Customer centricity as key for the digital breakthrough

What end-customer industries expect from mechanical engineering companies on platforms and apps

In cooperation

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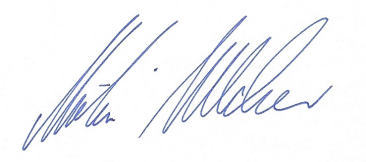
Welcome

There is no doubt about it: for some years now, digitization has been at the top of the agenda for mechanical and plant engineering companies as a topic with high future importance.

Despite a number of success stories, diverse efforts, and investments, the industry has yet to see a breakthrough on a broad front in the digital solutions business – especially in terms of sales and profit development. This raises some pivotal questions: How do the mechanical and plant engineering companies in Germany and other European countries view the topic of digital platforms and applications? Where does the industry currently stand and how do companies assess their customers' expectations in the digital sphere? Do digital platforms and applications offer a compelling opportunity for a separate business model in parallel to the sale of machinery and equipment? If so, would it make companies more resilient to exogenous shocks such as the 2008 financial crisis or the COVID-19 pandemic? Or do digital solutions first and foremost present an opportunity for companies to increase customer loyalty and differentiate themselves more clearly from the competition?

Regardless of the answers to these core questions, one thing is already evident: the digital transformation of the industrial sector requires mechanical engineering companies to thoroughly rethink their stance. The question is no longer who can build the machinery and equipment with the greatest possible technical finesse, but how to generate the greatest possible added value for customers, beyond simply offering a competitive machine. To this end, it is imperative that the development of digital solutions such as platforms and applications is thought through from the customer's point of view. More than that, it is necessary to break new ground in many respects during implementation, such as engaging in cooperation arrangements with competitors or setting up industry-specific consortia. Only in this way will it be possible to establish standards and at the same time use resources efficiently. The most important goal, however, is for mechanical and plant engineering to maintain its standing as one of Germany's most important industrial sectors going forward: both in international competition within the industry and in competition with new market entrants, such as start-ups and major tech players.

The Mechanical Engineering Industry Association (VDMA) wanted to examine these topics in greater depth for its member companies. Consequently, its third joint publication in collaboration with McKinsey & Company focuses on "digital platforms and applications" as a topic of critical importance for the future. The present study outlines insights critical for success, sets out differentiated recommendations for action with respect to specific end-customer industries, and shows how decision-makers in the mechanical and plant engineering sector can optimally design customer-specific strategies for digital solutions. In consideration of that, the study draws on findings compiled in a quantitative survey of mechanical engineering companies and qualitative interviews with their end customers.



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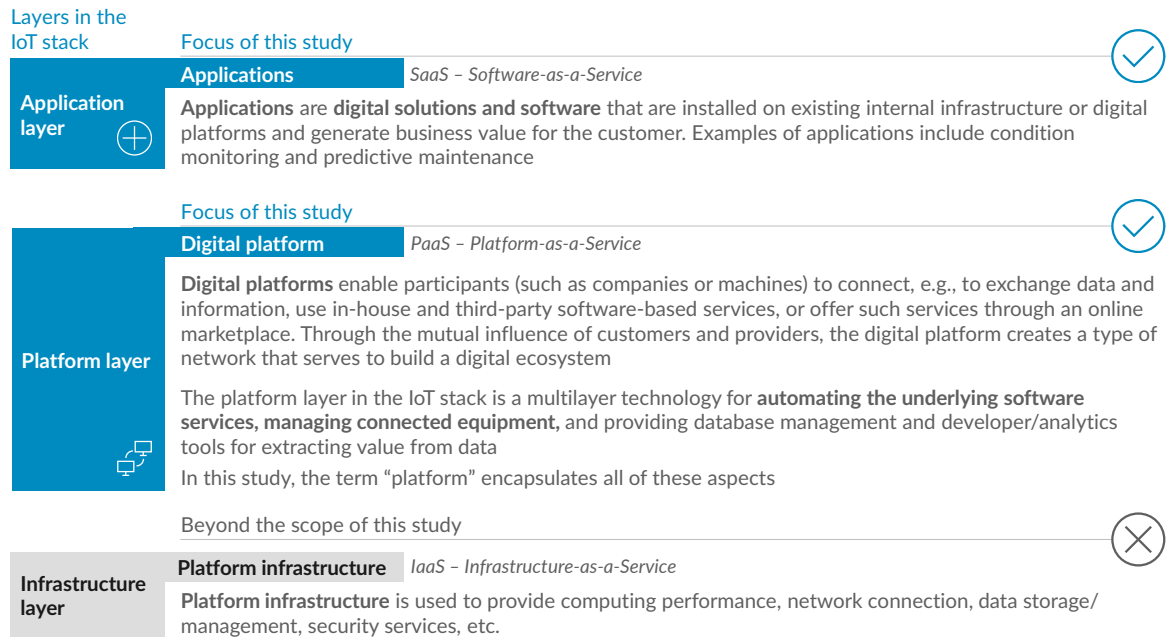
Introduction and key insights

Some of Germany's mechanical and plant engineering companies have long been intensively engaged in digitizing their product and service portfolios. These efforts have also been accompanied by initiatives to cultivate new business models. However, although considerable resources have already been invested in the development and expansion of digital infrastructure and services, and numerous innovative approaches and concepts have been tested in the market, the outcomes have nonetheless been mixed, at best. As a result, the industry finds itself in a situation that is uncertain and challenging, yet also full of promise.

Some companies have taken a proactive approach, developing digital platforms of their own, e.g., AXOOM and MindSphere. Others, such as ADAMOS, have forged alliances to develop a shared digital platform. In both cases, the underlying strategy has centered on setting up an innovative, industry-specific or cross-industry digital platform – with the aim of driving a fast-growing business in which the application layer provides the foundation for new business models (see Information box 1 for definitions). In many cases, however, these efforts have not yet turned out as successfully as hoped. The experience so far shows that mechanical engineering companies are still facing the challenge of successfully scaling digital platforms in the market; many fall short of expectations, which are often very high.

Information box 1

Study scope – digital platforms and applications



SOURCE: VDMA; McKinsey

Other mechanical engineering companies have established in-house units to speed up the development of digital solutions (e.g., Körber Digital, Voith Digital Ventures). At the same time, major tech players, among them Google, Amazon, and Microsoft, have in recent years invested vast resources in driving forward the building of industry platforms. As a result, they have been able to grow their stance in the manufacturing space of several end-customer industries, most notably in the automotive sector.

The COVID-19 crisis has had a two-fold impact on digitization in the mechanical and plant engineering sector: First, issues such as the health and safety of the workforce, employment protection measures, safeguarding supply chains, and the (expected) drop in order intake have pushed ongoing digitization efforts into the background. Second, digital innovations have become more relevant. Companies that had already invested in establishing and expanding their digital competencies prior to the pandemic have had a far easier time during the crisis with (remotely) serving their customers, keeping an eye on supply chains, deploying smart inventory management, and optimizing plant operations (especially in terms of go-live, maintenance, and service).[1]

In view of this dynamic context and the fact that digitization is seen as one of the most important areas for investment post-COVID-19,[2] this paper outlines the opportunities and challenges for digital platforms and applications for the mechanical and plant engineering industry. To this end, and drawing on our recent proprietary survey and interview findings and analyses (see Information box 2), the study explores three key questions with the aim of deriving specific recommendations for action:

- Where do mechanical engineering companies stand today in terms of digital platforms and applications? Which are the most promising strategies, and what pieces of the puzzle is the industry still missing for a genuine digital breakthrough?

- What do the customers of mechanical engineering companies demand in terms of the functionalities of digital platforms and the benefits of digital applications? And which market players are best able to satisfy these customer requirements?

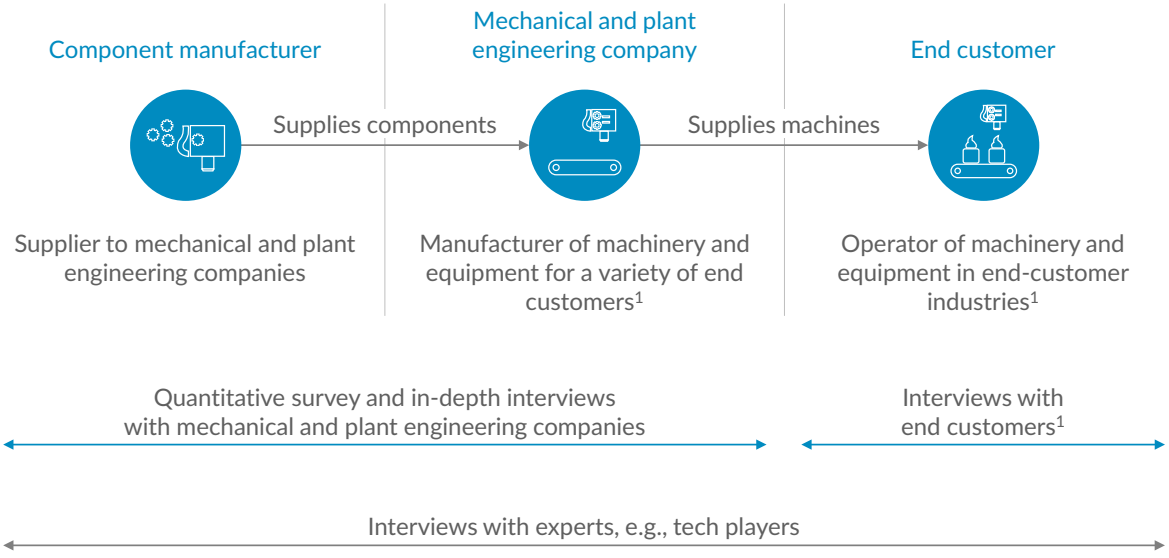
- What role can mechanical engineering companies convincingly and successfully play in the various end-customer industries, and with what strategy should they approach the subject of developing and driving forward digital platforms and applications?

1 Coronavirus: Industrial IoT in challenging times, McKinsey & Company 2020
2 https://ec.europa.eu/digital-single-market/en/europe-investing-digital-digital-europe-programme (downloaded: June 2020)

Information box 2

Based on a broad empirical survey of mechanical engineering companies ("internal" perspective) and on interviews with representatives of various end-customer industries ("outside-in" perspective), this study explores a range of vantage points on the needs of end customers (i.e., the companies that ultimately operate the machinery and equipment) with regard to digital platforms and applications (for detailed information on the survey and the interviews, see Exhibit 14 on page 59). It also provides detailed insights into the use of digital platforms and applications in the respective end-customer industries. Finally, the study derives and discusses concrete action recommendations for mechanical and plant engineering companies concerning improving their customer-centricity in five specific end-customer industries. Potential analogies with other end-customer industries are also illustrated. As such, this study provides a foundation for the mechanical and plant engineering industry to develop customer-centric strategies for its digital platforms and applications. As the study focuses on Western markets, the recommendations for action should be considered within this geographic context.

Exploring the perspectives of mechanical and plant engineering companies and end customers through a survey and interviews



1. E.g., automotive, construction
SOURCE: VDMA; McKinsey

In the following sections, we provide a more detailed discussion of these overarching key insights:

- The volume of the Western European market for IIoT platforms, applications, and services was approximately EUR 40 billion in 2019.[3] This market is expected to grow by an average of 10% per year through 2024. Applications account for the larger share by far, with approximately 40% (roughly EUR 16 billion) compared to digital platforms with approximately 8% (some EUR 3 billion). The remainder is attributable to other IIoT services and areas, such as IT security, consulting services, modules, and sensors. Mechanical engineering companies currently hold a combined market share of approximately 15% of the total Western European IIoT market. For mechanical engineering companies, the aim must be to identify market positions where they can occupy key control points. This would allow them to tap the market's favorable growth dynamics with value propositions specifically geared to customer needs.

- The majority of mechanical engineering companies have so far looked at technology as a starting point for their digital solutions. To be successful, however, digital solutions must be built around the value they offer to the actual customers that are operating the machines. Successful digital solutions call for senior management to clearly acknowledge the strategic relevance of digital solutions, as well as to prioritize business models and the ability to monetize them.

- Mechanical engineering companies should very carefully consider whether to invest in developing their own separate platform, since the market is rather small compared to applications and such platform initiatives are premised on the accumulation of new know-how. Given the "winner takes all" nature of the platform business – i.e., the dominant players are securing the majority of the market – such efforts are not advisable for the majority of mechanical engineering companies.

- In some sectors (e.g., automotive), mechanical engineering companies are already too late to the party. However, in industries with many smaller end customers, where industry standards are yet to be established, they still have opportunities. For example, they can develop an industry-specific platform, consolidate, or open up existing platforms to create an industry solution for their customers at scale. That said, to capture this opportunity they would also need to be willing to play a first-mover role, perhaps in a partnership or in a consortium with other companies, possibly even competitors.

- Most mechanical engineering companies are convinced that – compared with companies from other industries (e.g., tech players, software companies) – they are best positioned to satisfy the needs of their customers in terms of digital platforms. And yet each end-customer industry has its own very distinct makeup. Above all in the construction industry, in metal production and processing, and in the food and beverage / pharmaceutical industry, mechanical and plant engineering companies see themselves in a good position in this regard. Some end customers would only agree to this view to a certain extent, however. In particular, end customers with a high level of digital maturity have partially already built up their own platforms, usually in partnership with tech players or major software firms.

3 McKinsey analyses based on IDC data (May 2020); see Exhibit 1 for further details

- Digital apps should be seen as a promising segment for mechanical engineering companies in all end-customer industries. Moreover, they are becoming an increasingly relevant differentiating factor in global competition. With their understanding of production processes and technology know-how, mechanical engineering companies are considered well positioned to satisfy customer needs. In this context, they should focus on applications that offer clear, measurable value, such as optimizing equipment performance and efficiency (potentially even across process steps). Machine operators are also interested in solutions that are not bound to a specific manufacturer, as well as in the user-friendliness of applications. Assuming the role of first mover while conserving resources calls for risk-sharing structures and partnerships between mechanical engineering companies, thus enabling the development of scalable and manufacturer-independent solutions.

- Due to their vastly different needs, it is essential to clearly understand each respective end-customer industry. For this reason, companies need to underscore the value add of applications to end customers when developing their own business model, and then realize this value add using a three-step process: (i) define the market segment, (ii) identify the value add for end customers, and (iii) build a dedicated business model.

Interviews with end customers and experts revealed specific priority recommendations for mechanical engineering companies in five end-customer industries:

- **Automotive**
  No new platforms should be established since automotive OEMs and suppliers often have their own IoT platforms or are in the process of designing them; the aim here for mechanical engineering companies needs to be to maximize compatibility with existing ecosystems. The focus should be on applications that improve efficiency and quality by enhancing the integration of heterogeneous machinery and equipment (manufacturer independence). The extended focus should be on optimizing service and installation costs through remote installation and go-live (possibly supported by augmented reality).

