

strategy&

Global Digital Operations Study 2018

Digital Champions

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**How industry leaders
build integrated
operations ecosystems
to deliver end-to-end
customer solutions**

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Foreword

Digital operations, or Industry 4.0, is on the agenda of manufacturing companies around the globe. Yet most business leaders have still not come to terms with the challenges and opportunities of digital transformation or with the conceptual leap it represents.

Distinct from Industry 3.0, which involved the automation of single machines and processes, Industry 4.0 encompasses end-to-end digitization and data integration of the value chain: offering digital products and services, operating connected physical and virtual assets, transforming and integrating all operations and internal activities, building partnerships, and optimizing customer-facing activities.

Mastering Industry 4.0 requires a deep understanding of collaboration, the commitment of top management, and a clear strategy. Companies that fail to embrace this radical change will likely struggle to survive. Yet only a very few companies are poised at this moment to benefit from Industry 4.0. We call this select group Digital Champions.

For this 2018 study, we surveyed more than 1,100 executives at global manufacturing companies about their views on digital operations and Industry 4.0. Our goal was to explore the role of Digital Champions and the practices that allow them to outpace competitors. We found that they excel at managing and integrating four critical ecosystems — Customer Solutions, Operations, Technology, and People — each of which represents an array of partners, suppliers, products and services, employees, third-party advisors, factories, outsourcing arrangements, technology, and customers. To Digital Champions, they present vast opportunities for value creation.

In this study, we look at the unique characteristics of Digital Champions, including their structural composition and the capabilities that set them apart. In so doing, we offer you practical steps to transform your company into a true digital leader.



Dr. Reinhard Geissbauer

PwC Strategy& Germany, Global Head of the Digital Operations Impact Center

Executive summary



For the 2018 Global Digital Operations Study, we interviewed 1,155 manufacturing executives in 26 countries. We developed an index that ranks companies by digital operations maturity (or, in short, digital maturity). We grouped the companies into one of four categories: Digital Novices, Digital Followers, Digital Innovators, or Digital Champions. Based on the study data, we were able to assess what it takes to be a Digital Champion through the lens of four essential ecosystem layers: Customer Solutions, Operations, Technology, and People. We provide guidelines for companies seeking to mature into Digital Champions. The executives' responses can be summarized into eight key findings:

1. Just 10 percent of global manufacturing companies are Digital Champions, while almost two-thirds have barely or not yet begun on the digital journey. Digital transformation has been on every CXO's agenda for a number of years, but almost two-thirds of global manufacturing companies have just started or have not yet embarked on their digital transformation.

Just 10 percent of the manufacturing companies we surveyed can be categorized as Digital Champions, with an established digital product and service offering and multichannel interaction in their Customer Solutions ecosystem. They have also integrated and aligned their Operations, Technology, and People ecosystems with their Customer Solutions ecosystem.

The automotive and electronics industries have the most Digital Champions, with 20 percent of automotive and 14 percent of electronics companies implementing innovative solutions across their marketplace and facilities. In the process industries, consumer goods, and industrial manufacturing sectors, only a few companies have emerged as Digital Champions so far.

2. Among global regions, Asia-Pacific (APAC) is leading the way to digitization. In Asia, 19 percent of surveyed manufacturers have achieved Digital Champion status, compared with 11 percent in the Americas and 5 percent in Europe, the Middle East, and Africa (EMEA).

Asian companies have introduced digital products and services at a much faster rate than their counterparts in the other global areas, the result of the enthusiasm of the region's young, tech-savvy corporate managers to embrace digital technologies, as well as soaring compensation and production costs that are forcing Asian companies to digitize key operations processes to maintain competitiveness.

Because of the number of Digital Champions, Asia-Pacific companies expect 17 percent growth in digital revenue over the next five years, compared with the 13 percent growth anticipated by EMEA companies. And that gap will likely continue to widen, as 32 percent of Asian companies plan to have established mature digital ecosystems in the next five years, compared with 15 percent in EMEA and 24 percent in the Americas.

3. Digital Champions create value through integrated Customer Solutions ecosystems. Digital Champions continuously strengthen and enhance their digital product and service offerings as well as their access to customers, directly or through third parties. They excel in creating customer insights, and they match customer requirements to compelling and tailored solutions, enhancing traditional products with services, software, data analytics, and additional value from extended partner networks. To achieve this, Digital Champions utilize open platforms and tear down internal and external boundaries.

More than 50 percent of Digital Champions' revenues already come from digitally enhanced or purely digital products and services, and two-thirds of Digital Champions already rely on partners in their Customer Solutions ecosystem to create customer value. Investments in new technologies and digital ecosystems are expected to result in revenue gains of 15 percent over the next five years.

4. Digital Champions serve customers by integrating Operations, Technology, and People ecosystems to serve customers with competitive, end-to-end solutions. A cutting-edge Customer Solutions ecosystem serves clients with complete digital product and service solutions, mostly with an established partner network. Customer Solutions must be supported by a fit-for-purpose Operations ecosystem — the right set of technologies as well as the people and culture to drive them. Digital Champions align these aspects of their businesses by building on their own and their partners' core strengths to define the Customer Solutions and in turn letting the customer's requirements set the targets for the Operations and enabling (Technology and People) ecosystems. Through this alignment, Digital Champions create a whole that is greater than its parts, turning it into a strategic advantage. More than three out of four Digital Champions excel in both the Customer Solutions and the Operations ecosystems.

Digital Champions continuously strengthen and enhance their digital product and service offerings as well as their access to customers, directly or through third parties.

5. Digital Champions implement new technologies to connect and collaborate along the end-to-end value chain. On average, Digital Champions have implemented nearly two-thirds of the most critical technologies that propel digitization. These technologies include integrated end-to-end supply chain planning (adopted by 87 percent of Digital Champions), Industrial Internet of Things (78 percent), manufacturing execution systems (75 percent), collaborative and smart robots (72 percent), and predictive maintenance solutions (70 percent).

The key to success for Digital Champions is a holistic approach in connecting essential technologies across the organization and with strategic partners instead of isolated implementations. Digital Champions expect to achieve significant gains in cost savings and efficiency from technology implementations, with 16 percent cost savings in the next five years, versus 10 percent for Digital Novices.

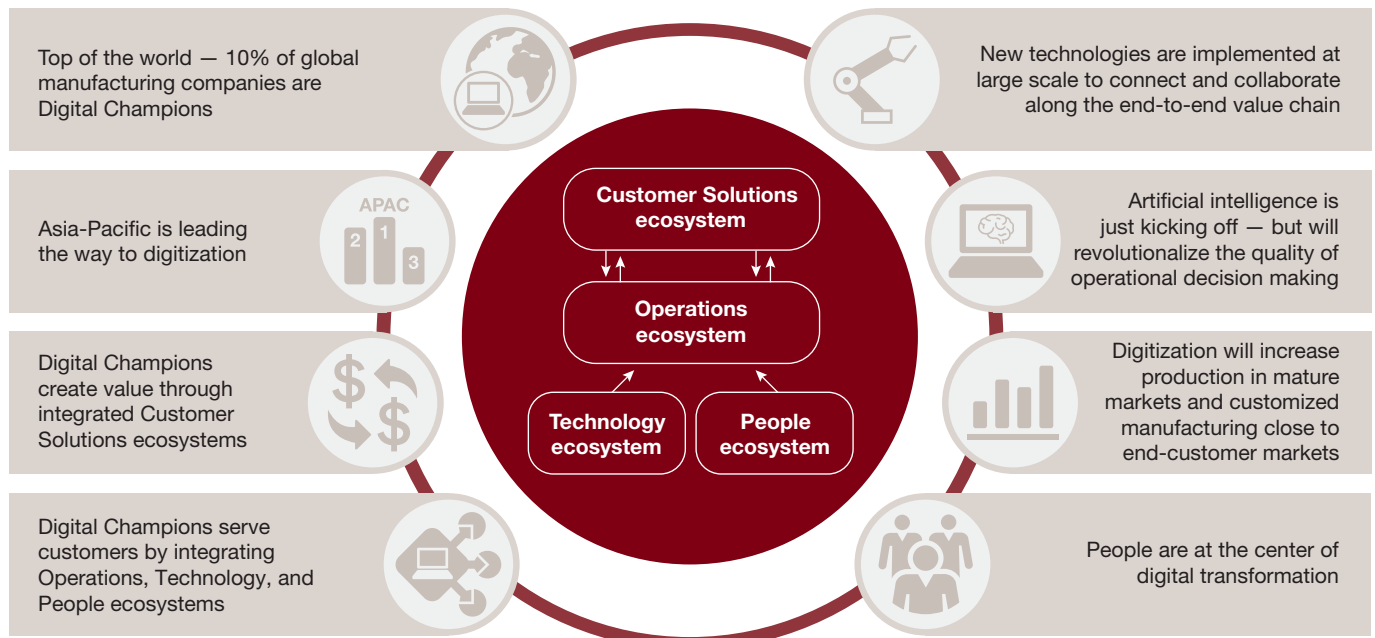
6. Artificial intelligence is just kicking off, but will revolutionize the quality of operational decision making. Only 9 percent of companies have already implemented artificial intelligence (AI) applications to improve operational decision making. One-third of Digital Champions have adopted AI across major functions, primarily focusing on assisted and autonomous intelligence for automating manual and cognitive tasks. Most companies appreciate AI's significant potential, but core use cases are just emerging as companies experiment broadly to quantify its value. Even among Digital Champions, 52 percent say they lack the people skills to broadly implement AI systems and many are hesitant about full-scale AI because they are uncertain about the maturity of the data produced by the AI systems themselves. Overall, Asian companies are at the forefront of AI, with 15 percent implementing significant AI solutions, and EMEA-based companies are lagging behind, at 5 percent.

7. Digitization will increase production in mature markets and customized manufacturing close to end-customer markets. Globally, digitization will lead to higher productivity and wealth. Digitization and smart automation are expected to contribute as much as 14 percent to global GDP gains by 2030, equivalent to about US\$15 trillion in today's value. Mature markets will benefit more as digitization reduces operations costs, enabling companies to rely less on labor arbitrage and increase production in home markets. In turn, demand for skilled labor will rise, as will salaries. As the need for skilled labor jumps — especially for digital experts, data analysts, and workers educated in science, technology, engineering, and math (STEM) — new ways of sourcing and finding access to talent, and training programs tailored to Industry 4.0, will be crucial.

8. People are at the center of digital transformation. Two-thirds of all companies do not have a clear digital vision and strategy to support digital transformation and culture. Only 27 percent of survey respondents said their employees have the required qualifications to master the digital future. Limited progress has been made since our previous global study in 2016.

On the other hand, the leaders of more than 70 percent of Digital Champions have a clear vision for the digital future and serve as role models for digital change in their organizations. Digital Champions invest heavily in people development and training and cultivate multidisciplinary teams to foster innovation across functional boundaries.

Exhibit 1
Eight key findings of the Global Digital Operations Study 2018



Source: PwC's Strategy & Global Digital Operations Study 2018

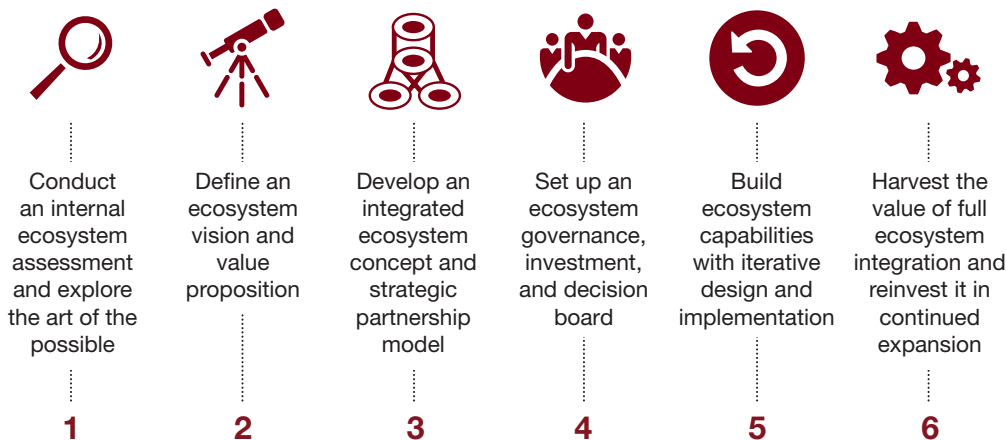
Blueprint for implementation success

Digital Champions achieve their competitive advantage by successfully orchestrating and integrating the four ecosystem layers: Customer Solutions, Operations, Technology, and People. The starting point on the journey toward becoming a Digital Champion is the definition of a compelling ecosystem vision and value proposition based on an internal ecosystem assessment and an exploration of the art of the possible (see Exhibit 2). Digital Champions develop an integrated ecosystem concept and a strategic partnership model that clearly lays out how external partners can be integrated into their ecosystem.

An effective ecosystem governance that ensures prioritization of activities, enables fast decision making, and makes the best use of digital investments is key to successfully deploying the four ecosystem layers. It is also critical to follow a highly iterative approach while designing and implementing the ecosystem capabilities. This enables companies to deliver and learn through early and continuous deliveries.

Digital Champions are harvesting the value of fully integrated ecosystems through permanently investing in continued expansion and enhancement of their Customer Solutions, Operations, Technology, and People ecosystem layers.

Exhibit 2 Blueprint for becoming a Digital Champion



Source: PwC's Strategy & Global Digital Operations Study 2018

What is a Digital Champion?

Although Industry 4.0 is transforming manufacturing rapidly, in novel ways that were unimaginable just a decade ago, only a small group of companies is in a position to gain real competitive advantages from this operations revolution. These companies, which we call Digital Champions, are noteworthy because they view digitization in ways that are far-reaching and aggressively innovative, well beyond mere automation and networking.

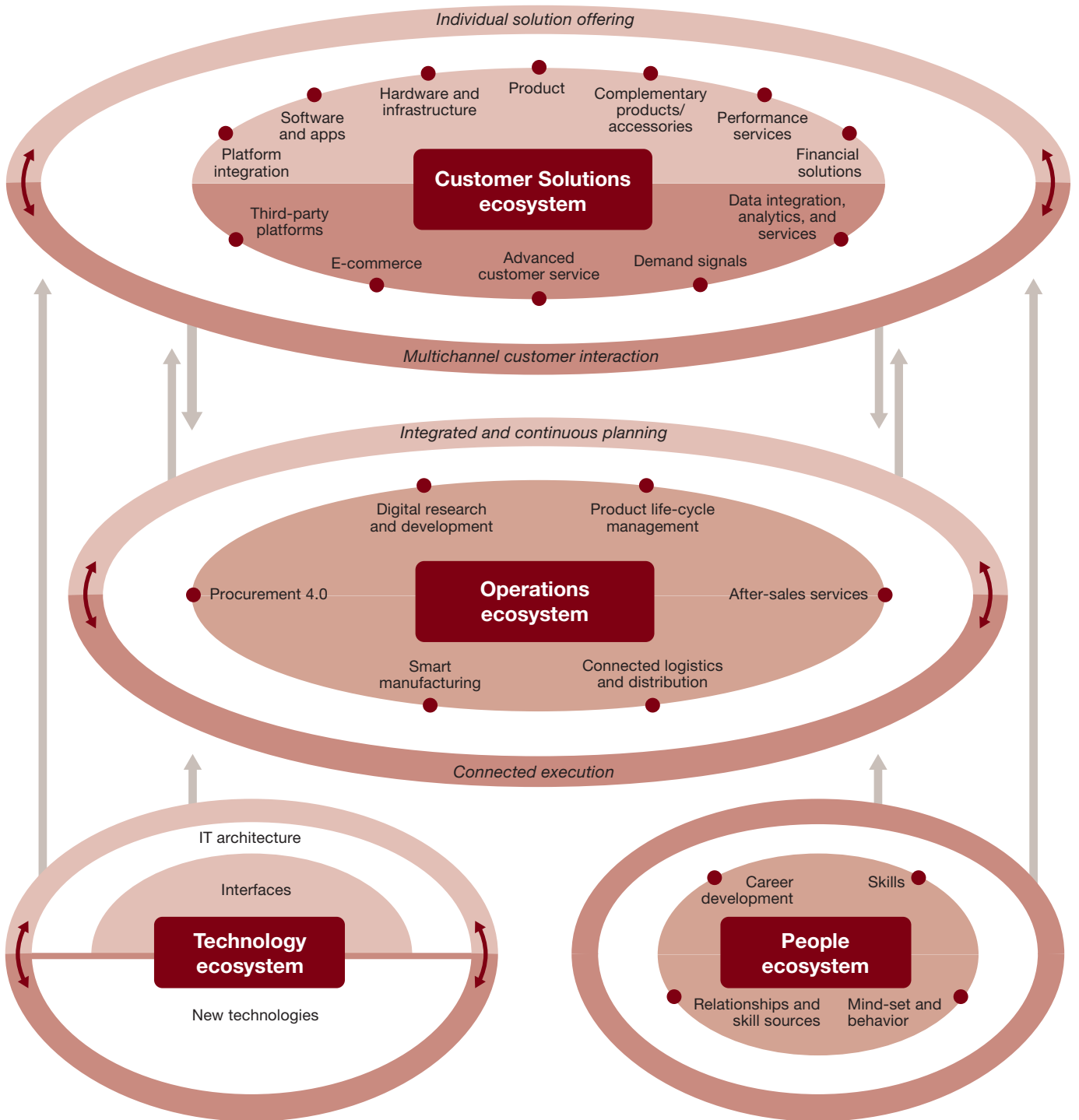
To better understand the vision, structure, and capabilities of Digital Champions and why they are potentially so successful, we explored the factors that they have in common and that separate them from other organizations today. They distinguish themselves through their mastery of four critical business ecosystem layers: Customer Solutions, Operations, Technology, and People. These are the four primary business layers that serve as the thread connecting the organization's activities. They form the basis of the enhanced digital value chain (see Exhibit 3, next page):

Each of the four ecosystem layers represents a cluster of activities, some occurring inside the organization and some outside. These activities are tied together through common digital connections and practices.

