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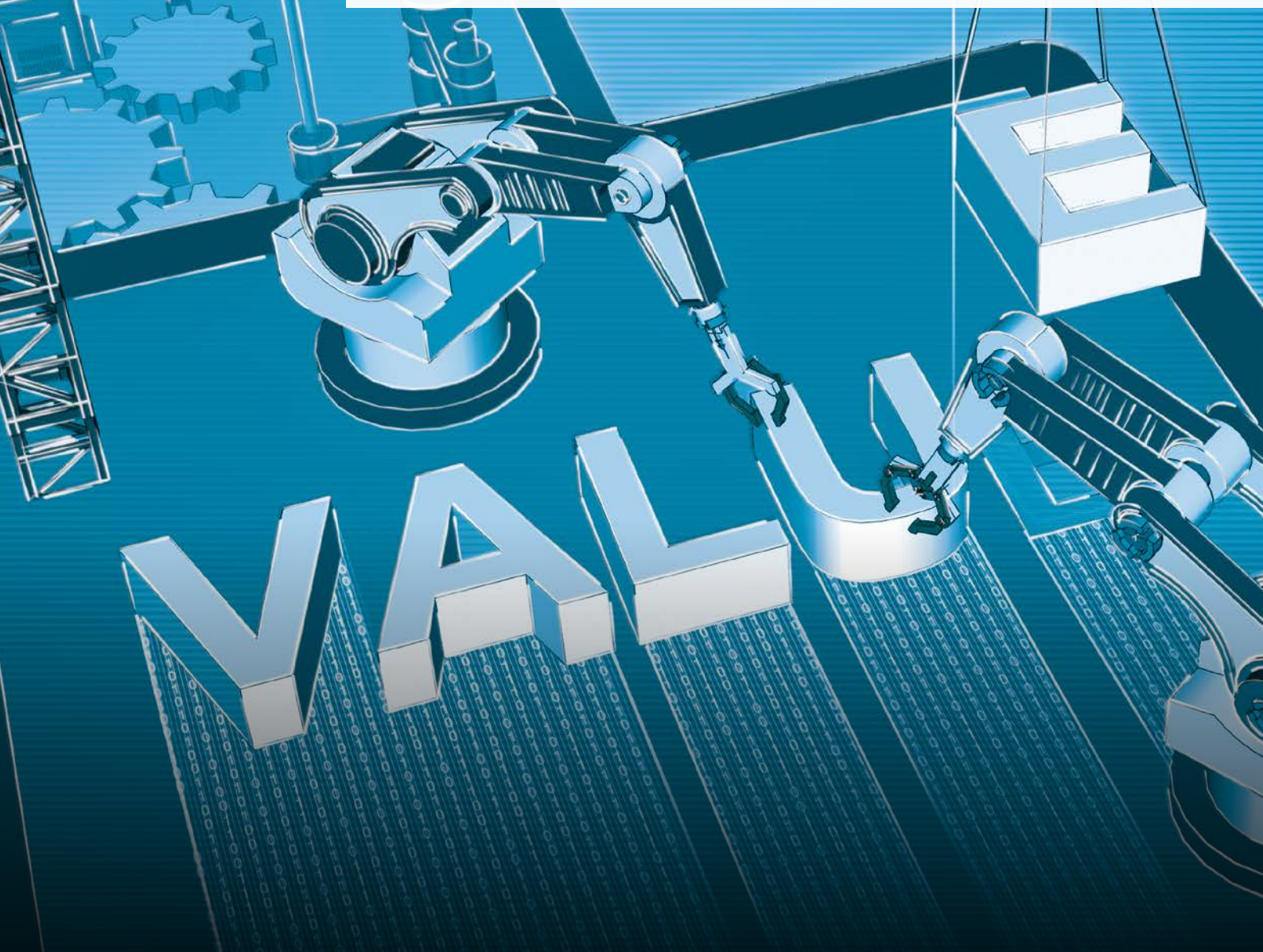
# Industry 4.0 after the initial hype

## Where manufacturers are finding value and how they can best capture it

McKinsey Digital

2016



# Industry 4.0 after the initial hype

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# Introduction

A lot of positive hype has built up around Industry 4.0 over the last few years, creating awareness of the topic within many companies and contributing significantly to the rejuvenation of "good old industry" in the public mind. In its aftermath, industry leaders remain optimistic overall, but a degree of disillusionment has also crept in as the actual implementation results so far are mixed.

On the one hand, we still see high uncertainty among manufacturers regarding what implementing Industry 4.0 really requires of them – and many are still struggling to even get started. On the other hand, most technology suppliers have moved relatively fast in adjusting their portfolios towards Industry 4.0. We are also seeing a growing number of manufacturers report substantial progress, especially when moving beyond the Industry 4.0 umbrella term and focusing on valuable, business-specific applications. To get there, many clients have told us they have even renamed their "Industry 4.0" projects to shake off an initial sense of disillusionment while keeping the elements that created true value.

To take stock of these complex and diverse developments and shed light on why some players are making progress while others are not, McKinsey has repeated its Industry 4.0 Global Expert Survey, exploring changes in attitudes towards Industry 4.0 and progress made in its implementation. In the first part of this publication, we draw upon the survey results to present and discuss the status quo of the implementation of Industry 4.0 along three dimensions:

- **Perception.** To what extent have attitudes towards Industry 4.0 changed over the last year?
- **Progress.** How much progress have companies made in implementing Industry 4.0? Which Industry 4.0 applications have companies had the most success implementing?
- **Problems.** What are the key barriers to implementation that held back manufacturers?

In the second part of the publication, we will build on these insights, as well as on selected case studies and our own experience from client work, to outline five pragmatic steps that manufacturers can take to unlock value from Industry 4.0.

# 1.

# While optimism prevails, companies have achieved varying degrees of success in implementing Industry 4.0

We conducted the second edition of our Industry 4.0 Global Expert Survey in January 2016. The survey engaged a panel of 300 industry experts in Germany, the US, and Japan and focused on potential changes in attitudes towards Industry 4.0, progress made implementing Industry 4.0, drivers of that progress, as well as implementation barriers.

### Text box 1:
### Background of and key results from the McKinsey Industry 4.0 Global Expert Survey

In January 2016, McKinsey conducted the second edition of its Industry 4.0 Global Expert Survey (the first round was conducted in January 2015). This time, the survey posed 23 questions and allowed different types of answers, such as importance- and significance-rating questions as well as ranking questions. The survey was administered to 300 experts, split evenly across the US, Germany, and Japan, and representing companies of all sizes, but with at least 50 employees.

The experts who participated in the survey came from the following industries: automotive OEM, automotive supplier, chemicals, consumer goods, healthcare, paper and packaging, software, transport and logistics, industrial equipment, industrial automation, and semiconductor. Both Industry 4.0 technology suppliers and manufacturers are represented in the survey.

The survey's key results are:

#### Expectations and attitudes

- Most German players (67 percent) and Japanese players (74 percent) are as optimistic about the potential of Industry 4.0 as they were a year ago while 44 percent of US companies say they have become even more optimistic.

- 90 percent say their competitiveness will increase or stay the same with Industry 4.0. Yet, while 89 percent expect Industry 4.0 to impact their operational effectiveness, only 80 percent foresee Industry 4.0 having an impact on their business model.

- 70 percent expect new competitors from other industries to use Industry 4.0 to enter their markets; this expectation is much more pronounced in the US and Japan (81 and 75 percent) than in Germany (55 percent) and among technology suppliers (80 percent) than among manufacturers (65 percent).

- Six out of ten survey participants consider their company well prepared for Industry 4.0, but this varies by region with more German and American companies (68 and 71 percent) feeling prepared than Japanese companies (36 percent).

### Actions taken and progress made

- While "feeling" prepared, only 30 percent of technology suppliers and 16 percent of manufacturers have an overall Industry 4.0 strategy in place, and only 24 percent have assigned clear responsibilities for Industry 4.0.

