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# Automation, robotics, and the factory of the future

By Jonathan Tilley

Cheaper, more capable, and more flexible technologies are accelerating the growth of fully automated production facilities. The key challenge for companies will be deciding how best to harness their power.

**A**t one Fanuc plant in Oshino, Japan, industrial robots produce industrial robots, supervised by a staff of only four workers per shift. In a Philips plant producing electric razors in the Netherlands, robots outnumber the nine production workers by more than 14 to 1. Camera maker Canon began phasing out human labor at several of its factories in 2013.

This “lights out” production concept—where manufacturing activities and material flows are handled entirely automatically—is becoming an increasingly common attribute of modern manufacturing. In part, the new wave of automation will be driven by the same things that first brought robotics and automation into the workplace: to free human workers from dirty, dull, or dangerous jobs; to improve quality by eliminating errors and reducing variability; and to cut manufacturing costs by replacing increasingly expensive people with ever-cheaper machines. Today’s most advanced automation systems have additional capabilities, however, enabling their use in environments that have not been suitable for automation up to now and allowing the capture of entirely new sources of value in manufacturing.

## Falling robot prices

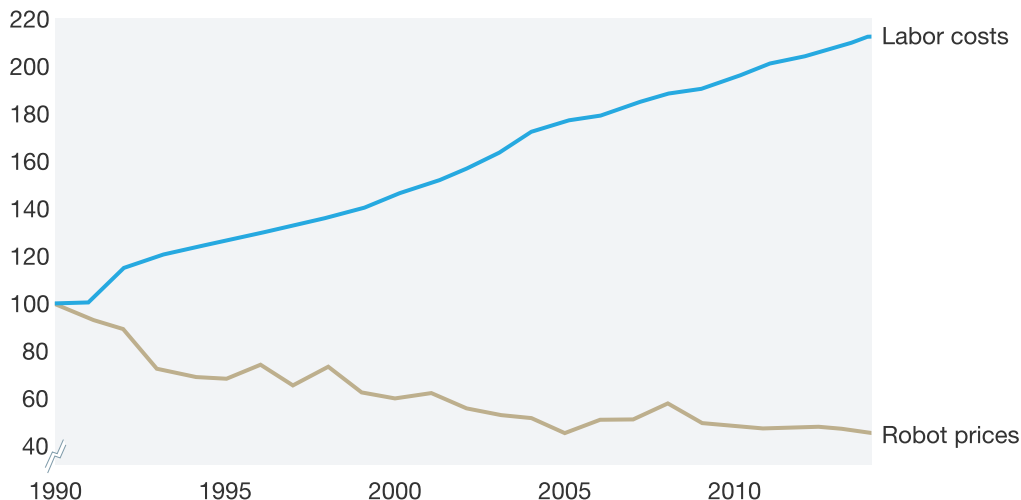
As robot production has increased, costs have gone down. Over the past 30 years, the average robot price has fallen by half in real terms, and even further relative to labor costs (Exhibit 1). As demand from emerging economies encourages the production of robots to shift to lower-cost regions, they are likely to become cheaper still.

## Exhibit 1

### Robot prices have fallen in comparison with labor costs.

#### Cost of automation

Index of average robot prices and labor compensation in manufacturing in United States, 1990 = 100%



Source: Economist Intelligence Unit; IMB; Institut für Arbeitsmarkt- und Berufsforschung; International Robot Federation; US Social Security data; McKinsey analysis

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## Accessible talent

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 manufacture. The

availability of software, such as simulation packages and offline programming systems that can test robotic applications, has reduced engineering time and risk. It's also made the task of programming robots easier and cheaper.

## Ease of integration

Advances in computing power, software-development techniques, and networking technologies have made assembling, installing, and maintaining robots faster and less costly than before. For example, while sensors and actuators once had to be individually connected to robot controllers with dedicated wiring through terminal racks, connectors, and junction boxes, they now use plug-and-play technologies in which components can be connected using simpler network wiring. The components will identify themselves automatically to the control system, greatly reducing setup time. These 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. Other standards and network technologies make it similarly straightforward to link robots to wider production systems.

## New capabilities

Robots are getting smarter, too. Where early robots blindly followed the same path, and later iterations used lasers or vision systems to detect the orientation of parts and materials, the latest generations of robots can integrate information from multiple sensors and adapt their movements in real time. This allows them, for example, to use force feedback to mimic the skill of a craftsman in grinding, deburring, or polishing applications. They can also make use of more powerful computer technology and big data-style analysis. For instance, they can use spectral analysis to check the quality of a weld as it is being made, dramatically reducing the amount of postmanufacture inspection required.

## Robots take on new roles

Today, these factors are helping to boost robot adoption in the kinds of application they already excel at today: repetitive, high-volume production activities. As the cost and complexity of automating tasks with robots goes down, it is likely that the kinds of companies already using robots will use even more of them. In the next five to ten years, however, we expect a more fundamental change in the kinds of tasks for which robots become both technically and economically viable (Exhibit 2). Here are some examples.

