



Sensors as drivers of Industry 4.0

A study on Germany, Switzerland and Austria



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Industry 4.0

Smart sensors are the drivers of Industry 4.0 and the Internet of Things (IoT) in factories and workplaces. Once implemented at scale, the combination of sophisticated sensors and increased computational power will enable new ways to analyze data and gain actionable insights to improve many areas of operations. The result will be responsive and agile production processes that ensure and enhance performance across a range of industrial sectors.

When looking at the use of those types of technologies and the overall level of integration of digital skills, Germany and Austria are slightly above the EU average, while Switzerland is a front runner within Europe and globally in fields such as connectivity and digital integration. However, across the Germany, Switzerland, Austria (GSA) region, there remains significant potential for the impact of sensors on company performance, primarily through cost savings, but also via the development of new business models and practices, and ensuing revenue growth. Indeed, companies in the region need to seize the opportunities provided by sensor technologies in order not to be left behind by their peers in the United States, China and elsewhere, or to experience their long-entrenched business models being disrupted by newcomers that do make full use of Industry 4.0 and the IoT. Surviving and prospering in the coming era will require significant investment both in the technologies themselves and, equally importantly, in the people who can extract value from those technologies.

Cost savings

The impact of sensors on company performance, both today and in the coming years, will be primarily through cost savings. We analyze four ways in which companies stand to attain cost savings through implementing sensor technologies:

- ▶ **Increasing production flexibility and worker responsiveness:** Smart sensors can make a clear contribution to production flexibility by optimizing the use of Just-in-Time processes. The challenge is to ensure that those people in operational positions are able to move quickly enough to respond to the information that they are receiving.

- ▶ **Reducing equipment downtime through predictive maintenance:** The well-integrated use of smart sensor technology, which is now at the point where the data collected can enable equipment to be self-monitoring and self-calibrating, is able to improve system reliability while reducing installation, configuration and maintenance costs.
- ▶ **Improving quality control and reducing waste:** The ability to reduce waste during manufacturing means that industries in which waste is very prevalent have the potential to benefit most. It will also be possible, as part of the quality control process, to reduce the number of non-compliant products. Companies may also consider making data from smart sensors available to regulators, to demonstrate that they are in compliance with regulations throughout the manufacturing process.
- ▶ **Improving understanding of cost structures:** Increasing a company's understanding of the factors affecting unit profit and loss during production is among the biggest opportunities associated with sensors and IoT. Sensors provide the potential to understand the profit and loss associated with each unit sold, with the results of real-time data collection helping to optimize energy and materials consumption.

Beyond cost savings: Transforming businesses

Beyond the implementation of specific tasks, sensors can allow for quicker responses to consumer feedback and order modifications, helping to make it more profitable for a company to produce smaller numbers of customized products. In addition, the combination of smart sensors with artificial intelligence that is a central aspect of Industry 4.0 means that sensors can be self-testing, monitoring and improving their own performance, and so reducing the instances of corrupted data. Optimal industrial processes will increasingly involve sensors that warn that they are becoming damaged before a failure occurs. ▶

Early adoption of smart sensor technology has been concentrated on improving the manufacturing process of existing products. But the ultimate revolution associated with Industry 4.0 lies not simply in cost savings through optimizing the production process, but with new business models, services and individualized products. Such new products are likely to be developed first through customization and subsequently through the conjunction of smart sensor data and data analytics to enable companies to offer a combination of high precision, high reliability, and high volume. In addition, data collected by sensors will help to create new services linked to the use of particular products.

Over time, divergent corporate performance is likely to be driven in part by companies' assessments of how sensors can impact performance, and the speed and scale at which companies decide to implement sensors.

New roles for employees

Many companies invest a lot of money in new technologies for their factories. Yet they also need to consider what the impact will be on their workers in terms of the need for new training. A company is also likely to need to expand its existing skills base through the hiring of external talent. Employees will need to have a flexible outlook, engage in active learning, and have high cognitive abilities and be literate when it comes to digital technologies. Examples of new types of jobs include robot coordinators, industrial data scientists, supply chain coordinators, and simulation experts, along with digitally-assisted service engineers.

Smart sensors are not very expensive. It is more expensive to employ the data scientists to work on the data gathered by the sensors. A byproduct of the automation that sensors allow, the above new job roles will be focused on 'making sense' of the data and communicating it. The result will be more interaction and integration between departments and along the value chain, and less-siloed thinking as the data and analytics will motivate increased collaboration.

Skills that allow people to 'get inside' the data and extract value will become a critical resource. Individuals who are successful in this new terrain of extracting and communicating insights produced by data can be seen as bridge builders within firms.

— Quantifying the impact

Our quantification of the impact of sensors over the period to 2030 compares nine sectors: Industrial products and machinery, consumer goods and electronics, ICT, automotive, construction, real estate, chemicals, logistics, and power and utilities.

EY model suggests that the improvement in profitability from sensor adoption by companies in GSA will be significant in the coming years, across a range of sectors. Under the best-case 'high implementation' scenario, the EBITDA margin could increase by 11%-34%, depending on the sector. While it will be unlikely for such an ambitious level of adoption to be attained by 2030, even under a more moderate rate of adoption the likely EBITDA impact could be substantial.

Automotive and ICT are the two sectors that are likely to see the biggest impact in terms of boost to EBITDA, followed by industrial products and machinery. Both automotive and ICT have margins of 12%-13% at present, and both sectors could see 2030 operating margins of 15%-17% under a 'high implementation' scenario. In these and other sectors, the challenge facing corporate leadership teams in the coming years will be how to transform their companies to make such increases in profitability possible. —

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Foreword

Looking ahead to how the implementation of sensors can help companies, the fundamental question is: *Who will be owning the data and the information being generated by sensors - the provider of the sensor and data processing infrastructure or the users that are generating the data?* If companies get access to, or even ownership of, user-generated data by providing the infrastructure, then they will certainly have a competitive advantage. They can develop additional services and gain early insights into client demands. There will be significant entry barriers into such ecosystems, however. Clients and companies are reluctant to share “their” data, although this is already happening on the consumer side, for example in passenger vehicles or from most Apps that are given access to information on consumers’ smart phones.

Digital sensors can help to increase revenue growth because companies can sell insights. They can build the sensor infrastructure into a product and sell access to the information generated from the sensor data. That could include benchmarks or hints for optimal parameter settings. Details about the current equipment or product condition can also be of high value to customers. For example, heavy production equipment currently needs to be shut down for inspections. By using sensor data provided by the equipment manufacturers, operators could turn to flexible inspection intervals.

As more sensors are built into products, they can predict demand for replacements or consumables, thus enabling more agile responses in the value chain. You can expect a disruptive reallocation of after-market service and parts supply structures across all sectors. Additional, lower-cost sensors will enrich the information gathering process significantly and predictive analytics will help the switch to a proactive way of running equipment and processes.

Sensors can also be used to shift costs from time-based to condition-based monitoring. That could be an interesting topic for technical inspection of cars or real estate infrastructure such as elevators. Using sensor data for online monitoring can dramatically reduce downtime, improve safety and boost efficiency. —



Martin Neuhold, Leader EY GSA Supply Chain & Operations

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The state of play in Germany, Switzerland and Austria

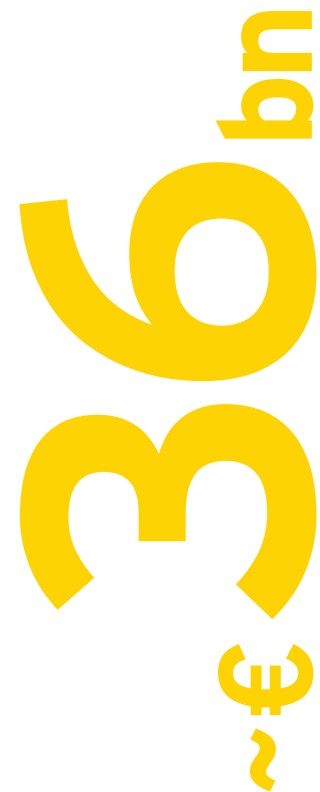
The term Industry 4.0 refers to the introduction of internet-connected technologies (meaning internet protocols and software methodology as well as software, sensors, and actuators connected to networks) within an industrial context.¹ When correctly implemented, the combination of the increased availability of sophisticated sensors with the transmission capacity available via the internet of things (IoT), backed by increasing computational power, will enable a new level of data resolution and new ways to synthesize and analyze data that companies can use to improve many areas of operations.² The result will be responsive and agile production processes that ensure and enhance performance across a range of industrial sectors.

Germany, Switzerland, and Austria (GSA) are putting significant resources into digitalization efforts that will enable industrial sectors to benefit from the opportunities offered by Industry 4.0 technologies. When looking at the use of those types of technologies and the overall level of integration of digital skills, Germany and Austria are slightly above the EU average, while Switzerland is a front runner within Europe and globally in fields such as connectivity and digital integration.³ The IoT market in the GSA region has a total value of around 36 billion euros. Germany, as the largest national economy in the region, accounts for the lion's share, 24 billion euros. The Swiss market is worth 7.6 billion

euros; in Austria, total spending on the IoT currently amounts to 4.2 billion euros.⁴ According to the German Federal Ministry for Economic Affairs and Energy, Industry 4.0 encompasses the entire life cycle of a product, from the initial concept to manufacturing, maintenance and, eventually, recycling.⁵

Germany

The term Industry 4.0 was coined in Germany in 2011, where implementation of Industry 4.0 is seen as a strategic initiative that can entrench Germany's leading position in mechanical engineering, automation, process, IT, electrical or systems engineering and expand its position in technological innovation and manufacturing.⁶ The emphasis is driven by growing competition from the United States and, increasingly, from China.⁷ Japan and South Korea are also leaders in this space. For example, though it is seen as lagging behind Germany in terms



Total value of the IoT market in the GSA region

Smart manufacturing in Germany

Bauer et al conducted a survey of 385 applications of smart manufacturing in Germany (70% of which were in a production-line setting. Most were found to be in services, design and logistics. Machine operators were the key human stakeholder in these applications (42% of cases) followed by service technicians (27% of cases). Around two-thirds of applications were motivated by the need to solve a problem (eg, deal with increasing complexity or higher time pressure), whereas a third were intended to increase the competitive strength of the firm (eg, by increasing flexibility or efficiency). Interestingly, only 11% of cases involved sensor technology, suggesting significant room for growth when it comes to sensors. It is also worth noting that only 19% of cases are intended to substitute technology for labor; the rest are intended to be collaborative and complementary to labor.

Source: Bauer, W., et al (2018), „Digitalization of industry value chains: A review and evaluation of existing use cases of industry 4.0 in Germany“, *Scientific Journal of Logistics* 14:3

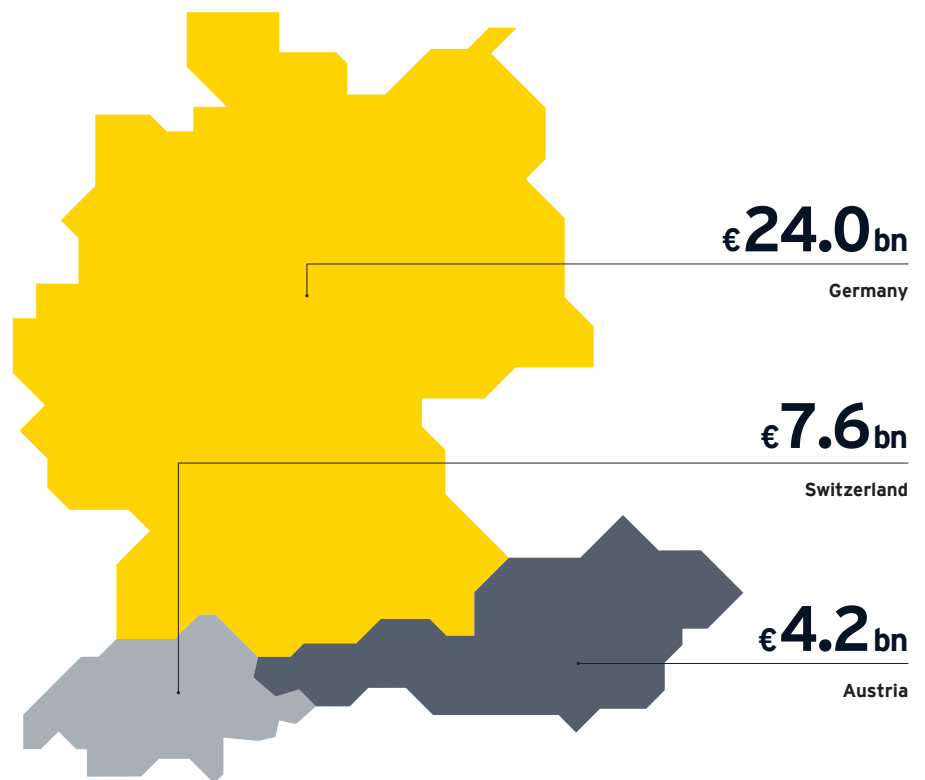
of smart manufacturing implementation, Japan is implementing the Industrial Value Chain Initiative, which aims to unite manufacturing and digital technologies.⁸ South Korea is also behind GSA states when it comes to Industry 4.0 competitiveness.⁹ Yet its top ranking¹⁰ when it comes to innovation means that it is likely to catch up quickly. South Korea is aiming for nationwide deployment of 5G networks by 2021. This will enable Samsung to become an Internet Information and Communications Technology (ICT) network provider and create an innovative backbone for the IoT that will outperform GSA by years.

Seeing Industry 4.0 as a unifying framework, German industry plans to invest 40 billion euros annually into Industry 4.0 initiatives by 2020.¹¹ Priority has been given to the Mittelstand for support in the transition to digitalization.¹² Germany now boasts 7.6 robots per thousand industrial workers, significantly more than the European average of 2.7.¹³ However, some researchers contend that 54% of German companies do not use any technology to gather data with the aim of enhancing production processes.¹⁴ German firms have also been described as not fully exploiting the potential offered by the smart sensors and other infrastructure equipment that underpins Industry 4.0.

Many companies are missing opportunities related to the provision of services around the digital ecosystems that are being created.¹⁵

In Germany, cooperation between the public and private sectors is at the core of the Industry 4.0 effort, and this is serving as an example to other countries, including Switzerland and Austria. ▶

Value of the IoT market in the GSA region



1 MDPI, *Requirements of the Smart Factory System: A Survey and Perspective*, June 1, 2018

2 IEEE *Industrial Electronics Magazine*, *Industrie 4.0: Hit or Hype*, June 2014

3 EY, *What if employment as we know it today disappears tomorrow?*

4 EY, *Digitalisierung in der Telekommunikation*

5 BMWI, *Digitale Transformation in der Industrie*

6 European Commission, *Germany: Industrie 4.0*, January 2017

7 Bloomberg, *Embattled German Industrials Pursue the Factory of the Future*, June 8, 2017

8 iv-i.org

9 *Technological Forecasting and Social Change, Industry 4.0: A Korea perspective*, November 2017

10 Bloomberg, *These Are the World's Most Innovative Countries*, January 22, 2019

11 BMWI, *Industrie 4.0*, accessed December 7, 2018

12 UNIDO, *What can policymakers learn from Germany's Industrie 4.0 development strategy?*, 2018

13 Dauth, Wolfgang, et al. "German Robots - The Impact of Industrial Robots on Workers." *Institute for Employment Research*, September 14, 2017

14 UNIDO, *What can policymakers learn from Germany's Industrie 4.0 development strategy?*, 2018

15 UNIDO, *What can policymakers learn from Germany's Industrie 4.0 development strategy?*, 2018

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Switzerland

Switzerland is currently the most digitally advanced among GSA countries. It lags only behind Scandinavia in terms of ICT infrastructure and its use within the economy, and only behind Japan in digital connectivity. Switzerland is also integrating new technologies faster than any other country in Europe. Swiss industry has been particularly active in using digital technologies to increase production efficiency and create the necessary front-end tools to more seamlessly interact with customers.