- About half of the US and German players (50 and 56 percent) report having made at least good/substantial progress last year in implementing Industry 4.0 applications, while only a small fraction of Japanese players (16 percent) report this level of progress. Also, technology suppliers claim to have made more progress (47 percent report at least good/substantial progress) than manufacturers (of which only 37 percent report at least good/substantial progress).

- In most US, German, and Japanese companies that have assigned clear responsibilities for Industry 4.0, Business Unit Heads are responsible (33 percent). CEOs are driving the Industry 4.0 strategy in only 19 percent of these companies.

- Companies remain conservative regarding their investment in Industry-4.0-related R&D – with an average investment of only 14 percent of their R&D budget and higher shares in the US and Germany (17 and 13 percent) than in Japan (10 percent).

- Industry 4.0 applications that companies have made the most progress in implementing over the last year include smart energy consumption, real-time supply chain optimization, remote monitoring and control, digital quality management, and digital performance management.

### Implementation barriers

- The main implementation barriers cited by companies were difficulties in coordinating actions across different organizational units; concerns about cybersecurity and data ownership when working with third-party providers; lack of courage to push through a radical transformation; and lack of necessary talent.

## Hopes for Industry 4.0 remain high

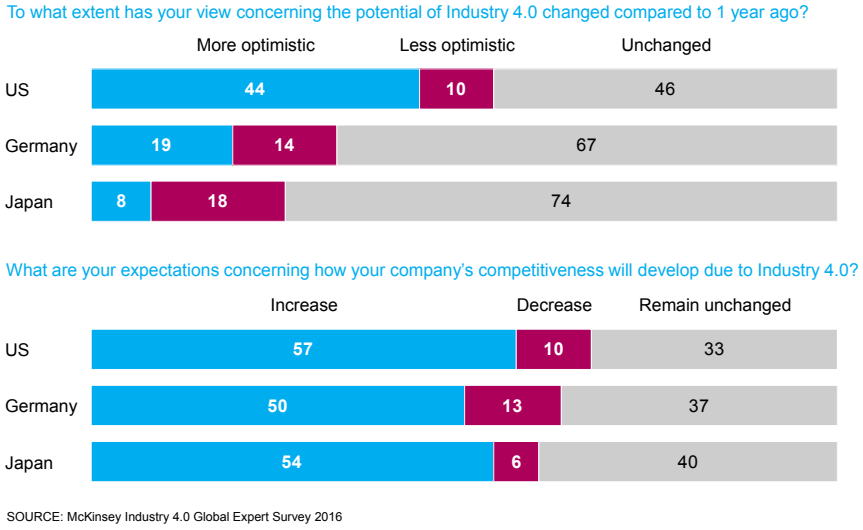
On a macro level, both technology suppliers and manufacturers continue to have a very positive outlook towards Industry 4.0 (Exhibit 1). As was the case in the results of last year's survey, nine out of ten companies see Industry 4.0 as an opportunity rather than a threat, with slightly more widespread optimism in Germany and the US (92 and 90 percent) than in Japan (78 percent).

Companies also remain hopeful about the impact of Industry 4.0 on their own company, with nine out of ten expecting their company's competitiveness to either increase or stay the same in the context of Industry 4.0, and only one out of ten fearing a decrease in competitiveness.

Exhibit 1

**Optimism about the potential of Industry 4.0 and its effect on competitiveness prevails – and has even grown further in the US**

Percent




SOURCE: McKinsey Industry 4.0 Global Expert Survey 2016

As one might guess, this increase in competitiveness continues to be attributed slightly more to improvements in operational effectiveness than to changes in business models. This is especially true in Germany, where 91 percent of respondents expect Industry 4.0 to increase their company's operational effectiveness, but only 76 percent foresee an impact on their business model. Similarly, only 55 percent of German companies expect competitors from outside their industry to use Industry 4.0 to attack traditional industry players, while 81 percent of US and 75 percent of Japanese companies believe that this attacker scenario is likely to happen.

## Progress has been made – but only by some manufacturers

Most companies continue to believe in the individual and collective potential of Industry 4.0, although many have yet to see results. Six out of ten have seen their companies make no or only limited progress in implementing Industry 4.0 applications/strategies during the last year. However, there are also the four out of ten companies that report having made at least good/substantial progress. Not surprisingly, this number is higher (47 percent) among suppliers of Industry 4.0 technologies than among users/manufacturers (37 percent). And there are regional differences: German companies report having made the most progress, with 56 percent claiming to have achieved at least good/substantial progress, followed by 50 percent in the US and only 16 percent in Japan (Exhibit 2).

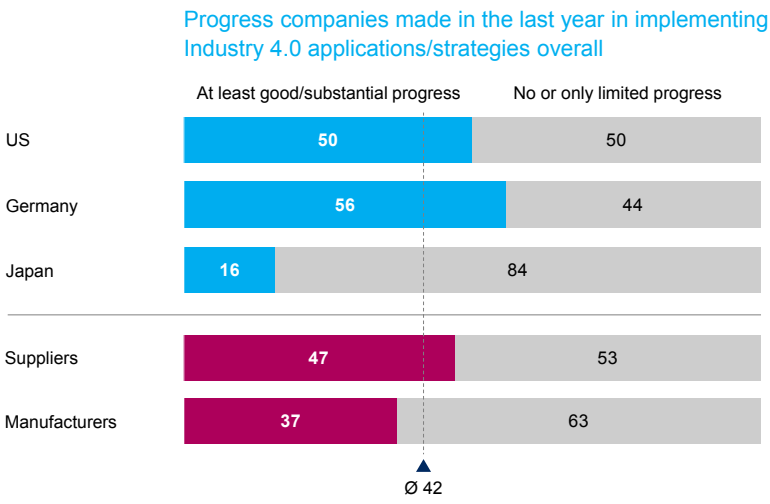
Preparation may play a role here, and there are strong differences, especially for manufacturers: of those manufacturers that report having made no or only limited progress, seven out of ten say they have neither an Industry 4.0 strategy nor assigned clear responsibilities, and they have yet to design an implementation road map. Of those that have achieved at least good/substantial progress, fewer than two out of ten are missing these essential elements.

R&D spend on Industry 4.0 seems to be a second driver. Companies that have made at least good/substantial progress with Industry 4.0 have spent, on average, 18 percent of their R&D budget on Industry 4.0 projects, while those with no or limited progress are spending less than 8 percent.

Exhibit 2

**Only 4 out of 10 companies made good progress – and progress was stronger in the US and Germany and for technology suppliers**

Percent

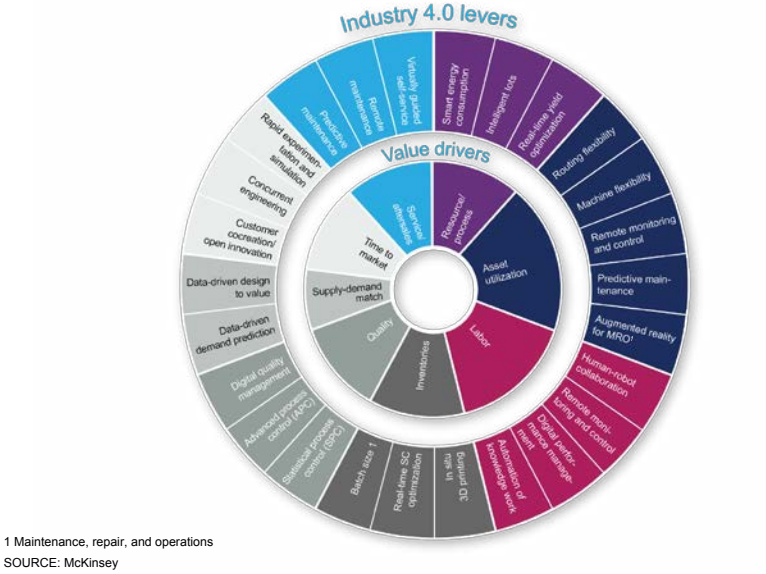



SOURCE: McKinsey Industry 4.0 Global Expert Survey 2016

Lastly, a stronger focus might have helped. Nine out of ten successful manufacturers prioritized specific Industry 4.0 applications, compared to seven out of ten in the group that achieved only limited progress. Of all the possible Industry 4.0 applications (for an exhaustive listing of these, see the McKinsey Digital Compass in Exhibit 3), successful manufacturers have most frequently prioritized digital performance management, real-time supply chain optimization, digital quality management, remote monitoring and control, predictive maintenance, and smart energy consumption.