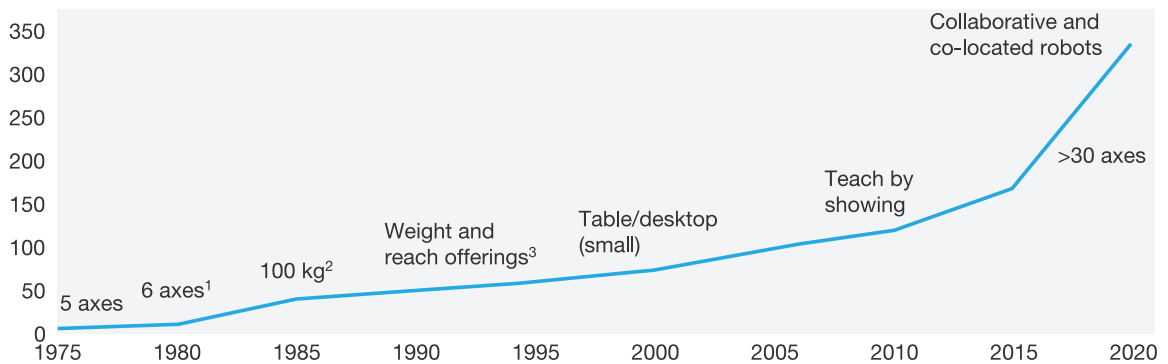
**Exhibit 2**

The increasing variety, size range, and capabilities of robots have driven market growth.

Growth of robots on the market

ILLUSTRATIVE

Base quantity SKUs



Number of axes	5	6 to 8	12	21	27	32
Capacity, kg	6	60	90	>120		1,000
Maximum reach, meters	1		2			3

<sup>1</sup>Allows arc welding, adhesives dispensing, machine loading.

<sup>2</sup>Spot welding, materials handling.

<sup>3</sup>All application areas; right size for the task.

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## Low-volume production

The inherent flexibility of a device that can be programmed quickly and easily will greatly reduce the number of times a robot needs to repeat a given task to justify the cost of buying and commissioning it. This will lower the threshold of volume and make

robots an economical choice for niche tasks, where annual volumes are measured in the tens or hundreds rather than in the thousands or hundreds of thousands. It will also make them viable for companies working with small batch sizes and significant product variety. For example, flex track products now used in aerospace can “crawl” on a fuselage using vision to direct their work. The cost savings offered by this kind of low-volume automation 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.

Emerging technologies are likely to simplify robot programming even further. While it is already common to teach robots by leading them through a series of movements, for example, rapidly improving voice-recognition technology means it may soon be possible to give them verbal instructions, too.

## Highly variable tasks

Advances in artificial intelligence and sensor technologies will allow robots to cope with a far greater degree of task-to-task variability. The ability to adapt their actions in response to changes in their environment will create opportunities for automation in areas such as the processing of agricultural products, where there is significant part-to-part variability. In Japan, trials have already demonstrated that robots can cut the time required to harvest strawberries by up to 40 percent, using a stereoscopic imaging system to identify the location of fruit and evaluate its ripeness.

These same capabilities will also drive quality improvements in all sectors. Robots will be able to compensate for potential quality issues during manufacturing. Examples here include altering the force used to assemble two parts based on the dimensional differences between them, or selecting and combining different sized components to achieve the right final dimensions.

Robot-generated data, and the advanced analysis techniques to make better use of them, will also be useful in understanding the underlying drivers of quality. If higher-than-normal torque requirements during assembly turn out to be associated with premature product failures in the field, for example, manufacturing processes can be adapted to detect and fix such issues during production.

## Complex tasks

While today's general-purpose robots can control their movement to within 0.10 millimeters, some current configurations of robots have repeatable accuracy of 0.02 millimeters. Future generations are likely to offer even higher levels of precision. Such capabilities will allow them to participate in increasingly delicate tasks, such as threading needles or assembling highly sophisticated electronic devices. Robots are also becoming better coordinated, with the availability of controllers that can simultaneously drive dozens of axes, allowing multiple robots to work together on the same task.

Finally, advanced sensor technologies, and the computer power needed to analyze the data from those sensors, will allow robots to take on tasks like cutting gemstones that previously required highly skilled craftspeople. The same technologies may even permit activities that cannot be done at all today: for example, adjusting the thickness or composition of coatings in real time as they are applied to compensate for deviations in the underlying material, or "painting" electronic circuits on the surface of structures.

## Working alongside people

Companies will also have far more freedom to decide which tasks to automate with robots and which to conduct manually. Advanced safety systems mean robots can take up new positions next to their human colleagues. If sensors indicate the risk of a collision with an operator, the robot will automatically slow down or alter its path to avoid it. This technology permits the use of robots for individual tasks on otherwise manual assembly lines. And the removal of safety fences and interlocks mean lower costs—a boon for smaller companies. The ability to put robots and people side by side and to reallocate tasks between them also helps productivity, since it allows companies to rebalance production lines as demand fluctuates.

