Leveraging industrial software stack advancement for digital transformation

How to capture impact at scale with IIoT platforms in the industrial equipment and machinery space

Digital/McKinsey

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Preface

Raising the topics of industrial software stack advancement, digital transformation, and IIoT platforms immediately prompts many questions: What does industrial software stack advancement really mean? Which are the indispensable capabilities that are crucial to understand? What do digital transformation and capturing impact at scale with IIoT platforms entail for the industrial equipment and machinery space? How profound will the impact be on the industry's business models and shifting value pools? What are the near-term challenges and business opportunities for my company? Some clients also ask whether IIoT platforms are simply hype. This myriad of mixed reactions reveals the intense uncertainty associated both with what industrial software stack advancement and IIoT platforms actually are and how companies should respond to the changing industrial environment.

Our aspiration in publishing this report is to provide not only deep but also ready-to-use insights into the various aspects posed by the influx of new technologies as a business enabler.

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Introduction and key messages

Traditionally, industrial equipment and machinery companies have focused on selling hardware (e.g., machines, components), and many of them have based their business models and success on the outstanding quality of their products. These days may be coming to an end as three powerful, mutually reinforcing developments are emerging across the industrial equipment and machinery sector requiring players to fundamentally rethink their current business models: intensifying global competition, commoditization of hardware, and a seismic shift in technology stack value pools due to customers' increasing demand for digital services.[1]

Our research and client discussions suggest that most industry players along with several tech firms and software giants are fully aware of these changes in the industrial equipment and machinery space. Seeing the limits of hardware-driven growth and the arising technological and business opportunities from the Industrial Internet of Things (IIoT), they are heavily investing in their digital transformation[2] as a highly attractive growth and value capture opportunity. Unsurprisingly, the global market for IIoT-enabled business models in the machinery space is expected to grow substantially. Intelligently linking industrial automation and IIoT platforms (for a working definition of this term, see Text box 1) is considered the new frontier in the machinery space. The monetization potential of IIoT platforms and IIoT platform-enabled applications is massive, but implementation is still in its early stages. Nevertheless, business models that facilitate capturing this potential are already emerging.

Text box 1: Definition of three key terms

"Industrial software stack," "platform," and "IIoT platform" have become buzzwords that are subject to multiple interpretations. To establish a common understanding, we have defined the terms as they are used in this report:

- The industrial software stack is the complete set of software products and tools required to gather data from an industrial end point (a machine), extract some useful information from the data, and either advise or initiate making a decision about how to operate the machine differently or support other decisions made about how to operate the underlying business more effectively.

- A platform is software and hardware that may include an operating environment, storage, computing power, security, development tools, and many other common functions. Platforms are designed to support multiple, smaller business solution applications.

- More specifically, in the IIoT, platforms are designed to deploy applications that monitor, manage, and control connected devices. IIoT platforms handle problems such as connecting and extracting data from a potentially high number and variety of end points, which are sometimes at inconvenient locations with only spotty connectivity.

Further details on IIoT platforms are discussed in Chapter 1.1. For further definitions and explanations, please refer to the factory automation glossary on pages 45 to 47.

1 For further details, especially on how technology is shaping the future of production, see World Economic Forum (in collaboration with McKinsey & Company); "The Next Economic Growth Engine: Scaling Fourth Industrial Revolution Technologies in Production" (January 2018), pages 5 to 6.

2 While the terms Industrial Internet of Things (IIoT) and Industry 4.0 are often used interchangeably at McKinsey and beyond, in this report, we decided, for the sake of simplicity and due to our focus on IIoT platforms, to consistently use the former one in abbreviated form.

Due to the importance of IIoT platforms to the industrial equipment and machinery sector, industry players should sooner rather than later develop a clear perspective for their organizations that answers a string of essential questions concerning, for example, the related value at stake in terms of revenue and profit; the expected time frame of the development of the market; technical enablers that should be put in place; the optimal level of investment in technologies and services; and the capabilities and partnerships to be built in order to support success.

As critical as these internally focused questions may be, based on our research and client discussions, we also know that industry players are currently thinking about how IIoT platforms open up new opportunities beyond the shop floor. Accordingly, they are looking for convincing and reliable answers to two key questions:

- Which value proposition can be offered to convince customers to share their data and preferences?
- Which data-related business models and use cases would maximize returns for the company?

Whether using technology to increase production efficiency or develop new customer-oriented, revenue-boosting business models, an IIoT transformation is required. With this broad set of possibilities and opportunities in mind, in the following we:

- Look at the impact that IIoT platforms have on the industrial equipment and machinery space, including the specific technologies that support the industrial automation stack and the resulting business opportunities (Chapter 1)
- Introduce and discuss the four building blocks for successfully setting up IIoT-enabled business models: attractive IIoT business models, a framework to help players assess their IIoT platform needs (and build or acquire as appropriate), a detailed outline of the strategic requirements and priorities of the various industrial equipment and machinery player archetypes, and an overview of monetization approaches (Chapter 2)
- Offer five broad recommendations that CXOs in the industrial equipment and machinery sector should consider, followed by a deep dive on an approach to IIoT that lends itself well to the many companies that – regarding their IIoT readiness – can be categorized as “stuck players” according to our segmentation of industrial equipment and machinery players (Chapter 3).

A guide for the quick reader

Not everyone interested in the role of IIoT in manufacturing will want to read this entire report from beginning to end. Since many readers are interested in specific topics, we have created a guide that notes those chapters most relevant to them.

- For the always-pressed-for-time CEO, board member, or general manager who suspects the need for fundamental change in the company’s core business but is not exactly sure what to do, first and foremost, read Chapters 1.3, 2.1, and 3.1 to brief yourself on 1) how IIoT platform technology enables new business opportunities and why these present substantial risks to traditional players’ core business; 2) the most attractive IIoT-based use cases with sizable value pools for industrial equipment and machinery players; and 3) McKinsey’s pragmatic recommendations for a successful IIoT journey for all types of industrial equipment and machinery players.

- For the CIO, COO, or R&D/innovation manager who firmly believes that IIoT platforms can move the business forward but is dissatisfied with the technology's performance so far, begin with Chapters 1.1 and 1.2, which provide the basis for a comprehensive understanding of industrial software stack advancement and IIoT platforms and their expected impact on digital transformations in the industrial equipment and machinery space. Chapter 3.2 is also a recommended read for you, especially if your company is one of the many so-called stuck players and could benefit substantially from our fresh insights into how the IIoT journeys of these players can be effectively resuscitated.
- For the chief strategist, head of marketing, or head of business development, who primarily needs to understand both how IIoT platform technology enables new business opportunities and what the building blocks are for successfully setting up IIoT-enabled business models, prioritize Chapters 1.3, 2.1, and 2.4. These chapters also offer useful descriptions of IIoT-enabled use cases, IIoT strategy directions for each of the four industrial equipment and machinery player archetypes, and a list of possible monetization approaches.

Our research and analyses yielded the following key insights, which will be explained in more detail in this report:

IIoT presents integration architecture challenges, but successfully addressing them can enable use cases that facilitate a massive business opportunity.

- ***IIoT adds complexity to the automation challenge of integrating machinery operations.*** ISA-95 addressed the rise of global production and distributed supply chains, but – even with the addition of new features – this standard does not address the issues of data and security that come with countless connected devices.

- ***IIoT platforms support the development and deployment of applications that manage a potentially vast number of connected devices.*** These platforms simplify the complexity by zeroing in on the common technology needs of a diverse set of applications, devices, and uses.

- ***IIoT technology presents an opportunity for substantial IIoT revenue growth and margin expansion in machinery.*** Platforms, software, and app development are the elements of IIoT that are expected to grow, while others, such as device cloud connectivity, have likely plateaued. Still others, such as hardware without service enablement, are expected to shrink. Industrial automation and shop floor communication equipment need to be integrated into the platforms of industrial equipment and machinery manufacturers to increase the profit margin of the services portfolio. Machine OEE optimization, predictive maintenance, and cross-vendor shop floor integration are among the most promising applications.

Applying strict considerations to use case development, platform selection, strategic development needs, and monetization approaches are essential to IIoT success.

- ***The development of potential use cases requires structured consideration.*** Assessing a use case's potential value, determining which monetization logic is most appropriate, and defining its technical as well as strategic and organizational requirements help establish its priority over other potential use cases. It is very important for each use case to have a clearly articulated and measurable value proposition.

- ***Strategic, organizational and technological maturity are the criteria for selecting the IIoT platform to run new digital applications.*** Industrial equipment and machinery players will need to evaluate how much a platform offers in terms of data ownership and contractual freedom and how much growth and scale it can accommodate. The platform's technological capabilities along the entire stack and its overall operational performance – including such criteria as security and cybersecurity – must also be assessed.

- ***Industrial equipment and machinery players fall into one of four categories along the dimensions of technological maturity on the one hand and strategic and organizational maturity on the other hand:*** mature in both dimensions ("leaders"), rather immature in the former dimension ("interested players"), rather immature in the latter dimension ("stuck players"), or immature in both ("avoiders"). A player's category will, at least in part, determine the priorities of its IIoT strategy and outline the road map for its transformation.

- ***Monetization strategy speaks to the model by which an IIoT use case will generate specific value.*** For "new revenue" use cases – such as Software as a Service (SaaS) – industrial equipment and machinery players will need to develop competitive pricing models and implement mechanisms that facilitate payment. "Revenue-enabling" use cases support the revenue generation of existing businesses – new or existing – via up-/cross-selling or efficiency gains.

While all industrial equipment and machinery players can take certain actions to support the success of their IIoT platforms, stuck players[3] should follow an action plan aligned with their specific levels of technological and organizational maturity.

- ***All industrial equipment and machinery players can make certain commitments to support the success of their implemented IIoT platforms,*** including a focus on a limited number of prioritized use cases. Additionally, players can build an ecosystem of business and tech partners and cultivate an organizational culture that is agile. Capabilities can be developed over time, but players should not be afraid to implement workarounds in order to get started early.

- ***Stuck players have already laid much of the groundwork for making strides in the technology aspects of IIoT implementation.*** In this regard, platform selection, performance improvement, and scale-up will help them continue in the right direction. More fundamentally, they need to build the foundation of a strategy and organization that supports their emerging IIoT use cases. Specifically, stuck players should develop and align around a vision for IIoT, integrate an IIoT solutions unit into their structure, and explore a strategy that helps them leverage the expertise and capabilities of other players.

3 Stuck players are basically "higher on tech and lower on strategy and organization" when it comes to maturity levels and thus are rather likely to get stuck in a so-called "pilot purgatory" when it comes to scaling their pilots.

1. Beyond the shop floor: what's new in IIoT platforms and how their emergence will impact the industrial equipment and machinery space

1.1 IIoT platform technology offers advances in industrial automation and IT/OT integration

For decades, the world's many industries have invested heavily in information technology (IT) to reduce costs, improve operational efficiency and visibility and, ultimately, to boost profits. In doing so, IT professionals have laid the foundation for what is called the digital enterprise, i.e., an organization that uses technology as a competitive advantage in its internal and external operations. Yet while IT used to be mostly about back offices – finance, accounting, HR, white-collar productivity, etc. – a ("fully") digital enterprise nowadays also leverages IT and connected devices in the very place where the company actually creates value for customers, such as, for industrial companies, in manufacturing, design, and service. Thus, for the extractive, manufacturing, and logistics industries, the digital enterprise also involves another form of IT on the shop floor side of an organization, which is commonly referred to as operational technology (OT).[4]

Companies have heavily invested in OT, much of it for increasingly smart machines and systems to automate discrete production tasks and continuous processes. This includes automation control and higher-level OT management platforms to efficiently operate, monitor, and optimize OT performance and maximize the utilization of capital assets.

Regarding IT/OT integration, many manufacturing companies have in the past implemented manufacturing execution systems (MES). These systems provide up-to-the-minute (often near real time), accurate production-related information, such as OEE, production costs, maintenance incidents, and quality status. For a while, the results were satisfactory, providing improved visibility and enabling better management of day-to-day operations, including scheduling adjustments where needed.

New challenges emerged, however, when globalization and outsourcing activities led to globally distributed production and supply chains. Since then, plant-focused MES systems have not been sufficient because operations and KPIs must also be consistent across manufacturing lines and plants.

Capturing IIoT's full value potential requires much more sophisticated integration approaches than current automation protocols provide

Connecting the two worlds of IT and OT would offer a truly end-to-end digital enterprise (see Text box 2). Full integration of the two structures would lay the foundation for a fast, reliable, secure, and modern IIoT platform (Exhibit 2). Unfortunately for far too many organizations, sharing data between these two worlds can be a struggle because their network infrastructures are neither up to date nor sufficiently connected.

4 For further information on operational technology in general and the International Society of Automation's (ISA) terminology and IT/OT integration standards (such as ISA-95) in particular, see www.isa.org/isa95/.