- **The Customer Solutions ecosystem:** In this grouping, also called the business model and customer value layer, companies put forth the distinctive products and services that they can best offer customers or consumers. They do this through personalization, customization, enhanced features, improved logistics, creative revenue models, and innovative designs and applications. This layer also includes external entities that the company is integrating into its solution to create additional value.
- **The Operations ecosystem:** Also called the solution enablement and value chain efficiency layer, this cluster encompasses the physical activities and flows that support the Customer Solutions ecosystem. These might include product development, planning, sourcing, manufacturing, warehousing, logistics, and services.

Digital Champions distinguish themselves through their mastery of four critical business ecosystem layers: Customer Solutions, Operations, Technology, and People.

Exhibit 3
The four digital ecosystem layers



Source: PwC's Strategy & Global Digital Operations Study 2018

Any external partners that are part of a company's operations, including contract manufacturers, logistics partners, and academia, are part of this ecosystem.

- **The Technology ecosystem:** This is an enabling ecosystem that covers IT architecture and interfaces as well as digital technologies, and drives or supports improvements and breakthroughs in the Customer Solutions, Operations, and People ecosystems. It includes such pivotal technologies for Industry 4.0 as artificial intelligence, 3D printing, the Industrial Internet of Things (IIoT) and sensors, augmented and virtual reality, and robots.
- **The People ecosystem:** Another enabling layer, this is the domain of organizational competence and culture. We have found that most companies, even those that realize the significant value of becoming Digital Champions, lack the vision, strategy, and culture to support digital transformation. This ecosystem covers skills, mind-set and behavior, and relationships and skill sources, as well as career development to support digital transformation.

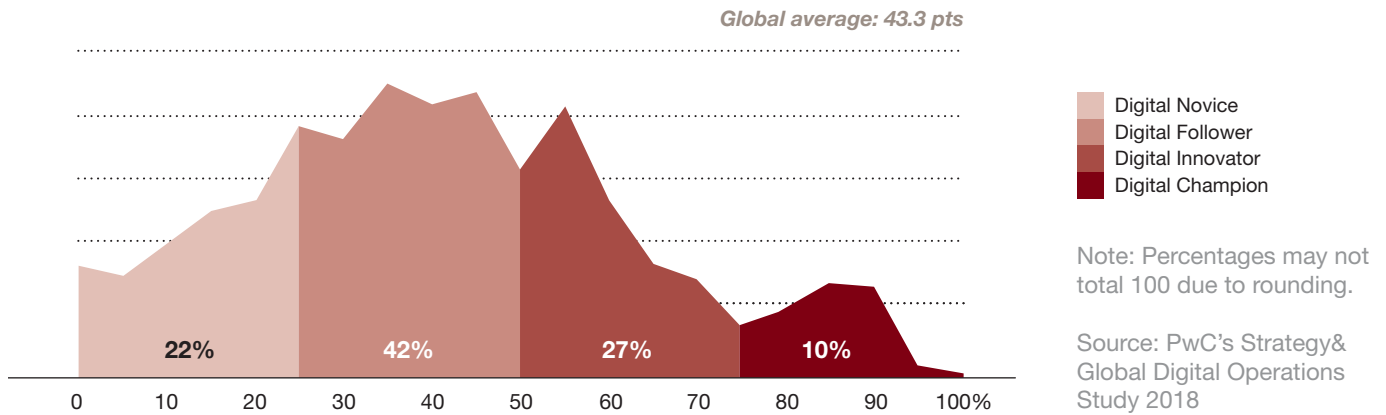
Not all Digital Champions are equally adept in each of the ecosystems. For instance, some have a relatively mature digital culture, while others have more seamlessly integrated external partners into their product and service development and go-to-market strategies. Still others are better at implementing a fully transparent and integrated supply chain. But on the whole, Digital Champions distinguish themselves by advancing their capabilities through all four ecosystem layers, creating an organizational environment that takes the greatest advantage of the opportunities from digitization. And their skills and digital leadership translate into a privileged position for digital maturity. Only 10 percent of the companies we surveyed can claim the distinction of being called Digital Champion (*see Exhibit 4, next page*). For more details on the survey methodology and the calculation of the maturity index, see page 59.

Digital Champions tend to be masters of integration and orchestration. To develop these ecosystems, they draw on internal and external partners and platforms. They also bring the four ecosystems together into a whole body of work. They align their organization around a clear and coherent overall strategy made up of a value proposition and distinctive capabilities. The ecosystems are the home of those capabilities: the source of the organization's advantage.

None of the ecosystems can be left out. For example, it's not enough to devise a Customer Solutions ecosystem that seems logical strategically and meshes well with market conditions. That's a good first step, but if

Only 10 percent of the companies we surveyed can claim the distinction of being called Digital Champion

Exhibit 4
Distribution of digital maturity levels



the Operations ecosystem does not have the requisite capabilities, partnerships, technology, and plan to propel efficiency and effectiveness, it will be impossible to achieve profitability and the business model will fall flat. In turn, the results will be disappointing. In short, true Digital Champions choreograph the movements of the four ecosystems together, integrate with partners effectively, and monetize the capabilities. They sit at the center of an efficient and innovative extended value chain that optimizes technology and people.

From a regional perspective, Asian (APAC) companies are clearly most advanced, with 19 percent of the companies from that region in the Digital Champion category, followed by the Americas, with 11 percent. European companies lag behind, with just 5 percent of companies in the Digital Champion segment. Asian companies have the advantage of setting up robust digital operations from essentially a blank slate in terms of factory automation, workforce, and even organizational IT networks as a whole — that is, without having numerous complex legacy systems and facilities to upgrade, integrate, or discard. In addition, Asian companies appear to be keener to try new business models and develop innovative products and services (see Exhibit 5, next page).

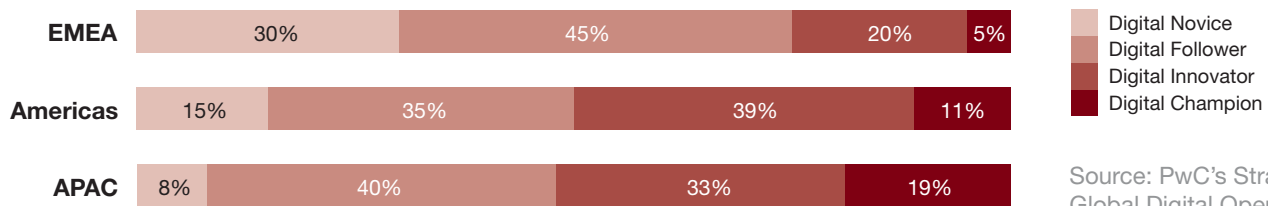
Among industries, automotive and electronics have the largest share of Digital Champions, at 20 and 14 percent, respectively. Operations in auto companies have been optimized, automated, and connected for decades, and electronics manufacturers have been at the forefront of

Among industries, automotive and electronics have the largest share of Digital Champions, at 20 and 14 percent, respectively.

outsourced manufacturing, which requires connecting and managing disparate systems and partners across an extended value chain. Consumer goods, industrial manufacturing, and process industries lag significantly behind (see Exhibit 6).

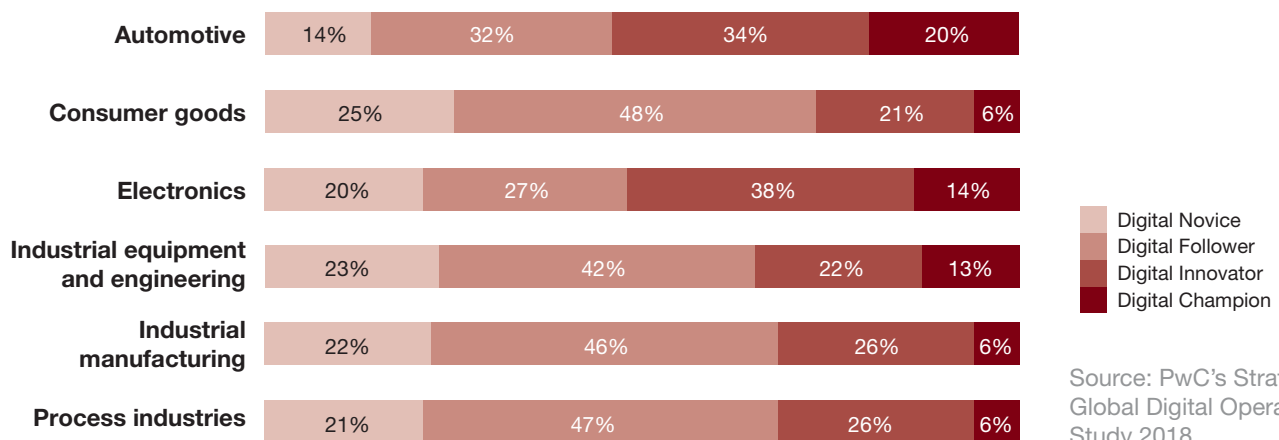
In the following sections, we take a deep dive into each of the four ecosystems, describing how they work and what Digital Champions do differently from other companies.

Exhibit 5
Levels of digital maturity by geographic region



Source: PwC's Strategy & Global Digital Operations Study 2018

Exhibit 6
Levels of digital maturity by industry



Source: PwC's Strategy & Global Digital Operations Study 2018

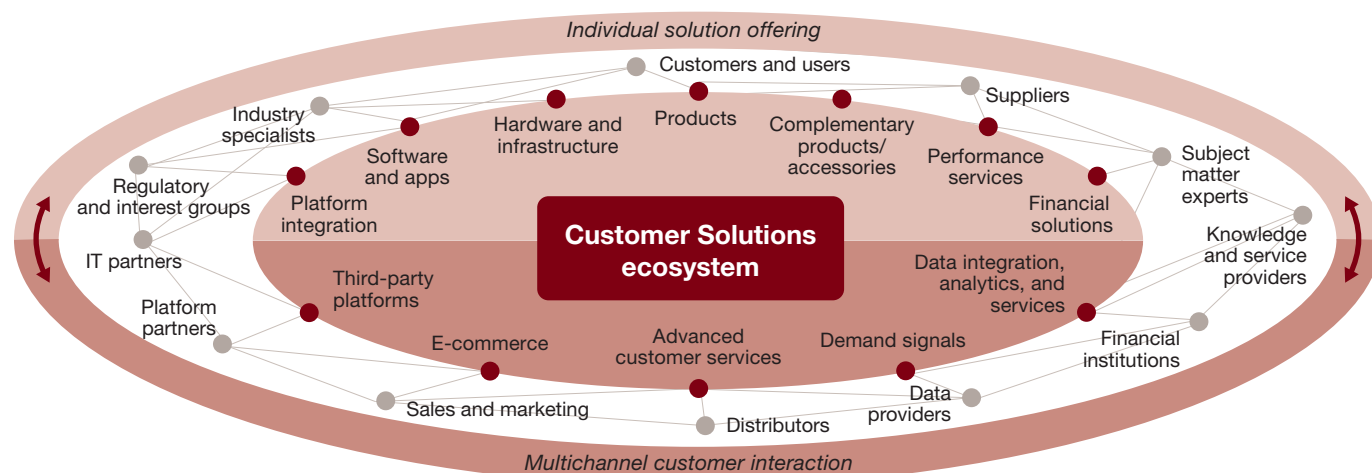
A close look at the four ecosystems

The Customer Solutions ecosystem

Digital Champions generate customer value by integrating individualized solutions offerings and multichannel customer interactions in the Customer Solutions ecosystem. Digital Champions continuously strengthen and enhance the solutions offering as well as access and reach out to customers across multiple channels, directly or through third parties (see Exhibit 7).

They excel in understanding the needs and preferences of their customers by capturing and integrating all relevant demand signals — generally through a network of internal and external partners — to create new customer insights that can be used in developing new and individualized products and services. This superior understanding

Exhibit 7
Overview of the Customer Solutions ecosystem



Source: PwC's Strategy & Global Digital Operations Study 2018

enables Digital Champions to turn customer insights into compelling solutions that provide customer value through a unique and tailored combination of core products (analog, augmented, digital) and complementary products and services. These are generally combinations of hardware, software, and apps or platform integration. In order to develop these solutions, Digital Champions rely on a network of partners such as suppliers, subject matter experts, knowledge and service providers, and IT partners.

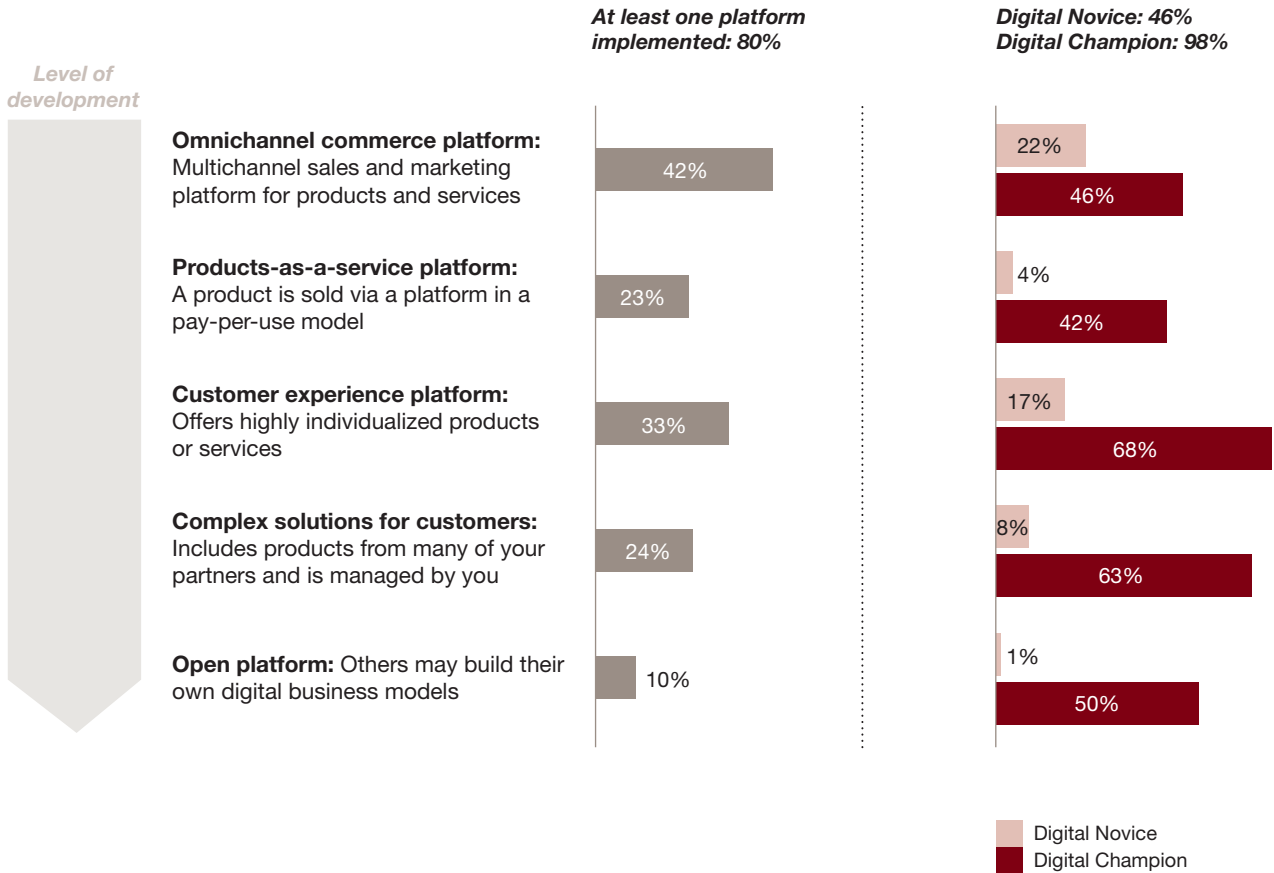
Digital Champions continuously enhance their solutions offering through tight integration and interaction with customers across all relevant channels — either directly via the sales and marketing department or through third parties such as platform partners, distributors, or data providers. The interaction with customers typically occurs across different routes to market, such as third-party vendor platforms; e-commerce platforms and apps; advanced customer services; or data integration, analytics and services (*see Exhibit 8, next page*).

Our study found that 50 percent of Digital Champions deploy open platforms for innovation and operational support. These platforms allow the Digital Champions to draw on a wide number of companies and individuals at low cost. This way, they can orchestrate otherwise unavailable solutions and develop unique skills and capabilities. Open platforms also enable partners and other ecosystem members to piggyback on the Digital Champion's business model: for example, to sell their own products via pay-per-use subscription programs and omnichannel commerce (hybrids of online and offline channels). The external ecosystem participants could be product and service development collaborators, digital innovation experts, suppliers, IT providers, and various complementary product providers in the private sector or, at times, academia.

A fine-tuned and mature Customer Solutions ecosystem tears down internal and external boundaries and creates value for all of the stakeholders, in ways that were previously not possible. For some companies that lag, it will be difficult to catch up with Digital Champions, which have invested time and resources in getting a running start in these innovative applications. The survey found that 68 percent of the Digital Champion respondents have adopted enhanced customer experience programs offering individualized products and services, while 63 percent are taking advantage of more intricate value chains that seamlessly provide supplier products to customers — as if the Digital Champion and its supply partner are the same company.

Exhibit 8
Business model platforms used by Digital Champions

Which types of platform are you focusing on to realize your business model?



Note: Multiple answers possible.
 Base was 1,155 companies.

