

# The struggle of sensor-based digital servitization: analysis and perspectives for organizational digital transformation in SMEs

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## Abstract

**Purpose** – The organizational digital transformation (ODT) in companies presents small and medium-sized enterprises (SMEs) – who remain at the beginning of this transformation – with the challenge of offering digital services based on sensor technologies. Against this backdrop, the present paper identifies ways SMEs can enable digital servitization through sensor technology and defines the possible scope of the organizational transformation process.

**Design/methodology/approach** – Around 21 semi-structured interviews were conducted with experts from different hierarchical levels across the German manufacturing SME ecosystem. Using the Gioia methodology, fields of action were identified by focusing on influencing factors and opportunities for developing these digital services to offer them successfully in the future.

**Findings** – The complexity of existing sensor offerings must be mastered, and employees' (data) understanding of the technology has increased. Knowledge gaps, which mainly relate to technical and organizational capabilities, must be overcome. The potential of sensor technology was considered on an individual, technical and organizational level. To enable the successful implementation of service offerings based on sensor technology, all relevant stakeholders in the ecosystem must network to facilitate shared value creation. This requires standardized technical and procedural adaptations and is an essential prerequisite for data mining.

**Originality/value** – Based on this study, current problem areas were analyzed, and potentials that create opportunities for offering digital sensor services to manufacturing SMEs were identified. The identified influencing factors form a conceptual framework that supports SMEs' future development of such services in a structured manner.

**Keywords** Digital transformation, SME, Organizational digital transformation, Sensor, Digital servitization, Capabilities

**Paper type** Research paper

## 1. Introduction

Digital transformation (DT) has become both a challenge and an opportunity for companies competing in dynamic markets (Ghosh *et al.*, 2022). Thus, organizations are not limited by digital technology itself but rather by the inability to translate technology into new ways of creating value (Sjödin *et al.*, 2020). Studies have shown that companies seeking to create



digital value in manufacturing sectors must replace 40–50% of the currently installed equipment, particularly around sensors and data mining networks (World Economic Forum, 2019).

Although integrating and using sensors (specifically, sensor technology) is an attractive solution to access data, companies need help with the complexity of the prevailing systems and the heterogeneity of the operating systems (Tantscher and Mayer, 2022). Data is connectivity medium to enable new value propositions for manufacturing companies, fostering opportunities for customer engagement throughout the product lifecycle (Jacobides *et al.*, 2018; Kiel *et al.*, 2017; Müller *et al.*, 2018). Therefore, products are increasingly enriched with data to facilitate emerging data-driven business models and provide innovative services (Ancillai *et al.*, 2023). In this context, it should be noted that data itself does not create value. Instead, value emerges through a process of integration, analysis, visualization and interpretation (Kühne and Böhmman, 2019).

Nonetheless, creating value-added services through increased digitalization is a significant challenge for the manufacturing industry. It is not merely a choice but an imperative for maintaining competitiveness (Raddats *et al.*, 2022). Considering dynamic and highly volatile markets, manufacturing companies must understand and rethink the processes of product and service innovation to position themselves favorably (Chuang and Chen, 2022; Visnjic *et al.*, 2016).

The focus of this analysis extends to small and medium-sized enterprises (SMEs) characterized by having fewer than 250 employees and a revenue of less than EUR 50 million (Federal Foreign Office, 2020). The decision to analyze SMEs was partly due to how the existing literature has predominantly centered on digital servitization within large-sized companies. This bias can be related to the perception that SMEs often seen as followers rather than early adopters of digitalization, face higher risks and resource constraints when undertaking DT initiatives (Paschou *et al.*, 2020; Shen *et al.*, 2023). It is important to emphasize that SMEs are predominant in many economic areas, constituting over 99.4% of all companies in Germany and 99% in the European Union (EU), particularly in the service and manufacturing sector, thereby making research indispensable (Bettiol *et al.*, 2023; Commission of the European Communities, 2003; European Commission, 2022, 2023; Statistisches Bundesamt, 2022a, 2022b).

The fundamental organizational transformation processes to realize digital services are vast and complex. They often require multiple organizational changes, including business processes, work practices and new knowledge and capabilities (Baines *et al.*, 2009; Queiroz *et al.*, 2020; Sjödin *et al.*, 2020).

In order to describe this transformation process, this study uses the term “organizational digital transformation” (ODT), which refers to a strategic intervention aimed at improving an organization’s digital capability to enhance its processes, services and business models in line with the framework proposed by Mhlungu *et al.* (2019). Furthermore, the study addresses the concept of digital servitization, which has attracted significant attention in recent research (Chuang and Chen, 2022; Gebauer *et al.*, 2021; Raddats *et al.*, 2019; Shen *et al.*, 2023). The term combines the two megatrends of digitization and servitization. It characterizes the expansion of the service business of traditional product-oriented companies with the help of digital technologies to analyze data and realize competitive advantages (Baines *et al.*, 2009; Gebauer *et al.*, 2021; Lamperti *et al.*, 2023; Vandermerwe and Rada, 1988).

In this context, the interplay between these two paradigms must be recognized as they collectively shape the business strategy. It reflects a strategic shift in business paradigms where companies not only embrace DT internally but also use these digital capabilities to enhance their external service offerings through digital servitization, thereby redefining their competitive positioning in the market (Chirumalla *et al.*, 2023).

Digital servitization in SMEs aims to pursue long-term success and maintain a competitive advantage (Cutolo and Kenney, 2021). However, most SMEs still need a digital strategy in place and a plan to implement one in future (Bouncken and Schmitt, 2022; North *et al.*, 2020). One fundamental research gap is the need for an in-depth understanding of the process of business model transformation in SMEs (Dörr *et al.*, 2023; Lamperti *et al.*, 2023; North *et al.*, 2020). For example, it remains unclear how SMEs can effectively identify new service offerings and develop the capabilities required to deliver and integrate these services into their existing (product-focused) business model (Iriarte *et al.*, 2023).