However, the Swiss government has been less active in efforts to promote Industry 4.0 and has invested less in digitizing its own services. As a result, Switzerland has relatively limited electronic interaction between businesses and the public sector. While the government provides funding streams for Industry 4.0 technologies, it has not yet brought together public and private sector executives to discuss appropriate policy responses. This could slow development of the country's technological infrastructure.¹⁶ If efforts are not improved in this area, the gap with the leading EU countries is likely to widen as other governments invest more heavily. Nevertheless, Switzerland has a solid base in automation to build on.¹⁷

ST Microelectronics

For example, ST Microelectronics, based in Geneva, is a world-leading supplier of sensors for industrial applications. In particular, these are used for early fault detection and predictive maintenance, especially to monitor and analyze vibration, temperature, pressure and sound.

Source: STMicroelectronics (2019), "MEMS and Sensors".

Austria

In Austria, the Ministry of Transport, Innovation and Technology has encouraged digitalization for companies. The government also has programs that support SMEs.¹⁸ Germany is Austria's main trading partner, accounting for more than 35% of imports and almost 30% of exports; these numbers will tie Austria's performance to Germany's future digital infrastructure. Vienna and the surrounding regions in Lower Austria will undoubtedly be the biggest beneficiaries of Industry 4.0.¹⁹

Opel's use of the Internet of Things

The Vienna operations of Opel GmbH are discussed in a 2016 study by Monostori et al as experimenting with IoT to better anticipate production-line failures. The maintenance of machine tools in the production process is the focus of the study, with sensor-based technology incorporated with historical datasets and computer models to optimize anticipatory maintenance of machine tools. The plant currently specializes in production of transmissions. It is also the site of Opel's first usage of automated factory vehicles to move parts between the warehouse and the factory floor.

Source: Linde Material Handling (2019), "Opel goes for automation", Linde Magazine.

However, access to high-speed broadband remains below EU and OECD averages, and well below the levels in Switzerland and Germany, restricting possible growth for services related to Industry 4.0.²⁰

16 EY, *What if employment as we know it today disappears tomorrow?*

17 EY, *What if employment as we know it today disappears tomorrow?*

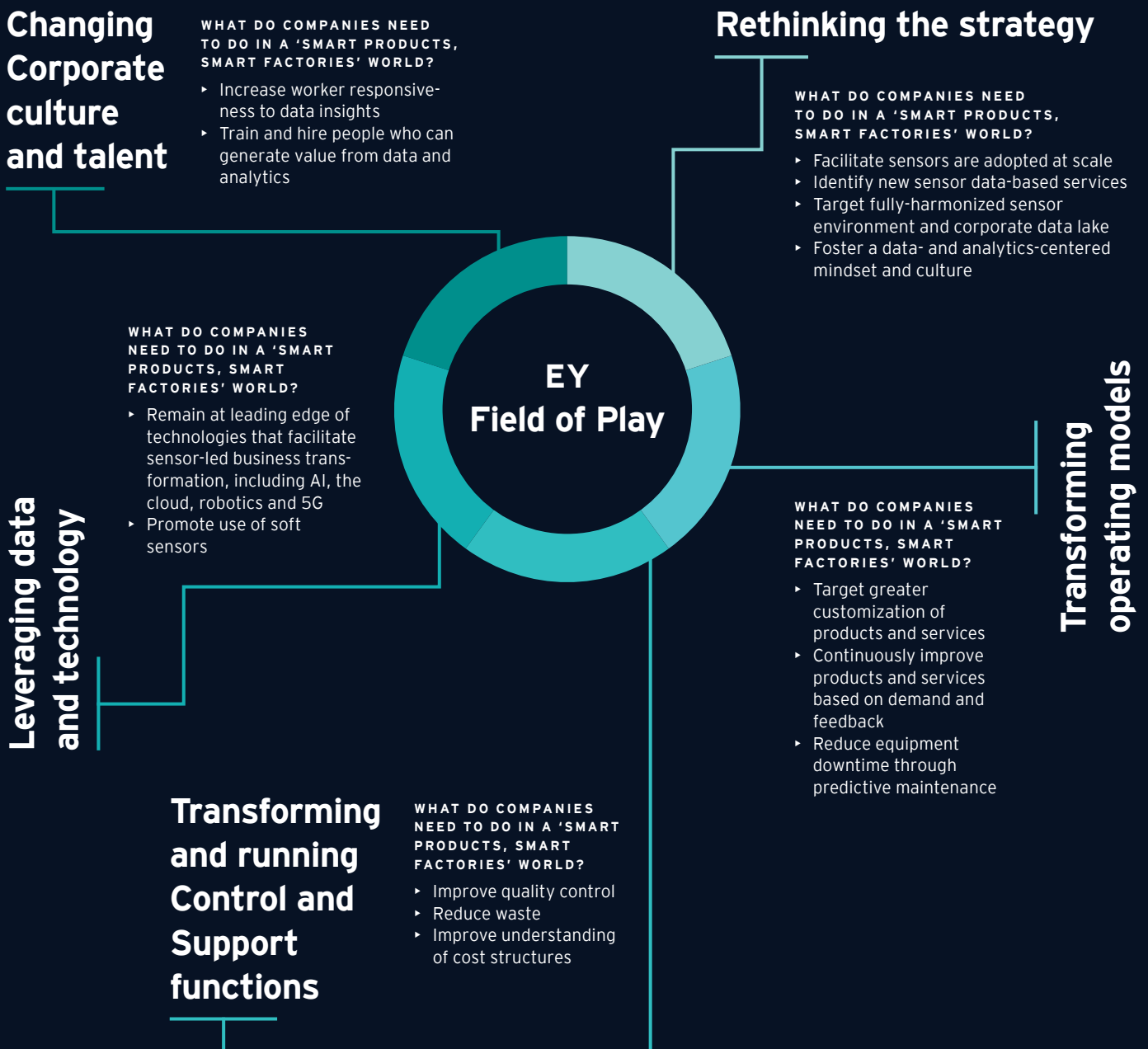
18 European Commission, *Austria: Plattform Industrie 4.0*, December 2017

19 EY, *What if employment as we know it today disappears tomorrow?*

20 EY, *What if employment as we know it today disappears tomorrow?*

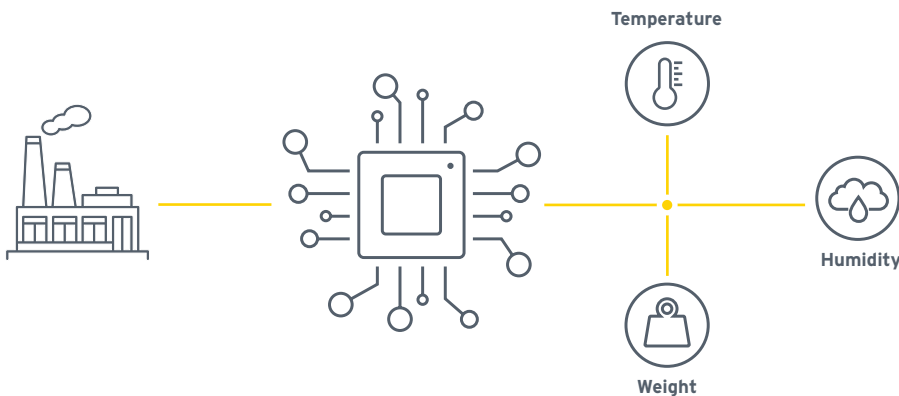
EY Five Fields of Play and Smart Products, Smart Factories

EY teams have identified five 'fields of play' that encompass its relationships with companies as the business world is transformed from 2005-2020. The content in this report can be mapped onto these:



Sensors: what they measure, why they matter

Smart sensors convert environmental inputs into readable data



Smart sensors are essential parts of smart factories, serving as the interface between the digital and physical worlds. This makes them the drivers of Industry 4.0.²¹

What are smart sensors?

A smart sensor can be defined as the combination of a sensor, microprocessor, and communication technology used to convert environmental inputs (eg humidity, weight, liquid detection, temperature) into readable data and transmit it onwards to a centralized repository. In contrast, traditional sensors rely on the manufacturer to perform the processing of inputs. Smart sensors allow for data to be transmitted with less errors, as the processing happens closer to the source, and can remain within a company's network. Additionally, smart sensors can be more easily customized for specific use cases while traditional sensors are generally mass produced.

Beyond the enhanced detecting technology within smart sensors, two factors make them smart. One is the extent to which they can be linked together over wireless networks and, increasingly, by 5G networks that can carry much larger volumes of data at significantly improved reliability. 5G also offers reduced latency - split second delays can have enormous consequences for industrial processes. Autonomous driving requires smart sensors and 5G connectivity in order to perform optimally.

The other factor is the relationship between the increasing array of measurements that sensors produce and the development of algorithms that can quickly assess their implications, thus connecting devices with human workers to implement tasks and produce goods. The result of analyzing measurements from all aspects of production can result in improved equipment and processes, ideally providing a competitive advantage.²²

Physical data are critical for being able to improve processes and so make manufacturing more efficient and hence more profitable.²³ Today, sensors are already used extensively in the manufacturing, chemicals, semiconductor and water technologies sectors, but they are also employed across a wide range of other sectors, including automotive, consumer

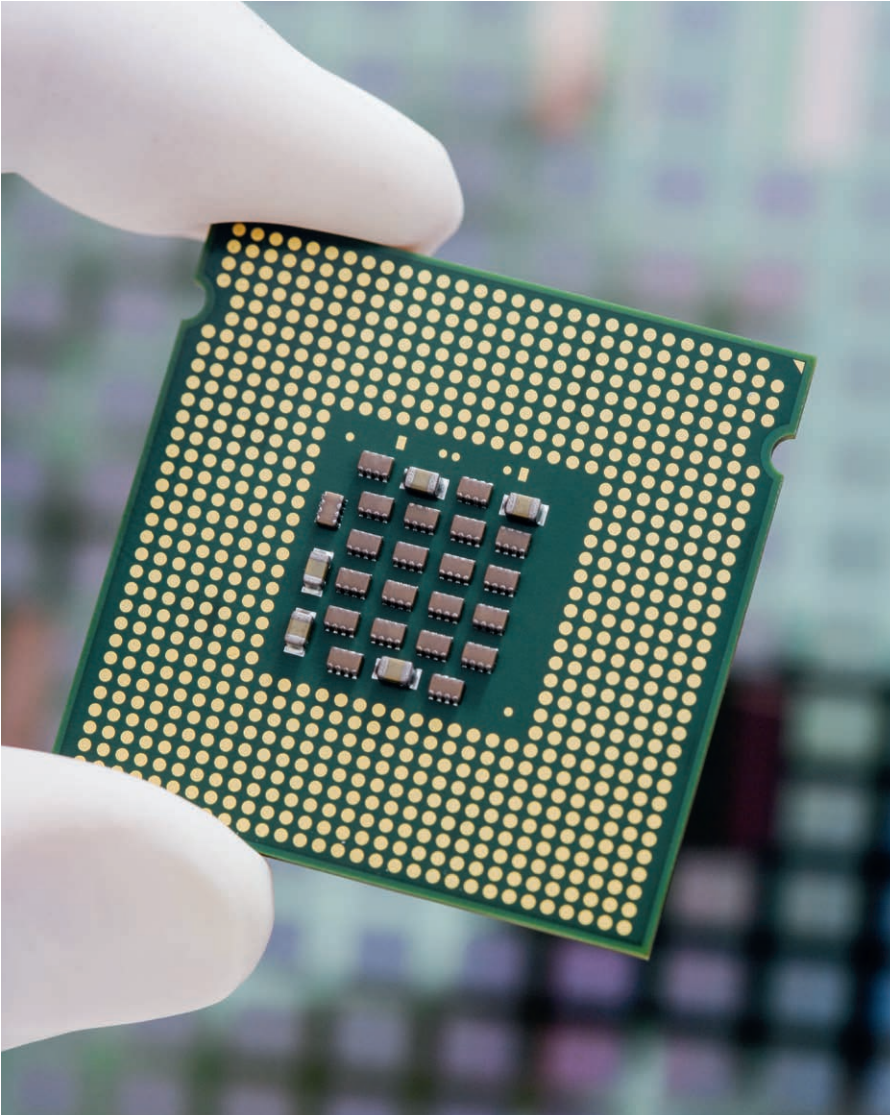
²¹ UNIDO, *What can policymakers learn from Germany's Industrie 4.0 development strategy?*, 2018

²² IEEE, *A step forward on Intelligent Factories: A Smart Sensor-oriented approach*, September 2014

²³ Interview with Expert 3

²⁴ Interview with Expert 2

²⁵ Interview with Expert 3



The main benefits offered by sensors within the Industry 4.0 framework are associated with cost savings.

goods and electronics, logistics, power and utilities, and agriculture.²⁴

The main benefits offered by sensors within the Industry 4.0 framework are associated with cost savings, and to a less extent also revenue growth. But, at a more existential level, Industry 4.0 offers firms a competitive advantage at a time when many traditional companies in the GSA region, operating in areas that have long been a major strength such as engineering and automobiles, are only just reacting

to the challenge from disruptive competitors.

Companies will need to become more flexible, specifically with the ability to adapt their business practices to a changing technology and business environment. Today, if consumer demand changes and a new type of product is required, then a new factory usually needs to be built or an existing factory needs to be modified with high effort. In the future, a factory powered by smart sensor

technology will be able to quickly adjust to producing different products because this will involve changes to the software that controls the factory.²⁵ In a symbiotic relationship, data from smart sensors will help to make improvements possible to any given product, while consumers will push this process from the demand side by expecting frequent updates to products. The demand for updates can be met through feedback received by the company via sensors in the products themselves, meaning that sensors will become ►

Sensors can also help with logistics. The Hamburg Port Authority uses smart sensors to optimize the stacking of containers.

embedded in the full product lifecycle. The role of the software engineer will be to contribute to a consistent program of process and product improvement to ensure that a company keeps pace with its competitors and sensor feedback is considered, from both the factory floor and consumer usage.

