The new hire: How a new generation of robots is transforming manufacturing

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Executive summary: The R generation

Industrial robots are on the verge of revolutionizing manufacturing. As they become smarter, faster and cheaper, they're being called upon to do more—well beyond traditional repetitive, onerous or even dangerous tasks such as welding and materials handling. They're taking on more "human" capabilities and traits such as sensing, dexterity, memory, trainability, and object recognition. As a result, they're taking on more jobs—such as picking and packaging, testing or inspecting products, or assembling minute electronics. In addition, a new generation of "collaborative" robots ushers in an era shepherding robots out of their cages and literally hand-in-hand with human workers who train them through physical demonstration. As costs of advanced robotics continue to fall (from several hundreds of thousands of dollars now to tens of thousands) and applications widen, industries beyond automotive—such as food and beverage—are adding them to their ranks. One major robotics company refers to its new-generation robot as an "intelligent industrial work assistant."

Presently, there are estimated 1.5 million robots toiling away globally, with about 230,000 in the US alone. Global shipments hit about 180,000 in 2013, an all-time high, with 200,000 forecasted for 2014, estimates the International Federation of Robots (IFR).[1,2] Robots have also caught the eyes of investors, such as recent high-profile pure-play robotics investments by Google and Amazon. According to PwC/NVCA MoneyTree Report based on data from Thomson Reuters, US venture capital investment in robotics technology has surged in the last couple of years.

This maturing "R generation" holds myriad implications for the future of manufacturing. Wider adoption of robots comes at a time when manufacturers—both big and small—are under increasing pressures to squeeze even greater productivity from their workforces and when wage arbitrage seems less attractive in some locales, such as China, as it was a decade ago for US manufacturers. Broader adoption of robots may even help to spur greater reshoring of manufacturing from overseas back to the US—or closer to the US market, such as in Mexico.

And, for small and medium-sized companies, a question is arising sooner than most probably expected: "Is now the time to hire some automated help?" That question isn't being prompted only as a result of increased affordability. The nascent age of "nearly human" robots is driving greater efficiencies, and holds promise to reduce labor force injuries. It's already showing signals of changing how the industrial workforce is composed—and even the very nature of industrial jobs as we now know them. Manufacturers are also finding that being competitive means injecting greater flexibility into their production in order to satisfy consumer demand for products with shorter life cycles and a greater variety of products or variants of existing products, and are tapping robots to help on this front as well.

All this opens new options, choices and paths for manufacturers. Can robots take on labor in ways that frees up and makes better use of human resources and unleashes innovation? Are there ways robots can be applied in applications that a current workforce is unable to carry out (such as those of high precision or force) which will open new opportunities of faster and greater production of existing products—or, perhaps more important, enable altogether new product development? Are robots an economically viable and realistic solution to the increasing difficulty of securing a sustainable manufacturing workforce? If robots displace employees, are there plans in place to move those employees to other tasks—preferably more interesting and attractive to them and more valuable to the company?

To get a better grasp on how US manufacturers are enlisting robots in their production lines—and future plans—PwC carried out a survey of 120 manufacturers.[3] We found that while the majority of respondents have already adopted robotics technology, there still exists real barriers for those which have yet to do so, citing limitations such as cost, the lack of perceived need, and expertise and skills needed to properly exploit them. Highlights from that survey include:

- 59% of manufacturers are currently using some sort of robotics technology
- 28% believe that replacement of workers will be the biggest impact of robots on the US manufacturing workforce in the next 3–5 years
- 35% believe the biggest impact will be the creation of new job opportunities to engineer advanced robots and robotic operating systems
- 27% listed "not having a need" as the biggest limitation for not adopting robotics in the next 3–5 years.

1 "Outlook on World Robotics 2014," IFR, June 4, 2014.
2 "Global robotics industry: Record beats record," IFR statistical department press release, June 4, 2014.
3 Disruptive Manufacturing Innovations Survey, PwC and Zpryme, 2014.

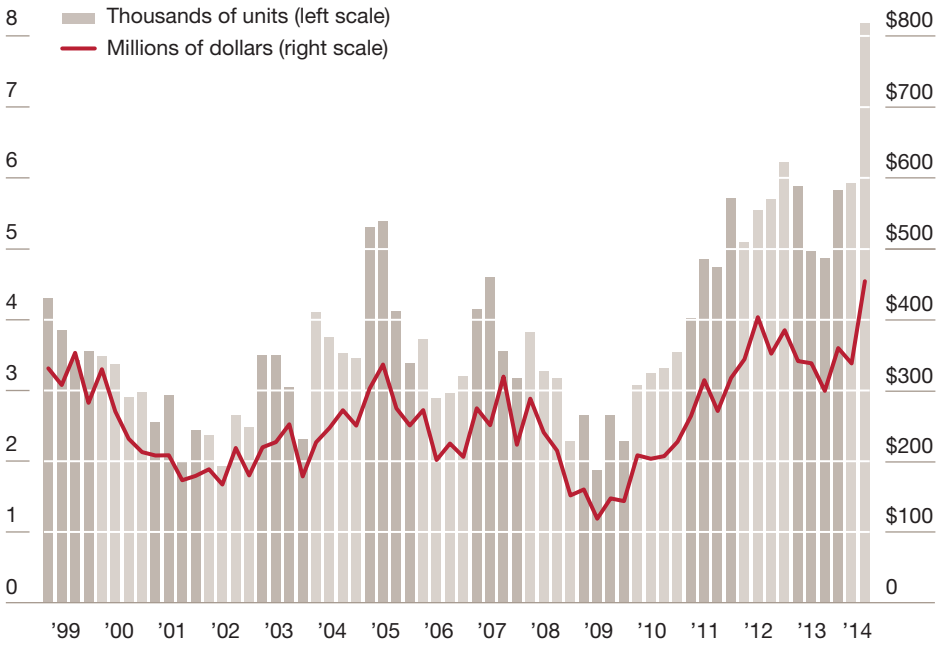
I. The rise of robots

Post-recession robot generation boom?

