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Case Study

Creating data-driven products and services in industry 4.0: a case study on companies in the German machine and tool industry

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Abstract
During the past ten years, lots of new data-driven products and services for tools, machinery and equipment have been developed. While several new players from other industries gained a certain market share, plant and machinery producers also started to enhance their portfolio to take on new data-driven products and services because of the technological changes in Industry 4.0. As a first part of the research, an extensive market study was carried out to analyze how many German companies already offer data-based products and services in addition to their core machines and understand what kind of offerings they make. To classify these offerings, a scheme based on established Industry 4.0 maturity models was developed. In brief, the market for data-driven products and services is still developing, with few technology leaders and fast movers taking the largest share. While the market study gave an overview of what was on offer, the second part of this contribution analyzes how the fast movers with a high level of Industry 4.0 maturity conducted their data-driven services and products. Thus, these few companies were analyzed in more detail, based on public material as well as subsequent expert interviews. Most fast movers in this study relied on the same patterns and approaches, especially when looking at organizational issues such as customer-driven innovation, agile organization of operations, mixed teams, partnering and portfolio enhancement.

1 Introduction

In the year 2011, the term „Industry 4.0" was used for the first time. In the most influential subsequent publications, one of the major technological drivers leading to this 4th industrial revolution were Cyber-Physical Systems, meaning physical systems such as machines with ubiquitous computation capabilities on the hand and the connection of assets through the worldwide web on the other hand [1]. These formed the technological basis for the paradigms characterizing the fourth industrial revolution–horizontal and vertical integration, decentralized intelligence and control as well as integrated digital engineering [2]. Some authors added topics such as 3D printing and biohybrid implants [3]. For the remainder of this contribution, the narrower focus on digitalized manufacturing systems is chosen in accordance with [4]. Once consisting solely of mechanical and electrical elements, products have transformed into complex systems, integrating hardware, sensors, data storage, microprocessors, software, and connectivity in various arrangements. Paired with a product cloud for storing and analyzing data, as well as running certain applications, these advancements are propelling significant enhancements in product functionality and performance [5]. This infrastructure revolutionizes

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product capabilities by enabling autonomous monitoring and reporting of conditions and surroundings, providing unprecedented insights into product performance. The synergy of monitoring data and remote control creates opportunities for optimization through algorithms, enhancing product performance, utilization, and integration with other products in extensive systems [6]. These factors promote adaptability, efficiency, and resilience while also catalyzing the emergence of new products within the realm of industrial automation [4]. Depending on the source cited, the additional economic created would range between 78 [7] and 110 [8] billion euros per year for Germany alone.

In pursuit of heightened product value, companies engage in innovation through the development of novel services or the refinement of existing ones. This strategic evolution transcends a traditional product-centric framework, incentivizing a paradigm shift towards delivering integrated packages that seamlessly incorporate both tangible goods and intangible services [9]. The integration of digital services, facilitated by embedding digital components into physical products, plays a pivotal role in fostering the emergence of innovative business models [10]. The academic discourse consistently identifies this transformative progression as servitization, digital servitization, or the overarching concept of a product-service system [10, 11]. A thorough examination of these conceptual frameworks is available in articles, exemplified by the seminal contributions of [12, 13]. In publications such as [14], aside from delineating the concept of digital servitization, the incorporation of the term digitalization is notable. As per [14], digitalization is defined as the strategic application of digital technology to unveil novel avenues for value creation and revenue generation, often intricately linked with the adoption of a servitization strategy. This transformative journey not only reshapes customers' value propositions but also redefines the mechanisms through which a company leverages its processes and capabilities to generate and capture value. Central to this paradigm shift is the emphasis on collaborative co-creation with customers, facilitating adaptive responses to their evolving needs.

The digitization of manufacturing companies lays the foundation for I4.0 principles such as interoperability, decentralization, virtualization, real-time capability, service orientation and modularity. At the same time, emerging technologies have the capacity to reshape business process management from its traditional version to a more exploratory variant [15].

Many of the potentials of Industry 4.0 are based on the generation of Big Data enabling the development of new data-driven business models, or data transparency and data analytics [16], and not only product and process innovations but also business model innovations are essential for future success. One of the models enabled by the fundamental technical foundations of I4.0 is the "product services business model", which relies heavily on data from CPS, IoT and Smart Factories. This type of business model is popular with manufacturing firms seeking closer customer contact, more stable revenue streams and better resource utilization and its products are known as data-driven products and services, where manufacturers move from being vendors to customer problem solvers or solution providers, bringing new value to the customer by mitigating risks and improving operational performance or asset efficiency [17].