Exhibit 3

**The McKinsey Digital Compass maps Industry 4.0 applications to the 8 main value drivers**




1 Maintenance, repair, and operations

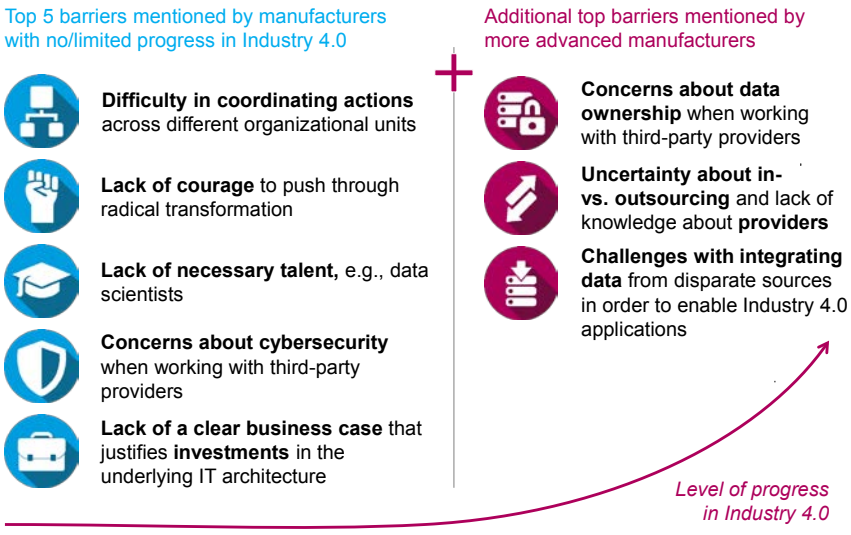
SOURCE: McKinsey

## Many other manufacturers are still being held back

Six out of ten manufacturers are facing implementation barriers that are so strong that they achieved either limited progress in the last year or none at all. Among the implementation barriers, some seem to be more relevant at the very beginning of an implementation journey while others only emerge when players are already more advanced (see Exhibit 4). The top five barriers mentioned by manufacturers that were still struggling with how to get started with Industry 4.0 implementation were:

Exhibit 4

**Manufacturers need to overcome major implementation barriers, of which some are more relevant for advanced players**




SOURCE: McKinsey Industry 4.0 Global Expert Survey 2016

**Difficulty in coordinating actions across different organizational units.** Many companies struggle to break the still very strong silos between, among others, R&D, manufacturing, sales, IT, and finance departments. These walls between functions make it difficult to coordinate Industry 4.0 strategy and projects across the entire organization.

**Lack of courage to push through radical transformation.** Many manufacturers say they are simply lacking the necessary courage to achieve the kind of technical and organizational changes that Industry 4.0 requires.

**Lack of necessary talent, e.g., data scientists.** Many manufacturers feel that they are lacking the necessary skills and expertise to make new Industry 4.0 applications work. When combined with concerns about working with third-party providers, this is paralyzing companies.

**Concerns about cybersecurity when working with third-party providers.** Implementing Industry 4.0 applications often requires working with third-party technology/software and implementation providers, and many companies are still hesitant to share their data out of concern about IT security on the partners' side or in transit.

**Lack of a clear business case that justifies investments in the underlying IT architecture.** Many companies have yet to develop a business case that sufficiently justifies the larger,

overarching investments in data and systems architecture that are needed to fully implement Industry 4.0 applications across the organization.

For organizations further along in their Industry 4.0 implementation journeys, three additional barriers, in particular, seemed to stand between them and continued progress:

**Concerns about data ownership when working with third-party providers.** In addition to concerns about cybersecurity, manufacturers are also worried that they might lose ownership over their data when working with third-party technology and software providers on Industry 4.0 applications. They also frequently discover that data ownership as formulated in current OEM contracts is already more limited than they had thought.

**Uncertainty about which Industry 4.0 applications to source internally and which to source from third-party providers as well as a lack of knowledge about suitable providers.** Many companies are unsure about which activities are potentially differentiating enough to be handled in-house and which are commodities that would benefit from a partnership with a third-party technology or implementation provider. In addition, many manufacturers say they lack an understanding of the relevant ecosystem of possible providers to cooperate with on Industry 4.0 applications.

**Challenges with integrating data from disparate sources to enable Industry 4.0 applications.** Most Industry 4.0 applications build on data from diverse sources. Pulling this data together is crucial to making Industry 4.0 work, but data integration can be a difficult task.

# 2.

# Five pragmatic recommendations for capturing value from Industry 4.0

There is certainly no singular, standardized approach to implementing Industry 4.0 throughout an organization. Our observations of the most successful manufacturers, however, reveal effective approaches and perspectives that other aspiring companies might adopt.

## I Focus your efforts on a limited number of applications

The manufacturers we see achieve the most progress with Industry 4.0 are focusing on a limited number of Industry 4.0 applications (see Text box 2 for examples of especially promising applications) – instead of trying to target all possible levers[1] at the same time.

### Text box 2: Top five applications in which manufacturers are finding value

Industry 4.0 has the potential to be applied throughout the manufacturing organization: top to bottom and end to end. Finding value, however, does not require a company to roll out all Industry 4.0 applications at once. Here is a list of the five Industry 4.0 applications where we see manufacturers capture the most value already today. Not all five applications will be equally useful for each manufacturer, and applications that don't appear in this list may be more suitable for some. But, given the success that many have had in these areas, we believe this list is a good starting point for manufacturers thinking about where they should aim first to capture value.

**Digital performance management.** Digital performance management can serve as the gateway to digital manufacturing due to its minimal resource requirements, and simple, rapidly deployable solutions. The application accelerates existing lean management processes, and helps to build digital capability and a data-driven mindset, laying the foundation for more advanced digital technologies. We have seen digital performance management tools, like digital dashboards to support performance dialogues, achieve as much as a 20 to 50 percent OEE improvement within three months by increasing engagement of frontline operators and management around data. Furthermore, digitized performance data persists beyond the shop-floor whiteboard and supports normalized calculations and reporting, allowing KPIs across previously siloed functions, plants, and business units to be shared and benchmarked for consistency and best-practice sharing.

**Predictive maintenance.** Even though the term predictive maintenance has been around for many years, significant progress in data availability, machine learning technology, and cloud technology is enabling an entirely new approach: a new version of predictive

1 Compare Exhibit 3 "The McKinsey Digital Compass" (p. 11); for a more comprehensive overview and discussion of Industry 4.0 levers, please see our 2015 report "Industry 4.0 – how to navigate digitization of the manufacturing sector."

maintenance that integrates diverse data sets and uses complex deep learning algorithms such as neural networks. We typically see an increase in machine availability and a reduction in maintenance costs – based on the introduction of new predictive maintenance algorithms – of 10 to 15 percent. Companies need three components to be successful in predictive maintenance: deep maintenance expertise and knowledge of the respective asset, strong advanced analytics know-how, and the appropriate change management capabilities.

**Yield, energy, and throughput optimization.** Integrating data from process control systems with other data, such as cost data, can go a long way towards helping companies optimize yield, energy, and throughput. We have seen that manufacturers already achieve a lot of improvement by combining plant data that is readily available, together with the right software. In addition, they have to build or source the know-how to create the right algorithms. Lastly, providing the right implementation support both for an initial pilot, and for scaling the efforts across different sites is crucial to succeed.

