Innovating Smart Product-Service Systems in Manufacturing SMEs: Current Practices, Affordances, and Constraints

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***Abstract*—How do manufacturing small and medium-sized enterprises perceive and realize the potential of emerging technologies for the innovation of smart product-service systems? We address this question by conducting nine expert interviews with representatives in the manufacturing sector. We apply qualitative content analysis to identify current practices, affordances, and constraints in the adoption of technologies to evolve offerings towards smart product-service systems.**

Building on this inductive empirical approach, we postulate three overarching affordances and four constraints that companies perceive in this process. We conclude by reflecting on applying affordances as our theoretical lens and postulate a multi-level approach to grasp and outline the multi-faceted implications of emerging digital technologies on organizations.

Keywords—smart product-service systems, SMEs, business innovation, digital transformation, affordances

I. INTRODUCTION

The rapid development of digital technologies has pushed today's industrial companies into the so-called 'digital servitization era', transforming the industry, economy, and society on a global scale [1]. Due to technological advancements, the resulting global competition, and changing customer expectations, more and more enterprises are switching from solely selling physical products to providing additional service solutions to their customers [2]. Based on the Internet of Things (IoT) paradigm, big data, and analytics, products are being enhanced by sensors or smart devices to achieve a level of smartness [3]. These enhanced offerings have recently received much attention in academia and industry under the term *smart product-service system* (sPSS).

sPSS can be described as an IT-enabled business solution consisting of a system of smart products and associated services to generate mutual benefit [2], [4]. Further, we define 'innovation' in an sPSS context as the creation of market offerings that result from the use of digital emerging technologies [5]. While large organizations seem to already already this opportunity, most small and medium-sized enterprises (SMEs) are lagging behind [6]. This is surprising as, in theory, their smaller size should allow for higher agility and flexibility, resulting in a head start when exploring the potential of sPSS [6]. SMEs represent the backbone of every industry and economy worldwide, as they represent 99.6 % of all firms and generate more than 50 % of GDP [7]. However, hardly any systematic work illuminates how SMEs implement emerging technologies for business innovation despite their economic relevance [8], [9]. Instead, research so far has focused on general digitalization issues SMEs face, like their insufficient knowledge of digital technologies or missing capabilities to exploit data adequately [10]. Existing research suggests that manufacturing SMEs struggle to develop integrated systems of smart products and digital services [11]. But the rising customer expectations and the increasing competition of global players force these enterprises to move towards sPSS to avoid the 'commodity trap,' which threatens them to lose their competitive edge when focusing only on improving their physical core products [12]. This transformation is not optional but an externally imposed necessity, however, something that most SMEs might not yet realize [13]. Hence, this work explores the current state of sPSS innovation in manufacturing SMEs. This is reflected in the following research question: *How do manufacturing SMEs perceive and realize the potential of emerging technologies for the innovation of sPSS?*

We conduct a qualitative study with nine semi-structured interviews and apply a qualitative content analysis [14] with inductive category formation to answer this research question. We rely on affordances and, in particular, Strong *et al.* [15]'s affordance-actualization perspective as a theoretical lens, considering both technological features and organizational capabilities and conditions. Looking for motivations and barriers to innovate sPSS, we identify three distinct affordances and four constraints for SMEs. Our work contributes to understanding how organizations–and particularly SMEs–adopt emerging technologies for business innovation. Our results highlight the interplay between technology potential and organizational factors, such as goals, skills, and capabilities for developing sPSS as a type of business innovation. Thus, this study lays the foundation for providing targeted support to SMEs in their innovation processes. It may serve as a theoretical base for further research to develop strategies, methods, and tools required for SMEs to master digital innovation and transformation.

The remainder of this paper is structured as follows: Section II provides an overview of the existing literature on sPSS and affordances. Section III describes our research method, followed by the presentation of results in Section IV. Section V concludes the article by outlining the implications and limitations of our study and opportunities for future research.

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II. FOUNDATIONS

In this section, we provide an overview of smart product-service systems, their innovation potential, and related work in the context of SMEs. Further, we introduce the idea of affordances that guides our research as a theoretical lens.

A. Innovating Smart Product-Service Systems

First coined by Goedkoop *et al.* [16], the concept of product-service systems (PSS) was introduced as a system of products, services, networks of players, and supporting infrastructure that continuously strives to be competitive and satisfy customer needs. Soon, this notion was adopted as a new strategy to shift away from pure product selling and, thus, differentiate from competitors [17]. In a PSS, a product or tangible commodity becomes the boundary object for the interaction between a service provider and service customer to network resources and align activities [18]. Further, 'service' in this case can be defined as the application of resources for the benefit of others with an economic value [19].