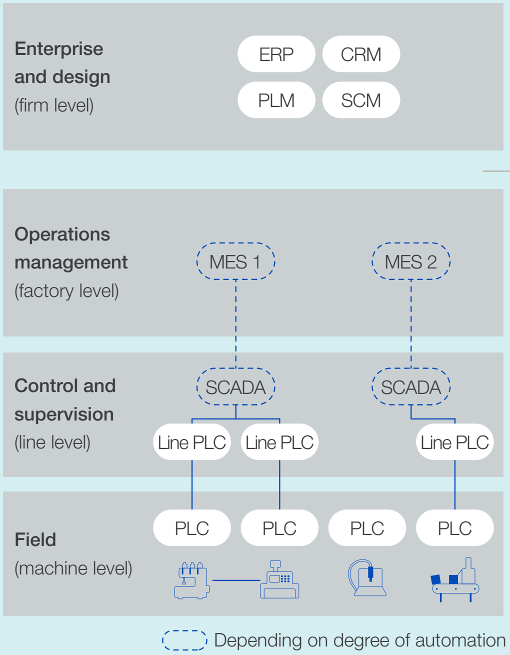
Text box 2: The promise of digital manufacturing platforms [5]

Seeing the growing importance and rise of cross-plant systems around the world – as well as the complexities related to integrating those systems into the existing enterprise information flow – some basic challenges in the industrial automation stack need to be resolved in order to enable a seamlessly integrated but still fluid and agile stack (Exhibit 1).

Exhibit 1

The challenges of the traditional industrial automation stack

Traditional industrial automation stack



Current observations

Enterprise software layer not connected consistently to factory, line, or machine level

Data not collected at all or divided up in organizations

Manual translation between enterprise and operations layer (often via PC-based software tools)

No MES or multiple MES for different value chain steps with no interconnectivity

Integration to SCM and other enterprise systems missing

Low level of interconnectivity between process steps

No sensors/analytics built in

Machines within lines not interconnected

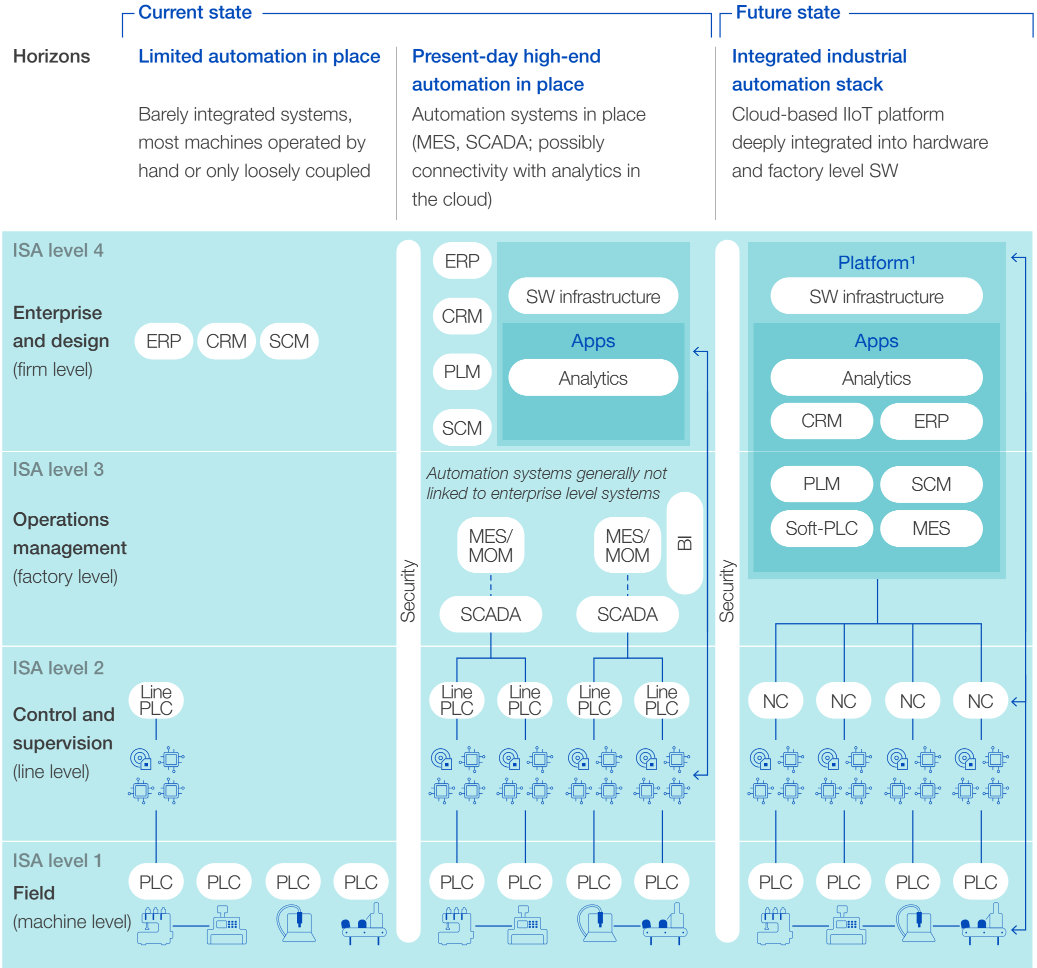
Definitions: PLC (programmable logic controller), NC (numerical control)
Source: McKinsey Industrial Automation and Machinery service line; McKinsey MGI "IIoT Market Model"

While MES was originally focused on providing production-based data for a single plant, manufacturing operations management systems have the capacity to make operations transparent (e.g., KPIs such as OLE and OEE being built on an identical basis) in areas such as maintenance, scheduling, quality, material handling, and logistics across the enterprise and the multiple manufacturing sites. IIoT-enabled manufacturing operations management systems will evolve into digital manufacturing platforms that will integrate traditional ERP, PLM, MES and shop floor systems, so they can enable seamless in-plant and cross-plant operations capabilities. Digital manufacturing platforms leverage advanced IIoT platform technologies (e.g., real-time analytics, machine learning algorithms) by capturing, integrating, and interpreting data from PLCs, industrial PCs and machines, various shop floor systems, such as MES, SCADA (supervisory control and data acquisition), and DCSs (distributed control systems), and by fostering the insights-to-action paradigm in manufacturing operations.

By accessing and combining vast amounts of data from multiple operations, these digital manufacturing platforms provide a more complete, real-time view of multiple plants and, increasingly, the supply chain, including planning and scheduling. This a prerequisite for optimized operations in a global manufacturing network. The IIoT-enabled digital platforms that are implemented as an integration point into a manufacturer's enterprise application layer create a potentially seamless information flow between all operations across the plant and the entire enterprise and thus provide a holistic view of the supply chain.

5 Digital manufacturing platforms, also known as IIoT platforms, present a new hybrid combination of IIoT and ISA-95 (i.e., MES plus ERP).

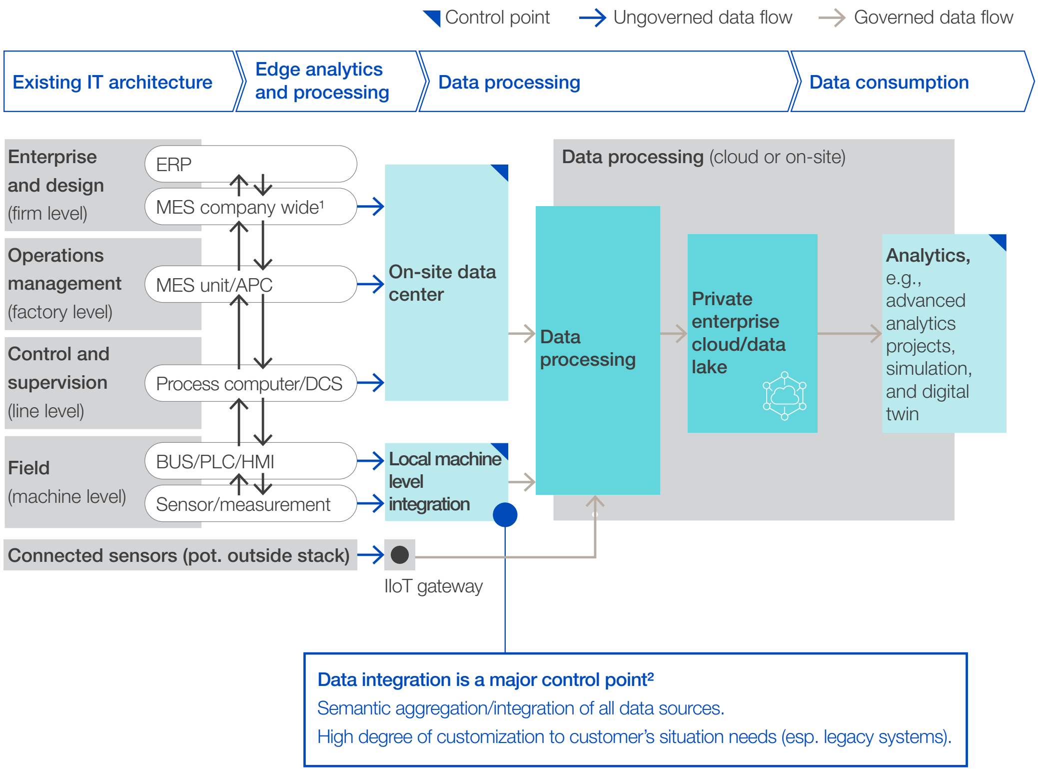
Exhibit 2 **The traditional stack will become interconnected and digitally enabled with an IIoT platform**



1 Platform can be hosted on-site, as company-internal service or through third party
Source: McKinsey

At the same time, manufacturers require not only information flow but also a data model standard with full transparency in all facilities and regions. They also require the control to put in motion as well as orchestrate operations across a heterogenous IT, OT, and application system landscape and a distributed enterprise impacting the supply chain. Thus, there are still challenges with the traditional automation stack, particularly for discrete manufacturers. There are also issues that relate to the supporting data architecture. Specifically, at the company, factory, line, and machine levels, the data architecture must support all data activities from collection to processing to consumption (Exhibit 3).

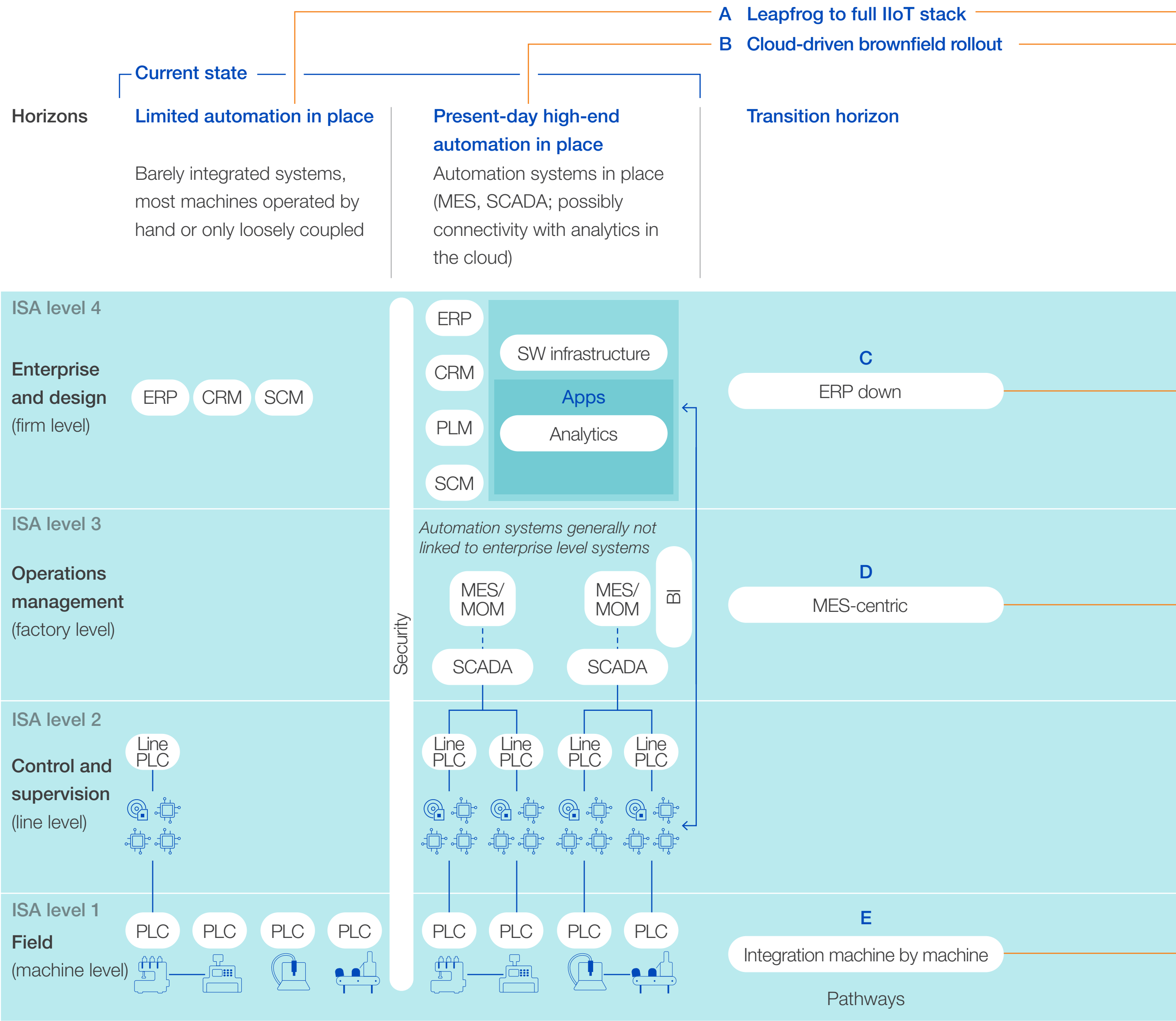
Exhibit 3 **The industrial automation stack requires a suitable data architecture**



1 If existing
2 Based on the current need for redundancy and latency, which is not given at the moment for purely cloud-based solutions
Source: McKinsey