**Next-level automation.** For almost all companies, there is still a lot of potential in increasing the use of automation in both blue-collar and white-collar work. In terms of blue-collar work, we expect that adoption of robotics will grow significantly in the next five to ten years. A drop in the cost of industrial robotics of approximately 10 percent p.a. until 2020 and improvements in sensor technology and artificial intelligence – allowing the potential use of robots in more complex systems and situations – are driving the growing accessibility and potential value of automation. We also find that in terms of white-collar work, automation of knowledge work in such functions as demand planning (e.g., use of predictive analytics) and order management (e.g., no-touch order management) in the supply chain process holds a lot of optimization potential.

**Digital quality management.** Manufacturers that are only starting off can reap substantial benefits (e.g., higher efficiency, improved ability to trace errors back, and cost reductions from recalls) by implementing digital documentation systems that help record and store quality, relevant production, and service information. Advanced quality control, including the use of new sensing technologies (e.g., computer vision) and semiautomated quality control (e.g., robots, wearables – see Text box 3), unlocks further value. More advanced players looking to step up their digital quality management are using advanced algorithms and big data for quality analyses, e.g., semiautomated root cause analyses.

### Text box 3:
### Smart glasses in digital quality management

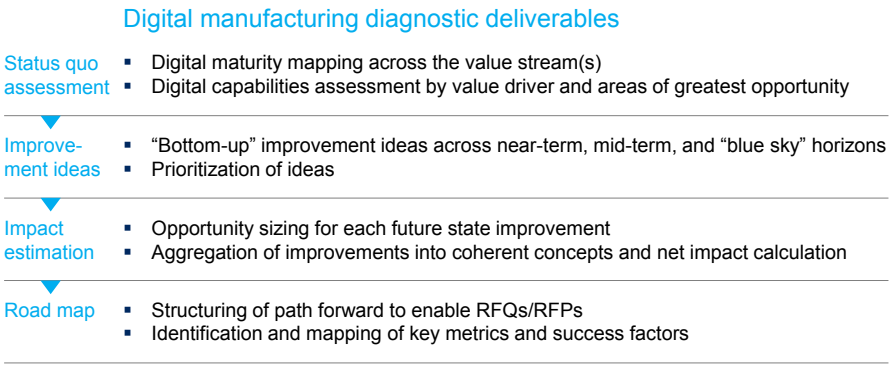
With the shift towards Industry 4.0, companies are taking the lead in turning to smart glasses to help drive efficiencies in their workforce. By allowing their "hands-on" workers to have information readily available in a head-up display, smart glasses are driving improvements in productivity and quality. One of the applications is in digital quality management, where wearable technology can improve and accelerate work flows. BMW has been piloting the use of Google Glass together with an xMake solution from Ubimax for visual inspection of their vehicles during preseries production. Workers use Google Glass to document potential deviations by taking photos or videos, allowing for a better and faster way to analyze and correct those later. Before, those issues were documented in writing and required much more back and forth between quality testers at the analysis center and development engineers.

In the following, we want to explain in detail how an initial diagnostic that concentrates on a number of critical manufacturing processes (including quality, maintenance, inventory and supply-demand management, energy management, and performance management) can provide concrete guidance on which applications to start with.

Our recommended Industry 4.0 diagnostic approach focuses on how manufacturers can use the data they already have to unlock new value and is conducted in four steps (Exhibit 5):

Exhibit 5

**McKinsey's Industry 4.0 diagnostic consists of 4 steps**




SOURCE: McKinsey

In a first step, the client-specific value streams and production centers are analyzed to assess the status quo of data creation, integration, and usage, as well as of automation usage. This can be done with a combination of "digital walk-throughs" of the production-related activities (see Text box 4 for an example) supplemented with interviews and a review of current performance KPIs and financials. The "digital walk-through" will assess the current data utilization, identify instances of "digital waste" (such as data leakages and system breaks, data dumps, uncontrolled processes, inflexible, nonlearning automation, and excess energy consumption) and reveal opportunities to improve the value stream through a better integration and usage of available data. At the same time, opportunities for further process automation will be identified.

### Text box 4:
### A value-identifying Industry 4.0 road map

German heating system manufacturer Viessmann developed an integrated Industry 4.0 road map to guide its activities in this area. Building on experiences from its own technology pilots, reference visits at other manufacturers, and a "digital walk-through" conducted by a cross-functional team from manufacturing and IT experts, Viessmann identified three main opportunity areas to focus on (end-to-end supply chain optimization being one of them). For each area, the manufacturer developed a high-level business case and a road map with key milestones for the next three years.

*We used the digital walk-through to identify leakages and system breaks in the current setup and develop additional improvement ideas to optimize the data stream along our value chain.*

***Gerhard Bastet,*** General Manager at Viessmann Werke Allendorf GmbH

The second step of the diagnostic focuses on improvement idea generation and prioritization. Improvement ideas are developed based on the outcomes of the walk-throughs and reviews of KPIs and financial data, as well as on idea generation workshops and best-practice benchmarking. As an example, in predictive maintenance, teams use data stream mapping techniques to assess the status quo of data creation, transfer, and utilization. They also benchmark the current process against Industry 4.0 best practices and perform a gap analysis to identify digital waste. Ideas are subsequently prioritized according to their impact and ease of implementation and organized along time horizons. The McKinsey Digital Compass App[2] can help identify opportunity areas with the highest estimated impact through a quick questionnaire-based assessment building on industry-specific typical potential.

In a third step, the prioritized ideas' net impact is calculated. In practice, this has to be based on selected deep dives into the most promising, short-listed levers like assessing the

2 Please contact your McKinsey contact person or *digital_compass_app@mckinsey.com* for further information.

feasibility of and setting up isolated pilots for high-potential solutions in order to allow sizing their opportunity with respect to each future state. Depending on the outcomes, the improvement ideas are then aggregated into coherent, holistic concepts for which the net impact can be calculated (including potential investments in the underlying infrastructure).

Lastly, based on the resulting list of prioritized levers for Industry 4.0 potential, a focused implementation road map with clear targets and KPIs is generated. Rollout preparation is comprised of three elements: creating a rollout plan for the entire value chain that makes Industry 4.0 an integral part of the manufacturer's process landscape and enables RFQs/RFPs to technology/implementation partners; developing a compelling Industry 4.0 change story; and setting up the project team for implementation, determining their skill gaps, and training the "Industry 4.0 team" to drive implementation and continuous analyses across the production network. Importantly, with regard to the manufacturer's approach to training, it is essential not only to develop the new skills required for change and identify and map key metrics and success factors, but also to foster understanding and conviction and to ensure role modeling.

### II Don't be afraid of "workarounds" today, but start laying the IT foundations for a more robust solution tomorrow

Oftentimes, we see clients failing to get started with implementing Industry 4.0 applications because of a lack of healthy pragmatism. Capturing the value from prioritized Industry 4.0 applications will, in almost all cases, involve substantial operational hurdles that manufacturers need to tackle. When these challenges arise in integrating data, a project is often paused to wait for some multiyear data architecture transformation, a relaunch of the ERP system, or some other larger effort.

The fact of the matter is that very successful clients manage to successfully complete projects even under difficult circumstances, such as missing data, incompatible IT systems, and a shortage of talent. For example, when supporting a life science client with a yield optimization effort, we found that the entire documentation of the batch process, which is crucial input data for the analysis, was available only on paper. Instead of waiting two years until the switch to digital documentation had been made and enough digital data had been accumulated in the data historian, the client scanned all physical data sheets (a total of 15,000 pages) and had a third-party provider in India convert them into machine-readable data tags. This took two weeks and a lot of effort, but it allowed the client to move forward with the project sooner rather than later and ultimately achieve a yield improvement of approximately 1 percent.

