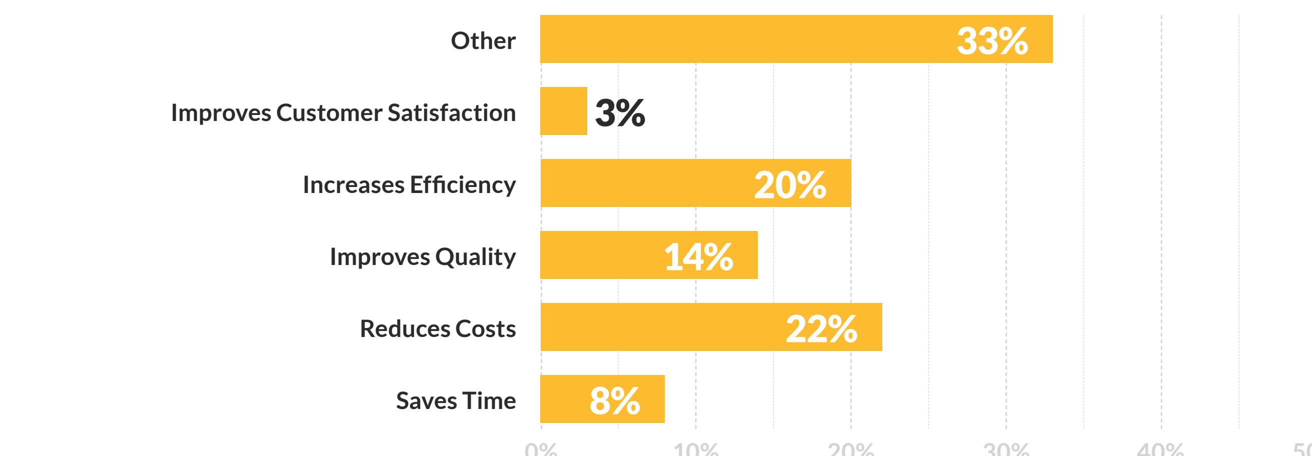
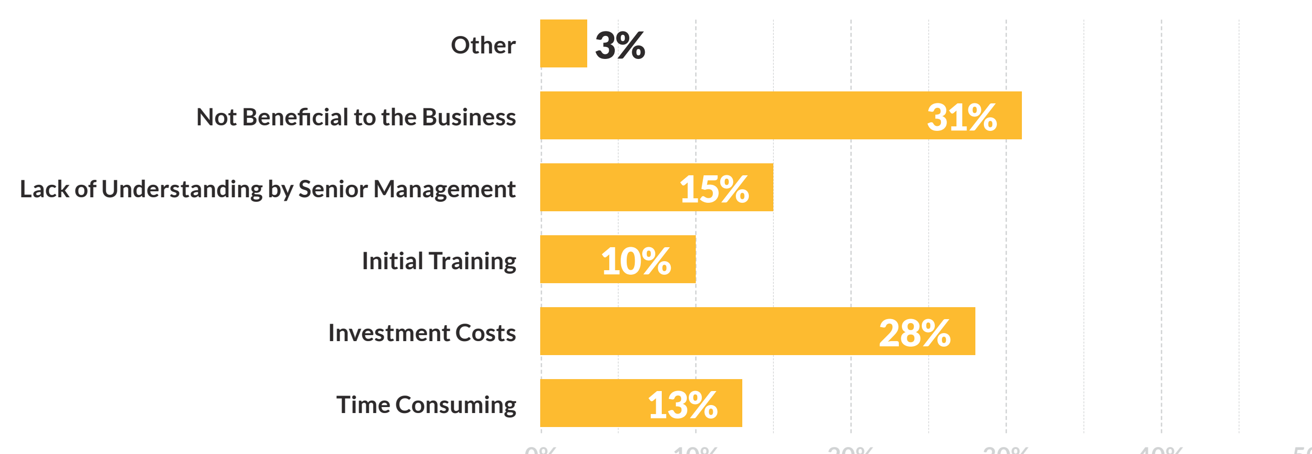


Figure 5: The Biggest Challenge of Using AI



Use Cases

Doxel Robots Use AI to Improve Accuracy & Efficiency on Large Construction Projects

Using AI and lidar (a remote sensing method that uses light in the form of a pulsed laser to measure ranges), a new robot can check that building projects are going to plan. Once a construction site shuts down for the night, robots deployed by Doxel can get to work. Using lidar, it scans the construction sites and feeds that data into deep-learning algorithms. The algorithms detect anything that deviates from building plans so that a manager can fix it the next day. If errors aren't noticed immediately on a work site, they can create compounding issues that take time and cost money. When a problem is solved instantly, the savings could be large. A recent pilot test of the technology on an office building project increased labor productivity by 38%. The project came in 11% under budget.

Anomaly Detection of Bearings at Altair Engineering

Bearings are critical components in the automotive industry. In this example from Altair Engineering, the health of bearings is monitored via sensor datasets as they age over time to predict a degradation starting point, which then can be flagged as an anomaly to the user. Recognizing anomalies as soon as they occur helps the end user in scheduling proper maintenance of bearings before they lead to irreversible issues, such as parts failures. Samples are correlated to healthy samples to get a sense of the present health of the bearings. Finally, an anomaly is flagged if there is a drop in correlation above 95% observed in five or more samples out of 10 consecutive checks. Machine learning is used to detect vibration pattern coming from the sensor in real time to Altair's SmartSight, where the user can see the status graphically and Altair's SmartCore sends an email alert to the user if an anomaly is detected.

AI from the Factory Floor to the Showroom at Mercedes-Benz

The automotive industry's deployment of AI applications throughout the manufacturing process has been well documented.

Now, OEMs are turning to AI to connect all areas of their business, including sales. Thanks to AI insights, companies know which product segment to sell, to whom and when.

A large-scale truck and bus production plant in Brazil run by Mercedes-Benz is using Microsoft Azure machine learning to revolutionize its sales process. "The tool brings together internal and external data, including registration numbers, macroeconomic indicators, local legislation, sales information and statistics. All this helps the brand's salespeople make the right offer, to the right person, at the right time." (Microsoft, 2018) In addition, the system can become smarter over time. As dealers input data reports each month, the tool ensures better recommendations in the future.