In today's connected world, smart products offer capabilities such as remote access and control, and allow the innovation of a wide range of service offerings [18], [20]. Typical technical features are sensors, data storage and processing, actuators, interfaces, and connectivity [18], [21]. These increase intelligence by combining monitoring, control, and optimization capabilities to increase autonomy [22]. Further expressions of smartness are self-organization, context awareness and the proactivity of the system [23]. To highlight the increasing importance of value-adding service offerings, so-called '*smart* product-service systems' (sPSS) recently gained popularity among scholars in various disciplines (e.g., technology & innovation management, production, or information systems) [2]. In our work, we define sPSS as "an IT-enabled business solution consisting of a system of smart products and services to generate a mutual benefit" [2], [4], [24].

Despite the pervasive research on sPSS, the available knowledge about the concept yet seems insufficient [25]: only a few fully comprehensive and overarching literature reviews have been conducted that have drawn different conclusions, with many issues remaining unresolved [2], [26]. Other works study the pitfalls of smart service systems and reveal that the methods available are "too complex, fragmented and time-consuming" [27, p. 115] and hence are "over-engineered [and] overwhelmingly cumbersome to use" [28, p. 378]. To address this increasing complexity, an updated methodological approach for sPSS innovation is required [27], and future research on sPSS should focus on easy-to-use toolboxes of "loosely coupled means" [29, p. 14].

SMEs form the "backbone of every industry and economy around the world" [9, p. 2] and are the driving force of many manufacturing economies [30]. But even though innovating sPSS is a challenge for enterprises of all sizes, it seems particularly difficult for SMEs, as the existing knowledge on sPSS innovation is "mainly focused on large enterprises rather than on SME[s]" [8, p. 1130]. Research on sPSS innovation in SMEs remains scarce, and current methods are "not directly adaptable for SMEs" [31, p. 2326]. Existing articles in this context indicate that SMEs differ significantly from larger enterprises. Because of their distinct characteristics, such as their smaller size and limited resources, they must overcome specific challenges, e.g., the lack of specialized personnel or missing data expertise [8], [9].

B. Affordances (of Emerging Technologies)

Originating from the work of Gibson [32] on affordances, goal-directed actors do not perceive objects as a set of characteristics or material features. Instead, they perceive how an object can be used (i.e., what it 'affords' the actors in terms of action possibilities for goal-oriented behavior) without requiring a cognitive analysis of it [32], [33]. For example, a reasonably sized chair affords a human the possibility to either sit down or reach something on a high shelf (according to her objectives) without depending on the conscious analysis of the chair's material features (e.g., stability or height) [33].

'Affordances' can be used as a lens for looking at various IS topics [34]. However, some key aspects should be considered when applying affordance theory to explore how IT artifacts are perceived and used by an individual or organizational actors: first, affordances constitute in the relationship between technology and its user–and not in the technology itself [33]. Thus, a technological artifact has not any affordances except concerning an actor with a set of tasks and goals [15], [33]. Second, affordances should be used to describe possibilities to act–not performed actions, objects, or states [15], [33]. In contrast, the actualization relates to the exact behavior making up the action [15], [33]. After realizing an affordance through actualization, an 'immediate concrete outcome' can be reached [15]. When applying the theory, many related frameworks have been presented and used (e.g., functional affordances [35], [36] or technology affordances and constraints [37], [38]). In this study, we take an affordance-actualization perspective introduced by Strong *et al.* [15] (Fig. 1).

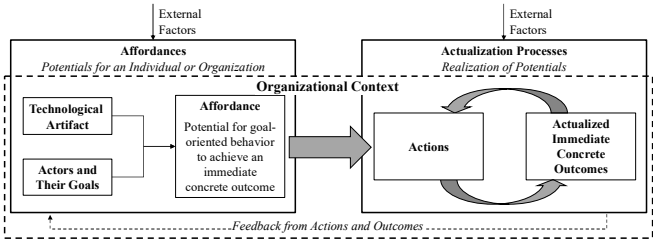

Fig. 1. Affordance-actualization framework, based on Strong *et al.* [15].

More recently, academia introduced the affordance lens to the academic discussion on smart products, services, and sPSS. While Knote *et al.* [35] use functional affordances to study value co-creation through and with smart personal assistants, others examine affordances in a rather IoT-driven context [39], [40]. Both apply a similar research design to identify affordances. Yet, they draw different conceptual conclusions: Naik *et al.* [39] identify three different types of affordances, and thus, a "step-by-step mechanism through which the IoT creates organizational outcomes" [39, p. 240]. In contrast, Heinz *et al.* [40] focus on their observation that a smart product's distinct features allow multiple actors to perceive and realize affordances at once.

As we discuss in section V, this study's approach differs from the related studies and considers affordances in a broader context–as Pentland *et al.* [41] suggest. Instead of focusing on certain artifacts, we examine the broad affordances of combined emerging technologies in the context of sPSS innovation for SMEs and inspect constraints that reduce the organization's entrepreneurial scope and flexibility.