The last several years have seen a sharp resurgence in orders of industrial robots, roughly tripling in the wake of the Great Recession, with annual orders in North America surpassing 20,000 units from 2011–2013, and a surge so far in the first half of 2014, according to the Robotic Industries Association (see chart).[4] Five countries (US, China, Japan, Korea and Germany) accounted for some 70% of all global shipments in 2013 (see chart). The global robotic systems market (including software peripherals and other related costs) was estimated at $26 billion in 2012, according to IFR and the global industrial robot market is estimated to reach $41 billion by 2020, according to Allied Market Research.[5,6]

North American industrial robot orders (RIA)

Quarterly, 1999–2014



Source: Robotic Industries Association.

Gripping investors

A flurry of investor activity has accompanied the rise in adoption of robots by manufacturers, piquing the interest of manufacturers of all stripes and, interestingly, firms outside traditional industrial manufacturing. Consider Google's dive—an acquisition of at least eight robotics companies since 2013, including Boston Dynamics, Redwood Robotics, Industrial Perception and Schaft Inc.[7] In 2012, Amazon demonstrated its commitment to using robotics for warehousing operations through its acquisition of Kiva Systems for $775 million. The online retailer plans to roll out 10,000 Kiva robots into a network of warehouses by the end of 2015, a move that could realize fulfilment cost-savings by up to $900 million—or up to 40% savings on cost per order (on picking, packing and shipping), according to an analysis published on Robohub.org.[8,9]

Estimated yearly shipments of multipurpose industrial robots

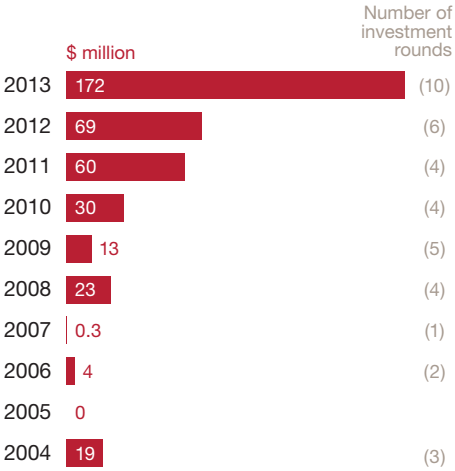
Number of units

	Japan	China	United States	Korea	Germany	Other
2011	27,894	22,577	20,555	25,536	19,533	50,316
2012	28,680	22,987	22,414	19,424	17,528	48,313
2013	25,110	36,560	23,679	21,307	18,297	54,179

Source: "World Robotics 2013 Industrial Robots," International Federation of Robotics 2013.
2013 figures provided to PwC from IFR Statistical Department.

4 "Record Year for Robots, healthier year for manufacturing", mhlnews.com, August 1, 2014.
5 "Industrial Robotics Market Is Expected to Reach $41.17 Billion, Globally, by 2020," Allied Market Research company press release, May 28, 2014.
6 "World Robotics 2013 Industrial Robots," International Federation of Robotics 2013.
7 "Google and robots: The real reasons behind the shopping spree)," Conner Forrest, March 5, 2014, techrepublic.com.
8 "Bezos expects 10,000 robots at Amazon warehouses by 2015," *The Seattle Times,* May 21, 2014.
9 Shawn Milne and Michael Carroll, "Forget the Octocopter, let's talk about Kiva," robohub.org, December 10, 2013.

US venture capital investments in robotics technology companies



Source: PwC/NVCA MoneyTree Report based on data from Thomson Reuters.

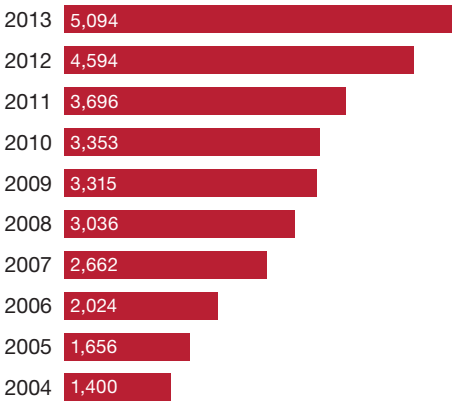
In Europe, euRobotics (comprising the European Commission and 180 companies and research groups) created a robotics research program called SPARC, to kindle a regional robotics hub, with investments of €700 million from the EC and €2.1 billion from euRobotics. The program is expected to create 240,000 jobs and lift Europe's market in robotics by about €4 billion per year.[10]

Venture capital investments in robotics technology start-ups are up, too. According to PwC/NVCA MoneyTree Report based on data from Thomson Reuters (which tracks VC investment in the US), capital investments by US venture capital firms rose to about $172 million (in 10 investment rounds) in 2013, nearly tripling 2011 levels (see chart). This rise is an especially meaningful signal that robotics industry could see an accelerated development as these VC-backed companies grow. It provides a window into the future as to what this investment community believes will be a promising (and profitable) sector.

Robotics patent race?