Advantages & Challenges of AI Implementation

Advantages

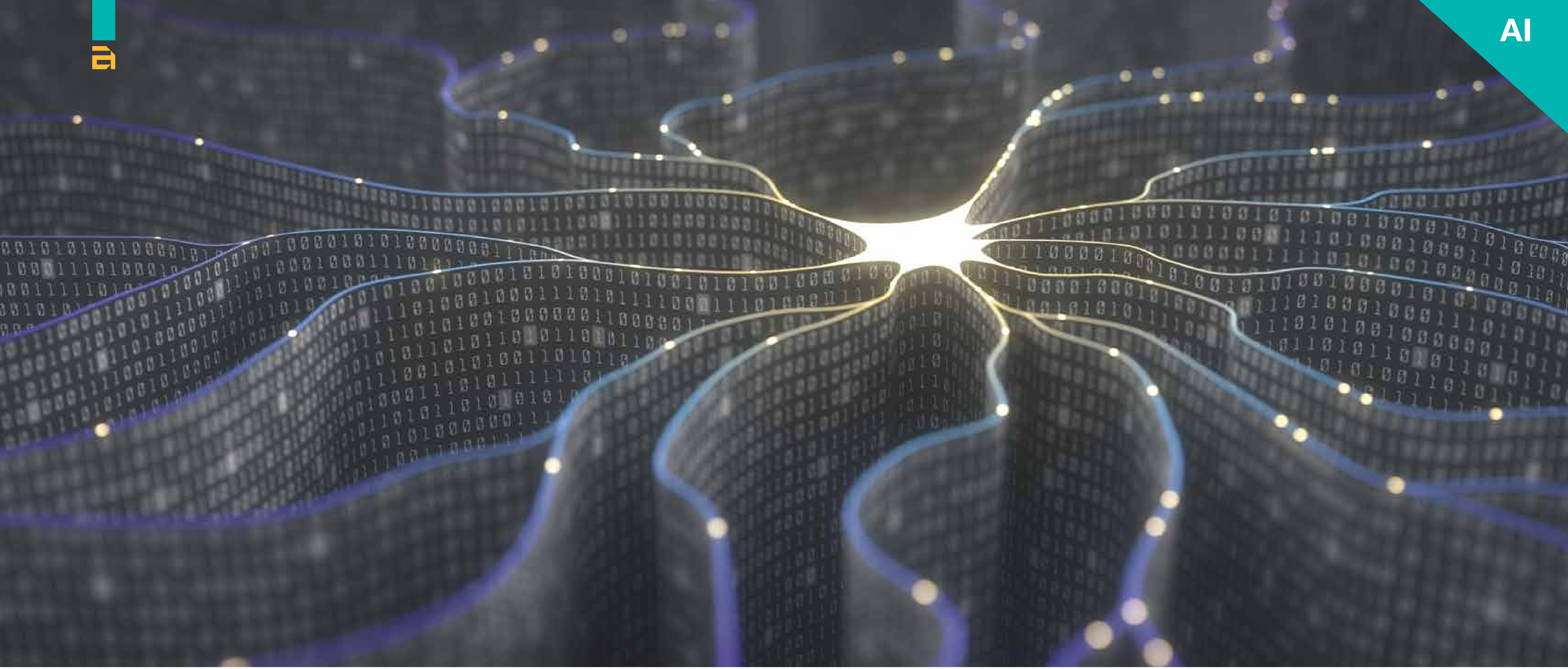
Incorporation of AI into manufacturing environments can lead to:

- Significant savings of labor costs due to troubleshooting, maintenance and repair.
- Better reliability and efficiency as time between failure is improved.
- Safer work environments as AI can sense and self-react to dangerous situations.
- Creation of new, rewarding jobs as AI infrastructure manages routine operations.
- Savings in power consumption or reduction in damaging vibrations.
- Accurate prediction and monitoring of trends such as anomaly detection.

Challenges

AI, like any new technology, is not without its challenges. Some of the challenges that implementors should be aware of are:

- Quality and quantity of data can be overwhelming. Manufacturing systems generate very large amount of data. One of the big challenges is how to understand, clean, use and store it.
- Team-based and mixed-initiative learning can cause confusion. The current machine learning systems mainly work in isolation to gather and analyze data whereas humans often work collaboratively within teams to collect and analyze data. Team-based and mixed-initiative learning is very important to bring diverse perspectives and experiments.
- Privacy and ownership issues may arise. Many corporations are currently collecting a lot of data for specific purposes which leads to several privacy issues. Society should decide about what data should be collected, who will have access to the data and who will get the ownership.
- Lack of standardization may hamper system-to-system communication and data exchanges. Only isolated solutions can be established if standardization is not available.
- Labeled training data may not be available. In supervised learning, predictive models learn from labeled datasets. Labels are not available for many datasets. The time required to annotate a training set is a major overhead of the classification task.
- Difficulty generalizing may require supporting multiple unique systems. It is hard to find one algorithm to be effective across a range of inputs and applications.