- **Mechanical engineering (as an end-customer industry)**
  There is no reason to focus on platforms in standard mechanical engineering since tech players are likely to offer solutions in this area, and corresponding standards will establish themselves (similarly to the case in the automotive industry). When it comes to special-purpose mechanical engineering, mechanical engineering companies have an opportunity to achieve successful scaling through open, cross-segment platforms that cover the relevant applications and process chains. The focus of the application layer should be on improving resource efficiency and plant flexibility, for which the user-friendliness of applications is decisive.

- **Food and beverage / pharmaceuticals**
  Due to existing standards and the heavily fragmented end-customer landscape, mechanical engineering companies are in a good starting position to establish an industry platform. Efforts should center on entire production lines or production processes, and on open standards enabling the integration of heterogeneous machinery and equipment as well as existing systems. Of particularly high relevance are applications that optimize the use of resources. Additional critical criteria for applications are production line flexibility and shortened changeover times – value propositions that end customers are willing to pay for.

- **Construction**
  Customers want platform standards to be established in the construction industry, e.g., by opening up existing platforms and improving compatibility with current systems. In the construction materials industry, offerings that include applications to improve efficiency and the use of resources are of high relevance, as well as those covering service and replacement part availability. In the case of mobile construction machinery, the companies buying machines are often not the companies that will ultimately operate them. Not surprisingly, the metrics that buyers and operators need optimized through applications, differ accordingly. The user-friendliness of applications plays an important role throughout the construction industry, as do action recommendations derived from compiled data.

- **Metal manufacturing and processing**
  In this industry, in many cases it is not so much a matter of establishing new platforms. Some already exist, especially in metal manufacturing. Instead, the focus should be on achieving maximum compatibility to enable connectivity throughout the end-to-end production process. Value-added services need to aim to improve quality, maintenance and repair, and logistics, e.g., by linking (mechanical engineering companies') equipment know-how and (end customers') process know-how.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Energy
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Performance

1. Digital solutions: Where the mechanical and plant engineering industry stands today

For European mechanical and plant engineering companies, digital solutions are increasingly becoming a differentiating factor as well as an instrument for securing customer loyalty. Digital solutions are also gaining importance as an additional revenue stream, albeit at a subordinate level.

The Western European market[4] for the Industrial Internet of Things (IIoT) solutions, excluding infrastructure, reached a volume of almost EUR 40 billion in 2019, of which approximately 40% was attributable to applications (Exhibit 1).

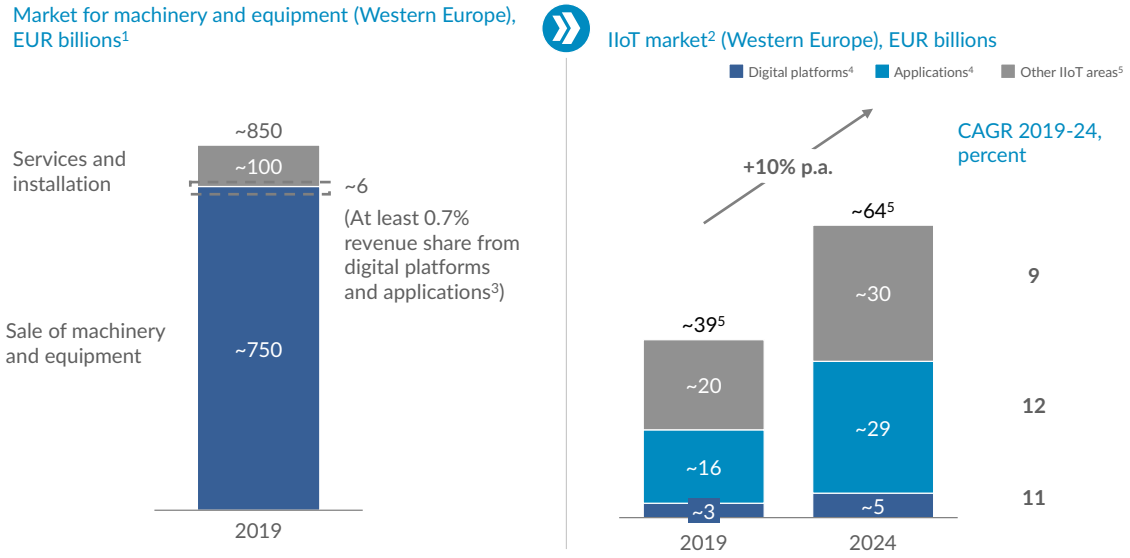
Double-digit annual growth rates are forecasted for the IIoT market. In view of the growing relevance and highly dynamic context, machine manufacturers should develop a plan for their companies and determine (i) which key control points they should occupy in this market in order to remain competitive in the long term, and (ii) which market segments offer them attractive revenue and profit opportunities. Further growth is clearly premised on significant value add that is either self-evident or at least measurable for customers. This is easier to achieve with the application layer than with digital platforms, which are often regarded as mere enablers. It is also important in this context to recognize that other players (possibly customers themselves or tech players) are in a better position to serve some segments of the IIoT market, such as platform solutions for certain end-customer industries.

It is clear that the IIoT market holds (growth) potential – especially in the application layer. In order to tap the market potential, mechanical engineering companies need a coherent approach, which entails developing focused strategies and using their resources efficiently. Above all, they have to be mindful of the benefit or added value for the end customer. Assuming that mechanical engineering companies currently generate at least 0.7% of their total sales with digital business (as indicated by our survey results), the extrapolated sales would come to EUR 6 billion. That would be equivalent to a share of the overall IIoT market in Western Europe of 15%. This relatively small market share and the forecasted double-digit annual growth of the IIoT market suggest that mechanical engineering companies have significant growth opportunities.

4 Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom

Exhibit 1

The industrial IoT market is a potential future growth driver for mechanical and plant engineering companies



1. Partly estimated
2. IIoT includes: discrete manufacturing, process industry, raw materials industry, and construction industry; pro rata derivation for Western Europe
3. Percentage shares based on VDMA-McKinsey survey
4. Separate calculation of segment sizes produced by aggregating revenue from IDC detailed categories: digital platforms (vertical industry, other software, horizontal), applications (analytics/applications, ongoing service/content as a service), other IIoT areas (connectivity, IT security, project work, modules and sensors, etc.)
5. Market volume does not include infrastructure segment revenue (i.e., revenue with servers, storage, hardware)

SOURCE: VDMA; McKinsey analysis based on IDC data (May 2020), VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020);

1.1 Current strategy and future prospects for mechanical engineering companies

In our survey of mechanical and plant engineering companies, 60% of companies felt they knew the needs of their end customers very well or well. In fact, about half of the companies surveyed already have experience with developing software-based services/applications, although they have less experience with the development of digital platforms. Looking ahead, mechanical engineering companies should consciously anchor their respective strengths relative to other players (start-ups associated with the industry or from other industries, tech players, or their own end customers) in their digital strategies. In this way, they can, e.g., create lasting added value for end customers based on the comprehensive equipment and process know-how.

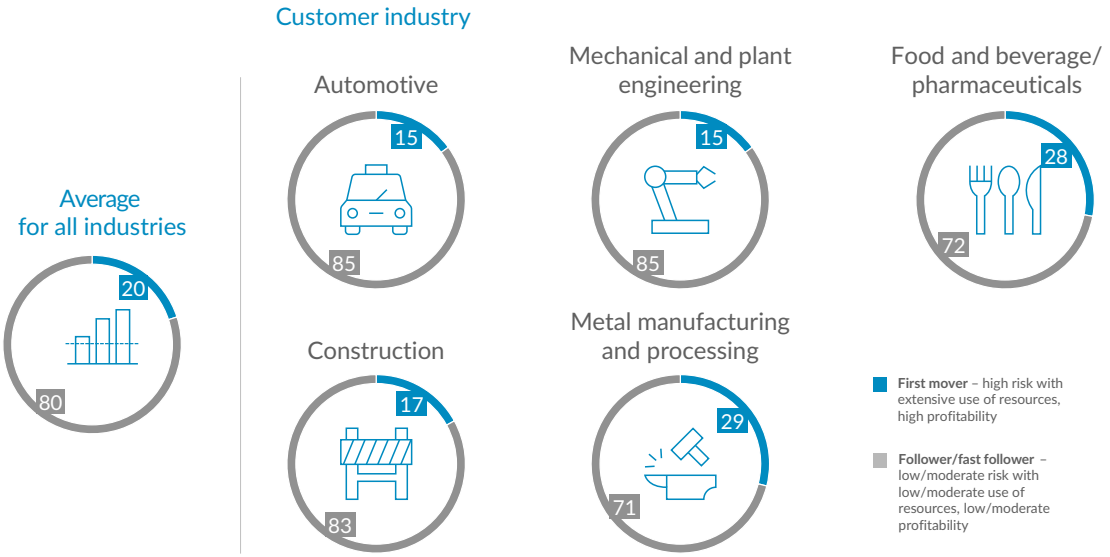
Mechanical engineering companies primarily adopt a fast-follower strategy

As the survey results show, only 20% of companies pursue a first-mover strategy when it comes to participating in digital platforms. Primarily in those digital topics with which the companies are already familiar and have gained practical experience, they assess their prospects for success as good (for details, please see Exhibits 15 to 17 in the Appendix).

Exhibit 2

From the perspective of mechanical engineering companies, participating in digital platforms using a follower strategy promises the greatest success

Share of responses, percent[1]



1. All industries (n = 202), automotive (n = 41), mechanical and plant engineering (n = 48), food and beverage and pharmaceuticals (n = 18), construction (n = 18), metal manufacturing and processing (n = 17)

SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

There is a particularly low number of first movers among component and plant manufacturers. This picture is largely homogeneous for companies exposed to the five different end-customer industries[5] analyzed in depth (Exhibit 2). The mechanical engineering companies expect to benefit from digitization with limited (investment) risk and, ideally, to learn from the mistakes of first movers. This may be a rational approach from the perspective of individual players seeking to mitigate risk, but it must be viewed with concern with regard to the overall European mechanical and plant engineering industry: On the one hand, it leads to a scenario in which first movers from within the industry – whom others might subsequently follow – lack critical mass. On the other hand, new players are pushing into the market, both start-ups within or outside the industry or from other industries as well as major tech players, who are increasingly present in digital platforms, especially in the automotive industry (e.g., BMW Open Manufacturing Platform (Azure) or Volkswagen Industrial Cloud (AWS)).[6] This heightens the risk that the European mechanical and plant engineering industry might slip behind the digital transformation curve unless it boldly rethinks its stance.

5 In the survey, each respondent was only permitted to choose one end customer industry. The five most frequently named end-customer industries in the survey were selected for the differentiated analysis. With more than 15 responses, they enable industry-specific, in-depth evaluations. Furthermore, they reflect the most important end-customer industries served by the German mechanical and plant engineering sector.

6 BMW Group und Microsoft führen Open Manufacturing Platform ein, 2019, https://news/microsoft.com/de-de/bmw-group-microsoft-open-manufacturing-platform/ (downloaded: May 2020) Volkswagen und Amazon Web Services entwickeln Industrial Cloud, 2019, https://www.volkswagenag.com/de/news/2019/03/volkswagen-and-amazon-web-services-to-develop-industrial-cloud.html (downloaded: May 2020)

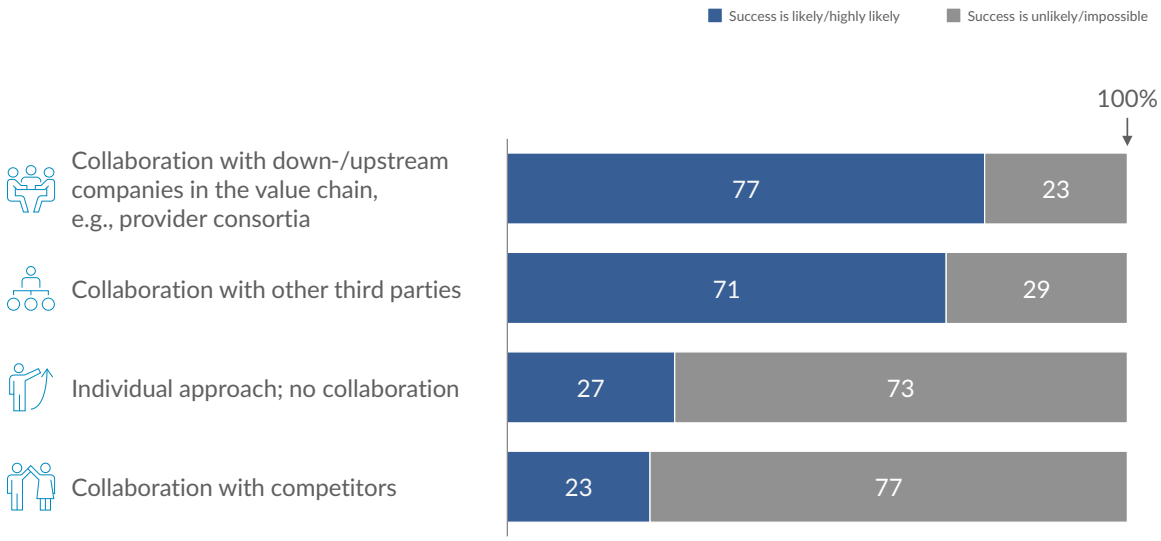
Cooperation as a key factor for successful digitization in mechanical and plant engineering

As the results of the survey, among other indicators, show, mechanical engineering companies do not view the "lone wolf" strategy as particularly promising: Only 27% of the companies surveyed believe that an approach only on their own has a high chance of being successful. In the opinion of 77% of the companies surveyed, collaboration – especially with companies along the value chain or the production process of the end customer – offers great prospects of success when setting up digital platforms (Exhibit 3).

Exhibit 3

Mechanical engineering companies have openly acknowledged the need for partnerships but often have concerns about collaborating with competitors

Share of responses, percent (n = 202)



SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

The prospects of success of collaboration with competitors are still viewed with skepticism. However, mechanical engineering companies should also consider the end customer's perspective: In many end-customer industries, customers are not interested in closed, manufacturer-specific solutions for fear of a potential lock-in effect. The agricultural industry has already demonstrated that, sooner or later, mechanical engineering companies that want to create added value for customers and use resources wisely have little choice but to open up their digital solutions to competitors as well.

