

Quad Cities Manufacturing Innovation Hub Playbook Series

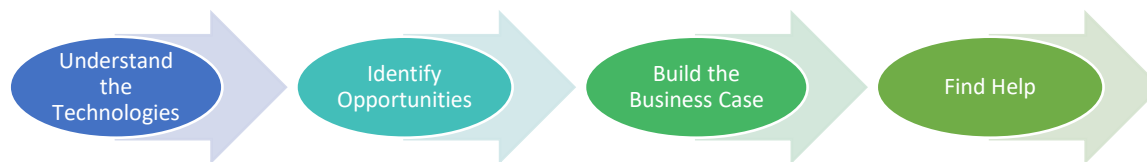
Robotics and Automation

How to Use This Playbook

Each Quad Cities Manufacturing Innovation Hub playbook is created with the business growth needs of our area's small and medium manufacturers in mind. By utilizing the information in the Robotics and Automation Playbook, you are taking the first steps to creating a competitive advantage for your company by innovating in the face of disruptive technologies.

This playbook follows a logical flow to guide you as you learn more about Robotics and Automation (see Fig. 1). Review the sections as they apply to your individual opportunities and resources, either in the order they're presented or jump around to fit your immediate needs.

Figure 1: Robotics and Automation Playbook Information Flow



This is *your* toolkit for plugging into the robotics and automation manufacturing network in the Quad Cities.

Together, all eight of our playbooks work in concert to uplift our regional manufacturers and Department of Defense suppliers through increasing digital readiness; working together to accelerate the understanding and investment in emerging technologies; and foster a culture of innovation in the manufacturing industry. We encourage you to review the other playbooks (see appendix for more information) as well.

[Whom can I contact at the Quad Cities Manufacturing Innovation Hub with questions?](#)

Email askthehub@quadcitieschamber.com and a member of the Hub team will respond to your question.

[About the Quad Cities Manufacturing Innovation Hub and Our Partners](#)

The Quad Cities Manufacturing Innovation Hub assists businesses by offering services such as operational assessments, registry in a regional catalog of manufacturers and suppliers, trade and business-to-business events, access to national and international marketing, access to subject matter experts through the Chamber's Critical Talent Network, connections to the Quad City Manufacturing Lab and national research, and training seminars targeted at key technologies. [More information on the Hub can be found online here.](#)

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Commerce and does not necessarily reflect the views of the OEA. For more information, please visit www.IllinoisDIA.org.

Robotics and Automation in the Quad Cities: At a Glance

What does “robotics and automation” for manufacturing encompass?

Robotics incorporates multiple engineering disciplines to design, build, program, and use robots to complete tasks—in our focus, manufacturing tasks. The purpose of industrial robots varies, and can include movement of products, materials, parts, and tools, as well as completing a wide variety of programmed tasks.¹ Industrial **automation** involves using machines, robots, and control systems to automate tasks within a manufacturing process. Automation uses a variety of technologies, including computer hardware, software, and machines, to perform tasks usually done by human workers.²

Why do robotics and automation matter to the QC manufacturing community?

Robotics and automation has the capacity to augment and replace current manufacturing processes in the future. Workers now are producing 47% more than 20 years ago. Through the development of automation, robotics, and advanced manufacturing, the sector has bounced back along with the overall economy.³ As of 2018, there are 74 robot units per 10,000 employees in the global manufacturing industry (up from 66 units in 2015),⁴ and total industrial robots now working in the United States number at least 230,000.⁵ In three to five years, manufacturers in our region will plan for robotics and automation opportunities when designing factory layouts, engineering and designing products, and upskilling current employees to increase efficiencies, save money, and remain competitive.

What are the biggest opportunity areas locally?

The Quad Cities Manufacturing Innovation Hub has identified three key opportunity areas in robotics and automation for area manufacturers:

- **Opportunity #1: Production efficiencies and cost savings.** Most manufacturers experience ROI in 12 to 18 months after adding robotic automation.⁶
- **Opportunity #2: Increased onsite safety.** Robots are designed with built-in safety functionality and are not prone to the same human errors.
- **Opportunity #3: Employee development.** Employees can develop their careers in new ways, stepping out of low skill-level tasks to explore other fields that benefit the company.

What are the business benefits of utilizing robotics and automation?

Though dependent on the robotics and automation opportunity area(s) you pursue, manufacturers witness many benefits from implementing these technologies, including lower production costs, reduced time to complete tasks, labor cost savings, increased onsite safety, and higher skilled employees. For a full list of metrics, scroll to the Metrics section

¹ <https://www.robots.com/faq/show/what-is-an-industrial-robot>

² <http://blog.robotiq.com/whats-the-difference-between-automation-and-robotics>

³ <https://www.brookings.edu/blog/techtank/2016/06/02/how-technology-is-changing-manufacturing/>

⁴ <https://ifr.org/ifr-press-releases/news/robot-density-rises-globally>

⁵ <https://www.pwc.com/us/en/industrial-products/publications/assets/pwc-industrial-robot-ready.pdf>

⁶ <http://www.boschpackaging.com/doboy/eng/pdf/bosch-delta-robot-white-paper1.pdf>

Where can I find help to get started?

There are local resources who can assist you with the development and implementation of robotics and automation solutions, hardware, machinery, software, and applications. There are also many free online resources, as well as educational courses offered by Quad City universities and colleges. Later in this playbook we offer a full list of area resources to jump start your use of robotics and automation.

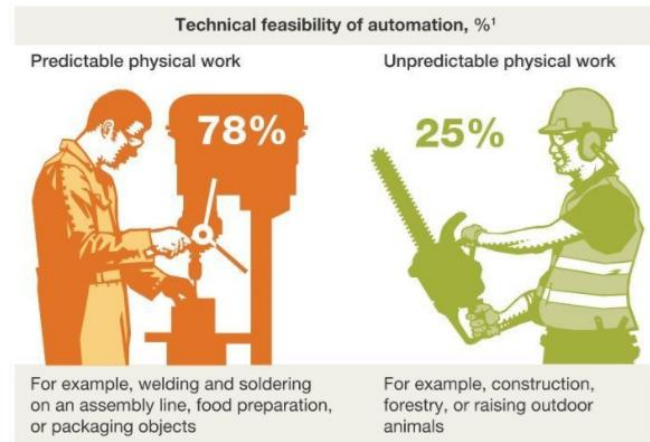
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Understand the Technologies

In the first section, we take a closer look at the technologies that enable robotics and automation. You'll gain a better understanding of how robotics and automation contribute to your company's digital technology and innovation strategy through diagrams, frameworks, and definitions of key terms used in the space. This section also details additional online resources for greater understanding.

Robotics incorporates multiple engineering and design disciplines to build, program, and use robots for task completion—in our focus, manufacturing tasks. Industrial robots are used by manufacturers to move products, parts, and tools, and perform many other programmed tasks.⁷ A subset of industrial robots, collaborative robots (or “cobots”) are designed to safely work alongside humans to perform manufacturing tasks that benefit from automation but cannot yet be fully automated. Cobots can also help manufacturers deal with labor shortage that can occur as workers age out of their jobs, as they supplement current employees through transition periods.



¹% of time spent on activities that can be automated by adapting currently demonstrated technology.

McKinsey&Company

Image: McKinsey & Co

Industrial **automation** involved using machines, robots, and control systems to automate tasks within a manufacturing process. Automation uses computer software, machines, and other technologies to carry out tasks which would otherwise be done by human workers.⁸ Various levels of automation, when combined with robotics, can complete tasks on a manufacturing floor.

By 2021, IDC predicts that 20% of top-performing manufacturers will depend on a secure backbone of embedded intelligence (using industrial Internet of Things (IIoT), blockchain, and cognitive intelligence) to automate large-scale processes and speed execution time by up to 25%.⁹ Both robotics and automation achieve their greatest value and traction as they're integrated with other technologies, like data analytics and cybersecurity programs (see related playbooks) in advanced manufacturing environments to deliver greater efficiencies and data security. Whether integrating with traditional tasks such as welding and picking/sorting; or new technologies like additive manufacturing, machine sensors, and artificial intelligence (AI); many manufacturers are finding additional value from utilizing robotics and automation to augment and improve existing processes that have historically required human involvement. This is especially true when considering the capabilities of collaborative robots that are more flexible and safer than traditional industrial robotic applications.

Glossary: Robotics and Automation Terms

⁷ <https://www.robots.com/faq/show/what-is-an-industrial-robot>

⁸ <http://blog.robotiq.com/whats-the-difference-between-automation-and-robotics>

⁹ “IDC FutureScape: Worldwide Manufacturing 2018 Predictions” as accessed via <https://bluecrux.com/wp-content/uploads/2018/05/IDC-FutureScape-Worldwide-Manufacturing-2018-Predictions.pdf>

Please refer to the glossary in the appendix for definitions of key robotics and automation terminology that is utilized in this playbook. Definitions provided for educational purposes as described by Robots.com unless otherwise noted.

