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Industrial service innovation: Exploring the transformation process to digital servitization in industrial goods companies

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ABSTRACT

The challenges of Industry 4.0 in the industrial goods markets lead to increasing dynamics and competition. As product suppliers can no longer secure their competitive position through former product-related competitive advantages, more complex product offerings and integrated solutions consisting of products and services, so-called “product-service systems (PSS)”, are increasingly being offered. But how can PSS implementation and the digital servitization transformation process be successfully accomplished? This paper addresses this research question and examines the transformation process of several companies using a mixed-methods approach that includes the evaluation of objective data-based efficiency for an idealized servitization path.

The study shows how important it is for companies to maintain or even strengthen former product-based competitive advantages and to build on them to develop new business areas. It also shows that companies are simultaneously implementing bi-directional product support services and customer support services. In addition, data-oriented services such as condition monitoring and remote services are proving to be the basis for offering more complex performance- and results-oriented PSS, where customers pay per unit produced rather than fixed fees. Moreover, for the first time, it can be concluded that digital services are the basis for the successful establishment of digital industrial IoT platforms.

1. Introduction

Optimizing the core business is no longer sufficient to maintain a competitive position, especially in the industrial goods market. In addition to the consistent expansion of customer loyalty, differentiation through digital value-added services is also necessary (Bauer et al., 2022). The increasing complexity of industrial products is leading to higher demand for supporting services from traditional product users (Bauer et al., 2022; Stark, Grosser, Beckmann-Dobrev, & Kind, 2014). To remain competitive, companies need to evolve and address these emerging needs.

Thus, it is necessary to offer more complex system offerings to capture the profit potential and to differentiate from competitors. Companies are shifting their focus from stand-alone product or service offerings to integrated solutions combining products and services (Velamuri, Neyer, & Möslein, 2011), influenced by Industry 4.0 developments along the value chain (Kraft, Helm, & Dowling, 2021). The Western European market for these services is expected to grow at a CAGR of 10% until 2024 (Brodtmann et al., 2020). By integrating products and services, companies can better meet growing market demands and ensure profitability.

In the context of industrial goods in the B2B sector, the term “product-service systems (PSS)” is gaining importance (Bauer et al., 2022). Product users appear to be eager to use PSS to enable them to focus on the core activities of their business models (Abramovici & Filos, 2011). As users increasingly prioritize operating expenses over capital expenditures, PSS in the market is evolving from transaction-based, product-oriented models to results-based models with output-oriented pricing (Deloitte, 2020). The evolving nature of PSS indicates a market shift towards more flexible and value-driven offerings. Since the combination of products and services in PSS is said to be able to offer users more value than is possible through the use of physical products alone (Rymaszewska, Helo, & Gunasekaran, 2017), research has paid more attention to the fulfillment of customer needs, the utility of PSS, and the competitiveness of providers (Pagoropoulos, Maier, & McAloone, 2017; Tukker, 2013). The separate study of physical goods and services is often no longer considered useful (Ng & Wakenshaw, 2016).

Tukker (2004) presents a widely accepted classification for PSS. He

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divides them into product-, performance- and results-based services, symbolizing the transformation process of servitization. However, Smith, Maull, and Ng (2014) highlight that “a change in mindset from the understanding of value as that created in the production and exchange of goods, to one in which value is attained from the use of an offering aimed at achieving customer goals” poses a significant challenge. Embracing Tukker’s classifications while understanding these shifts in value perception can lead to successful digital servitization.

In the industrial goods market, an embedded engineering culture emphasizing product centricity is often found. This frequently translates to a gap in understanding customer needs (Smith et al., 2014). As current research has not yet sufficiently explored digital technologies in the context of product-service systems and digital servitization, a closer look at company-specific digital initiatives and their transformative dynamics is required (Gebauer, Paiola, Saccani, & Rapaccini, 2020). In particular, the transformation path of digital servitization resulting in new business models has hardly been studied (Gebauer, Paiola, et al., 2020). In order to fully realize the potential of digital servitization, comprehensive research into its applications and challenges is necessary.

Despite the promise of digital offerings, the revenue increases from them remain low in practice (Gebauer et al., 2020; Iansiti & Lakhani, 2014). Firms encounter the digitalization paradox, wherein investments in digital PSS do not deliver the expected revenue growth, despite the growth potential of these digital technologies (Gebauer, Arzt, et al., 2020; Kohtamäki, Einola, & Rabetino, 2020). This growth potential is reflected in the estimated economic impact of IoT applications in factories of 3.3 trillion per year in 2030 – an 800% increase from 2020 estimates (Chui, Collins, & Patel, 2021). One of the explanations for is that companies fail to correctly sequence transformation phases, altering their business logic (Gebauer, Arzt, et al., 2020). In order to successfully evolve service offerings and realize the revenue potential of new digital technologies, a deeper understanding of these company-specific digital initiatives and transformation processes is required.

Therefore, this paper examines the transformation process of several companies and evaluates their efficiency. It contributes to the academic discussion and practice in multiple ways.

Research has not yet considered how new digital technologies influence the redesign of business models or transformation directions in tangible goods-oriented companies (Gebauer, Paiola, et al., 2020; Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2019). To be able to provide an idealized servitization path for companies in practice, these transformation directions need to be analyzed.

This paper addresses this issue and examines the transformation process of several companies using a mixed-methods approach, including the evaluation of objective data-based efficiency for an idealized servitization path. First, it provides empirical results on digital servitization transformation processes that need to be further investigated (Gebauer, Paiola, et al., 2020). Second, based on Raddats, Kowalkowski, Benedettini, Burton, and Gebauer (2019), and given the uncertainty about enhancing company profitability, the paper explores whether firms should adopt Services Supporting the Product (SSP) or Services Supporting the Customer (SSC) first, or both. Third, as Benkenstein et al. (2017) indicate that in the future “customers will demand platforms that empower them to manage and analyze their data much more extensively and independently,” we explore the correlation of digital servitization and IoT platforms, which represent the next stage of development beyond the offer of individual PSS. In this way, the study identifies the basic requirements for the successful establishment of multi-sided digital platforms in the market. This, in turn, helps managers and firms to increase their chances of business success with digital PSS.

The paper is structured as follows. The section “Theoretical Framework” describes the theoretical foundations of digital servitization and product service systems. After defining digital servitization and exploring its development in the context of Industry 4.0, a classification of product service systems follows. In the “Research Methods” section, the selected mixed-methods approach is explained before the selection of companies for the case studies is discussed and the analytical process is described. In the “Analysis” section, we divide the companies into efficient and less efficient firms before outlining the transformation processes of these groups. In addition, a pilot case study is used as an example to describe the results of the transformation processes of the eight companies studied. In the section “Discussion and Conclusion” the most important results are presented, and managerial implications are derived.

2. Theoretical framework

Traditionally, customer value has been derived from the production of tangible goods and the satisfaction of customer needs, but in servitization and PSS business models, value arises from product functionality and use over time, rather than ownership (Smith et al., 2014). Thus, the traditional goods-dominant view, which focuses on tangible output and discrete transactions, is shifting to a service-dominant view, in which intangibility, exchange processes, and relationships are the focus (Vargo & Lusch, 2004). In particular, this supports performance- and results-oriented PSS, where the provider and the customer must jointly determine the potential productivity gains over time (i.e., utility) (Kowalkowski, 2010).

2.1. Digital servitization

The concept of servitization spans a range between pure providers of tangible goods and pure providers of services. Within this spectrum, manufacturing companies are moving in the direction of service providers. Freije, de la Calle, and Ugarte (2021) describe this route as “moving from products to services” further explained as moving “from product-centric to service-oriented business models” (Frank, Mendes, Ayala, & Ghezzi, 2019). While the transformation offers innovative company capabilities and adds customer value through a blend of goods and services (Visnjic & Van Looy, 2012), current studies show that the mere addition of services does not always elevate company performance (Benedettini, Neely, & Swink, 2015; Kohtamäki, Partanen, Parida, & Wincent, 2013). New digital technologies, however, are changing the way product-oriented companies compete and offer services (Benkenstein et al., 2017; Lerch & Gotsch, 2015; Porter & Heppelmann, 2015).

In the context of Industry 4.0, emerging digital business models are enhancing established products and production systems, notably through product-service systems. With digitalization as a critical factor, the evolving dynamic competition disrupts existing value chains and business models (Endres, Weber, & Helm, 2015; Paschou, Adrodegari, Perona, & Saccani, 2018). Digital technologies enable product-oriented companies to offer new smart and connected products that change the nature of competition, the type of services offered, and thus value creation (Endres & Helm, 2015; Gebauer, Paiola, et al., 2020; Porter & Heppelmann, 2015).