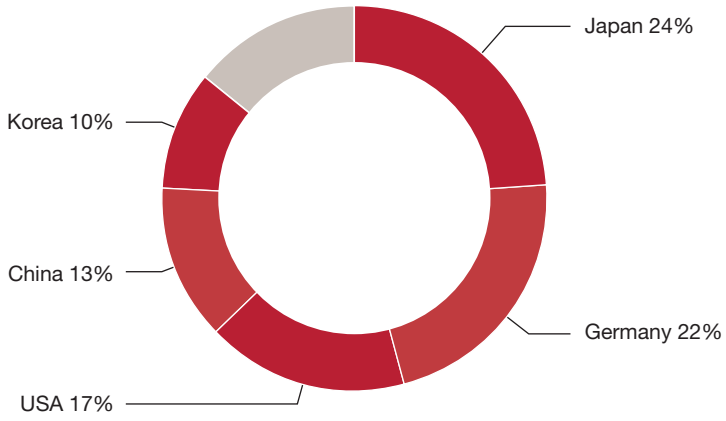
Patents for robotics and autonomous systems have swelled in the last decade as well, with double-digit year-on-year jumps in the last three years. According to a report published by the UK Intellectual Property Office, the number of global published patents for these technologies passed 5,000, the highest level ever, in 2013, up from 1,400 in 2004 (see chart). That translates into about 9% of all global patents across all technologies.[11] Japan, Germany and the US account for most of the patents (see chart).

Total number of published patents for robotics and autonomous systems



Source: "Eight Great Technologies Robotics and Autonomous Systems," UK Intellectual Property Office, June 2014 (figures supplied to PwC by Peter Keefe, Patent Informatics Analyst UK Intellectual Property Office).

Applicant country distribution of published patents for robotics and autonomous systems, 2004–2013



Source: "Eight Great Technologies Robotics and Autonomous Systems," UK Intellectual Property Office, June 2014 (figures supplied to PwC by Peter Keefe, Patent Informatics Analyst UK Intellectual Property Office).

10 "EU launches world's largest civilian robotics programme—240,000 new jobs expected," European Commission website, March 6, 2014.

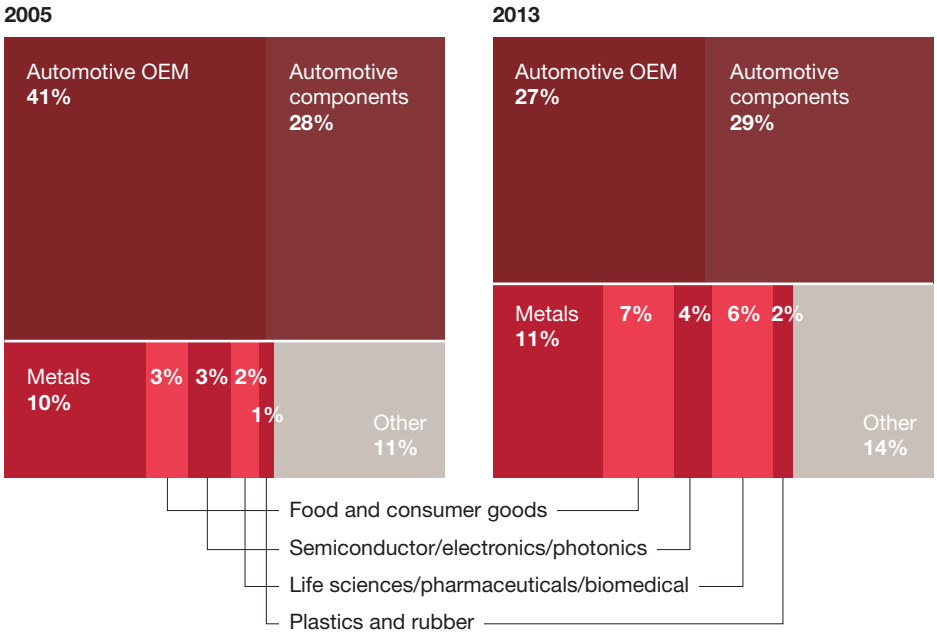
11 "Eight Great Technologies Robotics and Autonomous Systems." UK Intellectual Property Office, June 2014.

II. Landing new jobs … in new industries

Beyond automotive: making inroads across manufacturing sectors

For decades, advanced industrial robotics have been chiefly pioneered and deployed by the automotive industry, particularly Japanese carmakers such as Toyota, followed closely in their wake by European and North American counterparts. Indeed, in 2005, 69% of all industrial robot orders in North America were made by automotive OEMs (original equipment manufacturers) to automotive components companies, according to data from the Robotic Industries Association. By 2014, that figure had eroded to 56% (see chart), offset by increasing shares by other industries including the food and beverage, consumer goods, life sciences/pharmaceutical/biomedical and metals industries. "We have received orders from tier-one and tier-two suppliers to the automotive industry, but we are attracting interest from other industries such as the plastics, medical devices, food and beverage and high-tech industries," said Jim Lawton, CMO of Boston-based Rethink Robotics (maker of the Baxter collaborative robot) in an interview with PwC. Still, there is much room for growth in the non-automotive sectors. The "robot density" (robots per 10,000 employees) in the automotive industry in the US in 2013 is more than 10 times higher than that in general industry (1,091 vs. 76), according to IFR.[12]

Industrial robot orders in North America by industry, % of all



Source: Robotic Industries Association.

An expanding job description

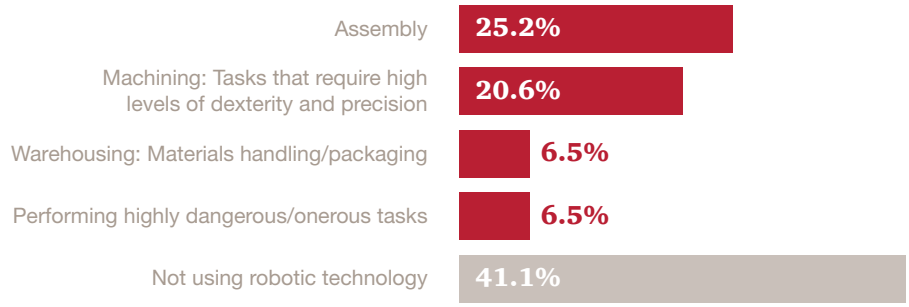
Industrial robots are most commonly used to carry out onerous, dangerous, repetitive or tedious tasks, with common applications including materials handling (e.g., tasks associated with machine tending or plastic molding) or robotic welding (e.g., arc welding operations). A PwC survey of US manufacturers found the most common task was assembly (25%) followed by machining (21%), with the least common tasks being warehousing and performing dangerous tasks (both 6.5%) (see chart).