Using workarounds such as this one will allow companies to start implementing new use cases quickly and create the often necessary proof of concept for further rollout of the applications. Cloud solutions are also helpful to allow "in the meantime," risk-free solutions. Companies can use the cloud to experiment with new use cases without being slowed down by the legacy IT infrastructure and architecture.

Despite the successes of early pilots, a large-scale Industry 4.0 rollout requires major investments in the overall technology stack. Among other investments in IoT applications and integration of business logic, the data stack plays a significant role. Preparing a business case that justifies data investments can be difficult due to the fact that Industry 4.0 technologies are relatively new, and success cases related to these technologies are still limited. Nevertheless, these investments lay an essential foundation for the capability to move from early Industry 4.0 pilots to scaled, enterprisewide implementations.

In addition to the technological investments, organizations also need to lay a foundation of clear business ownership to properly manage the device- or customer-related data. A central data management office along with a sensible data domain structure could be a solution for defining the overall data strategy and ensuring companywide data standardization.

Part of that effort must be a transformation towards a professionalized data operating model in which high-quality data is accessible and data flows are managed actively rather than locked up in private data stores. A data domain approach, i.e., the grouping of data elements belonging to the same business context, can help by establishing a corresponding data governance structure led by the business functions owning such data.

Finally, the data management office should facilitate the discussion around the optimal overarching data architecture, including a clear road map towards the target state. One of the key challenges here is the integration of existing master data with the transactional data flowing from sensors and equipment to enable advanced analytics as well as real-time capabilities to act upon complex events. Big data technologies, such as data lakes that can also cope with unstructured data (e.g., based on Hadoop) and message-processing technologies (such as ZeroMQ or Apache Kafka) could be elegant solutions for overcoming existing limitations, speeding up data accessibility, and initiating a paradigm shift in the technology that can also benefit the existing legacy landscape.

One thing manufacturers embarking on such a data transformation should keep in mind is the increasing integration of data across the entire product lifecycle, from product planning and engineering to manufacturing and sales. Companies have been striving for years already to employ holistic product lifecycle management (PLM) systems, i.e., a set of business solutions that allow consistent use of product definition data from concept to use. However, if we have a look under the hood, we still see major system breakdowns and data redundancies/inconsistencies. Leading companies, e.g., Audi AG, have started efforts to consolidate and "clean up" their production data landscape in order to build the foundation for advanced Industry 4.0 applications.

> *We are aiming at an enormous progress in efficiency and speed particularly in engineering, controlling, administration, and decision making. But this value will only be unlocked if we manage to integrate data across the entire product lifecycle.*
>
> ***Fred Schulemann,*** Head of Digital Production at Audi AG

### III Build a portfolio of third-party technology providers

When implementing Industry 4.0 applications, companies should think hard about which pieces of the process value chain are strategic "control points," where capabilities and data should be built and kept in-house to secure important competitive advantages, and which pieces are "commodities" and handled best by partnering with a strong third-party provider. For those pieces for which the latter option applies, there is an increasing number of Industry 4.0 solutions available that companies can choose from. New offerings like Siemens' MindSphere can serve as a platform for integrating a manufacturer's own data with third-party applications. Starting with existing solutions will allow companies to draw on specialized skills and enable faster implementation.

Industry 4.0 is causing a shift from the single-provider model to a set of integrated technology providers. To succeed in this realm, manufacturers need a well-developed portfolio of potential providers and a strong partner management approach. This starts with choosing the right partners, developing an understanding of the market, and building the capabilities to manage a "best-of-breed" provider structure.

Another critical element requiring strong management is ensuring the right data ownership structure when interacting with OEMs as well as software providers. Increasingly, we see clients unknowingly giving up data ownership to OEMs, a fact they typically only notice when in the middle of an Industry 4.0 project (see Text box 5 for an example). Thus, before signing contracts, manufacturers have to think hard about which data they will require access to.

### Text box 5:
### Jumping the data hurdles in the predictive analytics race

A major semiconductor manufacturer recently embarked on a journey to deploy advanced predictive analytics to predict tool failure and yield-related issues. The company ultimately ran a successful proof of concept – which revealed a potential reduction in maintenance costs of an additional 8 percent beyond what they were getting from traditional approaches – but they encountered a few barriers along the way:

- **Data ownership.** The semiconductor fabrication plant (fab) had to rewrite procurement contracts to allow it to access and store data that were being collected within the tools it used. Rotating equipment vendors seldomly provide access to "data IDs" if this is not explicitly written into the contract. Additionally, there was no "data requirement" written by the fab manufacturing team that integrated requirements across equipment. The fab narrowed the scope of initial impact and negotiated data agreements with targeted vendors. It is considering revamping its approach to incorporate the requirements up front into vendor and manufacturing contractor services.

- **Data infrastructure.** 50 percent of the fab's data was being downsampled and discarded. Moreover, real-time trace level data was not available for use, and the "historian" system was difficult to access. The fab created homegrown data integration software to integrate maintenance data from multiple collection systems. A new IT proposal is being considered to switch to a cloud architecture for easy access.

- **Analytical talent.** The fab realized that they needed to find the match between more than ten unique machine learning algorithms and more than 100 asset failure modes. The proof of concept created a validation approach to plug-and-play algorithms for failure types. It is important to note here that the fab had to contract out the analytical work due to a lack of data scientists who could deploy advanced algorithms.

## IV Build a strong internal team with an agile mindset

To really capture value from Industry 4.0, companies need to build up strong internal capabilities and establish a dedicated cross-functional team that drives innovation based on a culture open to change and experimentation.

For those pieces of the process chain that a company identifies as critical enough to cover internally, the necessary talent needs to be built up. This will primarily affect IT talent – from data scientists, who will help develop complex algorithms, to agile software developers, who can build up critical new applications internally. Given the high demand and limited supply of these roles, hiring them will require a clear value proposition from manufacturers. Some manufacturers are even going so far as to "move to where the talent is" by creating new units in start-up hubs like Silicon Valley or Berlin.

At the same time, these units – rich with IT talent – must work seamlessly with the manufacturers' other functions. There is no place for the traditional barriers that have separated the various internal functions. Industry 4.0 requires collaboration between experts from operations (who have the technical domain knowledge), experts from IT (who know about advanced analytics and the company's IT architecture and infrastructure), and experts from business (who know how to link investments to a clear business case). Working in close partnership, operations, IT, and business will define and execute an Industry 4.0 strategy. One company, for instance, has created a task force with representatives from each functional area who meet regularly to discuss new and existing Industry 4.0 projects and the resources necessary to support them. The task force (with input from the C-suite) has the authority to tap into every process flow, system, and database. Other players are even consolidating all relevant Industry 4.0 functions in a new organizational unit (see Text box 6).

### Text box 6: Consolidating expertise to harness digital strength and focus strategy

In 2015, the mechanical engineering company Voith established a new Group Division, Digital Solutions, to consolidate all of its digital and automation activities in the area of Industry 4.0 in one dedicated unit. The new unit's focus will be on the development of new digital business models for sectors that Voith already serves today as well as for completely new sectors that are not yet being served. Thereby, Voith is bundling its expertise in the areas of automation, software, IT, digitization, and sensor technology that were previously distributed over different Group Divisions. In addition, Voith plans to relocate all of its venture and start-up activities in the digital realm to the new unit.

> *The establishment of a dedicated digital unit allows us to bundle all relevant expertise and to pursue our Industry 4.0 strategy in an even more targeted way.*

***Dr. Roland Münch,*** CEO of Voith Digital Solutions Division

The cross-function team needs a strong mandate to be effective, but it also needs the freedom to create its own way of working, characterized by an agile mindset. A culture of fast experimentation and iterative improvement is crucial to drive Industry 4.0 projects with the necessary speed. Digital natives can provide examples of this mindset and speed. For example, one German e-commerce player conducted a hackathon to optimize the software behind the commissioning process in their warehouse. They brainstormed on Friday, adjusted the code over the weekend, piloted a "minimum viable process" on Monday, tested over the course of the week, went live the Monday after, and achieved 10 percent improvement in employee productivity.