Therefore, this paper aims to provide opportunities for SMEs to enable digital servitization through sensor technology. As a first step, it is necessary to understand the difficulties SMEs face regarding sensor technology as a driver of digital value creation in a data-driven economy (Verhoef *et al.*, 2021). Second, the conditions and perspectives of ODT must be assessed to identify opportunities and ways to overcome difficulties and thus enhance competitiveness (Mhlungu *et al.*, 2019; Wu *et al.*, 2023). Accordingly, a qualitative research approach was chosen to systematically and comprehensively explore the relationship between digital servitization and ODT, focusing on facilitating factors of digital servitization in SMEs. The following research questions (RQ) were defined:

*RQ1.* What are the impacts of digital servitization for SMEs, and how can SMEs manage the transition from product-oriented to service-oriented value creation?

*RQ2.* Which influencing conditions need to be considered for ODT in this context?

The paper analyzes action areas and recommendations for SMEs to develop sensor-based digital service activities in order to shed light on the relationship between digital servitization and ODT.

## 2. Theoretical underpinnings

### 2.1 Organizational digital transformation

According to Mhlungu *et al.* (2019), ODT is defined as the strategic intervention that enhances digital organizational capability, which in turn improves an organization's processes, services and business models to the satisfaction of its customers. Due to ODT being a strategic rather than a technical issue, a clear strategy for the adoption and use of digital technologies and services is critical to enable future business success (Mhlungu *et al.*, 2019). Several studies have indicated organizational structure, culture and customer centricity in improving customer experience and customer service as significant factors for ODT (Ramírez-Durán *et al.*, 2021).

The challenge for companies is to strive for the functionality and effectiveness of technologies and service offerings to enable shared value creation for all stakeholders within the ecosystem (Winby and Mohrman, 2018). To successfully implement digital technology and enable interactions between individuals, teams and organizations, it is fundamentally important to understand the complexity of the innovation ecosystem (Pasmore *et al.*, 2019; Piantoni *et al.*, 2023; Winby and Mohrman, 2018). Given the limited resources of SMEs, ecosystems can provide support and opportunities for collaboration to overcome these limitations and restrictions (Benitez *et al.*, 2020a; Ghobakhloo and Iranmanesh, 2021; Toth *et al.*, 2020). It is crucial to consider the role of employees in the organizational transformation and to foster their willingness to learn and openness to change as these are fundamental digital capabilities (Ghobakhloo and Iranmanesh, 2021; Zoppelletto *et al.*, 2020). There is an increasing need for the technical capabilities of employees, such as in software development or in using different digital tools (Brown and Souto-Otero, 2020; Brunetti *et al.*, 2020; Harteis and Goller, 2014; Sousa and Rocha, 2019b).

However, as a design element, the human factor is rarely considered in the planning and implementation of digital strategies in practice. It needs to be more represented (at best) in current Industry 4.0 research (Neumann *et al.*, 2021). Therefore, DT in general and the human factor in particular should be anchored in the strategic alignment of organizations (Oppl and Stry, 2019; Sinha and Fukey, 2021; Trabert *et al.*, 2022). Highlighting the added value for the entire company and demonstrating the benefits of technologies and services is crucial to achieving high employee engagement (Agostini and Nosella, 2020; Mukherjee *et al.*, 2018).

In summary, ODT refers to using digital technologies to transform organization's internal processes, systems and culture and consequently improving its performance, competitiveness and agility (Burchardt and Maisch, 2019; Troise *et al.*, 2022). Digital servitization, on the other hand, relates to the use of digital technologies to offer value-added services that complement a company's core products (Gebauer *et al.*, 2021). In other words, ODT is a broader concept that includes digital servitization as a potential application of digital technologies (Tronvoll *et al.*, 2020).

## 2.2 Sensor-based digital servitization in SMEs

As mentioned in Section 2.1, strategic service orientation is essential to product-centered markets (Mhlungu *et al.*, 2019; Saarikko *et al.*, 2020; Schüritz *et al.*, 2017). Digital servitization refers to the transformation toward offering digitally enabled advanced services that are directly linked to manufacturers' products (Chuang and Chen, 2022; Gebauer *et al.*, 2021). The interdependencies of ODT and digital servitization are crucial for success (Gebauer *et al.*, 2021; Satzger *et al.*, 2022; Tronvoll *et al.*, 2020).

In particular, technology-oriented SMEs with a product-centric mindset explore a transition that requires a series of changes regarding technologies, processes, human capabilities and offerings to create value (Kolagar *et al.*, 2022; Kowalkowski *et al.*, 2022; Peillon and Dubruc, 2019).

Evolving digital servitization demands an information and communication infrastructure as the backbone of the process, enabling the extraction of data, which is a key resource in the value-creation process (Dong and Yang, 2020; Mukherjee, 2018). SMEs face technological challenges (e.g., missing sensors) in obtaining data about their products (North *et al.*, 2020). One possible method for preparing existing machines to mine data and thus enable digital servitization is retrofitting: Existing machines, referred to as legacy equipment, can be upgraded by integrating sensors to support the transition towards Industry 4.0-capable shop floors. Hence, it can extend the lifecycle of machines in a feasible, time-saving and low-investment way (Jaspert *et al.*, 2021). As such, retrofitting allows SMEs to integrate digital solutions into their existing infrastructure, thus enabling access to shop-floor data without costly and disruptive equipment replacements (Javaid *et al.*, 2021). This approach empowers SMEs to stay competitive while minimizing the financial barriers associated with DT (Alqoud *et al.*, 2022). Furthermore, the replacement of working legacy equipment with Industry 4.0-capable machines to withstand the DT is also questionable from the perspective of sustainability (García *et al.*, 2022).