But enabling technologies are making robots smarter at a rapid clip: these include greater computing power, sensor technology to enable vision recognition, more sophisticated sound and movement detection and tactile, force and torque control sensing (giving robots the ability, for example, to sense when they are bumped and "give" to prevent hurting humans or sense when a human in nearby). Advances in artificial intelligence software, too, are enabling greater autonomy—to make decisions based on new situations in unstructured environments (as on a factory line or in a warehouse) as opposed to performing in one repetitive task while fixed and sequestered in a cell, or cage.

12 IFR World Robotics 2013.

How manufacturers are using robots

Q. If you are using robotic technology, what is its primary application?



Number of respondents: 107.
Source: PwC and Zpryme survey and analysis, "2014 Disruptive Manufacturing Innovations Survey," conducted in February 2014.

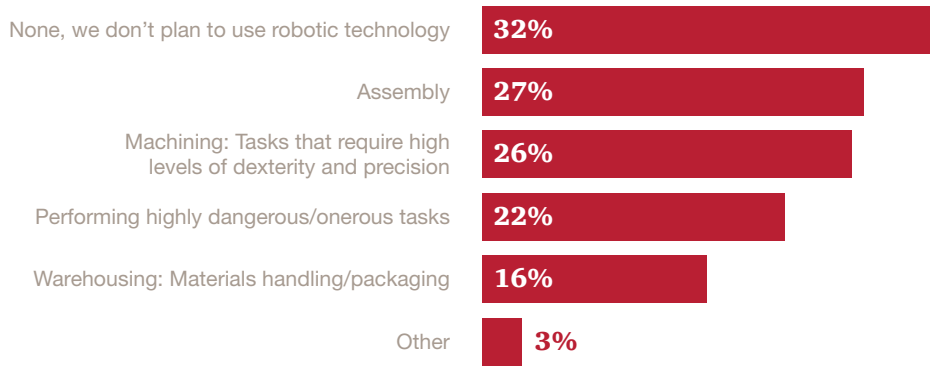
Planned investments in robots for assembly, machining

According to a PwC survey of US manufacturers, the areas that respondents plan to invest most in robotics technology were assembly (27%), followed by machining (26%) and performing dangerous tasks (22%) (see chart). When asked about what limitations will keep them from investing in robotics technology in the next three years, respondents cited the top reasons were that it was "not cost effective" (26%) and that they did not see a need for it (27%).

These advances are leading to a wider range of capability and applications. Robots are being enlisted to carry out tasks including transportation of materials or supplies, picking and packaging, product testing and inspection. They're also increasingly being deployed to work on products or components that are too tiny for humans to efficiently manipulate, such as micro-electro-mechanical systems (including micro sensors, motors or nozzles), a market that, by 2017, is estimated to hit $21 billion.[13] "Robots are doing more than fast automated tasks for the automotive industry," said Jeff Burnstein, president of the Robotic Industries Association, in an interview with PwC. "They're moving into other areas like filling, packaging, palletizing and loading. The next-gen robot is anthropomorphizing and moving out of the factories and warehouses to do new things. They're already performing in hospitals, and are working side-by-side with people," Burnstein added.

Banking on bots

Q. Looking ahead to the next 3 years, in which areas do you expect to make the highest capital investments in robotic technology? (Check all that apply.)



Number of respondents: 107.
Source: PwC and Zpryme survey and analysis, "2014 Disruptive Manufacturing Innovations Survey," conducted in February 2014.

13 "MEMS will continue to see steady, sustainable double digit growth for the next six years" says Yole Development" Yole Développement press release, July 4, 2012.

III. People and robots: Creating a new kind of manufacturing workforce

As legions of robots and other automation technologies wend their ways into not only production facilities and distribution centers—but also through supply chains—companies will grapple with the commingling of human and machine. Manufacturers could be looking at an awkward period of systemic human-resource change as they introduce robots to more varied manufacturing tasks and as they call for greater human-machine collaboration. Manufacturers will also prepare for the implications of displacing human workers with robots through so-called "botsourcing." Consider a recent study by University of Oxford which estimates that nearly half (47%) of U.S. employees are in jobs that could be at risk of being displaced by computerized technology.[14] As robotics become more pervasive on factory floors, employers and employees will need to manage not only the benefits but also the human-resource challenges that their rise will likely prompt.

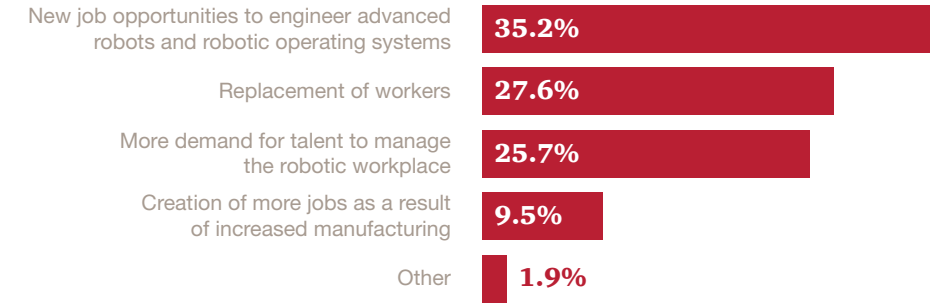
Jobs maker…or jobs taker?