Source: PwC's Strategy& Global Digital Operations Study 2018

Digital Champions are typically open to joint ventures or less formal partnerships with external companies. Some prominent recent partnerships:

- Apple and GE's agreement to bring Predix, GE's Industrial Internet of Things platform, to iOS devices, thus allowing industrial customers to write asset tracking and maintenance programs for iPhones and iPads and improve their mobility
- DuPont's joint venture with Chinese equipment company Hebei Nonghaha Agricultural Machinery Group to develop a device that precisely plants one corn seed per mound
- Deere & Company's partnership agreement with carbon fiber technology company King Agro to build high-quality, lightweight spray booms for Deere equipment
- Google and pharmaceutical company AbbVie's venture, researching diseases that afflict older people
- General Motors' alliance with Lyft to make an autonomous car

All of these deals have one thing in common: They are an attempt by companies to fill capabilities shortcomings in skill areas that are not their sweet spot, to better provide the distinctive product or service at the center of the ecosystem.

These examples also show that it is crucial for companies to accurately identify their appropriate position in the ecosystem. To illustrate this point, some Digital Champions place themselves at the hub of Customer Solutions ecosystems, in which all the participants communicate directly with the organization rather than with each other. Apple fits this category, with its huge coterie of app developers creating products and components directly for iPhones and iPads. So does Deere with its precision farming equipment, integrating technology and designs from third-party companies to help farmers accurately measure the use and performance of water resources, seeds, pesticides, soil enhancement products, and other agricultural elements.

Other Digital Champions prefer to establish Customer Solutions ecosystems with the organization at the core, but with more open and collaborative communication among members. For instance, Ford operates at the end of a traditional supply chain; its parts manufacturers have their own component makers, making Ford's Customer Solutions ecosystem a multitiered structure with frequent and necessary cooperation upstream and down. Chipmaker Qualcomm, which has its own centralized Customer Solutions ecosystem, is an external supplier

Digital Champions are typically open to joint ventures or less formal partnerships with external companies.

in Ford's, designing the automaker's vehicle-to-vehicle communications platform. And Ford itself is a supplier in Avis's rental car ecosystem as well as in ride-sharing company Lyft's autonomous car development program. All of these arrangements can be profitable for Digital Champions, providing that the ecosystems are designed to buttress the central activity: increasing customer value.

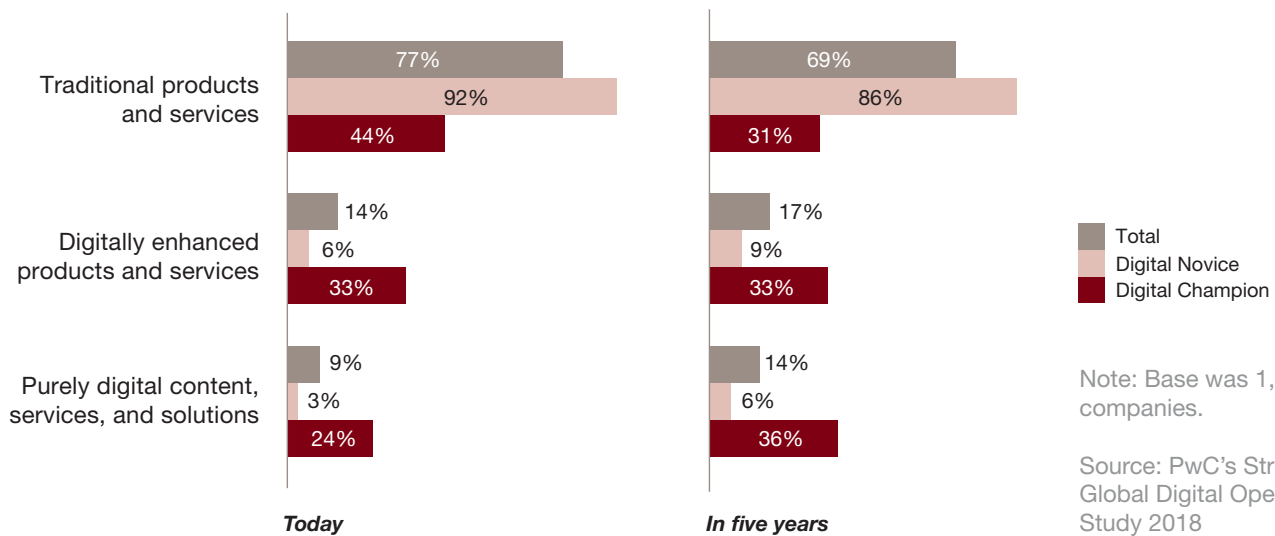
Our study found that more than 50 percent of Digital Champions' revenues come from digitally enhanced or purely digital products and services (see Exhibit 9). About two-thirds of the Digital Champions have already established a Customer Solutions ecosystem that includes interactivity with outside partners to create customer value. In the past, it may have been challenging to set up the technology and integration required to coordinate an ecosystem of numerous partners. Today's Digital Champions have overcome this obstacle by using their Customer Solutions ecosystem to its full advantage.

More than 50 percent of Digital Champions' revenues come from digitally enhanced or purely digital products and services.

Exhibit 9

Digital Champions achieve high revenues with digital products and services

What is the composition of your revenue today and in five years?



When asked about their prospects, Digital Champions were significantly optimistic. They expect their investment in new technologies and in improving their digital ecosystems to result in revenue increases of about 15 percent over the next five years (see Exhibit 10).

The benefits Digital Champions gain from their integrated Customer Solutions ecosystem are fourfold:

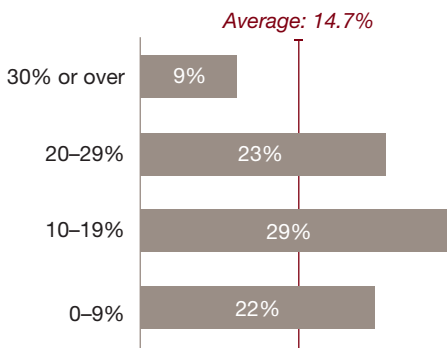
- Higher revenues from improvements in meeting customer needs across all relevant channels, through individualized solution offerings
- Higher margins through the optimal use of internal capabilities and an extended partner network
- Greater agility from managing a flexible network of partners
- Seamless connectivity to operations for greater efficiency and reduced costs

One noteworthy finding from our survey was the clear recognition of the importance of leading and managing these strong ecosystems. Fifty-one percent of the respondents said they believe they will make notable progress developing this layer within the next five years.

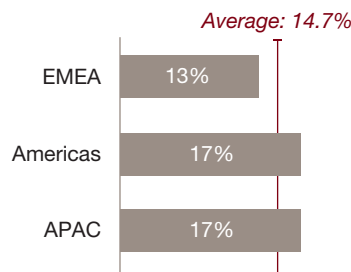
Exhibit 10
Expected benefits from investing in digital technologies

What benefits do you expect from your investments in digital technologies cumulatively over the next five years?

Additional five-year digital revenues



Additional five-year digital revenue by geographic region



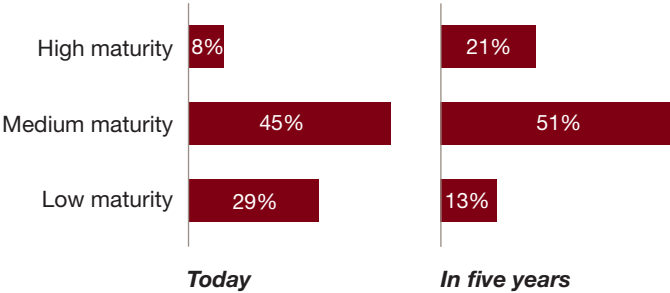
Note: Base was 1,155 companies.

Source: PwC’s Strategy & Global Digital Operations Study 2018

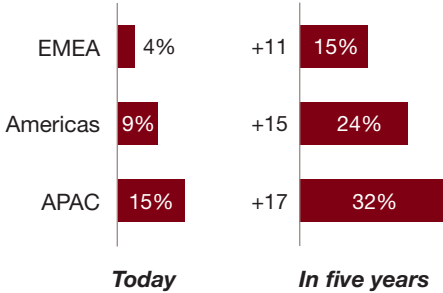
Regionally, Asian companies are putting the greatest effort into developing this ecosystem, as indicated by 42 percent of their responses. American companies are slightly behind at 30 percent, but only 17 percent of companies in EMEA (Europe, the Middle East, and Africa) indicated enthusiasm for this activity (see Exhibit 11).

Exhibit 11
Progress toward facilitating digital ecosystems

**To what extent have you made progress toward the implementation of digital ecosystems?
 And five years from now?**



Current digital ecosystem maturity and future development by geographic region



Note: Figures in percent, differences in percentage points. Base was 1,155 companies.

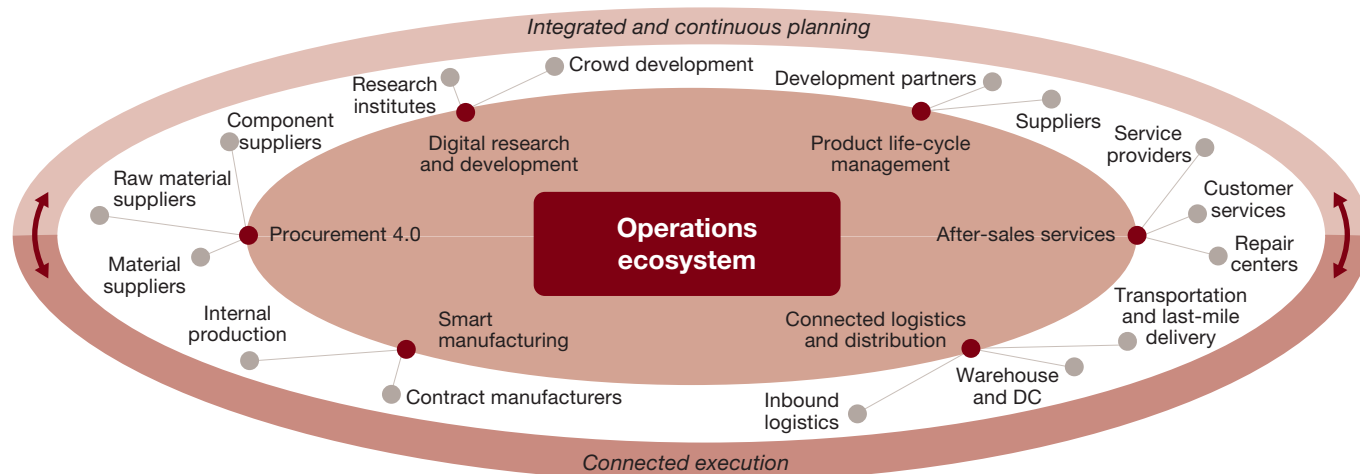
Source: PwC’s Strategy & Global Digital Operations Study 2018

A close look at the four ecosystems

The Operations ecosystem

This is the ecosystem layer that serves as the spine of the Digital Champion's value chain. The functions that support the Digital Champion in adding value to its relationships with consumers operate here: for example, the supply chain, product development, production, and distribution channels. The activities within the Operations ecosystem may be managed by external entities such as suppliers, contract manufacturers, distributors, logistics providers, and inventory managers. But they are in the orbit of the central Digital Champion, focused on meeting its needs (see Exhibit 12).

Exhibit 12
Overview of the Operations ecosystem



Source: PwC's Strategy & Global Digital Operations Study 2018

In Digital Champions, the Operations ecosystem allows for collaboration and full transparency across the entire value chain. It connects functions and partners horizontally in research and development, supply chain, and services. A highly functioning Operations ecosystem is especially valuable for planning and execution because it fosters *takt time*: the pacing of activity so that it continuously aligns supply chain execution (including production and replenishment) with real-time customer demand signals. For research and development, the Operations ecosystem coordinates a network of internal functions, suppliers, academia, researchers, and sourcing and logistics specialists. For manufacturing, this ecosystem vertically links and automates factories (owned by the Digital Champion or contracted out) and connects the shop floor directly to the supply chain and customer demand activities.

One important factor in becoming a Digital Champion is the dynamic relationship between the Operations and Customer Solutions ecosystems. Digitally mature companies derive the design of their Operations ecosystem directly from the needs of the Customer Solutions ecosystem. Our survey found that more than three out of four Digital Champions demonstrated a high degree of maturity in both ecosystems and more than half were champions in both domains. The significance of this correlation is apparent, for instance, in any company whose business model is based on customized products and that promises immediate shipments to customers. To meet these imperatives, the company must have a supply chain with total visibility, strong execution capabilities, and flexible manufacturing processes across its length.

As a Digital Champion's products or services change over time, the composition of the Operations ecosystem may be altered and continuously improved. Suppliers or factories may be needed in new regions; warehouses and parts management may require more flexibility to deliver on accelerated just-in-time schedules; and innovative logistics partners could be necessary to outpace competitors in providing customers with greater variety and convenience. It is critical to consistently reevaluate the Operations ecosystem against performance metrics and capability requirements drawn from the business model.

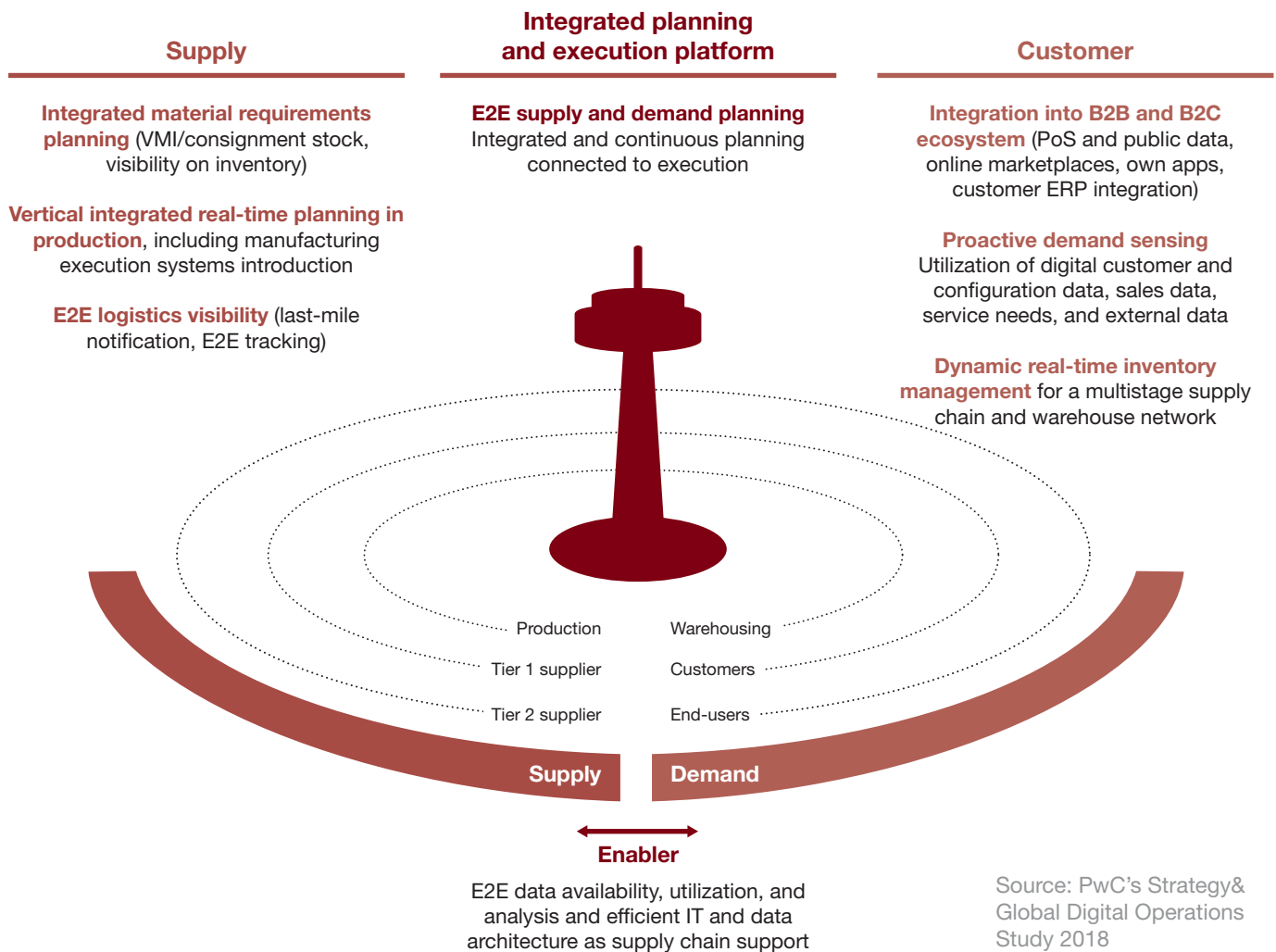
The Operations ecosystem is managed by an integrated planning and execution layer with far different attributes than the functional grid that has managed value chains in the past. Instead of the usual silos or separate departments, such as R&D, production, supply chain management, inventory control, sales, marketing, and the like, Digital Champions fashion a series of agile teams, consisting of internal and

Digitally mature companies derive the design of their Operations ecosystem directly from the requirements of their integrated solution offering and partner network.

external members. These are pulled together for specific tasks and projects, and dissolved when those projects are completed. The teams are charged with ensuring that the Operations ecosystem is serving the desired solutions targeted in the top layer. They may be created to address a single aspect of the Operations and Customer Solutions ecosystem interrelationship or multiple aspects.