### V Experiment with new business models

In our previous publication[3] we highlighted how the technologies behind Industry 4.0 will not only allow improvements in operational effectiveness but also provide new opportunities for digital integration and data-driven services that drive new business models such as platforms or as-a-service business models. Most Industry 4.0 quick wins will be found in improving operational effectiveness. Manufacturers that want to not only reap the immediate rewards of Industry 4.0 but also prepare themselves for future market disruptions should also start experimenting with new business models.

When looking for new business model opportunities, manufacturers can take examples from the playbooks of CLAAS and TRUMPF (see Text boxes 7 and 8), build new models around customers' needs, and draw on their deep domain knowledge and existing installed base.

**Text box 7:**
**Finding value in new Industry 4.0 business models**

In 2013, the agricultural machinery manufacturer CLAAS leveraged its deep domain knowledge, understanding of customer needs, and its large installed stock when founding subsidiary 365FarmNet, which offers a holistic planning, management, documentation, and analysis tool for farm operations. CLAAS made it a point to set up 365FarmNet as a manufacturer-independent platform with a diversified partner ecosystem that allows real-time data integration from machines via standardized ISOBUS interfaces. With this move, CLAAS extended its business model from that of a machine manufacturer to a software-as-a-service (SaaS) provider for its customers and positioned itself well in the growing smart farming software market.

> *The performance of our vehicles is largely exhausted, we need to change – from the classic manufacturer to a systematically networked problem solver – that's what our customers expect.*

***Dr. Hermann Garbers,*** former member of the Executive Board at CLAAS

3 "Industry 4.0 – how to navigate digitization of the manufacturing sector."

We expect that manufacturers will increasingly be able to draw on real-time data from their installed base to provide new value-added services for their customers. While in the past the link between manufacturers and their products was mostly cut off behind the point of sale, new sensor and communication technologies increasingly enable manufacturers to collect real-time data from their machines while they are in operation. This opens new possibilities for manufacturers to both improve existing aftersales services and add new value-added services that draw on data from the installed base. One example is the German compressed air system provider KAESER KOMPRESSOREN, which is increasing machine performance through advanced predictive maintenance models based on SAP HANA and recently added a "pay per $m^3$ compressed air" option to its service portfolio.

**Text box 8:**
**Leveraging existing skills to build competence as an Industry 4.0 enabler**

In 2015, TRUMPF founded subsidiary AXOOM to create a digital platform for the management of production processes. AXOOM is building a browser-based platform solution with software modules that encompass the entire value chain – from order to resource management to reporting. The platform connects processes, machines, and systems from different manufacturers and different technologies. TRUMPF hopes to draw from its intimate knowledge of production processes and technologies to enable small- and medium-size manufacturers that want to participate in the Industry 4.0 potential.

*Our key advantage is our installed machine base. We are a software provider who really knows the market.*

***Dr. Nicola Leibinger-Kammüller,*** President and Chairwoman of the Managing Board at TRUMPF

To position themselves for success in the new, competitive dynamics of Industry 4.0, manufacturers must strengthen their capability in business model innovation. While this will certainly involve the strategy department, the push to experiment with new business models needs to be CEO led. A good example of this is German metals trader Klöckner, whose CEO, Gisbert Rühl, made it his personal mission to adapt the company's business model to the digital age (see Text box 9).

### Text box 9:
### Getting ahead of digital disruption by making competitors customers

In 2013, the CEO of German metals trader Klöckner, Gisbert Rühl, embarked on a journey to Silicon Valley to learn about what potential disruptions the steel market could face in the next decade(s). He grew convinced that a digital marketplace platform for steel transactions is a real threat to Klöckner's current business model, which is still very much "pipe-like" with phone- and fax-based transactions. Since then, Mr. Rühl has personally led an ambitious digital transformation program, including the founding of kloeckner.i, a digital competence center, which is building Klöckner's digital transaction platform (which it aims to open to third parties as well), and kloeckner.v, a venture capital firm that aims to support start-ups that could potentially disrupt Klöckner's business model.

> *Speed is the key success factor in the digital transformation process of a company. Therefore, intensive personal involvement of the CEO is essential to enable rapid decision making.*
>
> ***Gisbert Rühl,*** CEO at Klöckner & Co SE

Oftentimes, companies can profit from seeking outside inspiration when thinking about business model adjustments, including from digital natives. Mr. Rühl, for example, started his digital journey by brainstorming with Silicon Valley venture capitalists and start-ups about how they would disrupt the steel market. Large companies might even think about implementing a "challenger board" with a healthy mix of entrepreneurs, industry veterans, venture capitalists, and others. Lastly, it must be made clear that given the current market dynamics, choosing the right business model can feel very much like shooting at a moving target. Thus, it will require an agile mindset of experimentation and reiteration as much as – if not even more than – improvement of operational effectiveness does.

# Outlook

Industry 4.0 raised high expectations, and not all have been met yet. Nonetheless, a handful of manufacturers have discovered numerous, specific applications for Industry 4.0 and are reaping the benefits. Industry 4.0 implementation is a multiyear process, and more applications will develop as technologies mature further. It is imperative that manufacturers in all countries start now with a set of concrete applications. This will build the organizational and technical muscle to tackle more ambitious projects in the future, such as the complete integration of data along the product lifecycle.

# Appendix

## Further key findings from the McKinsey Industry 4.0 Global Expert Survey 2016

The McKinsey Global Expert Survey included 23 questions on Industry 4.0. Since not all the results could be explicitly mentioned in the report, this Appendix provides some additional detail.

Exhibit 6

**Like last year, the vast majority of all US, German, and Japanese players perceive Industry 4.0 as an opportunity**

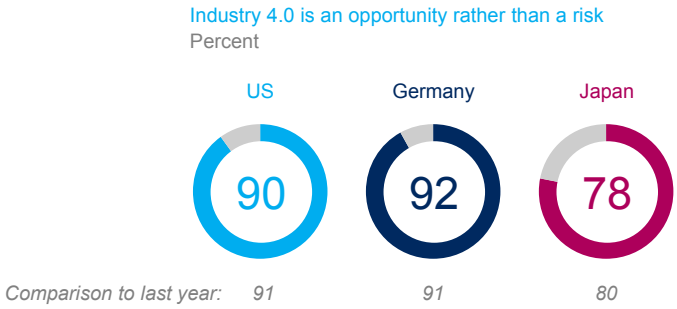



Exhibit 7

**While last year technology suppliers were more optimistic than manufacturers, there is less of a difference this year**


Exhibit 8

**Most German and Japanese players' views on the potential of Industry 4.0 are unchanged, while US companies became more optimistic**

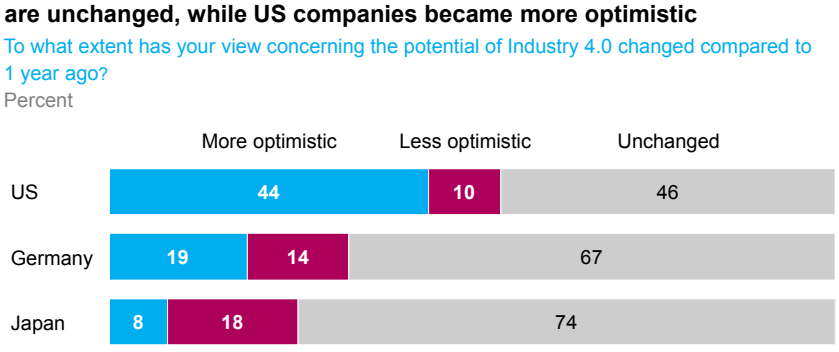


Exhibit 9

**2 out of 10 technology suppliers are less optimistic about the potential of Industry 4.0 than 1 year ago**

To what extent has your view concerning the potential of Industry 4.0 changed compared to 1 year ago?