For example, DataConnect is commonly used in the agricultural industry today. This cloud-to-cloud solution was developed by several large agricultural machinery manufacturers (John Deere, CLAAS, and CNH Industrial with the brands Case IH, New Holland, and Steyr) together with 365FarmNet. It enables users to manage and monitor the entire fleet of an agricultural enterprise – e.g., regarding machine position, tank level, and machine speed – through using only one system or portal. Functionalities based on the transmission of agronomic data are already in planning.[7]

Similarly to the successful example from the agricultural industry, mechanical engineering companies should, if necessary, also promote international collaboration in order to be able to act jointly as first movers by sharing risks and to secure their strong position with end customers against other market participants.

7 https://www.claas.de/aktuell/meldungen-veranstaltungen/meldungen/cnh-industrial-tritt-dataconnect-bei/2106268 (downloaded: May 2020)

1.2 Challenges and hurdles for mechanical engineering companies

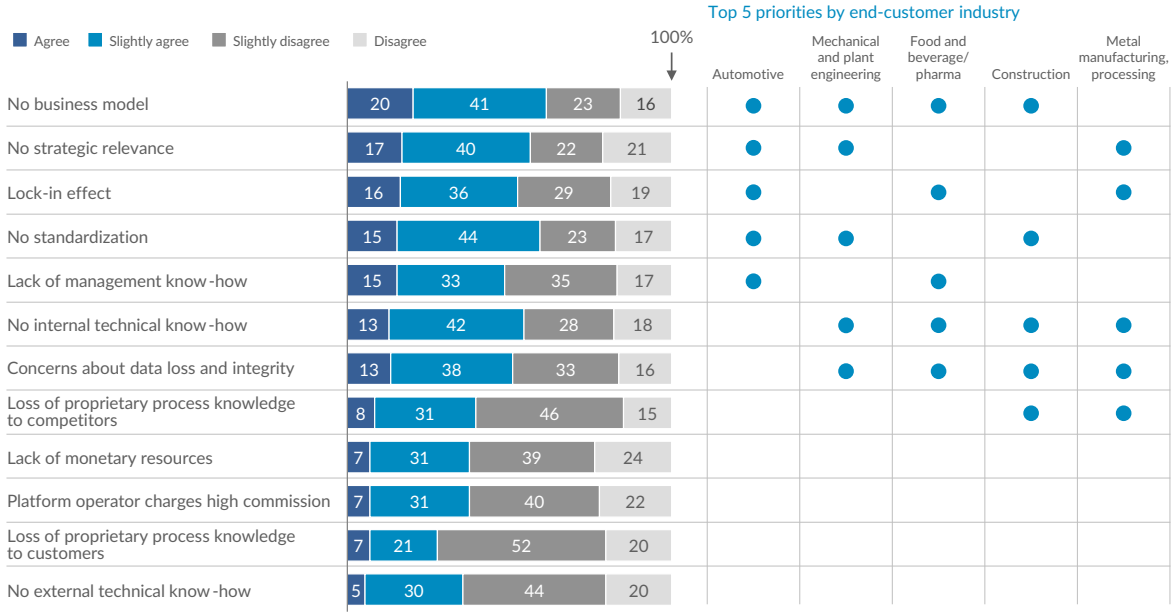
What is preventing today's mechanical engineering companies from participating in digital platforms and the applications business, and from further transforming the market through digitization? Our survey results proved surprising in this respect: The biggest hurdles are considered to be a lack of business models, insufficient strategic relevance, and an absence of standards. In contrast, companies are less concerned about the risk of losing know-how and the lack of monetary resources.

That said, a closer examination and analysis of the individual industries does reveal some intriguing differences nevertheless. For mechanical engineering companies in certain end-customer industries (e.g., the food and beverage industry), a lack of management and internal technical know-how and concerns about data loss and integrity pose major challenges, while a lack of standards or strategic relevance are of lesser concern (Exhibit 4).

Exhibit 4

Major hurdles for increasing engagement in digital platforms and applications are the lack of business models and strategic relevance

Share of responses, percent[1]



1. All industries (n = 202), automotive (n = 41), mechanical and plant engineering (n = 48), food and beverage and pharmaceuticals (n = 18), construction (n = 18), metal manufacturing and processing (n = 17)

NOTE: Numbers may not add up due to rounding

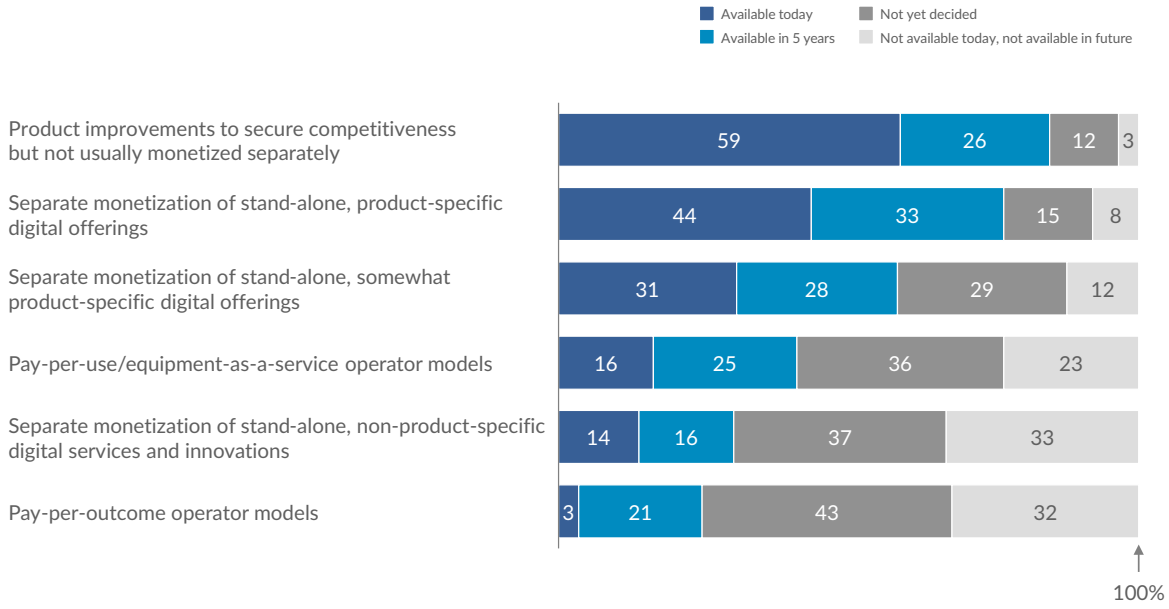
SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Today's business models around digital platforms and applications present a fragmented picture: The majority of companies use digital offerings to secure their competitiveness, usually without monetizing these separately. Almost half of the surveyed companies already offer digital solutions that are closely related to their product portfolio and are also sold separately. However, the sale of non-product-related digital solutions and offerings of business models such as pay-per-use (conceivable in the elevator business, for example) are neither of major relevance for mechanical engineering companies, nor are there clear plans to adopt them by the majority of the companies (Exhibit 5). This may in part reflect the fact that many mechanical engineering companies still consider digital platforms and applications to be of low strategic relevance.

Exhibit 5

Business models based on digital platforms and applications already available today; positive trend looking ahead

Share of responses, percent (n = 202)



NOTE: Numbers may not add up due to rounding

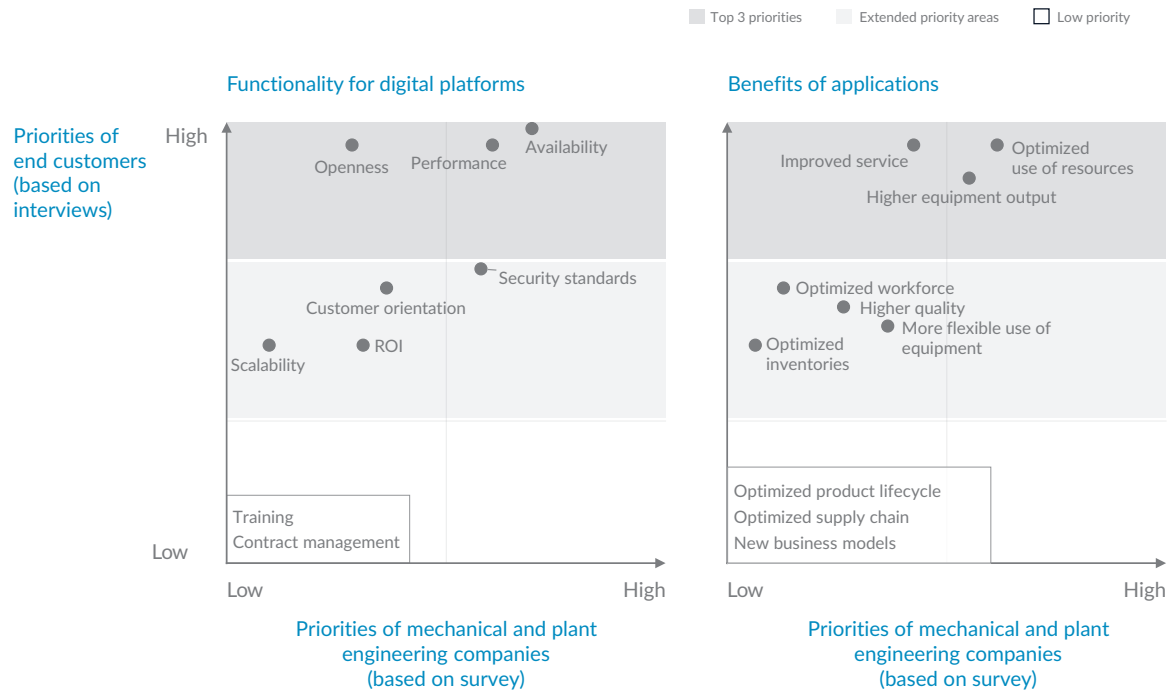
SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

2. Digital applications: What matters for customers of mechanical and plant engineering companies

What do end customers prioritize when it comes to digital platforms and applications? And: how well do mechanical engineering companies know the priorities of their end customers? Mechanical and plant engineering companies understand their end customers' priorities in many respects. Nevertheless, our interviews with their end customers suggest that there are needs mechanical engineering companies should address more diligently if they want to be successful in the digital business going forward (Exhibit 6).

Exhibit 6

Interviews with end customers highlight potential new priority areas for mechanical engineering companies



SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020); end-customer interviews

In terms of platform functionality, mechanical engineering companies currently believe that criteria such as availability (e.g., of real-time data) and performance are highly important to their customers. This is confirmed by their end customers' view.

Another topic that enjoys clear priority for both sides is security standards. Opinions differ, however, above all with respect to the criterion of platform "openness and compatibility" – end customers attach greater importance to open access and a high level of compatibility, especially the ability to integrate platforms into existing digital ecosystems. Criteria such as customer orientation, scalability, and direct return on investment have a moderate priority for end customers or are taken for granted to a certain extent, an assessment that is not yet shared equally by mechanical engineering companies across the board.

Both groups are in agreement regarding the benefits of applications where performance-oriented benefit aspects such as machine output and use of resources are concerned. End customers clearly place the focus on applications whose added value is documented by specific use case examples and that the manufacturer can to some extent also guarantee. Yet most end-customer industries (e.g., automotive) also give high priority to services/aftersales/maintenance topics, often in connection with "simpler" applications that, among other things, increase the transparency of spare part deliveries or services (e.g., construction).

2.1 Mechanical engineering companies' perspective on end-customer needs in detail

Requirements for digital platforms

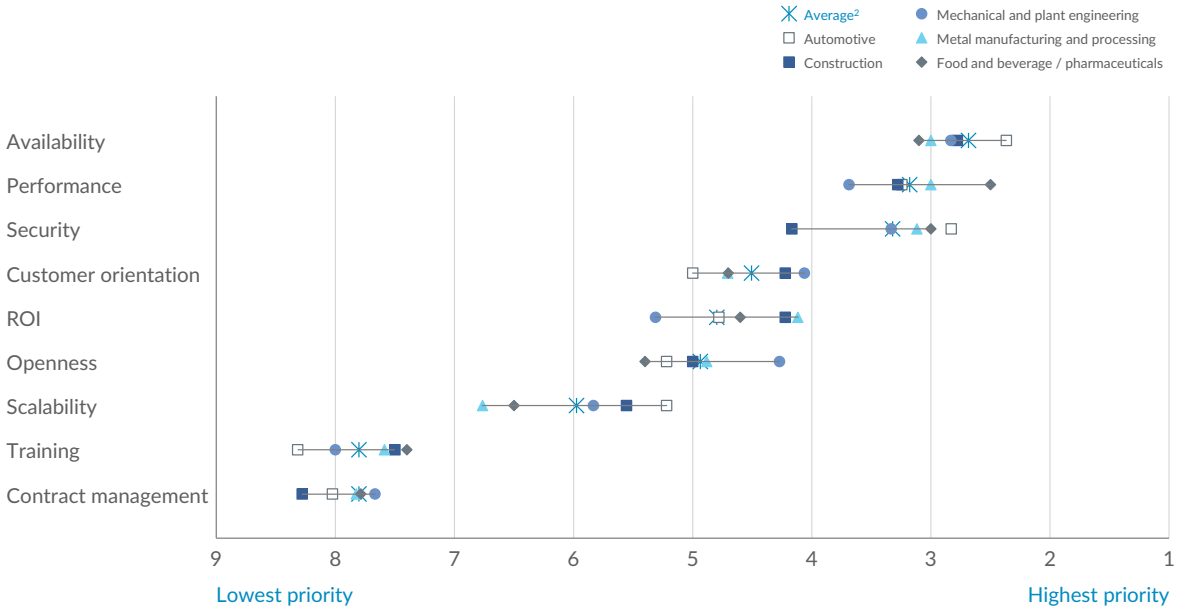
Mechanical engineering companies consider availability, performance, and security to be by far the most relevant platform functionalities for end customers (Exhibit 7) and do not distinguish much between the five end-customer industries analyzed in more detail in this study.