A smoothly functioning Operations ecosystem provides a seamless transition among suppliers, logistics providers, manufacturers, and customers (see Exhibit 13). For instance, these companies can exchange

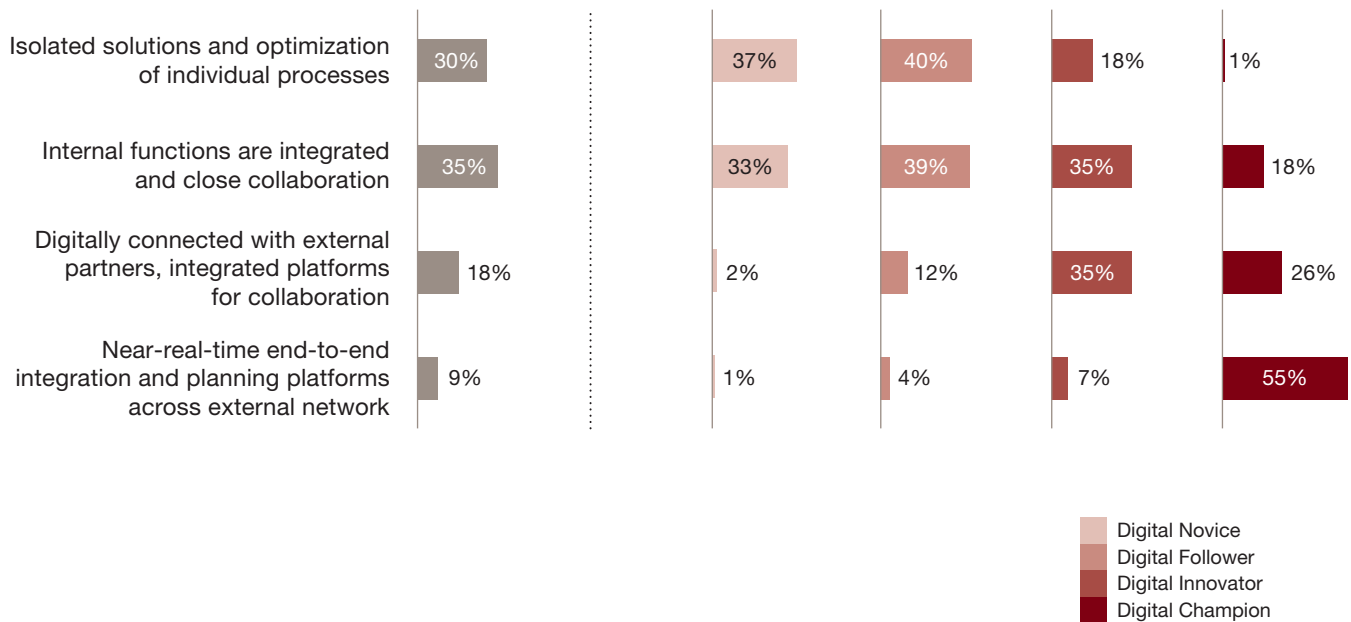
Exhibit 13
Characteristics of integrated, end-to-end supply and demand planning



product planning information across several stages of the value chain, almost instantaneously. This lets them quickly assess the impact of a change in demand across all members of the value chain and resolve any constraints that would hinder altering the production and distribution schedules. Digital Champions are well ahead of other companies in this area. More than 80 percent of Digital Champions are horizontally integrated with partners, while the average for all companies is only 27 percent (see Exhibit 14).

Exhibit 14
Supply chain integration by digital maturity level

Which statement best describes your supply chain?



Note: Base was 1,155 companies.

Source: PwC's Strategy& Global Digital Operations Study 2018

The benefits that Digital Champions gain from their Operations ecosystem are fivefold:

- **Transparency:** They have a complete end-to-end view of the Operations ecosystem.
- **Real-time data sharing:** All value chain members see information simultaneously.
- **Extended collaboration:** Collaboration with partners (such as suppliers) develops organically, becoming deeper and more synergistic as the solutions in the value chain require.
- **Immediate responsiveness and flexibility:** There is real-time response to demand changes from end customers, and prompt action at the planning and execution level across all tiers.
- **Connectivity:** The seamless integration of internal and external product life-cycle management, supply chain management, and customer information enables a well-connected end-to-end value chain from product creation to the consumer.

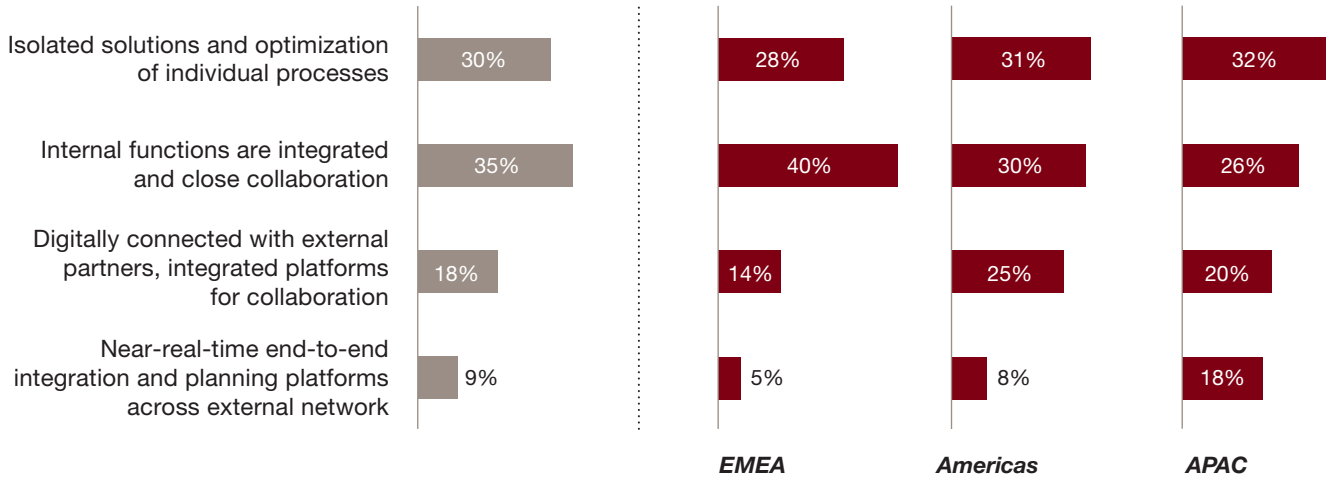
Among the industries we looked at, the highest degree of supply chain integration was in the auto sector, where 18 percent of companies have successfully embedded real-time planning and collaboration across the supplier network. This reflects the auto industry's well-established supply chains and its decades-old push to gain efficiencies, accelerate output, reduce waste, and recoup working capital through lean techniques. Electronics companies also scored high in this category due primarily to their long-standing close relationships with suppliers and their frequent use of outsourced contract manufacturers to meet high demand variation and short life cycles. In addition, the electronics industry had the greatest degree of factory automation, with the auto sector next in line.

As for regional breakdowns, supply chain integration maturity is highest in the Asia-Pacific area. Compared to the Americas and Europe, nearly twice as many Asia-Pacific companies qualify as advanced (*see Exhibit 15, next page*). Europe's record is particularly poor, with most of its companies no more than Digital Followers — that is, their internal functions are integrated and some close collaboration is evident, but there are no real-time end-to-end integration and planning platforms. The same could be said about manufacturing operations, where Asian companies again dominate and European companies lag. But in every region, less than 10 percent of the responding companies have fully automated their plants or communicate across production facilities.

As for regional breakdowns, supply chain integration maturity is highest in the Asia-Pacific area.

Exhibit 15
Supply chain integration by geographic region

Which statement best describes your supply chain?



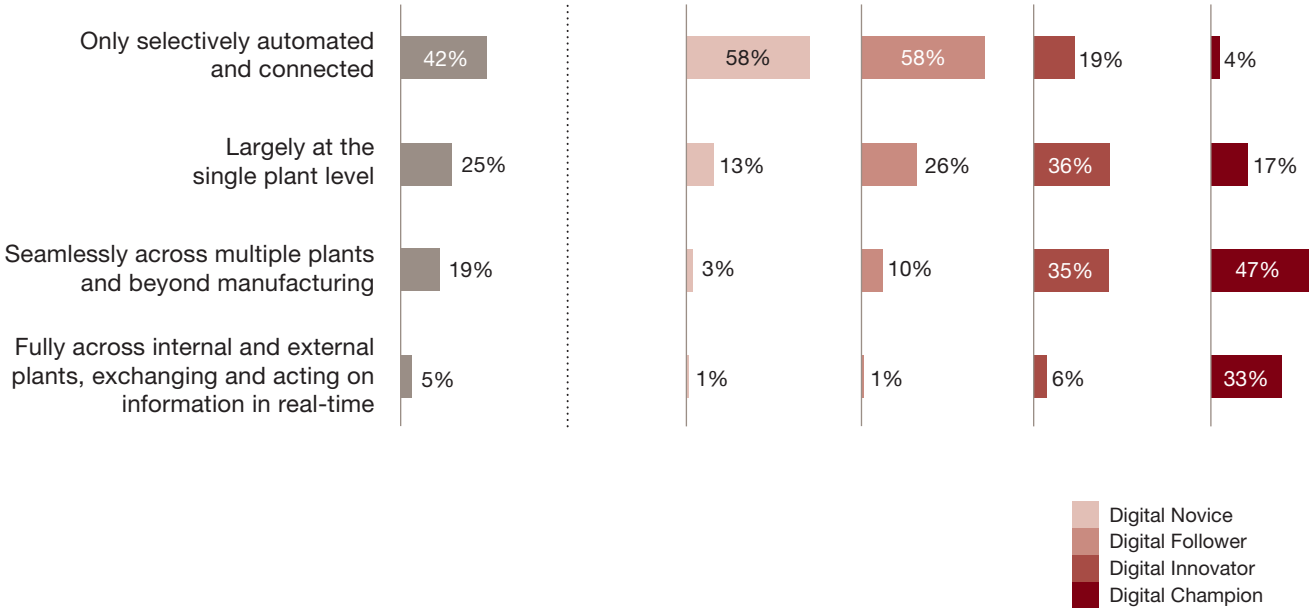
Note: Base was 1,155 companies.

Source: PwC's Strategy & Global Digital Operations Study 2018

Viewed through the manufacturing automation and connectivity lens, our study results showed that only about 5 percent of the companies interviewed are already embracing the futuristic vision of the digital factory — that is, their production operations are fully automated and transparently connected across internal and external plants, suppliers, and logistics channels (see Exhibits 16, below, and 17, page 32). All of these components are exchanging and acting on information in real time. Nineteen percent of the companies are at an intermediate step: Operations are largely automated and loosely connected across multiple plants and throughout the supplier community. Another 25 percent are followers: Operations are only selectively automated and connected beyond manufacturing. By far the largest cohort, 42 percent of the full group, belongs in the Digital Novices category.

Exhibit 16
Manufacturing automation and connectivity by digital maturity level

Which statement best describes the level of automation and connectivity at your manufacturing operations?



Note: Base was 1,155 companies.

Source: PwC’s Strategy & Global Digital Operations Study 2018

Bosch: Connecting the entire value stream

In the factory of the future, everything and everyone is connected. Sophisticated Industry 4.0 software solutions make everyday working life easier, while production processes become more transparent and efficient.

The factory of the future is the answer to rapidly changing market environments and demands. Customer requirements are shifting from mass products to individual, high-quality items. Markets are fast-paced; product life cycles are becoming shorter and shorter. Consequently, manufacturing companies are looking to reduce maintenance times and repair costs, and to achieve higher machine availability with less downtime.

To transform this vision into reality, companies require flexible and adaptable production concepts, where machines are constantly exchanging data with their environment. By connecting their value streams and by combining the strengths of humans and machines, manufacturing companies can react to the challenges of today and tomorrow.

Bosch sees itself as “mover and shaper” of the Internet of Things (IoT). In the industrial sector, this includes connecting entire value streams — from procurement (source) and manufacturing processes (make) to intralogistics and external logistics (deliver). But above all, humans play a key role in the development towards the connected factory.

Although the portfolio is driven by technology, the central issue for Bosch is always: What are the human needs? The superordinate role of Industry 4.0 is to make day-to-day work easier for employees, while optimizing manufacturing facilities regarding transparency, quality, flexibility, and productivity.

Accordingly, Industry 4.0 is an integral part of Bosch’s IoT strategy and, at the same time, one of the largest areas of



growth. The company’s goal is to realize cost savings of €1 billion with its own Industry 4.0 solutions, and generate additional revenue of similar size by 2020 by making these solutions available to external customers from different industries.

With the broad portfolio of intelligent Industry 4.0 software solutions and services, Bosch Connected Industry aims to provide solutions that address real challenges. All solutions are developed to support operators, maintenance staff, production supervisors, and factory managers in their daily work. Accordingly, the focus is on easy usage and a modular design.

“We eat what we cook” is how Bosch describes the attitude underlying this approach. With more than 130 years of manufacturing expertise and more than 270 production sites across the globe, Bosch has tried and tested all solutions in their own facilities. Based on the experience from the pilot projects, suitable solutions are further developed and — once they have reached market maturity — launched in the external market.

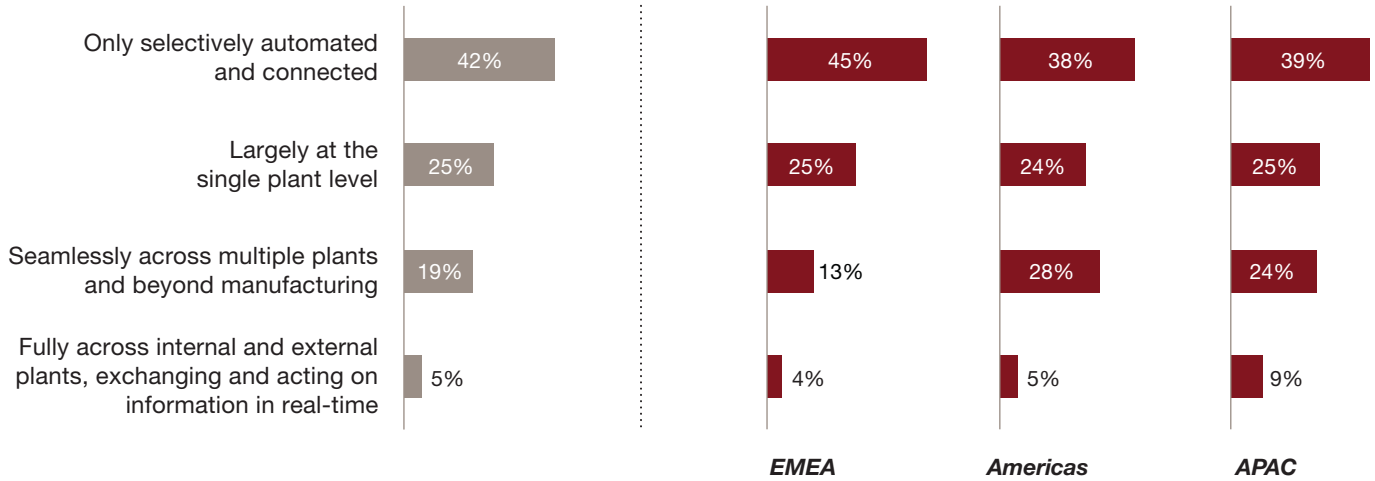
Following the analogy cited above, Bosch “offers only the best dishes” to its customers. This deep expertise and experience put Bosch in position to optimally support customers across their digitization process — from consulting and selecting the appropriate solutions to implementing them and supporting companies and staff in working with the new tools.

—Based on information from Robert Bosch GmbH, Germany

Exhibit 17

Manufacturing automation and connectivity by geographic region

Which statement best describes the level of automation and connectivity at your manufacturing operations?



Note: Base was 1,155 companies.

Source: PwC's Strategy & Global Digital Operations Study 2018

Their operations are only selectively automated and connected. Indeed, even among Digital Champions, 33 percent have achieved the highest level of maturity in the manufacturing sphere. This is a pivotal blind spot that companies need to work on to gain a fully integrated Operations ecosystem.

Daimler: Maximum flexibility and transparency

Digital transformation covers the entire value chain at the Car Division of Daimler AG. “Smart production” is the overarching target picture.

The vision of Mercedes-Benz Cars: Smart production is characterized by a very high degree of flexibility. It is transparent and extremely efficient. It assures and enhances the quality of products as well as the production processes by means of forward-looking and self-optimizing quality assurance processes. In full-flex plants, all vehicle architectures and drive types roll off the same production line. All plants and trades, as well as the supply chain with the suppliers, form a digital network in smart production. On the basis of digital twins of products and production, data is recorded and evaluated in real time. In this way, resources can be used even more efficiently. Digital methods support the implementation of green production. Employees work at ergonomically optimized workplaces and processes. Order planning supported by big data identifies and optimally meets the customers’ needs.

Digitization focuses on five key areas:

- Worldwide 360-degree networking of all plants and installations, starting with the smallest sensor
- A digital and continuous process chain, ranging from development and production to after-sales
- Use of big data — increasingly in real-time — for assuring and further enhancing quality and efficiency
- Adaptable factories that can be converted to new series within a few hours
- The transparent “smart supply chain” with driverless transport systems, intelligently commissioned product baskets, and paperless factories.

There is already worldwide implementation in all five core areas. For instance, in the field of 360-degree connectivity, Wi-Fi and location tracking are used, as is the software Integra, which connects all plants and production lines with one another. With regard to the digital process chain, the focus is on digital development, planning, and simulations. One example is the virtual assembly station Avatar, with which production ergonomics are assured by means of virtual reality at an early stage in the product development process. Further use cases are human-robot collaborations, big data analyses such as predictive maintenance, the use of artificial intelligence, and smart logistics, such as RFID chips and driverless transport systems.



Despite — or precisely because of — the use of such extremely modern technology, the digitization process also involves a cultural transformation of the company. Mercedes-Benz Cars flattens out hierarchies, thereby achieving extremely high speeds in decision-making processes. They tear down silos and thus maximize networking. The focus is always on humans as customers and employees.

Mercedes-Benz Cars Operations (MO) is responsible for car production at more than 30 locations worldwide. Within a flexible and efficient production network with approximately 78,000 employees, this includes the central functions of production planning, TECFACTORY, logistics, and quality management. The network structure is based on the production architectures of front-wheel drive (compact cars) and rear-wheel drive (for instance, S-, E-, and C-class) as well as the SUV and sports car architectures. This is accompanied by a production network for the powertrain (engines, gearboxes, axles, components). The focal point of every architecture production network is a lead factory, which acts as a center of competence for new production starts, technology, and quality assurance. With this strategy, MO is able to produce vehicles with even greater flexibility and efficiency combined with proven top quality. The Daimler division is able to respond more rapidly to changes in demand and also integrate electric vehicles in current serial production. The success is self-evident: As a result of the strong demand, Mercedes-Benz Cars set a further production record in 2017, manufacturing more than 2.4 million vehicles. This is the seventh production record in succession. With the aid of Industry 4.0, this growth strategy will be continued.