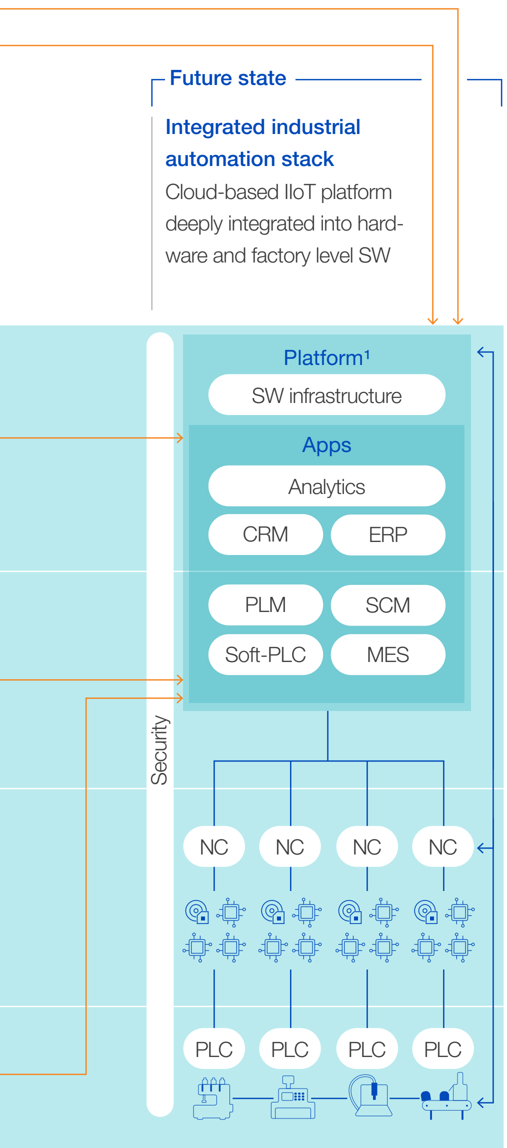
Some of these challenges require software solutions, which a company may prioritize in making its architecture and digital manufacturing platform selection. Ultimately, an industrial equipment or machinery player will need to decide how effective and responsive its operations infrastructure is and how well its performance supports the company's business strategy. Following an assessment of its current infrastructure, the industrial equipment or machinery company may follow one of many paths toward a fully integrated automation stack (Exhibit 4).

Exhibit 4 **Multiple starting points and transition paths possible to reach fully integrated automation stack**



Depending on industry, scale, and capabilities of players, certain players will remain in each of the horizons for longer – some may leapfrog earlier stages, esp. new entrants

1 Platform can be hosted on-site, as company-internal service or through third party



→ Possible transition paths

Transition scenarios

	Description	Potential applicable verticals	Key challenges
A	**Leapfrog to full IIoT stack**		
	Leapfrog from H0 to full platform, mostly in greenfield situations, with a clear vision for the IIoT architecture	In process industries: smaller/less complex factory operations with significant benefits from real-time factory control and analytics	Lack of experience may result in long ramp-up times Integration challenges on shop floor
B	**Cloud-driven brownfield rollout**		
	Upgrade from H1 in brownfield situations to a fully integrated plant (cloud-driven architecture)	In electronics: high affinity for digitization with much room for improvement in auto-mation	Integration of legacy systems and stepchange move
C	**ERP down**		
	Use existing ERP software as an integration backbone, moving down to MES layer	In electronics: new manu-facturing lines or new factories of large EMS players	Requires multiple instances in different plants Master data management (MDM) often separate from ERP
D	**MES-centric**		
	Build upon existing, well-established MES software and integrate both up- and downward	In automotive: OEMs that deploy mature MES to coordinate complex factory operations	Difficulty scaling up in plants Requires multiple instances in different plants
E	**Integration machine by machine**		
	Upgrade existing machines stepwise with edge analytics and/or develop integration on PLC/NC level to run overarching data intelligence	In process industries: factory operations with long machine lifecycles and interrelated processing steps (in need of error-tracking capabilities)	Full move to IIoT archi-tecture very challenging as no common foundation for integration Difficult to connect to competitor's PLCs

Source: McKinsey team analysis; company Websites

Since even the current ISA-95 integration standard[6] does not consider data input, output, device capabilities, security, etc. …

Achieving compliance with the ISA-95 standard is not enough, and some key challenges will remain unaddressed. This is because ISA-95 does not address the digital integration requirements that would enable IIoT technologies to be leveraged to support processes related to the enterprise, customers, and supply chain optimization.

The traditional industrial automation stack, in terms of ISA-95, should demonstrate flexibility by using the functional blocks of the stack layers in a more adaptive way. Specifically, when it comes to the IIoT framework of connected devices, equipment, and related data, a decentralized IIoT architecture provides access to more integration points and devices (see Exhibit 1 on page 13). The major imperative is to foster the compatibility between the applications, equipments, and devices of different vendors, considering retrofit necessities and capabilities as well.

… OPC UA[7] is expected to become the next universal serial bus for industrial network devices and machines

OT needs to ensure that a complex, often heterogeneous, technology landscape at the field level – including sensors, actuators, valves, instrumentation, and other devices – is functioning properly, often under harsh operating conditions. At the same time, all of these elements feed and draw operational data into and from a dynamic, vertical infrastructure consisting of a wide range of controllers, operator systems, and MES.

OT solutions used in discrete manufacturing typically must be fine-tuned across their operating network structures and constituent components (both hardware and software). Cycle timings, usually in milliseconds, and data communications need tight synchronization across all of those components. Thus, a crucial challenge for Industry 4.0 and IIoT is ensuring the secure, standardized exchange of data and information between devices, machines, and services.

Even in an ISA-95 and IIoT-converged world, we need to think beyond existing ISA-95 data structures and connections: information about data input, output, device capabilities, security, and many other attributes that are currently not covered by the ISA-95 framework. In this context, OPC UA is the comprehensive framework for information flow and industrial interoperability. Providers of digital platforms for the IIoT have been fostering the integration of the OPC UA definitions and capabilities for device and equipment interoperability. This orchestration includes device management, connectivity, and security.

6 See ISA's definition: "ANSI/ISA-95, or ISA95 as it is more commonly referred to, is an international standard for developing an automated interface between enterprise and control systems. This standard has been developed for global manufacturers. It was developed to be applied in all industries, and in all sorts of processes, like batch processes, continuous and repetitive processes. The objectives of ISA-95 are to provide consistent terminology that is a foundation for supplier and manufacturer communications, provide consistent information models, and to provide consistent operations models which is a foundation for clarifying application functionality and how information is to be used." (source: https://www.isa.org/belgium/standards-publications/ISA95/).

7 Open platform communication unified architecture

For this connectivity to be efficient, a single data model for information exchange is required to format the data consistently. The protocol used for transporting the data, on the other hand, is irrelevant, although many people tend to mistakenly focus on this. This is where the power of open-source industrial interoperability standards like OPC UA becomes critical. OPC UA has an extensible information model, allowing for easy mapping of many of the standards used in the industrial sector today and the creation of a single data model.

The tools needed for this seamless integration are readily available from industrial automation and IIoT platform providers. To make these tools available worldwide and keep them scalable requires significant investment. Machine builders and factory owners should therefore not try to build these tools themselves but focus on their machine and manufacturing process expertise and add value where they can differentiate.

To enable digital continuity across the enterprise – acknowledging the heterogeneity of IT and application landscapes – a future-proof digital platform needs to embed the ISA-95 framework and current IIoT communication frameworks and protocols.

Adapting machines to become compatible with OPC UA is a non-intrusive, cost-effective way to connect factory assets. Adapters to field buses are available through an extensive ecosystem of vendors. As a result, users gain enhanced flexibility to innovate and create more customer-centric products, improving manufacturers' abilities to compete on a global scale.

OPC UA has a decreasing need for flash storage in devices; therefore, it can be applied to increasingly more network products. The vision is that OPC UA will become the next universal serial bus for industrial network devices and machines.

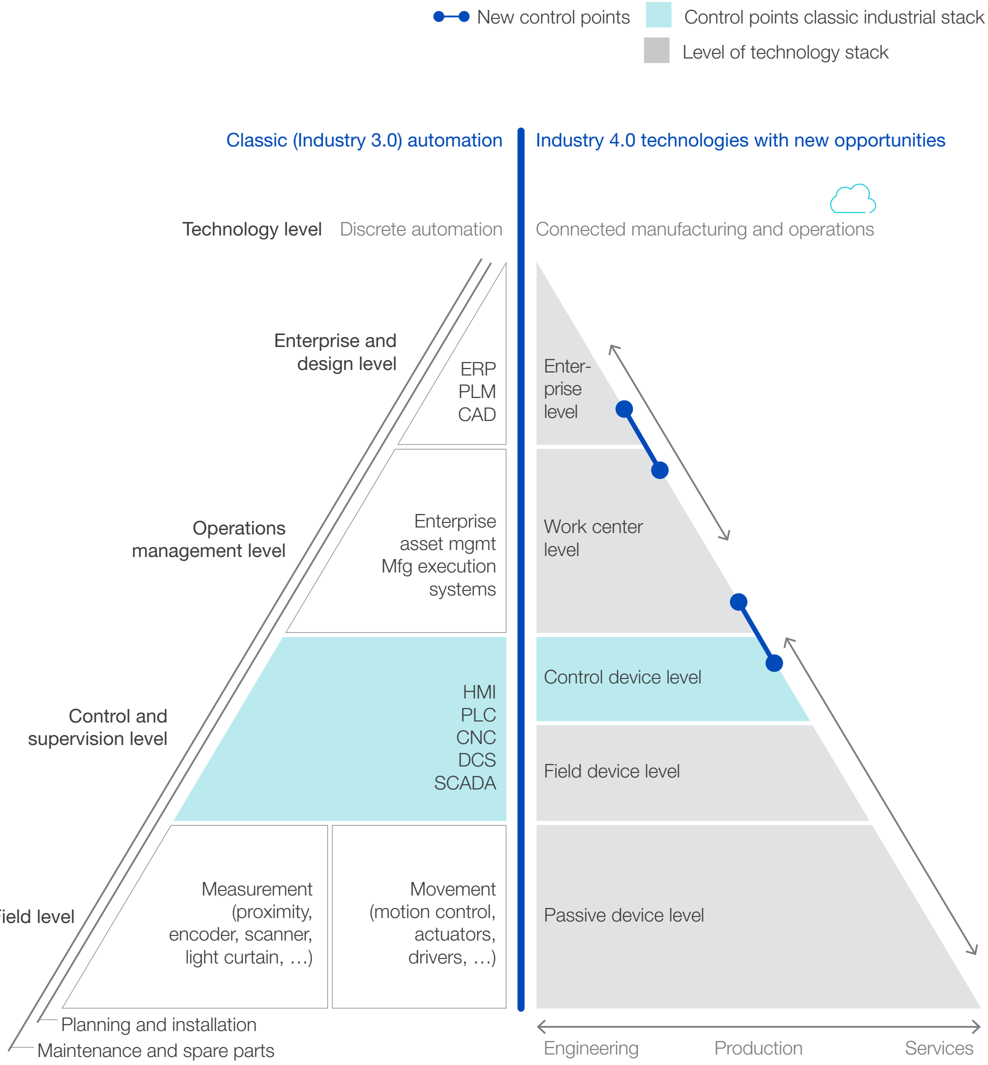
1.2 Due to their key characteristics, IIoT platforms will strongly impact the industrial automation stack

Comprising software and hardware – which may include an operating environment, storage, computing power, security, development tools, and many other common functions – platforms are designed to support many smaller programs that solve business problems.

Platforms are helpful because they abstract common functions away from the specific application logic. For example, regardless of whether you are trying to write an application to optimize fuel consumption or classroom space, many of the underlying technology needs are essentially the same. Application developers want to focus on the specific problem they are solving and use common capabilities for computing power, storage, or security. A good platform dramatically reduces the cost of developing and maintaining applications.

In the IIoT, platforms are designed to deploy applications that monitor, manage, and control connected devices (Exhibit 5). IIoT platforms must handle problems such as connecting and extracting data from a potentially high number and wide variety of end points, which are sometimes at inconvenient locations with only spotty connectivity.

Exhibit 5 **Industry 4.0 technologies present opportunities for new players to enter the market and vie for control points**



Source: ARC Advisory Group (2014); McKinsey

As interoperability is key, an IIoT platform needs to be agnostic regarding its device model and its connectivity method. A flexible, future-proof IIoT middleware platform can enable innovative business models and provide capabilities, such as secure device management, edge services, historical data, anomaly detection, a rules engine, data analytics, and data-streaming capabilities on a product and solution level.

Combined, the middleware, edge device management, and analytics products enable the generation of a uniform data stream from the edge, where the end points sit (e.g., machines, motors, drives). The data is integrated via the middleware into a data management system to be enriched. This provides the foundation for applications, analytical solutions, and use cases such as anomaly detection and predictive maintenance. It also provides the foundation for all of the applications related to connected products and the processes related to connected manufacturing (with possibilities for data monetization).