Selamat and Windasari (2021) argued that a deeper understanding of customers' needs and processes is essential for creating the value proposition of complex services. Close customer relationships can be helpful in this process, as customers would be more willing to provide data and information. Hence, it is necessary to clarify and redesign existing processes and workflows to pivot toward digital servitization strategically (Alkhatib *et al.*, 2019; Khan *et al.*, 2016; Martinelli *et al.*, 2021).

## 3. Methodology

### 3.1 Research design and data collection

Due to the nature of the RQs and the explanatory focus of this research, a qualitative approach was deemed beneficial considering the conducted expert interviews (Bluhm *et al.*, 2011; Corbin and Strauss, 2015).

In order to ensure a valuable dataset, a sample was composed of existing contacts from the research project’s cooperation partners. Therefore, German high-tech manufacturing companies, as well as innovation and software consultancies, were selected to consider a holistic view by analyzing the cross-value-added ecosystem (Garzoni *et al.*, 2020). On the one hand, manufacturing companies work with machines and enable access to sensors and data collection. Conversely, consultancies help address SMEs’ lack of resources by focusing specifically on knowledge and strategic approaches. Furthermore, the interviewees were selected from different hierarchical levels within the companies (Langley and Abdallah, 2015). The following selection criteria were applied: (1) employee of an SME in manufacturing or consultancy, (2) active engagement in ODT processes, (3) involvement in sensor selection and integration.

Table 1 below summarizes the sample and dataset used. By conducting 21 semi-structured expert interviews, it was possible to gain valuable insights to answer the RQs regarding complex social and organizational phenomena (Qu and Dumay, 2011). The qualitative data enabled a deeper understanding of digital servitization in SMEs because it was possible to capture the opinions and perceptions of the interviewees on a complex topic (Eisenhardt and Graebner, 2007). The interview guide was derived from relevant scientific literature, which is vital for developing a theory (Corbin and Strauss, 2015).

3.2 Data analysis

The data were analyzed with the help of the Gioia methodology, which can aid in closing research gaps and deriving new theories (Gioia *et al.*, 2013). An interpretive approach supports the aim to extend and draw on existing theories (Suddaby, 2006b).

A pattern-inducing technique was applied by gathering qualitative data, clustering interview segments into meaningful themes and making sense of these categories (Corbin and Strauss, 2015; Gioia *et al.*, 2013). Two of the three involved researchers participated in the coding process, so one researcher was able to maintain a suitable distance to provide helpful

**Table 1.**  
Sample and data set of  
underlying research

|  |  |
|--|--|
| Sample and data set                        |  |
| Country                                    | Germany  |
| Industry                                   | Manufacturing industry<br>Innovation consulting<br>Software consulting   |
| Total interviews                           | 21 interviews  |
| Selection criteria company characteristics | 1) Manufacturing companies (~62%) due to access to sensor solutions and data<br>2) Software consulting (~24%) due to bridging the knowledge gap of Information and Communication technology<br>3) Innovation management consulting (~14%) due to establishing value-adding services based on data mining |
| Selection criteria company Size            | SMEs (100%)<br><250 employees and<br>< EUR 50 million revenue  |
| Selection criteria interviewees            | 1) Strategic top-management perspective (~43%)<br>2) Tactical mid-management perspective (~38%)<br>3) Shop floor worker (~19%)   |
| Period of data collection                  | August 2021–November 2022  |
| Total data set                             | 14 h 7 min   |
| Average duration                           | 37 min 34 s  |
| Source(s):                                 | Authors’ own work  |

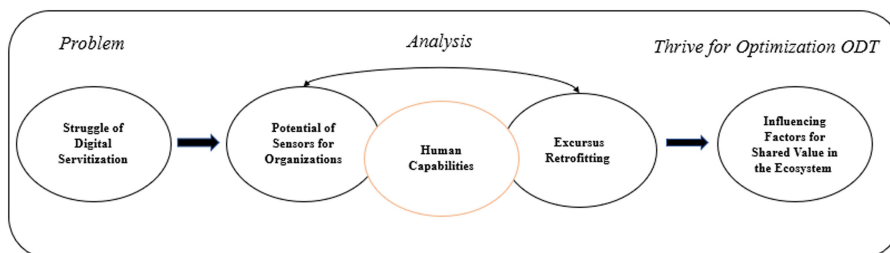
feedback (Crosina and Pratt, 2019; Gioia *et al.*, 2013; Morgan, 2007). Due to the iterative process, the created structure was critically revised by continuously going back and forth between theory and data (Anderson, 2010; Charmaz, 2006; Suddaby, 2006a, b). A three-step approach based on Gioia *et al.* (2013) was used to structure the data. The coding process was organized in three steps: open coding, axial coding and theoretical coding (Hurley *et al.*, 1997; Pratt *et al.*, 2006; Williams and Moser, 2019). Despite its being presented in a linear fashion, the analysis was dynamic and iterative (Suddaby, 2006b). The complete representation of the Gioia structure can be found in the [appendix](#).

In the first step, first-order codes were developed by systematically analyzing similarities and differences between the actual statements (688 codes). Hence, first-order codes evolved more descriptively and were closer to the statements made in the interviews. In total, 577 first-order codes were identified. The descriptive first-order codes were systematically structured through iterations. Second, axial coding was used to group the first-order codes in a more theoretical manner. Hence, 25 second-order themes were developed based on the ongoing iterative process. For instance, the codes “Information so that workers can perform their work optimally,” “Objective data collection to create a common understanding,” or “Increasing the transparency of the process” were grouped into the second-order theme “Process understanding enables optimization.” Third, theoretical coding was applied to create aggregated dimensions. Therefore, the second-order themes were revised based on the underlying data structure. Consequently, five aggregated dimensions were defined: (1) Struggle of Digital Servitization, (2) Potential of Sensors for Organizations, (3) Human Capabilities, (4) Excursus Retrofit and (5) Influencing Factors for Shared Value in the Ecosystem.