AI

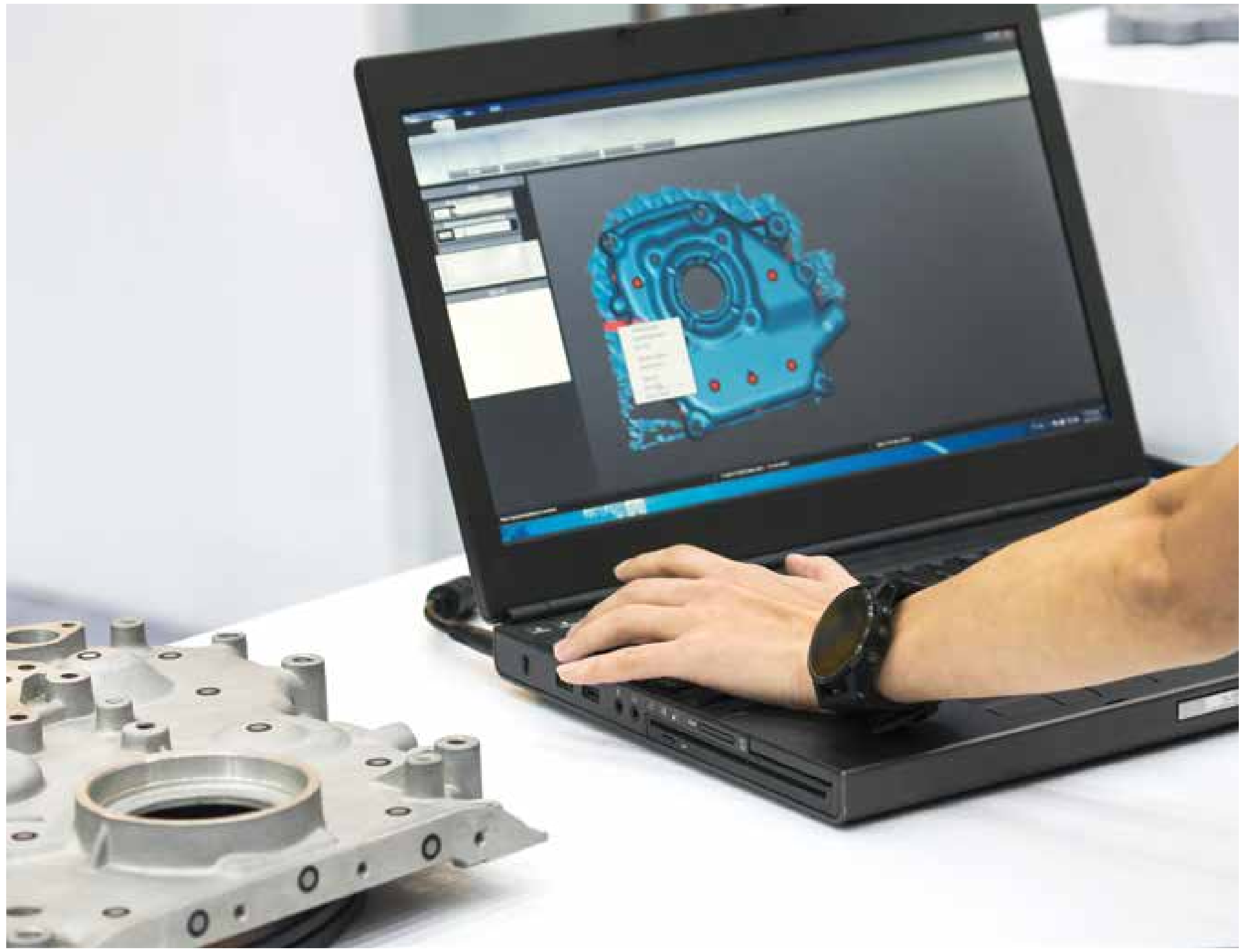
Conclusions

- There are many definitions of AI and sub-sectors that are still emerging. AI adoption outside of the technology sector is still at an early, often experimental stage.
- Other Industry 4.0 technologies including IoT, Big Data, the cloud and cybersecurity are empowering the development and application of AI.
- Deep learning transforms manufacturing into highly optimized smart facilities. Some benefits include reducing operating costs, improving productivity and reducing downtime.
- IT infrastructure investment trade-offs and an AI talent pipeline are the keys to unlocking the power of AI.
- Today, the most common benefits to using AI include enhancing customer value and improving quality. We've only begun to explore the power of this technology.

Action Items

- Companies should assess the internal and external AI landscape to determine the most appropriate applications of AI to provide value to their business and their customers.
- Industry and educators should improve collaboration to enhance the talent pipeline to provide an AI-ready workforce.
- Companies should invest in human resource development around AI skillsets.
- A public-private partnership is needed to establish standards and protocols to develop and disseminate robust AI strategies and tactics for business application.
- Companies are encouraged to experiment with AI in an effort to develop their own capabilities and capacity to create and leverage robust data ecosystems.

Modeling, Simulation, Visualization & Immersion



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Modeling, Simulation and Visualization (MSV) is a set of technologies used in the design, analysis, verification and validation of a product, process or service. Often referred to in industry as digital twin, this set of technologies provides businesses with a complete digital product footprint. Coupled with the immersive (I) technologies augmented and virtual reality (AR and VR), MSVI is being used today to detect physical issues sooner, predict outcomes more accurately, train workers and build better products.

Many of today's large manufacturers understand the magnitude of MSVI. Its proliferation within their organizations is well documented. However, the adoption of MSVI among small to medium-sized manufacturers has been much slower.

MSVI is being used to detect physical issues sooner, predict outcomes more accurately, train workers and build better products.

This section will provide a glimpse into MSVI's applications, implementation challenges and future advancements. It will delve into MSVI use cases and provide some conclusions and actions that all companies along the supply chain can use to navigate this growing and dynamic field.

Emerging Trends

Developments in MSVI technologies in a variety of areas are encouraging a host of future opportunities for the advancement of this technology. Outlined below are some of the major trends:

Integration with the Internet of Things (IoT)

The rise of the Internet of Things (IoT)—embedded sensors and wireless connectivity—means more information can now be shared between devices, customers, computers and facilities. As a result, some manufacturers are now attempting to connect their simulation models with factory floor IoT devices to enhance their model's intelligence. Just as mapping software introduced real-time feeds of traffic data, manufacturers are looking to enhance their model's predictive capabilities by feeding them with real-time data generated from embedded sensors on their machinery, forklifts and inventory shelves. This can drastically improve a model's predictive powers.

Distributed Modeling

Linked to the proliferation of IoT is the concept of distributed MSVI. Distributed MSVI essentially enables simulation models throughout the supply chain to share information to enhance intelligence of each supplier as well as the entire manufacturing process. For example, a model capturing data from a machine can be shared with a model capturing data from an identical machine in a different geographical area. As a result, the models are more intelligent, the whole system is improved and better decisions are made.

Real-time Visualization

With the advancement of Big Data analytics, visual representation of relevant data is growing as there is more data to sort through, organize and interpret. Digital twins have become near-real-time digital images of a physical object or process that helps optimize business performance. Until recently, the digital twin—and the massive amounts of data it processes—often remained elusive to enterprises due to limitations in digital technology capabilities as well as prohibitive computing, storage and bandwidth costs. (Deloitte Insights, 2017)

Immersive Wearables

Until recently, the lack of cost-affordable devices was the main barrier to the widespread adoption of augmented reality (AR) and virtual reality (VR) applications within the manufacturing industry. Mobile devices have, however, removed this limitation, as smartphones and tablets feature all the sensors and processing units needed to develop and deploy these immersive applications on the factory floor. Industry is now moving forward with wearable AR and VR technology, including glasses and contact lenses. (De Pace, at el, 2018)

The global market for immersive technologies is growing fast. For example, the global VR market was valued at $3.1 billion in 2017 and is expected to reach $49.7 billion by 2023. (Draper, 2019) This pervasive adoption implies an undeniable impact on society. It is now possible to identify at least five major areas of application for immersive technologies in the industry domain: 1) Human-robot collaboration, 2) maintenance assembly and repair, 3) training, 4) products inspection and 5) building monitoring. (De Pace, at el, 2018)

Industry Analysis

Global competition is continually pressuring today's large OEMs to lower price points, increase the speed at which they react to market demands and shrink the time it takes to launch new products. As a result, manufacturers are continually looking for ways to use MSVI to experiment with new changes in product designs, assembly line processes, factory floor layouts and work cell flows before making these changes in their physical operations. They are finding that solidly designed models and simulations can reveal issues with a planned assembly line process change, for example, before it is actually implemented. This is saving them significant time and expense in identifying the most optimal process change.

Outlined below are just a few of the most common MSVI applications being used among today's manufacturers:

Product Design: MSVI has become integral in the design of physical products. It is increasingly being used to test the safety and quality of products before physical prototypes are developed. This has drastically reduced the number of physical prototypes necessary to complete a design cycle which in turn expedites a product's market entry. This is particularly important in today's competitive arena. New innovative hardware products are entering the market at a record pace. As a result, speed to market has become crucial for manufacturers.