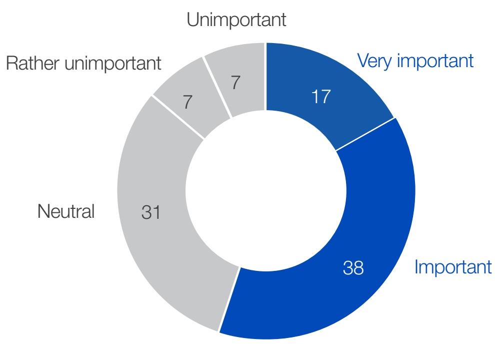
1.3 IIoT platform technology enables new business opportunities – which also present substantial risks to traditional players' core business

The emergence of the IIoT platform technology trend (discussed in Chapter 1.1) coincides with two powerful, mutually reinforcing developments across the industrial equipment and machinery sector:

- On the demand side, customers of industrial equipment or machinery players expect digital services (Exhibit 6). They see the benefits (e.g., increases in plant productivity, process improvements) not as an end in themselves but as a means to a stronger bottom line. The clear and ultimately monetary benefit to customers makes digital a highly monetizable service for plant constructors.

Exhibit 6 **Most industrial equipment and machinery players believe that digital services are important or very important to their customers**

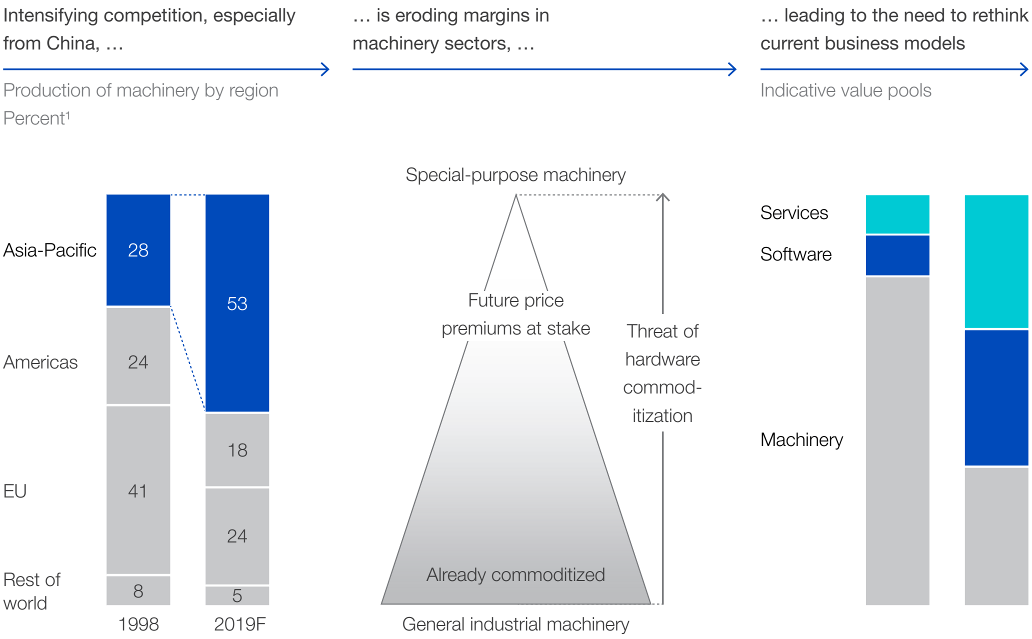
Survey question: How important are digital solutions and products for your customers?
Percent of respondents



Source: McKinsey survey

- On the supply/industrial equipment and machinery player side, global competition is intensifying, hardware is commoditizing, and technology stack value pools are undergoing a seismic shift (above all, due to customers' increasing demand for digital services) (Exhibit 7). Therefore, players are required – and rather eager – to consider reshaping their business models and offering products and services in order to stay competitive and tap into new revenue pools.

Exhibit 7 **Intensifying global competition and increasing commoditization are shifting value pools from machinery products to software and services**



Sense of urgency created the need for a comprehensive digital transformation program to reach strategic growth targets

1 Due to rounding, figures may not add to 100 percent

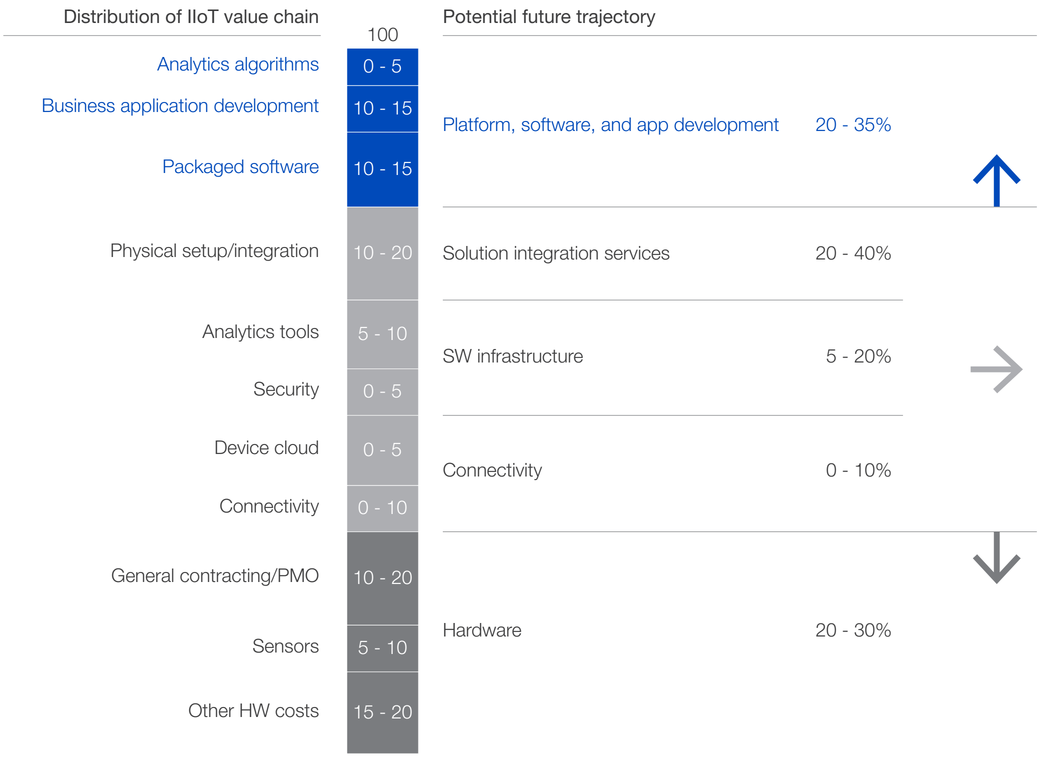
Source: Matthias Breunig and Niko Mohr: "Digital machinery: How companies can win the changing manufacturing game" (McKinsey, December 2017)

Beyond the change in the industrial automation stack, new risks and opportunities will be created and, thereby, shift value pools and reshape the supplier landscape. With the commoditization of hardware and a significant shift of the value pools toward software and services, industrial equipment and machinery players face a significant disruption. To stay competitive in their domain, these companies should build up significant new capabilities and technologies, especially in the software field, so as to transform themselves into mixed hardware-software-services companies. Otherwise, they risk being swept away by new competition from software and tech giants and losing a significant share of the value pools in their domain.

In addition to the accompanying challenges, the technological disruption also offers opportunities to occupy new control points in the industrial automation stack (see Exhibit 4 on page 16), develop new business models for new value pools, and enter new markets. The resulting IIoT revenue growth will be driven by platforms as well as software and application development and is expected to be in the range of 20 to 35 percent (Exhibit 8).

Exhibit 8 **Growth in IIoT revenue will be driven by platforms and software and app development**

Percent



Source: Industry interviews; McKinsey analysis

Against this backdrop and in order to optimally capture their share of revenue growth, industrial equipment and machinery companies first need to understand their clients' real needs and pain points. Then, they will need to identify services that can add value for the customer (often very specific to a certain industry or customer segment). This domain know-how can be one of the most important competitive advantages over tech and software players. These players are eager to enter the industrial equipment and machinery space, and they are well positioned to target the new value pools with their advanced technologies and software development powerhouses. However, they often lack the industry-specific insights and relationships critical to developing use cases with relevance and impact; thus, this is the very space where incumbent industrial equipment and machinery companies can and should flex their competitive muscle.

When doing this, however, they should be aware that a set of considerations and organizing principles applies to the development of new use cases. The most promising use case objectives – i.e., the use cases with sizable value pools – tend to be process optimization, predictive maintenance, and cross-vendor shop floor integration. These use cases are discussed in detail in Chapter 2 and in the context of three more building blocks for successfully setting up IIoT-enabled business models. Here is the road map to developing new use cases:

I. Identified use cases should be classified and then prioritized according to the size of their value pool and the feasibility of implementation. Assessing a use case's potential value, determining which monetization logic is most appropriate, and defining its technical and organizational requirements help establish its priority over other potential use cases. It is very important for each use case to have a clearly articulated and measurable value proposition. That said, it is actually not necessarily the case that stack-ranking business cases in an attempt to pick the prioritized use case is a good long-term value creation strategy. Better results can be obtained by picking a few different use cases that represent solid value, executing them with precision, and focusing on scalability. There is a learning curve to IIoT applying continuous business improvement in terms of "structured agility." Structured agility — an approach that is both organized and adaptive – is the optimal way to realize the IIoT's business improvement potential.

II. Next, the technical and organizational requirements of the use cases need to be defined. The products in your factory will need to be built with the same level of security that your customers will employ in the usage of those products. In other words, production requires a solid set of secure networks that will protect your factory equipment from intrusion, enabling access to external products and services that will be used during the manufacturing and maintenance of your products.

III. Also to be defined are the processes and infrastructure needed to enable and accommodate the customization of your products as required by certain customers or specific applications. The product options and configurations will most likely change with each order. Managing, tracking, and tracing configured products in the supply chain will require innovative solutions. With the convergence of IT and OT, you will have to manage the lifecycle of firmware or software embedded in the products, matching the factory equipment software needed to load and test each individual item.

IV. In the next step, the design of the target enterprise architecture should be informed by an understanding of how well the current IT and OT inventory might meet the needs of the target landscape. Insights from IIoT technology experts and external IT/OT supplier road maps also suggest that mapping the entire value chain – from R&D to aftermarket sales and services – is essential to evaluating the set of enterprise architecture options.

V. Finally, it is crucial to understand where and how you need to consolidate, integrate, or replace IT and OT systems, ensuring a sustainable value gain. An IIoT platform should enable you to realize value in the short and medium term without replatforming your entire IT and OT landscape.[8] It is also important to understand that business improvement is an ongoing journey. The enterprise architecture you design will never be final. Improvement may rely on a cycle of retrofitting some legacy equipment followed by the replacement of other equipment. What is clear, however, is that improvement must be continuous.

8 For further details on state-of-the-art approaches to IT modernization, see the McKinsey articles "Two ways to modernize IT systems for the digital era" (August 2015; https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/two-ways-to-modernize-it-systems-for-the-digital-era) and "Cloud adoption to accelerate IT modernization" (April 2018; https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/cloud-adoption-to-accelerate-it-modernization)

2. Claiming your spot: four building blocks for successfully setting up IIoT-enabled business models

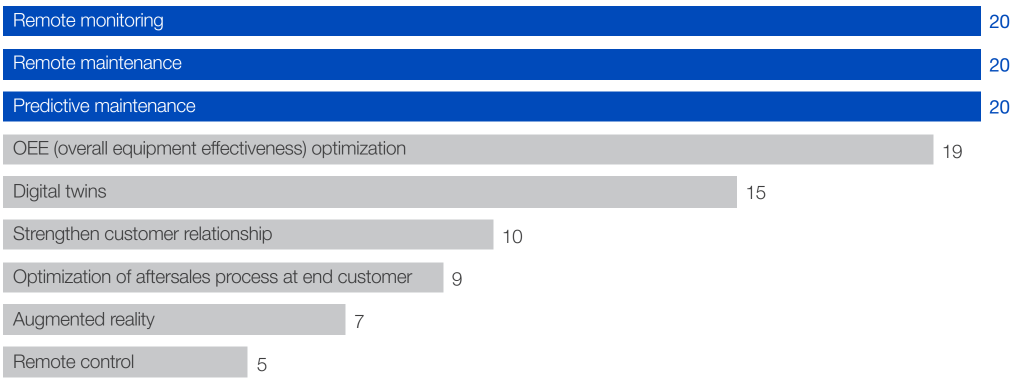
Given the importance of fast and successful IIoT transformations for players in the industrial equipment and machinery sector,[9] in the following we will first discuss three typical new use cases and their implementation.[10] Next, we will shed light on key criteria for assessing and choosing IIoT platforms as well as on what customized and targeted approaches to IIoT transformation require for different types of industrial equipment and machinery players. Finally, we will introduce a framework for monetizing IIoT use cases in the industrial equipment and machinery space.

2.1 IIoT-based use cases with sizable value pools for industrial equipment and machinery players

According to our industry experience and insights gained from recent client discussions, three use cases stand out and are by far the most promising for industrial equipment and machinery players (Exhibit 9). In the following, we explain what makes them so attractive, which underlying technologies/resources they require, and the shape of their impact/output potential.

