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Manufacturers managing complexity during the digital servitization journey

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Abstract

Purpose – Manufacturers face various challenges and risks during their digital servitization (DS), due to the complexity caused by introducing breakthrough technologies, increasingly complex product-service solutions and new stakeholders in the business network. The process necessitates the implementation of various changes that usually happen over a long period of time. Using complexity management as a theoretical lens, this paper delves into manufacturers' DS journeys and explores how manufacturers manage the associated complexities.
Design/methodology/approach – This paper investigates the DS journey of two manufacturers in a longitudinal case study from 2014 to 2021.
Findings – Three main complexity management actions during the DS journey were identified: shaping the digital service system, shaping the organization and shaping the network. Tied to different types of complexities, these actions demonstrate how manufacturers navigate their journey. The findings also reveal different complexity management approaches used at the different stages of this journey.
Originality/value – This paper offers a comprehensive framework for understanding complexity management in the DS journey, including the types of complexities, complexity management actions and complexity management approaches and their rationale. This paper shows that different requirements are created during emerge, consolidate and evolve stages of the DS journey. Manufacturers need a dynamic approach that considers changes in complexities and actions over time.

Keywords Digital servitization journey, Complexity management, Manufacturing firm, Organizational change, Longitudinal case study
Paper type Research paper

Quick value overview

Interesting because: The paper offers a comprehensive framework for managing complexities in the digital servitization (DS) journey, encompassing complexity types, complexity

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management actions and approaches of manufacturing firms. DS is a complex and lengthy transition, and its dynamics are weakly understood. By adopting a complexity management lens, this study offers new insights into different complexity management approaches manufacturers use at the different stages of the journey (here labeled as emerge, consolidate and evolve) and the need for a dynamic approach that considers changes over time.

Theoretical value: Three types of complexity management actions were identified: shaping the digital service system, the organization and the network. The findings expand the current understanding of DS as a trial-and-error journey and reveal combinations of key actions for handling this transformation. The studied manufacturers primarily adopted a complexity absorption approach during the emerge stage, setting the stage for their DS journey. Complexity management approaches differed in the consolidate stage, based on organizational context. In the evolve stage, manufacturers balanced complexity reduction and absorption to drive growth and exploit new opportunities.

Practical value: DS is a continuous journey requiring ongoing adaptation, evaluation of initiatives and openness to new opportunities. Manufacturers should adopt an appropriate complexity management approach aligned with their structure. They should also embrace a DS journey that considers both complex reduction approaches, such as simplifying processes and streamlining decision-making, as well as complexity absorption approaches aimed at innovation and flexibility.

1. Introduction

Digital technologies such as the Internet of Things (IoT), cloud computing and predictive analytics are increasingly impacting manufacturers (Ardolino *et al.*, 2018) by enabling DS, i.e. *"the utilization of digital tools for the transformational processes whereby a company shifts from a product-centric to a service-centric business model and logic"* (Solem *et al.*, 2022). Compared to digital transformation, a broader change enabled by digital technologies, DS specifically targets the shift from product-centric to service-centric business models, leveraging digital tools to deliver enhanced services and customer experiences (Bortoluzzi *et al.*, 2022). Manufacturers can benefit from DS in numerous ways. For instance, to differentiate their solutions from those of their rivals, they can use digital breakthroughs, lower their costs and exploit the data collected from equipment connected with the IoT to improve their products (Coreynen *et al.*, 2017; Kanovska and Tomaskova, 2018). However, the DS journey can take a long time, requiring persistence from the manufacturer and its partners (Peillon and Dubruc, 2019).

This study is motivated by the need to understand manufacturers' DS journeys over time as they face increasing degrees of complexity, both internally within the company and externally within their network. Implementing a DS strategy requires relevant changes to the organization's capabilities (Ardolino *et al.*, 2018; Cenamor *et al.*, 2017; Kohtamäki *et al.*, 2019b). In fact, DS can be considered a risky transition process that has a notable impact on product-centric business models (Paiola and Gebauer, 2020). Manufacturers continually strive to enhance their offerings by developing and integrating digital services, resulting in a continuum of product–service combinations (Grubic and Peppard, 2016). This ever-increasing complexity signifies the continuous adaptation and expansion of manufacturers' operations (Romagnoli *et al.*, 2023), reflecting the ongoing evolution of the servitization process (Kimita *et al.*, 2022).