—Based on information from Daimler AG, Germany

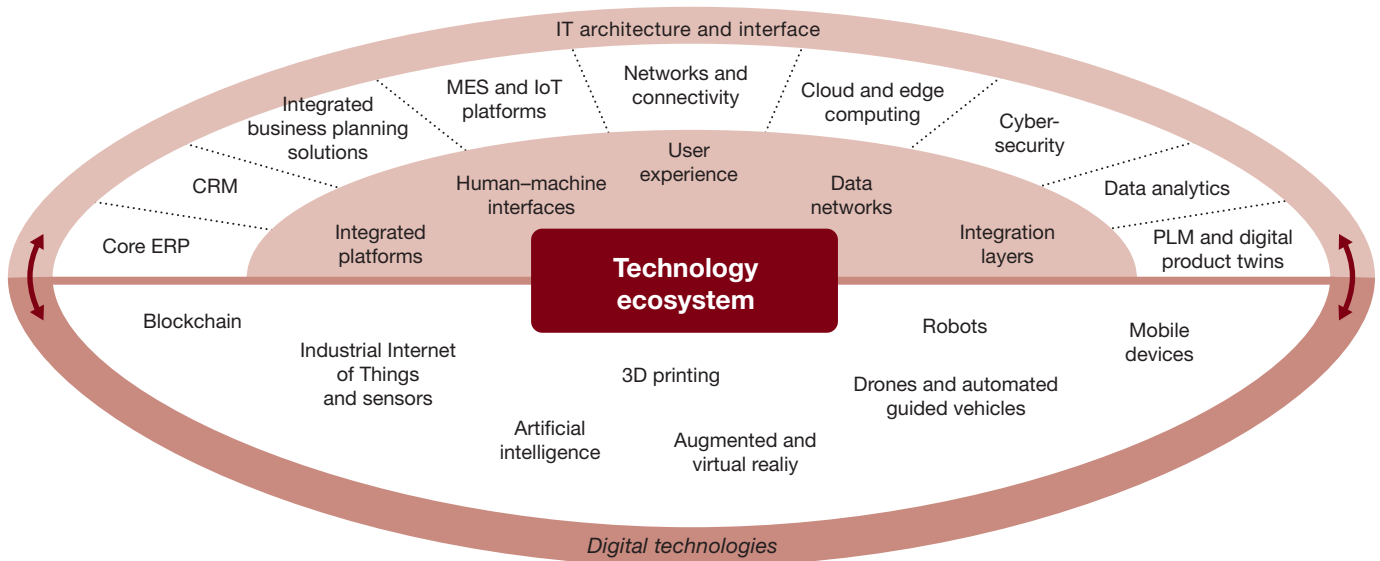
The Technology ecosystem

This is an enabling ecosystem that includes IT architecture and interfaces as well as digital technologies. This ecosystem drives and supports improvements and breakthroughs in the Customer Solutions, Operations, and People ecosystems. Since the Customer Solutions ecosystem determines the company's business model, its customer value layer, and, in turn, its operational imperatives, most Digital Champions have clearly identified the types of technology they need to master to provide added value to customers, and they have established expected outcomes. These outcomes are primarily performance improvements that further the company's ability to provide value to their customers. In addition, Digital Champions choose their IT architecture and interfaces to most efficiently and effectively leverage digital technologies and connect them internally and externally.

The information technology architecture (the outer layer in the top part of the Technology ecosystem) is the critical backbone for enabling and implementing new technologies across the organization. One of its most important tasks is to support the digitization of standard business process operations, such as integrated business planning, manufacturing execution, customer service, and product life-cycle management. These new business process programs are often built on cloud and data analytics applications with the highest data security standards. Interfaces link the IT architecture to the user through integrated platforms, human-machine interfaces, user experience designs, data networks, and integration layers. All of these are developed in a coordinated way, to provide the user with a high-quality experience, reliability, and efficiency (*see Exhibit 18, next page*).

Digital Champions are adept at smartly expanding their Technology ecosystem. They form partnerships with outside vendors of platforms, hardware, and software to quickly implement digital strategies, rather than slowing the process down by relying on homegrown and stand-alone systems. Ultimately, these partnerships provide innovation that can be used throughout the company's entire series of ecosystems, internal and external.

Exhibit 18
Overview of the Technology ecosystem



Source: PwC's Strategy & Global Digital Operations Study 2018

Among Digital Champions, early adoption of new technologies and building on the accrued benefits to further their digital maturity are commonplace. The benefits include increased sales and efficiency gains. Furthermore, through the technology transformation it facilitates in the Operations ecosystem, the Technology ecosystem influences the company's culture — reflected in the composition and skill sets of its labor pool.

In our survey, three main points stand out about the importance of technology and the role it plays in supporting Digital Champions' Customer Solutions offerings:

1. Digital Champions have already implemented about two-thirds of the key digital technologies. They have adopted a holistic approach for implementing and connecting technologies — across the organization and with strategic partners — and eschew isolated technology implementations.

2. Digital Champions forecast significantly higher efficiencies from technology than Digital Novices do (16.2 percent vs. 10.5 percent over the next five years), and they create a virtuous circle fueled by smart technology decisions to leverage these benefits.
3. One of three Digital Champions are using artificial intelligence (AI) with applications spanning all functions, while 99 percent of Digital Novices have not started to use AI at all.

In our interviews we found that Digital Champions don't implement technology just for the sake of technology alone, or to keep up with trends. Rather, they understand clearly how specific technologies drive the components of competitive advantage — speed, flexibility, customization, and efficiency. They pick technologies that are most crucial to their operations and that best support the requirements of their Customer Solutions ecosystem. These companies continuously reevaluate the technologies they are using to support the entire value chain, all the way to the distinctive offerings they present to customers — and they are not shy about pushing implementation of technologies that they deem critical.

At least 90 percent of Digital Champions have already implemented, piloted, or planned some of the most critical current technologies, many of them still evolving. Among these technologies:

- Integrated end-to-end supply chain planning (100 percent of Digital Champions)
- Predictive maintenance of assets and products (96 percent)
- Manufacturing execution systems (94 percent)
- Industrial Internet of Things (97 percent)
- Digital twins, which essentially are virtual versions of physical assets or products, such as factories, that can be used for digitally supported planning, scheduling, and product development, among other possibilities (94 percent)
- Advanced robotics (90 percent)

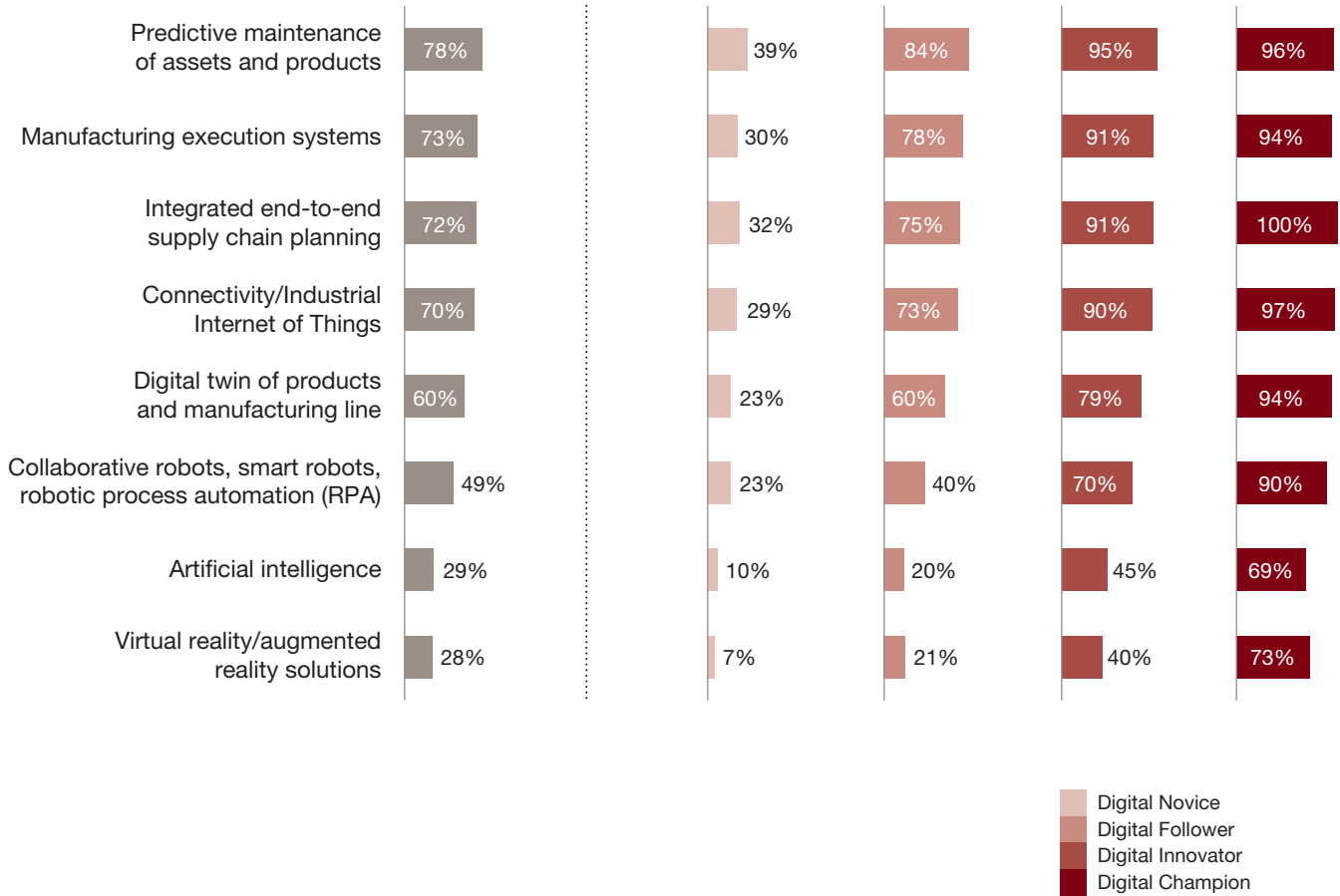
By comparison, only about one-third of Digital Novices have adopted the most common operational technologies, like predictive maintenance (39 percent) and integrated supply chain planning (32 percent) (see Exhibit 19, next page).

Digital Champions understand clearly how specific technologies drive the components of competitive advantage.

Exhibit 19

Implementation of new technologies by digital maturity level

To what extent have you implemented, piloted, or planned to implement the following technologies within your company?



Note: Base was 1,155 companies.

Source: PwC's Strategy & Global Digital Operations Study 2018

Digital Champions have also been active in implementing and piloting augmented reality (AR) and virtual reality (VR) technologies. These provide computer-generated simulation of three-dimensional images or complete landscapes that allow viewers to interact with the digital environment in realistic ways. These technologies are valuable for maintenance, service, and quality assurance. They are also useful for self-learning and training. Digital Champions use them to alert their workforces quickly about changes in their operating procedures or about new ways that employee tasks are expected to be integrated with the digital workflow and assets.

Of the companies we surveyed, 28 percent have implemented, piloted, or planned to implement AR and/or VR technology, with the Asia-Pacific region — where 44 percent of the companies have adopted these technologies — boasting the greatest penetration. Meanwhile, 73 percent of Digital Champions have implemented, have piloted, or plan to implement AR/VR programs in hopes of adopting this technology soon. That's a high number for such a recent technological breakthrough. By contrast, only 40 percent of Digital Innovators have gone as far as Digital Champions in embracing these advances (*see Exhibit 20, next page*).

Having already realized tangible benefits from adopting new technologies, Digital Champions are looking forward to more in the coming years. They expect the advantages and returns from technological improvements will be significant, especially as newer, more complex achievements occur in AI and robotics.

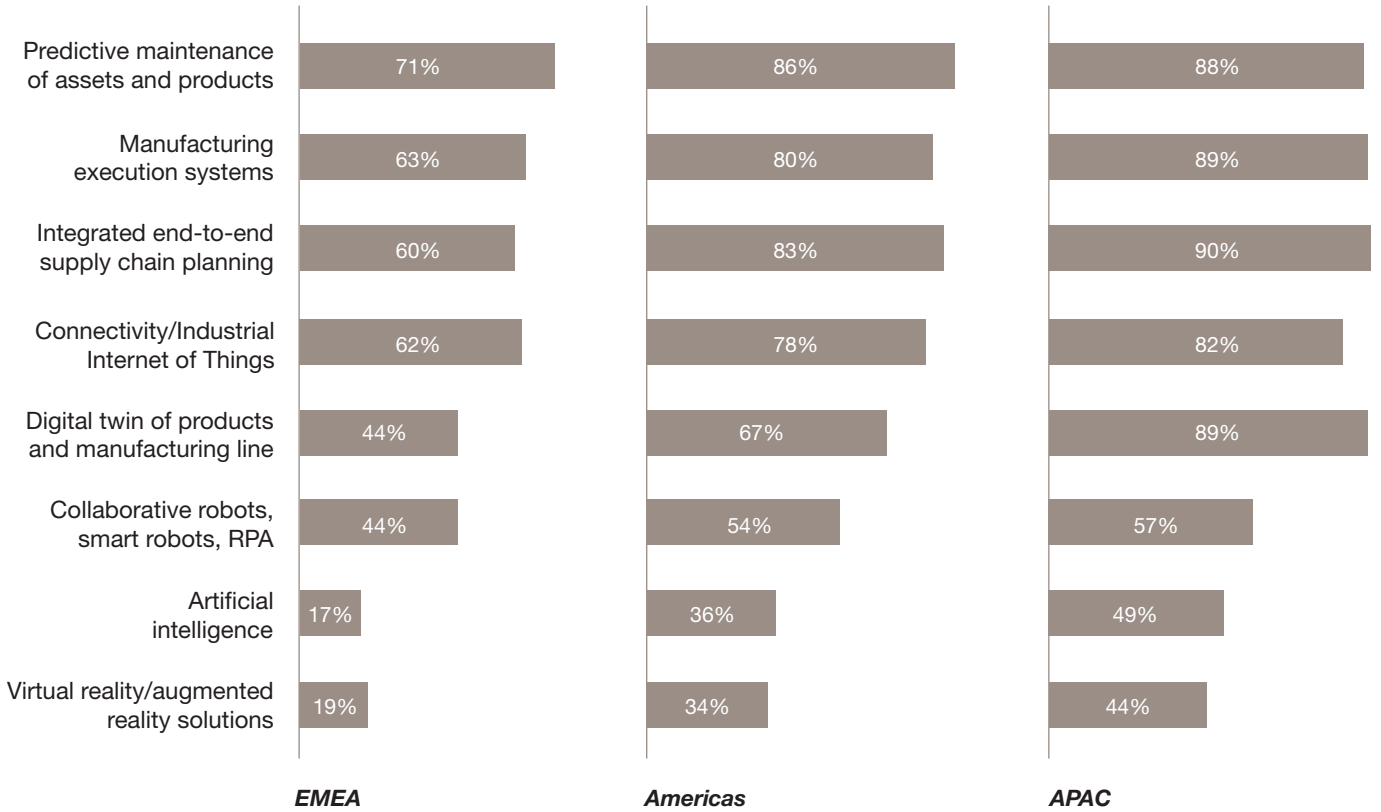
Asked to forecast their revenue gains from investments in technology over the next five years, Digital Champions said they anticipate a mean of about 17.2 percent growth in the top line, compared with the 9.5 percent that Digital Novices expect (*see Exhibit 21, page 40*). Similarly, Digital Champions are looking for 16.2 percent improvement in efficiency gains and cost reductions from technology adoption, compared with 10.5 percent for Digital Novices.

One interesting statistic that came out of this portion of our study concerned Digital Innovators, the group next to Digital Champions in their digital maturity. These companies foresee revenue gains of nearly 20 percent, outpacing Digital Champions. We suspect that this slightly higher figure for Digital Innovators reflects the fact that Digital Champions have already enjoyed initial revenue gains from technology investments, while Digital Innovators are a step behind and will reap these improvements over the next few years if they act urgently to adopt Digital Champion strategies and innovative methods. However, laggards will likely find themselves left behind, hurt by their hesitation.

Exhibit 20

Implementation of new technologies by geographic region

To what extent have you implemented, piloted, or planned to implement the following technologies within your company?



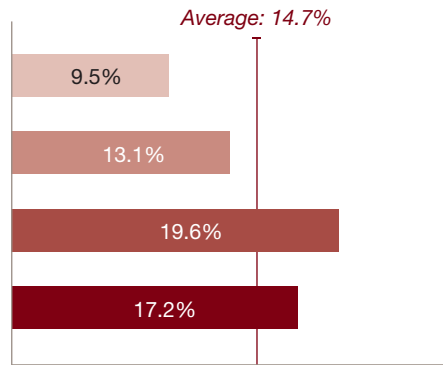
Note: Base was 1,155 companies.

Source: PwC's Strategy & Global Digital Operations Study 2018

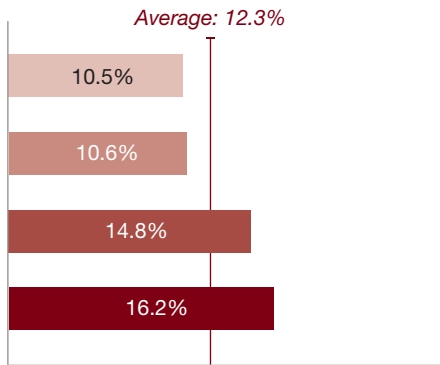
Exhibit 21
Expected benefits of investing in digital technologies

What benefits do you expect from your investments in digital technologies cumulatively over the next five years?