Exhibit 9 **Industrial equipment and machinery players rank remote monitoring, remote and predictive maintenance, and OEE optimization as the most important IIoT use cases**

Survey question: What are the most important use cases from your point of view?
Percent of respondents choosing important as top 3



Source: McKinsey survey

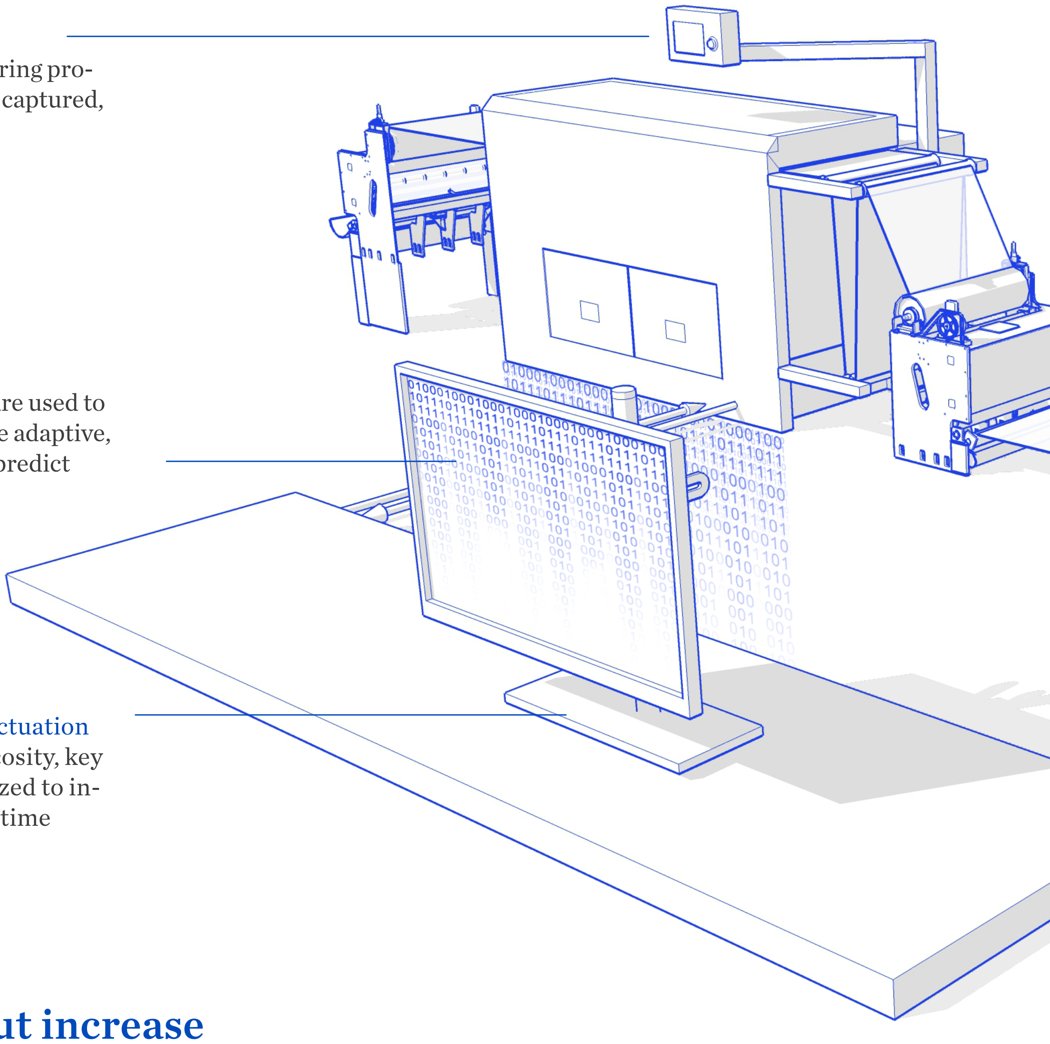
9 For further details, especially on the challenges involved in escaping from "pilot purgatory" in the Fourth Industrial Revolution, see World Economic Forum (in collaboration with McKinsey & Company); "The Next Economic Growth Engine: Scaling Fourth Industrial Revolution Technologies in Production" (January 2018), pages 7 to 8.

10 For a comprehensive overview of relevant IIoT-based use cases, see World Economic Forum (in collaboration with McKinsey & Company); "The Next Economic Growth Engine: Scaling Fourth Industrial Revolution Technologies in Production" (January 2018), pages 24 to 26.

IIoT-based use case no. 1: process optimization

One of the most important use cases in IIoT is process optimization. This use case aims to improve machine OEE, reduce the use of energy and consumables, increase quality, or raise throughput by monitoring and optimizing key performance indicators. This can include optimizing the machine speed, surface pressure, temperature, etc. This use case has sizable monetary value as it can significantly reduce the operating costs of machines and improve throughput. See Exhibit 10 for an example of how throughput was increased at a pulp and paper factory by using advanced analytics.

Exhibit 10

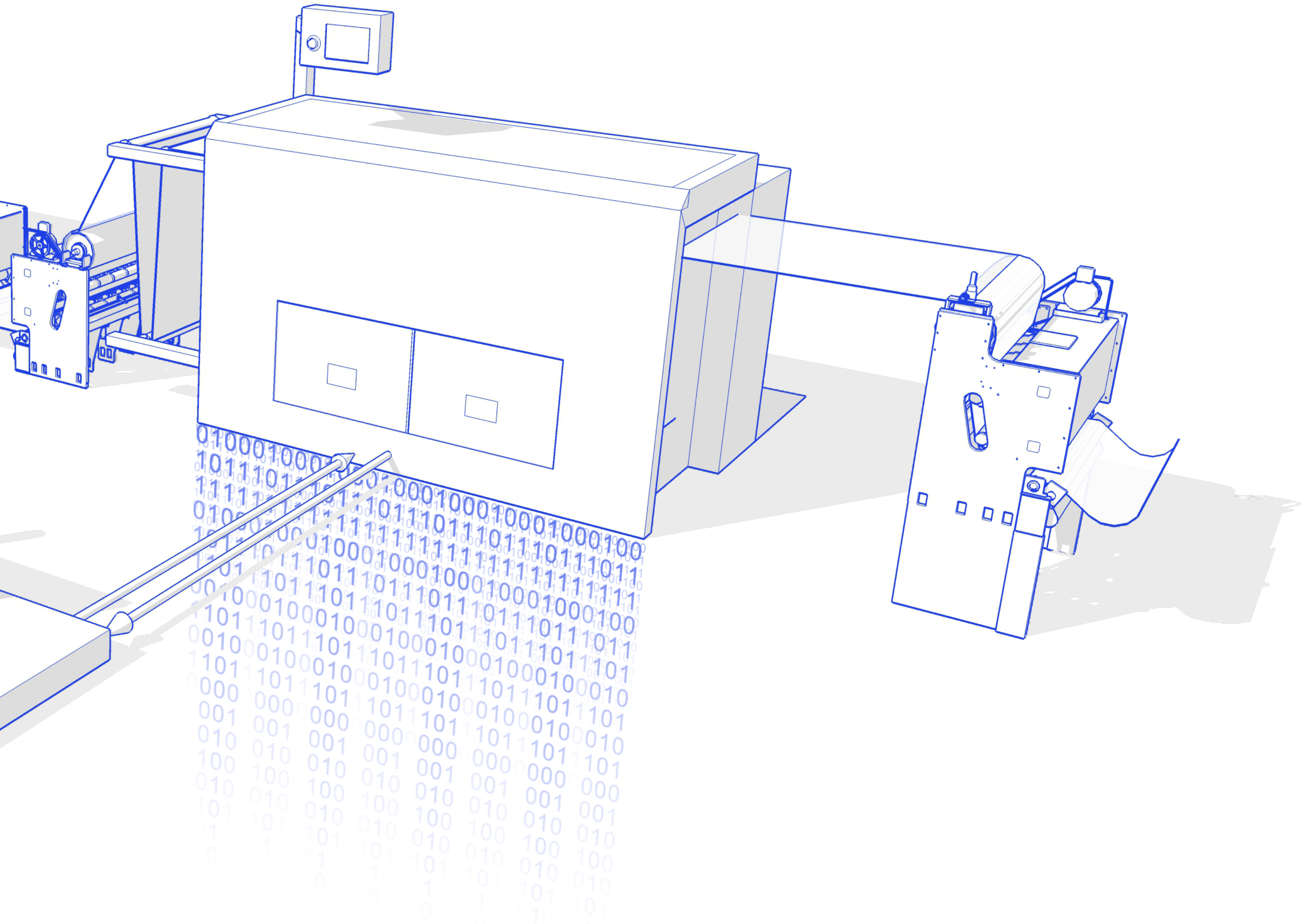


1 | Sensing and capturing
Data from sensors monitoring process variables of the site is captured, cleaned, and structured

2 | Analysis and modeling
Advanced analytics tools are used to analyze the data and create adaptive, self-learning models that predict product viscosity

3 | Decision making and actuation
Based on the inferred viscosity, key parameters can be optimized to increase throughput in real time

Impact:
~ 9% throughput increase



IIoT-based use case no. 2: predictive maintenance

IIoT-enabled use cases in predictive maintenance deploy a process that makes maintenance a time- and cost-efficient proposition. Specifically, sensors collect a range of equipment data that are indicators of or proxies for machine performance. Regression and/or neural networks interpret changes in these data as predictors of equipment failure. By getting ahead of and surgically targeting maintenance issues, predictive-maintenance use cases reduce costs by eliminating nonessential maintenance. Additionally, the data collected in these use cases offer insights that can further enhance asset productivity. See Exhibit 11 for a description of the general predictive-maintenance process.

Exhibit 11

I.
Collect data from equipment and process

Equipment data (e.g., vibration, temperature, pressure) and process data collected using sensors

II.
Interpret sensor data using advanced analytics

Models based on regression or neural networks use historical data to predict possible future failures

III.
Implement change initiatives with live tracking

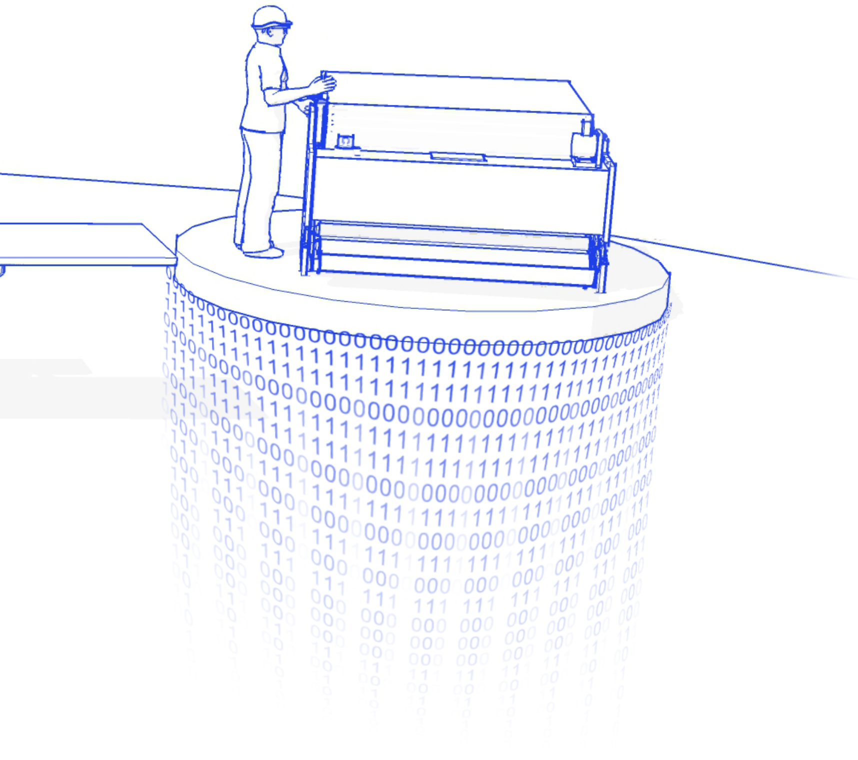
Maintenance is provided when required, thereby reducing maintenance costs and unplanned shutdowns

Impact:

10 - 30% reduction in maintenance spend

IV.
Replace equipment only when required

Procurement orders replacements only when equipment needs replacing, rather than when it is prescribed by the OEM



Business implications

- Predict when parts will fail and replace parts in a planned way at the optimal time
- Avoid failures by identifying undesired patterns (e.g., preventive actions on roads with poor conditions to prevent truck failures)
- Reduce costs by eliminating nonessential maintenance

Technology implications

- Advanced analytics generates previously untapped insights into maintenance and asset productivity using big data that would not be possible using conventional techniques

Design implications

- Maintenance teams can be redesigned to avoid regular noncritical service trips: instead, they can be strategically assigned to equipment needing specific preemptive maintenance

IIoT-based use case model no. 3: cross-vendor shop floor integration – horizontal line optimization and OEE improvement

Today's shop floor is anything but consistent when it comes to hardware, with a mix of legacy machines and new machines from various vendors being rather the rule than the exception in most factories. The variety of components and sensors means a wide range of controls (e.g., PLCs, NCs) communicating in different protocols and languages. One major challenge with IIoT is enabling a fully integrated shop floor, including machine-to-machine communication requiring standardized semantics (i.e., protocols and communication languages). This is also the foundation for the integration with MES and enterprise systems, such as PLM and ERP, needed to bring together information from various sources. A cross-vendor shop floor integration that successfully integrates these systems can leverage data from all machines on the shop floor to holistically optimize output and quality – as opposed to optimizing machine by machine – and enables optimization across the value stream by, for example, obtaining data feedback directly from the shop floor and feeding it into the PLM system for product design. See Exhibit 12 for a visual presentation of how MES integrates the machines of multiple vendors.

Exhibit 12

The cloud

- Cloud environment
- IIoT platform
- Analytics engine, apps, etc.