Through digitalization and the associated dematerialization of tangible products, the trends of servitization and digitalization are merging in companies’ product offerings (Lerch & Gotsch, 2015; Vendrell-Herrero, Bustinza, Parry, & Georgantzis, 2017). An incipient and growing body of research analyzes the role of digital technologies in tertiary producers under the term “digital servitization” (Bustinza, Gomes, Vendrell-Herrero, & Tarba, 2018; Vendrell-Herrero et al., 2017). This research direction examines how digital technologies can be a driver and enabler of servitization, thereby increasing the efficiency of service delivery and the benefits of the new product-service systems (Vendrell-Herrero et al., 2017). While digital solutions offer the potential for new services, there remains a research gap in understanding digital servitization’s nuances, necessitating more in-depth analysis of company-specific digital initiatives (Gebauer, Paiola, et al., 2020). In particular, the transformation path of digital servitization has hardly been explored (Gebauer, Paiola, et al., 2020).

Over the years, several research directions have evolved from the concept of servitization in the literature (Paschou et al., 2018). One such direction explores the evolution of companies expanding their service offerings, the so-called product-service continuum (Lightfoot, Baines, & Smart, 2013; Paschou et al., 2018). Another deals with product-service systems (PSS), seen as the output of servitization, i.e., of this transformation process (Frank et al., 2019; Kowalkowski, Gebauer, & Oliva, 2017). This study, using the concept of product-service systems, explores the specific transformation processes of the digital servitization of eight industrial goods companies in order to understand their digital initiatives and extrapolate an ideal servitization path.

2.2. Product-service systems

PSS can be viewed as an output of servitization, i.e., the transformation process (Frank et al., 2019; Kowalkowski et al., 2017). In this context, PSS can be understood as business models or business model innovations encapsulating both goods and services into an integrated bundle (Frank et al., 2019; Gebauer, Saul, Haldimann, & Gustafsson, 2016; Kowalkowski et al., 2017; Meier, Roy, & Seliger, 2010).

As previously stated, companies are shifting from isolated sales of goods and services to integrated offerings to meet specific customer needs (Oliva & Kallenberg, 2003; Tukker, 2004; Velamuri et al., 2011). Within these business models, tangible goods represent a medium for submitting an additional service offer (Kowalkowski, 2010). The delivery of the service, embedded in a value proposition, can vary, resulting in different levels of servitization (Frank et al., 2019; Martinez, Neely, Velu, Leinster-Evans, & Bisessar, 2017).

There are several classifications in the literature. Tukker (2004) PSS classification, widely recognized in literature, categorizes PSS into product-oriented, use-oriented, and results-oriented. While product-oriented PSS provide users with a specific input, with the focus on the product and some additional services, the value proposition of use-oriented PSS is not the product itself, but an agreed-upon performance. Conversely, results-oriented PSS guarantee specific outcomes (Kindström & Kowalkowski, 2014; Tukker, 2004). The value propositions of these PSS aim to cater to customers' varying needs, ranging from self-service to complete dependence on the provider (Baines & Lightfoot, 2013). However, Parida, Sjödin, Wincent, and Kohtamäki (2014) contend that "these categories are highly generalized" and propose a more nuanced categorization. Therefore, a second categorization based on a service-oriented approach is used, which identifies two additional dimensions within these PSS: Services Supporting the Product (SSP) and Services Supporting the Customer (SSC) (Coreynen, Matthyssens, & Van Bockhaven, 2016; Oliva & Kallenberg, 2003). While SSP focus on products and their functionality, SSC shift the focus from the product to the end user's process, thereby helping them to improve the effectiveness of their installed base and business processes (Oliva & Kallenberg, 2003; Ulaga & Reinartz, 2011). Aligned with Coreynen et al. (2016), this classification combination facilitates clear structuring of the offered PSS for enhanced consideration and analysis in this study.

The matrix illustrated in Fig. 1 aids to better understanding, operationalizing, and distinguishing between traditional PSS, digital PSS, and digital platforms. This matrix employs Tukker (2004) classification on the horizontal level, transitioning the terminology from use-oriented to performance-oriented services in line with Coreynen et al. (2016) for a more precise value proposition articulation as noted above. On the vertical level, it splits the three PSS business model types into SSP and SSC clusters. This allows six ideal-typical PSS categories to be abstracted in line with Coreynen et al. (2016). Product Lifecycle Services, Product Performance Services, Product Result Services are assigned to the SSP while and Process Support Services, Process Delegation Services, and Hybrid Solutions are assigned to the SSC. In addition, these PSS business models are divided vertically by their digital characteristics into traditional PSS, digital PSS, and digital platforms. In general, traditional and digital PSS can be distinguished by the use of digital technologies. While traditional PSS, such as maintenance and repair, do not use digital technologies, digital PSS incorporate elements such as sensors, actuators, and software for data collection and analysis of product conditions, performance, and usage (Beverungen, Müller, Matzner, Mendling, & vom Brocke, 2019; Gebauer, Arzt, et al., 2020). Digital platforms provide the foundation and infrastructure to deliver connectable PSS.

The transformation process once considered unidirectional and incremental by Oliva and Kallenberg (2003) now seems more complex. Recent research shows that companies introduce different PSS in parallel (Yang, Smart, Kumar, Jolly, & Evans, 2018), not following a linear product-service continuum (Frank et al., 2019). They vary or offer different PSS in different ways, depending on the challenges and opportunities in their industry lifecycle (Frank et al., 2019). Moreover, there is debate on whether manufacturers should develop SSPs, SSCs, or both to improve their profitability (Raddats et al., 2019). Literature shows that, on the one hand, companies try to set a foundation for the service business with SSP in order to subsequently develop a broader portfolio of SSC and, therefore, address a wider range of customer needs

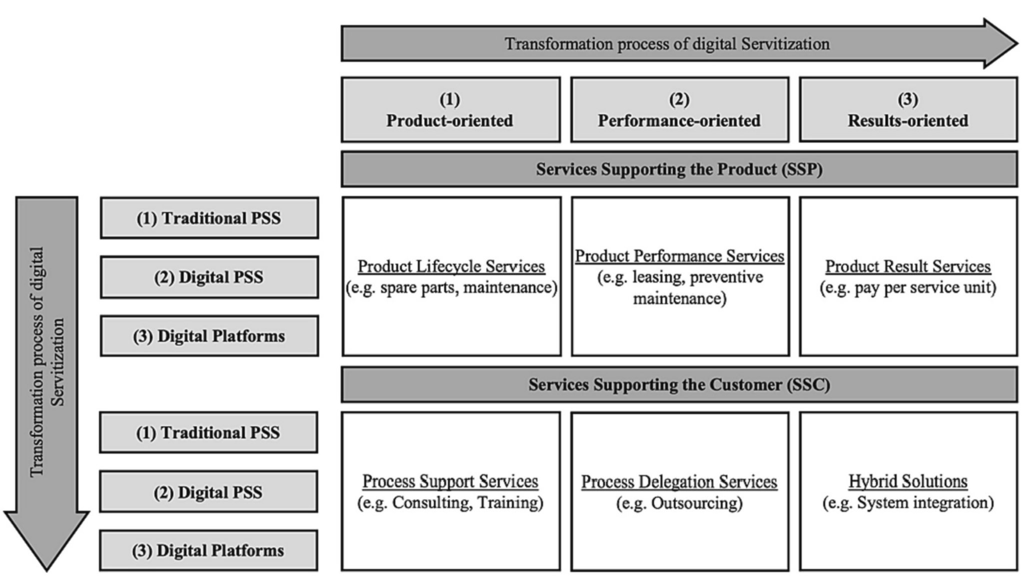


Fig. 1. PSS Business Model Types in Transformation Process. Based on Coreynen et al. (2016).

Table 1
Selected companies for the study.

	Company A	Company B	Company C	Company D	Company E	Company F	Company G	Company H
Employees	about – 2500	about – 2500	5000–7000	5000–7000	2500–5000	5000–7500	2500–5000	10,000–12,500
Revenue [Mio. Euro]	500–750	250–500	1500–1750	1250–1500	500–750	1250–1500	750–1000	2250–2500
Interview-partner	8	2	5	3	2	2	3	2

(Eggert, Hogreve, Ulaga, & Muenkhoff, 2014). On the other hand, Antioco, Moenaert, Feinberg, and Wetzels (2008) call on producers to develop SSC to increase product sales, followed by the development of SSP to increase service volumes. Additionally, Sousa and da Silveira (2017) note that natural development paths of servitization point to a balanced level of basic and advanced services. Although various empirical studies exist, there remains a lack of clarity on the most effective PSS implementation strategy (Raddats et al., 2019).

This study seeks to address the existing ambiguity in PSS implementation strategies. By providing an in-depth, decade-long analysis of the individual transformation steps in selected companies, this research aims to offer more conclusive insights.