Figure 1: Types of Industrial Automation Systems. Approved for reuse by ElectricalTechnology.org¹⁰

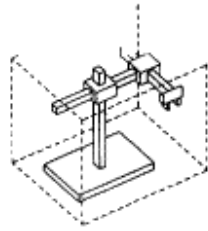
Automation Type	Description	Uses
Fixed or Hard Automation	This type of automation is employed to perform fixed and repetitive operations in order to achieve high production rates. It uses special purpose or dedicated equipment to automate the fixed sequence assembling or processing operations.	Once it is employed, it is relatively hard to change or vary the product design. Therefore, it is inflexible in providing product variety, but increases the efficiency with higher production rate and reduces unit cost. Some of these automated systems are distilled process, paint shops and conveyors.
Programmable Automation	In this automation, a specific class of product changes and also assembling or processing operations can be changed with the modification of control program in the automated equipment.	This automation is best suited for batch production process where product volume is medium to high. But in this, it is hard to change and reconfigure the system for a new product or sequence of operations. It requires a long setup. Examples of this automation system are numerically controlled machines, paper mills, steel rolling mills, and industrial robots.
Flexible or Soft Automation	This automation system provides the automatic control equipment that offers a great flexibility for making changes in the product design. These changes can be performed quickly through the commands given in the form of codes by the human operators.	This automation allows the manufacturers to produce multiple products with different ranges as a combined combination process rather than separate. Some of the examples of this automation system are automatic guided vehicles, automobiles, and multipurpose CNC machines.

*Figure 2. Types and Classifications of Robots
2.1 Below diagram and description, via OSHA¹¹*

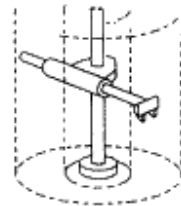
Industrial robots are available commercially in a wide range of sizes, shapes, and configurations. They are designed and fabricated with different design configurations and a different number of axes or degrees of freedom. These factors of a robot's design influence its working envelope (the volume of working or reaching space). Diagrams of the different robot design configurations are shown below.

¹⁰ <https://www.electricaltechnology.org/2015/09/what-is-industrial-automation.html>

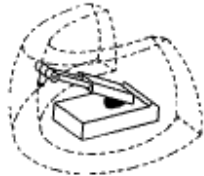
¹¹ https://www.osha.gov/dts/osta/otm/otm_iv/otm_iv_4.html



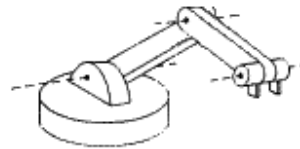
Rectangular Coordinate Robot



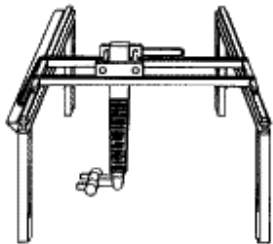
Cylindrical Coordinate Robot



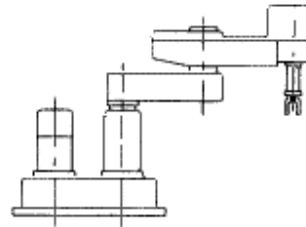
Spherical Coordinate Robot



Articulated Arm Robot

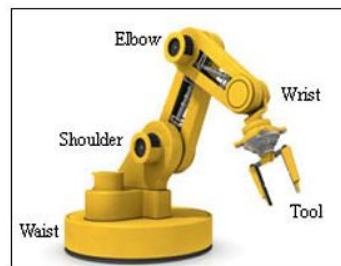
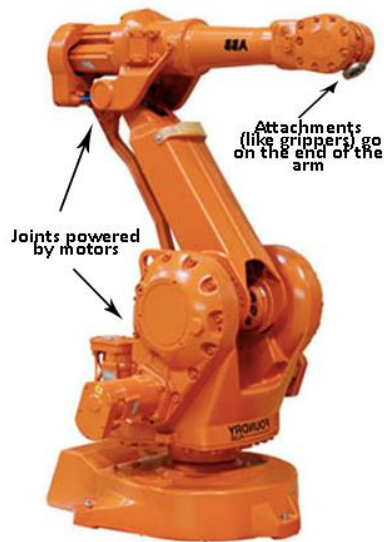


Gantry Robot



SCARA Robot

2.2 A closer look at articulated arm robot anatomy. Approved for reuse by ICT Lounge¹² :



Robotic arm showing joints and a gripper tool



Robotic arm with a welding tool attachment

¹² https://www.ictlounge.com/html/applications_in_manufacturing.htm

2.3 Capabilities of Traditional Robots vs. Collaborative Robots (“Cobots”). Approved for reuse by Universal Robots.¹³ Collaborative robots are designed to work alongside human workers, in operations that cannot be fully automated.

If you need...	...consider a traditional industrial robot	...consider a collaborative robot (“cobot”)
High-volume, high-speed production	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Similar throughput as a human worker	<input type="checkbox"/>	<input checked="" type="checkbox"/>
High payload or very long reach, especially at high speed	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Ability to program and set robot up in-house	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Ability to easily redeploy robot to different processes/tasks	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Extremely high accuracy, including at high speed	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Minimal changes to existing production layout	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Human workers to enter the robot cell to complete their tasks	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Integration options with other machines and robots	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Low initial cost and payback in under a year	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Ability to run processes with few or no employees	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Automation of processes or products that won't change over time	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

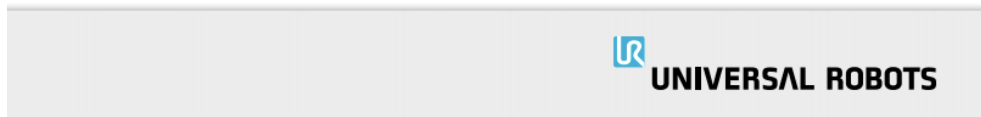
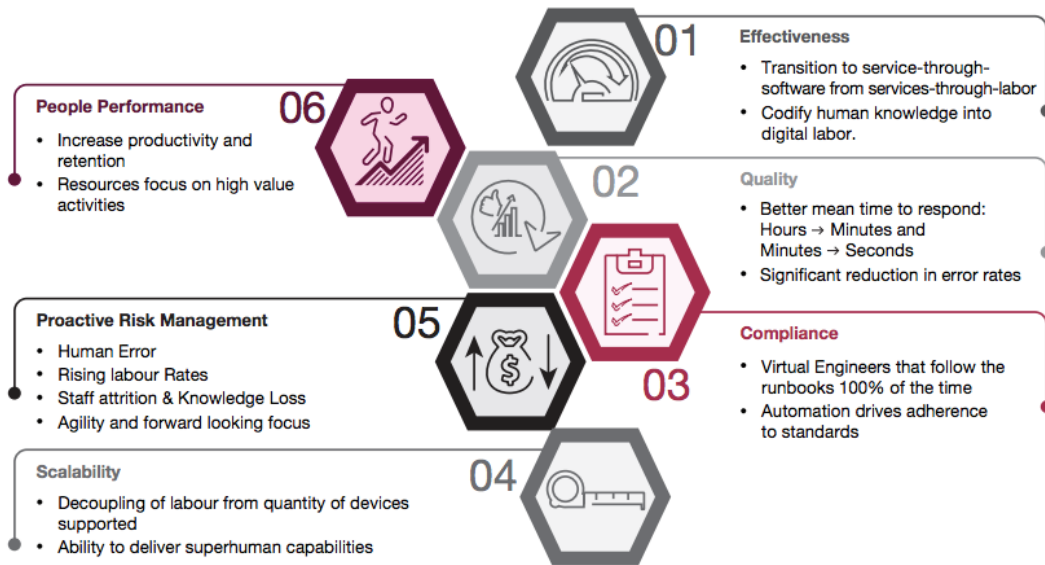


Figure 3: Benefits of Robotics Process Automation, via Capgemini Consulting¹⁴



© Capgemini Consulting 2016

Additional Online Resources

There are many online resources for review to deepen your understanding of robotics and automation machinery, software, applications, technologies, use cases, opportunities, challenges, and more. We’ve outlined a few below:

¹³ <https://info.universal-robots.com/cobots-vs-traditional-industrial-robots>

¹⁴ <https://www.capgemini.com/consulting-de/wp-content/uploads/sites/32/2017/08/robotic-process-automation-study.pdf>

- **Automate this: The business leader’s guide to robotic and intelligent automation**, via Deloitte. [Read the whitepaper guide here](#). In this guide, you’ll find the nuts and bolts of process and enterprise automation in manufacturing. Additionally, find common myths debunked related to intelligent automation, ways to get started step-by-step with robotics, as well as a glimpse into the future of manufacturing automation.
- **The new hire: How a new generation of robots is transforming manufacturing**, via PWC. [Download the report here](#). This report delves into how the rise of robots in manufacturing has created new jobs in new industries, how current workers can interact with robots, and how the collaboration creates a new workforce. You’ll also find outlines of the benefits of flexibility and competitiveness, definitions of barriers to widespread adoption, cost breakdowns, and a handy self-assessment of your readiness for robotics.
- **Robot-ready: Adopting a new generation of industrial robots**, via PWC. [Download the whitepaper here](#). This report focuses on the automation of physical tasks as opposed to information-driven processes (eg. RPA, “robotics process automation”). You’ll learn the capabilities and strategies companies need to harness to best optimize returns on investments in—and deployment of—robotics in manufacturing.