Integration layer

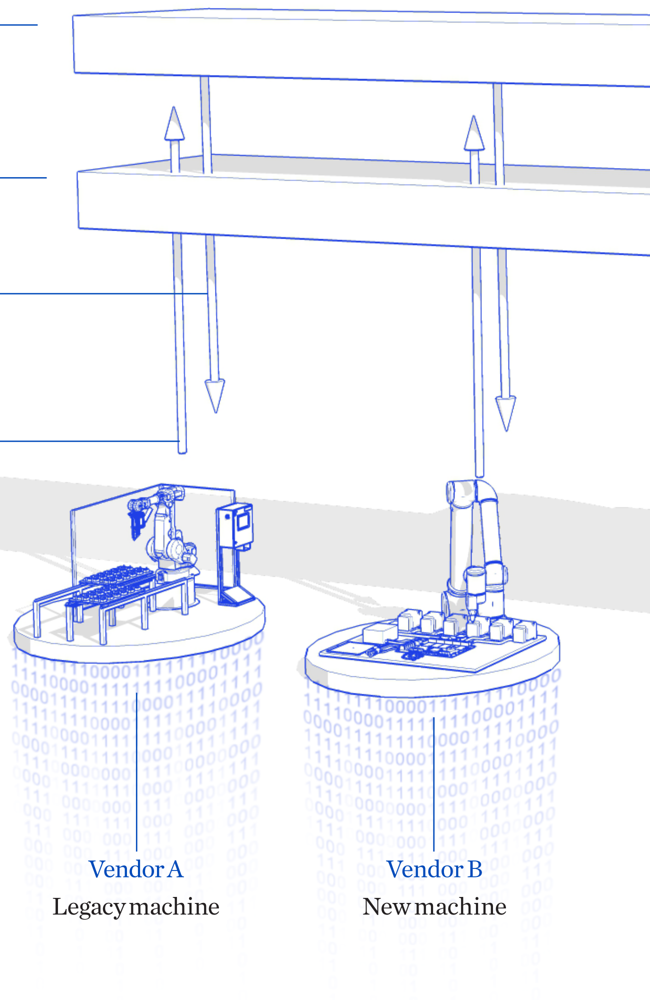
- Integration layer for data collection and distribution

Semantics unification

Cross-vendor integrated data collection

- Unification of semantics to a standard protocol
- Connectivity via gateways

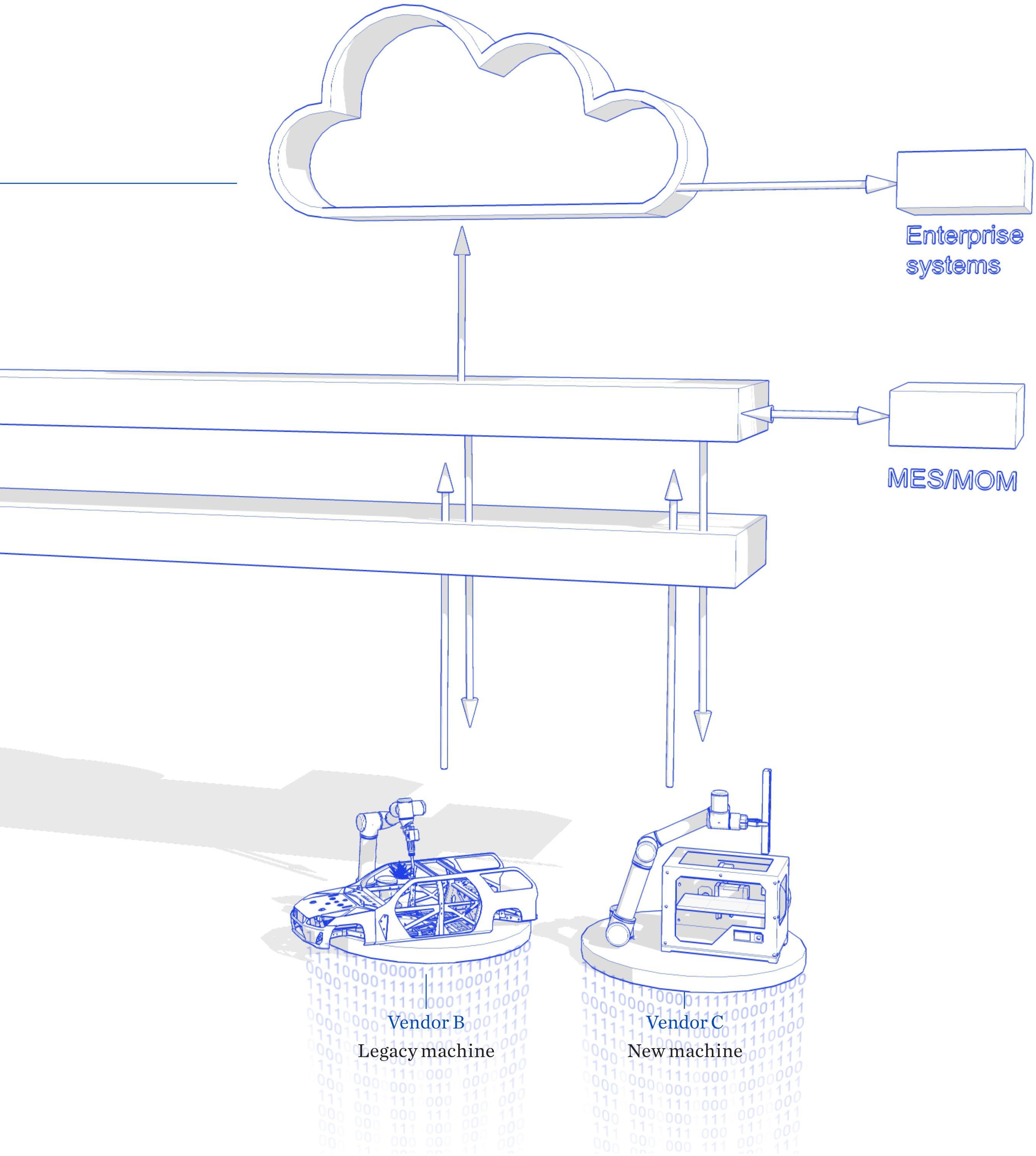
Integrated product line control for line optimization



Unified semantics and cross-vendor integration will allow horizontal product line optimization via machine-to-machine communication

Impact:
Throughput increase*

* In the absence of a sufficiently large number of full implementations of this use case, we refrain from providing an impact figure here



Enterprise systems
MES/MOM
Vendor B
Legacy machine
Vendor C
New machine

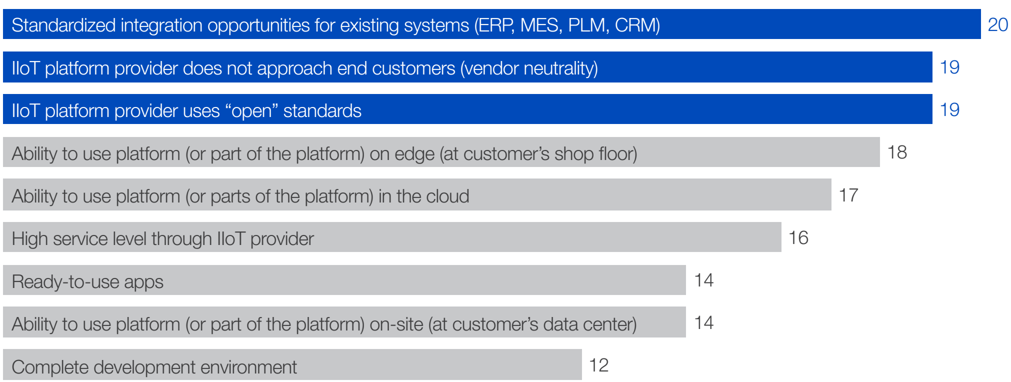
2.2 A framework for assessing and choosing IIoT platforms

A common question of industrial players is which IIoT platform to choose. Today, there is no one-size-fits-all platform available, and it will likely be several years before any player emerges as the dominant IIoT platform provider. Until then, choosing a platform should start with a good understanding of your IIoT strategy and by asking yourself, "what and where?" Specifically, with an idea of what kind of business problem you are seeking to solve and where the biggest challenges lie,[11] you will be able to quickly create a shortlist of potential platforms that will best match your needs and help you avoid investing substantial resources in the wrong platform.

To then assist you in making an informed choice and picking the best match from the shortlist, McKinsey has identified – among other things and on the basis of survey findings on key selection criteria (Exhibit 13) – the feature categories most likely to differentiate platforms in an important and sustainable way.

Exhibit 13 **When selecting an IIoT platform, industrial equipment and machinery players are most concerned with vendor neutrality, the use of open standards, and the ability to integrate into existing systems**

Survey question: What are the most important factors for selecting an IIoT platform?
Percent of respondents choosing factor as top 3



Source: McKinsey survey

In the following, we provide a holistic framework that is based on our findings concerning the relevant characteristics/feature areas of IIoT platforms. This detail and specificity enables industry players to comprehensively assess IIoT platform providers regarding the categories that are most relevant to their individual cases.

11 For guidance on how to develop a precise understanding of what kind of business problem you are solving and where the biggest challenges lie, see Eric Lamarre, Brett May; "Making sense of Internet of Things platforms" (McKinsey & Company, May 2017). The article not only lists the top-ten questions that industrial companies should ask themselves before choosing an IIoT platform provider but also offers extensive further guidance on determining which technological factors may be most relevant to choosing an IIoT platform (provider).

Overall, IIoT platforms and providers should be assessed along two dimensions: organizational maturity and technological maturity.

A platform's organizational maturity is derived from the scope and scalability of its business model and its level of market readiness:

- Mature business models provide customers/partners with solid answers when it comes to questions of data ownership and the contractual freedom between users and their end customers.[12] Business model maturity is also characterized by the ability to ensure efficient ecosystem onboarding. Finally, mature business models ensure a wide range of professional service offerings with a focus on scalability. Platforms that are designed to scale have the potential to not only leverage economies of scale but also economies of density, thus ensuring that existing users provide additional value to new users.

- Market-ready platforms are defined by simple and predictable pricing, demonstrably efficient and effective governance, successful partnering strategies, and a neutrality that avoids direct competition with its customers.

A platform's technological maturity is determined by its use case offering, its development capabilities, available technologies, and handling of operations:

- Use case offerings are assessed on their diversity, comprehensiveness, and consumability as well as their ease of implementation.

- Development capabilities are determined by the size and focus of the active developer community, the extent to which specific industry know-how and requirements are considered in platform development, and the consumability and functionality of the development and testing environments.

- Technology availability is an outcome of the openness and modularity of the platform architecture, the maturity along and the completeness of the technology stack, and the available deployment options. Furthermore, the available security (including cybersecurity[13]) and authentication options as well as the – still widely lacking – approach to standardizing the semantics and facilitating machine-to-machine communication across vendors may be relevant to IIoT platform customers.

- Operational performance is best judged by looking at how development and delivery processes are handled, how platform operations and support are organized, and how the platform portfolio – including the definition of the development road map – is managed.

The dimensions of maturity described above help assess a platform's readiness, performance, and longevity. What a particular industrial equipment or machinery player requires in terms of a platform's maturity depends on the organizational and technological demands of the individual use case. Assessing prospective platforms on the above-mentioned criteria and comparing the assessment results against the specifications of the IIoT use case at hand will help industrial equipment and machinery organizations make the most informed choice.

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12 For details, especially on questions of data ownership, see Text box 3 " Understanding data ownership details and developing data-sharing partnerships" on page 39.

13 For guidance on key aspects of cybersecurity in a networked world, see the McKinsey report "A new posture for cyberrisk in a networked world" (December 2017)

2.3 Industrial equipment and machinery player archetypes and the IIoT strategy directions for each

While some industrial equipment and machinery players have already invested heavily in their IIoT offering, others are still at an early stage. In the end, IIoT strategies and transformation road maps always need to be individualized and targeted to each specific company, accounting for its strengths and weaknesses, available resources, past experiences, and market pressures.

Nevertheless, there are four distinct archetypes of industrial equipment and machinery players who face common challenges and have significant similarities with respect to their IIoT transformations (Exhibit 14). Knowing to which archetype a company belongs will be helpful in determining the next steps and how to deal with strategic, organizational, and technological hurdles.

Leaders are first movers and early adopters using their own capabilities to deploy several IIoT use cases. They have a clear IIoT vision, a defined road map that is anchored to their business strategy, and a high willingness to invest in IIoT topics. Therefore, leaders need advanced solutions and functionalities, various deployment options, and a comprehensive development and testing environment with virtual test data sources that can simulate the data flow of machines.

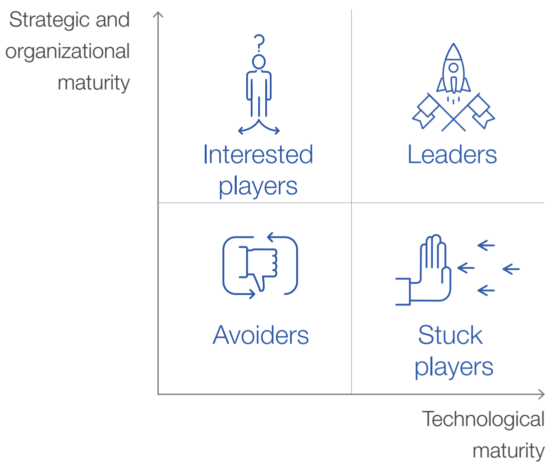
Yet even leaders typically have a long way to go on their IIoT journey. For many of them, the next steps in their IIoT transformation include the implementation of use cases across machines from different manufacturers and the holistic optimization of entire value chains. Other important steps are merging data from different sources, including, for example, data from business platforms or satellite imagery data, and applying artificial intelligence, particularly machine learning, to get the most out of their data.