While several new players from other industries gained a market share in manufacturing, domain knowledge is very often required to develop close to the market´s needs and meet the challenges involved. Thus, plant and machinery producers also started to enhance their portfolio to take on new, data-driven products and services as a consequence of the technological changes in Industry 4.0. Comparable to the introduction of services in the late 1990s and early 2000s, data-driven products, software and services tend to enhance the portfolio, provide additional revenue as well as present great potential to set themselves apart from the competition for high-quality producers from Germany. While a study conducted by KPMG in 2021 found that more than two-thirds of customers buying and using machinery and equipment are open towards new offerings [18], very few first "real" cases have become public, as e.g. in [19].

At the same time, developing software or data-driven services is very different from designing and building plants and machinery, from the perspective of technology as well as organization, culture and even business models. Thus, a lot of suppliers struggle to successfully adapt to these requirements.

Despite the wide range and popularity of data-driven products and services, there is few empirical data in the current academic literature on patterns and/or approaches to guide manufacturing companies in the process of creating data-driven products and services. Briard et al. [20] discussed in their paper what the challenges of data-driven design research in the development process phase of physical products are and present conjectures for future lines of research. Schäfer [21] presents data privacy challenges and measures to address them when offering data-driven products. Chen's [22] study proposes a research model of the digital service delivery process and states in his results that data-driven digital capabilities affect product support services and customer support services positively, indirectly improving firm competitiveness. Haifei Yu, Yanbin Gao & Yuanyuan Lu [23] formulate revenue models with no data sharing, unidirectional data sharing and bidirectional data sharing based on the Hotelling model and conclude that horizontal product differentiation has a positive influence on the willingness to share data and that the optimal data sharing strategy of companies depends on horizontal product differentiation, data absorption capability and market competition. On the other hand, in the study of Zuoxu Wang et al. [24] 172 articles concerning data-driven product design (DDPD) were analyzed, to conclude that DDPD has vitality in the Intelligence Era by combining the cutting-edge digital technologies, such as AI, additive manufacturing, digital twin, and so on. It was also determined that current DDPD studies could outperform classical design methods in well-defined tasks, but still cannot master creative/innovative design tasks that require cognitive ability. Meyer et al. [25] present 17 use cases that provide an overview of the possibilities offered by data analysis in product planning, reiterate the importance of data analysis, and point out that this topic is relatively new to many manufacturing companies and that many of these have little experience and/or expertise in this field [26]. Meyer et al. [27] offered practitioners a number and variety of investigations that can be performed with data in the use phases and at the end emphasizes that empirical research on this topic should gain even more importance. Meyera et al. [28] presented a methodology for planning optimized product generations and retrofits by systematically analyzing data and deriving new functions and features from the results. Furthermore, they focused on the fact that to integrate their approach in companies, a benchmarking process and the support of tools are necessary. The study by Grigoryan et al. [29] provides an analysis of the status quo and the challenges for companies with respect to data-driven product management research, an overview of the relevant data and proposes a detailed research roadmap, which provides professionals with a broad overview of this subject and allows them to reflect on how their product management should change in the future, in technical, organizational and human dimensions.

On the other hand, Bahrenburg et al. [30] state that approximately ten percent of companies are well positioned in terms of data and systems, and only one-third of them identify their own company as lacking or insufficiently prepared for the coming increase in complexity.

As seen from the previously cited sources, there is a lack of current literature that presents in depth the success factors or approaches and lessons learned from pioneering companies in the provision of data-driven products and services, especially in the machine and plant engineering sector. Thus, we conducted a study of fast movers, early adopters of software and data-driven products and services in the area of plant and machinery engineering. As [31] concluded that Germany has been one of the most important innovators in this field the study was conducted with a focus on German providers. The study was conducted in a three-step approach: First, a wide market search was conducted to study the extent to which German plant and machinery engineering companies currently provide both software and data-driven products and services. A wide gap can be observed between the classical deployment of software and the provision of data-driven services such as Equipment-as-a-Service or machine-learning-based performance enhancement. The latter seem to offer a higher margin, but also require more technical and organizational sophistication. Thus, in a second step publicly available material on providers of such advanced data-driven services and products was examined. Finally, expert interviews were conducted to analyze in depth the success factors and lessons learned from fast mover companies regarding the provision of data-driven products and services in the German plant and machinery engineering sector.