#### 4. Results

After generating the aggregated dimensions, it was possible to identify a correlation that enriched the answers to the RQs. It became clear that the identified dimensions were interdependent. The problem analysis revealed that manufacturing SMEs need help with developing service offerings because of the complexity of the technology and offering processes. The factors behind the struggle against digital servitization are diverse and examined in more detail below. While analyzing the potential of sensor solutions for SMEs, relevant aspects demonstrating the added value of technology became apparent. The analysis was conducted by providing a sensor use case around retrofitting. The implementation and operation of sensor technology requires different human capabilities, which link the struggle and potential of digital sensor-based servitization.

Based on the analysis of these perspectives, human capabilities can be interrelated with the factors that influence the ecosystem (see [Figure 1](#)). These framework dimensions can mitigate the problems mentioned at the beginning of this paper. As a result, a conceptual



Source(s): Authors own work

**Figure 1.**  
Analyzing digital  
sensor-based  
servitization within  
organizational digital  
transformation

framework was derived from these findings to enable the development of sensor-based services.

#### *4.1 Struggle of digital servitization*

Based on the coding of the expert interviews, five second-order themes were assigned to the first aggregated dimension. The struggle of digital servitization for SMEs emerged from the following perspectives: First, it became clear that, due to the complexity of sensor offerings in the market, SMEs struggle to find and understand the appropriate sensors, illustrated by quote one:

Quote 1: The challenge mainly relates to mastering and understanding this insane jungle of sensors. (Interviewee 3)

In addition, long delivery times complicate the procurement and implementation processes. Second, it was recognized that data mining generates the added value and not the sensor itself. Third, high costs and efforts are incurred for digital servitization. In this regard, a high upfront investment must initially be made to prepare for the implementation. Fourth, it also became apparent that the companies were struggling with data handling in terms of training employees and consequently, deriving of a company-specific vision to achieve added value from it. Furthermore, it is necessary to understand the customer's pain points to overcome the hurdle of data evaluation to create added value. Lastly, the participation of all stakeholders in the ecosystem is necessary for the digital servitization of sensor applications. The stakeholders were highly diverse and required different capabilities from different departments. It was noticed that SMEs must map these capabilities and tasks in the form of one or a few people, thus hindering focusing on digital servitization alongside the day-to-day business.

#### *4.2 Potential of sensors for organizations*

Regarding the second aggregated dimension of the presented structure, integrating sensors into the plant and machinery creates a high potential for organizations. Hence, the following five second-order themes were identified.

First, the collected and analyzed data provides the basis for a more comprehensive understanding of the process involved and thus enables optimization. Second, it was evident that increased transparency supports decision-making in that complex operations can be explained in a simplified way. Sensors provide a basis for objective data, which increases understanding and replaces decision-making based on gut feelings. Third, sensor technology provides relief for employees. Due to the increased transparency and process optimization, non-value-adding work can be identified, eliminated, or automatized. These results can lead to more comfort for the employees. Fourth, combining digital technology and increased process transparency can help identify new business models, such as increasing energy efficiency services or predictive maintenance. Fifth, in summary, sensors can be used as a tool for strategic enrichment. Key performance indicators (KPIs) can be defined and checked in the production network to measure and determine the progress or degree of achievement regarding important objectives or critical success factors, which leads to more reliable cost calculations. As a result, it is possible to offer more suitable services to the customers, as illustrated by the following quote:

Quote 2: It can be a tool, a decision-making aid, to find strategies, to readjust strategies, to build business models, to optimize business models, to optimize internal processes. So, sensor technology is simply a tool for gaining knowledge everywhere in an operational and strategic business, which ultimately supports me to develop my strategy in a business model accordingly, to realign it, to automate processes. (Interviewee 11)



#### 4.3 Human capabilities

As presented in the Gioia structure, human capabilities—including the following four second-order themes—are an essential factor for ODT. First, IT knowledge and its applicability are essential, which refers to programming skills, working with databases and analyzing data. As the implementation of new technologies depends on the use case, it is necessary to understand how these solutions can be scaled. Furthermore, it is essential to interpret and derive decisions from the results obtained. Second, all stakeholders must strive for further progress to facilitate positive development. In summary, a development with the market and its demands is required. Third, an understanding of and experience with digital technologies are essential in this context. However, the training of employees is insufficient for long-term success (see Quote 3). The willingness to acquire new knowledge and experience is a crucial factor.

Quote 3: And for this understanding, this experience, all parties involved still need to develop much more in the long term. (Interviewee 5)

A general sense of how technology works is important for understanding how measurement data is generated. Finally, ODT relies on interdisciplinary perspectives and employee capabilities, i.e., a cross-section of technical professions combined with management skills to create a vision of added value.

#### 4.4 Excursus retrofitting

The interviewees commented on the sensor-based use case of retrofitting. Retrofitting describes integrating of new technologies (especially sensors) into existing legacy equipment to extend the life cycle of existing machinery (Jaspert *et al.*, 2021). The following second-order themes were defined. First, the interviewees explained that only some solutions fit all retrofitting approaches. Moreover, there is a high need to manage complexity, which refers to such technological and infrastructural constraints as accessibility and space in machines or a variety of signals. Complexity also relates to the concentrated definition of the problem in line with the use case. Second, the possibility of gaining knowledge and experience without purchasing new machinery is an advantage of retrofitting. Iterative tests can enable an understanding of the system and the gathering of experience. Third, the implementation and overall retrofitting can be cost-intensive due to the system's complexity. Therefore, cost-benefit calculations for weighing the effort are essential for every project. Fourth, all stakeholders must be integrated into the process to be successful. Hence, it is recommended to achieve awareness within all levels of the hierarchy by promoting progressive thinking and showing added value. Lastly, thriving flexibility is an advantage of SMEs that can be promoted by retrofitting. Flat hierarchies facilitate the starting of retrofitting projects and gaining the above-listed advantages. Furthermore, it is tough for SMEs to survive in a highly volatile and competitive market without flexibility, as the following quote demonstrates:

Quote 4: [...] but SMEs also live from their flexibility, from this: 'I am going to do something in a hurry to get rid of this in the short term, but to eliminate activities where I cannot find any more people to do it anyway. (Interviewee 12)

#### 4.5 Influencing factors for shared value in the ecosystem

The factors influencing shared value in the ecosystem were assigned to the fifth aggregated dimension. First, the standardization of interfaces between companies is an essential factor. Thereby, it is possible to enable certified data exchanges with the ecosystem, which still needs to be created. The "Plug and Play" idea was expressed as a vision that would expedite the integration of sensor applications. Second, companies need to overcome the existing skills



gap. On the one hand, there is a lack of qualified employees. On the other hand, new (interdisciplinary) human capabilities addressing a general lack of experience with the use of sensors are required, such as an understanding of how to evaluate sensor information and select suitable sensors. Third, a functioning network is essential for maintaining the ecosystem idea, i.e., working with startups. In addition, the idea of building a friendly network was taken up as this could result in better supplier-customer relationships. Fourth, the ability of acceptance in combination with understanding represents a significant factor or problem area regarding implementing of new digital technologies. Moreover, the topic of generational change should be considered and skepticism regarding the fear of replacing employees must be addressed. Thus, the mindset of both employees and managers must shift toward being more open to opportunities. The experience in using sensors must be increased (i.e. “just try it out”) to realize the understanding of it. Fifth, the notion that speed increases implementation could be more widely established. If all data were available in a uniform structure for evaluation, processes could be simplified. However, uniform data availability still needs to be universally present at the surveyed SMEs, as time resources were limited in view of the number of employees. Sixth, the existing IT concept is a crucial function, which includes data protection and IT security to ensure that no data is lost in the ecosystem concept. In addition, IT-interfaces must be used to prepare the information in a way that simplifies access and enables uniform communication concepts. As an outlook, artificial intelligence was mentioned as a tool for enabling this process. Nevertheless, the SMEs surveyed were in the initial stage of this process, as each company was developing its solutions. Additional challenges are likely to arise in the future if the idea of shared value is not further pursued in the strategic alignment, as Quote 5 illustrates:

Quote 5: The topic of sensor technology will ultimately have a major impact on strategy development. [...] Because the topic of data-driven thinking and development of business models is taking on an ever-greater focus and is becoming increasingly important. (Interviewee 2)

## 5. Discussion

The discussion is based on the conceptual framework (see [Figure 1](#)). Concerning the first RQ, the results present an in-depth understanding of the process undertaken by SMEs to identify and create new digitally service-oriented values ([Iriarte et al., 2023](#); [Lamperti et al., 2023](#)). Furthermore, various factors influencing the creation of digital value-adding services in manufacturing SMEs were identified. The introduction of sensor technologies triggers these factors. The creation of digital services are multifaceted processes that are influenced by human, technological and organizational factors ([Oppl and Stary, 2019](#)). The results indicate that the surveyed SMEs are aware of the struggle of sensor-based digital servitization but remain in the initial phase of the transformation ([Dörr et al., 2023](#); [Jaspert et al., 2021](#)). This shift results from the fact that digital servitization is not yet anchored in company strategy ([Hess et al., 2016](#); [Oppl and Stary, 2019](#); [Wu et al., 2021b](#)). However, while most companies already have ideas about how to integrate sensor technologies to improve and expand their offerings, there is a lack of knowledge about their implementation ([Frank et al., 2019](#)). The respondents cited the complexity of the technologies available on the market as a major reason for the difficulties in digital servitization. This fact demonstrates the different scales of engagement of SMEs in the available technology ([Götz, 2019](#); [Pfister and Lehmann, 2021](#)). The interviewees clarify that they need to master the complexity and create an understanding of the technology among the employees before the implementation of ODT into the strategy and the alignment of the business models can occur ([Mukherjee, 2018](#); [Tronvoll et al., 2020](#); [Wu et al., 2021b](#)). This approach contrasts with previous studies, which have called for strategy alignment followed by the search for and implementation of appropriate technologies ([Bosman et al., 2020](#); [Sinha and Fukey, 2021](#)).

SME employees have indicated that there is a knowledge gap regarding the handling of the collected data. Likewise, the respondents suggested that it needs to be clarified how to create value-adding services from data. This problem was also mentioned by [Sjödin et al. \(2020\)](#). Limited capacities hinder the companies' ability to focus on digital servitization as the daily business must be served simultaneously ([North et al., 2020](#)). Furthermore, it is essential but complicated to estimate the investment and resulting benefit. Investing in new technologies is associated with high risk ([Buer et al., 2021](#); [Sinha and Fukey, 2021](#)). There is a lack of financial resources to test technologies in several projects. Hence, limited financial resources must be used in a targeted manner to mitigate risks ([Pfister and Lehmann, 2021](#)). Another reason why SMEs are struggling is the lack of transparency. In most cases, the machines are sold, and the manufacturers cannot collect data about their use. Hence, the interviewees highlighted retrofitting as a solution to gain data for already-sold legacy equipment to create more transparency ([Jaspert et al., 2021](#)). In summary, the barriers to facilitating digital servitization in SMEs are complex and must be considered in a structured process so that small steps can be taken toward ODT ([Buer et al., 2021](#); [Ramírez-Durán et al., 2021](#)).