Robots that can operate safely in proximity to people will also pave the way for applications away from the tightly controlled environment of the factory floor. Internet retailers and logistics companies are already adopting forms of robotic automation in their warehouses. Imagine the productivity benefits available to a parcel courier, though, if an onboard robot could presort packages in the delivery vehicle between drops.

## Agile production systems

Automation systems are becoming increasingly flexible and intelligent, adapting their behavior automatically to maximize output or minimize cost per unit. Expert systems used in beverage filling and packing lines can automatically adjust the speed of the whole production line to suit whichever activity is the critical constraint for a given batch. In automotive production, expert systems can automatically make tiny adjustments in line speed to improve the overall balance of individual lines and maximize the effectiveness of the whole manufacturing system.

While the vast majority of robots in use today still operate in high-speed, high-volume production applications, the most advanced systems can make adjustments on the fly, switching seamlessly between product types without the need to stop the line to change programs or reconfigure tooling. Many current and emerging production technologies, from computerized-numerical-control (CNC) cutting to 3-D printing, allow component geometry to be adjusted without any need for tool changes, making it possible to produce in batch sizes of one. One manufacturer of industrial components, for example, uses real-time communication from radio-frequency identification (RFID) tags to adjust components' shapes to suit the requirements of different models.

The replacement of fixed conveyor systems with automated guided vehicles (AGVs) even lets plants reconfigure the flow of products and components seamlessly between different workstations, allowing manufacturing sequences with entirely different process steps to be completed in a fully automated fashion. This kind of flexibility delivers a host of benefits: facilitating shorter lead times and a tighter link between supply and demand, accelerating new product introduction, and simplifying the manufacture of highly customized products.

## Making the right automation decisions

With so much technological potential at their fingertips, how do companies decide on the best automation strategy? It can be all too easy to get carried away with automation for its own sake, but the result of this approach is almost always projects that cost too much, take too long to implement, and fail to deliver against their business objectives.

A successful automation strategy requires good decisions on multiple levels. Companies must choose which activities to automate, what level of automation to use (from simple programmable-logic controllers to highly sophisticated robots guided by sensors and smart adaptive algorithms), and which technologies to adopt. At each of these levels, companies should ensure that their plans meet the following criteria.

***Automation strategy must align with business and operations strategy.*** As we have noted above, automation can achieve four key objectives: improving worker safety, reducing costs, improving quality, and increasing flexibility. Done well, automation may deliver improvements in all these areas, but the balance of benefits may vary with different technologies and approaches. The right balance for any organization will depend on its overall operations strategy and its business goals.

***Automation programs must start with a clear articulation of the problem.*** It's also important that this includes the reasons automation is the right solution. Every project should be able to identify where and how automation can offer improvements and show how these improvements link to the company's overall strategy.

***Automation must show a clear return on investment.*** Companies, especially large ones, should take care not to overspecify, overcomplicate, or overspend on their automation investments. Choosing the right level of complexity to meet current and foreseeable future needs requires a deep understanding of the organization's processes and manufacturing systems.

## Platforming and integration

Companies face increasing pressure to maximize the return on their capital investments and to reduce the time required to take new products from design to full-scale production. Building automation systems that are suitable only for a single line of products runs counter to both those aims, requiring repeated, lengthy, and expensive cycles of equipment design, procurement, and commissioning. A better approach is the use of production systems, cells, lines, and factories that can be easily modified and adapted.

Just as platforming and modularization strategies have simplified and reduced the cost of managing complex product portfolios, so a platform approach will become increasingly important for manufacturers seeking to maximize flexibility and economies of scale in their automation strategies.



Process platforms, such as a robot arm equipped with a weld gun, power supply, and control electronics, can be standardized, applied, and reused in multiple applications, simplifying programming, maintenance, and product support.

Automation systems will also need to be highly integrated into the organization's other systems. That integration starts with communication between machines on the factory floor, something that is made more straightforward by modern industrial-networking technologies. But it should also extend into the wider organization. Direct integration with computer-aided design, computer-integrated engineering, and enterprise-resource-planning systems will accelerate the design and deployment of new manufacturing configurations and allow flexible systems to respond in near real time to changes in demand or material availability. Data on process variables and manufacturing performance flowing the other way will be recorded for quality-assurance purposes and used to inform design improvements and future product generations.

Integration will also extend beyond the walls of the plant. Companies won't just require close collaboration and seamless exchange of information with customers and suppliers; they will also need to build such relationships with the manufacturers of processing equipment, who will increasingly hold much of the know-how and intellectual property required to make automation systems perform optimally. The technology required to permit this integration is becoming increasingly accessible, thanks to the availability of open architectures and networking protocols, but changes in culture, management processes, and mind-sets will be needed in order to balance the costs, benefits, and risks.

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Cheaper, smarter, and more adaptable automation systems are already transforming manufacturing in a host of different ways. While the technology will become more straightforward to implement, the business decisions will not. To capture the full value of the opportunities presented by these new systems, companies will need to take a holistic and systematic approach, aligning their automation strategy closely with the current and future needs of the business.

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*About the author(s)*

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