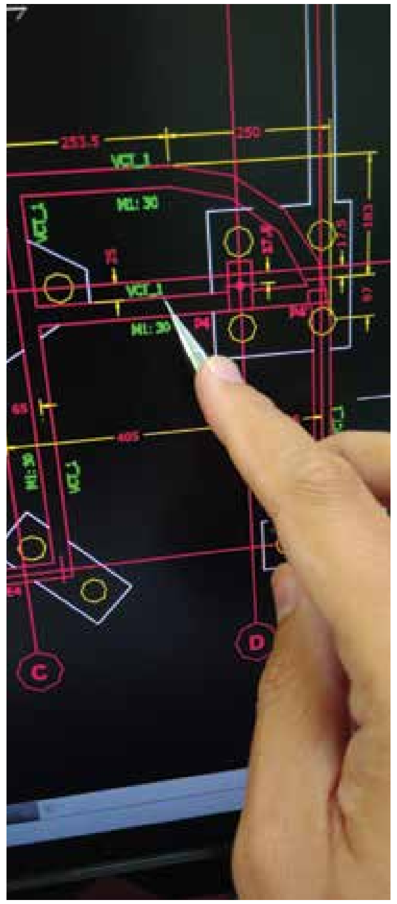
Manufacturing Process Design: Increasingly, manufacturers are using MSVI to experiment with changes in their assembly line processes in a digital environment before making any changes to their physical process. By creating a digital twin of an assembly line using sophisticated simulation software, a manufacturer can create a digital model of their assembly process that incorporates a wide variety of elements including staff, equipment, assembly, transportation, inventory and numerous others. This digital twin can then be used to test the impact of a proposed change before the actual change is made, saving significant time and expense.

Facility Design: Manufacturers are now in a position to use modeling to design and redesign their factory floor layouts. Software is able to create different digital layout designs given pre-defined parameters relating to space, furniture, equipment, storage, safety and other needs. These designs can then be tested to identify how they compare in performance in the areas of productivity, expense and other measures of effectiveness. Testing different layouts using a digital model before making changes in the physical operations has proven to reduce both time and expense of such endeavors. (Adsit, 2018)

Workforce Training: AR and VR are increasingly being used to train frontline workers particularly those who respond to emergencies or are at a higher safety risk. By using VR to create a fully immersive simulated environment, manufacturers can train control engineers to react to a variety of emergency situations including chemical leaks and explosions. Similarly, VR can be used to prepare frontline operators for product changeovers, equipment upgrades, or emergency situations. Training workers to react quickly to these situations increases productivity by reducing downtime, enhancing safety and maximizing worker performance. (Hegy, 2018)

Predictive Maintenance: Automated model building is a new technology that is being introduced to enhance predictive equipment maintenance programs. The technology captures a multitude of operational data from equipment sensors and uses machine learning to better predict when maintenance or replacement will be required. This eliminates downtime by enabling companies to perform more proactive maintenance. For example, a piece of equipment can be serviced or replaced while it is not in use, thereby preventing delays. This has significant implications for plant productivity. (Herve, et al, 2018)

Advantages & Challenges of MSVI Implementation



Advantages

MSVI technologies have several benefits for businesses of all sizes, including:

- Helping to address the skills gap
- Improving collaboration
- Reducing downtime
- Improving productivity
- Reducing costs
- Speeding up time to market
- Producing higher quality products
- Increasing profits

Challenges

As popular as MSVI is becoming, there are significant challenges associated with its broad implementation for manufacturers, several of which are provided below:

Data Integrity

The quality of the data being used to develop a simulation model continues to be a major challenge. It is crucial that the data is trustworthy, of sufficient quantity, secure and actionable. Otherwise, confidence in the model is

compromised. To address this challenge, experts recommend that manufacturers understand the data being collected and monitor its collection. To the degree possible, automated data collection through tools like sensors is preferable. Additionally, the use of effective manufacturing execution software is helpful. (Adsit, 2018)

Model Accuracy

It is imperative that the simulation model accurately reflect a manufacturer's operational reality. This is obvious but continues to be a challenge. For example, factory floor models need to incorporate accurate measurements and the nuances of the space including the existence of pillars and other structural barriers. To address this, new technologies enable a user to capture a digital scan of a space that can be inserted into a model thereby eliminating human errors in measurement. For other types of models, it is important that appropriate attention be given to ensuring they reflect reality. (Adsit, 2018)

Understanding Time and Skill Requirements

An additional challenge faced in deploying MSVI is understanding the resources needed to build a model. Some modeling software is easier to use and can produce simple models built in days with limited training necessary. However, very sophisticated models of assembly lines or factory floor layouts are more challenging to build and require more time and training. Distinguishing between these two appears to be a challenge for manufacturers. To build more sophisticated models, manufacturers are increasingly reaching out to universities with computer science and industrial/manufacturing engineering departments to recruit knowledgeable talent. Consultants and professional service firms are also assisting with model building and maintenance.

Use Cases

One of the biggest challenges among manufacturers is to ensure that MSVI is implemented throughout the supply chain. MSVI can help small manufactures respond to the pressures of decreased costs and improved quality that are placed on them by OEMs and Tier 1 suppliers looking to better compete globally.

To better understand the degree to which small manufacturers are implementing MSVI, we interviewed three leaders of such companies across Michigan. The findings are provided below.

K-Tec Systems

K-Tec Systems of Ferndale, Mich. designs and manufacturers test equipment and test benches that the automotive, aerospace, food and chemical industries use to control temperature, pressure and flow. Founded in 1989 as a distributor, the company has since moved into manufacturing. It is experiencing significant success by integrating new AR and VR technologies into its products.

In response to a client request to develop a test bench for an electric vehicle battery, K-Tec Systems used AR technologies to display a 3D file on the client's mobile phone overseas. As a result, the client could see a real-scale model of the product. This gave the client an opportunity to make modifications to the product before a prototype was built. It ultimately reduced the client's product development expenses by eliminating steps in the prototyping process.

K-Tec Systems' approach to leveraging technology did not end there. They also provided interactive AR instructions with their final product. The client simply needed to scan the product using K-Tec Systems' mobile app to see the instructions displayed on the product itself, eliminating the need for a hard copy instructions manual.

K-Tec Systems views their use of AR and VR technologies as a true differentiator that gives them a competitive advantage. The company is an excellent example of how rapidly a smaller manufacturer can advance when it stays educated and embraces technology adoption.