III. Research Method

To enhance our understanding of SMEs' sPSS innovation practices, we choose a qualitative empirical study approach. We rely on exploratory expert interviews to gather rich empirical data by revealing and highlighting knowledge and different perspectives of SME representatives. The interviewee is considered a representative of a larger group, in this case of their company [42]. We employ a purposive sampling approach [42] to identify suitable interview partners and collect the underlying data. The sample is limited to minimize cultural differences, and interview partners are specifically sought from manufacturing SMEs in Germany according to the Co-Determination Report No. 64 (i.e., number of employees <2000) [43]. The interviewees are SME representatives in business or technical roles. This includes decision-makers such as managing directors, product and development managers, or similar functions which deal with the consequences of adopting sPSS-related emerging technologies in their daily work.

We follow a semi-structured approach for conducting the interviews. Thereby, we ensure the similarity of the interview structure and the comparability of the results [44]. The interview guideline consists of open-ended questions arranged in 'question blocks' which can be adjusted flexibly and agilely [45]. The eight question-blocks allow us to deep-dive into current innovation practices: motivation, experience, methodical approaches, data competencies, internal and external corporate environment, potential and opportunities, challenges, and barriers as well as specific needs and requirements. Exemplary questions of the interview guideline are: "what potential and opportunities do you see in expanding the product portfolio with smart services?", or "where do you already have sensor data available and are there interfaces to related products?".

Nine interviews are conducted with manufacturing SMEs headquartered in Germany (TABLE I). Each interview is conducted virtually, with audio being recorded under a declaration of consent. On average, the interviews last 57 minutes. The companies were founded between 1908 and 2014, with half of them being either traditional family-owned or -controlled businesses. They offer conventional physical products manufactured in-house from scratch or assemble several components as part of their core business. Most of them operate in the niche segment as component manufacturers. The audio files were recorded and transcribed to serve as the basis for the subsequent data analysis.

We follow a qualitative content analysis approach [14] for iteratively analyzing the interview material. We draw upon the affordance-actualization framework as a theoretical lens, forming a broad set of categories that guide the analysis of the interview material. In addition, we apply an open coding approach to remain flexible in uncovering themes connected to current innovation practices for sPSS. After the initial open coding performed by a single researcher, the second-order coding for categorization is regularly discussed among three researchers. In doing so, we are able to map current innovation practices in SMEs regarding the elements of Strong *et al.* [15]'s affordance-actualization framework and abstract three general affordances and four constraints. We present evidence and representative citations from the qualitative interview data when presenting the results of our analysis in the subsequent section. The computer-aided tool MAXQDA has been used to facilitate the coding process.

TABLE I. Overview of nine interviews with manufacturing SMEs.

Organization	Role	Description	Employees	Duration
IoTCo	CEO	Industrial data, AI, and IoT solutions	28	47:28
LaserCo	Lean Manager	Processing optics for laser machining	120	55:24
ClosetCo	Software engineer	Electrical components and automation solutions	370	95:19
SealCo	CEO	Plastic and sealing components	55	50:06
RoomCo	CEO	Interior Design and fittings	100	47:30
ValveCo	Director R&D and Business Development	Hydraulic valve systems	55	55:12
ToolCo	CEO	Mechanical engineering	18	53:32
FilterCo	CEO	Various filter systems	33	60:08
DriveCo	Head of IIoT & Service	Motors and drive systems	1.000	59:49

IV. Results

Aiming to understand how manufacturing SMEs perceive and realize the potentials of emerging technologies for sPSS innovation, we first present an overview of the current practices in SMEs mapped to the affordance-actualization framework of Strong *et al.* [15]. Second, we discuss the affordances and constraints in detail highlighting three distinct affordances that SMEs perceive when implementing sPSS and discussing four related constraints.

A. Status Quo of sPSS Innovation in SMEs

Technological Artifact. The interviewed SMEs are at different stages of sPSS development maturity and differ in their technical starting position. Most SMEs seem to focus primarily on their purely physical products, with their services being less prioritized add-ons (RoomCo, ToolCo). Five out of nine companies have already integrated technical features related to smartness (e.g., sensors) into their machines or products, enabling them to collect product-specific data and remotely connect to the products or components. However, only two companies offer data-driven services in combination with their smart products in the sense of an sPSS offering. Entirely new product innovation seems infrequent, as products are often just "refined" or "interfaces added" (ClosetCo) and only a few companies have developed or launched new products at all in the last years (ValveCo, FilterCo, DriveCo).