Revenue increase over five years, by digital maturity level

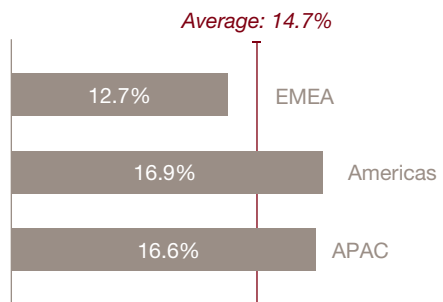


Efficiency gain/cost reduction over five years, by digital maturity level

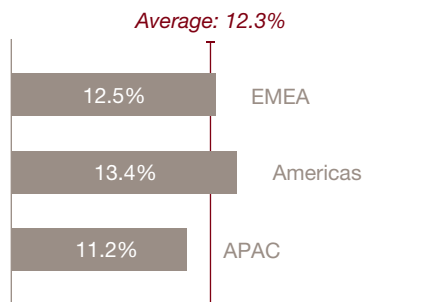


Digital Novice
 Digital Follower
 Digital Innovator
 Digital Champion

Revenue increase over five years, by geographic region



Efficiency gain/cost reduction over five years, by geographic region



Note: Base was 1,155 companies.

Source: PwC's Strategy & Global Digital Operations Study 2018

GE Digital: Powering a new era of industrial productivity

Digital transformation at GE is not just transforming productivity inside the company but is providing the springboard to lead the next wave of industrial productivity outside. The use of advanced digital technologies to transform industrial processes and efficiency is delivering tangible results. GE's target of delivering US\$1 billion of productivity gains between 2015 and 2020, for example, had already been reached by the end of 2017.

This achievement is a key step in the first stage of GE's digital industrial strategy — leveraging digital industrial capabilities to drive internal productivity and operational efficiency. The company calls it “GE for GE.” The learning from that is then used to provide automation and packaged applications to enable customers to benefit from these capabilities — “GE for Customers.” Finally, “GE for the World” uses an open-innovation approach that is available to virtually any company in virtually any industrial category through co-creation using the Predix application development platform for the Industrial IoT (IIoT).

A digital change agent

Within GE, GE Digital is acting as a “digital change agent,” with the goal of being the best digital industrial company in the world. Improved asset performance management (APM), field services, and operational efficiency have been the focal points for digital innovation. A considerable emphasis has been placed on sensing technology, data ingestion and management technology, and predictive maintenance technology. The gains, for example, can be seen in the impact of the collection of data and digitization of many of the manual processes involved in managing outages by GE's power business field services team. It has lowered costs



by around US\$200 million by reducing cycle times and the resources needed for a repair and maintenance event.

Moving forward, GE Digital is emphasizing the importance of edge technology, artificial intelligence (AI), and virtual reality (VR). The sheer volume of data coming from assets makes edge computing a key next step. A car, for example, can generate a petabyte (10^{15} bytes) of data on its own in a single month. Edge computing will, in effect, allow the extension of GE's Predix platform out to devices that sit on or next to the assets.

Gaining a future edge

The rapid development of AI and machine learning is enabling GE to analyze, model, and map disparate data sources to create a “digital twin” of an asset. In turn, this will help companies to better understand and predict performance, find new revenue streams, and change the way their business operates. GE is also looking to VR to play a key role — for example, with VR engines overlaying instructions onto a technician's safety glasses, shrinking the time spent on repair and maintenance tasks.

GE envisages digital transformation and the IIoT will bring a paradigm shift to the future of work. Employees will no longer have to tell the system what happened or what needs to happen. Instead, the system will tell employees the best options, augmenting their decision making. GE is also transforming the business model around service. Already, in some parts of its business, GE has introduced “power by the hour,” with the customer paying per hour of the operation of the device instead of paying a fee. In a service-based world, instead of selling assets, GE is selling the outcome the asset provides.

—Based on information from GE Digital, USA

On the other hand, Digital Champions are in line to do better than all the other categories in efficiency enhancements from technology, because technology benefits tend to be continuous, iterative, and cumulative. These benefits create a virtuous circle — each digital advance can be the starting point for additional technology improvements that accelerate digital maturity. Of course, to take advantage of this virtuous circle, companies must have a digital culture and the skill sets to figure out the optimal processes and materials for the best use of advanced technologies. This is not easy to do, but with the right investments of resources, a company can turn even off-the-shelf applications into proprietary programs that are uniquely suited to the organization’s value chain and operational needs.

The AI revolution

Companies are awash in data these days. Whether coming from customers, suppliers, machine sensors, factory monitoring devices, or automated maintenance programs — and all of that is just the tip of the iceberg — big data has become the centerpiece of many Industry 4.0 activities. Technologically savvy organizations are taking advantage of big data’s potential in multiple dimensions. They are expanding revenue streams through insight gained from marketing data analytics, understanding customer behavior and attitudes more completely, modeling operational changes to improve value chain efficiency, and automating support function manual tasks, thus improving process quality, speed, and agility.

But as much potential as these analytical activities have, many companies have not seen visible returns from their growing collection of data. That’s where, for Digital Champions, artificial intelligence is making a difference.

In our definition, AI is a collective term for computer systems that can sense their environment, think, learn, and take action in response to stimuli. These stimuli can include data derived from voluminous information-gathering programs as well as from visual, tactile, and other sensors. Forms of AI in use today include, among others, digital assistants, chatbots, and machine learning. AI works in four ways, each representing a different form of human–machine interaction:

- **Automation:** Automation of manual and cognitive tasks, including both routine and nonroutine tasks
- **Assisted intelligence:** Helping people perform tasks faster and better

Digital Champions are in line to do better than all the other categories in efficiency enhancements from technology, because technology benefits tend to be continuous, iterative, and cumulative.

- **Augmented intelligence:** Helping people make better decisions
- **Autonomous intelligence:** Automating decision-making processes without human intervention

Even in its least sophisticated forms, with automated intelligence alone, AI allows organizations to make the best use of big data. Machine intelligence can handle high volumes of disparate structured and unstructured data, managing and massaging it to produce analyses, assessments, and applications. These are already beginning to have a huge impact on vehicle development, smart technologies for individuals and homes, healthcare diagnosis and support, customized retail, supply chain optimization, and on-demand production (see Exhibit 22).

Exhibit 22
Four forms of artificial intelligence

	<i>Human in the loop</i>	<i>No human in the loop</i>
<i>Hardwired/ specific systems</i>	<p>Assisted intelligence AI systems that assist humans in making decisions or taking actions. Hardwired systems that do not learn from their interactions.</p>	<p>Automation Automation of manual and cognitive tasks that are either routine or nonroutine. This does not involve new ways of doing things, but automates existing tasks.</p>
<i>Adaptive systems</i>	<p>Augmented intelligence AI systems that augment human decision making and continuously learn from their interactions with humans and the environment.</p>	<p>Autonomous intelligence AI systems that can adapt to different situations and can act autonomously without human assistance.</p>

Source: PwC's Strategy & Global Digital Operations Study 2018

According to [Sizing the Prize](#), a 2017 PwC research report on AI prospects, global GDP will be as much as 14 percent higher in 2030 due to advances in AI and widespread implementation of the technology. These economic gains will be derived from productivity improvements in automating processes (including the use of robots and autonomous vehicles); businesses augmenting the quality and quantity of output from their existing labor force with AI technologies; and increased consumer demand resulting from the availability of personalized and more desirable AI-enhanced products and services.

Digital Champions are investing heavily in AI for a wide range of applications, but primarily to enhance their established value chain connections and their ability to manage the flow of big data.

Overall, 9 percent of companies around the world have already implemented AI, with Asia being at the forefront (15 percent of companies implemented) while EMEA is lagging (5 percent). Among the Digital Champions, every third company (34 percent) has implemented AI across major functions with the main goal of automating manual and cognitive tasks (44 percent), while 99 percent of Digital Novices have not implemented AI at all. Overall study results show that AI is at the beginning of its development. Levels of implementation across all functions suggest that companies see the large potential of AI, but specific core use cases are just developing, with companies experimenting broadly to quantify the value of the technology. The lack of people skills to implement AI (52 percent) and reliability of data (42 percent) are the major challenges for Digital Champions that implement AI (*see Exhibit 23, page 46*).

In general, AI is revolutionizing the way Digital Champions operate and how businesses will run in the future. Used in the most digitally mature companies, AI systems go beyond simple process automation to self-learning and autonomy that impacts some of the most critical aspects of a business, its culture, the way people work in the organization, the interaction between humans and machines, and the organization's growth strategy. The importance of the connection between human resources and digital transformation cannot be overstated. New digital environments have a large and lasting impact on the way companies operate and the capabilities that companies must have.

BASF: Leading the digital transformation in chemicals

The thinking behind ecosystems is nothing new for BASF. It is central to the “Verbund” (integration) principle, which is a traditional core strength of the company. Verbund emphasizes intelligent integration, not just of production plants, logistics flows, and infrastructure, but also expertise and demand. It has proven to be a strong foundation for the launch of BASF 4.0, a comprehensive digital initiative whose results are boosting efficiency and growth.

Greater efficiency

The initiative is driving digital transformation in all areas of the company’s activities. A key area is “smart manufacturing.” Augmented reality applications are supporting manufacturing employees in their daily activities. They are reducing changeover and turnover times by helping make tasks tangible and real as well as data instantaneously available at the right time and the right place. BASF is on target to roll out augmented reality in more than 400 plants worldwide within the next years. Predictive maintenance is similarly on track to be in place in 100 large production facilities. It predicts the performance curve of critical machinery and equipment. That data is used to trigger maintenance work or readjust operational process parameters. One focus topic in the area of digitization in R&D is scientific modeling and simulation with high-performance computers. BASF’s supercomputer Curiosity will help reduce time-to-market by enabling processing of a greater number of and much more complex simulations and modeling and by exploring previously unknown relationships. This boosts BASF’s efficiency in terms of cycle times and output of results. Examples include simulations of industrial catalysts and crop protection products. With catalysts, it is especially important to increase their efficiency — and, hence, sustainability — by decreasing raw material input and generating less waste. It is also critical that crop protection products work more efficiently, and in a more targeted manner, to better meet current and future requirements.



BASF is also using digital technologies to enhance data visibility and transparency throughout the entire supply chain. This improves delivery reliability and builds a closer relationship with customers, suppliers, and strategic partners. By jointly collaborating with its supply chain partners through an integrated ecosystem, BASF gains real-time visibility to enable proactive information management while increasing customer responsiveness and generating sustainable business growth.

Stronger growth

Digital business models are opening opportunities to sell new services to customers, including new streams of revenue beyond chemical products. BASF has developed more than 50 such models so far, many of which have come to fruition, enabling customers to collaborate in product specifications in ways that were not possible before.

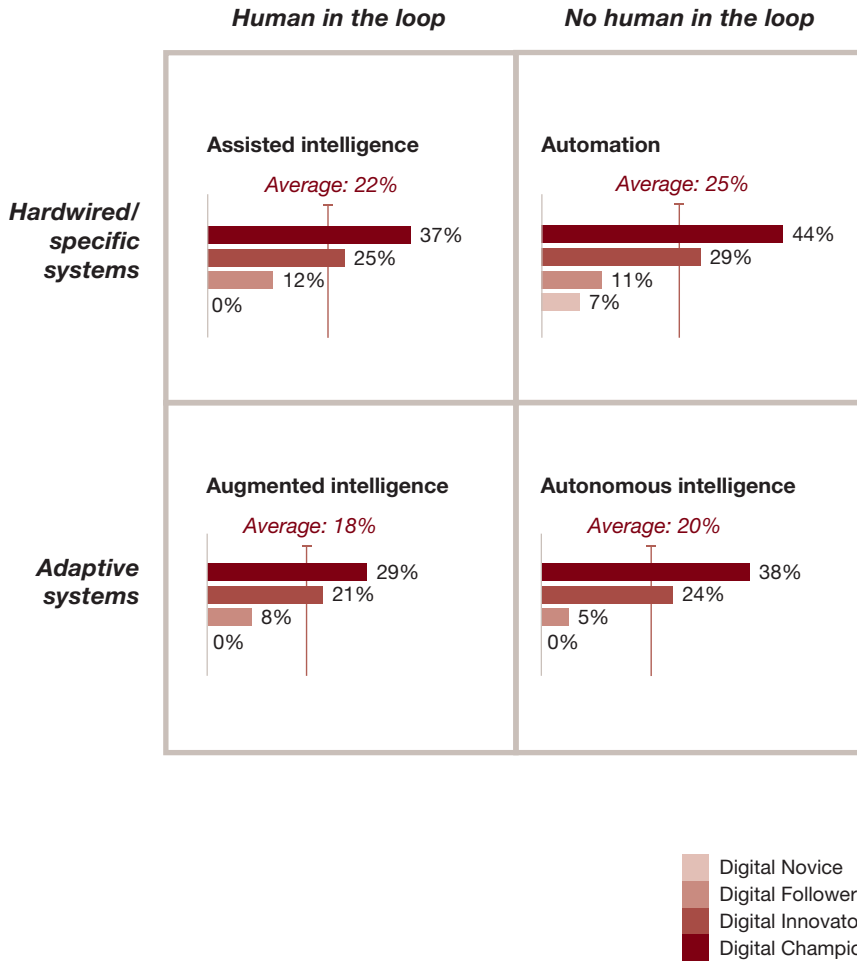
For example, BASF’s Maglis® digital product portfolio for farmers helps them manage fields and supports them in making better-informed decisions throughout the whole year on how to grow and market their crops. Together with BASF, farmers can create individual field and crop management plans that enable them to manage risk and improve yield. BASF sees agility, iterative improvement, and early customer involvement as keys to fully leveraging the power of digital technologies. In the gas treatment business, the OASE® connect online platform is live with customers who can simulate and improve the operating conditions of their plants, retrieve analytical results of their raw materials, and access e-learning material and general information.

BASF’s workforce is at the heart of its digital transformation. It involves 115,000 employees, who are spread over 13 operating divisions, seven functional divisions, three technology platforms, four regions, six Verbund sites, and an additional 347 production sites worldwide. A diverse portfolio of customer industries and business solutions requires a well-balanced digitization approach. At BASF, the Chief Digital Officer directly reports to the CEO and ensures the creation of a digital ecosystem in close alignment with a strong IT backbone. The Verbund principle serves as a strategic guidance in this long-term transformation process. By building digital ecosystems on top of the principles of Verbund, BASF is leading the digital transformation in the chemical industry.

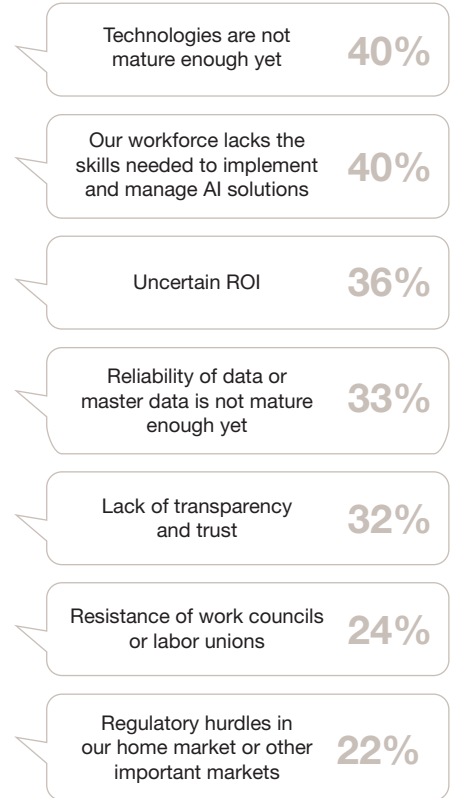
—Based on information from BASF SE, Germany

Exhibit 23
 Progress in and challenges of using artificial intelligence

In what way do you use artificial intelligence in your company?¹



In your opinion, what are the top three challenges associated with AI?²



1. Base was 98 companies that have implemented AI technologies.

2. Base was 1,155 companies.

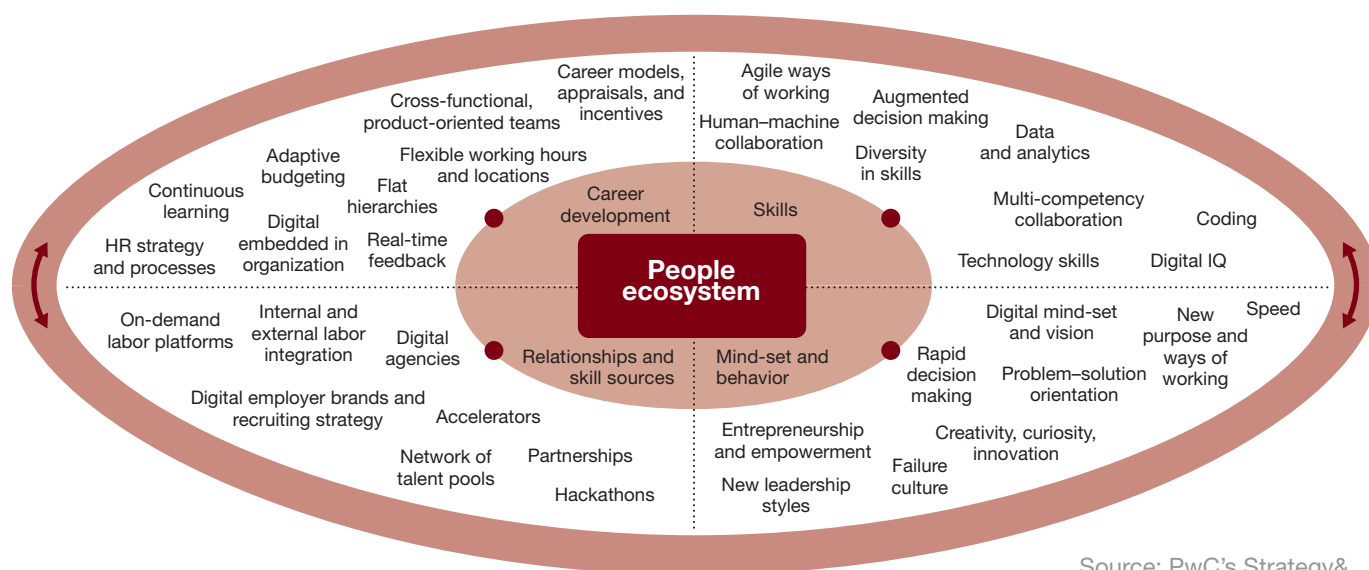
Source: PwC's Strategy& Global Digital Operations Study 2018

A close look at the four ecosystems

The People ecosystem

The People ecosystem enables and supports the efforts of the other three ecosystems. As a result, the contours of the People ecosystem can best be viewed through the lens of how digitization affects a company's strategic direction (its solutions) and its performance (its operations). By assessing these factors, a company can determine the types of workers and skills that will be needed to support its efforts to improve value chain results and operational outcomes. Importantly, the People ecosystem must encompass external as well as internal staff. It embodies the internal workforce, freelancers, contract workers from digital agencies or talent pools, on-demand labor platforms, and shared employees with partners for mutual projects (see Exhibit 24).