Exhibit 7

Mechanical and plant engineering companies' perspective

Availability, performance, and security aspects are believed to be the key functionalities of digital platforms for end customers

Average priority of platform functionality, by end-customer industry[1]



1. Automotive (n = 41), mechanical and plant engineering (n = 48), food and beverage and pharmaceuticals (n = 18), construction (n = 18), metal manufacturing and processing (n = 17)
2. Overall average of all industries (n = 202)

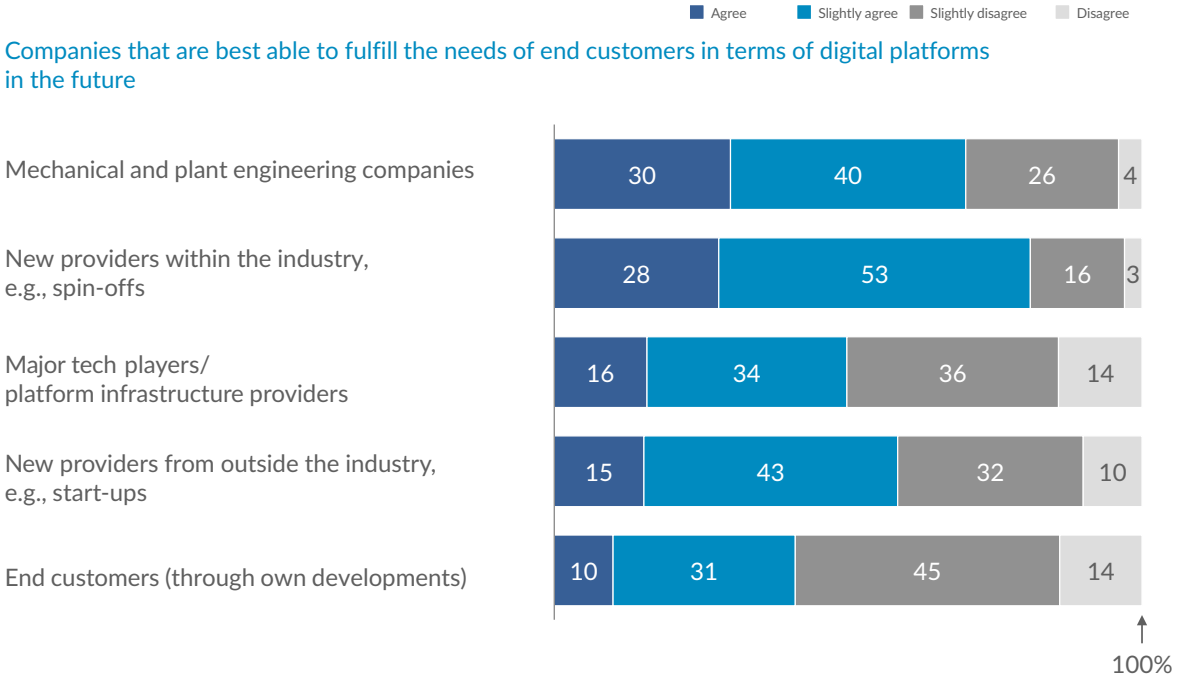
SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Exhibit 8

Mechanical and plant engineering companies' perspective

Mechanical and plant engineering companies believe they are best placed to meet end customers' needs in terms of digital platforms

Share of responses, percent (n = 202)



SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

The answers differ greatly, however, between end-customer industries (Exhibit 9). In the automotive and machinery end-customer industries, only around 20% of respondents believe that mechanical engineering companies are currently in the best position to meet end customers' needs with respect to platforms. By contrast, mechanical engineering companies serving end customers in the construction, food and beverage, or metal processing industries consider their own position to be very promising, with around 50% of respondents fully agreeing with the view that mechanical engineering companies are able to fulfill the needs of platform customers best.

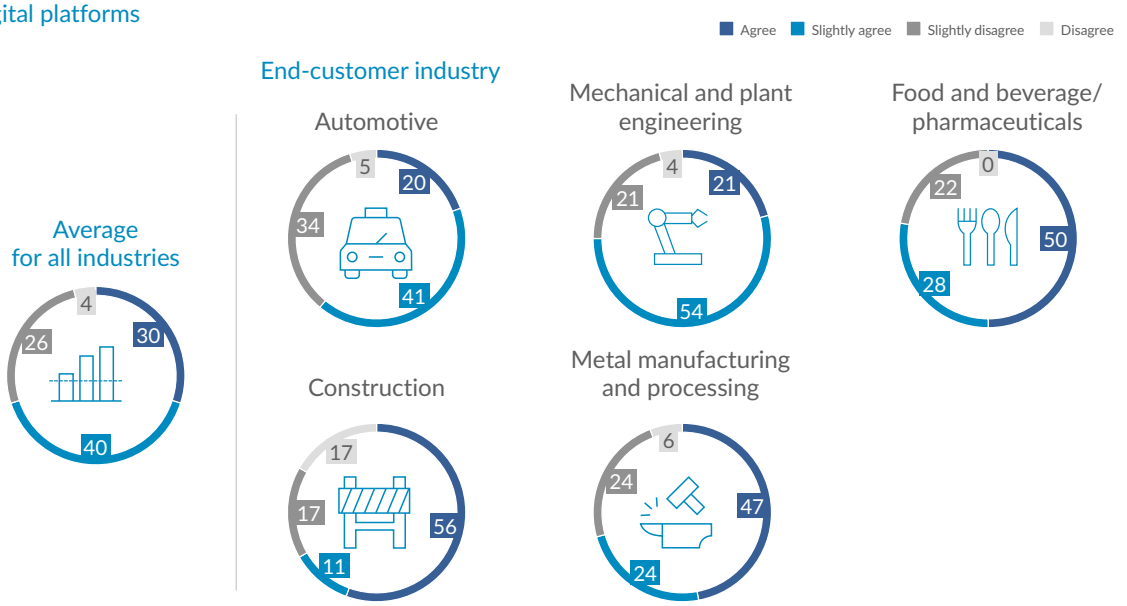
Exhibit 9

Mechanical and plant engineering companies' perspective

Mechanical engineering companies' self-assessment of their ability to meet end-customer requirements varies depending on the end-customer industry

Share of responses, percent[1]

Mechanical and plant engineering companies are best placed to fulfill end-customer requirements as regards to digital platforms



1. All industries (n = 202), automotive (n = 41), mechanical and plant engineering (n = 48), food and beverage and pharmaceuticals (n = 18), construction (n = 18), metal manufacturing and processing (n = 17)

NOTE: Numbers may not add up due to rounding

SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Requirements for applications

Mechanical engineering companies consider software-based services or applications that offer the following benefits to be most important to their end customers (Exhibit 10):

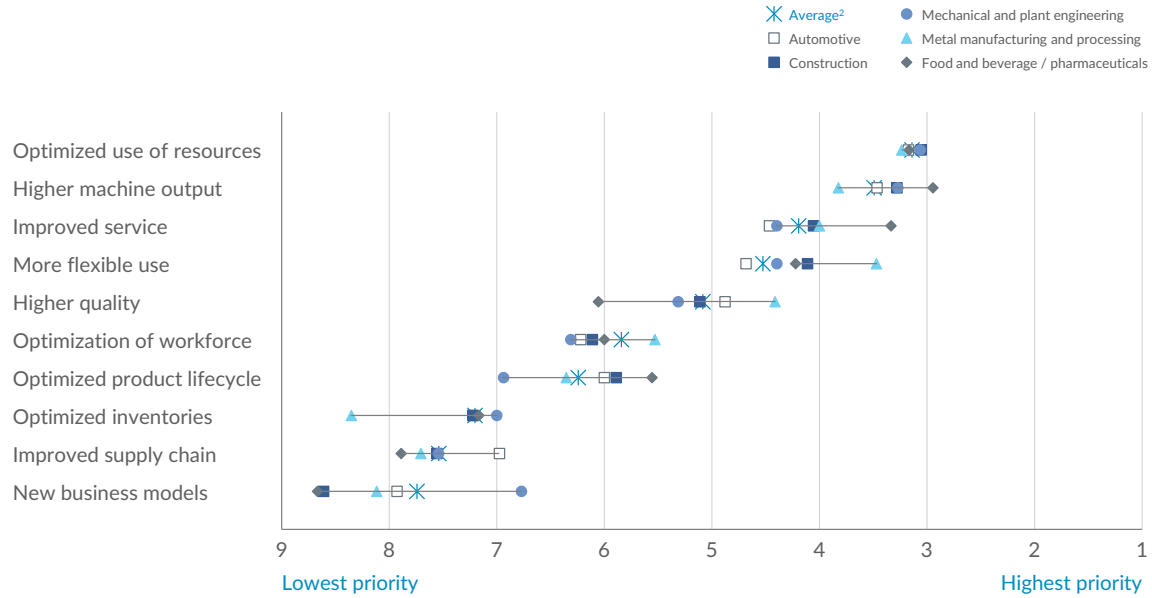
- **Optimized use of resources,** e.g., by reducing raw material and improving energy efficiency
- **Higher output or improved overall equipment effectiveness (OEE),** e.g., via a more efficient and connected process chain
- **Improved customer support/aftersales/maintenance,** especially through optimized maintenance (condition monitoring, predictive maintenance), remote support, and remote installation
- **More flexible use of machines,** e.g., via increased equipment flexibility or, better fleet management.

Exhibit 10

Mechanical and plant engineering companies' perspective

For digital applications, improvements in equipment efficiency and effectiveness are considered most important aspects for end customers

Average priority of the benefits of digital applications, by end-customer industry[1]



1. Automotive (n = 41), mechanical and plant engineering (n = 48), food and beverage and pharmaceuticals (n = 18), construction (n = 18), metal manufacturing and processing (n = 17)
2. Overall average of all industries (n = 202)

SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

2.2 What end customers require of digital platforms and applications

End-customer perspective on platform functionalities

An industry standard for platforms or a dominant market player was not yet evident in any of the five end-customer industries that we took a closer look at. However, some trends are emerging: Large tech players such as Google, Amazon, or Microsoft have invested vast resources to push ahead with building up industry platforms and they have been able to grow their stance in some manufacturing end-customer industries, especially in automotive.[8] Even in the automotive sector, however, there is to date no industry standard for digital platforms. Suppliers either use add-ons to existing systems, specifically buy suitable platforms on the market, or develop their own solutions. Overall, however, end customers – particularly automotive suppliers – expect the establishment of platform standards in the industry in the medium term. Mechanical engineering companies therefore do not play a major role as platform providers and are unlikely to do so in the future either.

This expectation of platform standards in the medium term is echoed by other industries such as construction, machinery, and food and beverage / pharmaceuticals. In our interviews, end customers repeatedly expressed an interest in open, easy-to-integrate platforms and the introduction of clear industry standards (e.g., Open Platform Communications Unified Architecture (OPC UA)).

Availability of real-time data, performance, and security aspects were frequently mentioned by end customers as the most important platform functionalities. In addition, interviewees from all industries stressed customer orientation and user-friendliness as a criterion that must be fulfilled for end customers

“We need real-time data so we can react quickly. Data a day old are of no use to anyone.”

(A building materials company)

“One of the tech players is expected to come up with an overarching solution; isolated solutions are unwanted.”

(An automotive OEM)

End-customer perspective on applications

Machinery manufacturers and the companies that ultimately operate those machines mostly share the same views about the benefits of applications. Both groups attach the greatest importance to improving machine efficiency and cost efficiency. End customers particularly emphasized in the interviews the importance of manufacturer independence, but also the user-friendliness of the application. Above all, they want to be able to clearly quantify the improvements attributable to the application layer. At the same time, they often expect mechanical engineering companies to commit to actually implementing

8 See footnote 6 on page 19

these improvements in live operations. Quite clearly they would welcome corresponding solutions and payment options for such performance-related elements (e.g., pay for applications that optimize resources if savings are in fact obtained in actual machine operations).

Aside from increasing efficiency, end customers see a broad scope for software-based services that add value, especially in terms of customer service. For the most part, it is remote monitoring, global remote customer support/service, or remote installation they have in mind (including interaction with augmented reality applications). In these areas, end customers consider mechanical engineering companies to be clearly predestined to dominate other players. End customers are also more willing to accept manufacturer-dependent solutions in these areas. In general, end customers hope to leverage applications to move away from the current paradigm based on a reactive management of maintenance measures, which is often associated with high efficiency losses and maintenance costs, toward a proactive management of their machines and equipment.

"In our pure commodities business, we want to be as efficient as possible."

(A building materials company)

In summary and across all industries, it can be stated that end customers clearly focus on customer utility, both for platforms and applications. From the end customer's point of view, platforms primarily function as "enablers" for (analytics) applications, value-added services, etc. and do not in themselves offer any measurable added value in operations.

In the case of applications, customers often make decisions based on clear ROI criteria. The services offered must have a significantly positive impact on operational and financial metrics or factors of success (e.g., OEE, maintenance and repair costs), or they must solve a major problem for the end customer (e.g., create transparency on spare parts deliveries); otherwise, there is very little willingness to invest. Here, first movers are seen as having an advantage – many players consider an application monetizable as long as it constitutes a differentiating feature.

3. Industry-specific strategies: How the mechanical and plant engineering sector can create tailored solutions

3.1 Core elements for the strategy development of mechanical engineering companies in the digital business

Which focus should a mechanical engineering company set for its digital business? Should it develop a platform or focus on a range of software-based applications? In the following, we set out the strategic framework for answering these questions.

Cooperation as a key factor for successful digitization in mechanical and plant engineering

Platforms

When designing a strategy for the digital business, mechanical engineering companies must first determine whether it makes sense to operate their own platform in the end-customer industries they serve. An investment in the development of a platform should only be considered if there is still a realistic possibility within the respective end-customer industry of establishing a specific industry standard, possibly as part of a consortium with others to enable scaling and a broad penetration in the target industry. Monetization might take the form of volume-based models (users pay according to traffic generated on the platform) or outcome-based models (users pay according to the level of detail of the analyses retrieved from the platform). Often, however, platforms are more difficult to monetize than applications – partly because the benefits of applications are easier to quantify. Therefore, the majority of mechanical engineering companies should place their strategic focus on maximizing compatibility with existing platforms.

Applications

In order to successfully establish offers related to the application layer in the long term, mechanical engineering companies can initially adopt a three-stage strategic approach:

1. **Market segmentation and specific solutions per end-customer application.** The first step is to segment the market according to application-specific characteristics, e.g., size, IT affinity, and digital maturity of customers and process know-how. One of the things that becomes clear from the segmentation is that it is generally not very promising for mechanical engineering companies that serve several end-customer industries, to rely on rolling out a technology in a “lighthouse industry” (traditionally often the

automotive industry) in order to subsequently generate synergies with other end-customer industries. This is because, while individual mechanical engineering companies may not be best positioned to address the automotive market, they are well placed to be successful with applications in other end-customer industries. In addition, a manufacturer of hydraulic components, for example, will need different solutions to meet the specific needs of the different end-customer industries it serves.

2. **Demonstrating the added value created for the end customer.** Segmentation should be followed by a detailed consideration and definition of the added value from the customer's perspective. Indeed, the companies operating the machines are willing to invest in digitization if it brings clear, immediate, and quantifiable benefits. Accordingly, the market has so far been particularly interested in applications that improve equipment availability (e.g., predictive maintenance), increase product quality or reduce rejects (e.g., fault detection), or reduce resource consumption (e.g., energy consumption). In all of these cases, the user-friendliness of applications is of paramount importance to customers, since high training costs or errors in operation can quickly erode, and indeed exceed, any added value.