Percent

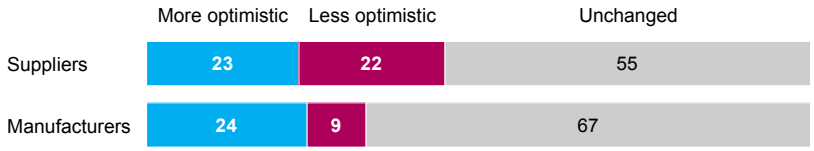



Exhibit 10

**Most US, German, and Japanese companies expect Industry 4.0 to increase their competitiveness**

What are your expectations concerning how your company's competitiveness will develop due to Industry 4.0?

Percent

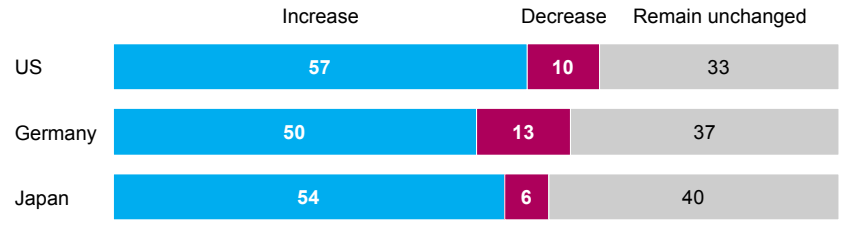



Exhibit 11

**A slight majority of both technology suppliers and manufacturers expect Industry 4.0 to increase their competitiveness**

What are your expectations concerning how your company's competitiveness will develop due to Industry 4.0?

Percent

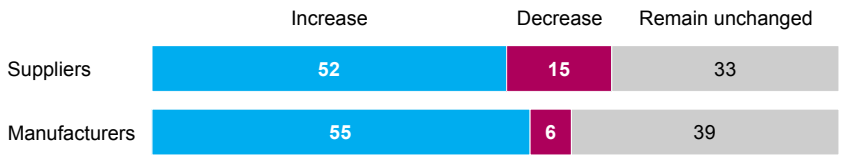
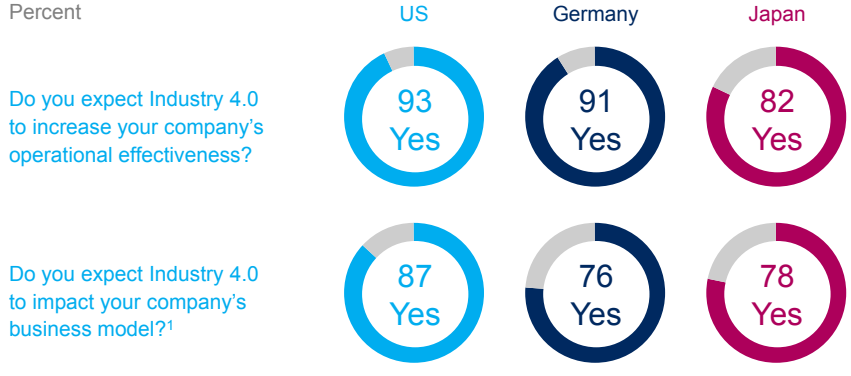



Exhibit 12

**The sense that Industry 4.0 will improve operational excellence outweighs the idea that it will impact business models – a gap especially pronounced in Germany**

Percent



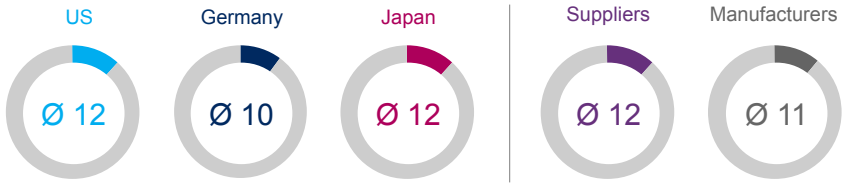

1 E.g., experiment with as-a-service business models, platforms, IPR-based business models, data-driven business models

Exhibit 13

**Most players expect cost and revenue improvements of 10 - 15% from Industry 4.0**

Percent

What cost improvements do you expect for your company as a result of Industry 4.0?




What revenue improvements do you expect for your company as a result of Industry 4.0?

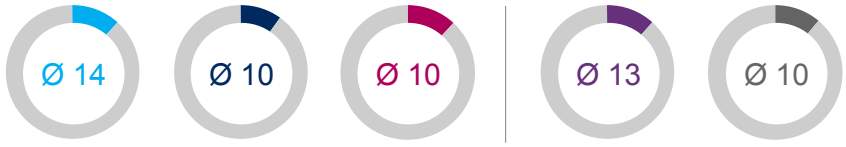



Exhibit 14

**A clear majority of US and Japanese companies expect competition from outside their industry, whereas in Germany the outlook is more split**

Do you expect competitors from outside your industry (e.g., IT companies) to use Industry 4.0 applications for attacking traditional industry players?

Percent


Exhibit 15

**US and German companies feel relatively well prepared while Japanese players feel unready**

Do you consider your company well prepared for Industry 4.0?

Percent


Exhibit 16

**Technology suppliers feel much better prepared than manufacturers**

Do you consider your company well prepared for Industry 4.0?

Percent

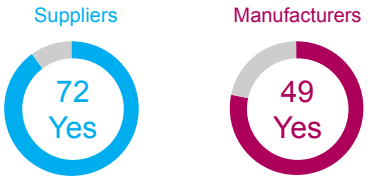


Exhibit 17

**While feeling prepared, less than 30% of companies have an overall Industry 4.0 strategy in place and even fewer have a clear road map**

Which of the following statements hold true for your company?

Percent

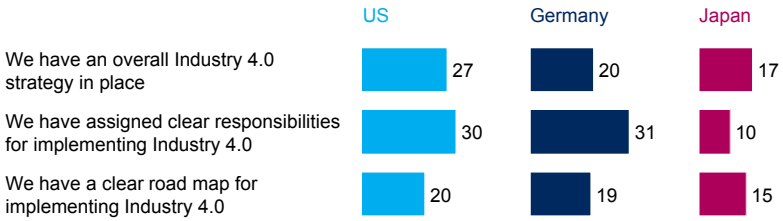



Exhibit 18

**Technology suppliers are advanced in terms of having an Industry 4.0 strategy, responsibilities, and a road map**

Which of the following statements hold true for your company?

Percent

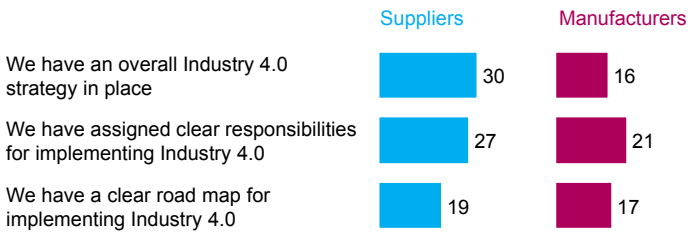



Exhibit 19

**Suppliers made more progress exploring new business models than manufacturers**

Progress in the last year in implementing Industry 4.0 applications/strategies aimed at …