2 Market research

As the first part of the research analysis, an extensive market study was carried out. Initially, we employed the list of exhibiting companies of two of the most important trade fairs for plant, machinery, tool and die making: the "Exposition Mondiale de la Machine Outil"—EMO in Hannover and the "International Exhibition for Metalworking Technologies"—METAV in Düsseldorf, which have more than 500 exhibitors each. To analyze this list in detail, we collected secondary data on each exhibiting company from its website, such as its product portfolio, and from additional websites where annual reports and company publications are presented. From this analysis, 202 German companies were identified that offer data-driven products and services in addition to their core products. By analogy with cyber-physical systems, these are suppliers of physical products such as machinery, systems or components that could be enhanced with computing and communications capabilities. Trading and software companies were eliminated from the analysis. In a second part, these 202 companies were analyzed according to their size, measured in annual turnover and number of employees, as well as their portfolio of Industry 4.0 offerings. To classify these offerings, we first had to develop a scheme based on established Industry 4.0 maturity models (see chapter 2.1).

Finally, to deepen the analysis and identify successful practices of pioneering companies in providing data-driven products and services from the machine and plant engineering sector, we analyzed more than 130 publicly available publications, ranging from press releases to marketing podcasts as well as conducted interviews with experts from some of these pioneering companies. The interviews resulted in 20 h of written conversations. The detailed results and analysis of these interviews and data are presented in Chapter 3, where we also describe the patterns and conclusive results of all Fast Movers and the most interesting individual expressions of the expert interviews.

2.1 Scheme for market data analysis—level of maturity

Industry 4.0 is often described as a stepwise evolution of systems and processes, thus necessitating an evaluation of its maturity. During the last years, more than 20 such maturity models have been derived and published, with a meta-analysis presented in [32]. Figure 1 depicts one of the most influential and most cited maturity models, as introduced by the National Academy of Science and Engineering acatech in 2017 [33]. The technological basis is set through computerization followed by connectivity. Together, these two elements create visibility as the lowest level of Industry 4.0 maturity. In a second step, understanding is developed before predictive capability is achieved. The highest level of maturity is seen as the ability to adapt based on prediction.

We employed this model of Industry 4.0 maturity, aggregated the steps where technically feasible (Fig. 2) and translated it into offering levels (Fig. 3):

On the lowest level, local computing power provides data aggregation, transparency, or even some feedback based on data from the automation level. Technologically, this is mostly achieved through well-studied and established technologies and implemented in solutions such as SCADA.

On the second level, aggregated data are available online through an internet connection. Technologically, this requires understanding and mastering the IIoT stack from an edge level to TCP/IP, MQTT, and others, but also includes aspects such as data stream architectures, network security, data privacy and safety, among others. Typically, these data streams are used to feed dashboards to provide information for domain experts.

On the third level, these data streams are connected to models and very specific domain knowledge to pursue specific goals, from process optimization to better maintenance and improved plant operations of even lower energy consumption. In all these cases, domain expertise needs to be matched with data processing capabilities, very often requiring sophisticated models, data science approaches and specifically designed applications.

On the fourth level, services are provided on top of these models and data streams. In addition to mastering the different technology stacks and domain expertise, this also requires redesigning the organization towards the provision of services, which typically includes most internal processes and even the basic business model.

It is important to realize that all lower steps must be mastered in order to reach a higher step. E.g., local data aggregation (level 1), data provision through IIoT (level 2) as well as machinery wear and tear models (level 3) need to be well understood before providing offers such as Equipment as a Service or Performance Improvement.

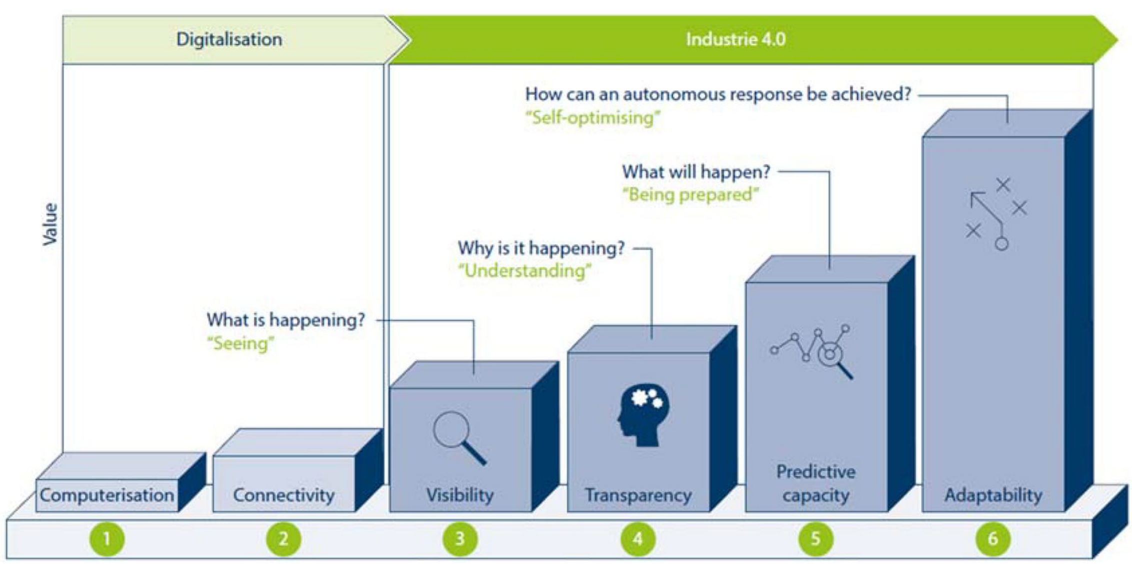


Fig. 1 Industry 4.0 maturity model as introduced by Schuh et al.