Identify Opportunities

Analyst firm IDC forecasts that industrial robotic solutions will account for the largest share of robotics spending in the market (more than 57%) in 2018. Discrete and process manufacturing will be the leading industries for robotics spending at more than \$54 billion combined this year!¹⁵

The time to act to stay competitive is now. As a high-level guide, assessment of manufacturing processes that can be robotically automated should follow the general [guidelines from Capgemini Consulting](#) listed below. These include not only manufacturing floor tasks (as typically associated with manufacturing “robotics and automation”), but also back-office tasks that involve other data systems, software, and even ERP. Examine tasks of medium complexity and frequency of process, as well as those that take approximately 15 minutes of medium-value work.¹⁶

- Repetitive tasks carried out at least 50x per day
- Process list and file storage
- Periodic reporting, data entry, and data analysis
- Mass email generation, archiving, and extracting
- Conversion of data and graphics
- ERP and other back-office transactions (See the ERP playbook for more opportunities)

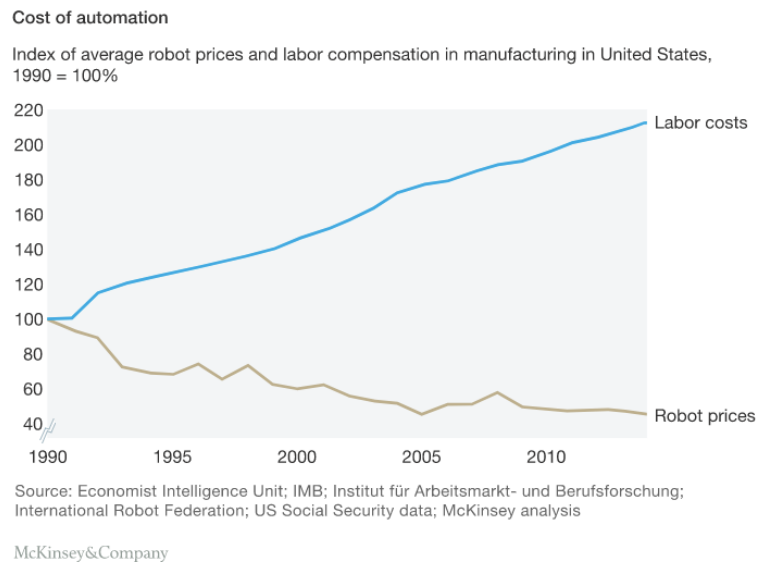
Robotics and automation opportunities abound for manufacturers of all sizes, including those small and medium manufacturers in the Quad Cities. The Hub has identified three key areas that can bring greatest benefit to our area’s small and medium manufacturers: production efficiencies and cost savings; onsite safety; and employee development.

Opportunity #1: Production Efficiencies and Cost Savings

¹⁵ <https://www.mhlnews.com/technology-automation/robotics-and-drone-market-growing-196-annually>

¹⁶ <https://www.capgemini.com/consulting-de/wp-content/uploads/sites/32/2017/08/robotic-process-automation-study.pdf>

Manufacturers find robotics and automation to offer significant return on investment, as robots continue to decline in cost (see Fig. 4, at right). Most manufacturers experience ROI in 12 to 18 months after adding robotic automation.¹⁷ When used to complete repetitious and menial manufacturing tasks, more product can be produced without quality slipping. Robotics and automation achieve the greatest cost savings within manufacturing environments that require high output and no-to-low margins of error, though as production shifts to smaller lots of different products, companies will look to achieve shorter time-to-market and rely on robots for quick, local customization.



Opportunity #2: Onsite Safety

The addition of robotics to a manufacturing environment reduces worker injury rates, especially in cases where employees would be working with typically dangerous equipment.

This is also a great asset to third-shift workers that may become more easily fatigued and prone to error during their shift. Robots are designed with all required safety functionality and are not prone to the same human errors, though necessary safety precautions must still be taken when integrating robots into collaborative manufacturing situations.

Opportunity #3: Employee Development

The addition of robotics and automation to a manufacturing company gives its employees the chance to develop their careers in new ways, stepping out of their menial or low skill-level tasks to explore other fields that benefit the company. These may include learning to operate robots, performing more intricate or customized manufacturing assignments, focus on continuing education, or even innovation for the company. Robots may cause short-term job displacements, but long-term benefits to workers as they develop new skills and pursue jobs of greater impact, fulfillment, and salary. In turn, this boosts disposable income and positive economic impact over time.

Benefits and Use Cases of Robotics and Automation Opportunities

In this section, we'll examine the key benefits of utilizing robotics and automation in each of the three opportunity areas previously identified. Below, you'll also find a case example for each opportunity area that shows how a manufacturer was able to utilize robotics and/or automation to produce results.

Opportunity #1: Production Efficiencies and Cost Savings

- **Increased efficiency and faster throughput:** Industrial robots can perform tasks quicker than humans, decreasing cycle time. Robots can work around the clock as well, enabling 24/7 operations.
- **Flexibility and scalability:** Once a process has been defined as a series of instructions for robot execution, it can be scheduled for a particular time—either for one robot, or many working in

¹⁷ <http://www.boschpackaging.com/doboy/eng/pdf/bosch-delta-robot-white-paper1.pdf>

unison. Robots can also be programmed to prioritize tasks, if one to-do is more important than another in an evolving scenario—as each robot is typically capable of performing many actions.

- **Improved accuracy:** Robots are programmed to follow rules and rarely make mistakes.
- **Ease of integration with existing machinery:** According to McKinsey, advances in computing power, software development, and networking technologies have made assembling, installing, and maintaining robots faster and less costly than before.¹⁸ Look for experience and industry expertise in a systems integrator that is tailored to your individual needs. Consider the integration needed to complement other new technologies as well—such as additive manufacturing, artificial intelligence, data sensors, and more.
- **Real-time data gathering:** Robot tasks can be monitored and analyzed at every step, producing valuable data that can support process improvement over time, and also help with regulatory compliance.¹⁹ McKinsey also reports that, “robotic sensors and actuators can also monitor themselves and report their status to the control system, to aid process control and collect data for maintenance, and for continuous improvement and troubleshooting purposes.”²⁰ Learn more about how to craft your data analytics strategy in our Data Analytics playbook.

Case Example #1: Vision-guided collaborative robots deliver fast return on investment in production of firehose valves²¹

Task Force Tips, an Indiana-based manufacturer of firefighting equipment, wanted to promote and maximize their personnel tending machining cells into more complex tasks while keeping spindle time up and product quality consistent. The manufacturer has now installed four collaborative robots, working alongside employees, to deliver savings resulting in a return on their investment in only 34 days. Task Force Tips installed three robots to tend CNC machines, and a fourth is mounted to a table on wheels and moved between tasks. Now, it only takes one hour per operator per shift to operate the robot, which includes laying out parts and staging the robot. That translates into the robot running for 21 hours unassisted and seven hours of time saved in each employee shift, freeing them up to do something else more productive.