Product-oriented PSS include services as an "add-on", i.e., influenced by product sales, selling services transactionally with the product (Tukker, 2004). As the focus shifts from pure sales to shared benefits, services begin to occupy a central role in the subsequent stage, the performance-oriented PSS (Tukker, 2004). Based on this development, we assume that companies initially start to add additional services to their products, signifying thereby the initial adoption of product-oriented PSS. Since companies implement different PSS in parallel (Yang et al., 2018), and based on literature insights that highlight strategies for the early implementation of both SSPs and SSCs (Antioco et al., 2008; Eggert et al., 2014), we assume that at the beginning, services in both areas are developed simultaneously. This parallel development facilitates organizational learning effects before the multidirectional extension of business models to performance-oriented and/or results-oriented PSS (SSP and SSC) takes place. Therefore, the following proposition can be derived:

P1. First, product-oriented PSS are implemented bidirectionally at the SSP and SSC level, before the multidirectional extension of the business models to performance-oriented and/or results-oriented PSS (SSP and SSC) also takes place.

Pure service companies differ from a producer in terms of the needs and characteristics. For example, a service of a producing company is closely connected with the corresponding product (Graf & Helm, 2018a, 2018b). This is also reflected within digitalization in the context of the complexity of service offerings and contribution services (Lerch & Gotsch, 2015). As services grow in complexity, the more support is needed from smart IT solutions (Gebauer, Gustafsson, & Witell, 2011; Lerch & Gotsch, 2015). Product complexity and batch size also directly influence digitalization efforts, with more complexity or smaller batches leading to tighter contracts and more individualized offerings to the customer (Lerch & Gotsch, 2015). These complex and individualized products and systems require accompanying services, some of which may be digital, highlighting the combination of digital services and physical products (Lerch & Gotsch, 2015). Digital PSS combine information and communication technologies with physical products within Industry 4.0 applications (Graf & Helm, 2018a).

Through built-in features (for example, sensors), a smart product can monitor itself and its environment and collect data (for example, usage, context, state data) accordingly. Furthermore, by using built-in features for data storage and processing, digital PSS autonomously respond to changes in the environment, state, and usage. Thus, digital PSS offer the collected data beyond its physical context to gain valuable insights through data analytics applications (Beverungen et al., 2019). This implies that traditional product-oriented PSS, such as repair and maintenance, can be extended or replaced by digital services (Graf & Helm, 2018a). Performance-oriented PSS typically entrust product ownership to suppliers, ensuring performance through their services (Tukker, 2004). In contrast, results-oriented PSS emphasize mutual agreement on results, usually over a longer phase of the life cycle, with the provider taking ownership of the service creation and associated responsibilities (Baines & Lightfoot, 2013; Cenamor, Rönnberg Sjödin, & Parida, 2017). The provider is rewarded according to the generated and contractually defined output (Tukker, 2004). Thus, it can be stated that digital PSS not only support but also enable the performance- and result-oriented PSS (Sjödin, Parida, Kohtamäki, & Wincent, 2020). We assume that the more data and insights are available through digital PSS, the easier it is for companies to implement performance- or results-oriented PSS and thus increase contract solution revenues. In addition, we assume that product innovation levels might play a crucial role in the adoption of new digital technologies (for example, integrated sensor technology). Literature shows that companies that are highly innovative tend to focus on SSC for profit enhancement, implying digital PSS's significant role in driving performance- and results-oriented PSS in SSC (Eggert, Hogreve, Ulaga, & Muenkhoff, 2011). Thus, we suppose that especially in the area of SSC digital PSS support the implementation of performance- and results-oriented PSS. Therefore, the following proposition can be derived:

P2. The more digital PSS are implemented, the easier it is for companies, especially in the context of SSC, to implement performance- and result-oriented PSS, so that the revenue share of contract solutions can be further increased.

Moreover, digital PSS can be used as platforms that provide added value for an ecosystem of third-party providers and the focal customer (Beverungen et al., 2019). In platform business models, the logic behind value generation changes from classic value chains to complex value networks, which consist of a dynamic set of actors and are significantly supported by digital technologies (Benkenstein et al., 2017; Gebauer, Arzt, et al., 2020; Suppatvech, Godsell, & Day, 2019; Vendrell-Herrero et al., 2017). These networks emphasize horizontal alliances rather than vertical ones (Benkenstein et al., 2017; Javanovic, Sjödin, & Parida, 2021). From this network perspective, customer value arises through the integration of products and services as well as through physical and digital offerings (Benkenstein et al., 2017; Tian, Coreynen, Matthyssens, & Shen, 2021). Since a major concern of B2B industrial platforms is the further development of the functional scope and to cope with challenges of interfirm cooperation, companies tend to first develop their own product platforms (Javanovic et al., 2021; Sandberg, Holmström, & Lyytinen, 2020; Svahn, Mathiassen, & Lindgren, 2017). To not only provide simple functions (for example, monitoring and alarming), higher-level platform services (for example, optimization and autonomous PSS) are subsequently integrated in the platform core through a complementary set of external modules, for example, in the form of advanced sensing, data analytics, and cloud solutions (Constantinides, Henfridsson, & Parker, 2018; Iansiti & Lakhani, 2020; Javanovic et al., 2021). The growth of platforms is influenced by network effects, which suggests that as technological benefits increase, the user base does as well (de Reuver, Sørensen, & Basole, 2018). In this context, increased adoption can trigger positive loopbacks, which further increase with the utility of technology (de Reuver et al., 2018). Thus, we assume that digital PSS are initially needed to implement multi-sided digital platforms. Thus, the following proposition can be derived:

P3. Only after digital PSS have been implemented is it possible to establish multi-sided digital platforms on the market.

3. Research methods

Servitization, as a new and insufficiently researched field, has been critically analyzed in this study through a blend of explanatory and exploratory methodologies. This study relies heavily on an intensive literature analysis to derive its propositions. By adopting the definition provided by Yin (2018), a case study is understood as a detailed examination of a present phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not obvious. However, the pure case study-centric approach in this research is complemented by a quantitative method, as suggested by Patton (2002), making this research a mixed-methods study. This integrated methodology thus offers a holistic understanding of servitization in its current form.

The criteria for selecting the appropriate cases for this multi-case study are firmly rooted in the guidelines provided by Eisenhardt (1989), Yin (2018) and Rabetino, Kohtamäki, and Gebauer (2016). These guidelines recommend 4 to 10 cases for a multi-case study and in the context of servitization, examine project-based machine manufacturers. Therefore, this study is conducted in the sector of industrial goods companies with a workforce of >2000 employees and revenues of >250 Mio. Euro. All selected companies share certain similarities such as partly identical industries (with identical customers), market leadership, and a DACH region-based headquarters with most of the companies operating worldwide. In order to pursue a direct and targeted selection approach (Patton, 2002), further criteria were defined: focus on PSS business models; digitization as part of the corporate strategy for a similar time span, but more than three years; and servitization strategies, such as the lifecycle perspective of the customer, being part of the company strategy for a long time (Rabetino et al., 2016). The companies developed product-oriented PSS in the early 2000s. This specification is necessary in order to obtain similar results for predictable reasons in the sense of “literal replication” (Yin, 2018).

The process of gathering data from these selected companies was thorough, involving direct interactions and interviews with key personnel over an extended period. The authors had personal contact with all companies. The interviews were conducted between September 2019 and May 2020. Moreover, at least two interview partners are part of the middle or upper management, such as CEOs, CIOs, CTOs, Head of Business Units, Product Manager IoT etc. These interviews, which lasted for an average of around 61 min each, were primarily face-to-face but some had to be conducted over the phone in 2020 owing to the pandemic restrictions. In addition to the interviews, the respective annual or consolidated financial statements were used to assess and compare the individual corporations.

A pilot case study was conducted to refine the data collection plan in terms of content and approach. The selection of the pilot case study depends on the expediency, access, geographic distance, and aspects of data collection (Yin, 2018). By meeting the above criteria Company A was selected for the pilot case study. This selection was further bolstered by our strong personal ties with Company A.

In terms of triangulation, a principle in which multiple data sources lead to the same result, it is important to use multiple sources of evidence. According to (Yin, 2018), six potential data sources exist: documentation, archived records, interviews, direct observation, participant observation, and physical objects. In this study, the interviews conducted are considered the most important evidence. However, to ensure comprehensive triangulation and high quality of the case study, we incorporated additional data sources (Yin, 2018). Direct observations, in the form of transcripts and audio recordings, and documentation, in the form of internal business/situation reports, project/workshop documentation, reports, strategy papers, presentations and websites contribute to the results. Archived documents, in terms of surveys, ERP analyses, planning/budget figures, investment figures, are another secondary source. Overall, very deep insights were gained.

Once the data had been collected, the material was processed qualitatively for each case study using structured content analysis. It was then evaluated using a code system. This system is based on the formation of a system of categories, where the categories are developed reciprocally between theory or the research question and the concrete material (Mayring, 2014). For this paper, a mixed form of deductive and inductive category formation was used since some main categories were already deductively available from a theoretical derivation. Based on these categories, potential subcategories were inductively derived. However, the inductively derived codes were aligned and adjusted based on the literature. This classification then allowed a structured analysis of the data (Mayring, 2014).