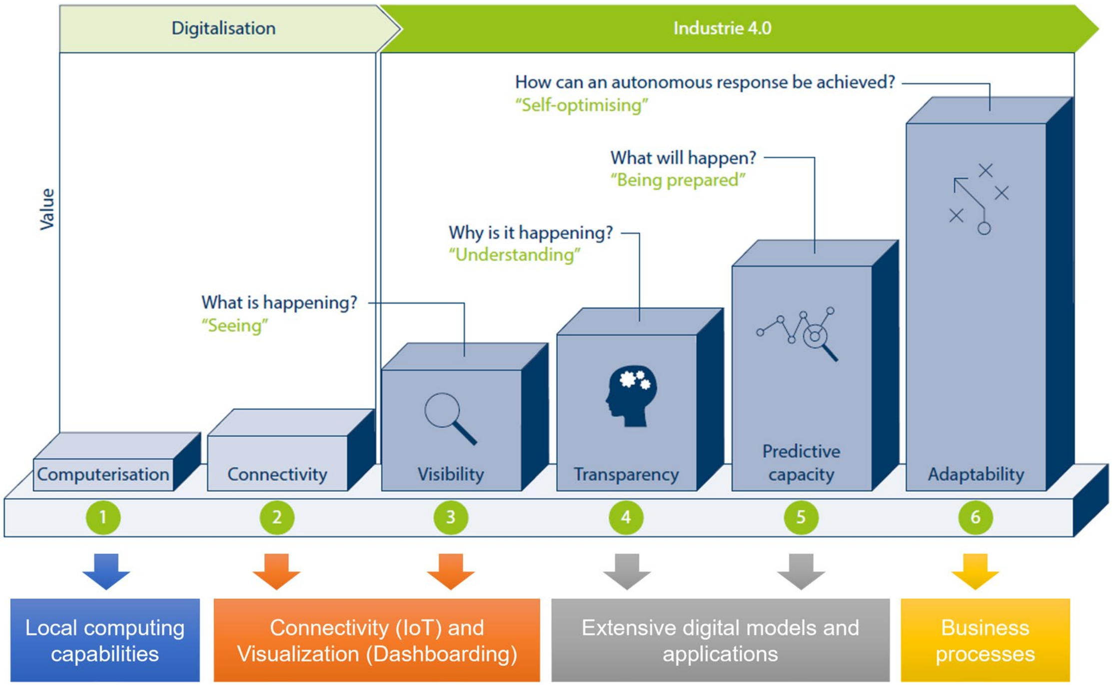


Fig. 2 Aggregation of maturity levels with respect to technologies

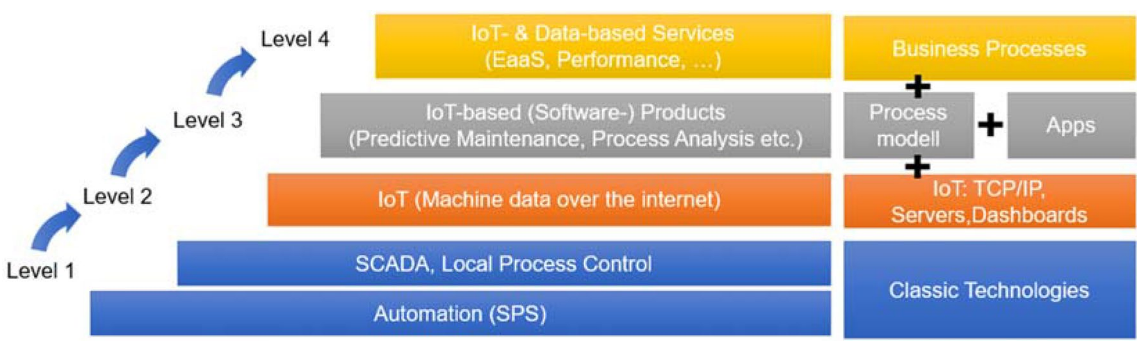


Fig. 3 The maturity level derived for the market analysis

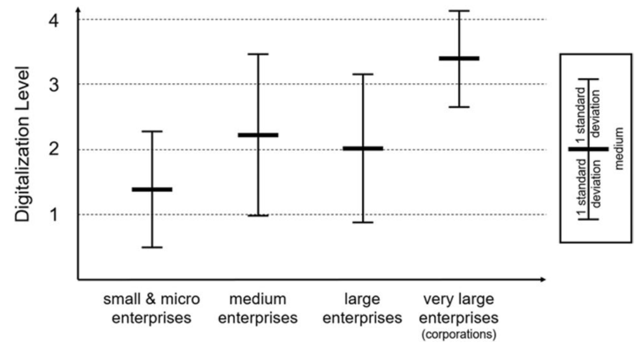
All of the companies included in our study were analyzed with respect to their offering portfolio and then classified according to this maturity level model. As domain-specific value generation and application cases varied across the different actors.

2.2 General findings of the market data

The companies researched ranged from the very small, with a single-digit number of employees, to those with a global presence. Of the 202 under scrutiny, 92 hat actual software or data-driven products and services in their portfolio, representing 43% of the total.

Following the EU definitions for the sizing of companies, 12 of these 92 companies fit into the category of micro or enterprises with less than 50 employees. On average, these companies employed 19 employees and had an annual sales volume of 2,7 million €. In the category of medium-sized companies (mostly referred to as SMEs) with fewer than 250 employees and less than 50 million euros in annual turnover, there are 26 companies with an actual offering of software or data-driven products and services. On average, these companies employed 122 employees and had an annual sales volume of 16 million €. As the remaining group of large companies had a very disparate number of employees, we decided to classify them into two subgroups: Companies with less than 1000 employees, which are represented by 34

Fig. 4 Maturity level over company size



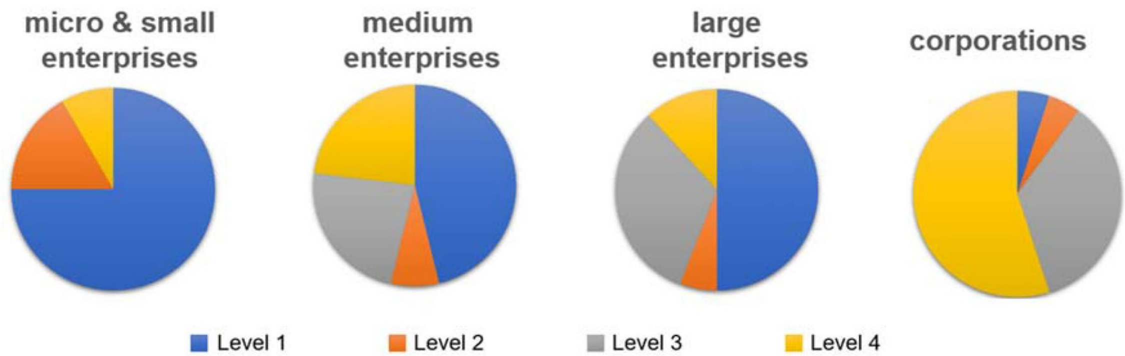


Fig. 5 Offer Portfolio for the different company categories