3. **Defining the business model and unique selling proposition for the mechanical engineering company.** The final step is to determine the best possible business model for the mechanical engineering company, to clearly define its unique selling proposition vis-à-vis competitors, and to comprehensively assess the technological advantage as well as risks of the new business model. Is the application layer to be monetized at fixed prices – either in return for a one-time payment or under alternative payment models such as subscription models and marketplace fees – and tailored to end customers' needs and willingness to pay (such as the software-related services offered by Tapio or Homag, some of which are available on a monthly or annual subscription basis)? Is the application an integral part of a combined offer (e.g., machine including application)? Or does the provider have to take a risk and base the monetization of the application on the actual value add achieved for the end customer? A related topic in the latter scenario is the evaluation of new performance-based compensation models attached to the achievement of predefined indicators (e.g., the aforementioned reduction in energy consumption or the shortening of average delivery times for spare parts). End customers expect providers to actually generate the measurable added value promised, and that providers under performance-based compensation models participate in the outcomes achieved and share the associated risks with the customers. In addition, the end customer's preferences with regard to capital expenditure and operating expenses may have to be taken into account.

Strategic recommendations across industries

The following cross-industry recommendations for a sustainable positioning of digital offerings by mechanical engineering companies were distilled from the interviews conducted and the survey amongst mechanical engineering companies:

Platforms. If a mechanical engineering company opts to set up a platform, a first-mover strategy is particularly important, preferably in cooperation with other mechanical engineering companies, since rapid scaling is often instrumental to the success of the "winner takes all" logic, which ensures a large share of end customers in the industry adopting the platform. The best way of promoting a platform's development depends on market conditions and the competitive situation prevailing in the respective end-customer industry:

- In end-customer industries with large end customers, in which tech players are currently establishing future platform standards (e.g., in the automotive industry; other industries will follow), it is already too late. Here, mechanical engineering companies would be well advised not to invest resources in the development of a new platform but instead concentrate on making progress with standards and compatibility.

- In end-customer industries with a fragmented market characterized by smaller end customers, where no platform standard exists yet, mechanical engineering companies should consider pursuing a bold strategy and, possibly, consider risk-sharing and resource-efficient structures such as cooperation with other market participants (e.g., competitors). The aim should be to develop an industry-specific platform or to consolidate and open up existing closed industry-specific platforms in a way that ensures the necessary scaling, i.e., a large share of the end customers in the industry uses the platform.

In summary, it should be noted that for the majority of mechanical engineering companies, investing in their own platform will not be worthwhile – they should focus on compatibility and standards. Companies that opt for building a platform should approach the task from a focused, industry-specific perspective, in a bid to gain a first-mover advantage. If necessary, they should partner with other players in order to establish a scalable and open solution that covers a complete end-customer industry.

Applications. Successfully monetizing the application layer requires an in-depth examination of customer needs, but also of the specific approach taken:

- A clear commitment to the strategic relevance of applications as a differentiating factor of the future value proposition is essential. In a first step, customer needs have to be thoroughly analyzed. The results of this analysis must then be leveraged coherently to develop focused offerings, solutions, and business models for the digital business – if necessary, together with those companies that will ultimately operate the machines and systems.

- Consequently, bold initiative is needed at the development and go-to-market stages. This is necessary above all because mechanical engineering companies' efforts to catch up in the development of digital solutions appear to be lagging far behind their developments in core technological areas.

  It can also be assumed that other market participants, possibly from outside the industry, or competitors from other regions will gain some degree of traction in the market with their digital solutions. European mechanical engineering companies will likely struggle to win back the fields new market entrants occupy.

- Mechanical engineering companies have an excellent starting position for growing their business with application offerings, particularly in light of their in-depth knowledge of equipment and processes. Moreover, in the case of applications, they benefit from the manageable investment risk and the applications market's highly appealing size and growth rate, especially in comparison to platforms. It also holds true that less is more. In other words, it is better to develop two or three software-based services that offer end customers tangible benefits – if possible, without being tied to a certain equipment manufacturer – than a large number of manufacturer-dependent applications that have no measurable benefit or need several years before they start paying off for end customers.

Let's take a closer look at two aspects that apply to platforms and applications alike:

Collaboration and standards. The majority of mechanical engineering companies have realized that collaborative strategies promise the greatest success in the digital business (around 70% of the companies surveyed are of this opinion). Mechanical engineering companies should therefore stop thinking they have to act alone. Instead, they should use strategic alliances to consistently tap into new potential for digital platforms (where it makes sense for mechanical engineering companies to invest) and the application layer. Collaboration – potentially even with competitors – would enable mechanical engineering companies to forge ahead with manufacturer-independent solutions and the standardized interfaces that customers often want. This is particularly true for customers operating machine parks that are heterogeneous in terms of age and machine manufacturer.

Standards and interfaces, such as OPC UA, play a central role in this respect. This is an aspect mechanical engineering companies should address directly with the aim of systematically driving forward the development of standards and setting them. Ultimately, end customers will give preference to providers offering clear standards and open interfaces. Mechanical engineering companies should therefore not fear making themselves replaceable but rather see standardization as an opportunity to improve the resource efficiency of their business operations. If mechanical engineering companies fail to take a proactive approach in setting standards, other players capable of providing the standards and open interfaces that end customers want will penetrate the market, especially in sectors with large end customers.

Besides, without compelling business models, the mechanical and plant engineering sector faces a difficult path to digitization. This is hardly surprising, considering that even (well-known) tech players have proven successful precisely because they pursue a simple, consistent business model. For example, Google's parent company, Alphabet, still generates around 84%[9] of its revenue from advertising on search engines. Instead of the frequent discussions of potential risks, the quest for a promising business model should therefore be a top priority for mechanical engineering companies.

9 https://www.statista.com/statistics/633651/alphabet-annual-global-revenue-by-segment/ (downloaded: May 2020)

Digital solutions, sometimes in combination with new business models, are already being offered, as the following examples display:

- With SIGMA SMART AIR,[10] KAESER offers a system for companies' entire compressed air supply, combined with a consumption-based payment model. Its core is the SIGMA AIR MANAGER 4.0 module, which takes care of all the compressed air station's control tasks. By combining it with other applications, end customers can digitally optimize their system in terms of efficiency and maintenance (predictive maintenance). Costs in this model are based on units of 1,000 m^3 with prices defined for the entire duration of the contract.

- With the Festo Cloud,[11] the Festo Group offers a cloud solution (based on Microsoft Azure) that enables customers to simply visualize the condition of mechatronics subsystems using apps. With "Dashboards," "Smartenance," and "Projects," the company meanwhile runs three applications. Dashboards simply visualizes the condition of components; Smartenance allows plant operators or maintenance managers to call up the maintenance calendar on a mobile device and see the assigned maintenance tasks. In addition, the system renders detailed instructions, including live photos, texts, and measured values. Projects functions as a life cycle management platform, systematically documenting data from all system components. The focus is on Festo components and systems.

10 https://www.kaeser.de/produkte/sigma-smart-air/ (downloaded: May 2020)
11 https://www.festo.com/cms/de_de/56644_63676.htm#id_63676 (downloaded: June 2020)

- In the wood processing industry, Homag has created and established the industry-specific platform solution Tapio.[12] This technology platform is open to all manufacturers of machinery, tools, and materials in the wood processing industry so they can offer their service and digital solutions to their customers (e.g., furniture manufacturers, carpenters). In this respect, Tapio functions as a neutral support platform and enabler, although it also provides access to some of the company's own apps. The applications are offered to end customers (mostly small businesses) under customer-friendly payment models tailored to their needs (e.g., free 30-day trial period, monthly or annual subscription). Experience has shown that the platform only appeals to customers if they can see added value. To ensure that the Tapio platform offers as many applications as possible, mechanical engineering companies only have to pay a modest annual membership fee. Beyond that, mechanical engineering companies pay a percentage-based fee to Tapio when their application is downloaded by customers. The applications offered on the platform are currently manufacturer-dependent, as there are no standardized interfaces yet. However, manufacturer-independent services are seen as the future, as customers seek applications for their entire machine park.[13]

- Digital solutions are also being offered in the packaging industry. Regardless of the existing machine park, Tetra Pak offers the Operational Benchmark Application as a service enabling end customers to reference anonymized external benchmarks.[14] On request, Tetra Pak[15] also connects filling machines so that they can communicate with the Performance Management Center during operation. Based on the operator's system data, the center then derives improvement potential for productivity and maintenance and feeds that information back to the end customer. Some end customers are even offered service packages with a "performance guarantee" to improve machines and production lines.[16]

To ensure full transparency and security for all platform participants and application users, a clear legal framework with standardized rules of access and use is also needed. Such uniform cross-industry and (potentially pan-European) standards should be defined and developed by the companies – together with industry associations and policy makers – in parallel to the strategic development of product areas. One initiative to be mentioned in this connection is GAIA-X, a project initiated by the German Federal Government in which VDMA is taking part together with more than 300 other organizations.[17] The goal is to develop concepts for a digital data infrastructure that meet the highest standards of data sovereignty while at the same time promoting innovation. The first use cases are expected to be implemented successfully in pilot operation by the end of 2020.

12 https://www.tapio.one/de/whatistapio (downloaded: June 2020)
13 Interview with experts (June 2020)
14 https://www.tetrapak.com/us/services/increase-profitability/journey-increased-profitability (downloaded: June 2020)
15 https://connectingthefoodindustry.tetrapak.com (downloaded: June 2020)
16 https://www.tetrapak.com/about/cases-articles/plant-care-with-performance-guarantee (downloaded: June 2020)
17 Das Projekt GAIA-X – Eine vernetzte Dateninfrastruktur als Wiege eines vitalen, europäischen Ökosystems, German Federal Ministry for Economic Affairs and Energy (October 2019)

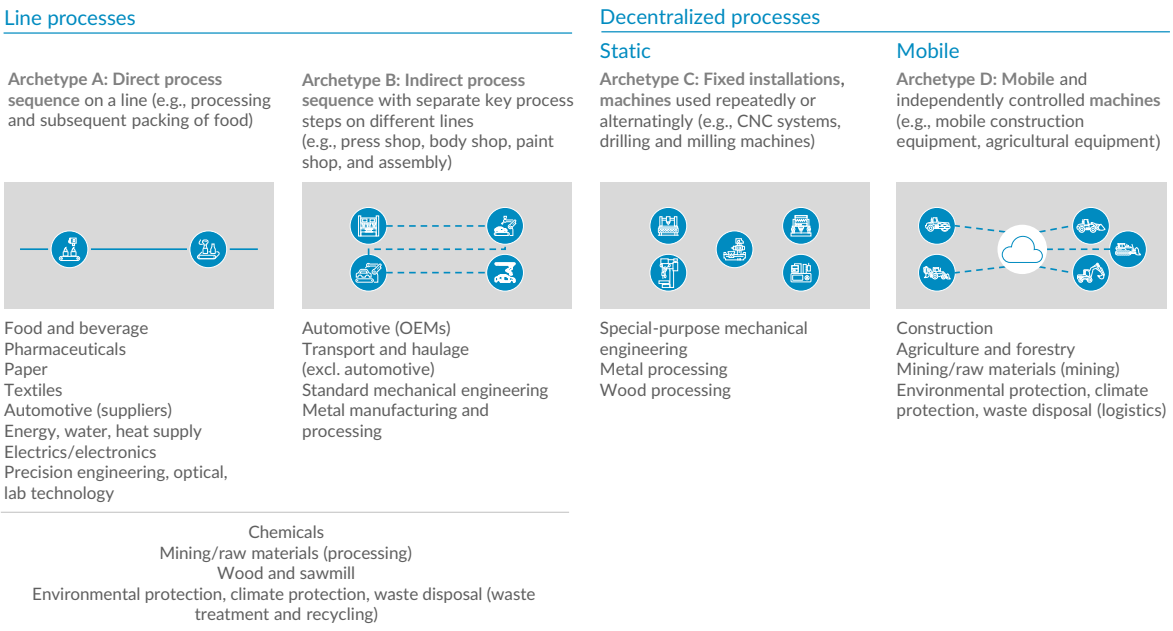
3.2 Recommendations by end-customer industry

Besides the general recommendations mentioned above, the mechanical engineering companies' strategy must be aligned with the conditions in the respective end-customer industry. There are two factors to consider that determine end customers' requirements regarding digital platforms and applications: first, the nature of the production process (defined by four process archetypes) and second, the end-customer industry's IoT power (defined by company size, digital maturity, and IT resources).

- **Process archetype.** Regarding the process archetype, a distinction is made between line and decentralized processes, with line processes broken down further into direct and indirect processes, and decentralized processes split into static and mobile machines (Exhibit 11). These process archetypes naturally do not reflect all possible nuances of a company's production processes and it is possible that other processes apply in some end-customer industries as well. Nevertheless, they do provide a reference framework with which it is possible to infer analogous conclusions for different industries.

Exhibit 11

Overview of 4 process archetypes and their application in individual end-customer industries



SOURCE: VDMA, McKinsey

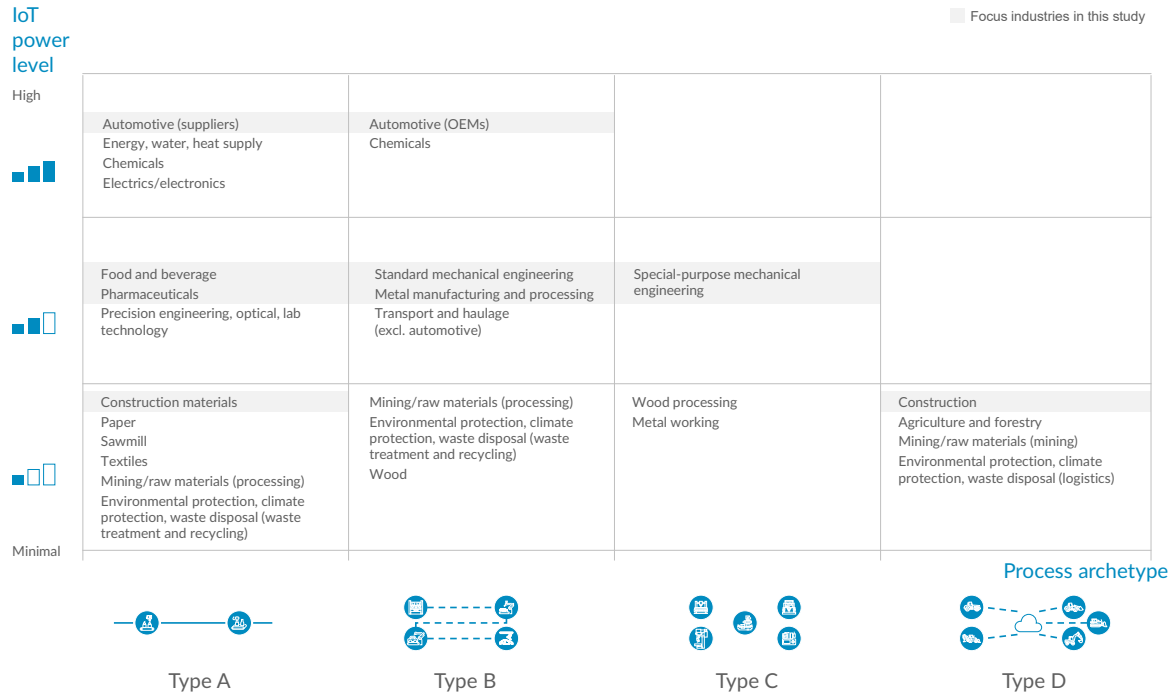
- **IoT power.** IoT power reflects structural preconditions in end-customer industries that permit players to make progress with digital platforms and applications themselves. Relevant criteria include the company size structure, size of the industry, available capex volume, and the digital maturity or IT resources in the respective end-customer industry.