Actors and Their Goals. Manufacturing companies are characterized by their deep technical know-how, as they often operate in niche segments (LaserCo, ClosetCo, ValveCo). Instead of mass production, they have refined their craft over the years and mainly manufacture customized solutions in small batches (e.g., SealCo, ToolCo, FilterCo). In comparison, most of them rate their digital capabilities and experience with digital emerging technologies relatively low (e.g., LaserCo, ToolCo). While digitalization as a trend is nothing new for them and despite being part of their agenda for several years (e.g., LaserCo, ClosetCo, SealCo), the first concrete initiatives and projects to digitalize their portfolio have only recently been launched (SealCo). This indicates that SMEs first focus on digitalizing their internal processes before venturing into digital offerings for their customers.

Currently, SMEs recognize an increasing competitive pressure. As their current practices slowly cease to work, they

still feel compelled to realign their business strategy to "survive" in the future (IoTCo, ToolCo). To achieve their overarching goal of maximizing profit (SealCo, ValveCo), many strive to be among the front-runners in their market segment (ClosetCo). In particular, the addition of digital services is seen as a "differentiator" (DriveCo) that sets the firms' offering apart from others and helps them attract customers by providing added value (e.g., SealCo, RoomCo). By utilizing data, "predictive maintenance" (DriveCo) also becomes a viable solution to retain customers. The SMEs recognize the opportunity to individualize their value proposition by providing courteous and responsive services wrapped around their products. The shift from short-term to long-term planning and the strong emphasis on customer needs make sPSS innovation an excellent lever for SMEs.

Organizational Context. Flat and straightforward organizational structures can be observed in the internal corporate environment. Due to the small and thus more easily manageable number of employees, quick execution is possible (IoTCo, LaserCo). SMEs usually have only a few simple business processes and describe themselves as relatively unstructured (ToolCo), as the planning effort often appears too high compared to the benefits given their "limited resources" (SealCo, ToolCo, FilterCo). While confidentiality and open and direct communication at "eye-level" (LaserCo) ensure strong teamwork within these organizations (ClosetCo, SealCo), efforts are made to involve more employees in the actual innovation processes.

Regarding an existing innovation culture, opinions differ. Some believe that none exists in their organization (ClosetCo). In contrast, others are actively working to establish and promote a culture where employees can contribute their ideas (e.g., ToolCo, FilterCo). Even though the corporate culture is open and supportive, operations are still anchored in traditions, as new ideas usually come from management or are "dominated by sales" (RoomCo). The CEO plays a key role in every SME. Decisions driving new projects are based on the CEOs' personal experience or gut feeling (IoTCo, ValveCo, FilterCo) and projects with management attention seem to be more likely to succeed (e.g., LaserCo, DriveCo). However, according to the interviewees, their management is reluctant to invest resources and often tries to reduce the investments to the bare minimum (IoTCo, ClosetCo, SealCo). Since employees are expected to become increasingly flexible, and many feel overwhelmed, a degree of resistance to new ideas and concepts persists (ValveCo). Many SMEs believe that people are fundamentally inert, stick to their habits, and are reluctant to leave their "comfort zone" (e.g., ClosetCo, ValveCo, ToolCo).

External Factors. Staying in close interaction is relatively easy given the local SMEs and their customers often have (ToolCo, FilterCo). This close interaction strengthens but also forges personal ties between them. However, customer contact takes place primarily through the sales department. Hence, other divisions like research and development or production often learn about new product requirements or specifications too late in the development process, or even only in the production phase (LaserCo, ClosetCo, RoomCo). With remarks lost in transition, this miscommunication often hinders companies' actions and may complicate the actualization of affordances (LaserCo, ClosetCo).

Especially a suitable and well-maintained partner network is crucial, as many respondents believe that cohesion in the industry community is vital (e.g., ToolCo, SealCo, FilterCo). SMEs typically rely on cooperating with partners to adopt emerging technologies as they have neither the capabilities nor the workforce to develop new solutions solely by themselves (DriveCo). Collaboration with smaller firms is preferred as they often face similar obstacles and appear to be more open to sharing best practices to support each other (ValveCo, FilterCo). Yet, finding the right partner is often difficult and tedious (ClosetCo, SealCo, DriveCo).

While the companies are aware of the ongoing change, the quickly changing technological trends are causing uncertainty among SMEs about which will stick and which will not (ClosetCo, ToolCo, FilterCo). The constant fear of being "too slow" (RoomCo, FilterCo) further hinders them from taking initiatives, as they may have "gambled their cards to make money with it." (FilterCo). SMEs continue not only to feel threatened in competition with larger companies, which "dictate" (DriveCo) the market conditions and technical standards but are also unsettled due to the increasing relocation of production abroad (e.g., ValveCo, FilterCo, DriveCo). Finally, companies are forced to respond flexibly to emerging customer needs and adapt accordingly (ClosetCo, RoomCo). DriveCo reports that first customers have asked for sPSS-type solutions. However, this appears to be the exception. Most respondents believe that their customers do not yet perceive or understand the added value of smart solutions. This lack of customer interest and demand discourages the companies from acting (e.g., ValveCo, FilterCo, DriveCo).