4C Plastics

4C Plastics, Shelby, Mich., provides manufacturers with injection molding, design, 3D printing and assembly services. The "4C" in the company's name represents its goal to provide services that are convenient to use, consistent in quality, connected to client needs and confidently provided by experts.

A significant portion of the company's clients are startups and small manufacturers providing products in the automotive, recreation, safety and health industries. An interview with their business development leader was conducted to better understand the utilization of AR among these smaller clients. The interview aimed to better understand whether the company's clients use AR to build models, request 4C Plastics to build such models, or are aware of the capabilities of such models.

The interview revealed that approximately 75% of 4C's clients know how to develop their models in 3D so that the company can use them to assist with design, advise on manufacturability and produce order quantities. However, none of the clients appear to use AR models nor overtly express an interest in 4C developing such models.

> **One of the biggest challenges among manufacturers is to ensure that MSVI is implemented throughout the supply chain.**

4C Plastics, a relatively new business in the marketplace, has developed the capability to build AR models should clients eventually start desiring them.

This reveals an interesting insight about startups and small manufacturers of products in Michigan. With relatively minimal investment, these companies have the ability to gain vast insights about their products by testing them using an AR model before moving forward with production. Yet, few of these companies are doing so or requesting providers like 4C Plastics do so.

Ghafari

Founded in 1982, Ghafari is a global firm with 15 locations across five continents that provides process engineering, architectural engineering, consulting, lean services and project management to a wide variety of industries from automotive to industrial manufacturing.

The company has developed a significant practice that provides small and medium-sized manufacturers with services in adopting MSVI. An interview with the company's industrial engineering project manager revealed three major challenges smaller clients typically face that impede their ability to implement MSVI and reap the benefits that more advanced companies experience like Siemens, Rockwell Automation and others.

Surprisingly, the quantity of data available to build models is not the issue. One of the biggest challenges is the quality of the data. Models are compromised when the data collected is not accurate, timely, or comprehensive. As a result, Ghafari works with clients to prepare them for enhanced data collection that can involve the adoption of a reputable and customizable manufacturing execution system that integrates with sensors for automated data collection.

A second challenge is ensuring the model reflects the real physical environment. Manual reviews of a company's current physical manufacturing process, factory floor layout, and/or staff resources must be completed and incorporated into the model in order for it to reflect the physical environment. Fortunately, there are ever-expanding data mining and sensor technologies that enable a company to digitally capture information from the physical world thereby decreasing manual review errors and increasing model integrity.

A third challenge is not immediate but could impact smaller companies once they overcome the hurdle of developing their first model. The model they build must be maintained if it is going to be of continuous value. Therefore, new adopters of MSVI must secure the necessary talent and connect with software providers who can help them maintain their models.

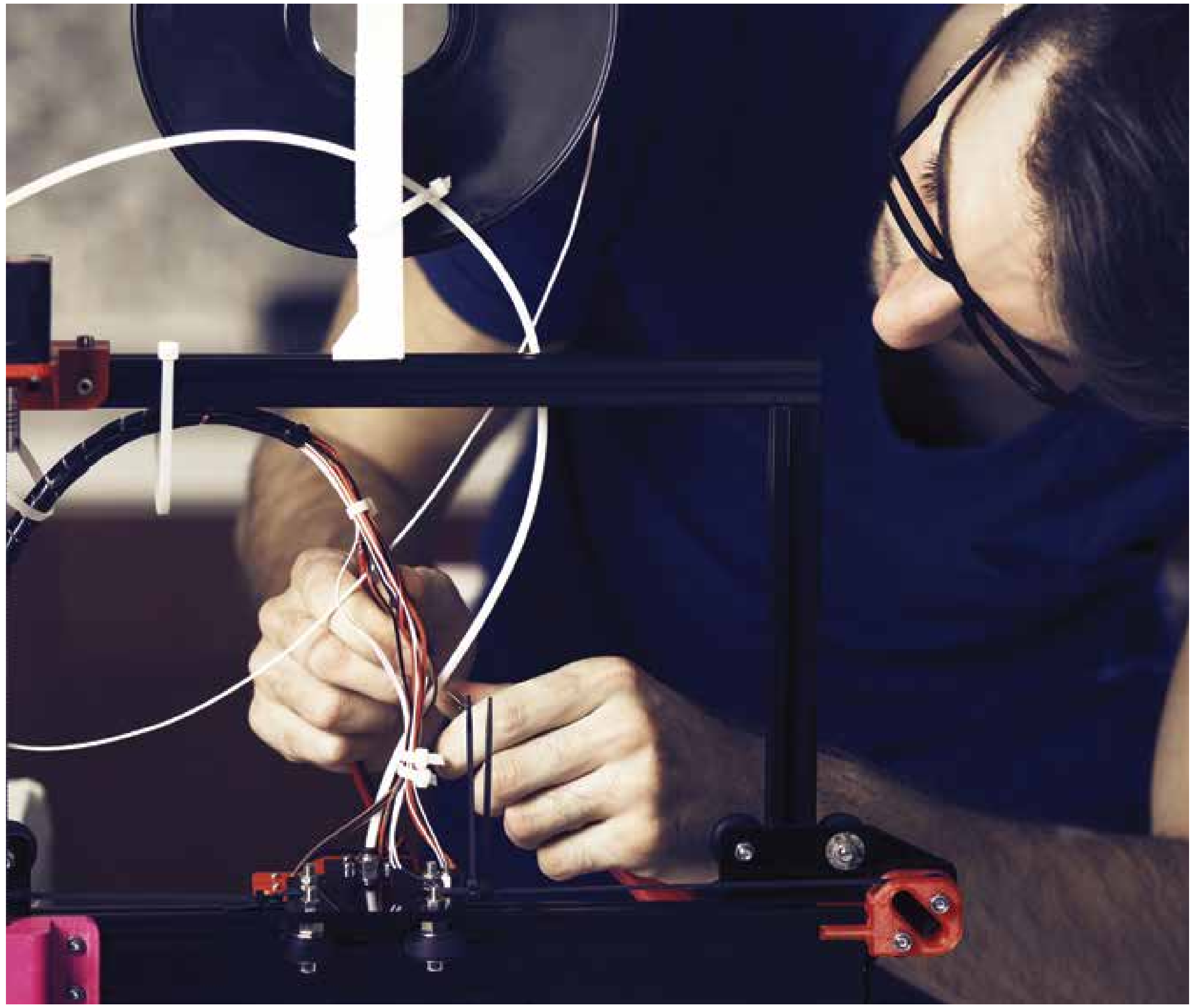
Conclusions

- MSVI has improved how manufacturers design products, develop processes, build facilities, train their workers and maintain equipment. Its adoption is likely to proliferate at an accelerated pace as new IoT and sensor technologies enhance the intelligence of models through real-time data feeds.
- MSVI is in the early stages of development and small and medium-sized businesses are yet to be convinced of its value.
- Distributed MSVI enables a common simulation model to be shared and utilized throughout the supply chain to improve efficient design and development of the entire manufacturing process.
- The global market for immersive technologies is growing and pervasive adoption would imply an undeniable impact on society.