Robots are being brought on lines to do work that's undesirable or dangerous, or that they can perform better (with greater precision, strength or stamina) than humans. But could a greater robotic workforce actually drive a need for more human talent to train, repair and minister to that growing robotic workforce? Not to mention the talent needed to develop the burgeoning robotic technology industry itself?

According to a PwC survey of US manufacturers, over one-third of manufacturers said that the biggest impact robots will have on the manufacturing workforce in the next three years is that they will lead to "new job opportunities to engineer advanced robots and robotic operating systems." And about one in four felt the biggest impact would be "more demand for

The robot effect on workforces

Q. What will be the biggest impact of robots on the US manufacturing workforce in the next 3–5 years?

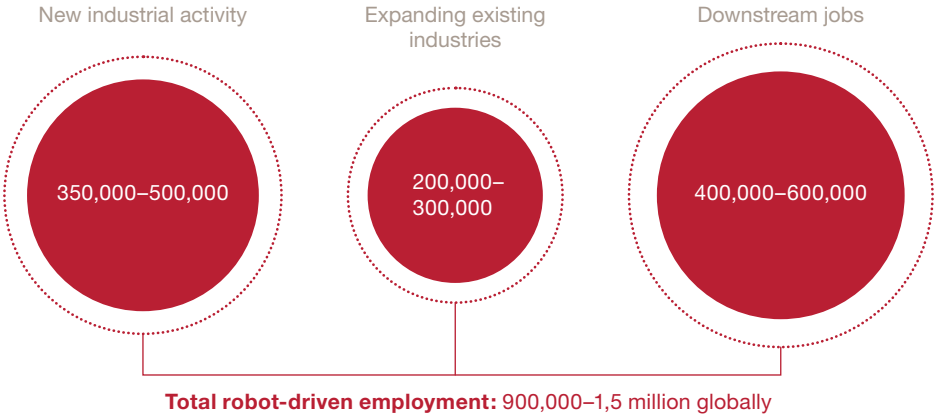


Number of respondents: 105.

Source: PwC and Zpryme survey and analysis, "2014 Disruptive Manufacturing Innovations Survey," conducted in February 2014.

1.5 million robot-driven jobs in next 2 years?

Potential global job creation, 2012–2016



Source: "Positive Impact of Industrial Robots", January 2013, International Federation of Robots.

14 "The Future of Employment: How Susceptible are Jobs to Computerization?," Carl Benedikt Frey and Michael A. Osborne, University of Oxford, September 17, 2013.

talent to manage the robotic workplace." Equally important is that 27% of manufacturers said the biggest impact would be "replacement of workers."

"The conventional thinking is that companies are buying robots to replace people. It's not that simple. In many cases, companies are using robots so they can expand and improve product quality and increase production. They end up hiring more people such as engineers or sales staff to support that growth," said Greg Selke, CEO of ONEXia, Inc., a Philadelphia-based provider of automation hardware and software to manufacturers. "One of our clients is an electronics company that needed a robot to apply epoxy on very small parts—the robot justified that functionality as the task would be very difficult for a human to accomplish. It had nothing to do with firing people," added Selke.

Consider electric auto-maker Tesla, now the largest auto-industry employer in California (employing more than 6,000 with plans to add another 500 by the end of 2014) but also renowned for its cutting-edge automation. The company deploys at least 160 robots to help produce its Model S—chipping in to install batteries, cabling components and to bend and form aluminum. The company is targeting production of 500,000 vehicles a year by 2020 and is mulling opening a factory (to mass produce car batteries) which would employ an additional 6,500 workers.[15, 16]

While in Tesla's case, automation has helped fuel overall growth which has, in turn, been followed by additional hiring, other companies could well find that the adding of robotics (and subsequent growth through automation) does not necessarily lead to increased hiring. Indeed, the effects of robotics on workforces are many and varied.

Botsourcing: an emotional thing

Deploying robotics is not only a functional or operational issue for companies and their employees. It can also be an emotional one. How best to keep morale up among human workers and to nurture professional mobility and avoid consternation amongst a workforce looking over its shoulder in fear of losing jobs to new robotic hires? Consider a recent Harvard study which explored German, British and Chinese workers' response to different conditions surrounding being replaced by a robot. It concluded that workers were more concerned over being botsourced (displaced by a robot) when their jobs are described as requiring more emotion than cognition. It also found that workers of different nationalities tend to define cognitive-oriented and emotion-oriented jobs differently.[17]

Robot-driven employment?

There is also speculation that robots could actually stimulate employment of humans—through not only their manufacturing, but also the talent needed to program, train, maintain and repair them. According to one study, global "robot-driven" job creation could reach 1.5 million through 2016 (see chart).[18] However, it is important to note that while new robotics-related job growth is likely, it is also likely that robot-linked job losses will also accompany that growth and that the net jobs growth as a product of robotics technologies will likely differ from company to company and sector to sector.