Percent

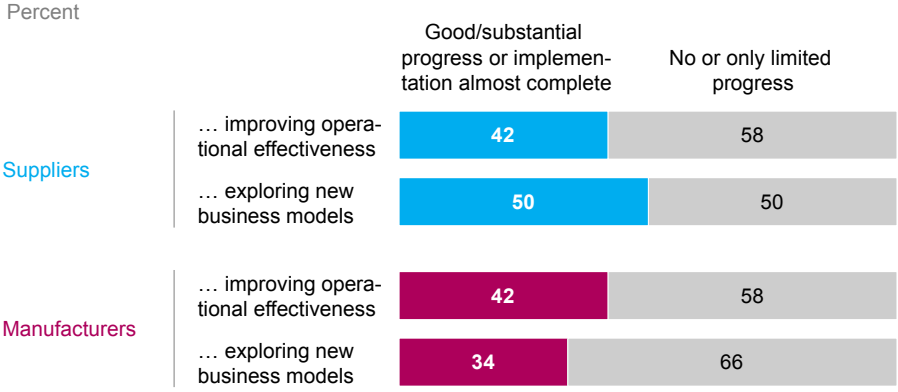
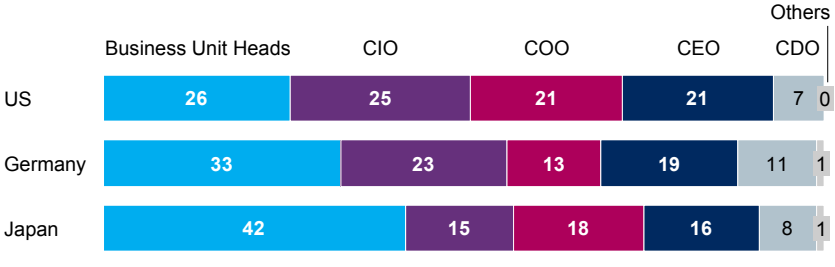



Exhibit 20

**Across all 3 countries, Business Unit Heads are most likely to be responsible for driving Industry 4.0 strategy in companies**

Share[1] of roles responsible for driving Industry 4.0 strategy

Percent

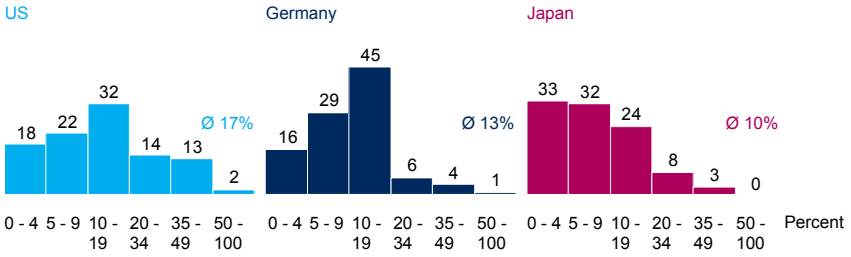



1 With regard to companies that have assigned clear responsibilities for Industry 4.0

Exhibit 21

## US and German companies invest more of their R&D budget in Industry 4.0 than Japanese players

What percentage of your company's total R&D budget is currently invested in Industry-4.0-related projects?
Percent

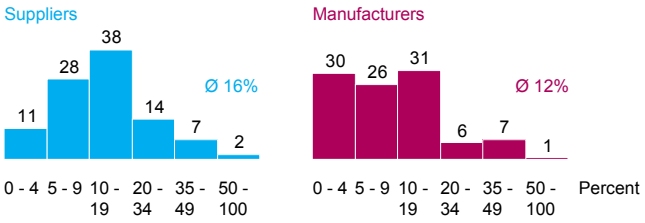



Do you consider that sufficient?
Percent


Exhibit 22

## Technology suppliers invest more of their R&D budget in Industry 4.0 compared to manufacturers

What percentage of your company's total R&D budget is currently invested in Industry-4.0-related projects?
Percent




Do you consider that sufficient?
Percent


Exhibit 23

## Manufacturers that achieved good progress invested an average of 18% of their R&D budget in Industry 4.0 projects

What percentage of your company's total R&D budget is currently invested in Industry-4.0-related projects?
Percent

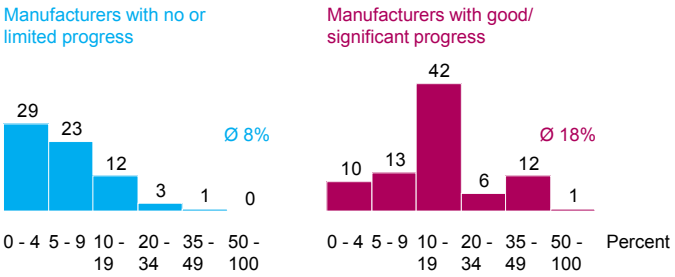


Exhibit 24

**Most US, German, and Japanese companies are actively engaging in industry platforms/consortia**

Is your company actively engaging in industry platforms/consortia in order to shape Industry 4.0 beyond its own premises?

Percent

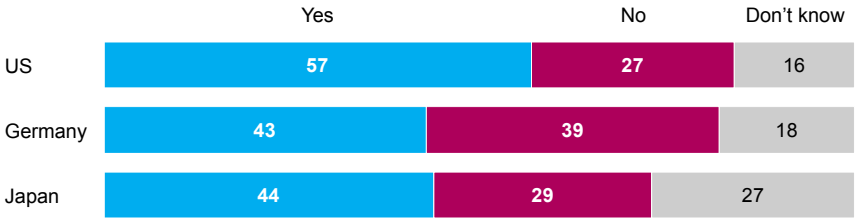



Exhibit 25

**Technology suppliers are much more active in industry platforms/ consortia than manufacturers**

Is your company actively engaging in industry platforms/consortia in order to shape Industry 4.0 beyond its own premises?

Percent

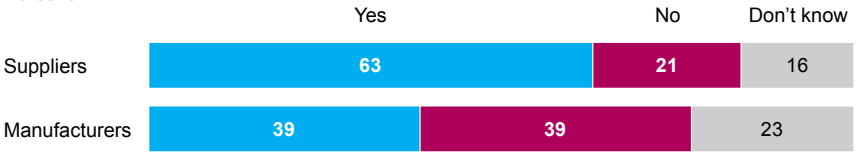



Exhibit 26

**Smart energy consumption was prioritized by technology suppliers, digital performance management by manufacturers**

Top 5 prioritized Industry 4.0 applications

Percent

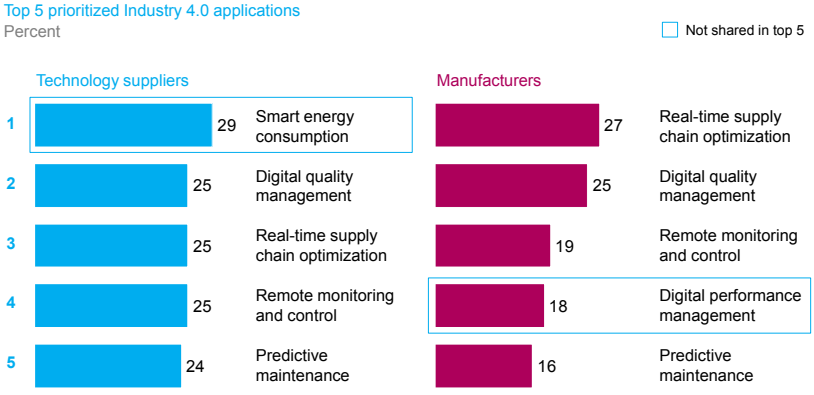
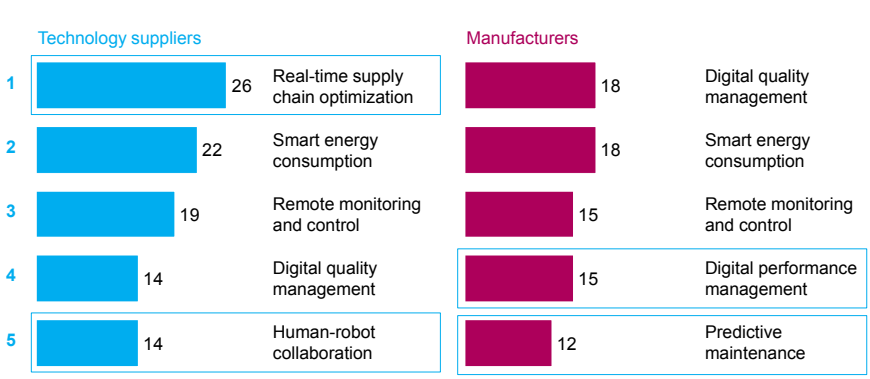



Exhibit 27

**Suppliers made strong progress with real-time supply chain optimization, manufacturers with digital quality management**

Top 5 Industry 4.0 applications with progress achieved

Percent



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