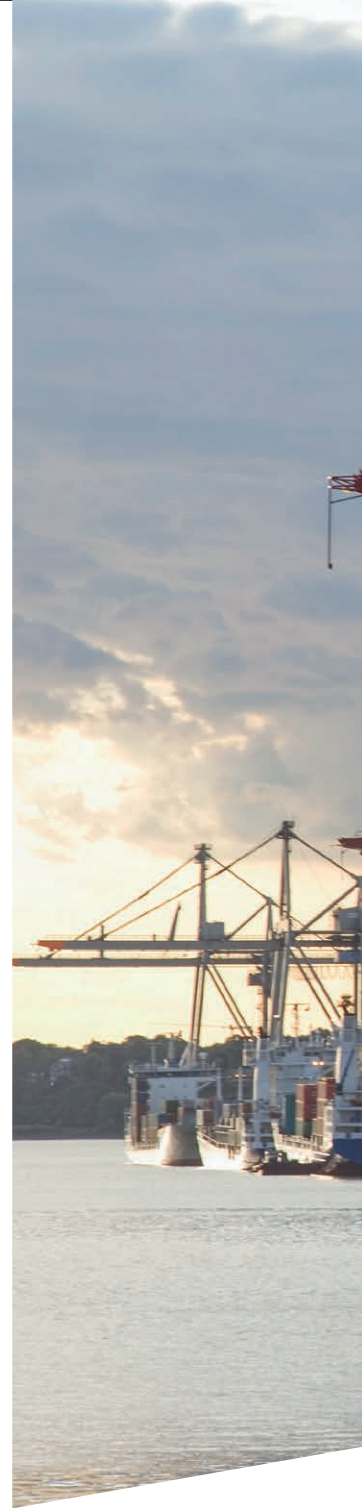
While this capacity still lies mostly in the future, sensors are already making a significant contribution to production processes. For example, in the automobile sector sensors are being used to detect surface imperfections on vehicle body parts. Along with detecting these kinds of issues, sensors can also be used to automatically recalibrate a system to certain conditions and measurements to avoid flaws that decrease the quality of the vehicle parts.²⁶ The welding industry offers another example: spectrometer devices can be used to evaluate and automatically infer the quality of resistance spot welding. By using sensors, the number of tests needed to assure quality can be reduced, keeping costs down.²⁷ Workers can be better trained – they can be taught how to react under different scenarios by applying conclusions from analysis of data collected using sensors. Smart sensors and the true implementation of Industry 4.0 can take these efforts to a new level.

Smart sensors as the heart of smart factories

The ability of smart sensors to 'connect the factory floor to the top floor' allows for real-time manufacturing, moving, learning and reporting. The term 'sensor' can be interpreted broadly and, for example, includes Radio Frequency ID (RFID) tags, which transmit information about the items to which they are attached. Smart sensors can play a crucial role in predictive maintenance by helping to identify when machines need servicing before they break down. Not only can this prevent costly unplanned production outages, but it can also reduce the downtime associated with scheduled, routine maintenance.

Sensors can also help with logistics. For example, the Hamburg Port Authority uses smart sensors to optimize the stacking of containers. Other examples include self-driving vehicles on the factory floor that use sensors to determine their locations so that they avoid contact with people. Further examples that are smaller in scale include a screwdriver with connected sensors that can understand how much torque to use when tightening a specific screw.

Beyond the implementation of specific tasks, sensors can allow for quicker responses to consumer feedback and order modifications, helping to make it more profitable for a company to produce smaller numbers of customized products. In addition, the combination of smart sensors with artificial intelligence that is a central aspect of Industry 4.0 means that sensors can be self-testing, monitoring and improving their own performance and so reducing the instances of corrupted data. ▶



²⁶ IEEE, *A step forward on Intelligent Factories: A Smart Sensor-oriented approach*, September 2014

²⁷ IEEE, *A step forward on Intelligent Factories: A Smart Sensor-oriented approach*, September 2014

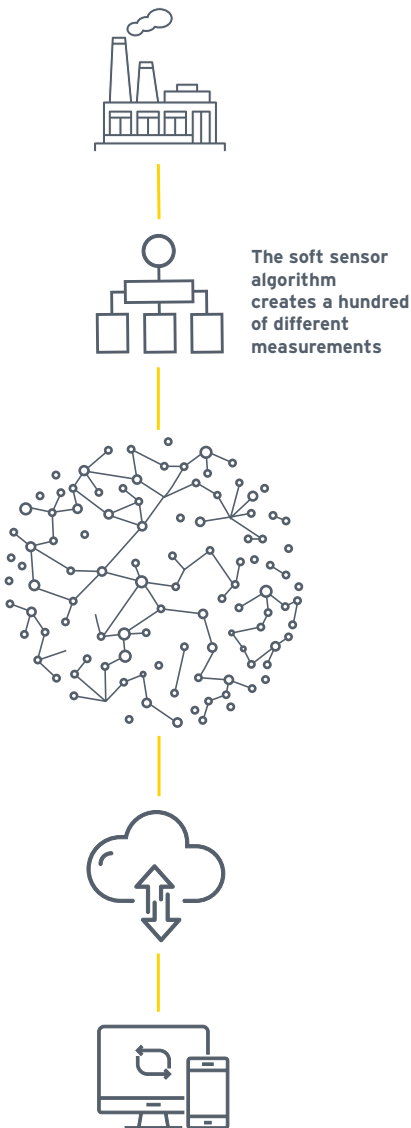


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Companies will need to become more flexible, specifically with the ability to adapt their business practices to a changing technology and business environment.



Definition of a soft sensor



Optimal industrial processes will increasingly involve sensors that warn that they are becoming damaged, before a failure occurs. However, configuring sensors for self-observation can be costly.²⁸

While the use of gauges and sensors in industry has a long history, the combination of multiple sensors and internet-connected devices envisioned in Industry 4.0 represents a fundamental change in how data can be used to improve processes. The ability to quickly gather and, crucially, analyze vast amounts of data has significant potential to expand the impact that sensors have on industry by maximizing the value of the data that sensors can collect.

Moreover, with sensors becoming less expensive, smaller in size, and requiring less energy to function, it is becoming easier to integrate greater numbers of sensors into individual products and factories. The ability of multiple connected sensors to confirm and cross-check findings is leading to an overall improvement in monitoring and correcting processes as issues arise. Increasingly, quality assurance during the production process will become integrated into feedback loops. Sensors will provide feedback on quality, allowing corrections to be made in real time.²⁹ And improvements

in network security will improve the protection of data from external intervention.³⁰

Issues and challenges remain, of course. For multiple sensors to work together well, they must be configured and integrated effectively.³¹ The quality of sensor feedback is also a challenge.

Soft sensors

The key characteristics of soft sensors for a smart factory are their ability to estimate real-time data, overcoming delays imposed by the slow dynamics of physical sensors, while working alongside traditional hardware in ways that increase reliability and improve the performance of control strategies. Moreover, they are relatively low in both energy use and capital cost despite offering significant enhancements by generating virtual data in addition to using real sampled data. Soft sensors can alleviate some of the issues related to power supply for battery-powered sensors and concerns related to energy efficiency. Soft sensors are especially important for smart factories because they can be used in areas where the real environment does not allow for implementation of hardware sensors, eg in chemical processing or combustion processes.



It is becoming easier to integrate greater numbers of sensors into individual products and factories.



A similar example is of a 20-year-old machine that does have sensors inside, but ones that need a human to manually download the data and format it for analysis. If the machine is functioning, a company may not want to change it. However, the machine manufacturer may not want to install new sensors inside; they would prefer to sell the company entirely new equipment.³³ Here also, soft sensors present a potential solution.

What are soft sensors?

Sensors have traditionally been associated with hardware with limited capacity. By contrast, soft sensors are software-based models that can use algorithms to process hundreds of measurements simultaneous together, and in doing so predict parameters that cannot be measured directly. The results can be continuously updated and presented to a process operator.

monitored equipment to be determined. So long as the model being used can adequately represent the dynamics of the system, then the virtual data will be accurate and reliable.³²

Soft sensors also represent a way to avoid corrupted data from impacting on processes or analysis. For example, within a production line a company may have a machine provided by a third-party that cannot be accessed to install sensors. Sensors could potentially be installed on the outside of the machine. Alternatively, soft sensors could be used to gain the necessary insights. Data scientists could use data in a way that that gives the company information as if new sensors were in the machine, without interfering with the device itself.

This virtual data is a central component of smart factories because it goes beyond the limited sampling period that many traditional sensors can provide. Soft sensor techniques allow the estimating of plant behavior through real data and appropriate algorithms. When the real sensor is not generating data, the soft sensor is still able to provide data to the controller through a mathematical model and the available real data. This allows the future behavior of the

Soft sensors are likely to be custom-made by specialized companies, in contrast to hardware-based sensors that tend to be standardized and made in large numbers.³⁴ With sensor systems growing more complex, even large corporations will not be able to build appropriate sensors themselves. Instead, almost all companies will buy sensors from third-party suppliers.³⁵ ▶

28 Interview with Expert 3

29 Interview with Expert 1

30 *International Journal of Modern Manufacturing Technologies, Smart factory for industry 4.0: A review, January 2015*

31 *IEEE, A step forward on Intelligent Factories: A Smart Sensor-oriented approach, September 2014*

32 *MDPI, The Benefits of Soft Sensor and Multi-Rate Control for the Implementation of Wireless Networked Control Systems, 1 October 2014*

33 *Michal Rutkowski, EY*

34 *Martin Neuhold, EY*

35 *Maciej Iwaniuk, EY*

With implementation of Industry 4.0 becoming more widespread, many companies will be closely monitoring developments in universities and among start-up companies that are looking to commercialize new breakthroughs in sensor design.³⁶ A particular challenge involved in the move to smart sensors is the extent to which manufacturers will feel comfortable about buying from start-up companies that may be first to market with new lines of the device. Are these new suppliers financially stable? Are they quickly able to ramp up production as required? And how reliable are their products at delivering what they promise? One consequence is that companies that provide their interfaces openly and allow for co-creation will be more likely to succeed, as they tend to be faster in updating those interfaces.³⁷

ServiceNow use of soft sensors in the IT sector

The company ServiceNow has built software for the IT sector that tracks how different devices in a data center communicate with each other. It monitors the whole data center and a huge number of communication flows between devices. The software can then pick up anomalies. For example, if two computers have not 'talked' to each other for two years, and then suddenly start talking to each other, this could be a sign of a fault in the system or of a security breach. Such Security Incident Event Management (SIEM) is an example of soft sensors being used.

Source: *Interview with Expert 4*

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Soft sensor technology is relevant wherever manufacturing or processing takes place.

The same logic employed by ServiceNow applies to other sectors, such as wind farms. The software (soft sensor) collects turbine data over time and figures out patterns. One pattern, for example, could be that turbines develop faults about one hour after overheating. Therefore, every time the sensor picks up excessive heat, the software can recommend that the turbine needs to be switched off or fixed. The soft sensor can give precise indications about the nature of the problem and what needs to be done to fix it. When fully optimized, the software may even be able to fix the problem automatically, a classic case of predictive maintenance.³⁸

Soft sensor technology is relevant wherever manufacturing or processing takes place. The automobile sector is a good illustration of this; it may be the sector in which soft sensors have

the highest potential, not only in the production process but also for monitoring the use of the finished product. Sensor technology that allows a car to have knowledge of its environment has made autonomous driving possible and remains crucial to its development and adoption.

More generally, in all industries where safety (eg, chemicals or oil and gas) and productivity are key, the potential impact from soft sensors is high. Instances where speed of production is also a factor will have an added incentive to work with soft sensor technology, as will those where the optimized use of materials during manufacturing can reduce waste. The latter consideration is particularly true in the aerospace sector, where the materials being used are often extremely expensive.³⁹ —

³⁶ Jan Gudat, EY

³⁷ Interview with Expert 1

³⁸ Interview with Expert 4

³⁹ Interview with Expert 3

Looking forward

The combination of smart sensors and a 5G wireless network designed to work with the IoT means that all components, products and other entities involved in industrial production will be able to have their own identity on the network. They could negotiate with each other, or could be interconnected and simulated, so that systems become virtually integrated, tested and optimized. Algorithms for autonomy optimization could revolutionize production planning as products navigate autonomously through the production line.

A major trend is 'edge computing', which sees data processed on an internet-connected device or a nearby computer, instead of a data processing center. With the computing power that allows such action becoming cheaper and requiring less energy, integrating more extensive data processing and sensors makes more and more sense.

Once the use of smart sensors within a production and logistics setting becomes established as part of the Industry 4.0 framework, the next step will be to link newly accessible data with a range of third-party services such as weather, calendars, payment services, or historical data. This will make possible further improvements in scheduling around the stocking of raw materials and the delivery of finished products. However, the ultimate revolution associated with Industry 4.0 lies not simply with the production process but with new business models, services and individualized products that the Industry 4.0 framework makes possible.⁴⁰

Some products will simply never need sensors, though many will, and still more will benefit from them during the production process. Currently, not all companies see the value in sensors, though many do. Over time, divergent performance is likely based on companies' assessments of how sensors can impact performance, and the speed and scale at which companies decide to implement sensors. —

40 IEEE Industrial Electronics Magazine, Industrie 4.0: Hit or Hype, June 2014



The combination of smart sensors and a 5G wireless network means that all entities will be able to have their own identity.

Questions & Answers

What are the key challenges for companies wanting to make use of sensors?

Low-cost sensors will lead to a massive increase in the use of sensors in industry, leading to significantly increased effort in engineering of those sensors. Hence, the key challenge is less the technology involved in the sensors themselves but ensuring their ability to act and react intelligently and reliably in a network - greater interoperability is needed. The focus of future sensors will move toward software capabilities that go beyond the measurement. It is important for sensors to have the capacity for self-identification and explorability in a network, as well as self-observation, to help identify when measurements are or will become wrong soon. Such 'asset management' opportunities have been known for a decade but configuring sensors for self-observation is costly. A broken sensor is not a problem if you know about it beforehand and can take remedial action. Optimal industrial processes would involve sensors that are bound in automatic asset management and warn that they are becoming damaged, before it happens.

What are the most critical preconditions for sensors to have a strong business impact in future?

To communicate with smart sensors in a network requires standardization of sensor and device software interfaces across vendors, so that they can communicate in a network using the same commands and semantics. Since the future of sensors will have a strong connection to software, decision makers and senior executives need to have a strong software mindset. In Germany, the industry mindset (eg, on corporate boards of many of the largest manufacturing companies) is still very hardware-focused. As a result of this, in big German corporations the innovation speed with regard to software is comparatively low. In hardware, meanwhile, it is fast. Most of the value from sensor data is created using software.

Prof. Dr.-Ing. Rainer Drath,
University of Applied Sciences, Pforzheim



How can sensors improve the competitiveness of firms?

Another impact of sensors is on corporate survival. Many successful traditional companies in the GSA region, eg, in the automotive sector, are slowly waking up to the challenge from disruptive competitors. In the future, companies will need to become more flexible. Today, factories typically can only produce a predefined set of product types. If demand changes and a new type of product is required, then the existing factory needs a costly modification, or a new factory needs to be built. In the future, the same factory will be able to switch quickly to producing different products on-the-fly while in operation, and this will be controlled by software changes.

In many sectors, there will be a big re-arrangement of who the leading players are. Companies quickly need to identify and implement software skills to survive. —

Cost saving

- 25 Increasing production flexibility and worker responsiveness
- 26 Reducing equipment downtime through predictive maintenance
- 27 Improving quality control and reducing waste
- 28 Improving understanding of cost structures

ings _____

So far, the emphasis with smart sensors has been on cost saving rather than boosting revenue, and even in terms of reducing costs there has been relatively little progress made in tapping the widely acknowledged potential that sensors offer. This is because most projects involving the use of smart sensors are still being conducted on a small scale.⁴¹ Areas that benefit from improvements in direct measurements are likely to realize gains more quickly than those involving indirect measurements.

There are three main areas in which the use of smart sensors can help to increase the efficient use of resources or reduce the costs associated with production.