Robotics-intensive sectors: more skilled workers, higher wages

As companies continue to embrace robotics and other types of automation and grow more data-driven, their success will largely hinge on shaping and building a workforce that can best exploit such technological advancements. To do that, manufacturers are feeling a growing need to pull from a wider—and deeper—pool of talent. According to a PwC analysis based on U.S. Bureau of Labor Statistics, the most robotics-intensive manufacturing sectors in the US as a proportion of the total workforce—i.e., automotive, electronics and metals—employ about 20% more mechanical and industrial engineers than do less robotics-intensive manufacturing sectors. They also happen to pay higher wages than other manufacturing sectors. These industries also employ a higher proportion (nearly twice) of installation maintenance and repair workers, than do other

15 "Tesla edges out Toyota as California's top auto employer," *Bloomberg BusinessWeek,* May 17, 2014.
16 "Peek inside Tesla's Robotic Factory," *Wired,* July 16, 2013.
17 Waytz, Adam, and Michael I. Norton. "Botsourcing and Outsourcing: Robot, British, Chinese, and German Workers Are for Thinking—Not Feeling—Jobs." Emotion 14, no. 2 (April 2014): 434–444.
18 "Positive Impact of Industrial Robots," January 2013, International Federation of Robots.

manufacturing sectors, partially due to their need to program, operate and service robots. Interestingly, these sectors also tend to have a higher proportion of production-line workers—and these workers earn higher wages than sectors that are less robotics-intensive. However, engineers at the most robotics-intensive manufacturing sectors earn slightly less than engineers employed by the overall manufacturing industry (see chart).

Human and robot collaboration

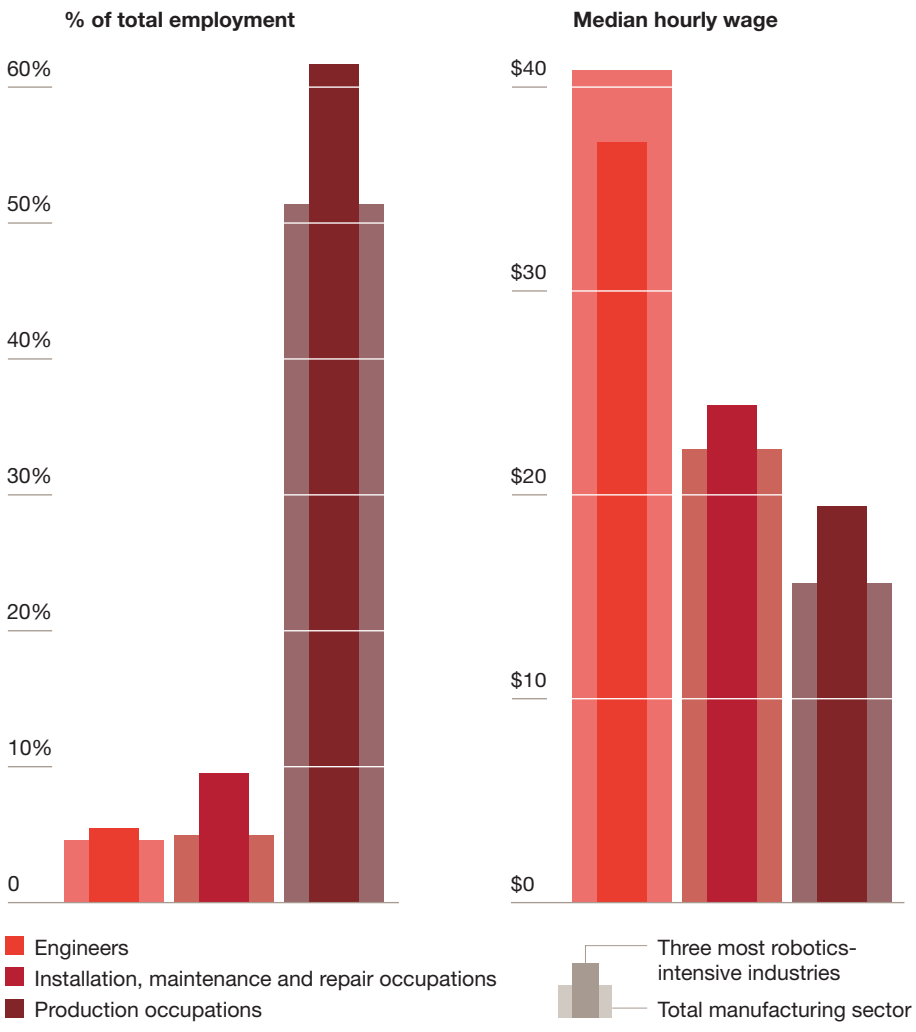
As manufacturers adopt a new generation of robots designed not only to be safe around humans but also to actually work collaboratively with humans, a new relationship will emerge between man and machine, with robots as *bona fide* co-workers and assistants—not just high-tech tools sequestered behind glass.

The entry of the collaborative robot (or so-called "co-bot") on the factory floors, assembly lines and distribution centers is already underway. Plug-and-play robots, such as the newest generations of Universal's UR5 and UR10 are designed to work next to people in warehouses and small businesses, doing tasks such as sorting packages, operating CNC machines or applying glue in an automotive factory. They're designed to be safe around people; they can slow their speed when a human enters their work space, then speed up after the human leaves.[19]

Rethink Robotics' Baxter, a humanoid-looking robot with a torso, two arms and even a screen with a face that shows facial expressions (e.g., of concentration, confusion or satisfaction) lets factory workers guide its arm through a task and program the activity through physical

Robotics, talent and wages: A connection?

Occupation and wages in robotics-intensive industries (automotive, electronics and metals) compared to all manufacturing sectors in US, as of May 2013



Sources: U.S. Bureau of Labor Statistics and PwC analysis.

19 "Universal robots show 3rd generation UR5, UR10 industrial robots," *Robotics Business Review,* June 24, 2014.

example, rather through programming. It can learn—through relatively fast physical demonstration—simple, repetitive tasks like picking up parts off a conveyor or packing and unpacking boxes. This saves time and costs on complex set-ups which can take weeks or even months, depending on the task, with traditional industrial robots. Ease of trainability of the next generation of robots will likely be useful especially for small and medium-sized enterprises which need to toggle between different products and produce in small batches.