Case Example #2: Harley Davidson Detects Defects and Streamlines Production

Harley Davidson uses smart systems to detect defects during production processes at its York, Penn., plant. Sensors monitor equipment performance and initiate action autonomously. Upon detection of measurement anomalies (of everything from humidity or temperature) beyond acceptable ranges, the machinery is automatically adjusted, preventing malfunctions.²² As reported in the Wall Street Journal, the data allows Harley Davidson to streamline production, eliminate bottlenecks, and anticipate problems predictively. Since implementation, Harley Davidson completes a new bike every 86 seconds.²³

¹⁸ <https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future>

¹⁹ <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf>

²⁰ <https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future>

²¹ <https://www.engineering.com/ResourceMain.aspx?resid=596>

²² https://www2.deloitte.com/content/dam/Deloitte/za/Documents/energy-resources/ZA_Deloitte-Industry4.0-manufacturing-ecosystems-Jun16.pdf

²³ <https://www.dqecom.com/resources/tech-talk/tags/internet-of-things/>

Case Example #3: Ridgeline Pipe Manufacturing Anticipates Demand and Auto-Adjusts Production

Ridgeline Pipe Manufacturing adopted a “flexible production system” to combat challenges of shifting customer demand, short lead times, and inefficient production changeover. With the autonomous system, the company is able to predict demand and adjust production accordingly via automated production controllers that react to real-time diagnostic performance data. Ridgeline is also able to analyze production data in order to predict machine failure ahead of an emergency or downtime.²⁴

Opportunity #2: Onsite Safety

- **Fewer accidents and injuries:** Many robot safety features and technologies have existed for quite some time with proven success, with robotic developers and integrators using safe zones, fencing, and other technologies to ensure safe robot operation. Though accidents can happen, it’s rare, and they’re often caused by either operator error, setup mistakes, or entering a robot’s operating zone.²⁵ Robots also oftentimes take on more dangerous or ergonomically challenging tasks, lessening the chance for worker on-the-job injury.
- **Faster reactions:** Industrial robots take up less space than they used to, and are armed with countless sensors to help increase reaction time, use appropriate force, and stop production when nearing humans or other collision points. If sensors indicate the risk of a collision with an operator, the robot will automatically slow down or alter its path to avoid it.
- **No safety training needed:** *Control Engineering* reports on the safety of collaborative robots, stating they are, “designed to understand their environment and interact with people, which is unlike a traditional robot that works on the assembly line. These technologies are intended to develop the natural interfaces that allow for the operation of complex robotic systems with less training and expended energy.”²⁶

Case Example: Ford Uses Collaborative Robots for Heavy Lifting, Outlook to Eliminate Employee Repetitive Strain Injuries²⁷

Ford Motor Co. has been testing new collaborative robots from KUKA Robotics at its assembly plant in Cologne, Germany, on an assembly line helping workers install shock absorbers. Rather than use a heavy shock absorber installation tool, the workers have the robot lift and automatically position the shock into the wheel arch before pushing a button to install the component. Working overhead with heavy air-powered tools is a tough job that requires strength, stamina, and accuracy. For many automotive applications in particular, collaborative robots that can lift a substantial amount of weight, show a lot of promise for alleviating a number of repetitive strain injuries among workers. The collaborative robots also stop immediately if they detect an arm or even a finger in their path, ensuring ultimate worker safety.



Opportunity #3: Employee Development

²⁴ <https://www.automation.com/portals/factory-discrete-automation/motion-control-motors-drives/rockwell-automation-controls-ridgeline-pipe-manufacturing> as accessed via https://www2.deloitte.com/content/dam/Deloitte/za/Documents/energy-resources/ZA_Deloitte-Industry4.0-manufacturing-ecosystems-Jun16.pdf

²⁵ <http://advancedmanufacturing.org/putting-safety-first-robotic-automation/>

²⁶ <http://www.controleng.com/single-article/robots-are-changing-the-global-manufacturing-market/49b483d71971ca291fdaf1fdbae27df2.html>

²⁷ <http://advancedmanufacturing.org/putting-safety-first-robotic-automation/>

- **“Upskilling” of workers:** Workers whose tasks are augmented by or fully replaced by robotics have the chance to develop their careers into new roles that will be created by automation. *World Economic Forum* predicts that, “as robots take over the most repetitive and arduous tasks, humans will transition to less physically demanding and straining roles,”²⁸ learning new skills in the process.
- **Larger talent pools:** McKinsey analysts find that people with the skills required to design, install, operate, and maintain robotic production systems are becoming more widely available, too. “Robotics engineers were once rare and expensive specialists. Today, these subjects are widely taught in schools and colleges around the world, either in dedicated courses or as part of more general education on manufacturing technologies or engineering design for manufacturers,” reports Jonathan Tilley.²⁹
- **Improved employee morale:** According to Deloitte, “the tasks and processes most suitable for automation are typically the most onerous and least enjoyed, and employees relieved of them can be refocused on more rewarding and higher value activities.”³⁰ This, in turn, positively impacts their morale and the overall culture of your company. This is particularly true when considering cobots, as they work alongside and not in place of existing employees. Cobots can relieve manufacturing workers of “drudge work,” and free them to focus on more mentally challenging tasks—ultimately fostering more valuable employees in the eyes of the manufacturer.³¹

Case Example: MIT research suggests that robot managers are not just more efficient, they’re preferred by manufacturing workers³²

New research coming out of MIT’s Computer Science and Artificial Intelligence Lab (CSAIL) sought to find that “sweet spot” for ensuring that the human workforce is both satisfied and productive working alongside robots in manufacturing environments. Research results concluded that the answer is to actually give machines more autonomy, if it helps people to work together more fluently with robot teammates. In the study, groups of two humans and one robot worked together in one of three conditions: manual (all tasks allocated by a human); fully autonomous (all tasks allocated by the robot); and semi-autonomous (one human allocates tasks to self, and a robot allocates tasks to other human). The fully-autonomous



condition proved to be not only the most effective for the task, but also the method preferred by human workers. The workers were more likely to say that the robots “better understood them” and “improved the efficiency of the team.” This study offers promise that collaborative robot-human manufacturing scenarios could lead to more positive workplace environments.

Build the Business Case and Begin Implementation

In this section, we’ll outline the steps to take in implementing robotics and automation technologies within your company, beginning with awareness and change management, through establishing

²⁸ <https://www.weforum.org/agenda/2017/05/sales-of-industrial-robots-are-surgin-so-what-does-this-mean-for-human-workers/>

²⁹ <https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future>

³⁰ <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf>

³¹ <https://www.roboticsbusinessreview.com/engineering/cobots-and-robots-as-a-service-help-scale-changing-workforce/>

³² <http://news.mit.edu/2014/want-happy-worker-let-robots-take-control>

partnerships and building use cases that will save you time and money. We understand that the idea of implementing robotics and automation is very different from traditional manufacturing equipment and processes that you may be accustomed to. We also understand that the prospect of this degree of change is daunting! It is our hope that, through the following content and previous look at the benefits of robotics and automation, you'll feel more comfortable exploring how you can utilize these technologies to achieve efficiencies throughout your company.

Change Management: Building the Case Requires Data and a “Test-and-Learn” Approach

For most small and medium manufacturers, the prospect of adopting robotics and/or automation seems risky, as it bucks the status quo and requires learning new technologies and procedures to remain relevant in a digital age. Only through experimentation, learning, and failing fast, can you quickly gain new expertise and experience that will benefit your company in years to come.

It's tempting to allow your self-defense mechanism to take over when faced with new technologies. It's natural for leaders to practice self-preservation to protect their role, team, and the future of the company at-large. However, it is in new technologies, like robotics and automation, that are shifting the manufacturing industry—beyond the Quad Cities. New strategies and tactics are emerging, and the only way to survive is to be proactive in your adoption of robotics and automation in ways that fit into your current culture and align with your business growth goals.

There are many ways for you to get started along the path to utilizing robotics and automation. Use the **change management tips** below to make the case for change and immediately begin proving results:

- **Understand the business value of both robotics and automation separately, and set goals accordingly.** Use our metrics outlined in this playbook, as well as your own data research to set realistic expectations of how you will measure the impact and success of integrating robotics and automation into your existing manufacturing technologies, equipment, and processes. This will help in resource planning if you're measuring the right benchmarks out of the gate. Focus on one or two main use cases first before building complexity. Also consider connecting your robotics/automation goals to existing technology innovation initiatives that already have momentum or proven use cases. Are you experimenting with additive manufacturing, machine sensors, or artificial intelligence? Could robotics/automation assist with achieving those goals?
- **Focus on getting every employee on board with the benefits of robotics and automation through peer education.** Get all stakeholders involved from the beginning via one-on-one conversations with leaders and all-company meetings to drive the vision. Make them as knowledgeable as you possibly can, taking ownership of digital platform initiatives. Innovative companies like GE promote “reverse mentoring” to foster understanding, create mutual empathy, and promote collaborate between disparate generations and team members. In reverse mentoring scenarios, a younger colleague mentors a more tenured employee as a way of getting everyone up-to-speed quickly with digital technologies and benefits. Find more education resources and tips later on in the playbook.
- **Keep communication lines open during the trial-and-error portion of experimentation.** Employees should understand that it's okay to fail, and fail fast, if it's part of a learning process that eventually leads to successfully implementing new robotics and automation strategies. This mindset must be led from the top-down within your company in order for employees to feel like they can experiment and innovate in order to achieve efficiencies. Breed risk-taking early.