- ▶ **Capital costs:** Companies that optimize their value chains and increase flexible manufacturing and automation reduce the amount of capital that is tied up in the manufacturing process.
- ▶ **Raw materials and energy costs:** Companies can cut costs by reducing consumption. This can be achieved by more efficient processes, predictive maintenance, less waste, and lower instances of error, as well as more efficient quality control and production planning. In addition, supply risks are reduced, and environmental sustainability increased.
- ▶ **Human resources:** Companies with a high degree of automation require fewer personnel in relation to their production volume. The personnel costs in relation to production value are therefore reduced, possibly also in absolute terms.⁴²

In addition to enabling a minimized use of resources, smart sensors can also save money by saving time. For example, products often need to be taken off the production line so that quality assurance tests can be performed in a laboratory. Depending on the product, this may take hours, as with solar cells, or even days. By integrating data from smart sensors into feedback loops, quality assurance can be done in real time. Generally, the more expensive the product and the more complex its production, the higher the potential efficiency gains through the use of sensor technology in this area.⁴³

There are four key areas of business activity in which sensors contribute to the type of cost and time savings described above. —

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In addition to enabling a minimized use of resources, smart sensors can also save money by saving time.

41 Maciej Iwaniuk, EY

42 Institute of Technology Assessment (ITA)
Austrian Academy of Sciences, Industry 4.0,
November 2015

43 Interview with Expert 1



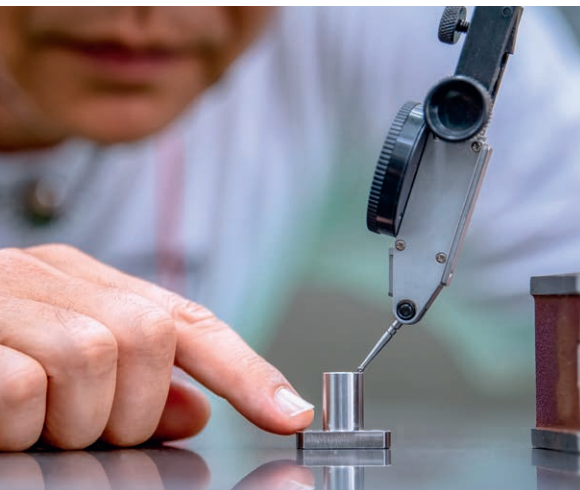
Increasing production flexibility and worker responsiveness

Smart sensors can make a clear contribution to production flexibility by optimizing the use of Just-in-Time processes. The challenge is to ensure that those people in operational positions are able to move quickly enough to respond to the information that they are receiving. This human factor is currently limiting the cost saving derived from the use of smart sensors in time-sensitive manufacturing to only about 30% of the potential impact.⁴⁴ Dashboards or other monitoring devices must be used by workers to understand various work streams based on the data being produced, which in turn means additional training and adjustment to new workflows.⁴⁵

Reducing stockouts

The cost savings through reducing stockouts are higher than in many other areas. The delivery of products can be tracked using GPS, and production plans changed accordingly (eg, daily). There is evidence of sensor technology that measured changes in weight on stock shelves reducing half of stockouts.

Source: Interview with Maciej Iwaniuk, EY



By integrating data from smart sensors into feedback loops, quality assurance can be done in real time.

⁴⁴ Maciej Iwaniuk, EY
⁴⁵ Sensors online, Can The Growth Of IoT Withstand The Challenges of PLM?, 3 May 2018

Reducing equipment downtime through predictive maintenance



Well-integrated use of smart sensor technology enables improvement of system reliability

The concept of predictive maintenance - performing maintenance when it becomes necessary rather than relying on a fixed schedule - has been in use since the 1970s. Savings can be difficult to measure. One issue is that testing of predictive maintenance is often done at the 'proof of concept' stage, but then is not implemented as much after the products have been sold, diminishing the possible return on investment.

Moreover, predictive maintenance is an area in which the adoption of new technologies is often slow because the processes being monitored can vary with the specific equipment being used. In addition, it requires specialized modeling experts with the ability to develop the mathematical models that match the real process, as well as time to develop/test such

models and to adjust the models in parallel with a changing process. Even then, while predictive maintenance can be modeled perfectly, it can be hard to translate the successes seen in theoretical modeling into real-life situations, either because of the difficulty of applying the model effectively or because not all relevant factors in a particular situation have been fully captured.

Also, corporate customers tend to have their views on how much to expect from predictive maintenance raised during the purchasing process. Those expectations are then difficult to fulfil once systems are in place. As a result, customers can often feel disappointed and lose interest. This factor can limit the market for solutions that really do offer a significant improvement over products that are currently available.⁴⁶

This presents a perception challenge that needs to be overcome. The well-integrated use of smart sensor technology, which is now at the point where the data collected can enable equipment to be self-monitoring and self-calibrating, is able to improve system reliability while reducing installation, configuration and maintenance costs. Much of the savings comes from the ability to process signals from an array of smart sensors to forecast the timing of maintenance requirements with a greater degree of accuracy, increasing the efficiency of the maintenance regime and reducing the time during which the equipment is offline. —

46 Maciej Iwaniuk, EY

Improving quality control and reducing waste

Sectors such as oil and gas production and chemicals manufacturing have a long history of using sensors and the data they provide. However, the big change in recent years involves what can be done with that data through the use of advanced analytics. Productivity gains (and therefore cost savings) of 5% - 10% are now common in these two sectors as a result of the greater ability to detect inefficiencies in production processes through improved data analysis techniques. These savings are coming in industries that are already highly skilled in using data analysis to optimize production.

In the consumer products, manufacturing, and automotive sectors, the ability of operators to respond to data regarding inefficiencies is lower, bringing down the potential cost savings available from more accurate sensor inputs. However, if this ability can be raised, then the potential for cost savings through new sensor technologies will also increase in these sectors. At present, many factories run at only 65% - 70% of potential in terms of efficiency.⁴⁷

The ability to reduce waste during manufacturing means that industries in which waste is very prevalent have the potential to benefit most. It will also be possible, as part of the quality control process, to reduce the number of non-compliant products. Companies may also consider making data from smart sensors available to regulators, to demonstrate that they are in compliance with regulations throughout the manufacturing process. In addition, some customers are

likely to pay more for products that present data to support claims regarding their quality.

The semiconductor industry has led the way in using analysis based on sensors, which allows manufacturers to check the yields of their production and learn about their processes. As a result, their products are extremely finely-tuned. Such capacity should soon be available to other sectors.⁴⁸ —

65% - 70%

efficiency potential is maximally used by many factories

Enhanced quality of production

In terms of cost savings, the impact of smart sensors is often initially evident through their contribution to a company's ability to reliably manufacture products to the minimum necessary specifications. For example, if a customer requires rings that weigh 10g, then the 'tolerance range' may be 9.91g to 10.09g. This means that any ring produced within this range will be accepted by the customer. With enhanced quality of production driven by sensor technology ('in-process measuring systems'), the producer will be able to manufacture all rings to weigh 9.91g, allowing costs to be saved on raw materials. If the rings are mass produced, this can lead to substantial cost savings by, for example, producing compliant products while using less material, though concerns related to the quality of the ring may arise.

⁴⁷ Maciej Iwaniuk, EY

⁴⁸ Interview with Expert 1

Improving understanding of cost structures

Increasing a company's understanding of the factors affecting unit profit and loss during production is among the biggest opportunities associated with sensors and IoT. Sensors provide the potential to understand the profit and loss associated with each unit sold,

with the results of real-time data collection helping to optimize energy and materials consumption.⁴⁹ —

49 Maciej Iwaniuk, EY

Employing workers able to understand how to work with data and make correlations between processes will be critical.



Questions & Answers



Jan Gudat,
Senior Manager,
Advisory

What are the main business benefits sensors present?

The main benefit resulting from the collection of data materializes when analyzed and automatic actions are triggered. The value is not in the data itself, but rather in using the data to perform use cases such as predictive analytics, which in turn can help to drive automation. Three layers provide a base for generating overall added value - acquiring, aggregating and analyzing. Taken together, these three layers enable companies to derive and assign next best actions, which should in the optimal case get triggered automatically. Owning the data is one thing, but how it is combined with other data and analyzed is the more value-creating part. Often you do not need that much data. A real-time data flow is crucial for most use cases.

What are the key challenges to gaining value from sensors?

Across all industries, the major challenge is the need for protocols that are compatible with each other. There are perhaps 150 protocols for how sensors talk to their hosts. Most companies do not create their own sensors. They instead scan what is happening at universities and among start-ups, along with some more established firms. Most big companies struggle to get a good overview of what is happening in the field and competitors tend to follow each other. The increasing complexity of the ecosystems arising with the use of sensors across companies and industries is a challenge that we have to develop answers for. Accelerating the speed of innovation, and setting up the appropriate type of organization and partner ecosystem under the given complex boundary conditions are key to success. —



Maciej Iwaniuk,
Senior Manager,
EY EMEA Advisory
Center

What is the potential to reduce equipment downtime by using predictive maintenance?

Although predictive maintenance has been around since the 1970s, the recent use of machine learning and predictive analytics has made it available for new fields of application. EY experience with projects in Germany, Italy and Portugal suggests that 'micro-stops' are a great target for application, with the potential for 40%-60% of 'micro stops' to be prevented.

What potential is there to improve quality control and reduce waste?

In sectors such as oil and gas and chemicals, sensors and data have been used for many years to control the process. However, what has changed in recent years is that there are new ways of using that data. Productivity gains (and therefore cost savings) of 5%-10% are common in these two sectors, as a result of identifying incorrect situations. The potential is not much higher because in these two sectors (and in power and utilities) the human operators are trained to react fast - faster than in other sectors. In other sectors, digital literacy is often not as high on the shop floor as in these sectors. Available research shows that approximately 30% of adults are not sufficiently skilled in using digital tools and techniques efficiently. —

Transforming businesses

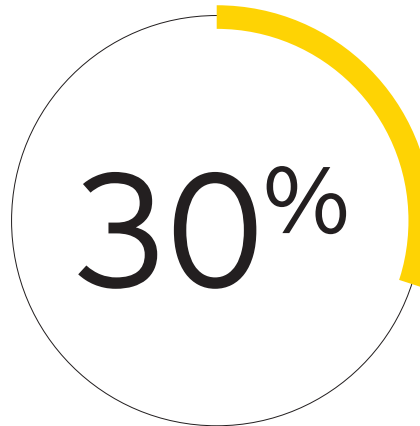
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- 32 Customization is the future
- 33 Potential for revenue growth
- 34 New products, new approaches
- 40 The importance of scale

Smart factories and sensors offer companies the ability to transform production rapidly to stay competitive and to increase revenues. In GSA, companies have so far experienced only about 7% in cost reduction but around 27% of the companies expect savings of more than 10% from implementing sensor technology.⁵⁰ However, even savings in the single digits can offer a competitive advantage for many companies. This is particularly true for companies that can use smart technologies to increase their ability to offer customized products.

The manufacturing and automotive sectors are among the leaders when it comes to this transformation, with sensors having been widely deployed. For example, VW expects productivity to increase by 30% by 2025 due to digitally connecting machines to ecosystems capable of analyzing the data being produced.⁵¹

In the consumer products sector, the ability of operators are less developed and therefore potential cost savings are lower. However, if this ability can be raised, then the potential for cost savings through sensor technologies will also increase in these sectors. —



expected increase by 2025 due to digitally connecting machines to ecosystems at VW

“

In GSA, companies have so far experienced only about 7% in cost reduction but around 27% of the companies expect savings of more than 10% from implementing sensor technology.

⁵⁰ Jan Gudat, EY

⁵¹ Jan Gudat, EY

Customization is the future

The main benefits of sensors for business lie not in the data provided by the sensor, but rather in analysis using that data.

Manufacturing is moving from an era of mass production to an era of mass customization, or the 'consumerization' of various products. In the future, some sectors will continue to concentrate on mass produced items that are widely used. But many sectors will move to using products that are produced on a mass scale but also capable of being customized. This represents a major step forward from the traditional association of customized products with small production runs.

There are already a number of examples of this trend in the consumer goods sector:

- ▶ Sports shoes can be customized to an individual's foot by analyzing data collected by sensors placed on different parts of the foot through an algorithm. This produces instructions from which a robot can undertake the complex task of cutting the materials needed for the shoe with great precision and minimal waste.
- ▶ Tailor-made suits can be ordered online by inputting measurements. Production is automated, and the finished article is sent directly to the customer's home.
- ▶ Headphone manufacturers use complex algorithms to process data from sensors about the shape of a customer's ears and then establish optimal acoustics according to customer preferences, eg, the acoustics of selected concert halls.



- ▶ Loudspeaker manufacturers use an array of sensors and complex algorithms to measure the room and the position of the loudspeaker within the room in order to autonomously optimize the acoustics or to listen to the people in the room and react to commands, even when the music plays loudly.

The increasing focus on customization through the use of sensors and automation may lead to the re-shoring of some industries, bringing them back from locations in developing economies to smart manufacturing facilities in Europe. Customization may also help industry to stay in Europe, if the customized product can attain an 'emotional' value associated with its European location. For example, Ferrari has an emotional value: consumers

want Ferraris produced in Italy, not elsewhere. Similarly, a customized shoe might attain such emotional value through a combination of location, personalization and branding.⁵² In addition, bringing the production close to the customers saves delivery time, logistics, transport, energy and natural resources.

One of the drivers of customization will be the use of data mining and artificial intelligence (AI) to identify consumers who may have a particular interest, as yet untapped, in product customization.⁵³ —

⁵² Interview with Expert 1

⁵³ Interview with Expert 2

Potential for revenue growth

The main benefits of sensors for business lie not in the data provided by the sensor, but rather in analysis using that data, which in turn can help to improve automated processes and perform predictive maintenance.⁵⁴ The three distinct aspects to making use of data in this context – collecting, aggregating, and analyzing – all need to be undertaken in order to maximize the benefits of smart sensor technology through the use of analytics.

Therefore, revenue growth that is related to Industry 4.0 is unlikely to come in the form of a one-off step change and instead will accrue over a prolonged period. Nor will the use of sensors cause a productivity explosion in the coming years. But the potential for revenue growth exists.

One recent study has concluded that in Germany the transition to Industry 4.0 has been accompanied by significant improvements in the return on capital employed (ROCE). As the rate of use of production equipment grew from 85% in 1998 to 95% in 2014, Germany's ROCE climbed from 12% in 2000 to over 30% in 2014.⁵⁵ However, low take-up of technology by small- and medium-sized enterprises (SMEs) remains an issue. Another recent study has found that German GDP growth could increase by three percentage points if SMEs used Industry 4.0 solutions more consistently. The problem appears to be linked to a lack of software mindset in SME management (eg, machine builders) as well as to a lack of qualified IT personnel with the ability to take on Industry 4.0-related projects, rather than to a lack of funding or initiative.⁵⁶

95%

rate of use
of production equipment

However, funding for internet technology can be difficult to obtain. CFOs want to see substantial revenue before new equipment is purchased, such as sensors. Even if an IoT initiative receives the necessary investment, only modest yields can be expected in the short term.⁵⁷ In some sectors, especially those involving heavy machinery, change will be even slower. For example, power plants will last for decades before they need replacing, so it will be a long time before sensor technology impacts their architecture. In sectors in which goods need replacing quickly (for example, fast-moving consumer goods), it is often quicker to introduce new technologies into manufacturing processes. This means a difference in the time required to see a return on investment in soft sensor technology between sectors where changes in production processes are relatively frequent and those where the cycle of change is substantially longer.

In some sectors, there is a tension between what is possible with sensor technology and what the sensors that are currently available can do reliably. In sectors where there is danger

involved, safety and reliability are critical. Therefore, companies will tread carefully when trying out what is possible with new sensor technologies.