The second RQ aimed to identify conditions that need to be considered for ODT in SMEs. Consequently, the perspectives that influence ODT in organizations were examined. In essence, ODT is more of an organizational than a technological issue ([Mhlungu et al., 2019](#)). Without a sufficient change in operations and learning, organizational performance has less of an impact on ODT ([Matt et al., 2015](#); [Mhlungu et al., 2019](#); [Tabrizi et al., 2019](#); [Wu et al., 2021a](#)). It became apparent that functioning processes and standardization are essential components of digital servitization in terms of making data uniformly available, evaluating and exchanging data and making data comprehensible ([Pasmore et al., 2019](#); [Winby and Mohrman, 2018](#); [Wu et al., 2021a](#)). This is possible when proceeding in the direction of shared value creation. Thus, data exchange can be pursued in a cross-company ecosystem ([Winby and Mohrman, 2018](#)). Accordingly, it needs to be more thoroughly considered in the strategic alignment of organizations ([Oppl and Stary, 2019](#)). Ultimately, the change associated with introducing new technologies should not be viewed as a one-time event but rather as a continuous process ([Winby and Mohrman, 2018](#)). Essentially, more activities regarding continuous change and adaptation must be conducted by SMEs in order to heighten their capacities to quickly respond to the realities of the marketplace ([Benítez et al., 2020b](#)).

Based on our results, SMEs encounter difficulties adapting to changing market conditions in time because the interfaces with necessary stakeholders still need to be created. These activities are executed mainly by one person due to a lack of resources.

Given the under-representation of the human factor in Industry 4.0 research ([Neumann et al., 2021](#)), interdisciplinary human capabilities, in addition to digital ones, are essential. These findings are congruent with the existing literature ([Crupi et al., 2020](#); [Sousa and Rocha, 2019a](#)). Indeed, within the context of SMEs, where human resources are often limited, we found that these capabilities typically relate to a single individual.

Furthermore, the development of digital services requires not only technical capabilities but also economic ones to establish them in the market ([Soluk and Kammerlander, 2021](#)). Many SMEs continue to rely on the experience of their workforce, highlighting the importance of subjectivity in strengthening SME resilience ([Sgarbossa et al., 2020](#)). In essence, fostering a culture of continuous learning is highly relevant for preparing for future challenges ([Schwarzmueller et al., 2018](#)). For example, such a culture can mitigate people's fears of change and provide them with new perspectives to ultimately improve interaction with technology – a finding confirmed in the existing literature ([Ghobakhloo and Iranmanesh, 2021](#)).

According to [Golan et al. \(2020\)](#), the interplay between people and technology is based on psychological readiness and employee motivation to increase the speed of technological

implementation. A functioning network of partners is required to master problems in the ecosystem. Hence, it is important to have a deep understanding of the general demands of the customer and the ecosystem (Winby and Mohrman, 2018). However, there is a close relationship between ODT and digital servitization. To effectively implement digital servitization strategies, companies often need to undergo organizational changes and transformations that are part of ODT (Mhlungu *et al.*, 2019). Companies should develop capabilities in data mining to offer value-added services and restructure their processes to support their delivery (Ghobakhloo and Iranmanesh, 2021; Zoppelletto *et al.*, 2020). ODT and digital servitization may be conceptually distinct but are closely related in practice. They often work in tandem as companies seek to leverage digital technologies to transform their operations and business models (Tronvoll *et al.*, 2020).

## 6. Conclusion

### 6.1 Theoretical implications

The proposed framework offers theoretical recommendations illuminating the current requirements and problems of digital servitization for SMEs. Furthermore, the framework answers the call within the existing literature for an in-depth understanding of the conceptualization and planning processes for digital servitization and value creation (Iriarte *et al.*, 2023; Lamperti *et al.*, 2023). Given the limited human and financial resources of SMEs, they must open up to the implementation of such complex servitization activities (North *et al.*, 2020). Finally, SMEs often rely on the experience of their employees. However, the development of capabilities for human-machine interaction is required in order to reap the benefits of digitization (Sousa and Rocha, 2019b). Therefore, the proposed framework provides for overcoming the knowledge gap and managing the complexity, for example, regarding sensor selection (Tantscher and Mayer, 2022). It was evident that understanding ODT and digital technologies is necessary for successfully implementing digital servitization projects. Moreover, it is imperative to highlight the added value of technologies and services for companies to promote and retain (Agostini and Nosella, 2020; Mukherjee *et al.*, 2018). The results emphasize the potential of sensor applications as they support SMEs to focus on sustainable solutions, such as retrofitting (Jaspert *et al.*, 2021). In order to successfully implement connected products and services, SMEs need to think in ecosystems and enable data exchange with other actors via standardized interfaces. Thus, data could be uniformly available, analyzable, shareable and understandable (Pasmore *et al.*, 2019; Wu *et al.*, 2021b). Accordingly, data sharing should be established in terms of a cross-enterprise ecosystem that enables shared value for all stakeholders (Bettiol *et al.*, 2023; Winby and Mohrman, 2018). In the future, SMEs must incorporate this approach into their strategic direction to respond to changing market conditions (Benitez *et al.*, 2020b). In addition, the human factor must be considered as a design element in ODT (Mhlungu *et al.*, 2019; Neumann *et al.*, 2021). This step is necessary because each stakeholder, whether at the individual or organizational level, must be involved to consistently promote ODT, especially in SMEs (Winby and Mohrman, 2018).