Action Items

- A best practice is to start with a small pilot project using a simple MSVI application. Build organizational capability and capacity from there.
- A public-private partnership is needed to help small and medium-sized manufacturers embrace MSVI's promising potential.
- Learning and development departments should be prototyping and testing MSVI to re-skill and upskill their workforce.
- Find a partner and collaborator with a common need or interest and begin to build a distributed MSVI infrastructure.
- Begin an internal digital twinning project. Explore how other sectors are leveraging MSVI for competitive advantage.

Additive Manufacturing & Advanced Materials



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Additive Manufacturing, commonly referred to as 3D printing, has been described as a slow revolution, but a revolution nevertheless due to its ability to enable new business models and redefine how we design and build products. (Farrando, 2018; Dhuru, 2018) The field will continue to grow in 2019 led by material innovations, cost reductions and an increase in 3D printing speed, quality and accuracy. By 2020, the additive manufacturing sector is expected to grow to at least $20 billion. (Mera, 2017) As the technologies of Industry 4.0 continue to become more intertwined, 3D printing is getting "smarter," too. Artificial intelligence (AI)-driven generative design and embedded electronics in the rapid-speed 3D printing of plastics and metals is an exciting and emerging trend revolutionizing this evolving field.

Technology and Features

Additive Manufacturing, also known as 3D printing, is a process of joining materials to make parts from 3D model data, layer by layer, which is a complete reversal of historical manufacturing methods. Traditionally, manufacturing is a subtractive process, whereby raw material needs to be cut away to form the desired part size and shape.

Emerging Trends

Innovations in Materials

While plastics are still the predominant material used in additive manufacturing, metal has increased in use between 2017 and 2018. (Sculpteo, 2018) A recent global survey conducted by Sculpteo of 1,000 industrial executives and engineers found that metal 3D printing continues to have the biggest impact on material trends. (Sculpteo, 2018) Advantages of metal 3D printing include the ability to create custom, complex parts that do not require assembly and that have less weight. Other materials used in additive manufacturing include ceramics, glass, cement, wood, paper, organic materials and even living cells. The most-used materials are shown in Figure 1.

Soft materials have been challenging to use for 3D printing, but new bioprinter machines are able to overcome this challenge. Materials such as bioinks provide support for living cells to proliferate and allow the creation of 3D printed organs for medical applications. (Smith, 2018) New materials specifically developed for 3D printing are expected to contribute to the continued growth of the field.

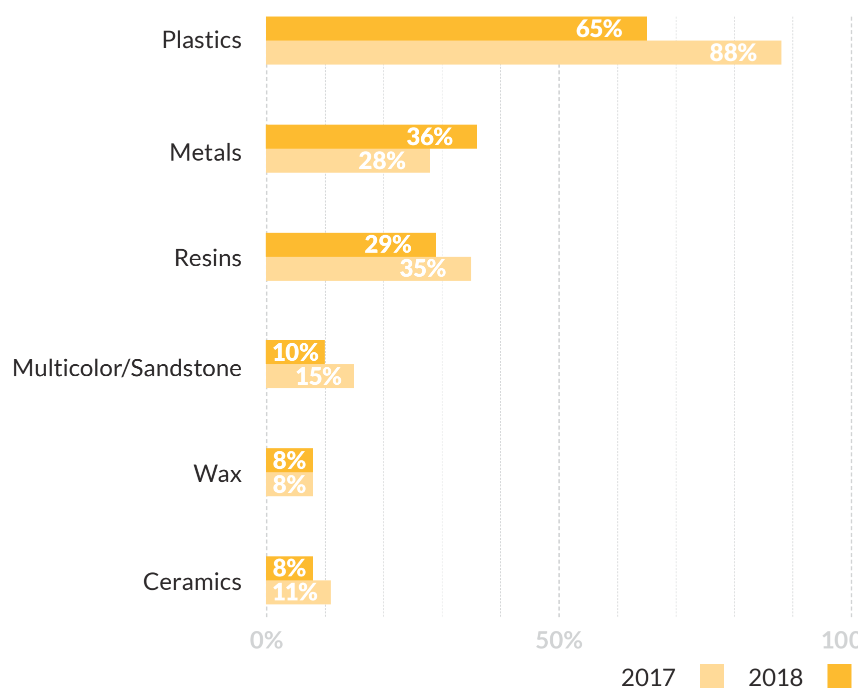
Although the metal 3D printing trend is growing, companies are still in the process of investigating its capabilities and applications. Companies are now testing the material properties of 3D printed metal parts and comparing them to a part made by traditional manufacturing. There is justifiable skepticism with respect to the quality of the metal and its ability to withstand the required durability compared to traditionally manufactured parts. The tests range from destructive testing to placing the part into the production environment and comparing it to traditional parts.

Printing Speed, Quality and Accuracy

Production speed has been one of the challenges associated with additive manufacturing. The historical trade-off between printing speed and part quality has made it difficult to reduce the production time. In 2019, however, additive manufacturing will break the speed and functionality barrier. Recent developments make it possible to substantially increase the speed of 3D printing without sacrificing quality. Digital Light Processing, used by companies such as Carbon and 3D Systems, is based on exposing the entire surface of photopolymer to light at the same time, resulting in increased speed.

Today, there are commercially available, cost-effective 3D printers that can produce parts about 40-times faster than the average 3D printer. These machines are capable of printing mechanical parts, prototyping and production tooling. (Forbes, 2019)

Figure 1: *Most-Used 3D Printing Materials*



Source: Sculpteo, 2018

3D Printing for Mass Manufacturing

Historically, 3D printing was mostly used to develop prototypes, as the material was not durable enough to withstand repeated use, and the 3D-printing process was not fast enough to print in mass production. Prototyping and proof of concept applications continue to increase and dominate the purpose for 3D printed parts. However, 3D printing for production parts has also increased and is gaining on prototyping. In Sculpteo's survey, respondents found an increase in the use of 3D printing for production parts from 22% in 2017 to 43% in 2018. (Sculpteo, 2018) Figure 2 shows various 3D printing applications.