Exhibit 24
Overview of the People ecosystem



Source: PwC's Strategy & Global Digital Operations Study 2018

Only companies with a clear digital vision, strategy, and culture to support digital transformation can hope to truly take advantage of it. Two-thirds of the companies we interviewed lack this vision. On the other hand, at more than 70 percent of Digital Champions, the leaders have a clear vision for the digital future and act as role models for the rest of the organization. We also found that Digital Champions invest heavily in training and developing the right skills for a digital environment and have succeeded in building a digital culture.

To assess whether an organization has successfully adopted a digital culture and is employing its People ecosystem to the greatest benefit, four aspects of Digital Champions offer clues:

- **Skills:** Workers exhibit diverse skills. They work in agile ways, and the organization has strong capabilities in data analytics, human-machine interaction, and technology-supported decision making. There are formal pathways for increasing the workforce's digital IQ.
- **Mind-set and behavior:** The characteristics of the organization include a digital mind-set and vision, entrepreneurship and new leadership styles, openness to new technology, a culture that is open to and learns from failure, creativity and innovation, general curiosity, a nonhierarchical "best idea counts" mentality, adaptive budgeting, rapid decision making, and a problem-solving orientation.
- **Relationships and skill sources:** The organization is made up of cross-functional teams with internal and external integration; on-demand labor from platforms of networks or talent pools; and resources from hackathons, accelerators, digital agencies, and even research institutes and universities. The enterprise is oriented toward an agile way of working. It is often a hybrid organization, fostering flexible teams inside a traditional hierarchy. It has a brand and recruiting strategy that reflects its digital maturity; it has set up a talent development program with universities and technical schools to access and onboard the right skills.
- **Career development:** The organization is set up to take full advantage of the People ecosystem in a variety of ways: appraisal, incentive, and compensation schemes that reward innovative and smart digital ideas; flexible work arrangements and telecommuting when appropriate; free time to support continuous improvement of company operations; and real-time employee feedback.

Only companies with a clear digital vision, strategy, and culture to support digital transformation can hope to truly gain the benefits. Two-thirds of the companies we interviewed lack this vision.

At more than 70 percent of Digital Champions, the leaders act as role models for the rest of the organization.

A wide gap exists between what could be called analog culture — the legacy culture in many companies — and the digital culture, which will be necessary to thrive in digital environments (see Exhibit 25). These distinctions encompass the response to customer demand, how decisions are made and innovation is allowed to blossom, often through trial and error, and how working teams are organized and collaborate. It is clear that companies unable to make the jump from analog to digital cultures will be stymied in their efforts to gain real benefits from digitization.

In our survey, Digital Champions excelled in all categories of digital culture. In fact, 59 percent have invested heavily in training to upgrade staff for digital transformation; 52 percent regard failures as an accepted part of the development process; and 52 percent have flat hierarchies and quick decision-making processes (see Exhibit 26, next page).

Exhibit 25
Differences between analog and digital company cultures

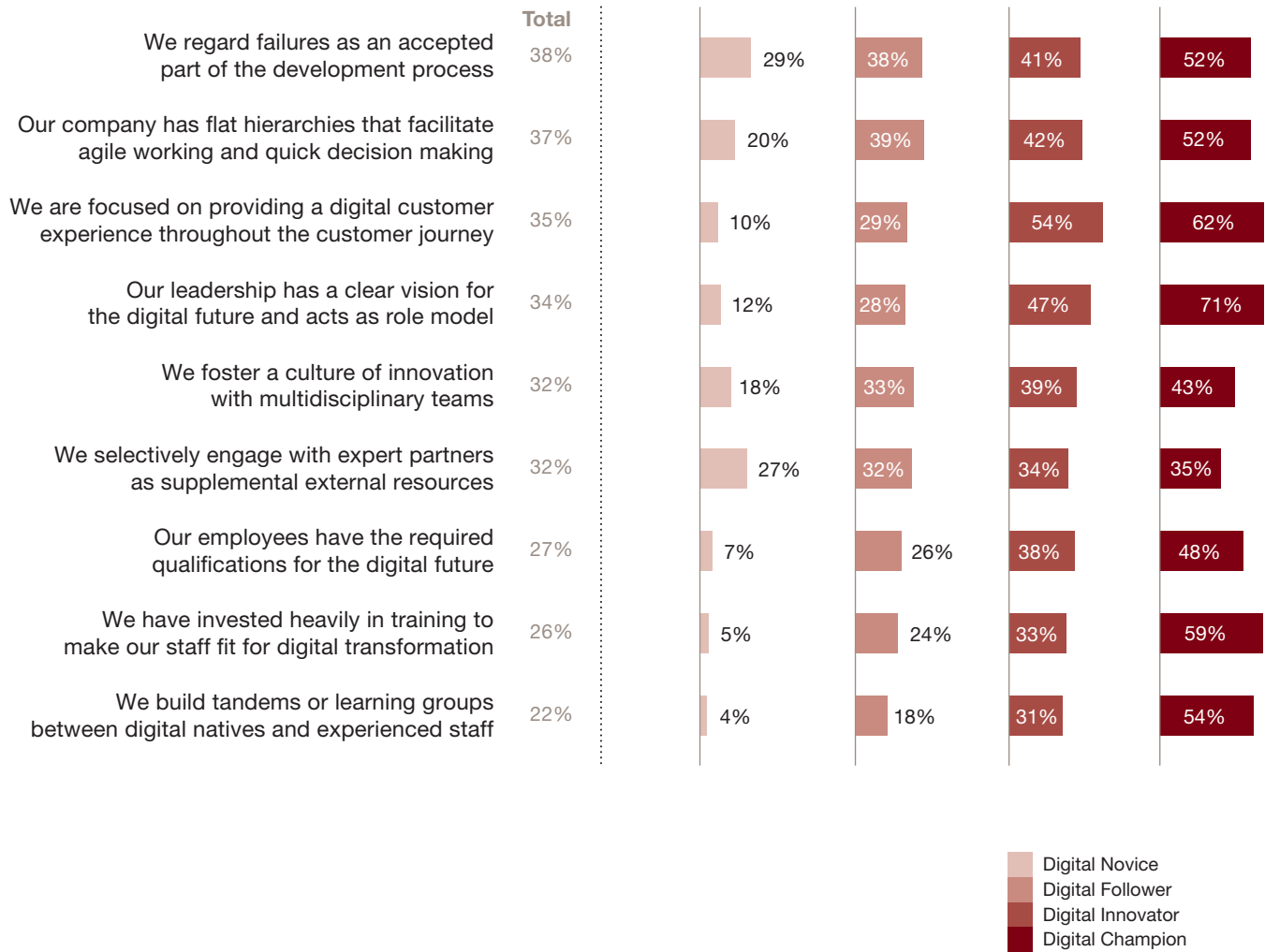
Analog culture		Digital culture
<ul style="list-style-type: none"> ■ Push products into the market, strongly purchasing-/supply-driven 	<div style="background-color: #d9d9d9; padding: 5px;"><i>Customers and demand</i></div>	<ul style="list-style-type: none"> ■ Pull: Customer demand drives supply of products
<ul style="list-style-type: none"> ■ Strong hierarchy and slow decision making ■ Process- and task-orientation, and employees with strongly predefined work (“do your tasks”) ■ Carry out, keep status quo, and accept barriers 	<div style="background-color: #d9d9d9; padding: 5px;"><i>Organization</i></div>	<ul style="list-style-type: none"> ■ Flat hierarchy and fast decision making ■ Results- and product-orientation, and empowered employees (“find a way to achieve a goal”) ■ Innovate, improve, and try to overcome barriers
<ul style="list-style-type: none"> ■ Good understanding of analog customers and learnings from the past ■ Experience and stability count ■ Homogeneous teams and work in departments ■ Working within tasks and silos ■ Career progression within predefined paths 	<div style="background-color: #d9d9d9; padding: 5px;"><i>Way of working</i></div>	<ul style="list-style-type: none"> ■ Good understanding of digital customers and new trends ■ Potential, vision, curiosity, motivation, flexibility, and adaptability count ■ Mixed teams and work in integrated communities ■ Strong collaboration ■ Rapid, unpredictable career progression

Source: PwC’s Strategy & Global Digital Operations Study 2018

Exhibit 26

Corporate culture and organizational setup by digital maturity

In what ways do your corporate culture and organizational structures enable digital transformation?



Note: Multiple answers possible. Base was 1,155 companies.

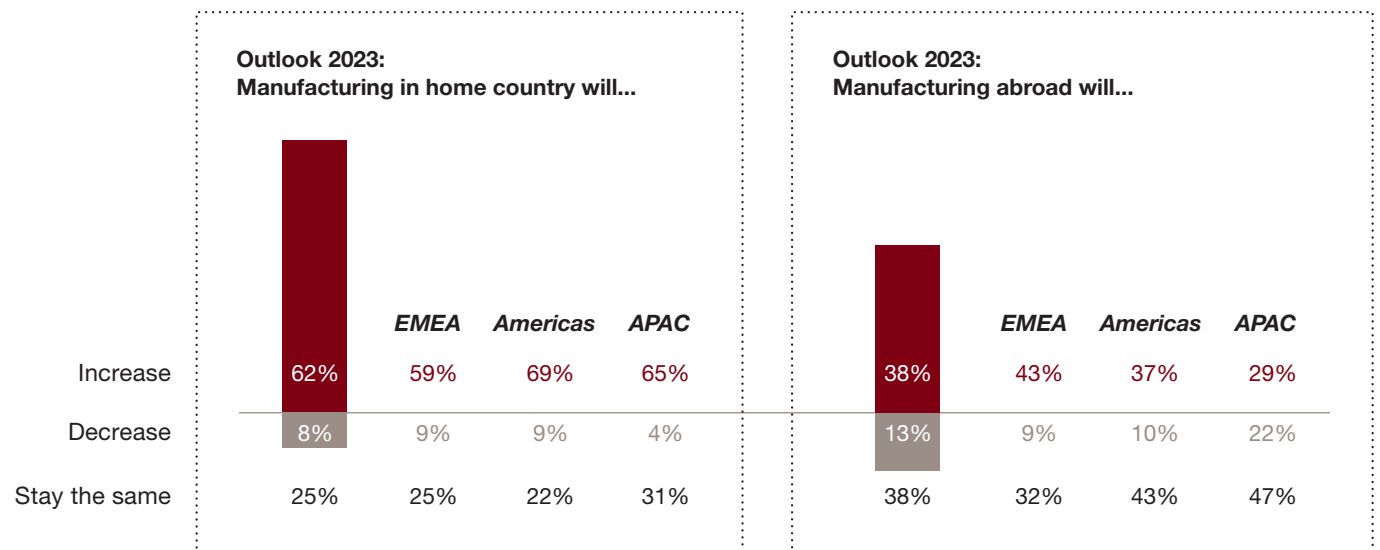
Source: PwC's Strategy & Global Digital Operations Study 2018

Digitization and smart automation will greatly affect workers and the kinds of employees companies hire, because these trends are expected to lead to higher productivity and wealth. In addition, digitization and automation will drive down operations costs in mature markets sufficiently to enable plants in developed regions such as Europe and the U.S. to compete with labor arbitrage from emerging markets. Some 62 percent of companies we surveyed anticipate reshoring and increasing production in home markets in the next five years because of more efficient and less operationally expensive digital factories. Meanwhile, 38 percent of companies said they expect to increase manufacturing abroad — primarily, we believe, to produce products for customers where they reside, enabling the high levels of customization and quick response to consumer preferences that are hallmarks of the Industry 4.0 concept (see Exhibit 27).

Exhibit 27

Expected impact of digital transformation on manufacturing footprint by 2023

What impact do you expect digital transformation to have on your company and your workforce over the next five years?



Note: Base was 1,155 companies.

Source: PwC's Strategy& Global Digital Operations Study 2018

Digital factories are heavily populated with state-of-the-art technology — including robotics, augmented and virtual reality, digital twins, and the Industrial Internet of Things — and the ecosystems they operate in have a great deal of open communication and interactivity. Consequently, there will be a great need for skilled workers able to program and operate complex equipment and make quick decisions in response to shifts in product lines, designs, and input from a range of partners. Some 58 percent of companies we interviewed said that digital transformation will result in greater demand for skilled employees over the next five years (*see Exhibit 28, page 54*). That figure is relatively consistent among Digital Champions (59 percent), Digital Innovators (61 percent), and Digital Followers (61 percent). Digital Novices will have less need for skilled employees; only 49 percent said they expect an increase in the number of these workers at their companies.

As the need for skilled labor increases, it will be crucial to develop new ways of sourcing and access to talent — often individuals educated in STEM — as well as tailored training programs in digital concepts and capabilities. To some degree, this will precipitate supply and demand imbalance favoring skilled labor. It will result in increased salaries for this coterie, who will likely command higher wages because of their education levels as well. Meanwhile, digitization is not expected to affect working hours one way or the other, according to 54 percent of the companies surveyed.

In an effective orientation for a smart and agile People ecosystem, the IT workforce is embedded into the organization's primary businesses and value offerings. This is a sharp departure from the traditional approach, in which IT separately owns all technology assets and hands them off to businesses, often not in the most efficient manner. This new model allows for business-driven IT solutions — that is, technology that addresses precisely what the business needs when it needs it — and data-driven decision making on all levels because the necessary tools are easily accessible and strategically targeted. For Digital Champions, this type of People ecosystem supports flexibility in go-to-market solutions and in setting up digital platforms throughout the Customer Solutions and Operations ecosystems.

Recruitment of new talent and evaluation of existing labor in a digital workforce transformation are often driven by a single question: Is this person the best talent to accelerate innovation? To recruit talented candidates and thus get to a “yes” answer, Digital Champions tap into all of the key sources for skilled labor in digital environments: joint ventures, M&A, freelancers, consultants, universities, competitor recruiting, and even hackathons. They also develop training programs that raise the skill levels of the workforce to meet the higher standards in a digital environment. Moreover, Digital Champions take pains to

There will be a great need for skilled workers able to program and operate complex equipment.

Safran: Digital ecosystems delivering a leap in growth

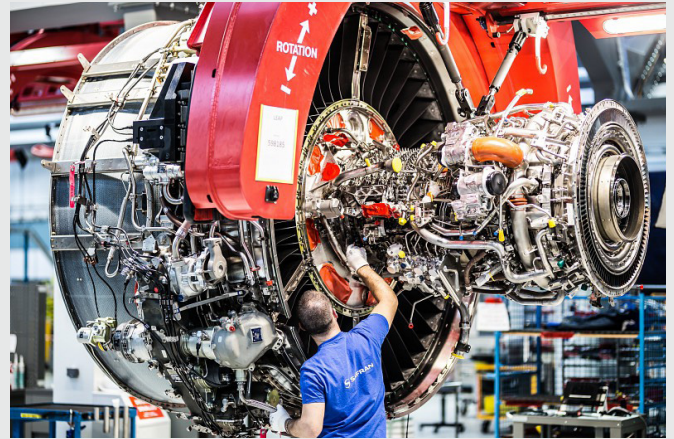
International high-technology group Safran is aiming for a quantum leap in competitiveness from its digital transformation program. The company serves customers in the aircraft propulsion and equipment, space, and defense markets. These markets have considerable challenges — not least, volume ramp-up, wide product portfolios, and diversity of parts to manufacture.

Safran’s “Factory of the Future” initiative is a key part of a digital transformation that is putting breakthrough and even disruptive technologies at the heart of its production facilities. It sees such futurization as central to addressing the unprecedented pace of market change. Its new LEAP® turbofan jet engine, for example, is set to experience a growth rate in just four years that its predecessor, the CFM56®, never reached in 20 years of volume production.

Technology ecosystems

The development of highly advanced technological and workforce ecosystems is a vital platform to meet this strong growth. Safran is showing that you don’t have to build a new factory to implement breakthrough production technologies. It has constructed innovative production lines in existing plants. The LEAP® engines, for example, are being manufactured along “pulse lines” featuring a digital projection system to help position the components and subassemblies, while a patented system holds and rotates the engine horizontally.

Safran has created its first automated production line for helicopter turbine blades, starting with the raw casting and turning out a finished part ready to be assembled on the engine. The company is also deploying “cobots” (co-



robots) on several production lines, allowing it to combine the capabilities of a robot (strength, precision, repeatability, etc.) with people-specific skills (know-how, analysis, decision making, etc.). The operator and robotic system work together directly or by remote control, or even with an exoskeleton that multiplies the capabilities of the human body.

Human-centric change

In addition to technology ecosystems to transform production, Safran recognizes that people are still an indispensable part of the “Factory of the Future” and is developing an extensive workforce ecosystem to enhance operators’ knowledge and skills in this new environment.

Workforce transition support has been a key part of the initiative. Closed-door machining, for example, is changing the role of operators. They move up the skills chain to become coordinators of a machining cell, capable of operating several machines at once, and calling on advanced communications (large screens and tablets, etc.) so they can concentrate on high value-added supervision and control tasks, while the machines operate independently.