companies in this subgroup. On average, these companies employed 489 employees and had an annual sales volume of 93,2 million €. The second subgroup, made up of large-scale enterprises (corporations) with more than 1000 employees, making up 20 companies in total. On average, these corporations employed 6.100 employees and had an annual sales volume of 1,2 billion €.

When ranging the companies according to their number of employees, a clear correlation between company size and Industry 4.0 maturity level was observed: While offerings at the highest level could be found in any subgroup, the number of large companies offering data-based services was much higher than that of small companies (see Fig. 4).

Figure 4 also illustrates that this correlation trend has a high range of variation. Even some small or micro enterprises were found to offer products and services with a high Industry 4.0 maturity level. Still, the overall correlation between company size and maturity level is positive. So, when it comes to the ability to develop new, data-driven products and services, size does matter.

2.3 Detailed view on maturity level in product portfolio

When looking at the different company sub-groups, the distinction discussed above became even clearer: For micro and small enterprises, 75% of all companies with digital offers stayed on level 1, thus offering products and services based on classical technologies with local applications only. In the same group, only one company offered data-driven services, thus exhibiting the highest maturity level. On the other side of the size scale, many mature offerings could be found. More than half of all large companies with more than 1000 employees had data-driven product and service offerings at maturity level 4, and almost the same number of companies showed offerings at level 3. Maturity levels 1 and 2 are very rare among this subgroup. Very often, small and medium-sized companies (as per EU definition) are described as the backbone of the German economy as well as a key driver for innovation and technological progress [34].