A Data Envelopment Analysis (DEA) was performed later to assess the efficiency ratings of the studied companies. Originating from the foundational works of Farrell (1957) and subsequently elaborated upon by Charnes, Cooper, and Rhodes (1978), DEA is a method for the efficiency-based performance comparison of different organizational or decision-making units (DMU, in this case, companies). Unlike other efficiency measurements that demand prior assumptions, DEA is characterized by its empirical orientation and does not require any a priori assumptions (Cooper, Seiford, & Zhu, 2011). The efficiency assessment of a DMU is carried out in comparison with other DMUs, i.e., the relative efficiency is determined (Cooper et al., 2011).

Information from the interviews, inquiries, internal documents, and official annual financial statements or consolidated financial statements from the period 2010 to 2020 served as data basis. However, an inconsistency arose in the depth of data across companies. In the pilot case study at Company A, it was also possible to collect very detailed internal data (for example, sales, contribution margins) for all PSS business models down to the product level. The internal data of companies B to H did not provide contribution margin calculations. Due to the similarities of the selected companies described above and for the comparability of these companies, these missing data were extrapolated from the data collection of Company A using the described approaches of Sarkis (2007). This applies in particular to the contribution margins of the companies B to H. The data for these companies was incomplete, an approximation of the data within the interviews and by means of trend lines (for example with straight-line equations, exponential functions) took place.

To ensure the confidentiality of the participating firms, the authors strategically distorted calculated values to safeguard their anonymity. By incorporating this quantitative DEA assessment, the authors not only facilitated a comparative analysis of the companies but also enriched this research with a mixed-methods approach. This, in turn, strengthened the linkage between the gathered data and our proposed theoretical constructs.

4. Analysis

To identify an ideal-typical transformation process, the individual transformations of the companies must be analyzed and evaluated according to their success. While this study focuses primarily on BMI implementation, it employs both object- and organization-oriented perspectives to depict an organizational outcome, which, in the realm of innovation, is termed as innovation effectiveness. Innovation effectiveness describes the benefits that an organization receives as a result of implementing an innovation (e.g., improvements in profitability, productivity, customer service, morale) (Klein & Sorra, 1996). In this context, the construct of effectiveness is understood as a dynamic conceptualization that focuses on how well an organization can acquire and use its resources efficiently in an ever-changing environment (Steers, 1975). Finding the most effective use of resources requires them to be used efficiently (Achabal, Heineke, & McIntyre, 1984; Keh, Chu, & Xu, 2006). For this reason, success in this work is defined with the efficiency of implementation, i.e., minimizing the input to provide a PSS compared to the output in terms of revenue.

DEA 1 refers to financial input factors, as recommended in the literature, such as costs and employees. DEA 2 ensures that these input factors are used to maximize the revenue, and DEA 3 allows the ratio of output to input to be used as an additional control variable.

To evaluate success, the efficient companies are first identified ex-ante with the help of DEA. Subsequently, exemplary interview results on the transformation process will be presented. Due to the number of companies studied and the volume of results, the results of the pilot case study (Company A) are presented before the transformation processes are analyzed based on the results of the DEA.

4.1. Identification of efficient companies using Data Envelopment Analysis (DEA)

A three-step process model based on Keh et al. (2006) is used for the DEA measurement model. Since multivariate ratios provide better insights, multiple input and output sources are considered in the calculation. According to Keh et al. (2006), a corresponding ratio, which is also valid for service processes, can be set up from several weighted output to input variables:

$$stage\ j: E_{ik} = \frac{\sum_{m=1}^{M_j} u_m O_{ijm}}{\sum_{n=1}^{N_j} v_n I_{ijn}}$$

The following notations are used: "j = 1, 2, 3" for the process stages; "E" is the efficiency indicator; "i = 1, 2, …, k" for the DMUs, i.e., the individual companies; each DMU produces "O" outputs with "I" inputs and a corresponding weighting "u" of outputs and "v" of inputs; the number of output factors is determined by "m = 1, 2, …, M" and the number of input factors is determined by "n = 1, 2, …, N" for each stage "j".

As shown in Fig. 2, efficiency (DEA 1) refers to the company's internal operational activities, i.e., to the decision as to which shares of the total costs or expenditures are distributed to the PSS business models. It can be assumed that management tries to optimize or minimize these inputs. The total cost shares are allocated to the generic PSS (product-, performance- and results-oriented). Subsequent to this allocation, effectivity (DEA 2) ensures optimal revenue generation from these expenditures. Meanwhile, productivity (DEA 3) serves as an added metric, comparing output to input as an additional control variable.

For the determination of efficiency (DEA 1), an input orientation is considered, i.e., the focus is on minimizing the input factors (total costs, number of employees). In contrast, DEA 2 (effectivity) and DEA 3 (productivity) are output-oriented. Here, the objective is to maximize the output factor (total sales), whereby the input factors are considered constant.

The efficiency of companies is differentiated by their capacity to

Table 2
Results of DEA calculations.

DMU	Efficiency	Effectiveness	Productivity
Company A	1**	0.501*	0.955**
Company B	0.930**	0.448*	0.895*
Company C	1**	0.652*	1**
Company D	0.461*	0.930**	0.942**
Company E	0.706*	0.807*	0.951**
Company F	0.750*	1**	0.986**
Company G	0.564*	0.958**	0.966**
Company H	1**	0.973**	0.944**

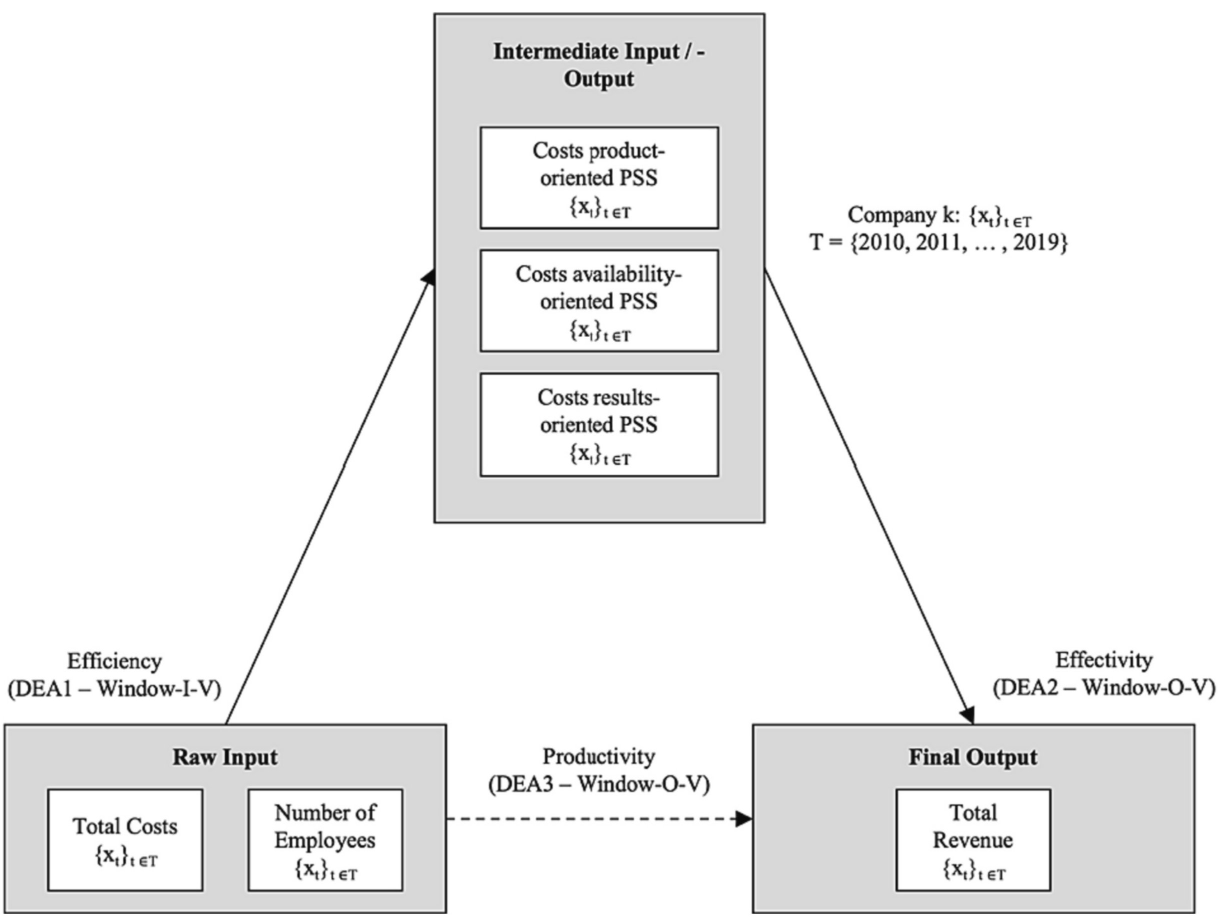


Fig. 2. Three step process model for efficiency determination. Based on Keh et al. (2006).