Getting closer to humans

The newer generation of co-bots is also lowering the barrier to entry for smaller companies with limited capital and expertise to program, calibrate and set-up traditional industrial robots. "What we're really talking about for the end-goal is for the human and the robot to move a heavy part together in a safe way," said Dr. S.K. Gupta, Professor, Department of Mechanical Engineering and Institute for Systems Research, University of Maryland, in an interview with PwC. "We are really close—I think within two years—from getting robots to genuinely and commonly take part in physical collaboration… Not just the dirty dangerous or hard tasks in structured environments, but say, for example, mix batch injection molding where a specific part is removed, cleaned, inspected and placed into a container," Gupta added.

Getting humans and robots to work more closely will likely come about as robotics developers continue to incorporate human characteristics in robotics systems. University of British Columbia researchers, for example, programmed a robot that uses human-like non-verbal communication cues and body language (e.g., head, neck and eye movements) to improve communication with humans. They found that movements such as eye gaze as a cue made a robot's handing over of a water bottle to a human more fluid.[20]

A blended approach

Robots are good at precision, for example to polish a part. But even polishing can require human touch or human perception. So, there are ways in which it makes sense for robots and humans to work on the same application, added Gupta, with each taking on sub-routines of a multiple-task job. "There are many instances in the final steps of assembly of a product that could require precise alignment, for example, bringing a part into place which takes a lot of dexterity and precision. You could break a large task into sub-tasks that bring into play human-robot collaboration. In these ways, instead of two humans working together, you could have one human and one or two robots working in a hybrid approach," Gupta said.

20 "Eye of the beholder: Improving the human-robot connection," University of British Columbia, ScienceDaily.com, April 11, 2014.

IV. Robots: A path to flexibility and greater competitiveness?

For decades, robotics and other forms of automation have delivered on the promises of speed, efficiency, productivity. But how will a widespread adoption of advanced robotics deliver on flexibility and adaptability to fast-changing customer needs—and on rising expectations for developing new products faster. Or, how will they help manufacturers produce variants and customization of existing products dictated both by varying geographical preferences and needs and even by the individual (the so-called "lot of one")?

Can robots help reshape manufacturers' operational footprint? As companies program or train their robotic fleets to perform more and more applications in one plant, what is the potential for a company to transfer that knowledge to robotic cohorts in another plant—even one on a different continent? Such machine-to-machine knowledge sharing could well make it easier for companies to switch production from one locale to another, or from the production of one product to another without the considerable investments in talent, training, set-up time and related costs. "Perhaps most exciting for the future of cloud computing in robotics is when one robot can impart something it perceives or learns instantaneously to other robots. This sharing could have a catalytic effect on the capabilities of robots, particularly in unstructured environments." said Dr. S.K. Gupta Professor, Department of Mechanical Engineering and Institute for Systems Research University of Maryland in an interview with PwC.

Could robotics, then, contribute to the beginning of an end to wage arbitrage? Going forward, the role of robots in a company's changing or expanding operational footprint could be significant, as companies rethink the viability and attractiveness of offshoring carried out to great extent in the last several decades. Robots could relieve pressure on companies to contend with rising wages, currency fluctuations and volatile transportation, logistics and trade-related costs. China, for example, which ordered more robots in 2013 than any other country (some 37,000), is ramping up automation in response to higher labor costs, availability of skilled labor and higher expectations and demand for higher-quality products.

Robots and manufacturing closer to the end-market

What role could robots play in making it easier for companies to manufacture closer to their end-markets? Merchant House International, Ltd., a Hong Kong based footwear maker, opened a factory in Jefferson City, Tennessee in 2013, to get closer to its end-market of US consumers, instead of having leather shipped to China only to have footwear produced from that leather shipped back to the US. The company's US plant is more automated than the company's plants in Asia, employing robots to "rough" leather before gluing to soles.[20] "It costs the same to buy the same robot in China or the US, so, for US companies selling to the US market, customizing to consumers' choice or preferences is a solid reason to bring manufacturing back to the US," said Scott Paul, President of the Alliance for American Manufacturing, in an interview with PwC. "With automation technology, it makes it easier to be closer to the customer and perform better for that local customer. Whichever economy uses and exploits robots and automation the best will have a distinct global advantage. For competitive reasons, this is no time for US manufacturers to shy away from this technology," Paul added. Part of the math that will go into offshoring or reshoring, then, may more importantly figure robotics costs into their total costs. Some collaborative robots, for example, cost roughly one-half of a human worker's salary in the US, or about three times that of a Chinese manufacturing salary, Paul noted.

"You have to use technology in any way you can to stay competitive, to reduce overall cost, to increase quality and productivity. There are companies that will tell you that the only reason they came back to the US is because of the automation. And I think this is a trend we'll see persist in the future."

—Jeff Burnstein, President, Robotic Industries Association

20 Hagerty, James R., "Shoemaking gets a foot in the door in the US", *The Wall Street Journal,* July 14, 2014.

Robots: helping manufacturers customize, innovate

The entry of faster, smarter robots is coming at a time when companies—from aerospace and defense to medical devices to consumer products—are under increasing pressure to respond quickly to customer preferences and expectations and as products' life cycles shorten. Faster set-up times and increasing applications will enable robots to play a greater role in companies following through with the mandate of customization. "For companies that are using robotics well, I look at companies that are both highly automated and those that can be flexible enough to quickly and cheaply change set-up to fabrications of different variations on the same product. That's the factory of the future. Some will be more customized than others, but most all plants will need to adapt to making different products quicker," said Scott Paul of Alliance for American Manufacturing.