Several research and funding lines as well as further support is guided towards this group of companies [35]. When looking at the maturity level of the data-driven offerings, this innovativeness can be seen: More than half of all companies from this sub-group had offerings of maturity levels 3 and 4 in their portfolios, with an almost equal split between these two. In this respect, SMEs had an even more mature portfolio than the next group of larger companies ranging from 250 to 1000 employees (Fig. 5).

2.4 Product portfolio in high maturity levels

Services based on IoT and data can take many forms. A navigation model of the St. Gallen University differentiated 66 patterns and more than ten different offerings in the area of Equipment-as-a-Service alone. These range from the service-based provision of software or consumables to hardware components, and equipment or even a complete fleet [36].

The companies under scrutiny in level 4 offered a comparable wide range of services: While Equipment-as-a-Service certainly is the most prominently advertised and discussed in many publications, the overall number of this pay-per-use offer was comparably small (33%) in comparison to performance packages (~60%). At the same time, Software-as-a-Service was often found even with company offerings on maturity level 3. It became clear that the offer of equipment, i.e. machinery on a per-use base, highly depended on the complexity and exchangeability of the equipment, or its opposite–the customer's level of specification. Generally speaking, companies offering machines that could be more easily exchanged and transported (compressors, lathes, etc.) are more likely to finance on a pay-per-use basis. On the other hand, even for highly customer-specific equipment, performance enhancement and other services could be offered as-a-service.

While this market study gave an overview of what was on offer, we wanted to understand how the fast movers with a high level of Industry 4.0 maturity conducted their data-driven services and products. Thus, we analyzed these few companies in more detail, which will be discussed in the next chapter.

3 Detail analysis of fast movers

In the following chapter, we present the in-depth findings of the analysis of the Fast Movers and subsequent expert interviews. Several findings and patterns had a high number of occurrences, these were summarized in chapter 3.3 as conclusive. Results and expressions with a close relation to the study that were voiced individually are briefly presented in chapter 3.4.

3.1 Design of the study

First, we isolated suppliers of machinery and equipment that provide offerings on the highest digital maturity level, as depicted in chapter 2. Overall, 20 companies could be identified and were thus labeled as "Fast Movers for data-driven products and services". All the companies under examination have been working on these offerings for some time. This resulted in tangible and technically mature offerings as well as extensive experience in designing, developing and selling these products and services. Furthermore, this entailed knowledge regarding stumbling blocks due to own failures and customer feedback. Fast Movers in data-driven products and services could be found among very large companies and corporations, but also medium-sized companies. Thus, size as well as organizational form were not distinguishing features. In their core business as OEMs, all companies under examination had several decades of market presence, reflecting extensive know-how in their respective industry and application.

A positive correlation could be observed between the innovativeness of organizations and their openness to reveal how they approach this. When looking at the Fast Movers, only 3 out of 20 have almost no tangible external image on how they develop data-driven products and services. For the remaining 17 Fast Movers, we analyzed more than 50 publications, such as press releases, articles in industry-related media channels and blogs as well as podcasts. As these are mostly "white literature" without scientific peer-review, we collected them in a separate annex. From these sources, some conclusive patterns arose: the mentioning of customer-integration into the innovation development (75%), the application of agile procedures (65%), the usage of external partners (60%) and mixed teams (55%). To clarify the findings from these sources, we conducted in-depth interviews with eight industry experts. These were either working as directors, vice presidents, or even C-level at the Fast Movers themselves or close business allies and service providers. First, we verified the validity of the patterns one by one, then asked interviewees to rank and prioritize them. In the third part of the interviews, we asked open questions to reveal missing parts.

3.2 Conclusive patterns and findings

Most Fast Movers in this study relied on the same patterns and approaches, especially when looking at organizational issues. The findings can be divided into customer-driven innovation, agile operations organization, mixed teams, partnering and portfolio enhancement.

3.2.1 Customer-driven innovation

A basic differentiation in innovation can be made between the introduction of new technologies and solutions never experienced (push) or the focus on solving existing problems (pull) [37]. In the study, all Fast Movers went for the market pull strategy. Most were familiar with the classic design thinking framework [38] or at least described procedures like this concept.

3.2.2 Agile operations organization

Data-driven products and services depict a software-intensive offer. Thus, all Fast Movers relied on agile organizational structures for product and service development, mostly in SCRUM [39]. Some even admitted to having tried classical, waterfall-like approaches before but found them unhelpful for this kind of development.

3.2.3 Mixed teams

Product and service development in SCRUM requires mixed teams with backgrounds in different IT-related fields to cover all necessary technologies [40], as well as domain experts in the roles of product owners, stakeholders, etc. to guide feature development in the right direction. All fast movers thus deployed mixed teams. While long-term employees with years of experience in the customer domain served as product owners, mostly new hires brought in the necessary technological skills such as software development, IoT and cloud infrastructure. This did not necessarily result in an age gap between these two groups, as experienced software developers often come from other industries.