manage resources in relation to their outcomes, as presented in Table 2. Based on criteria established by Toma, Dobre, Dona, and Cofas (2015), companies are categorized into two primary groups: efficient, falling within the value range of 0.9–1, and inefficient, ranked below 0.9. Consequently, companies A, B, C and H can be classified as efficient, while companies D, E, F and G are considered inefficient. These efficiency values reflect "Pure Technical Efficiency" (PTE), a metric that measures technical efficiency without scale efficiency and represents a construct for management performance in relation to process input variables (Kumar & Gulati, 2008). Notably, the efficient companies demonstrate better overall management performance. Remarkably, predominantly inefficient companies tend to be more effective, suggesting their superior capability in revenue generation. Such capabilities can be organizational capabilities such as product development capabilities (Bauer, Endres, Dowling, & Helm, 2018; Helm, Krinner, & Endres, 2020). Moreover, a productivity assessment illuminates that all but company B, are relatively productive. Again, inefficient firms perform better in productivity. Overall, the results support the postulated negative correlation between efficiency and effectiveness, as management in companies tries to minimize total costs and the number of employees, while at the same time trying to maximize total revenue (Keh et al., 2006). It also confirms that both efficiency and effectiveness are key factors for company's productivity (Keh et al., 2006).

DEA 1 "Efficiency" is to be considered in more depth, particularly the differentiation between pure technical efficiency and scale efficiency (SE). Notably, pure technical efficiency does not include scale efficiency, which could underpin inefficiency within some firms. Scale efficiency creates the opportunity to optimally allocate resources to achieve an expected process level (Avkiran, 2001; Ulas & Keskin, 2015). To calculate scale efficiency, the authors employed a window analysis with constant returns to scale (CRS) for DEA 1. This approach is rooted in the CCR model proposed by Charnes et al. (1978). The resulting efficiencies reflect the technical efficiency (TE), which, according to Ulas and Keskin (2015), describes a company's ability in maximizing output with specific input factors or minimizing the input to generate a desired output. Consequently, the quotient of technical efficiency to pure technical efficiency produces the scale efficiency (Avkiran, 2001).

$$Scale\ Efficiency = \frac{Technical\ Efficiency}{Pure\ Technical\ Efficiency}$$

When comparing technical efficiency between 2010 and 2019, all companies demonstrate an upward trend in their scores under constant returns on scale (CRS) (see Table 3). In terms of pure technical efficiency as a variable return on scale (VRS), 37.5% of the companies show a decrease in their efficiency score. However, a significant majority of 62.5% show either an increase or maintain a consistently high level of pure technical efficiency.

In terms of pure technical efficiency in 2019, 37.5% of companies are operating under best-practice conditions (see Table 4).

An increase in efficiency can be observed in the calculated averages, with constant returns on scale rising by 23% and variable returns on scale by 7.4% (see Table 5). While 75% of the companies operate with an average scale efficiency value of 0.920, suggesting potential for further input minimization to enhance technical efficiency, only 25% (specifically Company A and Company C) operate at their optimal scale yield.

Companies A, C, and H emerge from the eight firms analyzed, with A and C standing out clearly. Due to its pure technical efficiency, company H can also be counted among the companies with best practice conditions. Consequently, these three companies represent the efficient companies in this study. Before analyzing the transformation processes that differentiate efficient and inefficient companies, the interview results of Company A will be presented as an example.

4.2. Transformation process in Company A (pilot case study)

Company A, representing the pilot case study, is a machine manufacturer with a homogeneous customer structure within one industry. Initially, Company A centered its operations on product-oriented services such as spare parts, which were complemented by SSC, such as consulting and training. These services were further developed and extended by Service Level Agreements (SLA). A results-oriented PSS was introduced around this core product, pricing it based on the produced output. Additional SSC models, such as inventory solutions (for example, consignment stocks), productivity, availability, and maintenance models were implemented. These performance-oriented PSS solutions include maintenance services, production optimization, and spare parts supply, with a pricing based on a fixed price per output produced and a bonus-malus concept. A profit-sharing model does not exist. This model was constantly expanded, allowing the company to achieve a service revenue share of 6.0% in 2019. Thus, Company A's trajectory confirms the first proposition. The firm started with product-oriented services in the fields of Services Supporting the Product and Services Supporting the Customer and extended the business models in multiple directions heading for performance- and results-oriented services.

Table 4
DEA 1 - Efficiency classification – comparison 2010/2019.

Efficiency intervals	2010		2019	
	TE CRS [%]	PTE VRS [%]	TE CRS [%]	PTE VRS [%]
< 0.5	50.0	12.5	25.0	12.5
0.5–0.7	12.5	37.5	12.5	12.5
0.7–0.9	25.0	12.5	37.5	25.0
0.9–< 1	12.5	0	0	12.5
1	0	37.5	25.0	37.5

Table 3
DEA 1 - TE, PTE and SE values - comparison 2010/2019.

DMU	Technical Efficiency (CRS)	Pure Technical Efficiency (VRS)	Scale Efficiency	Technical Efficiency (CRS)	Pure Technical Efficiency (VRS)	Scale Efficiency	SE Variation [%]
	2010			2019			2019/2010
Company A	0.957234	1	0.957234	1	1	1	104.5%
Company B	0.751213	1	0.751213	0.792324	0.930204	0.851774	113.4%
Company C	0.622446	0.638079	0.975499	1	1	1	102.5%
Company D	0.406592	0.449453	0.904638	0.440265	0.461431	0.954132	105.5%
Company E	0.493360	0.716828	0.688255	0.639676	0.705518	0.906676	131.7%
Company F	0.498496	0.526890	0.946110	0.725440	0.749716	0.967621	102.3%
Company G	0.320986	0.636271	0.504479	0.471325	0.564102	0.835531	165.6%
Company H	0.756313	1	0.756313	0.841260	1	0.841260	111.2%

Table 5
DEA 1 – Average efficiency values - comparison 2010/2019.

	2010	2019	Variation [%]
CRS TE	0.601	0.736	123.0%
VRS PTE	0.746	0.801	107.4%
SE	0.810	0.920	113.5%

In addition, Company A launched a spare parts online shop, which has evolved into an eCommerce platform since 2018. Leveraging advancements in technology, they expanded their remote maintenance solution into a remote service platform that forms the basis for further digital IoT services established in 2017. For example, an IoT maintenance cloud solution is currently under development, representing a performance-oriented service in the field of Services Supporting the Customer. This supports the second proposition, demonstrating the company's ability to innovate based on past developments in digital PSS.

Moreover, after the unsuccessful cooperation with an external provider, the company is developing its own IoT platform to offer digital IoT operations support services (for example, condition monitoring). By 2020, the digital PSS had been enhanced with the inclusion of IoT apps and IoT smart glasses. In mid-2020, a further step was taken to offer a digital platform. They collaborated with a partial competitor, Company F, to develop a multi-sided industry platform, underlining the third proposition. Company A first developed a broad base of digital services (eCommerce platform, condition monitoring services, IoT smart glasses, etc.) before taking the coopetitive approach to develop a multi-sided industry platform.

Company A is also striving to broaden its scope of business from one part of the value creation to offering material and services for the complete customer needs of a plant. From 2020, they began offering intelligent intralogistics solutions (for example, AGVs, goods handling/control software, etc.). For a clearer perspective on their offerings, Table 6 shows the PSS provided by Company A, with the revenue share represented by the circle sizes.

Table 6
Business model portfolio of digital servitization—Company A.