  IoT power is considered relatively high in the automotive, energy, chemicals, and electrics/electronics industries – on the one hand based on the typical company structure and size and, on the other, because IT systems are already largely integrated in the sector's current production chains. Somewhat lower IoT power is attributed to what are mostly highly decentralized processes, e.g., in construction, agriculture, or the comparatively small-structured wood and metal processing business.

Exhibit 12 provides an overview of industries classified by process archetype and IoT power.

Exhibit 12

Overview of IoT power levels and process archetype(s) for the respective end-customer industries



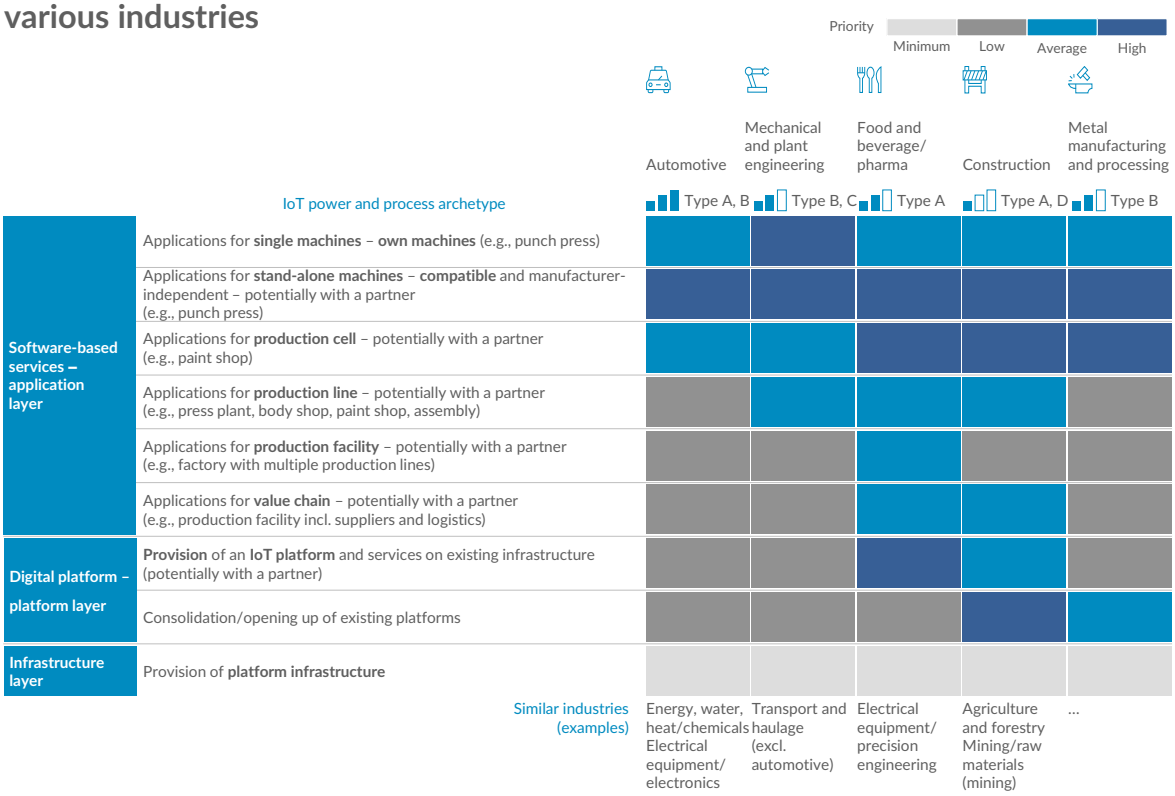
SOURCE: VDMA, McKinsey

The recommendations for action have been prioritized specifically for five end-customer industries of mechanical and plant engineering companies based on interviews with end customers and experts (Exhibit 13). The allocation of the end-customer industries by process archetype and IoT power permits analogies to additional end-customer industries to be drawn (see Exhibit 12).

There is no one-size-fits-all recommendation for each end-customer industry. Not only are mechanical engineering companies too diverse in terms of product portfolio and customer proximity, there are also considerable differences regarding their end customers' operating structure and digital maturity. The recommendations given below are therefore intended to provide orientation and permit divergences depending on the respective customers and providers.

Exhibit 13

Prioritization of strategic approaches for mechanical engineering companies in various industries



SOURCE: VDMA, McKinsey

While the five end-customer industries with the highest representation in the survey have been analyzed in detail for this study, the logic and the analysis by IoT power and process archetype permit drawing conclusions by analogy for other (related) end-customer industries as well. For instance, in end-customer industries where businesses tend to be small and medium-sized enterprises (e.g., woodworking, plastics processing, and metal working) that have a heterogeneous machine park and focus on special-purpose applications, an industry-specific platform (as in the wood processing industry) could also be successful. Here too, however, the strategic framework presented must be thought through from the customer's perspective, the digital solution's added value needs to be clearly defined, and the mechanical engineering company's own business model derived on that basis.

Automotive

For the automotive industry, it is recommended for mechanical engineering companies to not develop another platform, but rather to increase the compatibility of their own products. In addition, applications tailored to the industry but not tied to a manufacturer offer a broad solution space for growth and differentiation. The following recommendations for action (also see Overview 1) have been developed for mechanical engineering companies supplying the automotive industry:

Overview 1

- The development of a new platform has little chance of success, as various end customers (including automotive OEMs) are already developing their own platforms together with major tech players and setting standards.
- Companies should ensure that their own machinery and equipment offers maximum compatibility so that it can be integrated into existing ecosystems.
- Companies offering digital solutions of their own should ensure manufacturer independence. In contrast, manufacturer-dependent solutions may be acceptable in the service area.
- The focus should be on applications that improve effectiveness and efficiency (e.g., OEE) as well as quality.
- In addition, attention should be placed on optimizing end-to-end core process steps (e.g., painting line) and interfaces to adjacent process steps.

▶ **Do not focus on setting up a new, proprietary platform**

On account of the large average company size and comparatively high level of IT resources, end customers in this industry often already have IT platforms of their own.[18] This is true for automotive OEMs and some of the suppliers that we interviewed. As a result, there are currently many co-existing platforms. As tech players are investing heavily in building up large, open ecosystems together with automotive manufacturers, a setting comprising most likely three to four regional industry solutions or ecosystems is likely to emerge in the medium term. Automotive suppliers will follow and join the OEMs' ecosystems. To be considered by customers, mechanical engineering companies must therefore ensure that their products can be integrated in the respective platform. Accordingly, it would not make sense for mechanical engineering companies to establish new parallel platforms. This is especially the case if we consider that it is not (or no longer) so much the technical realization of a platform that customers see as a differentiating factor, but rather only the services and applications offered on it.

18 BMW Group und Microsoft führen Open Manufacturing Platform ein, 2019 (https://news.microsoft.com/de-de/bmw-group-microsoft-open-manufacturing-platform/) (downloaded: May 2020). Volkswagen und Amazon Web Services entwickeln Industrial Cloud, 2019 (https://www.volkswagenag.com/de/news/2019/03/volkswagen-and-amazon-web-services-to-develop-industrial-cloud.html) (downloaded: May 2020)

In summary, that means that, in light of automotive OEMs' and tech players' edge and corresponding economies of scale, digital platforms offer negligible opportunities for mechanical engineering companies in the automotive industry. They should therefore not invest any resources in setting up a new platform of their own.

- **Focus on further improving compatibility of own products**

  Since tech players have had a head start with setting up platforms and associated ecosystems that mechanical engineering companies cannot hope to close down, the latter must focus on achieving maximum compatibility between their products and existing platforms and ecosystems. That will allow them to participate, provided they are able to equip their machinery with universal interfaces that facilitate easy integration in existing platforms and ecosystems.

  "An overarching platform would be nice, but there's none on the horizon in the medium term. In terms of platforms, mechanical engineering companies should rather focus on standard interfaces."

  (An automotive supplier)

- **Develop applications to improve efficiency and quality**

  From the customers' perspective, the main benefit that applications can currently offer is a measurable improvement in cost performance (e.g., through the optimization of OEE, quality, resource consumption, service). This is something that can be provided for example by applications tracking process and quality data end to end. Aside from these solutions, there is a keen interest in applications that help to achieve an improvement in overall efficiency through cross-order planning and by monitoring the production status across different lines. The extent to which customers are willing to use the application layer therefore depends on the assessment of the business case from their perspective as machine operators. In other words: the willingness of automotive OEMs and suppliers to invest increases the quicker and easier it is to capture the additional (cost-saving) potential offered by applications, and the easier it is to measure the benefits.

  However, manufacturers of stand-alone machines in particular should design applications that are not limited to a specific manufacturer. That would permit them to run their applications on competitor products as well as in heterogeneous machine parks of automotive OEMs and suppliers. At the same time, it would allow them to scale up their offering on the market at a much faster rate. Customers are much less willing to invest in software-based services if they can only be used with some of their machines. Some end customers' expectations of the mechanical engineering companies are high; they are thus often thought to be well positioned to provide applications.

  "I expect from mechanical engineering companies to provide apps just like on a smartphone."

  (An automotive supplier)

- **Place extended focus on applications to optimize customer support and installation**

  The high service competency that end customers attest to mechanical engineering companies should also be leveraged as a competitive advantage when creating applications. Accordingly, the extended focus is on applications that enable end customers as machine operators to optimize costs in the service area (e.g., remote services and installation, potentially supported by augmented reality). Above all, companies in the automotive industry, which often have a global presence, value mechanical engineering companies that can provide service worldwide. When it comes to service, machine operators do accept manufacturer-dependent applications, but generally speaking they prefer a manufacturer-independent solution (in particular with respect to manufacturers of single/stand-alone machines).

  "You can already tell that companies with a high software competency are ahead of the field."

  (An automotive supplier)

- **Concentrate on manufacturer-independent applications to optimize a core process step end to end**

  End customers would rather not have a large number of manufacturer-dependent applications. If each of these applications optimizes only single machines or production cells within the core process, the complexity at the customer side increases. In view of the current machinery structure, there is greater demand for applications that enable optimizing a core process step holistically (e.g., a paint shop or assembly line). Applications of that nature deliver true added value for end customers. To offer such services, companies could consider entering into development and service collaboration arrangements with mechanical engineering companies offering products that are upstream or downstream of their own machines. Some large OEMs have already taken one step further in their (own) platform development activities and plan to cover several core process steps right through to entire factories. In a next step of the software-as-a-service paradigm, this will mean that mechanical engineering companies will have to open up to and – where it makes sense – offer applications across core processes (e.g., optimization from press plant to final assembly).

  "In future, it is companies also integrating upstream and downstream processes that will offer the greatest added value."

  (An automotive supplier)

  "German mechanical engineering companies will have to look out – they once had an edge through their precision engineering, but those times are over. In the future, applications will be a crucial element of a unique value proposition."

  (An automotive supplier)

Mechanical and plant engineering as an end-customer industry

Due to the complex value chains, the mechanical and plant engineering industry is also one of its own most important customer industries. When considering recommendations for action (also see Overview 2) for digital platforms and applications, a distinction must generally be made between standard and special-purpose mechanical engineering.

Overview 2

- The standard mechanical engineering industry is likely to see a development similar to the automotive industry; tech players will offer the relevant platforms. Thus mechanical engineering companies should focus on maximizing the compatibility of their products with existing platforms.
- In the heterogeneous special-purpose mechanical engineering sector, there is a possibility that open platforms covering specific applications (e.g., platforms for the sheet metal process chain or tool management platforms) may be accepted by the market if they are not manufacturer-specific and are easy to integrate in existing ecosystems.
- Platforms should be designed as open and user-friendly as possible.
- The focus should be placed on applications that offer measurable customer benefits, e.g., on optimizing the use of resources, workforce, and flexibility.

▶ Maximize compatibility with existing platforms in the standard mechanical engineering sector

Regarding the establishment of platforms in standard mechanical engineering, from today's perspective a trend similar to that seen with OEMs in the automotive industry can be expected. Tech players will develop platform solutions, possibly in collaboration with large end customers, and thereby likely set standards in the industry. These solutions will be of special interest to large end customers that have a more or less standardized product portfolio. Mechanical engineering companies that primarily supply end customers with standard machinery should therefore be open to such (emerging) platforms and not invest in developing a platform solution of their own. However, the establishment of platform standards can be expected in the medium term.

"As a standard, OPC UA is going to play a major role."

(A mechanical engineering SME)

- **Understand industry-specific platforms in (special-purpose) mechanical engineering as prospective opportunity**

  In some areas of the heterogeneous special-purpose mechanical engineering sector, mechanical engineering companies are able to successfully offer platforms (ideally in collaboration). Since the special-purpose mechanical engineering sector is highly fragmented and largely constituted by SMEs, an open, cross-segment platform that is easy to integrate and covering most of the desired functionalities is likely to be accepted and achieve the necessary scaling in the market. End customers expect that a small number of platforms provided by large mechanical engineering companies will sooner or later gain traction – and would like such platforms to be open and compatible. Specifically where smaller end customers are concerned, however, it seems most likely that company-specific ERP solutions will remain the leading systems at present and over the medium term, and thus compatibility should be ensured. Open, application-specific platforms (e.g., focusing on tools management or an end-to-end process chain such as sheet metal processing) that are easy to integrate into existing ecosystems would potentially be an option for standard machinery manufacturers as well.

  "If you can provide a solution for a specific use case, you have a clear advantage. Use cases are highly diverse in mechanical engineering. But we don't want a plethora of systems either."