3.2.4 Partnering

Customer-focused feature development, design thinking, agile development, and software often depicted new skill areas for the fast movers. Thus, external partners with more experience were often brought in to supply these. The way these partnerships were organized ranged from joint development [41] to outsourcing [42] and in some cases even the acquisition of existing companies [43].

3.2.5 Portfolio enhancement

Digitalization and data-driven products and services in the context of Industry 4.0 are often described as "disruptive", e.g. in [44] or [45]. In the classic "The innovator´s dilemma", new technologies often lead to disruption for the market incumbents as new challengers arise from external markets with lesser requirements where cheaper technologies can be developed to a certain maturity before moving into the market in question [46]. Successful fast movers were thus expected to test their technologies in other markets or customers that were not serviceable before. Instead, all fast movers stated that data-driven products and services are an enhancement of their existing portfolio with established clients. They indicated that the necessary trust, close cooperation and domain expertise to develop these new offerings could only be achieved under these conditions.

3.3 Individual expressions

Although the findings in chapter 3.2 were shared by all or at least most Fast Movers, some interesting individual expressions were shared during the interviews that yield additional need for research.

While some Fast Movers spun off separate daughter companies to develop and introduce data-driven services, others integrated this into existing business units. No consensus could be reached as to when or why to choose which way.

Whereas most Fast Movers relied on Design Thinking and customer-focused approaches in their development, some admitted to having started without knowing these methods and later discovered that they worked in alignment with them.

Some experts admitted that the market success of new data-driven products and services heavily depends on the willingness of customers to introduce these new concepts, but in traditional, conservative markets these customers are also slow to converge.

An additional interesting observation was that even though the problems on the customer site might seem similar, e.g. in their operations. But concerning the technological infrastructure and the knowledge level of the workforce involved, these similar problems are not best matched by the same solution approach, thus hampering the scalability of already developed products and services.

4 Organizational and managerial implications

In the interviews conducted in this study, Industry 4.0 Fast Movers mostly described organizational challenges and changes during their development. It can thus be concluded that developing data-driven products and services introduces more organizational challenges than technological ones. This also means that a large number of companies will require additional help to introduce concepts such as Design Thinking, Agile methods or DevOps practices in their organizations. Thus, the capabilities and focus of an organization need to be addressed rather than the technological building blocks for offerings on a higher level of Industry 4.0 maturity. This encompasses training, strategic partnerships and talent selection in hiring processes.

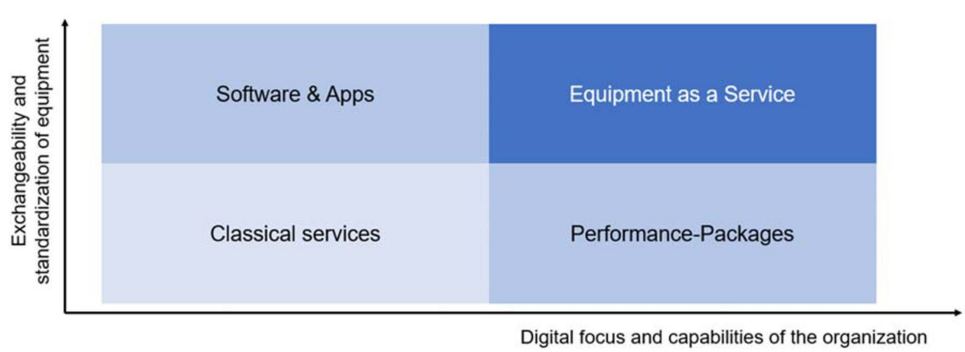
At the same time, the standardization of equipment had a clear influence on the products and services on offer, as scalability on the completely installed base needs to be considered. A consensus among all experts and Fast Mover companies can be found in the fact that only standardized equipment that is transportable can be used for high-level offerings such as EaaS. The risks involved in offering highly customized, non-transferable assets as a service completely negates the positive effects on the side of the OEMs.

Thus, different offerings and services need to be offered by machinery and equipment companies depending on their digital focus as well as the degree of standardization of their equipment, see Fig. 6: When a company is only starting its digital transformation, offering software and applications can make economic sense if a certain market can be addressed through standardized equipment. A digitally focused and capable organization with exchangeable and standardized equipment can offer EaaS. Is the equipment in focus customized or non-transportable, other packages such as performance enhancement should be considered.