Part of change management also lies in understanding and planning for the **challenges you will encounter** in integrating robotics and automation into your existing operations. Below are four challenges

we've identified through our research and conversations with area manufacturers. Become familiar with the potential roadblocks so you can steer clear of their hindrances early on.

- **Challenge 1: Robots are too expensive for small and medium manufacturers.** Many robots are flexible enough to be programmed quickly and easily, reducing the number of times it needs to repeat a task to justify the cost of buying and commissioning it. This makes industrial robots more economical for manufacturers who typically run small batch sizes, or have a variety of products. According to McKinsey, the cost savings will benefit many different kinds of organizations: small companies will be able to access robot technology for the first time, and larger ones could increase the variety of their product offerings.³³

New business models around “robots as a service” (RaaS) are emerging, wherein collaborative robots are available for rent to small and medium manufacturers in order to witness cost savings before a large investment is made. This helps manufacturers adapt to the shift in workforce needs and production processes more smoothly as employees learn to work alongside robotic counterparts.³⁴ Companies in the RaaS space include [Savioke](#), [Robosoft Services Robots](#), and [Acorn Product Development](#).

- **Challenge 2: Certain tasks are difficult to automate.** Ryan Weaver, automation engineer with Axis New England, elaborates: “as a machine becomes closer to 100% automated, the overall cost tends to rise exponentially. Certain tasks can be very challenging to automate, which adds significant cost. [Forbes](#) also details an example auto plant that invested millions in automation technology for windshield installation, only to find that by replacing the people who did the job they were actually *adding* cost to the process, as machine maintenance for the task outweighed the savings in trimming employees (even though it was more consistent in windshield adhesive application).³⁵

Tasks that include anything subjective, such as bin sorting, or complex inspection tasks, are those that require detailed cost assessment before implementation. Slow down the process and consider all variables, including utilizing cobots—as they allow human operators to be involved in the more challenging portions of the task, reducing automation cost.”³⁶

- **Challenge 3: Robots are not safe around workers.** Robots are designed with all required safety functionality, but a robot is only as safe as the entire system design. This is where integrators become incredibly important, as they take the necessary safety precautions when integrating a robot into any system. A risk assessment should be done for the whole robotic cell where the necessary safety of the robot (especially if cooperative) may not be enough to grant a sufficient level of safety to the entire cell, according to *Control Design*'s recommendations.³⁷
- **Challenge 4: Automating tasks eliminates too many human jobs.** Although automation can replace human employees on some repetitive tasks at greater efficiencies, it also offers the potential to create jobs in manufacturing as saving money on the lowest-paying labor costs contributes to lowering prices on goods. This creates more market appeal and the need for more workers. We see this scenario unfolding with retail behemoth Amazon. Over the past three years, the company has increased the number of robots working in its warehouses from 1,400 to 45,000. Over the same period, the rate at which it hires workers hasn't changed, according to Quartz.³⁸ Robots help Amazon keep prices low, causing increased consumer purchases, translating into the

³³ <https://www.mckinsey.com/business-functions/operations/our-insights/automation-robotics-and-the-factory-of-the-future>

³⁴ <https://www.roboticsbusinessreview.com/engineering/cobots-and-robots-as-a-service-help-scale-changing-workforce/>

³⁵ <https://www.forbes.com/sites/oliverwyman/2017/02/03/surprise-the-correct-answer-is-not-always-to-go-with-the-robot-just-ask-some-automakers/#5ae481120a>

³⁶ <http://www.controldesign.com/articles/2016/the-keys-to-robot-selection-safety-and-collaboration/>

³⁷ Ibid.

³⁸ <https://qz.com/904285/the-optimists-guide-to-the-robot-apocalypse/>

need for more employees to staff the additional warehouses (even with fewer human hours of labor needed per package).

Processes and Frameworks for Implementing Robotics and Automation

Integrating robotics and automation into your existing manufacturing processes requires a strategic approach. Utilize the workflows and frameworks on the following pages to aide in your high-level strategic prioritization of robotics and automation, and we recommend you search out specific frameworks for each technology and use case chosen to guide your implementation.

Framework 1: Robot Applications and Use Cases via Robot Worx³⁹

Each industrial robot application requires unique end of arm tooling, specific reach and payloads, and flexibility. An integrator will advise grouping them according to number of axes, structure type, size of work envelope, payload capacity and speed.

WELDING ROBOT APPLICATIONS



- Arc Welding
- Flux Cored Welding
- MAG Welding
- Orbital Welding
- Plasma Cutting
- Resistance Welding
- Spot Welding
- Tig Welding
- Welding Automation
- Electron Beam
- Laser Welding
- Mig Welding
- Oxyacetylene Welding
- Plasma Welding
- Shielded Metal Arc Welding
- Submerged Arc Welding
- TIP/TIG Welding

MATERIAL HANDLING ROBOT APPLICATIONS



- Collaborative
- Injection Molding
- Machine Tending
- Order Picking
- Palletizing
- Pick and Place
- Vision
- Dispensing
- Machine Loading
- Material Handling
- Packaging
- Part Transfer
- Press Tending

³⁹ <https://www.robots.com/applications>

OTHER ROBOT APPLICATIONS



- | | |
|----------------------------|----------------------|
| 3D Laser Vision | Appliance Automation |
| Assembly | Bonding / Sealing |
| Cleanroom | Coating |
| Cutting | Deburring |
| Drilling | Fiberglass Cutting |
| Foundry | Grinding |
| Laser Cutting | Material Removal |
| Meat Processing Automation | Milling |
| Painting Automation | Polishing |
| Refueling | Routing |
| Sanding | Spindling |
| Thermal Spray | Waterjet |

Framework 2: Five Steps to Developing an Automation Strategy in Manufacturing, via Deloitte⁴⁰

What?	Why?	How?	Who?	When?
Assess for automation opportunities	Build your business case	Determine the optimal operating model	Identify your automation partner(s)	Plan the automation roadmap
<ul style="list-style-type: none"> Which processes are good candidates for automation? Which processes would be suitable to pilot? How should the process owners be engaged to try automation? What are the impacts of proceeding with the pilot? 	<ul style="list-style-type: none"> Why does automation support your business needs? What are the benefits? What are the pain points being alleviated? What are the metrics to determine whether automation is valuable? What is the strategy for re-deploying existing resources after automation? 	<ul style="list-style-type: none"> Which operating model works best for your organization? Do you have the right team to support the solution and carry out responsibilities (e.g., assessing new processes for automation and testing the automated jobs)? Who will manage and monitor the software robot? 	<ul style="list-style-type: none"> Who are the main vendors in the RPA space? Who are the providers who cater to your business needs the most? Which sourcing option do you want? How should you compare the pricing models in order to understand what you are paying for? 	<ul style="list-style-type: none"> How long should your pilot be? What are the stages after the pilot? What is your strategy for scale? How will you ensure impacted stakeholders understand the what, why, and how of automation?

Resources Needed: Technology and Staffing

Resources required to manage implement robotics and automation technologies will vary by the use cases you've established. For example, utilizing collaborative robots alongside workers will yield a different cost structure than planning to use traditional stationary robots for automation of repetitive tasks. As previously outlined, you must create a strategic plan for *how* robotics and automation will augment or replace your current processes in the recommended opportunity areas before jumping the gun and investing in the latest "bright, shiny technology" or hiring unnecessary talent.

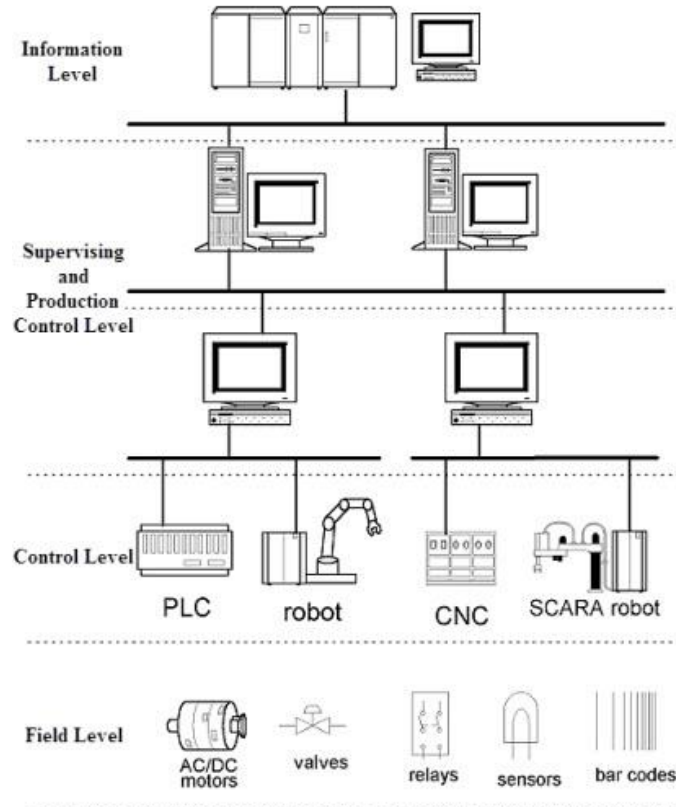
Use these recommendations to assist in the process of planning for your hard and soft costs:

- **Hardware:** There are many factors for consideration when deciding what types of robots are needed for your automated system, including size, payload capacity, repeatability, reach, and

⁴⁰ <https://www2.deloitte.com/content/dam/Deloitte/us/Documents/process-and-operations/us-sdt-process-automation.pdf>

more. Most often, automation systems are created by combining your existing equipment with new robotics that fit your production and plant requirements.⁴¹ See below for a general layout of the types of robotics hardware you'll utilize for automation:

Figure 5. *Hierarchy of an Industrial Automation System*



According to *Robotics.org*, when implementing robotics to a shop floor there are several components to review:⁴²

- Can the new equipment be reduced by simply adding on to existing peripherals?
- Power requirements: can existing output support the added technologies? Look at your power grid's consumption vs. the amount you have to work with, as well as the power needed for the additional robotics. You may need temporary generators to run everything.⁴³
- Floor management and building a "cell" for the robotics – a designated operating space for the robot. Prior to ordering, find out the exact dimensions and measure these on your plant's floor. Look at more than just the base of the machine's size. Consider the reach it has and how much space it will need to fully function when you're doing your measurements. Consider space for other machines or workers as needed.⁴⁴
- Determining how much and what type of work the robot will need to do.

⁴¹ <http://www.controldesign.com/articles/2017/how-to-get-started-with-robotics/>

⁴² https://www.robotics.org/content-detail.cfm/Industrial-Robotics-Industry-Insights/U-S-Alliance-in-Robotics-for-Manufacturing-Means-Innovation-Education-More-Jobs/content_id/6451

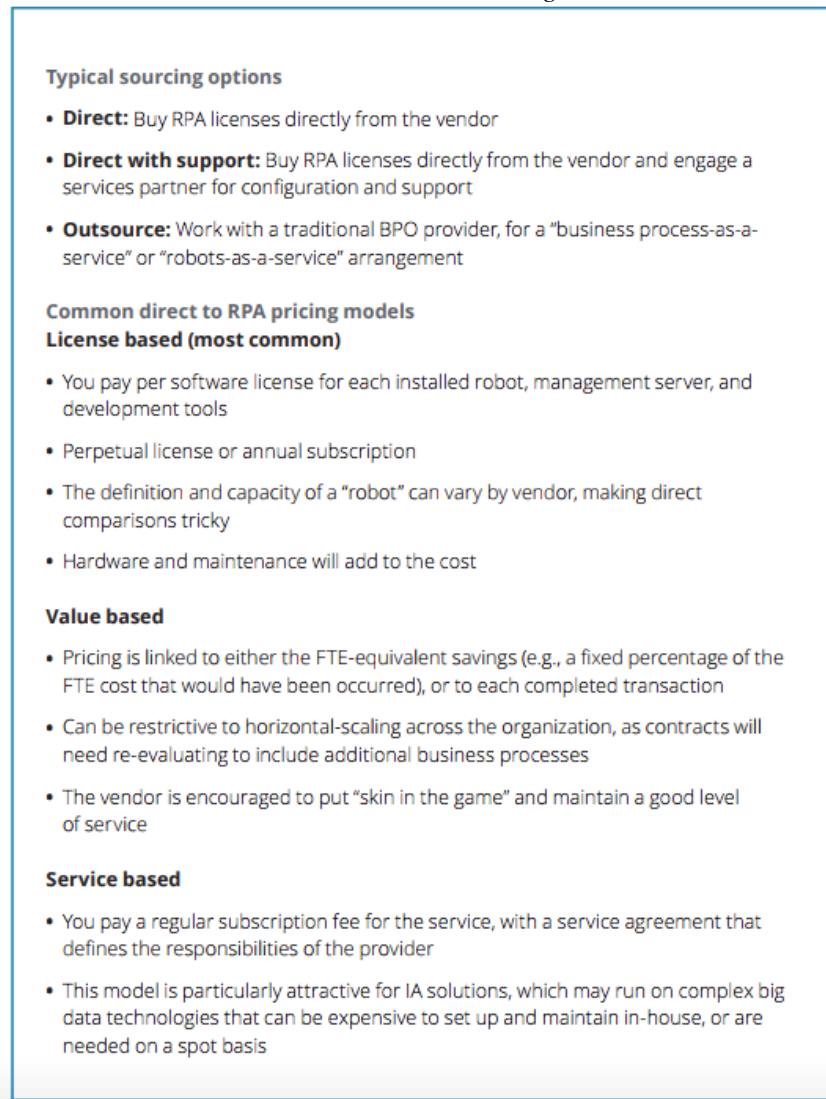
⁴³ <http://blog.robotiq.com/how-difficult-is-it-to-implement-robotics-into-a-manufacturing-plant>

⁴⁴ Ibid.

Hardware Costs: To make robotics and collaborative solutions more accessible, many robotics manufacturers have adopted a “service” policy that offers more accessibility to startups and cost-sensitive industries. Example from *Robotiq*: instead of selling farmers extremely expensive robotics, farmers can “rent” the robots at a certain price per acre driven or payload carried.⁴⁵ Collaborative robots are generally cheaper than traditional robots too, ranging from \$25,000 to \$45,000, whereas traditional factory floor robots can cost upward of \$100,000 each.⁴⁶

- **Software:** Running robotic machinery on your manufacturing floor requires computer software as well. See the figure below that breaks down your options for software sourcing and licensing.

Figure 6. *Typical Sourcing Options, via Deloitte. Note: RPA means Robotics Process Automation; and BPO means Business Process Outsourcing Provider.*



- **Employees and Hiring:** Assess your current employees for skillsets and experience in robotics and automation to determine if expertise and interest exists. Most manufacturers have in-house

⁴⁵ <http://blog.robotiq.com/3-trends-in-robotics-that-are-changing-manufacturing>

⁴⁶ <https://techcrunch.com/2016/10/09/industrial-robots-will-replace-manufacturing-jobs-and-thats-a-good-thing/>

talent that is skilled in machine operation who are ready and able to augment their current skills and learn how to operate or work alongside robots and automation systems. However, manufacturers opt to hire new employees with robotics and automation expertise to speed up the implementation process, as well as inject new, passionate approaches to innovation within the company. Work with the education and hiring partners listed later in the playbook to find robotics and automation employees with experience, or those that are freshly graduated, or as a temporary intern (with, ideally, intent to hire). Consider the necessary skillsets from PWC below, to guide your upskilling and hiring efforts:

- Configuring and programming for production jobs, especially for tasks needed for quick, infrequent runs
- Analyzing data collected from machines for insights such as condition-based maintenance, or rate and quality variability
- Managing the integration of robotics into workflow (at the right place and at the right pace of automation) and scheduling to prevent bottlenecks
- Monitoring, maintenance and repair of automation equipment and associated tooling⁴⁷

If you are just getting started, it is also reasonable to assume that you will want to engage the services of a **systems integrator** as well. *Control Design* advises to, “determine if the integrator has experience in your industry or application, evaluate the integrator’s background and capabilities, check references, assure the integrator has the technical expertise and staff to both provide the system and support it in the future and have the financial ability to procure the amount of materials needed for your system.”⁴⁸ [Rockwell Automation](#) and [Schneider Electric](#) also offer services to help manufacturers evaluate where they can modernize and apply manufacturing automation.

“Quick Wins” to Get Started with Robotics and Automation

Take a page from the best practices of Control Design, and of other manufacturers that are already up-and-running with robotics and automation, by following a few of their tips to jumpstart your use of these technologies.

- **Tip 1. Start small and grow in automation.** Invest in automating one process at a time in order to understand robotics involved and learn how to properly use machinery while also allowing time to observe potential productivity gains. Look into leasing/renting robotic machinery if you are unsure of your financial commitment. Utilize the checklist below, adapted from Capgemini Consulting’s report, “*Robotic Process Automation*,” as a starting point in determining which processes are ideal candidates for manufacturing and back-office automation.
 - Does the process require access to multiple systems?
 - Is it prone to human error?
 - Can it be broken down into detailed rules?
 - Does it need limited human intervention, once it’s begun?
 - Is it executed frequently, in large numbers?⁴⁹
- **Tip 2. Connect with robotics integrators.** Integrators will conduct an onsite visit and survey the factory/enterprise to help you better understand what robotics you may need and how they can be implemented best on the shop floor. They can evaluate your processes for tasks that are dangerous to humans, boring or repetitive tasks, heavy tasks that require excessive exertion or lifting that requires multiple employees, high-speed manual moves, and tasks that do not require

⁴⁷ <https://www.pwc.com/us/en/industrial-products/publications/assets/pwc-industrial-robot-ready.pdf>

⁴⁸ <http://www.controldesign.com/articles/2017/how-to-get-started-with-robotics/>

⁴⁹ <https://www.capgemini.com/consulting-de/wp-content/uploads/sites/32/2017/08/robotic-process-automation-study.pdf>

human decision-making.⁵⁰ Connect with multiple integrators and vet experience before choosing one.