Safety sensors provide sound business cases because of the high engineering and certification effort required. As long as the safety development methodologies achieve reasonable pricing, those methods can be applied in non-safety applications. A future value proposition of sensors would be reliability and robustness, aspects of significant business value in many industries with a high degree of automation.

Another way to increase revenue growth is by selling the measurements taken by smart sensors. This can be a product and offering access to the resulting data for a price. This type of data sharing is already happening on the consumer side, most notably through the process of telematics, in which sensors in vehicles capture and convey information on the way in which a vehicle is being driven. As this development in the auto sector shows, while companies may be reluctant to share data from sensors that collect data on their manufacturing processes, there may be an extended audience (which in the case of telematics is led by the insurance sector) for data on how the resulting products are subsequently used. —

⁵⁴ Sensors online, *Can The Growth Of IoT Withstand The Challenges of PLM?*, May 3, 2018

⁵⁵ Blanchet, Rinn and Dujin, 2016

⁵⁶ Von Kai, 2017

⁵⁷ Interview with Expert 4

New products, new approaches

Early adoption of smart sensor technology has been concentrated on improving the manufacturing process of existing products. But it is probable that the resulting improvements may themselves lead to the introduction of new products, first through customization and subsequently through the conjunction of smart sensor data and data analytics to enable companies to offer a combination of high precision, high reliability, and high volume. In addition, data collected by sensors will help to create new services linked to the use of particular products.

Despite the potential of these longer-term advances, however, it is likely that in the short term the adoption of smart sensor technology will proceed at a relatively slow pace. A central reason for this is the need to combine the sensors themselves with a range of other technologies in order to maximize their benefits. Additionally, it is necessary to integrate smart sensors with existing sensors.

There also remains the challenge of how best to structure the human elements of the processes to take best advantage of the new data.⁵⁸ The limited ability of human workers to react to the speed at which new data becomes available is a central limiting factor in improving systems in which human input remains crucial and is not itself subject to digitized automation. To some extent, reaction time can be improved with training but in general the human operators of machinery or managers of processes are not capable of acting fast enough on the analysis produced from sensor data.⁵⁹

A less obvious problem is the extent to which a reluctance to upgrade current sensor capabilities is linked to the challenges inherent in legacy systems. Grafting on new technologies can often require features and capacities that a company's current systems may not have, and the cost of the wider upgrade that their installation would require (in terms of labor as well as hardware) can often be regarded as prohibitive.⁶⁰

Additionally, senior business executives need to adopt a mindset that is oriented toward software. In Germany the industry mindset sometimes found on corporate boards of many of the largest manufacturing companies, for example, is still very hardware-focused. As a result of this, in big German corporations the innovation speed with regard to software is slow, while in hardware, it is fast. As noted above, most of the value from sensor data is created using software.⁶¹ ▶

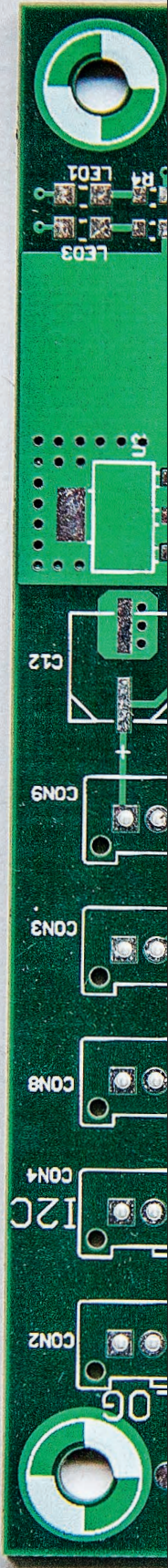
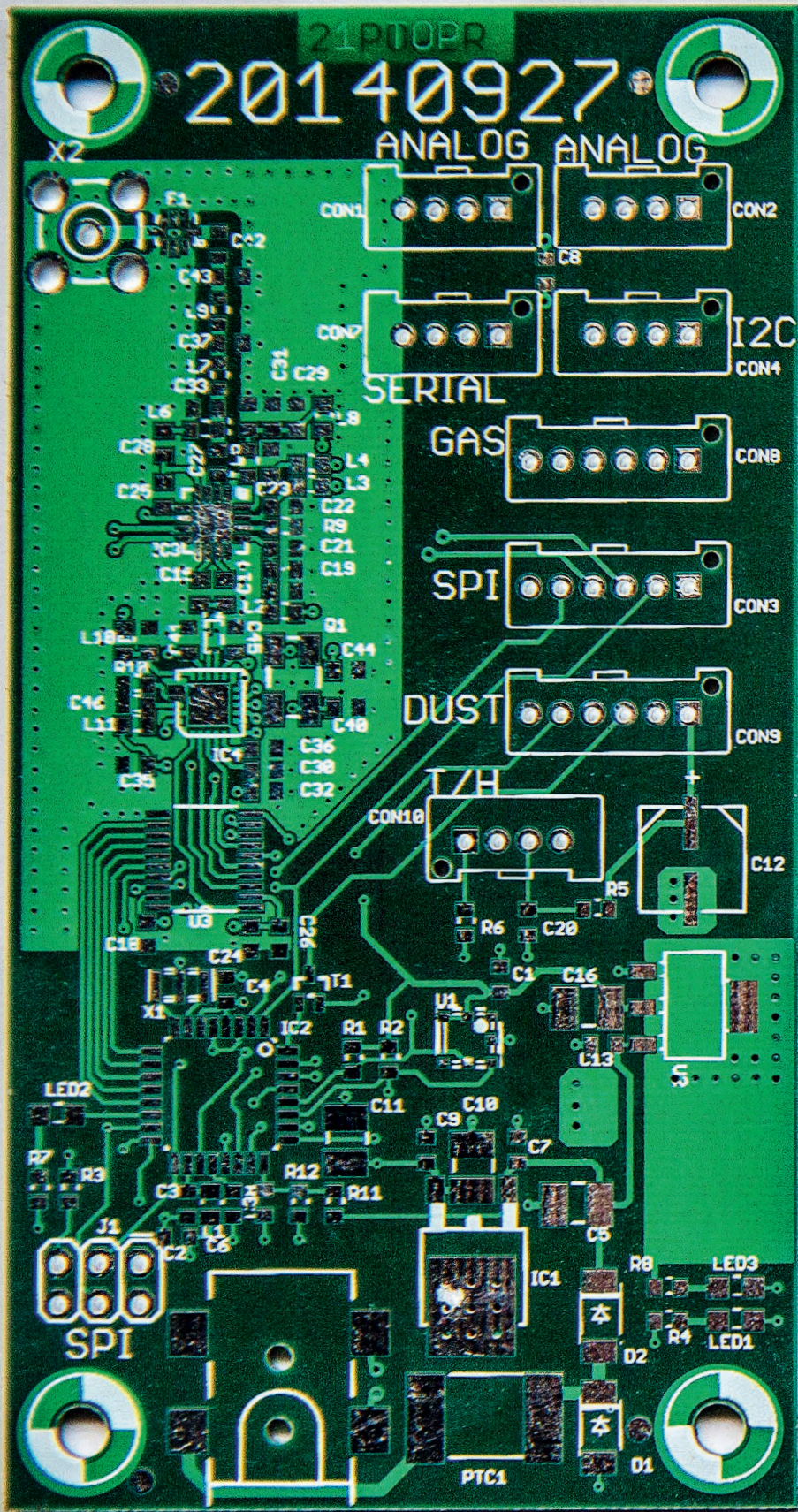
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One technology that companies will need to become fully familiar with is the effective use of the cloud.

⁵⁸ Interview with Expert 2

⁵⁹ Maciej Iwaniuk, EY

⁶⁰ IEEE, *A step forward on Intelligent Factories: A Smart Sensor-oriented approach*, September 2014

⁶¹ Interview with Expert 3



Digital twins

One technology that companies will need to become fully familiar with is the effective use of the cloud. Fortunately, cloud data storage is becoming very cheap. Developing and executing applications in the cloud are now services offered by multiple cloud providers.

An example of an application used in the industrial sector would be to store every product item's full history, which includes when and where it was produced, the particular batches of raw materials that were used in its production, when and where it was sold, and possibly data on how the product was subsequently used. All these data are attached to a data object stored in the cloud. It is related to its physical product or component and is searchable and explorable in the cloud infrastructure via internet technologies.

The product or component then has what is known as a digital twin, stored in the cloud. This means that, for example, if it is discovered that a car has developed a fault in one of its steel components, then the producer can immediately identify who purchased other vehicles that were made using steel from the same batch and recall them.

Digital twins can observe and maintain hardware, adapt the hardware functionality, and help establish new business models such as renting out production capacity rather than only selling the hardware for it. Companies also will need to adopt cloud technology quickly to survive, as the importance of 'digital twins' is going to rise. Digital twins can be combined with each other to create value. In the future, more physical objects are expected



Example of application used in the industrial sector

have a corresponding digital data object stored in the cloud, which holds digital information about it. While a physical object performs activities in the real world, the electronic data model holds digital data as 3D models, installation guides, function blocks, etc., enabling all sales, engineering, operation, and maintenance tools to work automatically with the latest data and real-time information.

Furthermore, when more data is attached to this data object, eg, geometry data, sales data, maintenance data, certificates, etc., the data object in the cloud becomes a valuable asset for each aspect of production. This is the core idea behind the digital twin; related software tools can connect to and benefit from it in order to generate value.

The concept of a digital twin can be extended even at a company level, rather than at a product level. It may become possible to model how a business unit or company might evolve if a company does not opt for integrating IoT and sensors versus if it does.⁶²

Digital twins and the digitalization of factory processes can also assist with one human resource challenge all companies are faced with: the transfer of company-specific knowledge when employees leave. For example, some employees spend entire careers working in a single factory. They have a huge amount of knowledge about the factory and its processes in their heads. If they leave, all this knowledge goes with them. A well-implemented IoT system means that the knowledge once held only by workers will be embedded within the system. New workers will more readily understand aspects about a factory that previously only a few knew.

Security

The downside of storing so much sensitive information is the extent to which security becomes an issue. There is not only data to be protected, both in terms of complying with data protection requirements and in terms of protection from hacking. The networks over which data travels and the smart sensors that collect the data are also points of vulnerability that can be attacked. Sensors, in particular, have already been singled out as a potential point of attack. Several attempts have been documented in which intruders have targeted sensors as a way to penetrate networks and access proprietary data.

In addition, sensors themselves can be used passively, to surreptitiously monitor processes, or actively in ways that include transferring malicious code, triggering messages designed to activate malware planted in other devices on the same network, or capturing sensitive personal information shared between devices. The current acceptance of insufficient security measures and a lack of understanding regarding the vulnerability of sensors will need to change if companies are to keep their data safe.⁶³ The development of security standards could be key in expanding adoption of the IoT in production processes. The number of attack vectors is exponentially higher in IoT applications than traditional network architecture.⁶⁴ The existence of these threats strongly suggests the need for on-premise security solutions, eg a cloud service system.

If sensors become truly pervasive and security continues to be lax, the threat may grow to face a whole sector rather than a single company. For example, companies in the automotive

The commercial rollout of 5G in the GSA region should begin at the earliest in

2022

industry may all use the same types of sensors in their vehicles, meaning that all companies would be vulnerable to malign use of that sensor type.

5G

The impact of sensors on factories will be substantially increased by the introduction of low-cost 5G wireless networks. Industry 4.0, combined with 5G, will bring smart sensors into industry on a larger scale than today.⁶⁵ 5G wireless networks can carry much higher volumes of data in much shorter times and with much higher reliability from sensors directly to computers that, in turn, will have an expanded capacity in term of processing power. Individual companies will be able to introduce company-hosted 5G connectivity into their factories early in the technology's rollout. The resulting ability to link large quantities of data at extremely fast speeds to algorithms that can process them at equally fast speeds may prove as or more important than the improvements in sensor technologies themselves. In addition, faster data transmission can make sensors more mobile. AI and machine learning-based solutions increase the motivation for 5G to be implemented. ▶

⁶² Interview with Expert 4

⁶³ Amit Kumar Sikder, et al. A Survey on Sensor-based Threats to Internet-of-Things (IoT) Devices and Applications, arXiv: 1802.02041v1, February 6, 2018

⁶⁴ Xu, L., Xu, E. and Li, L. (2018), „Industry 4.0: state of the art and future trends“, *International Journal of Production Research* 56:8

⁶⁵ Interview with Expert 2

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Companies have to find the right strategy
in their data modeling approaches.

So far, companies have been reluctant to use Wi-Fi sensors because of questions about their reliability and quality. However, a major feature of 5G, which is primarily aimed at

communications networks for industrial use. A private network offers coverage limited to a plant's premises and can only be used for specific purposes. A public network allows external providers access to machinery as needed (eg, for remote servicing). The two networks use common infrastructure, reducing costs.⁶⁸

connecting objects to the internet, is that companies will increasingly own the wireless networks they use. This will have a big impact on business practices.⁶⁶ One aspect that corporate 5G networks can offer is the ability to link together geographically disparate manufacturing facilities to increase their ability to share tasks, resources, and assets in meeting customer requirements.⁶⁷

New use cases for sensors will be enabled as 5G is implemented. It will primarily be beneficial for sensors that need to be mobile.⁶⁹ According to EY *Digitalisierung in der Telekommunikation* report, the commercial rollout of 5G in the GSA region should begin in 2020 at the earliest. This will support the development of new digital factories, which not only automate processes through self-learning intelligent control systems, but also constantly improve them and thus continuously adapt them to new market and technology demands. For this, the industry needs reliable data and communication links that work almost in real time, ie, 5G.⁷⁰

Further examples of this trend are the '5G industrial campus networks' being rolled out by Deutsche Telekom and OSRAM, which consist of closed

Companies need to focus now on transforming their business practices and prioritizing Industry 4.0 and its methods.



Standardization

Standardization will allow devices to communicate with each other within a smart factory and along the value chain. There are perhaps 150 protocols for how sensors talk to their hosts. EU common standards in these areas are lacking.⁷¹ However, it is likely that the market, rather than regulators, will bring about standardization over time, not least because regulators would find it difficult to pick the winning sensor technologies.⁷² Standardization will not happen overnight, but when it does it will empower robust ecosystems of interconnected firms and devices that will be able to push forward the next generation of industrial manufacturing, enabling automated processes along the value chain. Companies cannot wait for standardization efforts of industry associations or other groups. Instead, they have to find the right strategy in their data modeling approaches while also allowing for inclusion of industry standards when they emerge.

Increased international competition, especially from US and Chinese companies with strong expertise in making efficient use of data analytics, means that GSA companies need to focus now on transforming their business practices and prioritizing Industry 4.0 and its methods. The need to communicate the data to human audiences means that German-language proficiency will remain important and lend an advantage in the domestic market to GSA sensor manufacturers. For example, Chinese firms may possess a huge amount of Mandarin-language data expertise, while their German language expertise may be less. However, that gap is likely to close quickly, especially as Chinese firms become more entrenched in the European business landscape.

Robots

Sensors are a crucial element in the next phase of integrating robotics into the manufacturing process. This involves the interface between humans and robots when they are working in close proximity, as the relationship between the two is a long way from reaching its full potential in terms of either efficiency or safety. This will require the wider application of 'formal methods', ie, the optimization of decisions by describing the entire production environment using mathematical models and then simulating changes to that environment. Once achieved, this will help to reduce costs and improve production flexibility. Factory management will require more mathematicians, data engineers and physicists. AI can help to create and update the formal models.⁷³

While already in use in many factories, integrating robots will be a long-standing challenge, especially as they become able to carry out a greater number of tasks and become 'smarter' thanks to advances in sensors, machine learning and AI.