Actualization, Outcome, and Feedback Loop. First, it was observed that employees are increasingly encouraged to participate in the ideation process. (e.g., SealCo). Workshops were held with customers to integrate their, understand their actual needs, and provide tailored solutions (LaserCo, DriveCo). Second, before embarking on a large-scale innovation project, the feasibility and associated risks are estimated and the effort by outlining the next steps in a roadmap. For example, DriveCo formed an "innovation steering committee". Third, prototypes are built in the form of a black box or mockup (e.g., ClosetCo, SealCo, ToolCo, FilterCo), and typically, pilot projects are conducted before the actual implementation (DriveCo). Fourth, SMEs often rely on external support in realizing ideas and, thus, enter joint ventures or actively seek funding opportunities (e.g., SealCo, ToolCo, FilterCo). Especially when dealing with digital emerging technologies, they seek advice from IT consultants or join innovation collaborations as part of research projects (LaserCo, ValveCo). As specific expertise must be acquired for implementation, SMEs either outsource it or look for new, qualified personnel. However, given the difficulties with both approaches, most companies are currently also focusing on measures to train their existing staff.

B. Perceived Affordances of SMEs

This article focuses on organizational-level affordances, which arise from technological artifacts' interaction with SMEs, motivated by their organizational goals [16]. The companies were asked about their perceived potentials and challenges when developing and offering emerging technologies such as sPSS. After compiling 32 first-order categories (divided into affordances and constraints), we aggregate these findings to a higher level of abstraction, identifying three affordances and four constraints. The coding structure for the affordances can be seen in Fig. 2.

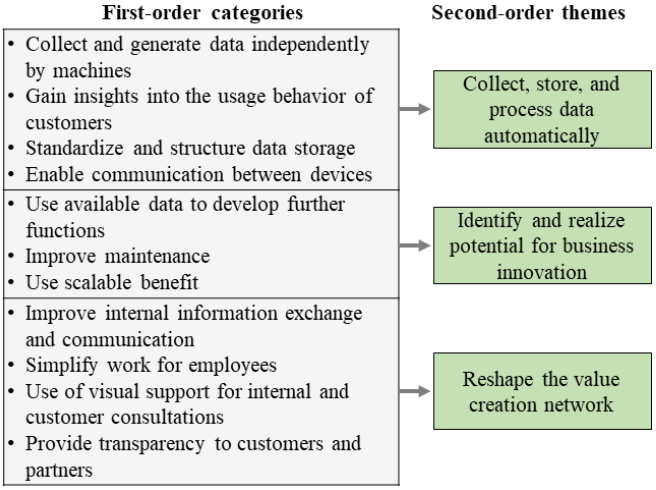

Fig. 2. First- and second-order categories of perceived affordances.

Affordance 1: Collect, Store, and Process Data Automatically. SMEs perceive the affordance to automatically capture, store, and process customer-specific product usage data with the help of smart products. A growing number of products feature integrated sensors, cameras, or other smart components, enabling them to collect and generate data independently (LaserCo). This allows to understand their clients' usage behavior better. Also, "standardized and structured data management" (IoTCo) is seen as a potential, as it makes it easier to evaluate the correct parameters for calibrating machines or allows for a quick implementation of digital solutions (IoTCo, DriveCo, FilterCo). Since smart components form the foundation for devices to communicate with each other, they enable efficient data exchange, the development of software applications, and ultimately, the provision of services to the customer. Every interviewed company perceives this affordance

"We have a lot of data lying around in the project, and we could use it a lot more." (RoomCo)

Affordance 2: Identify and Realize Potential for Business Innovation. SMEs identify and realize the potential for innovation by implementing new products and services. Since adopted smart technologies serve as a "catalyst for many ideas" (SealCo), many companies perceive the opportunity to develop additional functionality based upon the available data (e.g., FilterCo, DriveCo). Thus, procurement, assessment, and maintenance services can be revised to increase customer value (LaserCo, ClosetCo, FilterCo). Furthermore, these benefits are perceived as easily scalable since the services and software often can be rolled out across the entire portfolio (e.g., LaserCo, SealCo, ValveCo). A modular architecture allows for continuously developing and integrating add-ons. Each interviewed company perceives this affordance.

"When a product is developed and ready, making improvements on it is much easier." (ValveCo)

Affordance 3: Reshape the Value Creation Network. Finally, SMEs perceive affordances to reshape their existing value creation network. Smart solutions may enable them to increase internal efficiency and improve their communication and collaboration with customers and partners (LaserCo). Simple off-the-shelf components or easy-to-use programs are suitable for SMEs to create digital features, as they have less expertise and resources to spend (SealCo). Even simple dashboards provide an excellent basis to visualize ideas and visions and convince customers and partners (IoTCo, SealCo, FilterCo). Furthermore, companies see the opportunity to position themselves to their customers as a more open and collaborative partner by providing them with insights into the development process and the prior status in advance (RoomCo, ValveCo, FilterCo). Five out of nine companies perceive this affordance (e.g., ValveCo, FilterCo, DriveCo).