Leaders' experience in single-manufacturer IIoT use cases makes them instrumental in shaping the development of IIoT platforms.

Leaders' strategy development needs include a road map for implementing use cases across different manufacturers' machines and along the entire value chain.

Exhibit 14 **Knowing to which archetype an industrial equipment and machinery company belongs ...**

Overview of 4 distinct archetypes of industrial equipment and machinery players



High organizational maturity if ...

IIoT strategy and business model are aligned

Effective governance and road map for IIoT initiatives are in place (incl. state-of-the-art IIoT talent management and a Digital Academy)

High organizational willingness

High technological maturity if ...

IIoT use cases are consolidated and prioritized

App development capabilities and skills are available

IIoT platform considerations and technology validation is in progress

Interested players see the potential value in IIoT. From a strategic and organizational perspective, they are ready for an IIoT transformation, but they lack some of the technological capabilities and capacity. This means that they may have implemented some early IIoT use cases – or at least deployed some prototypes – but need support in a larger rollout of digital services and IIoT initiatives.

Interested players may have tested IIoT prototypes but are far from full deployment.

Interested players' strategy development needs include identifying their technology gaps and selecting a platform provider accordingly in order to move ahead with their IIoT rollout.

Interested players need solutions that are easy to implement, such as ready-to-use apps, analytics tools, and other software assets, such as dashboards. Additionally, they benefit strongly from a comprehensive professional services offering. An IIoT transformation for interested players starts with a clear identification of their own technological competences and gaps. This will inform their selection of the right IIoT platform provider (as well as other technology partners) to help keep the investment requirements manageable and focused and to progress quickly. Often, these companies can become early adopters in their field and achieve competitive advantages if they manage to move fast and prioritize their IIoT efforts wisely.

… will be helpful in understanding its strategy development needs

Overview of each archetype's strategy development needs

Interested players

Finding of easy-to-implement solutions

Clear identification of own technological competences and gaps

Fast moving and wise prioritization of IIoT efforts

Leaders

Implementation of use cases

Holistic optimization of entire value chains

Merging of data from different sources

AI application

Avoiders

Development of an overarching IIoT perspective

Improvement of capabilities with own lighthouse use cases

Embedding of these use cases in a comprehensive IIoT strategy focused on quickly achieving ROI

Stuck players

Development of a common IIoT perspective

Delineation of an IIoT strategy that is aligned across the company

Choosing of one's own IIoT platform provider

Source: McKinsey

Stuck players have begun some isolated IIoT initiatives, but they lack strategic and organizational maturity regarding IIoT. Their technology capabilities have led to the development of some use cases, but strategic and organizational immaturity means that no clear platform solution has been implemented. It also means that they do not have a clear view of future organizational IIoT needs or a strategy or perspective on how value is created for the customer.

Stuck players demonstrate interest in but do not necessarily have a unified strategic and organizational approach to IIoT.

Stuck players' strategy development needs include the definition of a clear vision for IIoT that is aligned across the whole organization.

Stuck players may first require convincing by lighthouse use cases that demonstrate the return on investment and the value of implementation requirements. These players then need to develop a common perspective on IIoT and an IIoT strategy that is aligned across the company. Therefore, choosing their IIoT platform provider is only one of many steps that are required before implementing further use cases.[14]

Avoiders have no clear perspective on or vision of IIoT and do not see the value that it can generate for them. They have no capabilities (and thus no use cases) in the area of IIoT, no perspective on their own IIoT needs, no IIoT aspirations, and no concept of the relevance of IIoT in their own field.

Avoiders do not yet see the value of IIoT in machinery.

Avoiders' strategy development needs include an honest assessment of the future of the industry and a look at light-house cases that may convince them of the necessity of an IIoT transformation.

While investing in IIoT may still seem premature for many avoiders, many of them will soon realize that they are missing out on significant value opportunities and are risking marginalization as commodity hardware suppliers begin to dominate.

Avoiders, therefore, should start looking at exactly how their markets are expected to change and search for convincing lighthouse use cases that have provided demonstrable impact for other players. Starting the IIoT journey may seem harder than it is, as these players can substantially benefit from the lessons learned by the other player archetypes. After having passed the "convincing" stage, their next step is to develop an overarching IIoT perspective and improve their capabilities by implementing one or two of their own lighthouse use cases. These use cases would then be embedded in a comprehensive IIoT strategy that should be very focused on quickly achieving a return on investment.

14 For further details concerning the unique IIoT journey for stuck players, see Chapter 3.2.

2.4 Approaches to monetizing IIoT-based use cases in the manufacturing space

In general, there are two strategic directions for the monetization of use cases, which differ inherently in terms of the revenue streams:

Use case as individual revenue stream. The IIoT use cases that directly deliver revenue include applications such as Software as a Service (SaaS). To move in this strategic direction, manufacturers will need to estimate the value of these use cases by determining their precise customer impact. If the value is deemed sufficient, the manufacturer will then focus on developing a profitable and competitive pricing model, e.g., one-off, subscription, usage based. If pricing is tied to usage (e.g., traffic, volume) then a metering solution will need to be created. Finally, a mechanism that enables simple, low transaction-cost/high-transparency payments must be put in place that also accounts for any legal and organizational matters related to cross-border payments.

Use case as revenue enabler. IIoT use cases can also be applied to grow or sustain existing revenue streams by, for example, better enabling up-selling and/or cross-selling. Use cases in this category can also facilitate the monetization of new hardware or service business models, such as Machine as a Service. These use cases require clear structuring between upselling (e.g., hardware plus software solutions as additional service) and cross-selling (e.g., software solutions as individual products, which contribute to additional revenue via services). Manufacturing players will also need to determine how to value the up-selling or cross-selling potential as well as the internal resource effort for digital solutions that do not generate individual, measurable revenue streams.

3. Getting started with capturing impact at scale: your journey to implementing and monetizing IIoT-platform-enabled applications

3.1 Pragmatic no-regret moves for all four industrial equipment and machinery player archetypes

There is certainly no single, standardized approach to getting started and enabling an organization to implement and monetize IIoT platforms. Our findings concerning IIoT platform implementation and monetization as well as our observations of the most successful players in adjacent industries with similar digitization challenges, however, reveal effective approaches and perspectives that aspiring players in the digital machinery and equipment space might adopt in order to achieve impact at scale.[15]

1. ***Set the ambition at CEO level.*** IIoT platform monetization entails a profound rethinking of the value chain for industry players, potentially entailing new revenue streams and capabilities, and potential cannibalization.

2. ***Focus efforts on a limited number of relevant use cases.*** The players most likely to achieve sustainable success in the area of IIoT platform monetization will be the ones who focus on a limited number of use cases – instead of trying to target as many use cases as possible.

3. ***Do not be afraid of workarounds today while laying the IT foundations for a more robust solution tomorrow.***[16] The required organizational capabilities of long-term IIoT platform monetization success are numerous, but achieving excellence in each area is not a prerequisite to getting started. Industrial equipment and machinery players should act early in the areas where they are most prepared, create interim solutions to address current gaps, and also work on building more permanent capabilities that allow them to achieve even greater success in the future.

4. ***Build an ecosystem of business and technology partners.*** As described above, part of the capability building needed will require working relationships with a wide array of external players and institutions. Companies should begin thinking about which aspects of IIoT platform implementation and monetization they want to "own" as well as which are best addressed through outsourcing, long-term collaboration, or other types of partnerships. Importantly, in this context companies also need to find answers to questions concerning data ownership and cybersecurity (see Text box 3). They should then start identifying who those partners might be and engaging them pragmatically.

5. ***Build a strong internal team with an agile mindset.*** To fully capture value from IIoT platforms, companies need to build up strong internal capabilities and establish a dedicated cross-functional team that drives innovation based on a culture open to change and experimentation (see Text box 4 "Building agile teams – what business leaders need to know about roles and principles"). This team must be located outside of the organization if current internal processes are not agile enough to allow for development and field testing of IIoT-platform-enabled use cases at "high-tech player" speed.

15 For a more comprehensive list of recommendations for business leaders on how to accelerate adoption of Fourth Industrial Revolution technologies, see World Economic Forum (in collaboration with McKinsey & Company); "The Next Economic Growth Engine: Scaling Fourth Industrial Revolution Technologies in Production" (January 2018), pages 9 to16.

16 For further information on this, see the McKinsey publications referenced in footnote 8 on page 24.

Text box 3: Understanding data ownership details and developing data-sharing partnerships

Success in the new digital ecosystems of business and technology partners is often closely linked to which party owns which kind of data. Various sets of data – operations/maintenance data, component/sensor data and IIoT-platform-related data – are needed for the switch towards implementing and monetizing IIoT platforms in the industrial equipment and machinery space.

As data ownership is usually distributed across several players, all of them need to get in conversation and settle on agreements that suit their target state. Careful, up-front consideration of the following questions can help players avoid getting locked into unfavorable terms for the duration of an IIoT-based business case's life (or even longer in the case of strategic longer-term negotiations):

- What kind of data is being or should be generated to implement condition monitoring or predictive schemes, and how can this data be extracted in real time or at least in near time?
- Who owns which data and what data rights should other parties in potential cooperation models have?
- Is data shared between the parties and, if so, how?
- Who could take on the role of a "Data Trustee[17]"?
- What IT solution is used as a platform? Is exclusivity desired, or is the aspiration a solution that benefits the sector as a whole?
- Should data be shared with other parties (e.g., analytics start-ups, system suppliers) who are potentially involved and, if so, how?
- What measures should be taken to prevent data breaches and asset manipulation, and how can cybersecurity be enforced?

If neither the industrial equipment or machinery players nor IIoT platform providers are willing to hand over or sell the data generated to the other party, both will find it beneficial to at least cooperate with each other to have access to the full picture and capture the entire potential of IIoT-platform-based use cases. What's more, as tons of data will soon be generated and extracted from the industrial equipment or machinery player's shop floor and the platforms' apps in real time, the danger of data being manipulated or used as a gateway to intrude into the players' operating system, apps, or IIoT platform will increase. Therefore, incorporating principles of cybersecurity[18] will become one of the most crucial efforts in setting up new digital ecosystems of business and technology partners.

17 Data Trustees are accountable for the security, privacy, data definitions, data quality, and compliance to data management policies and standards for a specific data domain. Their day-to-day Data Governance responsibilities are typically delegated to Data Stewards and Data Custodians within their organization. (source: http://www.dataversity.net/data-governance-demystified-lessons-from-the-trenches/)

18 For guidance concerning cybersecurity-related key questions, see the McKinsey report "A new posture for cyberrisk in a networked world" (December 2017)

Text box 4: "Building agile teams" – what business leaders need to know about roles and principles

Agile development and digitization go hand in hand: senior business leaders have realized that their companies cannot take full advantage of digital tools and technologies without a well-equipped team able to master the requisite new, amped-up digital management processes. The knowledge that the value of these processes is immense has also spread. What is less well known about agile teams is which roles are critical and how are they sourced, i.e., internally or externally. In this context, it may suffice to say that in summary, "agile" is a team sport aligned around quickly building valuable software and solutions.[19] To this end, the three key roles needed are:

Product owner – responsible for "building the right thing," the product owner makes decisions about the product, ensures product quality, represents the voice of the customer, and incorporates feedback from field tests.

Architect – skilled in "building the thing right," the architect drives the technical direction of the project by coaching the team, creating the technical architecture, and helping the team implement software engineering practices.

Scrum master – tasked with "building the thing fast," the scrum master oversees the scrum process and coaches the team, removes impediments to progress, and enables cooperation across all roles and functions.

Another mystery surrounding agile teams is often how exactly the team should function. With key leadership roles in place, agile teams are most likely to find success in driving their organizations' digital efforts if they can commit to 8 key principles related to function, setup, capabilities, and mindset:

1. **"Self-organizing":** The team decides how to organize itself to meet its goals.
2. **"Self-managing":** Each member of the team "manages" the team.
3. **"Cross-functional":** The team is equipped with the range of skills needed to go from product backlog to production-ready solution.
4. **"Right-sized":** The team consists of 7 team members (+/- 2).
5. **"Committed":** The team is committed to delivering features for the sprint.
6. **"Empowered":** The team has authority to do what is needed to meet the required functionality (within certain constraints).
7. **"Focused":** Timewise, team members are dedicated or at least not spread too thin (e.g., 100% or 75% dedicated to the team).
8. **"Immutable":** Team structure remains stable during sprints.