Services

Firms that excel at analyzing data will be able to sell services based on sensor data and its interpretation. High proficiency in this area will be a competitive advantage for firms.⁷⁴ Some big companies are increasingly likely to offer IoT analytics to other big companies. For example, aerospace engine manufacturers, such as Boeing, have been selling predictive maintenance to airlines for a long time. Technology and business process consultancies will also offer their ability to understand data and processes as a service.⁷⁵

Additional revenue streams

Herterich et al examined eleven cases of cyber-physical systems giving rise to additional revenue streams beyond the original intent of manufacturing the product. In some cases, these are revenue streams derived from aftermarket servicing of the product, enabled by the product's continued linkage to the 'smart' production process and aftermarket data collection. These are classed as "Predict and trigger service activities", "Remote diagnostics", and "Optimization of field services". Firms have to decide whether to follow an "open systems" or "closed systems" approach to such aftermarket services - in other words, whether to keep the information and remediation proprietary (closed system) or open it to third parties. In other cases, the service spinoffs include the sale of data and insights derived from the firm's own cyber-physical system experience.

Source: Herterich et al 2015, p. 327

Traditional companies that are used to selling products are faced with challenges when transforming to a service-based company, eg, implementation of usage-based accounting systems and new legal and tax requirements. —

66 Interview with Expert 3

67 IEEE, *The Future of Industrial Communication*, March 2017

68 Telekom, *Premiere for the smart factory: Telekom and OSRAM launch Campus Network*, February 25, 2019

69 Michal Rutkowski, EY

70 EY, *Digitalisierung in der Telekommunikation*.

71 Jan Gudat, EY

72 Interview with Expert 1

73 Interview with Expert 2

74 Interview with Expert 4

75 Interview with Expert 4

The importance of scale

Amid a slow adoption of smart sensors, the technology will only see its potential achieved when it is widely used across individual companies and sectors. Insight from data, which across the world is being recognized as a new resource, will drive forward competition, innovation, and corporate profits. While physical sensors and soft sensors are by no means a 'holy grail' that will allow one company to succeed over another, their widespread use offers the tools to gather data and gain a competitive advantage.

Yet, in GSA, many executives at companies not yet using smart sensors and IoT devices believe that their adoption is not urgently needed. New innovations intended to assist companies to operate more efficiently may even be seen as a threat. Alongside this, the IoT and smart sensors are in many ways victims of 'hype', with pundits expounding on their use by using buzzwords in ways that undermine the potential benefits of these new technologies. Similarly, early adopters have used complex technical terminology that makes some companies question whether the IoT and smart sensors are the right solution for them. An 'if it's not broke, don't fix it' mentality can dominate business decision making and impede the implementation of Industry 4.0.

Instead, adoption of the IoT and smart sensors should be considered in the same context of the key question business leaders ask when considering strategy. What is the business objective? Ultimately, the

value offered by these technologies does not come down to the number of connected sensors. The real prize on offer is the incremental value creation that can be based on a range of data assets and the actionable knowledge extracted from the data. Therefore, successfully scaling IoT and smart sensor operations can better help a company achieve its objectives.⁷⁶

The scaling up of the IoT and smart sensor adoption within even a small group of companies can have an impact across an entire sector. For example, a company that gains knowledge from smart sensors could optimize its operations in a way that lessens their impact on the environment. Consistent success with this could provide a competitive edge to that specific firm, while also stimulating other companies in that sector to catch up by adopting IoT and smart sensors in a similar way.⁷⁷ Thus, the entire sector would benefit. —

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Insight from data, which across the world is being recognized as a new resource, will drive forward competition, innovation, and corporate profits.

⁷⁶ Vitalii Onoshko, EY

⁷⁷ Vitalii Onoshko, EY

Questions & Answers

Zied Bahrouni, Managing Director and Co-Founder at Motius GmbH, and external board member of the Innogy Digital Transformation Board



Can you describe how more GSA companies can integrate the IoT into their products?

Consider that most of the companies that work in the IoT today come from a hardware legacy. For them, it is very rarely a question of “let’s go to market with an IoT device and make money off it”. Instead, it is more a question of how to turn hardware that they are already producing into an IoT device by adding connectivity and sensors. This is an approach seen in some sectors, such as automotive, over the past seven years or so. It has never been the case of rolling out a new IoT product with a finished business plan. The strategy has always been about making the product more usable, and also generating more data, with the hope of building a business strategy for that data later. That is the second phase of IoT adoption.

Why do specific companies need customized software to gain the most from the IoT?

Our company does deep tech work, which always involves software. It almost always has embedded hardware or a mechanical backbone. Operator-driven software, machine learning in an industrial context, that is the type of

software that we develop. That is mainly custom-made software. The need for it is clear because you do not have a lot of off-the-shelf solutions that meet the needs of individual companies. There is still a lot of development necessary. And, of course, a lot of those technologies are still relatively young, so there is a big need for customization for each use case.

What is the biggest challenge integrating smart sensors in GSA industry?

The hardware-centric mentality in GSA is the biggest challenge. Also, building the in-house software capabilities is a challenge. This requires a cultural change. If you have been a small industrial company in rural Bavaria for the last 100 years, it is difficult to attract the best IT talent.

How do you go about choosing a sensor for a particular use case?

Sometimes you have to develop them yourself if the need is very niche. You can buy components off the shelf and build the sensor yourself. Most of the time though, you can directly purchase the sensors that you need. The environmental sensors that we used for a project in Dubai, those were sourced from suppliers in Asia and Europe. Sensors are not the problem most of the time, nor are finding the components for customized sensors. Now and then a new breakthrough comes, and you will have a new software that senses something that you have not been able to sense or there is a significant price or size reduction. Or, in extreme cases they can sense something that you have not been able to sense before. You come back to the software question of what you can make out of the data that you collected. Also, an architectural challenge comes. Can you do this in real time? Where do you save the data? What is the communication between the sensor and the back-end and the front-end and some hardware device somewhere else? Can you save bandwidth? These questions are all an architectural challenge. —

Questions & Answers



Christof Brunner,

President and CEO at LTW Intralogistics, Inc.

What kind of appetite do you see in GSA countries for smart factories?

In the GSA market the level of automation is already quite high. Investing in technology like our Automated Storage and Retrieval Systems (ASRS), is one of the last steps that companies do. Investing a huge amount of money into an ASRS system does not necessarily enhance your production capabilities or give you more resources. It does improve the process and make it more efficient.

It is highly sector dependent though. Take the automotive industry, for example: Those are huge companies and they already have a lot of very well-defined processes. From an economic perspective, automation is nice because manual labor always includes the possibility of failure. If you have a business that is appropriate for automation it will of course improve efficiency. Ultimately, automation needs people to maintain the system, who do the programming, who are behind the logic, who are designing the processes. Especially because the business environment changes constantly. Consumer demand changes. You need to be very adaptive these days to design new products. In terms of automation, this means that you will consistently need to rethink your processes.

What are the sectors that could improve the most in terms of the IoT?

The transportation and logistics sectors will benefit hugely from the automation that smart sensors make possible. There is a beautiful project in Switzerland called Cargo Sous Terrain. It is the holy grail of cargo transport automation. Around Zurich there is a lot of traffic. The concept is to get transport underground and make it fully automatic. You have distribution centers at some points. But the main transport is underground. You will not have traffic on the streets any more. You will gain valuable space. Also, if you had an automated system that could load and unload container ships, you could save money. Now it is not done efficiently. Of course, these are very expensive and involve large investments. The political issue with these systems is that many of the huge harbors and railway stations are subsidized heavily by government. That is of course a barrier to the implementation of automation.

How can data assist the service that you offer and also empower you customers?

Data is very important for us. Many customers are not aware of the data that they have to provide. Our service is only effective if we get the right data regarding products in a warehouse. What is the product? What is the volume? How long will it be stored? The more precise the information is, the better the whole system works. An automated system is only as good as the input it gets. In recent years we have had many more customer inquiries about wanting to have the data gathered by our systems. They want to monetize it. Even heavy industry wants to use it. They want as much data as they can in order to improve their own processes. We are of course working in this direction, to help customers collect data and use it. —

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Changing corporate needs

If smart sensors are at the heart of smart factories, human workers will remain the brain. Many companies invest a lot of money in new technologies for their factories. Yet they also need to consider what the impact will be on their workers in terms of the need for new training. A company is also likely to need to expand its existing skills base through the hiring of external talent.⁷⁸

Certain types of traditional jobs will be reduced, while new jobs will be created. The number of jobs in operations planning is likely to drop as sensors can monitor an entire supply network. Similarly, production planning jobs will decrease along with human roles along the assembly and production line and back office administration. Quality control jobs will be reduced as data allows for waste reduction. However, across many industries there will continue to exist the need for many high-skilled and other jobs that cannot easily be replaced by automation. The data obtained from smart sensors has little value without those engineers and data scientists to correctly interpret and communicate it. These individuals will use a range of skills - from writing new applications to creating visualizations - to separate the signal from the noise and harness data to drive cross-departmental collaboration, as well as cooperation along the value chain.

Overall, employees will need to have a flexible outlook, engage in active learning, and have high cognitive abilities and be literate when it comes to digital technologies. Examples of new types of jobs include robot

coordinators, industrial data scientists, supply chain coordinators, and simulation experts, along with digitally-assisted service engineers.

Technical skills

Employing workers able to understand how to work with data and make correlations between processes will be critical. While companies have machines and staff for their current operations, they often lack data scientists who have the ability to obtain the most powerful insights from the data gathered by sensors. Skills that allow people to 'get inside' the data and extract value will become a critical resource. Reflecting their increasing importance to smart manufacturing, engineers with relevant skills are becoming increasingly expensive.⁷⁹ In the future, the number of graduates with Industry 4.0 skills will need to rise to keep up with the demand.

IT teams

One approach being considered by some firms navigating the digital transformation is to stop the IT department from being walled off from other operations. Instead, IT staff can be embedded directly within teams working on a specific task in order to smooth operations and build digital capabilities from the onset of a project or on a continuous basis. This approach is more efficient compared to logging requests with a separate IT department or, for example, getting the cyber security-related elements of the project signed off only after it is complete, and then needing to update based on feedback

from the relevant IT staff. Instead, being sure that teams have the IT and technology skills present on an ongoing basis means addressing issues earlier and creating a more seamless process.

Communications skills

Individuals who are successful in communicating insights produced by data can be seen as bridge builders within firms. Such individuals will be critical in driving forward smart manufacturing. Most importantly, communications must improve between leading decision makers and those with the more technical skills related to smart manufacturing; at present these two key stakeholders in the digital transition often 'talk past each other', because they have very different communications skills sets, built up over many years: corporate executives tend to have strong soft skills, while technical specialists may lack these; conversely, corporate executives are often unable to translate business problems into 'computational' terms that can be incorporated into decision making around smart products and smart factories.⁸⁰ In all likelihood, there is going to be a sharp rise in demand for staff skilled in internal corporate communications (and also external communications) who can understand the languages of both sides and facilitate communication between the two, as well as across the company more broadly and outside the company. —

⁷⁸ Ivan Hernandez, EY

⁷⁹ L. Bonekamp, M. Sure: *Consequences of Industry 4.0 on Human Labour and Work Organisation*

⁸⁰ *Harvard Business Review, Why AI Underperforms and What Companies Can Do About It, March 2019*

Embracing change

Integrating Industry 4.0 often brings significant changes for companies. Reluctance to change may be a natural human trait, but it is exactly such willingness to embrace change that companies need to foster at all levels.

Many industrial companies have a very niche market. Instead of asking why the company should become part of Industry 4.0, workers should be encouraged to think how their company can benefit from Industry 4.0. Ultimately, building digital capabilities into a company's current products and experimenting to discover use cases for the data at a later stage will be the only way to stay competitive in tomorrow's technology-enabled business environment.⁸¹

“

It is exactly such willingness to embrace change that companies need to foster at all levels.

Automotive sector strategy

Twenty years ago, workers joined GSA automotive companies because they were fascinated by cars and wanted to work as car engineers. The conversation in the automotive industry then shifted to questioning whether being satisfied with producing hardware - vehicles - was adequate when other companies were producing software that not only enhanced the consumer's experience but offered feedback on the product experience. The conclusion was that the automotive manufacturers would add digital services. Companies in the sector have even changed their self-description, and now refer to themselves as mobility companies, signaling that they offer a broader range of services than just vehicles.

However, while this change in strategy has occurred, many of the people that work for GSA car manufacturers are still car engineers. The firms are building departments dedicated to digital services. Many workers who were not previously in the automotive industry are now working with GSA manufacturers to build digital services based on the products - the vehicles - that companies already have. Today, the car has become more of a digital product, and the industry's path serves as an instructive example for others.

Even after companies have spent millions of euros on sensors and IoT systems, arguments can still break out regarding how they should be used.⁸² Within the automotive sector, which is rapidly becoming more advanced when it comes to the implementation

of Industry 4.0, those working to make the digital transition real have over time found increasing support. Budgets, recognition from colleagues, cooperation with other departments to help in rolling out various initiatives - all may have been lacking in the

past, but today are starting to fall into place.

Today, digitalization is the top priority for automotive companies. Inter-departmental education, lobbying, and awareness building all had to take place in order to make the transition toward digitalization. For example, tele-operated driving solutions exist that allow a worker to take control of an autonomous vehicle if it becomes stuck and the occupant, perhaps a child or person without a license, cannot take control. The solution combines the use of a range of sensors with augmented reality.⁸³

⁸¹ Interview with Expert 6

⁸² Interview with Expert 5

⁸³ Interview with Expert 6

Optimizing work with technology

Smart sensors are not very expensive. It is more expensive to employ the data scientists to work on the data gathered by the sensors. A byproduct of the automation that sensors allow, these new job roles will be focused on 'making sense' of the data and communicating it. The result will be more interaction and integration between departments and along the value chain, and less-siloed thinking as the data and analytics will break down reasons for a lack of collaboration. Key Performance Indicators (KPIs) may need to be adjusted as new goals are set for individuals and teams when new technologies come online.⁸⁴

Firms will have to decide if a company's own staff should work on the data or if consultants should be hired to do it. Companies that successfully use software either in their products and factories can supplement their workforce to a degree by outsourcing. A software engineer can perform work for GSA companies from Vienna, Zurich, or Mumbai. Yet, companies with bigger operations will need to invest in a sophisticated in-house software department, highlighting the need to build up such skills.⁸⁵

Firms tend to take one of two different approaches when it comes to the IoT and the impact on employees:

1

There are the companies that focus on using technology to augment their current employees, looking at how technology can have a positive role in helping workers to create more value. These companies offer employees the training and development necessary to make this approach possible.

These two different strategies - augmentation or automation - will be chosen based on the business objectives of a company. It should also be noted that the mass use of robots across sectors will take time - possibly more than 20 years.⁸⁶ For now and in the coming years, people will need to be present alongside robots and other hardware. —

Exposure to technology will help existing workers adjust to Industry 4.0.

2

Then there are companies that are heavily focused on automation. These firms would like to replace humans with robots as much as possible in order to expedite workflows. Jobs that are automatable are likely to see a shift to being carried out by hardware (robots) or software (algorithms). The cost savings aspect of this is likely to be seen as an opportunity by any company that can effectively harness these technologies. However, even in these companies, new jobs related to data analysis, directing automated processes, and internal and external communications will emerge.