  (A mechanical engineering SME)

- **Prioritize platform integration aspects, openness, and user-friendliness**

  Most of all, end customers in both mechanical engineering segments want to be able to seamlessly integrate their heterogeneous and historically grown machine and equipment park into a single platform. Much as in other end-customer industries, issues such as availability and platform security are also rated as highly important by end customers in the mechanical and plant engineering industry. In the long term, the sector's end customers operating the machines hope that platforms will open up on a broad front. They currently believe that it will not be possible to cover all aspects with any one platform and therefore give priority to standards and interfaces for the equipment and machinery. In addition, the focus should be placed on the platforms' user-friendliness.

  "The cloud could perhaps offer greater security than a small, internal solution."

  (A mechanical engineering SME)

▶ Offer applications focusing on use of resources, service, workforce optimization, and flexibility

Like other end customer industries, the mechanical engineering sector considers the optimization of its use of resources to be one of the key fields of application for software as a service. The majority of end customers believe that their suppliers in the mechanical engineering sector are best able to deliver in this respect, as they are close to the process.

Two further points need to be considered with respect to special-purpose machines: First, applications are expected to deliver results that are easy to interpret and can, accordingly, be directly implemented by employees. This should also permit a more flexible staffing on the different machines. Second, end customers in the special-purpose machinery sector have expressed a growing interest in applications that allow or simplify a more flexible use of the machines. The companies operating the machines hope that this will enable them to gain efficiency and flexibility in their broad, yet heterogeneous portfolio. Apart from these factors, end customers would welcome services that create transparency in service, spare parts, and supply chains. In the standard machinery sector, expectations regarding service are similar to those in the automotive industry.

End customers generally want applications that are intuitive to use and see this as an area where suppliers in the mechanical and plant engineering sector can still improve. Ideally, end customers would be able to use a standard interface with the same operating functionalities, irrespective of the underlying process or platform used.

“From a production perspective, purchasing is a black box – transparency in the supply chain (knowing what’s coming when) would offer great savings potential.”

(A mechanical engineering company)

Food and beverage / pharmaceuticals

The food and beverage industry is one of the end-customer industries in which mechanical engineering companies might succeed in establishing a standard industry platform. In this sector, applications should aim to optimize the use of resources, besides increasing flexibility and shortening changeover times. The recommendations for action (also see Overview 3) for mechanical engineering companies serving food and beverage manufacturers, the pharmaceutical industry, or producers of fast-moving consumer goods can be summarized as follows:

Overview 3

- Existing industry standards should be used and opportunities taken to establish an industry-specific platform.
- It should be ensured that solutions are not manufacturer-specific and can be integrated into existing ecosystems.
- The focus should initially be on applications that improve the use of resources and product quality and that optimize transparency with respect to spare parts availability.
- Machine and plant flexibility should be maximized using digital solutions to meet end customers‘ requirements for a diverse or fast-changing product range.

▶ Use the opportunity to establish an industry-specific platform

The proportion of customers in this industry using digital platforms can be assumed to be rather low at present. However, especially large end customers with an – in many cases – global footprint, may have already established internal, closed digital platforms. In part, these are operated and developed further using internal resources. The end customers' decision whether to use platforms hinges on the extent to which these can enhance their own ability to create value. Especially on straightforward lines (e.g., for grinding, heat treatment, packaging in the food industry), customers believe that digital solutions can hardly generate significant further added value, as the manufacturing costs account for only a very small share of total product costs.

“Alliances between mechanical engineering companies would be predestined to offer that kind of thing [i.e., industry platforms].”

(A consumer goods manufacturer)

Mechanical engineering companies are nonetheless still in a good position to establish a platform in this sector, possibly even a standard industry platform. End customers have a twofold interest in such a development: on the one hand, to reduce platform development costs and operating expenses or making it easier (compared with in-house solutions) to estimate them. And on the other hand, to obtain access to different applications offering extended benefits. For end customers, this is all predicated on platforms permitting straightforward integration of their often heterogeneous machine park and being compatible with existing ecosystems.

The Weihenstephan Standards[19] have already defined data communication for food production and packaging machines (data format/content, technical communication protocol, etc.). These standards can serve as a basis for platform-based automation concepts but need to be developed further for open networks, especially regarding security aspects. With the communication standards already defined, mechanical engineering companies hold a good position to establish further platform standards. In future, the trend is likely to veer toward industry-specific platforms, which would make sense especially considering the high share of end-to-end line processes.

"We are not interested in manufacturer-specific platforms – we need open platforms that can stretch to cover other fields or machines."

(A food and beverage manufacturer)

▶ Optimize the use of resources across core process steps

In the food and beverage industry, the cost of raw materials makes up a large portion of production costs. Manufacturers hence have a substantial interest in applications that optimize raw materials consumption and are also able to determine and measure the quality of the products. That would enable them to respond to factors or incidents undermining quality standards with adjustments at an early stage of the production process. In addition, end customers attach value to optimizing the use of resources, and they believe that mechanical engineering companies are able to deliver in this respect thanks to their in-depth process knowledge.

End customers would also like applications to be usable for as many machines as possible, even entire lines. Only in the case of very local, machine-related applications would the customers consider manufacturer-specific solutions as well. In the field of service and maintenance, they would welcome greater transparency about spare parts and repairs needed (e.g., predictive maintenance) – similarly to assembly line processes in other industries. This also applies to the underlying ordering and shipping logistics, where it is hoped applications will deliver process improvements.

"Predictive maintenance is extremely important – if we can foresee problems with machines, we can solve them ourselves in good time."

(A consumer goods manufacturer)

19 http://www.weihenstephaner-standards.de/index.php?id=2 (Stand Mai 2020); https://www.vdma.org/v2viewer/-/v2article/render/20067764 (downloaded: May 2020)

On the basis of an IoT platform and cross-process applications, mechanical engineering companies would also be able to offer performance-based payment models right through to operator models (pay per use or pay per outcome). This could be interesting for end customers whose core processes or primary value creation mainly relate to development and marketing rather than product manufacturing.

▶ Increase flexibility and shorten changeover times

Food manufacturers in particular also rate highly digital solutions that can increase plant flexibility and reduce changeover times. This flexibility is highly relevant for companies operating machines in the field of customized products to enable them to switch quickly between different products on one line. At the same time, the objective is to keep changeover times to a minimum. The more product changeovers a manufacturer has to manage, the greater the relevance of this aspect. As customized products are gaining in importance compared with the standard portfolio, end customers hope that platforms and applications will provide support and help dismantle complexity.

"Greater machine flexibility is very important to us – the greater the flexibility and speed with which I can switch production on the line, the better."

(A food and beverage manufacturer)

Construction

In particular in the mobile construction industry with its frequently diverse machinery and equipment setup, there is a trend away from individual machine applications and toward platform-based ecosystems.[20] Construction machinery manufacturers have a few years ago already viewed telematics and remote monitoring as the key technology trends in the industry.[21] When considering the recommendations for action in the construction industry, it is generally necessary to distinguish between applications for mobile construction equipment (construction machinery) and process- or line-oriented applications in the construction materials industry. The recommendations for action (also see Overview 4) for mechanical engineering companies serving the construction industry can be summarized as follows:

Overview 4

- Customers would like existing platforms for both construction equipment and construction materials to be as open and compatible as possible.
- Applications in the construction materials industry should focus on the use of resources and efficiency; mechanical engineering companies could start with individual process steps before scaling up to (entire) systems. The added value for construction equipment depends on the customer group.
- Customers producing construction materials attach great importance to improving the scheduling of maintenance work (e.g., using predictive maintenance), remote service options, and optimizing transparency about spare parts availability and logistics.
- The user-friendliness of applications and clear and intuitive recommended actions derived from the compiled data play an important role for the construction industry as a whole.
- Defined interfaces and compatibility with building information modeling (BIM) systems have to be ensured.

▶ Construction equipment: Drive forward platform standards through consolidation/by opening up

Construction companies currently use a range of different platforms (e.g., Komatsu's KOMTRAX™ or Caterpillar's Fleet Monitoring)[22]. Therefore mechanical engineering companies will need to find a way to collaborate with their customers who will want to ensure platforms are open and compatible with each other. Indeed, end customers as operators of construction machinery state that the key area where they would like to see improvement is the data exchange and transfer between different systems.

20 The next normal in construction, McKinsey & Company (downloaded: June 2020)
21 Reengineering construction equipment: from operations focused to customer centric, McKinsey & Company (downloaded: April 2016)
22 https://www.komatsu.eu/de/komtrax (downloaded: June 2020), https://www.cat.com/de_DE/support/operations/technology/fleet-management-solutions.html (downloaded: June 2020)

- **Construction equipment: Applications depending on the customer**

  A special challenge in the construction machinery industry is that the companies that buy the equipment might not necessarily operate it themselves but might instead be in the business of renting out construction equipment, for example. As a result, the focus of applications varies: While equipment operators are interested mainly in applications that optimize machine output, rental companies primarily tend to favor applications that optimize machine availability (e.g., early warning that servicing and repairs are needed). Having said that, rental companies of construction equipment are increasingly moving toward output-based payment models, and their interest in increasing the output of machines is growing accordingly. As the equipment users change frequently, in some cases daily, it is also important for applications to be particularly intuitive and readily usable without intensive training.

- **Construction materials: Ensure maximum compatibility for existing platforms in the construction materials industry**

  In the construction materials industry, extensive data are already being recorded and at least in some cases transferred to existing platforms. End customers only see relatively low added value in the provision of further manufacturer-specific platforms, as digital platform solutions are realized either with large software companies or, in rare cases, with in-house IT resources. Customers attach much more importance to mechanical engineering companies ensuring maximum compatibility by providing suitable interfaces and thereby facilitating seamless integration.

  "Today's market is very complex – we need manufacturer-independent platforms."

  (A construction materials manufacturer)

  "As end customer, we want to avoid becoming dependent on one platform – we want to keep our options open."

  (A construction materials manufacturer)

- **Construction materials: Develop applications to optimize the use of resources and efficiency for individual or core process steps in the construction materials industry**

  In the construction materials industry, which is often focused on commodities, increasing plant efficiency through software-based services has utmost priority. Manufacturers should initially find digital solutions for small process steps while, at the same time, offering the option of scaling to other units or process steps at a later date. End customers appear highly willing to gradually expand their technology and application know-how for software-based services. However, the same applies here as in other end-customer industries: Business and contracting models need to be designed such that mechanical engineering companies can to some extent contractually guarantee the improvement potential expected by the companies operating the machines and the fees for use of the applications are linked to the actual savings realized. Without risk sharing, end customers signal little willingness to invest in applications.

  "It's not necessarily quality that makes machines stand out – output, efficiency, and aftersales are crucial."

  (A construction materials manufacturer)

▶ Construction materials: Ensure user-friendliness of applications

In developing applications, mechanical engineering companies should also center on user-friendliness. The digital solutions must be straightforward, easy, and intuitive ensuring that they can be used effectively and error-free in the production of construction materials, which is typically a global activity. At present, the problem is often that a large volume of data is recorded, but data analytics (if attempted at all) are insufficiently translated into concrete and easy-to-follow guidance (assuming actionable guidance can be obtained). The limited availability of human resources and their flexible deployment at production lines in the construction industry should also be borne in mind in this context.

"Using virtual reality for machine scheduling would deliver genuine added value, as every unbuilt square meter along with possible downtimes costs money – we still see big untapped potential there."

(A construction materials manufacturer)

▶ Construction materials: Offer machine monitoring, spare parts availability, and optimization of customer support/installation

In the construction industry, software-based services for improving spare parts availability are key and offer a relatively wide field of potential uses – from comprehensive (machine- and equipment-specific) spare parts catalogs to displaying availability and delivery periods right through to automatic reordering and detailed assembly and installation instructions at the respective machine or piece of equipment.

"We often request remote support."

(A construction materials manufacturer)

▶ Construction machinery and construction materials: Optimize the entire construction industry value chain

Aside from machine- and equipment-centered platforms and applications, some digital planning and collaboration solutions have already established themselves in the construction industry. Most of these solutions are based on building information modeling (BIM) to connect all planners, trades carrying out the work, and other parties involved in the project. As a rule, BIMs currently record five building planning dimensions and provide digital representations of the project's realization (including all three physical dimensions, planning timelines, and budget/cost data). Mechanical engineering companies should be able to read out and use relevant (planning) information from these systems and solutions but also be capable of feeding in current data.

Metal manufacturing and processing

With respect to the recommendations for action in the metal manufacturing and processing industry, a distinction must be made between companies that manufacture and process metals (e.g., steel works, aluminum smelters, foundries) and the downstream metal-working sector (e.g., metal cutting production, locksmitheries). The recommendations for action in this section (also see Overview 5) relate to manufacturing and processing companies. In summary, the recommendations are as follows:

Overview 5

- Maximum compatibility with the existing – in metal manufacturing often customer-specific – platforms should be ensured.
- Applications should focus on improving quality, service, and logistics; this is premised on the clear interpretability of data and analytics enabling specific operational improvements.

▶ Move toward more open access to customer-specific platforms

In the metal manufacturing sector, large companies already use operator-specific platforms, most of which are based on existing software systems (e.g., SAP). These platforms are usually operated and also developed further by customers themselves because of their extremely heterogeneous machine parks and individual requirements. High platform performance is elementary to customers to ensure that they have real-time data and high data quality. For metal processing machines, some large end customers have developed additional platforms to optimize the use of machinery and equipment, such as thyssenkrupp Materials' toii®,[23] a platform originally developed in-house that is now offered and made available to other companies.

It would not appear to make sense for mechanical engineering companies to attempt to establish more platforms in this area, as platforms already exist and are mostly very specific (particularly in metal manufacturing). Instead, they should focus on ensuring a high level of compatibility with existing platforms to reduce the costs both for companies operating the machines and for mechanical engineering companies themselves. Providing data still presents both parties with particular challenges in some cases and requires a comparatively high investment. The companies operating the machines would therefore above all welcome digital solutions that make it as easy as possible to integrate machine and equipment data in existing platforms.

"A standard process interface that makes it easier to integrate the units would give a mechanical engineering company a competitive edge."

(A metal manufacturer)

23 https://www.thyssenkrupp-materials-iot.com/ (downloaded: June 2020)

▶ Improve quality, service, and logistics for individual core process steps

The ability to readily extract mass data and link these across several process steps is a key lever for generating new insights and, in turn, an opportunity for end customers to realize improvement potential. Companies active in metal manufacturing prefer applications that improve quality, maintenance, and repairs, as well as logistics. It is decisive for the companies operating the machines, that they can easily interpret the data and have the possibility to put information derived and knowledge gained on that basis into practice as a concrete operational improvement.