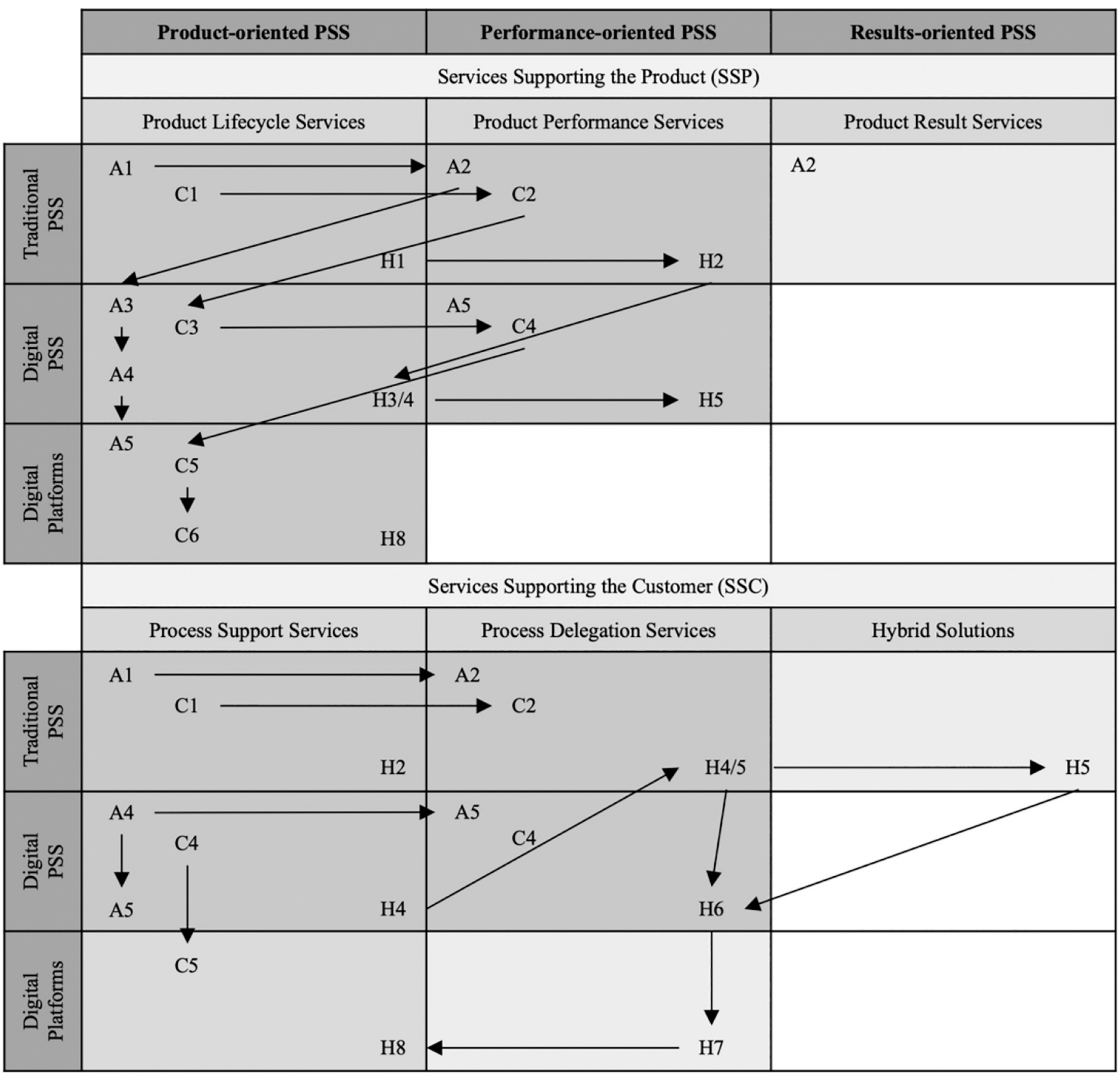
	Product-oriented PSS	**Performance-oriented PSS**	**Results-oriented PSS**
	Services Supporting the Product (SSP)		
	Product Lifecycle Services	Product Performance Services	Product Result Services
Traditional PSS	Spare Parts and Consumables 57.5 %; Upgrades 9.6 %; Repair / Maintenance 5.9 %	Leasing 0 %; Service Level Agreements 0.9 %	Performance based spare parts supply 6.0 %
Digital PSS	IoT Shop / eCommerce 6.5 %; MES-Software (Start 2020); IoT Remote Services (Smart Glasses) (Start 2020)	IoT Maintenance Management (in development)	
Digital Platforms	IoT Industry Platform / Online-Mall (in development)		
	Services Supporting the Customer (SSC)		
	Process Support Services	Process Delegation Services	Hybrid Solutions
Traditional PSS	Consulting / Training 0.3 %	Inventory Solutions 2.6 %; Productivity, Availability and Maintenance Models 9.0 %	
Digital PSS	IoT Operations Support (Condition Monitoring / Alarming) 0.2 %; IoT Apps (Start 2020); IoT Training (in development)	IoT Maintenance Cloud (in development)	
Digital Platforms			

4.3. Transformation processes

Based on the DEA analysis, companies have been categorized into two groups: efficient (A, C, H) and inefficient (B, D, E, F, G). The transformation processes of these groups warrant a detailed exploration. Table 7, shows the digital servitization process of the efficient companies (A, C, and H) and shows that they span across nine business model clusters. Notably, all of them provide Product Lifecycle Services, Product Performance Services, Process Support Services, and Process Delegation Services. A standout observation is the bidirectional starting point of all three companies in both the Product Lifecycle Services in the area of Services Supporting the Product and Process Support Services in the area of Services Supporting the Customer. In the further course of traditional servitization, Product Performance Services were mostly established in the form of Services Level Agreements. Early on, Company A implemented a results-oriented PSS based on wear parts on the market. Companies A and C placed various PSS under Process Delegation Services based on technical OEE with a bonus-malus contract. Advancing to the Industry 4.0 era, the initial focus was predominantly on digital PSS in Product Lifecycle Services. Soon after, offerings expanded to include digital PSS for customer processes, especially through condition monitoring and alarming solutions. Ultimately, the digital PSS in the field of Product Lifecycle Services, which were predominantly established first, will become mostly parallel multi-directional transformation stages in the next development paths:

- Direction 1: From Product Lifecycle Services to Product Performance Services. Horizontal movement at the level of digital PSS in the area of Services Supporting the Product.
- Direction 2: From Product Lifecycle Services to Process Support Services. Vertical movement at the level of digital PSS from the Services Supporting the Product area into Services Supporting the Customer.
- Parallel to 1 and 2: Positioning in Process Delegation Services (digital PSS).
- Direction 3: Establishment of digital platforms in both Services Supporting the Product and Services Supporting the Customer.

Table 7
Digital servitization process—Companies A, C, H.



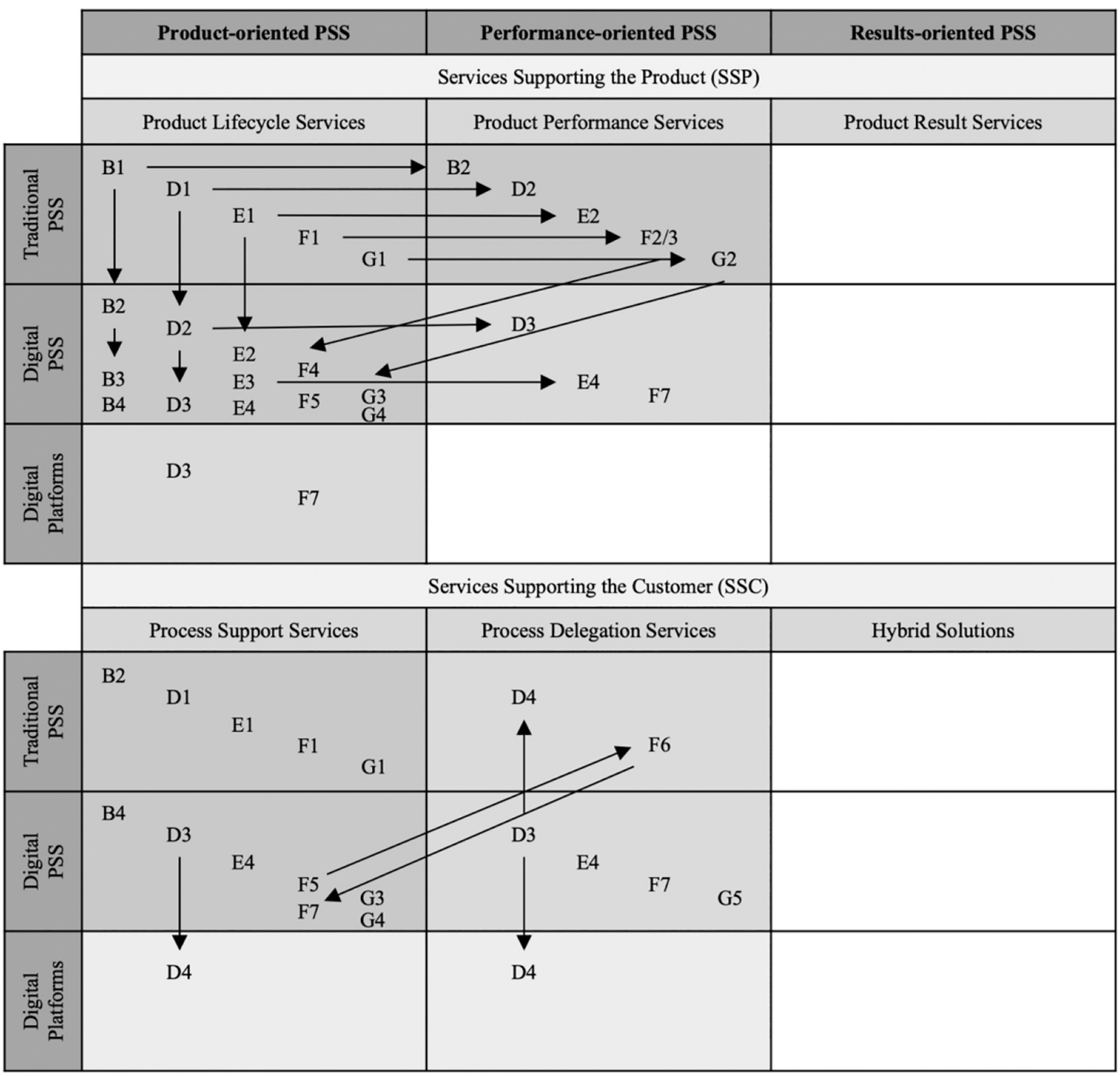
Efficient companies predominantly implement their PSS in the Services Supporting the Customer area due to the influence of digital PSS. It shows that they occupy seven out of nine Services Supporting the Customer segments and six out of nine Services Supporting the Product. This transformation aligns with Proposition 1, which states that companies first introduce product-oriented PSS in both Services Supporting the Product and Services Supporting the Customer sectors, and then expand in multiple directions. Building on this, the initial digital services in Product Lifecycle Services and Process Support Services pave the way for further PSS business models, especially within the Services Supporting the Customer sectors, thereby bolstering Proposition 2. It suggests a serial evolution of firms through the three PSS categories. Moreover, the fact that the creation of digital platforms is the final step in this transformation and that most firms are still in the development phase further supports Proposition 3. Consequently, for efficient firms like A, C, and H, all three propositions hold true.