Additive manufacturing technology has improved, software is now tailored to fit additive manufacturing processes and materials—particularly metal—have come down in price, all resulting in the growth of additive manufacturing for production. (Smith, 2018)

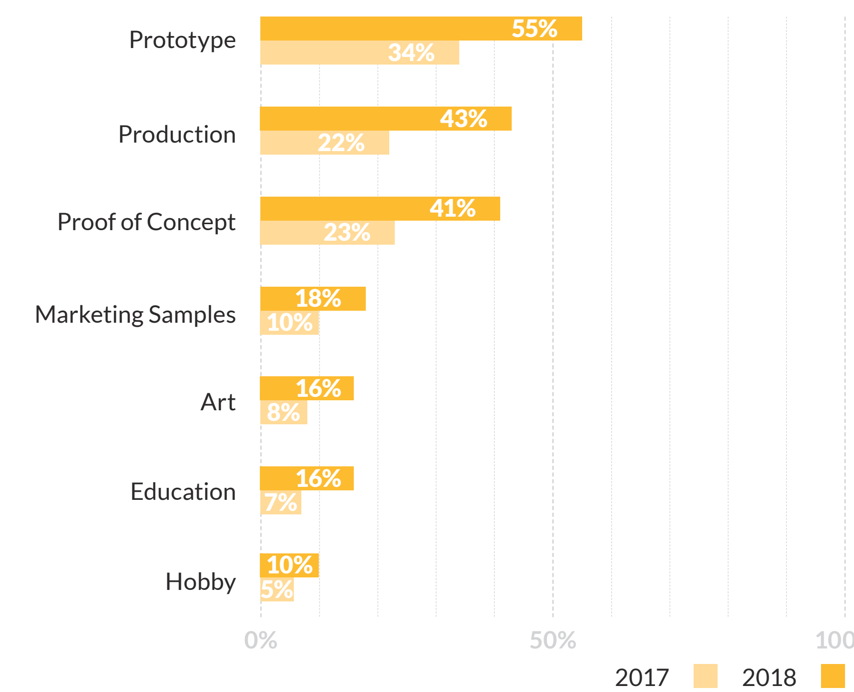
3D Printing Gets Smarter

The growing use of 3D printing has created a shift in design concepts, as designing for additive manufacturing is different from traditional manufacturing. (Farrando, Dhuru, 2018) Advanced use of software includes using simulation software prior to creating expensive metal 3D parts, and generative design, which combines machine learning with cloud computing to create a large number of possible designs from a given set of parameters. (Akella, 2018)

Also known as design thinking, AI-driven generative design, coupled with 3D printing, will revolutionize manufacturing over the next decade. This new approach enables engineers using computer-aided design (CAD) to define an engineering problem, which is then solved over and over again by an adaptive AI program, yielding different results each time. (Association of Equipment Manufacturers, 2018)

In addition, electrified geometries with embedded electronics are becoming mainstream in the additive manufacturing space. With billions of connected devices in the marketplace, the next logical step for 3D printing is products with sensors, antennae and encapsulation. 3D-printed electronics can lower traditional design and development processes from days to hours. (Forbes, 2019)

Figure 2: *Top 3D Printing Applications*



Source: Sculpteo, 2018

Industry Analysis

Additive manufacturing is an exciting technology that is receiving much attention due to its ability to create parts, seemingly out of nothing.

This excitement is reflected in the increased usage of 3D printing in recent years. The direct market for additive manufacturing is expected to grow to at least $20 billion by 2020. However, the overall economic impact of additive manufacturing is estimated to be much higher, reaching $100 billion to $250 billion by 2025 if adoption across industries continues at today's rate. (Mera, 2017)

In Sculpteo's recent survey with 1,000 industrial executives and engineers, 70% of respondents indicated that overall investment in additive manufacturing at their companies increased in 2018 compared to 2017. (Sculpteo, 2018) In the same study, 93% of respondents considered 3D printing to be a competitive advantage in their business. Interestingly, knowledge in 3D printing also increased, from 20% of respondents considering themselves experts in the technology in 2017 to 44% in 2018.

In another 2018 survey of more than 300 professionals responsible for 3D printing at manufacturing companies, a majority expected to at least double their 3D printing use in the coming year. (Luciano, 2018) In Automation Alley's recent small survey of Michigan's small and medium-sized manufacturing companies, about half of the respondents identified as users of 3D printing. Out of these, half use it for some production while the others are testing it. While half of the respondents don't have any plans for implementing 3D printing, the others plan to implement 3D printing in the next two years.

Industry Examples

Some companies have fully embraced 3D printing and have created targeted product applications. Recently, shoemakers such as Adidas, Nike and New Balance have partnered with 3D printing companies like HP and Carbon to create custom footwear. In the automotive industry, MINI is now offering custom detailing of their cars to consumers based on additive manufacturing. (Smith, 2018) In addition, Luxexcel is revolutionizing the production of eyeware by 3D printing lenses, decreasing waste and cost in the process. (Essop, 2019)

Top 10 3D Printing Equipment Firms by Revenue

1. HP - Market cap: $40.8 billion

2. Proto Labs - Market cap: $4.4 billion

3. 3D Systems - Market cap: $2.2 billion

4. Stratasys - Market cap: $1.3 billion

5. Materialise - Market cap: $646.5 million

6. SLM Solutions Group - Market cap: $434 million

7. Nano Dimension - Market cap: $200.9 million

8. ExOne - Market cap: $153.8 million

9. Organovo - Market cap: $136.7 million

10. Voxeljet - Market cap: $75.4 million

Source: RSM

What Materials are Used in Additive Manufacturing?

Metals

- Titanium
- Stainless Steel
- High-Performance Alloys
- Aluminum
- Precious Metals

Today's Applications: Aircraft components, rocket motors and dental work.

Tomorrow's Applications: High-speed, mass-produced and intricately designed metal parts that reduce waste and production costs.

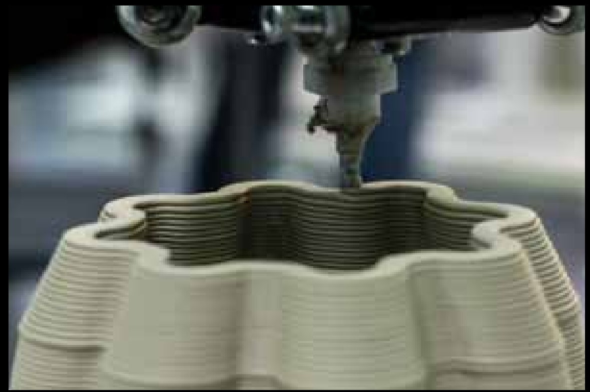
Polymers (Thermoplastics)

- Acrylonitrile Butadiene Styrene (ABS)
- Polylactide (PLA)
- Nylon
- Polycarbonate (PC)
- Polyvinyl Alcohol (PVA)

Today's Applications: A wide variety of parts serving numerous industries, including bodywork of cars, appliances, mobile phone cases, load-bearing prosthetics and more.

Tomorrow's Applications: Polymer 3D printing for serial additive production, achieving the same level of productivity as injection molding.