- **Tip 3. Consider collaborative robots as a jumping-off point.** Though machines cannot replace human workers in many production processes, even the smallest companies are finding collaborative robots (co-bots) an easy-to-deploy solution for their worker shortage. Case in point from *Automation World: Creating Revolutions* was experiencing double-digit product rejection rates because of faulty assembly, and it was also unable to find skilled workers. Seeking an alternative solution for these production problems, the company turned to Hirebotics, a company that rents collaborative robot by the hour. Renting from Hirebotics eliminated the capital expense barriers for new technology that were facing *Creating Revolutions*. Using the robot also reduced product rejection rates to nearly zero.⁵¹
- **Tip 4. Usher your employees along as automation supporters, not detractors.** In order to keep employees worry-free and also dedicated to their role (and the company's innovation vision), manufacturers must introduce robotics and related task automation in steps. This ensures employees don't feel as though they're being replaced, and that managers can retain those employees whose talents can be upskilled down the road—in areas like robot management, engineering, and repair, as well as those that will be part of the robotic workflow. Infrastructure, processes, governance, and organizational hierarchy will shift, and if employees do not buy in to the positive aspects of intended change, you're in for a bumpy ride that could ultimately derail any potential progress or cost-savings. Think of the new opportunities your employees will be afforded in training, make those known, and then begin to help their transition to new career paths that integrate bots and human skillsets and strengths.⁵²

Metrics for Success: How to Measure Impact

When setting your objectives for robotics and automation, you'll need to tie goals to business impact using metrics for success. Without measuring and benchmarking the performance against traditional strategies, it will be more difficult to consistently improve processes, assess weaknesses, and secure future resources.

Take a page from PWC's recommendations on questions to ask yourself that will help yield a realistic and accurate ROI estimate:

1. What are all the actual costs and feasibility of acquiring the exact robot (configuration, operation, maintenance, repair, new software, training workers)?
2. Is the robot "future-proofed" (easily updated with software/ hardware), or is it vulnerable to emerging disruptive technology?
3. Will the robot "pay for itself" in cost savings, and, if so, over what time period?
4. Are you assessing the right needs and estimating the right amount of value?
5. Are there alternatives to robots or automation that can create value?⁵³

Once you've answered the above foundational ROI questions, consider the following key performance indicators below to benchmark and measure the success of your automation implementation(s):

- Lower production costs
- Reduced time to complete tasks (speed of process increase)

⁵⁰ Ibid.

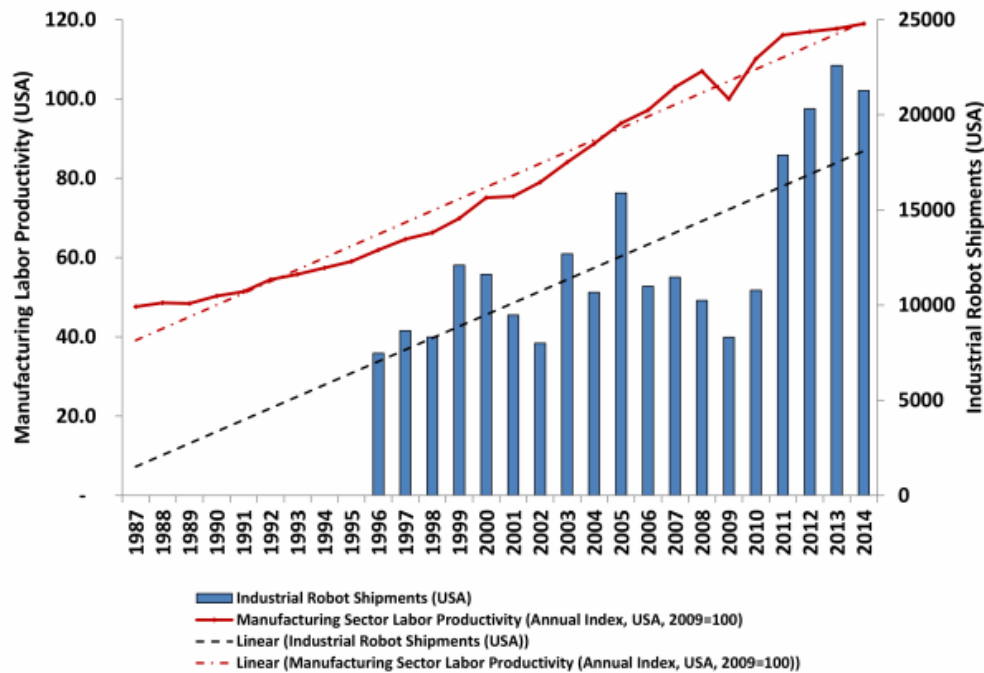
⁵¹ <https://www.automationworld.com/article/technologies/robotics/turning-out-lights-factory-floor>

⁵² <https://www.forbes.com/sites/oliverwyman/2017/02/03/surprise-the-correct-answer-is-not-always-to-go-with-the-robot-just-ask-some-automakers/#5ae481120a>

⁵³ <https://www.pwc.com/us/en/industrial-products/publications/assets/pwc-industrial-robot-ready.pdf>

- Greater real estate utilization (robots take up less space than needed for human workers)
- Increase in labor demand (as a result of higher product demand from lower product prices)
- Labor cost savings. Estimates for labor cost savings in various countries through automation and robotics now are averaging around 16% in industrialized nations.⁵⁴ This may be realized by reduction in headcount.
- Increased onsite safety and lower accident rate
- Higher skilled employees with greater longevity
- Reduction in changeover time
- Improved quality of work
- Increased employee satisfaction
- Reduced risk and improving compliance
- Increased product standardization
- Increased labor productivity (see figure below)

Figure 7. Manufacturing Labor Productivity (Output/Hour) and Industrial Robot Shipments, via Bureau of Labor Statistics⁵⁵



Find Help with Regional Assets and Partners

In delivering this Robotics and Automation Playbook, among the seven other playbooks provided by the Quad Cities Manufacturing and Innovation Hub, our goal is to connect you to local resources you need to learn about and implement new technologies that will impact your business and our region in the future.

⁵⁴ <https://www.brookings.edu/blog/techtank/2016/06/02/how-technology-is-changing-manufacturing/>

⁵⁵ <https://www.a3automate.org/docs/A3WhitePaper.pdf>

In this section, you'll find local experts, agencies, consultants, and specialists to help you succeed. Additionally, we've outlined national and global resources in some categories if local resources do not exist and/or the national resource is reputable.

Robotics System Integrators

Genesis Systems Group

www.genesis-systems.com

Genesis specializes in factory automation with robots for welding, cutting, non-destructive inspection, adhesive application, material removal and material handling. Genesis is also AS9100D and ISO 9001:2008 Certified. Its expertise is centered on the design, manufacture and implementation of systems for welded assemblies, mechanical assembly, handling/tending, non-destructive inspection, abrasive waterjet cutting and material finishing.

Hawk Technology

www.hawktechnology.com

Hawk Technology offers true "turn-key" solutions. Its onsite tooling department will integrate your robotic needs as well as create the tooling for seamless manufacturing solutions. Hawk Technology provides: HMI packages that display work instructions in real time; Custom HMI packages tailored to your solution; Single-source tooling and integration; Custom cells designed on site; Standard line of cells Offline programming; and Simulation services. It is a FANUC authorized system integrator.

Vizient Manufacturing Solutions

www.vizient.com

Vizient Manufacturing Solutions, Inc. specializes in robotic integration solutions. Its team of automation specialists have been providing robotic systems integration, dedicated customer service, and tooling solutions since 2004, installing more than 300 robotic systems. All of Vizient's products are engineered and manufactured in-house, giving them complete control over product quality and project timelines. Vizient is a Rock Island Arsenal certified robot integrator, and a FANUC authorized system integrator.