"It would allow us to share information across companies, which in turn would help customers and us to collaborate and optimize the value chain." (LaserCo)

C. *Perceived Constraints of SMEs*

The companies identify great potential in adopting and implementing emerging technologies but name manifold firm-individual barriers that prevent them from actualizing their perceived affordances. Four constraints were identified based on the coding of first-order categories (Fig. 3).

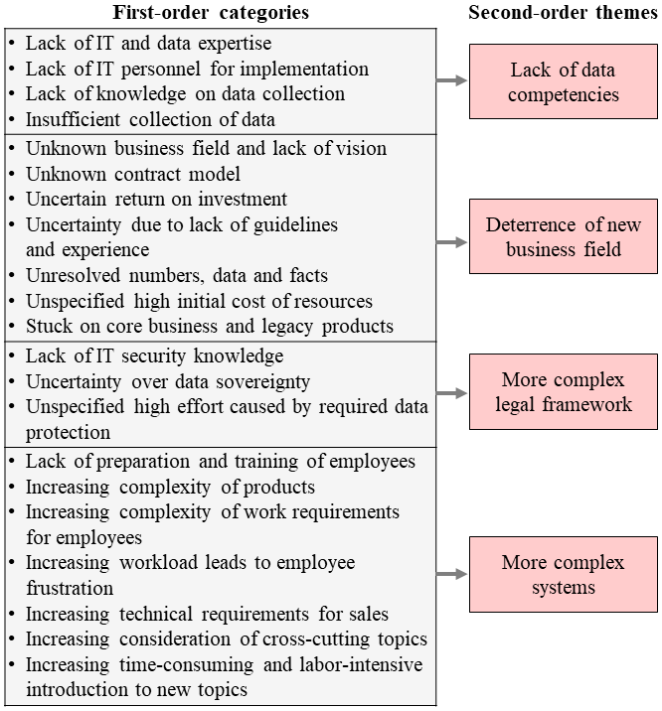

Fig. 3. First- and second-order categories of perceived constraints

Constraint 1: Lack of Data Competencies. Manufacturing SMEs often have little to no experience implementing digital, smart services (ClosetCo). This is because such traditional manufacturing companies do not usually employ specialists having expertise in applying IT in an innovation context. While most of their engineers possess basic IT knowledge, they still need to learn about many more advanced emerging technologies from scratch (SealCo, ToolCo, FilterCo). The missing experience is also reflected in the fact that some enterprises lack knowledge on systematic data collection processes, let alone identifying the correct data they need (e.g., IoTCo, SealCo, FilterCo). Systematic data collection and analysis is a non-intuitive and hard-to-understand process. This process remains a "black box" (FilterCo) that holds many uncertainties and unknowns for the interviewed SMEs. In cases where data could already be systematically obtained, it was also reported that insufficient or even incorrect data were collected (DriveCo).

Constraint 2: Deterrence of New Business Field. Many SMEs lack the vision or understanding of smart products'

innovative potential (IoTCo, SealCo). Further, many are intimidated by the risk of entering a new business field (e.g., ClosetCo, FilterCo), as "figures, data, and facts" are not clarified yet (LaserCo, ClosetCo). Few have already thought about the legal conditions and what kind of strategic business models and partnerships might be possible and most suitable for them (IoTCo, SealCo, DriveCo). Since SMEs have limited resources and managers are already reluctant to spend them, the high and difficult to estimate initial investment costs further discourage them (e.g., LaserCo, ToolCo, FilterCo).

Adding to this uncertainty is the lack of experience in how pricing of such digital solutions might work and what prices can be marketed (LaserCo, ClosetCo). This uncertain return on investment is a significant constraint (e.g., ToolCo, FilterCo, DriveCo), as it is unknown "how far it can be monetized and how far it will fly as a business model afterward" (DriveCo). Companies seem hesitant because they cannot turn to their own experience. They look for guidelines and regulations in the industry, which are not established yet due to the novelty of the subject matter. Therefore, companies concentrate more on their core business and legacy products (IoTCo, ClosetCo) to focus more on their currently reliable revenue source (ClosetCo).

Constraint 3: More Complex Legal Framework. SMEs are confronted with unanswered legal issues related to data sovereignty (DriveCo). It must be clarified who is permitted access to the data and what may be done with it to what extent (ClosetCo). On the one hand, companies partly lack the knowledge on IT security to realize the legal requirements (IoTCo, SealCo, DriveCo) and to ensure a reliable and safe infrastructure in all situations. On the other hand, companies are constrained by the high effort due to the required degree of data protection (RoomCo, ToolCo). Especially processing sensitive data for which specific authorizations are needed for some industries can slow down the flow of work (RoomCo).