84 Ivan Hernandez, EY
85 Interview with Expert 5
86 Ivan Hernandez, EY

Expansion of HR function

As companies look to implement more digital skills into their workflows, human resources (HR) departments are likely to expand and take more of a central role in retraining existing workers, external hiring to build digital capabilities, and fostering an environment that promotes more seamless cross-departmental collaboration and communication. Building trust among various types of workers will be HR's most critical task.

Many GSA workers who have not worked with digital systems in the past are likely to be able to use new technologies. Some have a technical background and curiosity, and they may not face major hurdles learning new technologies. Still, accepting a new type of role and learning the necessary skills takes time. Someone who has worked for twenty years as a hardware engineer is unlikely to become a professional coder, a very difficult discipline. Given the right approach, which will be led by HR, it will be possible to train such a worker to operate in a more interdisciplinary way, for example by introducing work management methods that are compatible with software and hardware.⁸⁷

Promoting interdisciplinary work methods and exposure to technology will help existing workers adjust to Industry 4.0. Even individuals who are not expected to become coders or to analyze sensor data could be given the opportunity to attend a course on these subjects, in order to make them more comfortable with them and able to better coexist with the workers who are focused on digital tasks.⁸⁸

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Ideally, everyone needs to be motivated and digitally-enabled in order to succeed in the journey.

It is therefore important that each company's HR department is considered a trusted asset by the entire range of workers. The role of HR will include:

- ▶ Support for workers as they frequently retrain to develop new skills and qualifications.
- ▶ Hiring employees with skills immediately applicable to Industry 4.0.
- ▶ Institutionalizing better cross-departmental communication.

The exact balance of skills required will vary on a company by company basis. However, a different type of skilled labor will be needed, and HR can take the lead in reshaping a company's workforce.

Over time, the broader adoption of Industry 4.0 will create the type of workforce necessary to meet its needs. Along with companies potentially supporting university departments to foster specific skills, or even opening their own academies to create a pipeline of employees, this will be achieved by thinking far enough ahead in terms of planning the need for workers, an objective HR can achieve. HR will drive what is increasingly recognized as an obligation on the part of companies to support their workers through this transition. The companies that do not can expect to encounter massive difficulties in the coming years related to their workforce. Many different approaches exist within companies that aim to transform and operationalize innovation. Ideally, everyone from senior management to shop floor personnel needs to be motivated and digitally-enabled in order for the company as a whole to succeed in the journey. —

⁸⁷ F. Hecklau, M. Galeitzke, S. Flachs, H. Kohl: *Holistic approach for human resource management in Industry 4.0*

⁸⁸ Interview with Expert 6

Quantifying the impact

49 Methodology

50 Impact on profitability

Methodology

Our quantification of the impact of sensors over the period to 2030 considers nine sectors: Industrial products and machinery, consumer goods and electronics, ICT, automotive, construction, real estate, chemicals, logistics, and power and utilities.

For each of these sectors in GSA we estimated the percentage increases in EBITDA margin that could result from smart manufacturing techniques. By increasing current sector-average EBITDA by these increases, we report

the EBITDA margins of these sectors under three scenarios of implementation of smart manufacturing techniques. In EY model, sensor impact on margin is derived from cost-savings impact, assessed on the basis of nine drivers of sensor adoption identified during the research and interviews for this study (see Table 1).⁸⁹ These nine drivers have different strengths in terms of their impact on sensor adoption, and their applicability across sectors also varies. This is all captured in EY modeling (see Appendix).

EY analysis will help companies to judge whether they are likely to be ahead of the curve, in line with their competitors, or behind the curve on sensor adoption, and what that means for their potential profitability relative to their peers. —

89 We examined revenue-expansion impacts, for example due to after-sales services and increased responsiveness to market changes but exclude them here due to their smaller size and lack of adequate data points

Nine drivers of sensor adoption

Workforce preparedness in 2019	The data provided by sensors alone is insufficient to drive value. A well-trained, capable workforce is required to analyze, communicate and react to the data provided by sensors. In sectors where the current level of sensor adoption is already higher than in others, the workforce is likely to have relevant experience already. The ICT sector is a good example of this.
Speed of product replacement	In some sectors (eg, consumer goods and electronics) products are replaced frequently. This provides more opportunities for sensors to be used or added to new products. In sectors where products are replaced only infrequently (eg, power plants), it may take longer for sensors to be adopted.
Complexity of production process	Generally, complex production processes provide more opportunities for efficiency gains from adoption of sensors.
Potential for product customization	Where the potential for customization is high, this creates more opportunities for sensor adoption to drive revenue growth.
Competition (incl. disruption from new players)	A high level of competition, especially from disruptive newcomers, may force existing industry leaders to speed up their adoption of sensors to survive, as is currently happening in the automotive sector.
Danger to humans-/need for safety compliance	In sectors such as chemicals, where working conditions during the production process may present dangers to humans (eg, from heat or toxic fumes), sensor adoption is likely to be higher. To some degree, this has already been a strong driver of adoption, but it will remain a driver in future.
Waste generation	Where a production process generates a lot of waste, there is often potential for optimization/waste reduction through increased use of sensors.
Potential for reversal of offshoring trend	In some sectors, sensor adoption may be related to the potential for reshoring of production to GSA. Sensor adoption could be both a driver of reshoring and be driven by it.
Potential for value chain integration	Long value chains may have a higher potential for optimization, and therefore sensor adoption, than shorter ones.

Impact on profitability

We project low, medium and high implementation scenarios for smart-manufacturing implementation. These correspond to realization of 25%, 50% and 100% respectively of the potential (maximum) cost savings identified in EY model. In other words, under a high-implementation scenario, all of the percentage increase in EBITDA margin indicated by EY model is realized by the sector; under a low-implementation scenario, only 25% of the cost savings are realized. In order for companies not to be left behind as smart manufacturing progresses, we regard the low-implementation scenarios as the minimum level of implementation

needed; but to do well, companies should aim for the high-implementation scenario.

EY model suggests that the improvement in profitability from sensor adoption by companies in GSA will be significant in the coming years, across a range of sectors. Under the high-implementation scenario, the EBITDA margin could increase by 11%-34% across the sectors (see Figure 1). This is the percent increase in EBITDA margin as a percent of revenue; it is not the percentage-point increase in EBITDA.

Figure 1: Potential percentage increase in EBITDA margin under three scenarios, 2019 - 2030

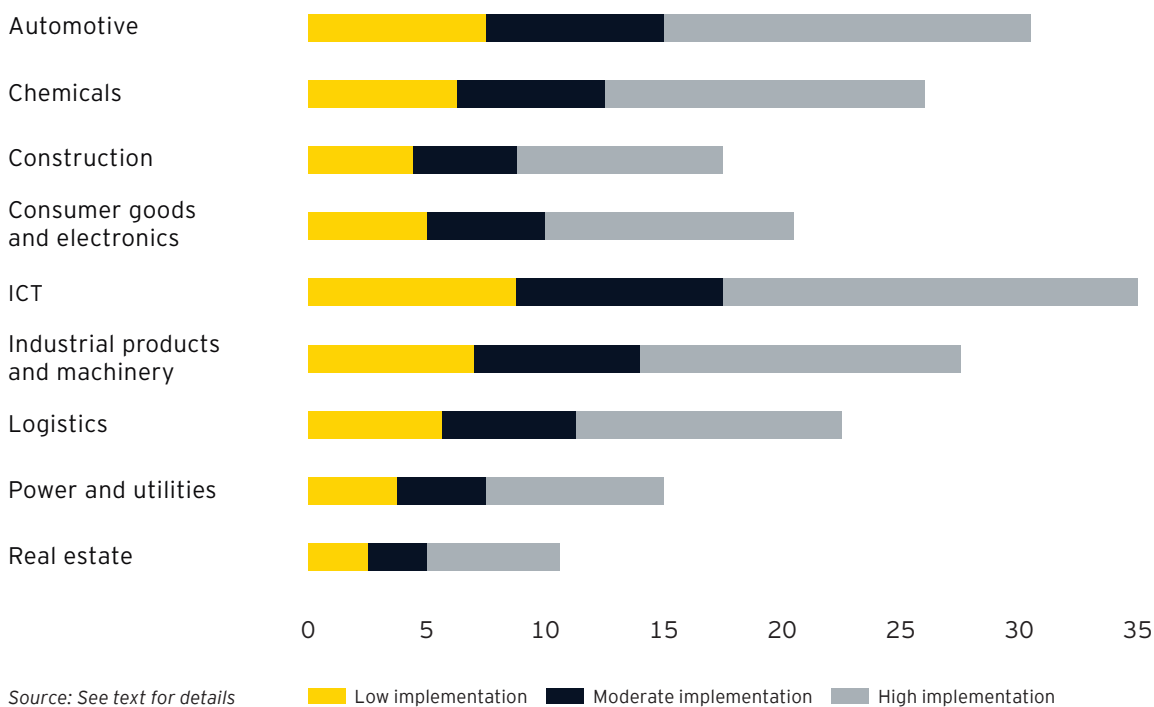
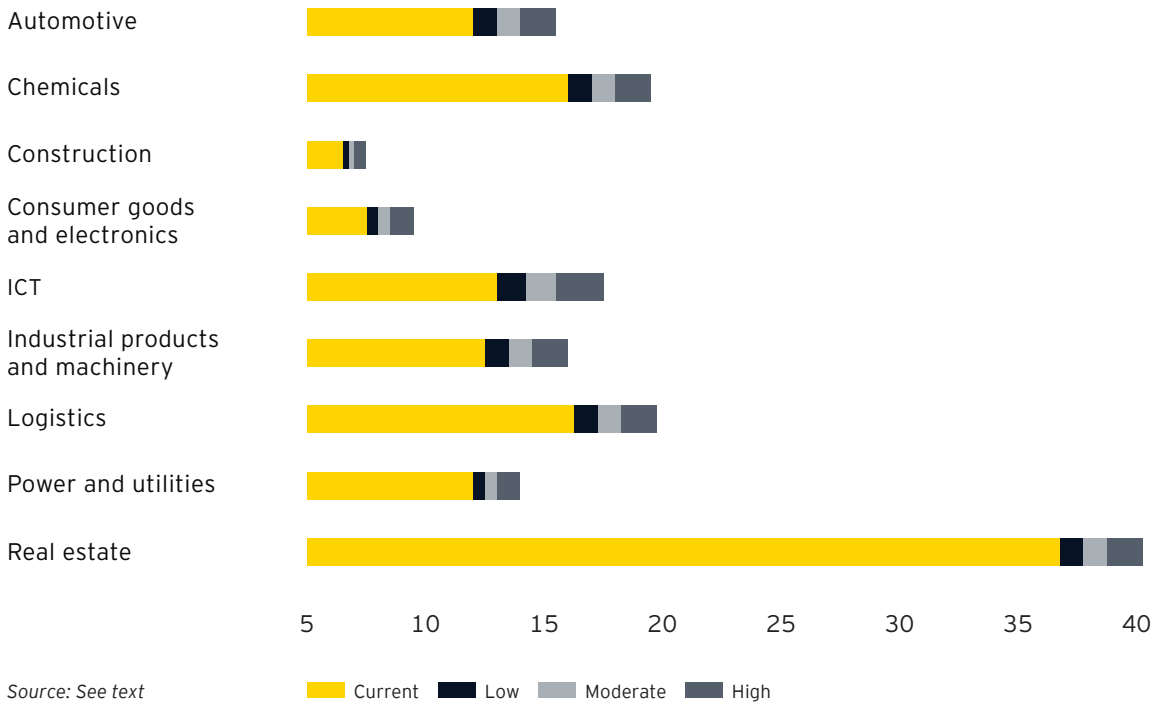


Figure 2: Potential EBITDA (% of revenue) in 2030 with implementation of sensors



The biggest impact in terms of boost to the EBITDA margin is likely to be felt in industry, with the automotive and ICT sectors seeing a potential of over 30% increase in EBITDA margin. Industrial products and machinery is not far behind, at more than 25% increase in EBITDA margin.

Figure 2 shows the corresponding percentage increases in EBITDA by 2030 under the three scenarios. EBITDA as a percentage of revenue in the ICT sector is set to jump from 13% to 17% under a high implementation scenario, and in the automotive sector from 12% to 15%. In industrial products and machinery, the corresponding increase is from 12% to 16% and in chemicals from 16% to 20% (see Appendix for the increases in each of the nine sectors).



The improvement in profitability from sensor adoption by companies in GSA will be significant in the coming years, across a range of sectors.

90 Average of 10 years ending 2018 (GSA listed companies over 50 million US dollars in revenue)

This study has explained the significant potential for profitability improvement that lies in the adoption of sensor technologies. In order for GSA companies to become global leaders in Industry 4.0, business and government have to jointly drive the required innovation, for example to increase the speed in deploying 5G, to implement supportive legislation, and to create a new type of workforce.

The opportunity is primarily a technological one and realizing the potential gains will require a deepened understanding by companies not only of the technology itself, but also of how to integrate that technological change and its impacts into corporate strategy, operations, and processes. Further prerequisites for a successful transition to a smart manufacturing company are a refining of corporate culture and a

refreshed focus on human capital. In other words, translating the opportunities offered by sensor adoption into higher corporate margins will require actions in each of EY Five Fields of Play. —

Conclusion: Call to action

Changing Corporate culture and talent

WHAT DO COMPANIES NEED TO DO IN A 'SMART PRODUCTS, SMART FACTORIES' WORLD?

- ▶ Increase worker responsiveness to data insights
- ▶ Train and hire people who can generate value from data and analytics

CALL TO ACTION

- ▶ Expand internal communications functions to ensure different functions talk more to each other
- ▶ Give HR function more decision-making power, to react fast to emerging trends and needs

Leveraging data and technology

WHAT DO COMPANIES NEED TO DO IN A 'SMART PRODUCTS, SMART FACTORIES' WORLD?

- ▶ Remain at leading edge of technologies that facilitate sensor-led business transformation, including AI, the cloud, robotics and 5G
- ▶ Promote use of soft sensors

WHAT DO COMPANIES NEED TO DO IN A 'SMART PRODUCTS, SMART FACTORIES' WORLD?

- ▶ Move IT function from a centralized function to one that is embedded in business functions
- ▶ Set up new teams to rapidly test use-cases for sensor-driven products and service improvements, and then quickly scale up success stories
- ▶ CEO-mandated initiative to create harmonized data lake for whole company; Chief Information Officer to coordinate its implementation

Rethinking the strategy

WHAT DO COMPANIES NEED TO DO IN A 'SMART PRODUCTS, SMART FACTORIES' WORLD?

- ▶ Facilitate sensors are adopted at scale
- ▶ Identify new sensor data-based services
- ▶ Target fully-harmonized sensor environment and corporate data lake
- ▶ Foster a data- and analytics-centered mindset and culture

CALL TO ACTION

- ▶ CEO to ensure full commitment from all function heads
- ▶ Develop the digital understanding of the Corporate Board; consider establishment of a Board-level digitalization committee
- ▶ Chief Strategy Officer to work closely with Finance function to base strategy more on data-based insights and less on human judgement

Transforming operating models

WHAT DO COMPANIES NEED TO DO IN A 'SMART PRODUCTS, SMART FACTORIES' WORLD?