Electrical Engineers for Automation Solutions

Tri-City Electric

www.tricityelectric.com

One of Tri-City Electric's areas of expertise is automation and control systems. Capabilities/expertise include: Design & functional specification; Machine/Process control upgrades; Project engineering & management; Allen-Bradley, Siemens, GE, Wago; Variable frequency drives; Motion/Servo Control; DC drives; Motor starter control; Ethernet, wireless Ethernet, ControlNet, DeviceNet, Remote I/O, DH+, Profibus; Control system documentation; and Operator/Maintenance training.

Educational Institutions

Eastern Iowa Community Colleges (EICC) — Engineering Technology, Associate in Applied Science Degree

www.eicc.edu/future-students/our-programs/engineering/

EICC's Engineering Technology program trains students in the practical application and implementation of existing technology used in the manufacturing world. Engineering Technology is available at all three EICC colleges: Clinton, Muscatine, and Scott Community Colleges. Students have the choice of specializing in four different areas: Automation, Electro/Mechanical, Process Control or Renewable Energy. This is a great option for upskilling current workers or hiring new graduates who understand the importance of automation and robotics within your manufacturing environment.

Western Illinois University (WIU) — Mechanical Engineering Degree

www.wiu.edu/academics/majors/business_and_technology/mechanical-engineering.php

Nationally, 20% of all engineers are mechanical engineers, but can and do work in virtually all areas of human design and manufacturing. The most prevalent areas of specialization are: automotive systems; combustion and propulsion; design of machinery; **robotics; automation;** dynamic systems and controls; energy systems and thermodynamics; fluid mechanics; heat transfer; manufacturing and production; materials behavior and processing; bioengineering; and microscale and nanoscale sensors and systems. The Mechanical Engineering degree is offered at the Macomb and Quad Cities campuses.

Industry Organizations

Advanced Robotics for Manufacturing Institute (ARM) Institute

www.arminstitute.org

A resource for manufacturers of any size to utilize, ARM focuses on empowering manufacturers and providing them with the proper information on how technology can assist their company. ARM also helps on the front of educating manufacturing employees on robotics/automation usage as well as works toward overall workforce development. It is the first nationwide initiative of its kind to bring together leadership and expertise from academia, research, industry, government, and nonprofits in a collaborative effort to help revitalize American manufacturing.

Appendix

Glossary: Key Robotics and Automation Terms

All definitions from Robots.com for educational purposes.

- Actuator** – A piece of equipment that allows a robot to move by conversion of different energy types such as electrical or mechanical processes using liquid or air.
- Assembly Robot** – A robot designed specifically for mating, fitting, or otherwise assembling various parts or components into completed products. Primarily used for grasping parts and mating or fitting them together, such as in assembly line production.
- Axis** – The point that something such as a tool rotates around. The number of axes a robot has varies, but the majority of industrial robots are 4-axis or 6-axis.
- Base** – The stable platform to which an industrial robotic arm is attached.
- Cartesian Robot/Manipulator** – A Cartesian Manipulator is a robot arm with prismatic joints, which allows movement along one or more of the three- axes in the x, y, z coordinate system.
- Control Device** – An instrument that allows a person to have control over a robot or automated system for times such as startup or an emergency.
- Degrees of Freedom** – The amount of values in a system possible of variation. A robotic joint is equal to one degree of freedom.
- Drive** – A speed (gear) reducer to convert high speed low torque to low speed high torque
- Drive Power** – Actuators convert this source of energy into usable energy for the robot's movement.
- Dynamics** – Analysis of the causes of motion by the sources of forces and energy.

Emergency Stop – The operation of a circuit using hardware-based components that overrides all other robot controls, removes drive power from the robot actuators, and causes all moving parts to stop.

Enabling Device – A manually operated device which when continuously activated, permits motion. Releasing the device shall stop robot motion and motion of associated equipment that may present a hazard.

End-Effector – An accessory device or tool specifically designed for attachment to the robot wrist or tool mounting plate to enable the robot to perform its intended task. (Examples may include gripper, spot weld gun, arc weld gun, spray point gun, or any other application tools.)

Error – The difference between the actual response of a robot and a command issued.

Error Function – A number is chosen to stand for a discrepancy in the actual value and the desired value for a dependent variable.

Feedback – A signal from the robot equipment about conditions as they actually exist, rather than as the computer has directed them to exist.

Flexibility – The diverse jobs that a robot is capable of executing.

Gripper – An end effector that is designed for seizing and holding (ISO 8373), and "grips" or grabs an object. It is attached to the last link of the arm. It may hold an object using several different methods, such as: applying pressure between its "fingers", or may use magnetization or vacuum to hold the object, etc.

Hazardous Motion – Unintended/unexpected robot motion that may cause injury.

Home Position – A known and fixed location on the basic coordinate axis of the manipulator where it comes to rest, or to an indicated zero position for each axis. This position is unique for each model of manipulator.

Integrate – To fit together different subsystems, such as robots and other automation devices, or at least different versions of subsystems in the same control shell.

Integrator – A company that combines and coordinates separate parts or elements into a unified whole using mechanical means.

Joint – A part of the manipulator system, which allows a rotation and/or translational degree of freedom of a link of end-effector.

Joint Space – The area and coordinate system the joints of the robot consume.

Kinematics – The relationship between the motion of the endpoint of a robot and the motion of the joints.

Limiting Device – A separate apparatus that places a restriction on the maximum envelope. This restriction occurs by terminating motion of the robot.

Link – A rigid part of a manipulator, which connects adjacent joints.

Manipulator – A machine or robotic mechanism of which usually consists of a series of segments jointed or sliding relative to one another, for the purpose of grasping and/or moving objects (pieces or tools) usually in several degrees of freedom. The control of the manipulator may be by an operator, a programmable electronic controller, or any logic system (for example cam device, wired, etc.)

Motion Axis – The line defining the axis of motion either linear or rotary, of a segment of a manipulator.

Normalize – The process of relating factors into similar magnitudes by scaling.

Off-Line Programming – A way to store procedure information for a robot on a computer to be used in the future.

On-Line Programming – A means of programming a robot while the robot is functioning. This becomes important in manufacturing and assembly line production due to keeping productivity high while the robot is being programmed for other tasks.

Operator – This person begins and ends processes the robot performs while observing to ensure proper procedures are occurring.

Pendant – A hand-held input device linked to the control system with which a robot can be programmed or moved. This enables the human operator to stand in the most favorable position to observe, control, and record the desired movements in the robot's memory.

Pick and Place Robot – A type of robot that moves parts from one place to another.

Point-To-Point – The user specifies points for the robot to follow along the path. The movement is point to point as opposed to a continuous motion.

Presence-Sensing Safeguarding Device – A device designed, constructed, and installed to create a sensing field to detect an intrusion into such field by people, robots, or objects.

Programmable Logic Controller (PLC) – A solid-state control system, which has a user programmable memory for storage of instructions to implement specific functions such as: I/O control logic, timing, counting arithmetic, and data manipulation. A PLC consists of a central processor, input/output interface, memory, and programming device, which typically uses relay equivalent symbols. The PLC is purposely designed as an industrial control system, which may perform functions equivalent to a relay panel or a wired solid-state logic control system, and may be integrated into the robot control system.

Reach – The distance from the center of the robot to the fullest extension of the robotic arm. The work envelope is determined from this distance.

Reliability – A measure of the robot's end-effector's ability to perform similar operations multiple times based on similar operating conditions.

Repeatability – The variability of the end-effector's position and orientation as the robot makes the same moves under the same conditions (load, temp, etc.)

Remanufacture – To upgrade or modify robots to the revised specifications of the manufacturer.

Robot – A piece of equipment with the capability to be programmed to perform quick and accurate operations multiple times.

SCARA Robot – A type of robot consisting of two concurrent joints that rotate and meet certain needs within the same plane.

Sensor – A device that responds to physical stimuli (such as heat, light, sound, pressure, magnetism, motion, etc.) and transmits the resulting signal or data for providing a measurement, operating a control, or both.

Simulation – A graphical computer program that represents the robot and its environment, which emulates the robot's behavior during a simulated run of the robot. This is used to determine a robot's behavior in certain situations, before actually commanding the robot to perform such tasks.

Singularity – A point in the robot's movement where the joints become redundant.

Teach – To program a manipulator arm by manually guiding it through a series of motions and recording the position in the robot controller memory for playback.

Tool – A term used loosely to define a working apparatus mounted to the end of the robot arm, such as a hand, gripper, welding torch, screw driver, etc. See Arm, Gripper, and End-Effector.

Work Envelope – The set of all points which a manipulator can reach without intrusion. Sometimes the shape of the work space, and the position of the manipulator itself can restrict the work envelope.

Wrist – The end-effector is connected to this joint on the manipulator arm.

Yaw – Rotation of the end-effector in a horizontal plane around the end of the manipulator arm. Side to side motion at an axis.