Finally, it can be concluded that data-driven products and services in the area of Industry 4.0 require a high degree of domain expertise. Thus, engineers often serve as domain experts, product managers and the like, emphasizing the need for more education of engineering students and re-training for the experienced workforce in this new domain.

Finally, the development of data-driven products and services depicts an unknown area for most equipment manufacturers. This implies a huge uncertainty towards customers expectations, product specifications and service delivery as well as internal structures such as sales and accounting. Thus, developing these new services is a typical example for the applicability of agile methods such as Design Thinking, Minimum Viable Products and SCRUM. As *Grove* pointed out [47], in this type of environment, classical management structures build around individual goals and performance reviews do not work. Thus, in addition to different processes in product development, management tools for goal setting and performance measurement will need to be adjusted. [48] introduced Objectives and Key Results (OKRs) as a methodology to manage and control this type of organization. Introducing such organizational changes in itself will require excessive change management and result in additional efforts and costs to manufacturing companies. While large

Fig. 6 Selecting the most feasible data-driven offerings



companies have been observed to experiment with these structures and management methodologies (see Sect. 3), small and medium sized companies find an additional entry barrier to developing data-driven products and services. This will add on top of technical challenges such as reliability, data security and the like. Overall, research regarding managerial and organizational implications of data-driven products and services is often overlooked. Few authors such as [49] or [50] researched these implications. Very often, entry barriers to Industry 4.0 are perceived as pure technological [51].

5 Conclusions

The market study clearly showed that less than half of all companies in focus are offering data-driven products and services in addition to their core business yet. While some of the Fast Movers are already far ahead in their development, most of those companies with data-driven products and services remain at a lower maturity level. It can thus be concluded that most companies in the German machinery and equipment market are not yet on their way toward offerings in the area of Industry 4.0., even though additional revenues and higher profits might be expected.

This paper also contributes to enriching and expanding the emerging literature on the creation of digital products and services in traditional industries such as machine and plant engineering. Previous studies on servitization such as [52] present key factors in the process of digital product creation such as partnerships, ranging from co-development to outsourcing and even acquisition of existing companies. As well as the implementation of agile co-creation models and the concept of customer-driven innovation. On the other hand, previous studies on the use of agile processes for product co-creation in digital servitization and software such as [53–55] emphasize the benefits of using agile processes in the creation of digital products, as well as including key challenges faced by companies such as the use or creation of mixed teams, customer-driven innovation, cooperation or creation of spin-offs and the expansion of their product portfolio based on customer feedback.

It could be observed clearly that developing data-driven products and services in the domain of machines tools is not purely a technical task, but entails organizational and managerial changes. Most authors especially in the beginning of Industry 4.0 such as [2] or [5] focused on technological advancements and competitive advantages [8]. Even in strategic research outlines such as [4], the topics of organizational and managerial changes were underrepresented. On the other side, this kind of technological focus seems characteristic for the manufacturing companies as well. As [51] showed in a market study, the focus of companies, especially SMEs, in developing data-driven products and services is also technological, putting an emphasis on technological barriers and risks.

Introducing agile methods and management tools again is not suitable for the development of classical mechanical equipment. Yet, it is again best-fitted for data-driven products and services in their early development stage. This can lead to parallel structures for the different kind of products and puts additional strain on manufacturers, as it introduces organizational complexity. Especially for SMEs, this depicts an area of tension and possible conflict. As has been observed especially in the interviews (see Sect. 3), no best practice has yet been established regarding the integration of organizational units focusing on data-driven products and services. While some companies prefer clearly separated business units or subsidiaries, others want to keep the areas of OEM and data-driven business as close together as possible.

Thus, it can be deducted from our research that to help the majority of companies, especially SMEs, that have not yet unlocked their market potential regarding data-driven products and services, more research focus needs to be put on managerial and organizational changes. Frameworks to integrate both agile and classical management tools and methods as well as guidelines to their integration are needed. Additionally, future efforts need to be spent on the implications for company culture: Agile means to fail fast and often, while classical project management and development focuses on not failing at all. The latter is reflected not only in structures and processes, but also hearts and minds, thus depicting a major need to change for manufacturers in the tool and die industry.

Author contributions Eike Permin and Lina Castillo carried out the market analysis and interviews together as well as wrote the main manuscript. Both reviewed the manuscript.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate This research was conducted in accordance to the Regulations for Safeguarding and good Scientific Practice, published by the TH Köln in 2023 and aligned with the Good Research Practice of the Deutsche Forschungsgemeinschaft DFG. The need for written approval of the ethics committee of the TH Köln–University of Applied Sciences–was waived based on the self-assessment guidelines and tool. Informed consent to Participate and Consent to Publish were obtained from all participants, none of which was under the age of 18.

Competing interests The authors declare no competing interests.

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