Conversely, the journey of inefficient companies, as illustrated in Table 8, shows a different picture. Initially, PSS are offered in the area of Product Lifecycle Services and Process Support Services. Further along, all companies offer traditional services in the field of Product Performance Services before digital PSS emerge in the field of Product Lifecycle Services. After the first digital solutions have been implemented in the field of Services Supporting the Product, digital PSS are also offered in the field of Services Supporting the Customer in the areas of Process Support Services and Process Delegation Services. Compared to the efficient companies, only two firms offer digital platforms in the field of Services Supporting the Product and only one in the area of Services Supporting the Customer.

This results in the following transformation directions:

- Direction 1: further development of digital PSS in the Product Lifecycle Services segment and parallel establishment of digital PSS in the Process Support Services segment.
- Direction 2: parallel or serial movement in Product Performance Services in the area of Services Supporting the Product and Process Delegation Services in the area of Services Supporting the Customer.

Table 8
Digital servitization process—Companies B, D, E, F, G.



- Direction 3: only two companies develop digital platforms in the area of Services Supporting the Product and only one company in Services Supporting the Customer.

Inefficient companies tend to offer PSS primarily in the Services Supporting the Product area, and they lack sequential development stages in the Services Supporting the Customer area. Despite these differences, Proposition 1 is still upheld because for the efficient companies, the starting point for multidirectional transformation is product-oriented PSS in the area of Services Supporting the Product as well as Services Supporting the Customer. Proposition 2 finds support among the inefficient companies differently: although they offer initial digital PSS in the area of Product Lifecycle Services and Process Support Services, few performance- and results-oriented services build upon. Several barriers, such as lack of demand, expertise, standardization, and customer data, explain this stagnation. Therefore, Proposition 2 suggests that without a solid foundation in digital product-oriented PSS, evolving into more complex PSS becomes challenging.

In line with Proposition 2, Proposition 3 is also reinforced. Only two of the companies are developing digital platforms, further confirming the importance of establishing strong digital product-oriented PSS foundations. Overall, the inefficient companies fully occupy five business model segments. A further six segments are partially occupied. Within digital servitization, the inefficient companies undertake a bidirectional vertical movement within product-oriented PSS. In contrast, the efficient companies mostly take an intermediate step via horizontal movement to Product Performance Services. The inefficient companies take this step in their second transformation direction and, like the efficient ones, adopt Process Delegation Services in the area of Services Supporting the Customer. The final step to digital platforms is not very pronounced in the inefficient group. In summary, the inefficient companies lean more towards the Services Supporting the Product area. This is the main difference from the efficient companies: The efficient companies are already implementing the first performance-oriented PSS in the SSC segment at an early stage and then undertake the transformational direction of PSS in the area of Services Supporting the Customer. This distinction becomes clearer when considering that the efficient companies with 12.3 each offer about 28% more PSS models than the inefficient ones with an average of 9.6 services, revealing a higher activity in offering services.

Interview insights further highlight the contrasting strategies of the two groups. Efficient companies prioritize customer-centric service development, involving them from the early stages, whereas inefficient companies, having faced initial setbacks, are more hesitant to innovate.

Table 9
Aggregated revenue shares—digital servitization process.

	Product-oriented PSS	Performance-oriented PSS	Results-oriented PSS	
	Services Supporting the Product (SSP)			
	Product Lifecycle Services	Product Performance Services	Product Result Services	
Traditional PSS	Spare Parts, Consumables, Upgrades, Repair and Maintenance 80.8 %	Leasing, Service Level Agreements 2.9 %	Performance based spare parts supply 0.8 %	84.5 % (of total revenues)
Digital PSS	eCommerce, Design Services, CAD/CAM Software 10.4 % Started: IoT Services (Smart Glasses, Remote, Ticketing)	IoT Maintenance Management 0.1 %		10.5 % (of total revenues)
Digital Platforms	In development / planning: IoT Industry Platform (eCommerce, App Store, Profit Sharing Models)			0 % (of total revenues)
	Services Supporting the Customer (SSC)			
	Process Support Services	Process Delegation Services	Hybrid Solutions	
Traditional PSS	Consulting, Training, Process Development and Optimization 1.6 %	Inventory Management, Productivity, Availability and Maintenance Models Started: Manufacturing Execution System 2.1 %	Subscription Models 0.4 %	4.1 % (of total revenues)
Digital PSS	IoT Support Services (Condition Monitoring, Alarming, eLearning, BI, Benchmarking, Knowledge DB, Process Optimization and Management, Asset Management) 0.9 %	IoT Stock / Inventory / Machine, Material and Tools Management, Fleet Management, End-to-End Process Management 0.2 %		1.1 % (of total revenues)
Digital Platforms	In development / planning: IoT Industry Platform (Profit Sharing Models, Full-Asset Management)	In development / planning: IoT Industry Platform (Material, Tools, Supplier / Customer Management)		0 % (of total revenues)
	93.7 % (of total revenues)	5.3 % (of total revenues)	1.2 % (of total revenues)	

An example here is Company H, which implemented the first operator models as early as 2017 with a low barrier to entry and in collaboration with customers. As a result, by the end of 2020, 400 customers were using this service, generating 10% of total revenue. Conversely, the inefficient companies fear potential service cannibalization and thus restrain further PSS evolution. In summary, the efficient companies, in contrast to the inefficient companies, put the customers, their needs and requirements, much more at the center of development. They involve the customers in the development of the PSS at an early stage, build customer-oriented structures in their own company, implement their own sales teams for digital PSS, and are thus more capable of meeting the requirements and expectations described at the beginning with regard to the entire customer process. This, in turn, translates into better implementation of PSS in the market.

Finally, revenue shares for individual PSSs can provide insight into not only transformation, but also market penetration. As shown in Table 9, revenue shares, represented by circle sizes and averaged across all companies, show the current overall revenue relevance of each PSS, ensuring a comparative perspective.

The analysis reveals a strong dominance of product-oriented PSS, accounting for a remarkable 93.7% of the total, with the category of product lifecycle services category accounting for 80.8% of this figure. Digital PSS of Product Lifecycle Services rank second with 10.4%. In contrast, performance-oriented PSS constitute a minor 5.3%, and results-oriented PSS make up an even smaller fraction at 1.2%. This distribution underscores that digital PSS and digital platforms are in the early stages of their life cycle.

5. Discussion and conclusion

Current research has provided limited insights into the role of digital technologies in product-service systems and digital servitization. Digital servitization, especially the transformation process leading to new business models, remains an understudied area, highlighting the need for a deeper understanding of firm-specific digital initiatives (Gebauer, Paiola, et al., 2020). To address this gap, we examine the transformation processes of different firms using a multiple case study approach, thereby enriching the existing body of literature on digital servitization.