- ▶ Target greater customization of products and services
- ▶ Continuously improve products and services based on demand and feedback
- ▶ Reduce equipment downtime through predictive maintenance

CALL TO ACTION

- ▶ Chief Financial Officer to become Chief Value Officer, providing data and analytics to business functions for better decision making
- ▶ Business functions to become more open to sharing data and business knowledge with other functions

**EY
Field of Play**

Transforming and running Control and Support functions

WHAT DO COMPANIES NEED TO DO IN A 'SMART PRODUCTS, SMART FACTORIES' WORLD?

- ▶ Improve quality control
- ▶ Reduce waste
- ▶ Improve understanding of cost structures

CALL TO ACTION

- ▶ Control and Support functions to become heavily automated
- ▶ Control and Support staff to develop more forward-looking, strategic roles, based on predictive analytics

Methodology

Our quantification of the impact of sensors over the period to 2030 considers nine sectors: Industrial products and machinery, consumer goods and electronics, ICT, automotive, construction, real estate, chemicals, logistics, and power and utilities.

For each of these sectors in GSA we estimated the percentage increases in EBITDA margin that could result from smart manufacturing techniques. By increasing current sector-average EBITDA by these increases, we report the EBITDA margins of these sectors under three scenarios of implementation of smart manufacturing techniques.

EY analysis will help companies to judge whether they are likely to be ahead of the curve, in line with their competitors, or behind the curve on sensor adoption, and what that means for their potential profitability relative to their peers.

EBITDA impact

We report the average EBITDA of firms in GSA by sector over the recent ten-year period or less (depending upon firm history) and exclude outlying observations indicative of large investment projects or start-up losses. The data is based on sector averages from a sample of over 600

Table 1: Driver applicability scores	Auto- motive	Chemicals	Con- struction
Workforce preparedness in 2019	3	3	1
Speed of product replacement	3	3	1
Complexity of production process	3	3	1
Potential for product customization	2	3	2
Competition (incl. disruption from new players)	3	2	2
Danger to humans-/ need for safety compliance	3	3	3
Waste generation	3	3	3
Potential for reversal of offshoring trend	1	2	1
Potential for value chain integration	3	3	2

1=low applicability 2=medium applicability 3=high applicability

firms from GSA with revenues of 50 million dollars (44 million euros) or more.⁹¹ We then increase these margins for the period 2019-2030 by the percentage indicated in our sensor-impact analysis (see below).

Sensor-impact analysis

In EY model, sensor impact on margin is derived from cost-savings impact.⁹²

We first derive the weighted sum of driver impacts of sensor adoption. This weighted sum is the combination of the applicability of each driver to each sector (see Table 1) and the importance weights of the drivers (see Table 2, page 56). Both the appli-

cability scores and the importance weights are derived from the judgements of members of our academic and industry expert panel interviewed for this report, combined with the judgements of Oxford Analytica's in-house team who conducted the research and interviews for this study.

Drivers of sensor adoption

The nine drivers of sensor adoption, identified during the research and interviews for this study, are listed in Table 2, page 56. The list also reports the importance weight attached to each driver based on judgements provided by members of our expert

panel combined with the judgement of the Oxford Analytica panel. When the applicability scores are multiplied by the importance weights, their sum is the driver-importance-weighted applicability of each driver to each sector (referred to as 'driver importance' below). This sum by definition falls in a range of 1 to 3 since the weights add up to 100%.

The driver-importance proportion ('driver importance') is then the importance-weighted sum of driver impacts divided by the maximum possible (ie, if every driver were rated "3" for every sector). The driver importance scores are summarized in Table 3, page 56. —

	Consumer goods and electronics	ICT	Industrial products and machinery	Logistics	Power and utilities	Real estate
	2	3	3	2	2	1
	2	3	1	2	2	1
	2	3	2	3	2	1
	2	3	3	3	2	2
	3	3	2	2	1	2
	1	1	3	2	3	3
	3	3	3	1	2	3
	1	2	2	2	2	1
	2	3	3	3	2	2

⁹¹ To check the robustness of these averages, we compared them to other publicly-available sources, including the FCF Valuation Monitor (a survey of small & mid-cap companies in 2018), SageWorks and FactSet. We are satisfied that our averages are sufficiently in line with these other datasets

⁹² We examined revenue-expansion impacts, for example due to after-sales services and increased responsiveness to market changes, but exclude them here due to their smaller size and lack of adequate data points

Table 2:**Nine drivers of sensor adoption**

	Driver description	Weight
Workforce preparedness in 2019	The data provided by sensors alone is insufficient to drive value. A well-trained, capable workforce is required to analyze, communicate and react to the data provided by sensors. In sectors where the current level of sensor adoption is already higher than in others, the workforce is likely to have relevant experience already. The ICT sector is a good example of this.	7%
Speed of product replacement	In some sectors (eg, consumer goods and electronics) products are replaced frequently. This provides more opportunities for sensors to be used or added to new products. In sectors where products are replaced only infrequently (eg, power plants), it may take longer for sensors to be adopted.	4%
Complexity of production process	Generally, complex production processes provide more opportunities for efficiency gains from adoption of sensors.	11%
Potential for product customization	Where the potential for customization is high, this creates more opportunities for sensor adoption to drive revenue growth.	15%
Competition (incl. disruption from new players)	A high level of competition, especially from disruptive newcomers, may force existing industry leaders to speed up their adoption of sensors to survive, as is currently happening in the automotive sector.	28%
Danger to humans- / need for safety compliance	In sectors such as chemicals, where working conditions during the production process may present dangers to humans (eg, from heat or toxic fumes), sensor adoption is likely to be higher. To some degree, this has already been a strong driver of adoption, but it will remain a driver in future.	13%
Waste generation	Where a production process generates a lot of waste, there is often potential for optimization/waste reduction through increased use of sensors.	9%
Potential for reversal of offshoring trend	In some sectors, sensor adoption may be related to the potential for reshoring of production to GSA. Sensor adoption could be both a driver of reshoring and be driven by it.	5%
Potential for value chain integration	Long value chains may have a higher potential for optimization, and therefore sensor adoption, than shorter ones.	10%

Table 3: Driver importance by sector

	Sum of weighted drivers	Percent of full-impact
Automotive	2.75	92%
Chemicals	2.68	89%
Construction	1.95	65%
Consumer goods and electronics	2.19	73%
ICT	2.70	90%
Industrial products and machinery	2.49	83%
Logistics	2.28	76%
Power and utilities	1.85	62%
Real estate	1.95	65%

max possible = 3

Cost savings

Cost savings are based on categories and data ranges obtained during an interview with an EY professional⁹³. We vary these cost savings across sectors, staying within the indicated range (see Table 4).

To fine-tune the cost savings, we weight the cost savings by cost-importance weights, which vary by sector (see Table 5). These cost-importance

weights were derived from the judgements of members of our expert panel interviewed for this report, combined with the judgements of Oxford Analytica's in-house team who conducted the research and interviews for this study.

By summing the product of the cost-importance weights (Table 5) and the cost savings percentage

impacts (Table 4), we arrive at a maximum cost impact by sector. To get the expected cost impact, we multiply this weighted sum by the 'driver-importance proportion' for each sector (Table 3). —

93 Jan Gudat, EY. The figures are based on cross-sector project experience and are estimates only

Table 4: Cost savings possible in each sector, 2019-2030 (%)

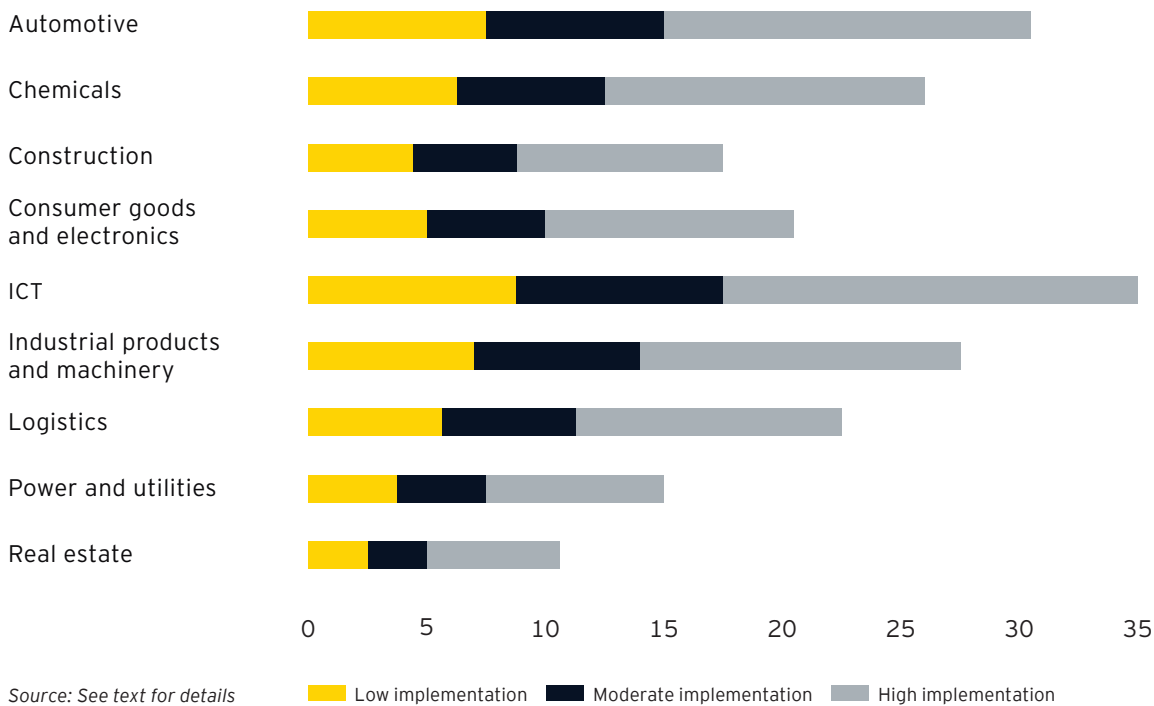
	Inventory	Production	Logistics	Complexity	Quality	Maintenance
Automotive	35	20	15	70	20	30
Chemicals	35	15	15	65	10	25
Construction	35	10	20	65	10	20
Consumer goods and electronics	35	20	15	65	20	25
ICT	35	20	15	70	20	25
Industrial products and machinery	35	20	15	70	15	30
Logistics	30	10	20	70	10	20
Power and utilities	30	10	15	60	10	30
Real estate	30	10	10	60	10	20

Table 5: Cost-importance weights (%)

	Inventory	Production	Logistics	Complexity	Quality	Maintenance
Automotive	20	20	20	20	10	10
Chemicals	20	20	20	20	10	10
Construction	30	5	30	10	20	5
Consumer goods and electronics	30	20	20	10	10	10
ICT	20	20	10	30	10	10
Industrial products and machinery	20	20	20	20	10	10
Logistics	10	10	50	20	5	5
Power and utilities	10	20	10	5	5	50
Real estate	5	25	25	5	10	30

Impact on profitability

Figure 1: Potential percentage increase in EBITDA margin under three scenarios, 2019 - 2030



Total EBITDA percentage improvement in 2019-2030 is derived from the proportion of applicability of drivers in each sector multiplied by the total cost impact.

We project three scenarios for smart-manufacturing implementation: low, medium and high implementation. These correspond to realization of 25%, 50% and 100% respectively of the potential (maximum) cost savings identified in EY model. In other words, under a high-implementation scenario, all of the percentage increase in EBITDA margin indicated by EY model is realized by the sector; under a low-implementation

scenario, only 25% of the cost savings are realized.

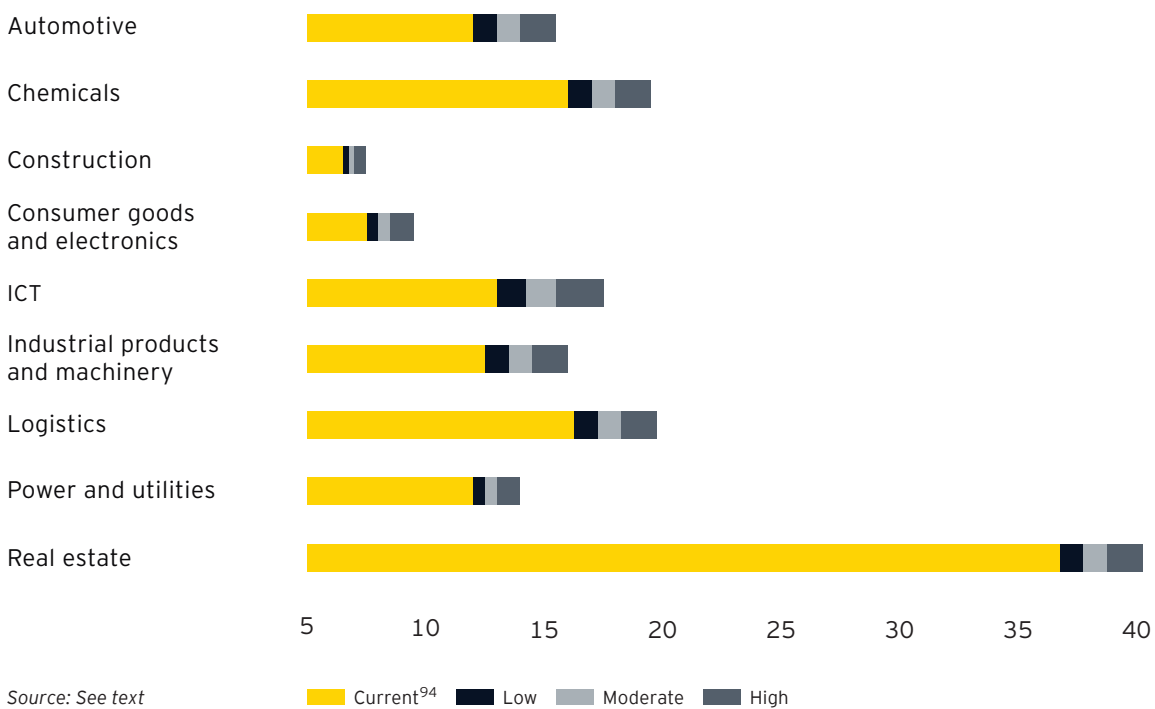
EY model suggests that the improvement in profitability from sensor adoption by companies in GSA will be significant in the coming years, across a range of sectors. Under the high-implementation scenario, the EBITDA margin could increase by 11%-34% across the sectors (Figure 2). This is the percent increase in EBITDA margin as a percent of revenue; it is not the percentage-point increase in EBITDA.

The biggest impact in terms of boost to the EBITDA margin is likely to be

felt in industry, with the automotive and ICT sectors seeing a potential of 30% or more in EBITDA margin. Chemicals, along with Industrial products and machinery, are not far behind, at more than 25% increase in EBITDA margin. —

94 Average of 10 years ending 2018 (GSA listed companies over 50 million US dollars in revenue)

95 Current is last 10 years depending upon company age; excluding startup years or high-investment years

Figure 2: EBITDA (% revenue) in 2030**Table 3: Margin impacts, current margin and future margin (high-implementation scenario) by sector**

	% EBITDA improvement	EBITDA (% revenue) current and 2030 ⁹⁵
Automotive	30	12 to 15
Chemicals	26	16 to 20
Construction	17	6 to 7
Consumer goods and electronics	21	8 to 10
ICT	34	13 to 17
Industrial products and machinery	27	12 to 16
Logistics	22	16 to 20
Power and utilities	15	11 to 13
Real estate	11	36 to 40

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