### 6.2 Practical implications

The present study has high practical relevance for SME managers and consultants, and it offers concrete recommendations for companies seeking to enhance their business performance through digital servitization. The study highlighted the apparent need to understand ODT and to design digital innovation projects transparently. It was recognized that the use and integration of sensor technology as an essential tool enriches the strategic orientation toward the digital servitization of SMEs. Significant potentials and fields of action were highlighted in the study. In this context, the proactive involvement of customers, as well

as all stakeholders in these projects, is highly relevant (Bettiol *et al.*, 2023; Winby and Mohrman, 2018). Further to the deficits in terms of competence requirements, SMEs may not be able to map the lack of human resources fully (Ramírez-Durán *et al.*, 2021; Soluk and Kammerlander, 2021). It is becoming increasingly clear that interdisciplinary capabilities will play a pivotal role in addressing this challenge in the future (Crupi *et al.*, 2020). Moreover, it was recognized that the role of employees in the design of transformation projects should receive more attention (Neumann *et al.*, 2021). Furthermore, SMEs must focus on expanding ecosystems to pursue shared value creation through partnership networks (Di Minin *et al.*, 2019; Sklyar *et al.*, 2019). In addition, standardized interfaces need to be created to simplify data exchange and further reduce the complexity of servitization projects. The acquired knowledge can be used to improve the process further and to drive sensor-based servitization in SMEs in the future. The presented findings can assist companies that require a structured overview for the use case of sensor technology. The framework also provides an overview of the capabilities needed to achieve digital servitization within the presented use case. Finally, sustainable business opportunities were identified to ultimately boost and optimize the ODT of SMEs through sensor-based digital servitization. The opportunities primarily lie within data analysis to simplify processes and make them more transparent. In addition, sensor technologies represent a lucrative way, especially for SMEs, to modernize existing machines to extend their longevity.

### 6.3 Limitations and further research

The results presented in this paper are subject to certain limitations and require further investigation regarding the following points: First, the sample size of the surveyed companies of  $n = 21$  appears comparatively small. We expect that larger samples will yield more reliable results. Second, the sample was geographically limited to companies in Germany. Exploring other nations that boast many SMEs would likely yield intriguing insights. These include Italy, France and Spain, which have the highest number of European SMEs (European Commission, 2022). An international comparison between different countries would also influence and challenge the results of this work positively. Third, new studies could apply a quantitative framework for validating and strengthening the identified implications. This would require the collection of measurable results over the longer term to facilitate a quantitative comparison. In addition, the transferability of the results should be examined as the companies surveyed are still in the early stages of developing sensor-based digital services. For this purpose, it would be interesting to observe companies over a more extended period and examine the transformation process against the background of the developed recommendations. Finally, it is worth mentioning that SMEs need help to keep up with the pace of change on their own due to their limited resources and the rapid transformation of digital technologies. Therefore, SMEs are advised to focus on ecosystems, as partners can complement their resources, capabilities and technologies to enable digital servitization. Thus, further research should explore how SMEs can successfully build such ecosystems.