Constraint 4: More Complex Work Systems. New smart functionalities and features make the companies' products more complex (e.g., ValveCo, FilterCo). This is mainly reflected in the increased work requirements for their employees (e.g., ClosetCo, ValveCo, ToolCo) as traditional tasks have constantly evolved. With each new product, new demands are placed on the workforce. In addition, companies recently recognized the growing importance of "cross-cutting topics" (IoTCo, SealCo). They are making targeted efforts to drive them forward, as several skills are required across multiple departments.

A particular difficulty in this context is enabling sales representatives to communicate the product-service system's benefits and new functionalities to the customer. Since the advantages of smart products and services cannot always be directly observed or are often intangible, more extensive explanations are required. The requirements are constantly growing, while employees' lack of adequate preparation and training is criticized (LaserCo). Strategic realignments and changes are usually ordered directly and at short notice by the CEO, while employees have little time to adjust to the new requirements (e.g., LaserCo, ClosetCo, ValveCo). Alongside the constantly increasing complexity of tasks, employees are expected to be more flexible (SealCo, ToolCo). Many of them feel overwhelmed and frustrated (e.g., LaserCo, SealCo), and they perceive familiarizing with new topics as particularly time-consuming (SealCo, ValveCo, ToolCo).

V. Discussion and Conclusion

In this study, we set out to understand how manufacturing SMEs perceive and realize the affordances of emerging technologies for the innovation of sPSS. For this purpose, this article presents the key findings from nine expert interviews with manufacturing SMEs. In the previous section, we first draw a general picture of SME-specific circumstances in the context of sPSS innovation. Then, we unveil three broader affordances and contrast these potentials with four perceived constraints hindering SMEs in their innovation process. In this section, we reflect on our findings by pointing out the implications of our research for practitioners, discussing implications and unresolved issues of choosing affordances as a theoretical approach, and finally, highlighting our study's limitations and the consequent potential for future work.

A. Managerial Implications

Several studies have already indicated that SMEs differ from large firms and, thus, their needs and requirements regarding methods and support vary [31], [46]. Our results reveal that familiar SME characteristics also have implications for the context of sPSS innovation at hand.

First, we confirm that SMEs are severely restricted by their limited resources and must act more thoughtfully than larger-sized players. SMEs observe a permanent bottleneck in time and workforce and rely primarily on short-term planning to adapt to the changing needs of their larger-sized clients. Further, they have even more difficulties than large companies in recruiting young and qualified workers, which results in a lack of IT and data expertise. Especially for the innovation and development of sPSS, personnel who can handle and implement the new technologies are needed. On the other hand, SMEs can benefit in their innovation processes from their flat hierarchies and encouraging work culture, which allows their employees to pursue ideas proactively and in a self-determined manner.

Second, SMEs essentially rely on close relationships with technology providers and consultants due to resource constraints. Thus, SMEs require guidance on setting the right priorities in make-or-buy decisions in the context of sPSS innovation to use their available resources effectively. SMEs appear to have a tendency towards openness to mutual support within their sector and among other SMEs, particularly with those companies in their local proximity (e.g., LaserCo, ToolCo, FilterCo). While many large companies seek to protect their innovative edge through confidentiality, SMEs' niche segment orientation allows them agile and more flexible communication and collaboration with their partners (FilterCo). However, the interviewed SMEs often lack guidance in finding a complementary partner that addresses their application-specific needs, particularly in the highly fragmented field of IoT, cloud computing, and others.

Third, a key finding of our research is the importance of top-management support. Strategic decisions such as investing in emerging technologies are typically made by a tiny group of stakeholders around the SME's CEO. To support the decision processes, SMEs require a clear roadmap, assessment of success, and a stepwise agenda to build trust in such technologies and internal capabilities to handle them [46]. Our interviews confirmed that SMEs still highly rely on their wealth of experience in their specific domain. However, as emerging technologies raise unknown questions, they face difficulties in their decision-making processes, which can

impede or slow down technology adoption. SMEs should seek out internal or external "lighthouse projects" of successful innovation to tackle this issue.

B. Theoretical Implications and Unresolved Issues

Existing IS research on affordances provided a functional language and concepts to guide our data collection, analysis, and synthesis. We applied this theoretical lens to examine the adoption of a set of emerging technologies within a group of akin organizations (manufacturing SMEs) to realize the vague goal of becoming a provider of sPSS solutions. Despite the individual context of an organization's digital transformation, we could generalize specific findings for most examined SMEs and thus, provide transferable knowledge. Due to the high relevance of supporting SMEs' successful digital transformation, future research should take the identified affordances and constraints as potentially rewarding starting points for applied research. Such research could, e.g., further unfold the SME-specific success factors while actualizing the presented affordances or provide applicable insights on how to act towards overcoming the typical constraints.