Ceramics



Today's Applications: Specialized components for mass-produced and customized products.

Tomorrow's Applications: High-performance ceramics to radically alter the manufacturing landscape.

Glass

Today's Applications: 3D printed ophthalmic lenses.

Tomorrow's Applications: Fiber optics built into printed glass building facades.

Sources: GE, HP

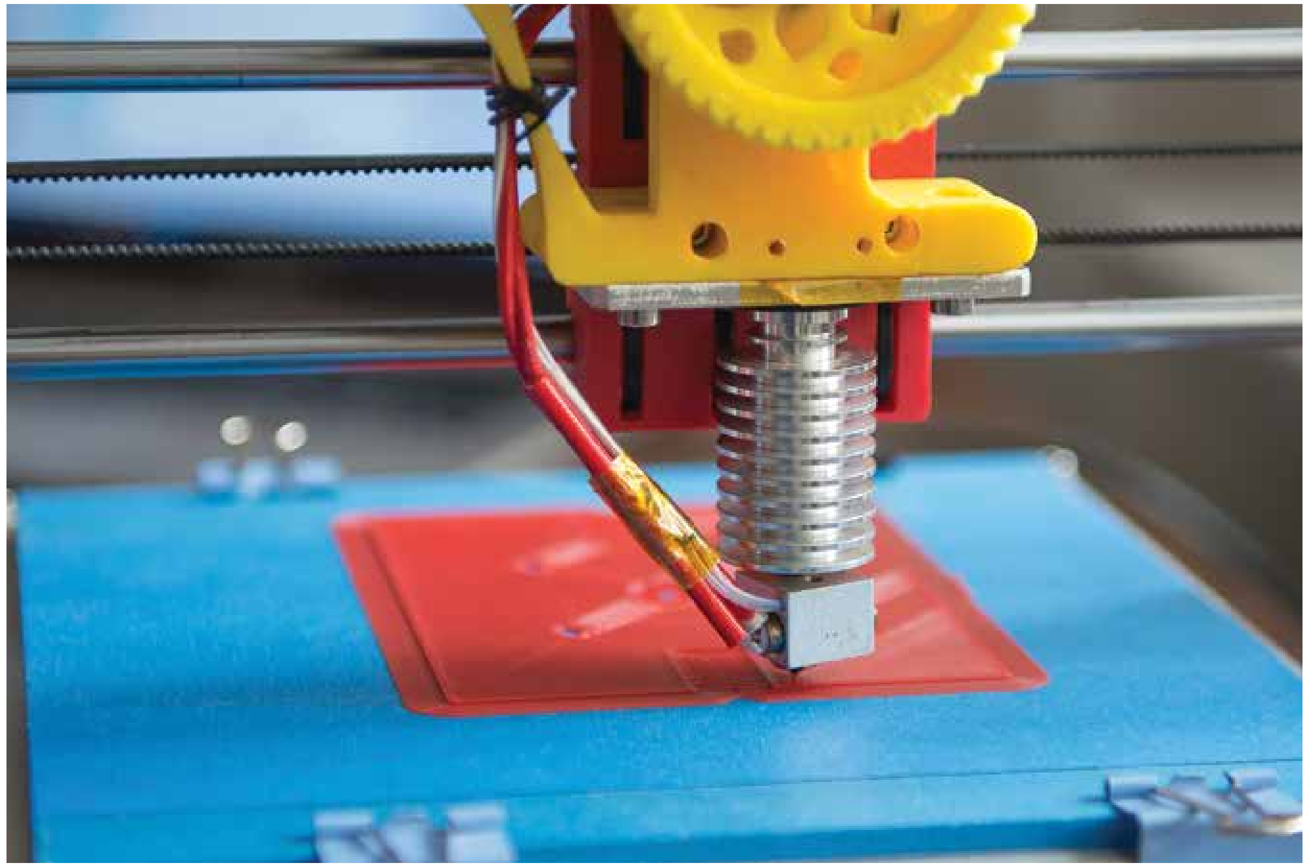
Advantages & Challenges of Additive Manufacturing

Advantages

- Additive manufacturing provides the ability to produce complex geometries not achievable by traditional manufacturing methods.
- 3D printed prototype parts can be produced faster and less expensively than traditional manufactured parts.
- Mass customization is possible with 3D printing due to the ability to produce individual components efficiently and cost effectively.
- Combining 3D printing with software design applications can optimize the structural design by laying material in orientations that take advantage of structural support and weight reduction.
- 3D printing allows for the reduction of inventory and replacement parts, as new parts can be printed on demand.

Challenges

- For large volume production parts, it is more costly and time consuming to produce 3D-printed parts compared to traditional manufacturing.
- Design for 3D printing requires a different approach than traditional design for manufacturing, requiring training and new expertise.
- Material cost for 3D printing can be a hindrance, depending on the material and amount of parts to be produced.
- 3D printing technologies vary with respect to functionality and applications, resulting in significant upfront investment in determining the appropriate technology.



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Conclusions

- Additive manufacturing is gaining in popularity due to overall cost reductions, material innovations, the increases in print speed, the ability for mass customization and software improvements.
- While 3D printing has gained acceptance as a prototyping and low-volume manufacturing tool, it has not yet reached a mature state in mass production, as technology and applications continue to evolve.
- 3D printing is becoming smarter as developments in AI-driven design thinking and embedded electronics hit the market.
- The direct market for additive manufacturing is expected to grow to at least $20 billion by 2020, with the overall economic impact reaching $100 billion to $250 billion by 2025.
- The potential for continued growth in the additive manufacturing industry is dependent on improvements to the technology, as well as innovations to the material properties of 3D-printed parts.

Action Items

- Research creative applications for 3D printing prototyping to save costs and enhance your traditional prototyping processes.
- There are numerous resources available for outsourcing your additive manufacturing projects. Develop a strategy to utilize these sources to determine your potential in-house return on investment.
- Evaluate current complex parts and consider a new approach to design them for 3D printing applications, which have different capabilities and may eliminate roadblocks associated with traditional manufacturing.
- Take advantage of collaboration opportunities within the manufacturing ecosystem to efficiently explore various 3D printing technologies.

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About Automation Alley

Automation Alley is a nonprofit manufacturing and technology business association and Michigan's Industry 4.0 knowledge center, with a global outlook and a regional focus. We connect industry, academia and government to fuel Michigan's economy and accelerate innovation. We offer programs, resources and knowledge to help our members grow and prosper in the digital age.

Our Mission

The mission of Automation Alley is to position Michigan as a global leader in Industry 4.0 by helping our members increase revenue, reduce costs and make strategic decisions during a time of rapid technological change.

Our Vision

Michigan is the leading applied technology and innovation state in the world.

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