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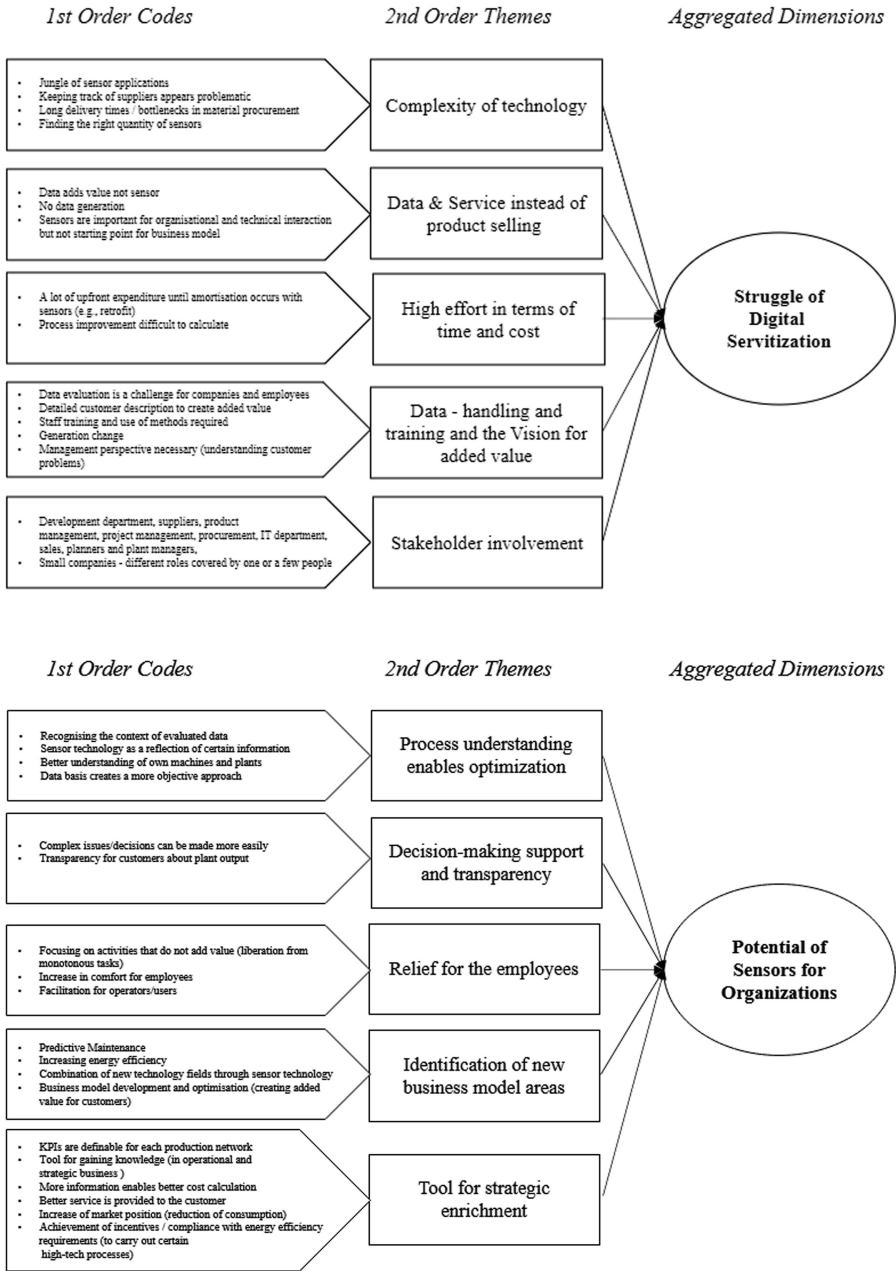
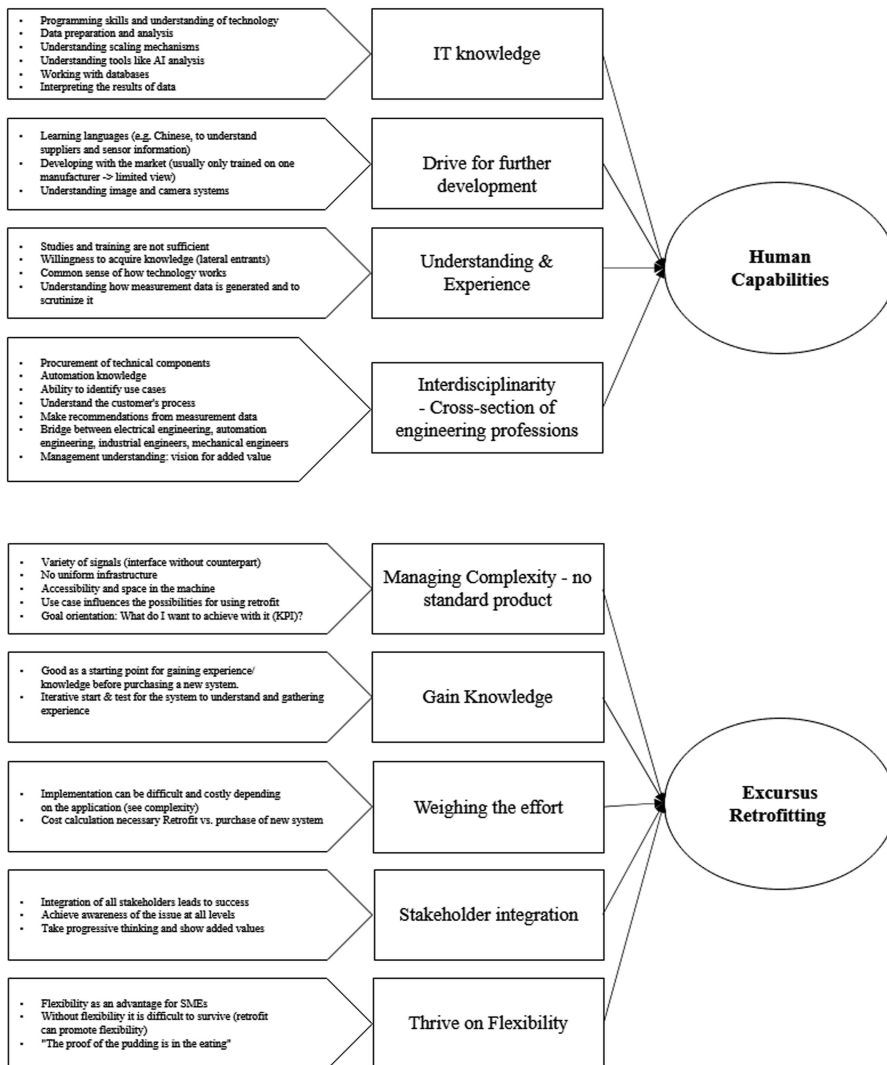
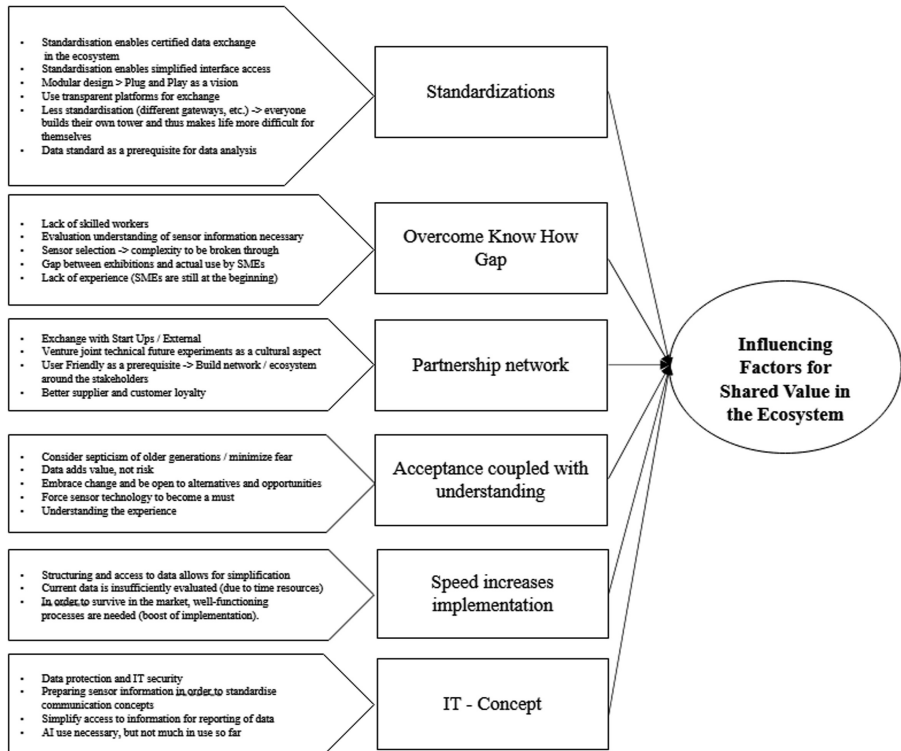


Figure A1.  
Gioia structure of  
research results

(continued)



(continued) **Figure A1.**



Source(s): Authors own work

Figure A1.

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