However, our research also unveiled some unresolved theoretical issues while applying an affordance lens, emphasizing recent calls for further conceptualization in this stream of research. In contrast to prior related studies [39], [40] that dealt with early adopters, our interview sample mainly consisted of organizations just at the beginning of sPSS adoption. Therefore, most interviewed organizations have not yet evolved their existing product into advanced smart products as instantiated technological artifacts. Even more, they have not yet been able to take further actions to fully realize the arising potential (e.g., by establishing novel business models or changing the company's strategic position in its ecosystem). Only these concrete potentials (and the future achievable outcomes) could be paraphrased as affordances related to smart products in a narrower sense.

To resolve this issue, we suggest that affordances should also (or instead) be studied on a "macro-level"–considering multiple artifacts, actions, and maybe actors [41]. Only then can research fully grasp the multi-faceted implications of emerging digital technologies on the potential for business innovation and transformation. Our research mainly focused on leveraging emerging technologies in innovating novel artifacts, which ultimately allows achieving an organization's goals (e.g., generating and maintaining revenue streams). This business innovation could either result in products as a novel or adapted market offering ("product innovation," e.g., DriveCo) or artifacts that improve existing internal value-creating activities ("process innovation," e.g., LaserCo).

To illustrate and theoretically embed our research, Fig. 4 suggests a potential extension of existing affordance models (Fig. 1). We incorporate the affordance-actualization processes of technological artifacts ("narrow affordances" and actualization processes) on the right side of the framework. In line with existing frameworks, the "narrow affordances" must be realized via actualization processes to achieve an outcome and realize value. However, on the left side, we add the process of *business innovation,* which we thus define as "realizing the broad affordances of a set of emerging technologies, i.e., their organization-specific potentials for technology adoption, by creating a (set of) technological artifact(s)." Like "narrow affordances," we argue that "broad affordances" are also constituted in the relationship between technology and a socio-organizational actor.

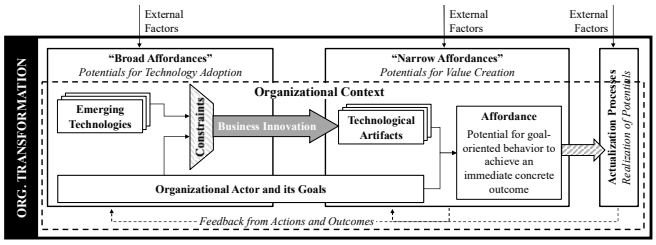

Fig. 4. Broad and narrow affordances in business innovation.

Further, we hypothesize that socio-technical constraints arise from this relationship. These constraints decrease an organization's flexibility regarding innovation and, hence, act as an initial "innovation funnel", reducing the set of potential innovation paths of an organization. Also, we hypothesize that–in parallel to existing conceptualizations of "narrow affordances"–there is another ongoing feedback process so that realizing a "broad affordance" by innovating technological artifacts over time can give rise to further "broad affordances" as pathways for innovation. Ultimately, we frame this conceptualization of possible and actual actions related to business innovation as a trajectory of (potential) *organizational transformation*.

By choosing a particular application scenario (the innovation of sPSS in manufacturing SMEs), we illuminate Pentland *et al.* [41] "path-centric theory of emerging technology and organizing" and respond to their call for research that examines such broader affordances. We propose an applicable yet unverified conceptual framework by extending existing affordance-actualization models (Fig. 1). Further, we present insights that suggest that constraints reducing an organization's flexibility do not come from specific technology *or* human factors but can instead be arranged on a socio-technical continuum of the relationship of both. Future studies should further examine the distinction between broad and narrow affordances and embed the conceptualization into existing research.

C. Limitations and Outlook

The results presented in this article certainly are subject to limitations. First, the results rely on only nine expert interviews. Although the experts covered many manufacturing SMEs, the limited sample size cannot represent the complete picture of sPSS innovation in the enterprises under investigation. Second, only one expert per company was interviewed, limiting the available information, and increasing the subjectivity towards the interviewee's perspective. Third, the interviewed firms collaborated with universities or other research institutions through previous projects in some cases, which might slightly bias the views and data collected.

Our study's findings and limitations provide a promising avenue for future research. First, we recommend drawing a more extensive sample covering a broader range of SMEs to explore whether the same affordances and constraints can be confirmed. Further, a longitudinal study is recommended to observe the progress of sPSS innovation over time. Finally, these findings may aid in designing suitable tools and means specifically for them [33]. Second, besides the challenges of digital innovation and transformation, its opportunities and advantages need to be examined in more detail to understand how these potentials can be better exploited while mitigating the risks. Third, different configurations of elements in the affordance-actualization process must be considered. Due to the fast-moving nature of digital technologies, further research

is needed to develop various theories of affordance and actualization that address these dynamics [34]. Future studies should investigate how our findings can be confirmed and generalized to other emerging technologies [15].

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