Safran is partnering with other industrial companies to setup a training center in Bondoufle, near Paris, that will result in substantial upskilling. From 2018 onwards, around 300 students will be on work-study schemes in a three-year program while a further 300 people will be taking continuing training courses in new production methods: networked machines, the Internet of Things, additive manufacturing, augmented reality, cobots, and other advanced technologies.

—Based on information from Safran S.A., France

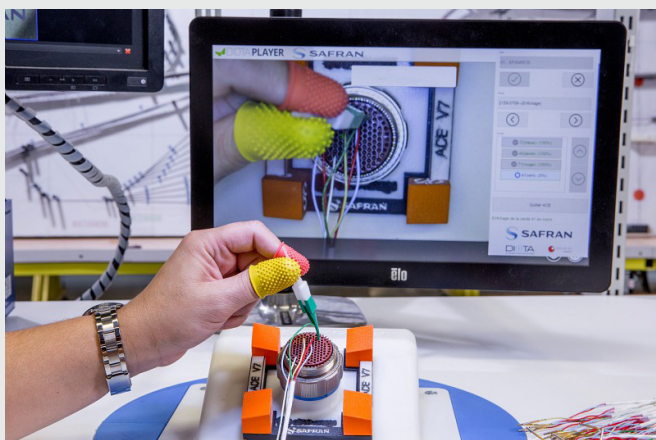
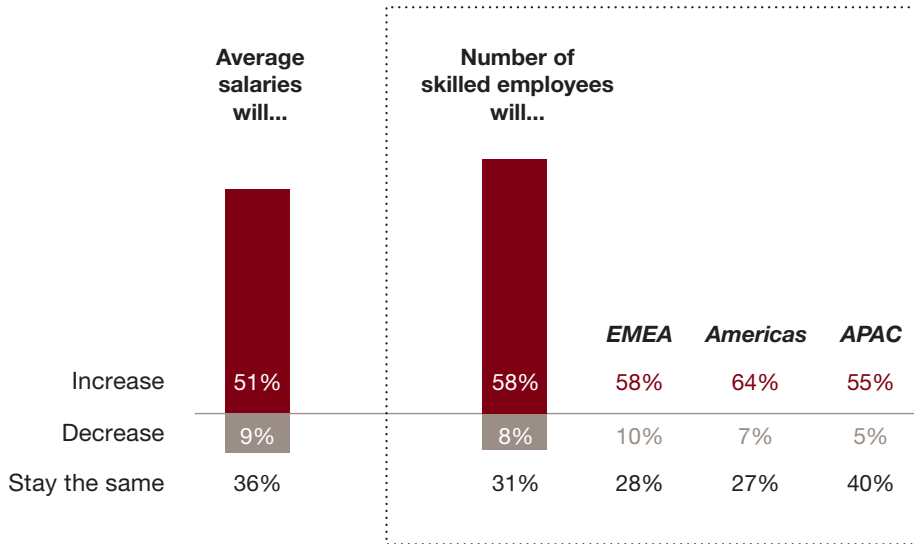


Exhibit 28

Expected impact of digital transformation on the workforce by 2023

What impact do you expect digital transformation to have on your company and your workforce over the next five years?



Note: Base was 1,155 companies.

Source: PwC’s Strategy & Global Digital Operations Study 2018

understand that creating digital business leaders requires understanding how new generations of workers learn and what they want from their jobs. In our analysis, we found that this new workforce is attracted to companies that offer quality learning, challenging tasks, remote and flexible working arrangements, and greater career mobility through training and skills development opportunities.

An effective and well-designed People ecosystem is core to a company becoming a Digital Champion. Yet only 27 percent of respondents to our survey claimed that “our employees have the required qualifications for the digital future.” And only one in four companies has invested heavily in training to make its staff fit for digital transformation. To make this transformation, Digital Champions assess the status quo of their workforce; advance the best and brightest and most digitally oriented existing talent while training others to also achieve this status; inject new talent into the organization where gaps in people’s skill sets and capabilities are revealed; and accelerate the digital capabilities and development of both existing and new talent.

Blueprint to become a Digital Champion

A Digital Champion's primary achievement is its ability to orchestrate and integrate its four ecosystems — Customer Solutions, Operations, Technology, and People — into a seamless, fine-tuned digital machine that leverages an extended network of partners.

In our experience, companies move through four stages of increasing maturity when expanding the capabilities and effectiveness of their ecosystems (*see Exhibit 29, next page*):

- **Stage 1:** Digital Novice with functional silos that are not connected
- **Stage 2:** Digital Follower with functionally connected practices
- **Stage 3:** Digital Innovator with cross-functionally connected practices that may include establishing an Operations ecosystem that is linked to Technology and People ecosystems
- **Stage 4:** Digital Champion with fully integrated Customer Solutions, Operations, Technology, and People ecosystems

In the journey toward becoming a Digital Champion, it is critical to take an iterative approach that involves diverging activities (to develop ecosystem-layer-specific capabilities) and converging activities (driving integration across all four ecosystem layers).

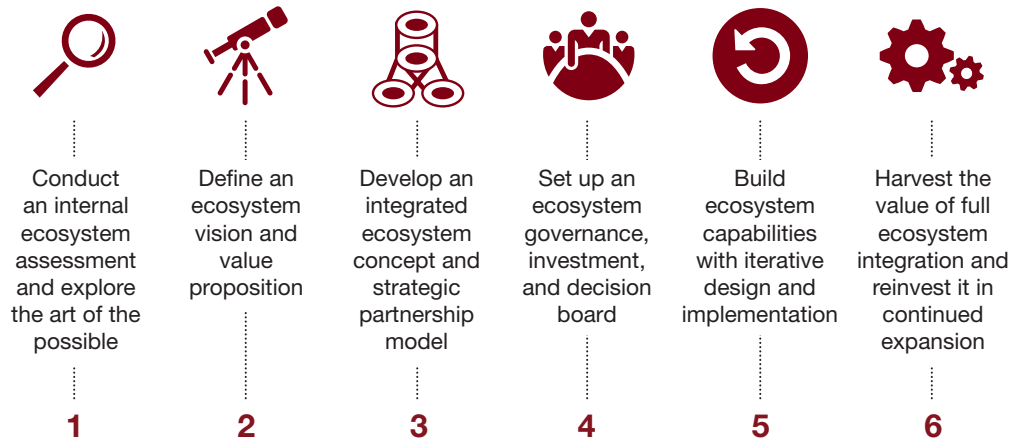
We have developed a blueprint for mastering and managing ecosystems, consisting of six steps:

1. Conduct an internal ecosystem assessment and explore the art of the possible

The “art of the possible” refers to digital strategies based not on past constraints but on new capabilities: “What can we do now that we couldn’t do before, thanks to changes in technology and user behavior?”

Exhibit 29

Blueprint for becoming a Digital Champion



Source: PwC's Strategy & Global Digital Operations Study 2018

This initial step involves creating transparency within the organization about the current position of the company — generally, at the starting point of change. The company conducts an internal assessment and explores the art of the possible of a more successful digital future. Leaders look at market developments, competitor moves, customer expectations, evolving ecosystems, regulatory changes, and technological advances. The aim is to initially determine the state of the company's value proposition to customers, its operational capabilities, its technology capabilities, and the skills of its people. The company's shortcomings must be analyzed, as well as its track record in meeting growth and performance objectives.

2. Define an ecosystem vision and value proposition

Based on the analysis conducted during step 1, the leaders of the company generate an ecosystem vision, which embodies the organization's aspirations. In this step, companies decide where to position products and services, which value propositions to offer to consumers, and how to offer these individualized solutions through multichannel customer interactions.

3. Develop an integrated ecosystem concept and strategic partnership model

In this step the company leaders design an ecosystem concept that spans all four ecosystem layers. First, the company focuses on the Customer Solutions ecosystem, identifying the best potential partners, whether to make or buy new capabilities, which capabilities are available internally, and which capabilities need to be developed through partnerships and other arrangements. With these choices made, the Operations ecosystem can be created to meet the associated requirements. Then, the Technology and People ecosystems can be built to enable the first two ecosystems. It's essential to develop an integration framework that includes interfaces, interdependencies, connections, technology, and data to ensure seamless interaction among the ecosystems. Indeed, the ecosystems should be aligned to support structured but open communication, enhance the digital maturity and culture of the organization, foster value chain solutions and operations, and catalyze a continuous improvement virtuous circle.

4. Set up an ecosystem governance, investment, and decision board

Before starting the iterative design and implementation of the ecosystems, create clear “ecosystem governance” processes that steer the design and implementation efforts. These governance procedures, which are the responsibility of top management to supervise and carry out, should cover setting priorities and key milestones, reviewing and approving design and implementation outcomes, and making investment decisions. This may include appointing a board to oversee the transition and keep the effort on track.

5. Build ecosystem capabilities with iterative design and implementation

Using the clear definition of the organization's goals and ecosystem design as a blueprint, the organization creates each ecosystem to serve solely as a conduit for achieving these goals. This primarily involves two activities.

The first is iterative design and implementation of ecosystem capabilities done in sprints. These rapid, fluid, project-based team efforts are dissolved when no longer needed, and are the main efforts that build the future Customer Solutions, Operations, Technology, and People ecosystems.

This design step should include collaboration models for connecting required internal and external assets. Digitization should be freely implemented to connect and share operations among partners; vendors; operational components like factories, logistics providers, or contract manufacturers; advisors; ad hoc workforces and permanent employees; and short-term and long-term relationships, among many other possibilities. Iterative implementation allows the sprints to produce quick results based on prototypes and pilots that can be minimized or enhanced before developing the next element in the ecosystem rollout.

The second key activity is converging after each sprint to integrate the results of the Customer Solutions, Operations, Technology, and People ecosystems to support seamless integration.

6. Harvest the value of full ecosystem integration and reinvest it in continued expansion

With the four ecosystems in place, the organization implements its strategic imperatives to fully take advantage of the new value chain. The leaders monitor the new practices and processes, ensuring that digitization continues to drive improvements and efficiencies in each ecosystem and that external partnerships integrate smoothly with internal capabilities, functions, and efforts to deliver enhanced customer value. As the ecosystems evolve, the company should continue to mature by reinvesting in continued growth of the four ecosystems model, in the process moving closer to becoming a Digital Champion or strengthening its position as a Digital Champion.

Survey methodology

To explore Digital Champions and the global landscape of manufacturing companies, we interviewed 1,155 executives in 26 countries, asking them primarily about their attempts to implement Industry 4.0 and the progress they are making. These companies covered a wide gamut of sectors: automotive, electronics, industrial equipment and engineering, process industries, consumer goods, and industrial manufacturing (*see Exhibit 30, next page*).

Our interviews focused on three areas:

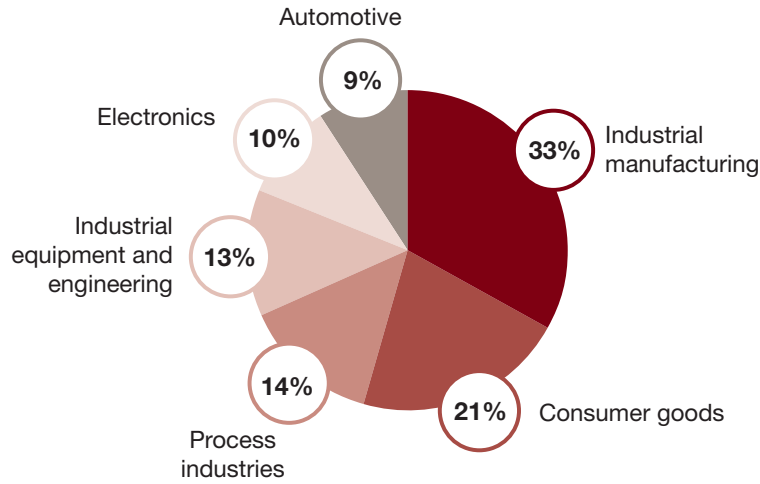
- **Ecosystems**, including the share of revenue from digital products and services, maturity in building up digital ecosystems, types of platforms used to realize the business model, and the digital maturity of supply chains and manufacturing
- **New technologies**, encompassing the degree of implementation of digital advances such as 3D printing, artificial intelligence, robotics, and the Internet of Things
- **Digital culture**, examining the leadership's digital vision, the company's way of working, and the relevant investments in people and training

Based on these interviews, we defined four categories of companies at different stages along the continuum of digital maturity, with Digital Champions at the leading edge of their industries:

1. **Digital Novice.** The company employs some isolated digital solutions and applications, but these exist at the functional or department level within the organization.
2. **Digital Follower.** Internal functions such as sales, manufacturing, sourcing, and engineering are integrated and collaborate closely. But there is little activity beyond vertical digital integration within the company. The culture and workforce at these companies are not yet digitally oriented.

Exhibit 30
Survey participants

Interviews per industry



Participating territories



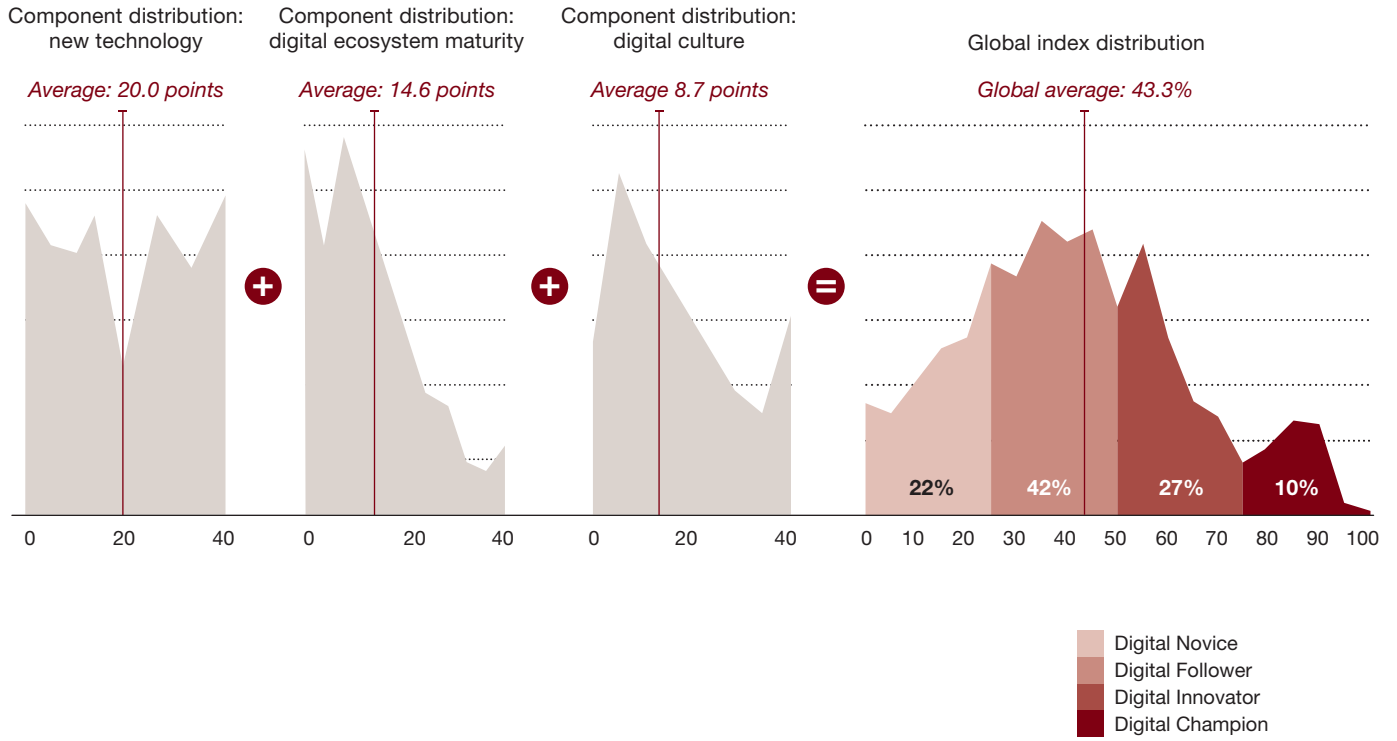
Source: PwC's Strategy & Global Digital Operations Study 2018

3. **Digital Innovator.** The enterprise is digitally connected to external partners and customers, using integrated platforms for information exchange and collaboration. But the horizontal digitization is limited to the immediate supply chain, with no wider ecosystem for Customer Solutions, Technology, or People. Digital Innovators prize digitization and encourage the workforce to help identify new digital solutions, but their advances are limited in scope.
4. **Digital Champion.** The enterprise has a clear strategic position in the marketplace with complex and tailored customer solutions, offered via multilevel customer interactions. These companies have implemented near-real-time end-to-end integration and connectivity of their value chain across internal and external networks. These companies know how to leverage technology to connect customers, partners, operations, and people to create value through ecosystems in new ways. Digital Champions have built a digital culture by establishing new ways of working and making substantial investments in training, sourcing, and developing new capabilities and skills.

To measure where particular companies fit in these groupings, we designed a digital maturity index, in which points were allocated for different levels of digital capabilities and advances — a maximum of 40 points for digital ecosystem maturity, 40 points for implementation of new technologies, and 20 points for fostering a digital culture. Only 10 percent of the enterprises we spoke to scored between 75 and 100 points, the Digital Champion category. The lion's share of companies — 42 percent — ranked as Digital Followers, in line with the global average of 43 percent (*see Exhibit 31, next page*).

We then supplemented this research with more in-depth interviews with companies that were identified as Digital Champions. Those interviews led to the full-page inserts about particular companies included in this report, which have all been checked with and approved by the companies mentioned.

Exhibit 31
Key results from the digital maturity index



Note: Base was 1,155 companies. Percentages may not total 100 due to rounding.

Source: PwC's Strategy & Global Digital Operations Study 2018

Acknowledgments

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