19 For further information on how to build agile teams, see the McKinsey article "A business leader's guide to agile" (July 2017), https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/a-business-leaders-guide-to-agile

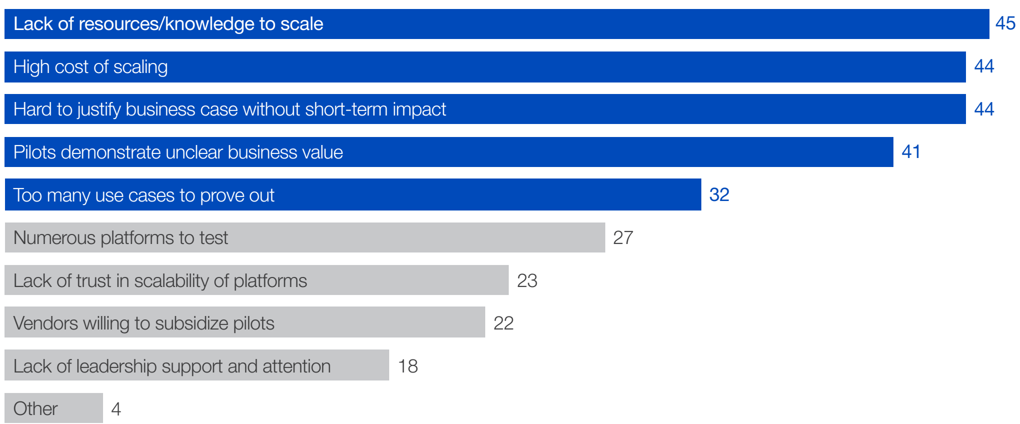
3.2 Stuck players' exemplary IIoT journey to achieving impact at scale

As outlined above, strategic and organizational maturity as well as technological maturity are fundamental to IIoT success. In general, the developmental path forward in these two areas is shaped by a player's starting point as illustrated by the four archetypes: leaders, interested players, stuck players, avoiders. These archetypes represent players in significantly different parts of the tech/strategy & org maturity matrix, and each has its own set of priorities and milestones on the road to IIoT success and scaling.

In the following, we describe the priority action areas for stuck players in greater detail.[20] These players are basically "higher on tech and lower on strategy & org" when it comes to maturity. We have decided to present a deep dive on this archetype primarily because quite a large number of industrial equipment and machinery players belong to this segment. This is indicated, for example, by findings of two recent McKinsey surveys, which revealed that "84 percent of companies with IIoT pilots say that they were stuck in "pilot purgatory" for over a year[21] and that the top five reasons preventing companies from moving from pilots to rollout are all org & strategy-related, while tech-related issues are much less of a hindrance (Exhibit 15).

Exhibit 15 **The main challenges to scalability are due to the difficulties in value alignment, the cost of the needed resources and efforts, and strategic ambiguities**

Reasons preventing move from pilots to rollout
Percent of respondents choosing reason as top 3



Source: McKinsey in collaboration with the World Economic Forum

What this looks like, practically speaking, is that players in this category have made some initial steps in technology by, for example, forming small task forces that have developed technical prototypes. In some cases, players have even launched the first products and applications. As they possess some level of technological maturity – as demonstrated by their ability to make product-related strides – the action steps outlined for them to make improvements in this regard are categorized as an enhancement area.

20 In this context, also see "Avoid pilot purgatory in 7 steps", a recent McKinsey publication on the seven secrets of achieving scale-up success that shows how to avoid the very "pilot purgatory" in which – as a recent McKinsey survey revealed – 84 percent of companies with IoT pilots were stuck in for over a year.

21 Ibid.

Overall, however, stuck players are most lacking in the strategic and organizational maturity to holistically tackle the IIoT disruption and capture impact at scale. They typically do not have a dedicated organizational unit or a clear strategic vision and direction, which dilutes the effectiveness of their technological progress. The action steps required in this dimension of maturity are categorized as an emphasis area.

Enhancement area: technological maturity

While stuck players typically have some technology solutions and capabilities in place, they often lack the structured approach and comprehensiveness in the technology offering to actually provide an operationally mature offering. Typically, customer needs are not yet addressed holistically by these players and not integrated into a working business model that actually generates revenue. Therefore, stuck players need to address the following technology-related topics:

"IIoT platform selection"
Develop a process for determining which IIoT platform should be used for IIoT solutions, and select the platform with the offering that best meets the industrial equipment and machinery player's specific needs (compare assessment frameworks in Chapter 1.2) in terms of technology and business process integration and provisioning.

Determine whether in-house development or an outside provider makes the most sense. Distinguishing between differentiating/IP-leveraging and commoditized platform elements can help companies decide between an in-house or acquired solution.

"Lighthouse to scale-up"
Decide which use cases are the most important for the business. These are the ones that are most feasible in terms of ease of implementation and the ones that represent the biggest long-term value opportunity. These lighthouse use cases can demonstrate technological capabilities, relevance, and impact and can then be used to develop the business case.

Determine how to scale and roll out. The transition from prototypes to MVPs (minimum viable products) must be mapped out, as does the transition from MVPs to market-ready, scalable product offerings.

"Product functionality and performance"
Define and implement processes that ensure smooth and stable operations, including a plan to ensure the technological integration of use cases and applications with the hardware product portfolio.

Ensure seamless communication between hardware and software. Ease of interaction and inter-operability is a must, not just between the hardware and software within a player's own offering but potentially across vendors as well.

Emphasis area: strategic and organizational maturity

Stuck players typically need to place emphasis on developing strategic and organizational maturity to tackle the disruption of IIoT and scale successfully. Therefore, it is essential to work specifically (but not exclusively) on the following topics:

"Strategic vision and business perspective model for IIoT"
Create a clear strategic vision on IIoT in the relevant domain and understand how the markets are evolving, including the identification of pockets of growth and other relevant industry trends. A perspective on competition is also important, including an understanding of current players and new entrants and how they address IIoT disruption.

Develop an outlook on IIoT in the relevant domain that identifies which regions and subindustries make sense for them to compete in and forecasts which traditional hardware businesses will be mostly commoditized, thus requiring additional IIoT solutions to remain competitive in the market.

Assess strengths, weaknesses, and opportunities. This assessment includes an understanding of any unique in-house capabilities that can be developed into value propositions that are attractive for target markets, as well as identifying any current technological solutions that can or should be scaled up.

"M&A and alliance strategy"
Determine how the current M&A strategy needs to be adapted to the IIoT disruption. This includes the identification of targets that offer relevant technology assets, solutions, and/or capabilities as well as those that might help push the envelope of IIoT offerings, increase speed, and enhance agility in the new business fields.

Identify potential strategic alliances and a setup that minimizes the risk of giving away value pools. Alliances with other players in the industry help to join forces to remove roadblocks and address challenges, such as the competitive threat from nonindustry players, e.g., tech players. Alliances with nonindustry players can create synergies by leveraging assets, expertise, and resources.

"Digital/IIoT solutions unit"
Establish a dedicated digital/IIoT solutions unit within the organization. The unit should be given appropriate authority to ensure that priority is given and resources are allocated to creating digital solutions. To this end, the unit should concentrate, in particluar, on two things: defining (and recruiting for) new and critical roles across the organization – such as the roles of Data Architects, Data Scientists, Data Engineers, and Data Translators – and setting up a broader Digital Academy that focuses on both fostering digital capabilities and developing digital talent in order to scale data- and digital-related compentences and enable continuous business improvement.

Integrate the unit with the traditional part of business. The unit needs to seamlessly work with other BUs and combine hardware, software, and service portfolios into an integrated offering.

"Customer service"
Create a structure that facilitates quality service. Remote online services based on connected machines, among other things, can ensure quick, software-focused customer service.

By exploring these areas and taking action where appropriate, industrial equipment and machinery players can establish a clear strategic direction for prioritizing efforts and resources, developing a clear view of organizational and technological requirements, and creating a structure that facilitates and sustains an IIoT business model that achieves sustainable impact at scale.

Outlook

The application of IIoT platforms to business problems and the monetization of IIoT-platform-enabled applications has never been as easy and promising as today. All pieces of the puzzle – effective IIoT platform technologies, high-performance computing hardware, sensors generating data, and the growing demand for digital services from the customers of industrial equipment and machinery players – have fallen into place and IIoT-platform-enabled applications are ready to scale.

Among industries, the industrial equipment and machinery sector with its highly automatable tasks and increasingly connected devices, has especially great potential to benefit from IIoT platforms. We have demonstrated – based on three practical use cases – that even today IIoT-platform-enabled applications can lead to performance and revenue boosts as well as new business models in the industrial equipment and machinery sector. Five pragmatic recommendations guide the way to getting started.

Testing the first prospective applications of IIoT platforms in your company does not require long preparation or a large up-front investment. Jumping in provides the benefit of producing early results and helping your company make quick progress on its journey to becoming an organization that almost immediately embraces the full potential of intelligently linking IIoT platforms, enterprise applications, and shop-floor systems towards a seamlessly integrated industrial software stack.

What are you waiting for?

Factory automation glossary

The definitions in this glossary reflect how the respective terms are used and abbreviated in this report.

Computer-aided design (CAD): CAD is a software system that allows engineers to originate or modify a vast range of original equipment designs via a computer interface. Once a product is designed using CAD, it can be sent as a computer file and produced through a variety of production processes, e.g., traditional machines, CNC (computer numeric control machining), or 3D printing.

Computer numerical control (CNC): CNC is the automation of machine tools by means of computers executing preprogrammed sequences of machine control commands. This is in contrast to machines that are manually controlled by hand wheels or levers or mechanically automated by computer-aided manufacturing (CAM) software alone. In modern CNC systems, the design of a mechanical part and its manufacturing program is highly automated. The part's mechanical dimensions are defined using computer-aided design (CAD) software, and then translated into manufacturing directives by CAM software. The resulting directives are transformed (with post processing software) into the specific commands necessary for a particular machine to produce the component, and are then loaded into the CNC machine.

Distributed control systems (DCS): Complex automated industrial systems used in discrete manufacturing and production processing require a DCS in order to operate. Organized as a hierarchy, a DCS starts by linking the various components – actuators, contactors, motors, sensors, switches, and valves – that do the work at the field level (e.g., shop or production floor) to programmable logic controllers (PLCs). PLCs are microcomputers with software that monitors and controls the operations of these devices, such as turning motors on or off and opening or closing valves. PLCs can also control the motion of industrial robots, but they require precise data timing to do so. In turn, PLCs are connected to an HMI, typically a display of some kind that enables human operators to monitor overall system performance and component behaviors and, if necessary, adjust parameter set points accordingly.

Enterprise resource planning (ERP): ERP is a software system that integrates information across an organization, incorporating supply chain data, inventory, sales/service orders, and customer information. This system facilitates the flow of information between all business functions and manages connections to outside customers.

Industrial Internet of Things (IIoT): IIoT is the use of Internet of Things technology in an industrial setting, usually in a business-to-business environment (B2B) and often focusing on areas of operations, such as manufacturing, supply chain, and logistics.

Industrial Internet of Things (IIoT) platforms: More specifically, in the IIoT, platforms are designed to deploy applications that monitor, manage, and control connected devices. IIoT platforms handle problems such as connecting and extracting data from a potentially vast number and variety of end points, which are sometimes in inconvenient locations with only spotty connectivity.

Industrial software stack: The industrial software stack is the complete set of software products and tools required to gather data from an industrial end point (a machine), extract some useful information from that data, and either inform or initiate a decision on how to operate the machine differently or support other decisions on how to operate the underlying business more effectively.

Industry 4.0: Industry 4.0 is a name given to the current trend of automation and data exchange in manufacturing technologies, and includes cyber-physical systems, the Internet of Things, cloud computing and cognitive computing. Industry 4.0 is commonly referred to as the fourth industrial revolution and fosters what has been called a "smart factory." Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real time both internally and across organizational services offered and used by participants of the value chain.

Internet of Things (IoT): IoT refers to the connectivity of devices to the Internet, which were formerly not connected, enabling the exchange of data, etc. IoT in this context refers to consumer-oriented applications (B2C) in contrast to industrial IIoT.

Manufacturing execution system (MES): MES manages manufacturing operations within a factory. The MES receives product definitions, electronic work instructions, and equipment settings from the PLM and order requirements from the ERP. The MES then reports production performance results and consumed materials to the ERP.

Manufacturing operations management (MOM) system: MOM is a methodology for viewing an end-to-end manufacturing process with a view to optimizing efficiency. The many types of MOM software include software for production management, performance analysis, quality and compliance, and human machine interface (HMI). Production management software provides real-time information about jobs and orders, labor and materials, machine status, and product shipments. Performance analysis software displays metrics at the machine, line, plant and enterprise level for situational or historical analysis. Quality and compliance software is used to promote compliance with standards and specifications for operational processes and procedures. HMI software is a form of MOM software that enables operators to manage industrial and process control machinery using a computer-based interface.

Platform: A platform is software and hardware which may include an operating environment, storage, computing power, security, development tools, and many other common functions. Platforms are designed to support multiple, smaller business solution applications.

Product lifecycle management (PLM): PLM is a software system that consolidates production information and facilitates the design, manufacturing, service, and disposal of resources involved in the production process.

Programmable logic controller (PLC): A PLC is a small, modular solid-state computer with customized instructions for performing a particular task. PLCs, which are used in industrial control systems (ICS) for a wide variety of industries, have largely replaced mechanical relays, drum sequencers, and CAM timers.

Supervisory control and data acquisition (SCADA): SCADA is a control system architecture that uses computers, networked data communications, and graphical user interfaces for high-level process supervisory management as well as other peripheral devices, such as programmable logic controllers and discrete PID controllers, to interface with the process plant or machinery. The operator interfaces that enable monitoring and issuing of process commands, such as controller set point changes, are handled by the SCADA computer system. However, the real-time control logic or controller calculations are performed by networked modules that connect to the field sensors and actuators.

Supply chain management software (SCMS): SCMS is the software tools or modules used in executing supply chain transactions, managing supplier relationships, and controlling associated business processes. While functionality in such systems can often be broad, it commonly includes customer requirement processing, purchase order processing, sales and distribution, inventory management, goods receipt and warehouse management, and supplier management/sourcing.

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