"Extracting concrete steps from the data – that's a fine art."

(A metal manufacturer)

To this end, applications should center around the respective process. That is why for new solutions, companies operating metal manufacturing and processing equipment are already turning to process specialists (e.g., maintenance and logistics specialists) that implement corresponding solutions. This offers mechanical engineering companies the opportunity to combine their existing deep machinery expertise with the operators' process know-how and establish machine-specific applications as a basis for improving processes.

"If machine manufacturers and operators were each to invest their respective know-how in joint Industry 4.0 solutions, both would stand to benefit."

(A metal manufacturer)

"We need something like an advanced SCART connector where you can plug in and the machine simply hands over its data."

(A metal manufacturer)

Outlook

End customers expect mechanical and plant engineering companies to offer standardized interfaces and open, compatible digital solutions that produce measurable value added above all. Evidently, there is no one-size-fits-all answer to the question of how mechanical engineering companies should go about determinedly initiating and driving forward the company-internal process of shaping a radically new mindset and cultural change, which is required to leverage the potential inherent in digital business. Nevertheless, the industry-specific recommendations for action highlighted in this publication provide mechanical engineering companies with a clear point of reference for examining the topics that should be prioritized in each of the end-customer industries analyzed. With respect to company culture, the path to take is in the direction of a closer exchange (and potentially alliances) – both among providers and with end customers. In most cases, close collaboration and open interactions are needed to create solutions that provide end customers with added value. This requires a clear change in mindset from established approaches.

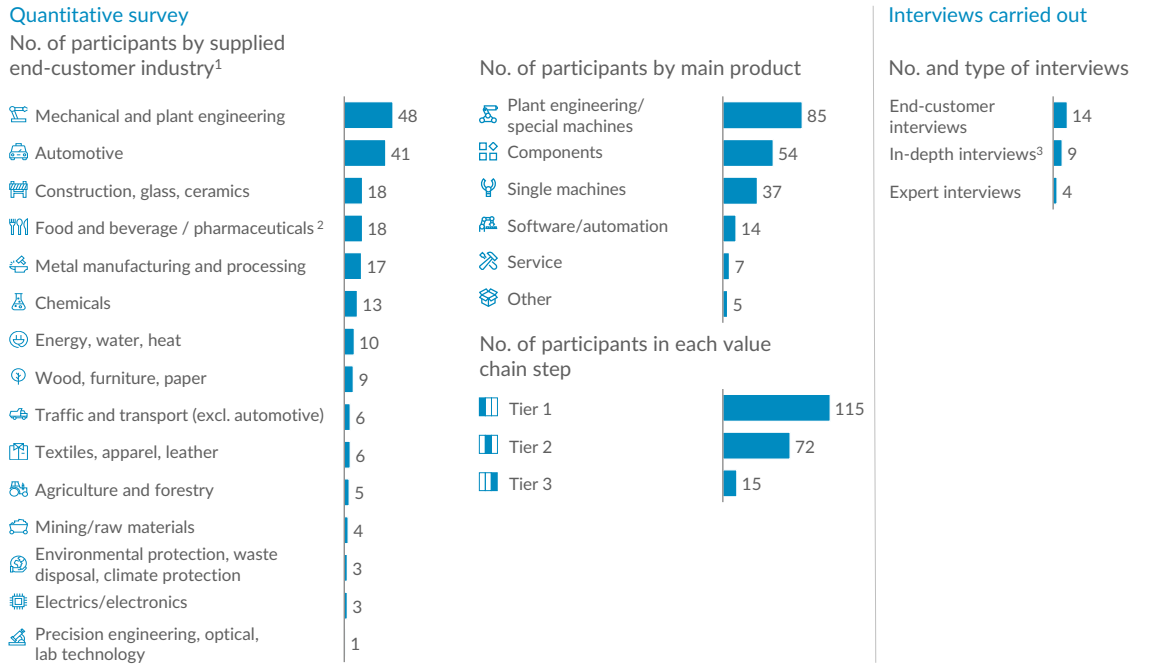
Mechanical engineering companies have no time to waste to set the course for a digital future, if they intend to safeguard their key positions in the long term and be able to benefit from their intimate process know-how. Otherwise, they risk losing touch with the technology curve. While the mechanical and plant engineering sector will remain an attractive industry in the medium and long term, it is facing considerable upheaval at present. Prospects are good for companies realizing that digital platforms and software-based services are already more than simply a nice-to-have digital add-on to their current business, and that they are set to become a make-or-break factor in the near future. Yet companies do not necessarily need to develop platforms of their own or a broad range of different applications. Instead, they should adopt a clear strategy that defines when and in what areas they want to drive forward or adopt standards in order to ensure greater compatibility with existing systems. And they should also decide in which areas it is worthwhile to develop focused applications that offer end customers quantifiable benefits. Companies that are quick off the mark are more likely to outpace the competition in the medium and long term and defend their position against new market entrants – this alone should be reason enough to adopt the right strategic measures now and get in shape for the industry's digital age.

Appendix

Detailed information on the VDMA-McKinsey survey and conducted interviews

Exhibit 14

Quantitative survey and interview statistics



1. The survey participants were asked to select the main end-customer industry they serve
2. Aggregated analysis of both industries to secure totality of data above the cutoff
3. In addition to the survey, qualitative interviews with mechanical and plant engineering companies to better understand their perspective on end-customer needs

SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Additional key findings

The VDMA-McKinsey study covered around 40 questions on customer-centric digital platforms and applications in the mechanical engineering sector. As it was not possible to explicitly mention all findings in this report, this appendix section provides some additional detailed insights.

Exhibit 15

Around 60% of mechanical engineering companies see the likelihood of success in developing online stores as "high" or "very high"

Share of responses, percent (n = 194), mechanical and plant engineering industry perspective

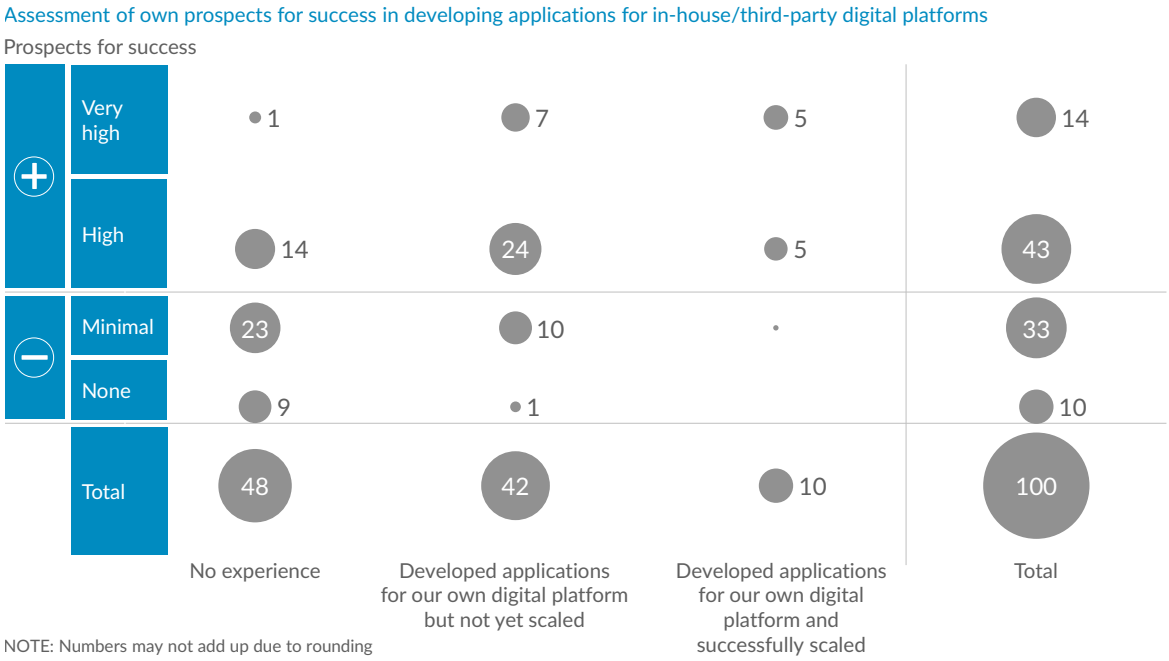
NOTE: Numbers may not add up due to rounding

SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Exhibit 16

Almost 50% of mechanical engineering companies have no experience in developing applications

Share of responses, percent (n = 187), mechanical and plant engineering industry perspective



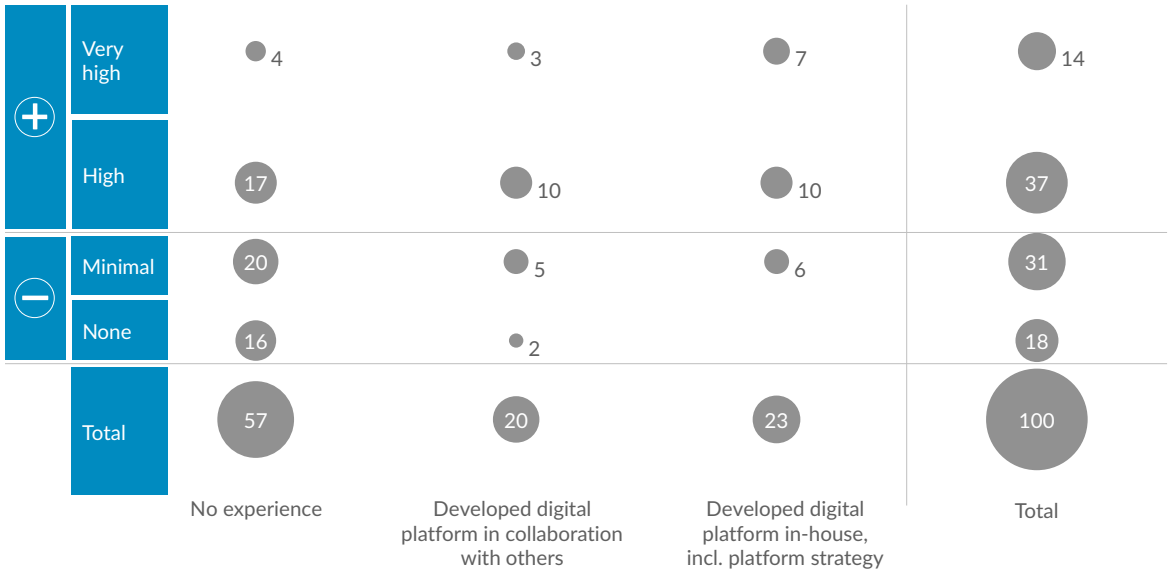
NOTE: Numbers may not add up due to rounding

SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Exhibit 17

Around half of mechanical engineering companies see good prospects for success in developing digital platforms, incl. platform strategy

Share of responses, percent (n = 186), mechanical and plant engineering industry perspective



SOURCE: VDMA-McKinsey survey on customer-centric digital platforms in mechanical engineering (2020)

Glossary

Analytics applications – Digital applications that provide information (e.g., on machine conditions) derived from the data collected using analytical techniques

"As-a-service" models (e.g., software, platforms, and infrastructure) – Under these models, customers use software, platforms, or infrastructure operated by an external party and provided to customers as a service instead of the customer purchasing it. Customers may, e.g., buy the provision of data center infrastructure as a service (e.g., from a cloud provider), thereby saving the high costs involved in purchasing the infrastructure (servers, computers, network capacities, communication devices, storage space, etc.)

Augmented reality – Experience of real-world environment is enhanced by computer-generated information, e.g., using smart glasses

BIM – Building information modeling; concept for optimized planning, execution, and management of buildings using software

CAGR – Compound annual growth rate

Capex – Capital expenditure

Commodities – Raw materials and standard goods without any significantly differentiating product features

Condition monitoring – Regular or permanent recording of a machine's condition by measuring and evaluating operating parameters

Cloud (computing) – Provision of technology data, software, and services over the Internet (or other networks)

COVID-19 – Infectious disease resulting from infection with the SARS-CoV-2 virus

Digital maturity – Skills and existing prerequisites in companies to use and apply digital technologies

ERP – Enterprise resource planning; system used to manage, plan, and control a company's resources (e.g., capital, personnel, material)

Fast follower – A company that quickly adapts its products to new technologies on the market

First mover – A company that is first to bring a technology or product to the market and thereby gains an advantage over its competitors

Fleet management – Planning, controlling, and administration of fleets (e.g., machines, vehicles)

Follower – A company that waits to adapt its products to new technologies until they have become established on the market

GAIA-X – Project to create the next generation of a European data infrastructure; the goal is to create secure and networked data infrastructure that meets the highest standards of digital sovereignty and promotes innovation

IIoT – Industrial Internet of Things; interconnectivity of machinery and equipment via and with the Internet, allowing data exchange

IoT – Internet of Things; a system of devices and everyday objects that are interconnected via and with the Internet

IoT power – Capabilities and prerequisites of various end-customer industries to operate digital platforms and applications; aggregated indicator comprising structural features of the respective end-customer industry (e.g., size of companies, capex) as well as the digital maturity level and IT know-how

IoT stack – Technological layers that enable the IoT (e.g., connecting devices, creating applications)

Lock-in effect – Potential (long-term) dependency of a customer on its vendor/supplier when it opts to adopt a given solution/technology

OEE – Overall equipment effectiveness; metric for measuring overall effectiveness of equipment

OEM – Original equipment manufacturer; manufacturer whose products are used in the production of vehicles and machines, often used as a synonym for vehicle and machine manufacturers

OPC UA – Open platform communications unified architecture; standards for communication and data exchange in industrial automation

Opex – Operating expenditures for business operations

Performance – Monitoring and recording performance-related data of machines and equipment

Predictive maintenance – Predictive planning of servicing and maintenance work on the basis of digitally supported forecasts, thus preventing machine downtime

Process archetype – Production types according to which customer/end-customer industries can be classified

Remote installation – Support from a distance (e.g., using digital tools) for the installation of machines and equipment eliminating the need to deploy personnel on site

Remote support – Support troubleshooting or optimizing the operation of current machines and equipment without the need to deploy personnel on site (e.g., by obtaining remote access to machine and equipment networks)

ROI – Return on invest; metric for evaluating the success of an entrepreneurial endeavor based on the ratio of capital employed and the corresponding return

Spin-off – Establishment of a new entity through a carve-out or new formation of an organizational unit from existing corporate structures

Tech player – Primarily global technology groups with cloud offerings (e.g., IBM, Microsoft, Amazon)

Tier (suppliers) – Reference to vendors in the supplier pyramid (e.g., tier 1 are direct suppliers to an end customer/the company operating the machinery)

Authors and project team

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