5.1. Theoretical contributions

Regarding the theoretical contributions of this research, this study first highlights the initial implementation of product-oriented PSS at the level of Services Supporting the Product and at the level of Services Supporting the Customer, followed by the extension of the business models to performance- and/or results-oriented PSS in both clusters. Contrary to previous claims that transformation paths in the digital servitization process are linear and focused on a single business model (Kowalkowski et al., 2017; Oliva & Kallenberg, 2003), our findings demonstrate multidirectional and simultaneous development paths for various PSS business models confirming Proposition 1. This refutes the notion of a linear progression and instead supports parallel evolution as suggested by Frank et al. (2019) and Yang et al. (2018). The holistic approach of this study helps to describe the dynamics of the transformation process and the interdependencies of business models. While Sousa and da Silveira (2017) state that the development paths of servitization point to a balanced level of basic and advanced services, our study paints a different picture. In terms of revenue streams, traditional product-oriented PSS (e.g., spare/wear parts, upgrades, repair and maintenance) dominate with about 80% total service revenues. Digital PSS, especially in the area of Product Lifecycle Services follow with a significant 10%. All other PSS business model types play a minor role, although it is important to note that most firms are still in the early stages of digital PSS and digital platforms. Company H strongly demonstrates that digital PSS enable operator models (outcome-based PSS). Specifically, there is evidence of an exponential revenue trend for such contract models of the companies in 2020 and 2021. Thus, challenging the claim of Sousa and da Silveira (2017), our data reveals an imbalance between basic and advanced services. The product-oriented PSS within their traditional PSS still play a major role in terms of revenue. This can be explained by the early stage of most companies' engagement with digital PSS, both on the supplier and customer side. Therefore, customers also need to transform in order to use digital PSS. This includes process changes and employee acceptance. In terms of the number of services offered, our research shows a majority of advanced services. Therefore, the claim of Sousa and da Silveira (2017) has to be refuted.

In addition, the study highlights that companies initially focus on digital PSS within the Product Lifecycle Services cluster before branching out to other areas, underscoring the foundational role of digital PSS for more complex PSS. All participating companies start their journey with digital PSS in the Product Lifecycle Services cluster, and in parallel or soon after, delve into the Process Support Services cluster. By confirming Proposition 2 and in accordance with Sjödin et al. (2020), this paper verifies that only with digital PSS can more complex performance-oriented and results-oriented PSS be implemented on the market. The underlying reason is that digital PSS provide the necessary infrastructure, such as e-commerce platforms or inventory management systems, for facilitating the execution of more complex PSS models. Hence, well-established digital PSS not only streamline the introduction of performance- and result-oriented PSS but also augment the revenue potential from contractual solutions.

However, the transformation journey to advanced PSS is not without its challenges, as evidenced by the struggles faced by the inefficient companies. As these inefficient companies show, a lack of data and acceptance from the customers can influence the transformation process as it hinders the development of performance- and results-oriented PSS. Thus, the challenge does not lie merely in developing data-based systems but ensuring a successful establishment on the market in order to gain customer acceptance and generate data for future developments. This study not only aligns with Eggert et al. (2011) findings that firms with low product innovation contribute both SSP and SSC and firms with high product innovation contribute only SSC to profitability improvement, but also shows inefficient firms focusing primarily on SSPs for various reasons, such as negative experience or negative market assessment. Unlike inefficient firms, efficient companies, in contrast, have a higher customer focus, implement services primarily in the area of SSC, and are able to successfully establish them in the market.

The transformation path to digital platforms that support digital servitization has been understudied, with Ardolino, Saccani, Adrodegari, and Perona (2020) highlighting their support but not the path to it. While Cenamor et al. (2017) note that platforms foster the establishment of more complex PSS, this study takes it further. By confirming Proposition 3, this study shows that only digital PSS allow the establishment of more complex PSS, and thus also digital platforms (for example, industry platforms/ecosystems), which in turn are conducive to digital servitization. In other words, it is only through the implementation of digital PSS that it is possible to establish multi-sided digital platforms on the market. Furthermore, this study confirms that companies first integrate their own product platforms into their installed base (Javanovic et al., 2021; Sandberg et al., 2020; Svahn et al., 2017). Therefore, the priority for management should be the effective implementation of digital PSS in the market, which can subsequently lead to the creation of digital platforms by connecting them.

As noted above, the research to date paints a mixed picture in terms of improved profitability. It is unclear whether manufacturers should focus on developing SSP, SSC, or both (Raddats et al., 2019). The present study provides a clear result: Companies, both efficient and inefficient, start by bidirectionally establishing diverse PSS business models in both Services Supporting the Product and Services Supporting the Customer areas. However, the distinction arises in their subsequent positioning: inefficient firms lean more towards Services Supporting the Product, while efficient companies gear their transformational efforts towards

Services Supporting the Customer, emphasizing digital services in Services Supporting the Product. These digital services lay the foundation for the development of further Services Supporting the Customer and more complex performance and results-oriented PSS in general. Therefore, in terms of profitability, the focus should not be on Services Supporting the Product or Services Supporting the Customer, but on both, and in particular on the successful implementation of digital PSS that provide the necessary infrastructure and data access to enable the development of more complex PSS and increase the revenue share of contractual solutions.

5.2. Practical implications

Based on the results, an idealized servitization path was generated as a guideline for managers of digital initiatives in industrial goods companies to help them better manage the transformation process and implement the corresponding PSS in the market in small innovation steps. The efficient cluster of companies is primarily used for this purpose. It offers a dominant design for actual practice. Fig. 3 depicts the idealized servitization path.

Companies should first extend their predominantly product-oriented PSS and then establish service level agreements to offer the first contract-oriented business models. In the second phase, product- and performance-oriented digital PSS should be established in parallel, so that a) all relevant asset and process data can be accessed in real time in order to b) derive further digital business models, c) as well as to create the basis for internal company digitalization, and d) to establish potential new sector and industry platforms in the market. Due to the improved data situation, this results in lower risks for the companies to be able to offer performance-oriented PSS with a bonus-malus contract up to results-oriented PSS (for example operator models) in the further transformation steps. However, these developments require the successful implementation of digital PSS in the product-oriented area. Success is measured primarily by market acceptance and the amount of data generated.

5.3. Summary and further research

Despite years of focus on “digital transformation” or “Industry 4.0”, digital PSS business models and digital platforms have only recently been brought to market, resulting in modest service revenues from these innovations. However, the transformation process reveals that it is precisely the data-oriented service bundles that form the basis for the successful implementation of more complex performance- and results-oriented PSS. Building on this, this study visualizes a detailed digital servitization process with new types of digital PSS business models, providing guidance for research and practice. Strategically, the importance of multiple positioning and the associated bidirectional integration direction emerges, which enables companies to strengthen their core competencies on the one hand and to open up new business areas on the other. This results in a deliberate customer process orientation towards Services Supporting the Customer. Furthermore, for the first time digital PSS can be said to lay the foundation for the establishment of digital platforms. In addition, two companies have been able to use digital PSS to successfully introduce performance-oriented or results-oriented PSS to the market, underlining the essential role of digital PSS in the introduction of complex PSS.

As with all scientific work, this study is not without limitations. Despite the similarity and the experience of the authors, the extrapolation of the data in terms of contribution margins could benefit from more

1. Product-oriented traditional PSS
a) SSP: e.g. Spare and Wear Parts, Repair, Maintenance, Upgrades
b) SSC: e.g. Consulting Services

2. Performance-oriented traditional PSS (SSP)
e.g. Service Level Agreements, Leasing

3.1 Performance-oriented traditional PSS (SSC) e.g. Productivity and Maintenance Models	**3.2 Results-oriented traditional PSS (SSP)** e.g. Performance based Spare and Wear Parts Supply

Traditional Servitization

Digital Servitization

4.1 Product-oriented digital PSS a) SSP: e.g. eCommerce solutions, AR-/VR-Services b) SSC: e.g. Condition Monitoring & Alarming, Benchmarking	**4.2 Performance-oriented digital PSS** a) SSP: e.g. IoT Maintenance Management b) SSC: e.g. IoT Stock / Inventory Management
5.1 Product-oriented digital Platforms a) SSP: eCommerce Industry Platform, App Store b) SSC: Full-Asset Management Industry Platform	**5.2 Performance-oriented digital Platforms (SSC)** e.g. Industry Platform for Material, Tools, Supplier and Customer Management

6. Performance-oriented traditional PSS (SSC)
e.g. Availability Models with Bonus-Malus Contracts

7. Results-oriented traditional PSS (SSC)
e.g. Operator / Subscription Models

Fig. 3. Idealized digital servitization process.

detailed company-specific data. It should also be noted that this extrapolation cannot be applied directly to other industries. In addition, other success factors besides efficiency, such as employee competence, could be included in future research. Due to the size of the study, this paper focuses on efficiency. Another limitation is that only one industry could be analyzed. Other sectors and industries are underrepresented and can be considered in future research.

Future qualitative and quantitative research projects could address the impact of the success of digital PSS on business efficiency in general. In addition, digital PSS and digital platforms, which have not been the subject of much research to date, can be considered, especially how sales organizations and the various roles in the buying center should be designed in detail. In this context, attention should also be paid to the different actors in the network. It also remains unclear how the digital PSS will continue to serve in terms of revenue relevance, either a) as independent business models or b) as a prerequisite for establishing more complex performance- and results-oriented PSS.

CRediT authorship contribution statement

Stephan Soellner: Conceptualization, Data curation, Investigation, Writing – original draft, Writing – review & editing. **Roland Helm:** Project administration, Supervision, Writing – review & editing. **Patrick Klee:** Data curation, Investigation, Writing – original draft, Writing – review & editing. **Herbert Endres:** Investigation, Supervision, Writing – original draft, Writing – review & editing.

Data availability

The data that has been used is confidential.

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