"In some cases, robotics has been mis-deployed and has made it hard for companies to innovate continuously. When twelve-year old girls buy red nail polish one month but blue is the rave next month, how do manufacturers respond quickly to that change in consumer demand?"

—Jim Lawton, CMO, Rethink Robotics

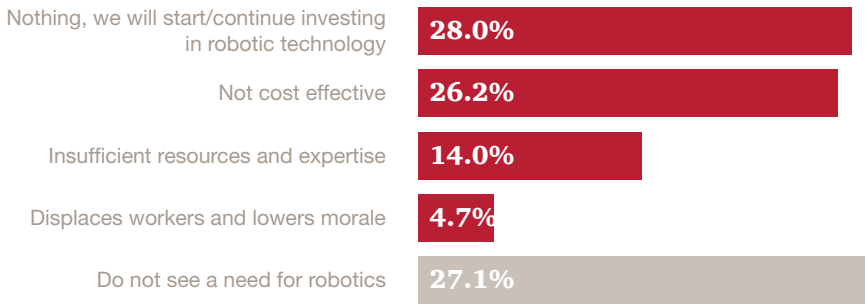
V. Barriers to widespread adoption: Cost, user-friendliness

Despite strong momentum surrounding the development and adoption of robotic technology described in this report, there nevertheless still exists resistance to their use holding back widespread adoption. Much of this resistance seems to be tied to cost, expertise and a lack of understanding of how they could produce an attractive return on their investment—both up front and ongoing through maintenance and programming of new tasks. According to our survey of US manufacturers, some 41% of companies surveyed do not currently use advanced robotics technology. Top reasons for limiting investment in robotics technology in the next three years include: "they are not cost effective" and "see no need" (see chart).

According to Greg Selke, CEO of ONExia, the total cost of a robotics system (in the hundreds of thousands of dollars) is approximately three times the cost of the robot itself, when figuring in software, controller, technical help, set-up and work cell, etc., and can take weeks or months to install, surround with a cage and program. "But prices are coming down, and programming can be less cumbersome, Selke said in an interview with PwC. "In the last three or four years we've seen sales get much stronger with robots, but the rise is largely attributed to large companies," added Selke. "The smaller companies are still struggling with their adoption and are slower to adopt new technologies. The cost of entry is somewhat high, and they have trouble making the leap either because of staff or because of the cost. But the new breed of robots will make it easier for them to find ways to innovate and compete. Even at $35,000 a collaborative robot, it's a compelling argument to buy one even if you're a very small operation—it can work 24-hours a day," Selke said.

Limits to robotics adoption

Q. Looking ahead to the next 3 years, what would limit your future investment in robotic technology?



Number of respondents: 107.

Source: PwC and Zpryme survey and analysis, "2014 Disruptive Manufacturing Innovations Survey," conducted in February 2014.

Small and medium-sized manufacturers will likely need robotics that can accommodate smaller production runs and more frequent set-ups and re-programming of their robotic workers to adapt quickly for production of new products or variants of existing ones. Bigger growth in robot adoption, then, will likely come when robots can easily produce in small lots situations. Programming a robot can take hours for small specialty batches of product. Most small and medium-sized enterprises will need cheaper and more easily programmable robots to make that happen.

"Robots get dirty and might fail and people cannot stop what they're doing on the factory floor to fix the problem or call a company help desk or technician to resolve the issue. The new robots will really need to be ones that are easy to use—as easy almost as a robotic vacuum cleaner. You won't need to learn how to use it. It doesn't make sense for an expert human welder to write code to program a robot—he or she needs to spend the time teaching the robot through physical demonstration—which we call "learning from demonstration."

—SK Gupta, Professor, Department of Mechanical Engineering and Institute for Systems Research University of Maryland

VI. Robot-ready? A self-assessment of whether robots are for you

Certainly, manufacturers are approaching robotics in many and varied ways, and assessing the degree of need and spotting the "right" application differs across industries and from manufacturing plant to manufacturing plant. As companies—especially small and mid-sized enterprises—look for new and viable ways to integrate robotics and automation into their operations, robots are becoming a stronger factor in manufacturing competitiveness globally.

A few questions companies might ask themselves as a sort of "robot-ready self-assessment" include:

- Have you audited your manufacturing processes and identified repetitive, onerous or dangerous tasks done by humans that could be carried out by robots?
- Have you explored what sorts of gains in productivity, efficiency and waste reduction could be achieved by deploying robots in your operations?
- Are there manufacturing processes that require high precision and dexterity for which you find it difficult to secure human talent to perform?
- Have you assessed what a possible return on investment and cost-benefit analysis robotics would bring (comparing initial and ongoing cost of robotics system, and expected useful life span of that system) versus cost of relying on human labor?
- Does your company have the talent to exploit robotics technology to the fullest (e.g., train, repair, clean, de-bug, program for quick set-up)?
- Is your workforce prepared to integrate robotics into their workspace and be able to offload some of their responsibilities to a machine? Are they prepared to explore other work that relies on their experience, perception and judgment and less upon their physical skills?
- Have you assessed how applying robotics technology could help you shift production more easily to a new geographical location, or to reshore back to the US?
- Is your company prepared to graduate workers displaced by robots to higher skill-level tasks/jobs?
- Have you assessed the potential savings on health care costs and the effect on the wellness and morale of your workforce by using robots to relieve tedious or potentially deleterious tasks?
- What useful life are you expecting for your robotics technology?
- How can robotics contribute to your firm spending more time on innovating (new product development, improvements in production strategies) and less time on labor- and human resource-related issues and costs?
- How can robotics technology add to your company's flexibility (i.e., ability to customize products, unleash innovation for new product development, replicate manufacturing more easily from one facility to another)?

About Zpryme Research Survey

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