The literature addressing the DS transition over time is rather scant (Hsuan *et al.*, 2021; Kohtamäki *et al.*, 2021) and the underpinning dynamics are weakly understood (Rapaccini *et al.*, 2023). DS is viewed as a trial-and-error journey (Paiola *et al.*, 2022) that creates internal (i.e. between departments) and external (i.e. between the manufacturer and its partners) tensions and complexity (Kamalaldin *et al.*, 2020). Manufacturers need to find a way to avoid being overwhelmed by this complexity (Kanovska and Tomaskova, 2018; Paiola and Gebauer, 2020).

This paper adopts complexity management theory (Ashmos *et al.*, 2000; Boisot and Child, 1999) as a lens to deepen the understanding of the DS journey. Overall, the complexity of DS arises from the multifaceted nature of the transition, involving an increasing number of varying and interacting elements of technology, organization, business models and ecosystems (Kohtamäki *et al.*, 2019b). Due to the overwhelming complexity, manufacturers may struggle in analyzing data and information, decision-making, coordination and collaboration and resource and change management. Successfully managing this complexity is crucial for companies seeking to unlock the potential benefits of DS. The previous research investigated specific types of DS complexities with a cross-sectional approach (Dahmani *et al.*, 2016; Eloranta and Turunen, 2016; Eloranta *et al.*, 2021; Yan *et al.*, 2022; Zou *et al.*, 2018). To help resolve complexity-related challenges and support manufacturers in their DS journeys, a need exists to develop a comprehensive view of actions. By 'actions', we refer to the specific tasks, activities and operational steps taken by manufacturers during their DS journey. These actions encompass a wide range of activities such as recruiting, training, adopting remote monitoring technologies, sharing databases and organizational restructuring (Rabetino *et al.*, 2017). Understanding the variations of these actions along the DS journey is crucial for managing the complexity.

Against this background, the goal of this study is to offer new knowledge on manufacturers' DS journey and ways of managing complexity during it, with the following research question: *How do manufacturers manage complexity during the DS journey?* This study makes two primary contributions. First, it provides a framework and rationale for understanding complexity management during the DS journey, including types of complexities, complexity management actions and approaches. Second, it reveals the evolving nature of the DS journey and shows its different requirements at different stages, which calls for using a dynamic approach that considers changes in complexities and actions over time.

The paper outlines as follows: Section 2 analyzes literature linking DS journeys and complexity management, leading to the research framework. Section 3 introduces the research method, i.e. a longitudinal case study of two manufacturers across three stages of the DS journey. Section 4 reports the complexity management actions and approaches. Section 5 discusses complexity management during the DS journey and develops some propositions. Finally, Section 6 concludes with implications and limitations and future research suggestions.

2. Theoretical background

2.1 Digital servitization journey

DS is a strategy that falls under the larger umbrella of servitization, emphasizing the crucial role of digital technologies in transforming traditional product-service offerings into innovative, technology-enabled service experiences for customers (Paschou *et al.*, 2020). Previous studies agree that DS combines the advantages of servitization and digitization (Gebauer *et al.*, 2021), leading to strategic and operational benefits (Vendrell-Herrero *et al.*, 2017). Table 1 presents the key differences between servitization and DS.

Traditional servitization emphasizes the shift from products to services, focusing on customer relationships, customized services and long-term customer satisfaction (Gebauer *et al.*, 2021). DS, in turn, emphasizes integrating advanced digital technologies, such as IoT, artificial intelligence (AI) and data analytics, into services. This trajectory requires significant financial and operational investment in technology, a shift in organizational mindset and a focus on real-time data analysis and predictive capabilities (Paschou *et al.*, 2020). The adoption of digital technologies requires notable changes to organizational structure, operational practices, information systems, human resources and supplier relationships (Baines and Lightfoot, 2014; Ortt *et al.*, 2020).

	Servitization	Digital servitization
Scope	A broader concept that encompasses various types of services, not necessarily dependent on digital technologies (Vandermerwe and Rada, 1988)	A subset of servitization, focusing specifically on the digitization aspect (Paschou *et al.*, 2020)
Focus	Shifting from products to services (Oliva and Kallenberg, 2003)	Enhancing services through digital technologies (Paschou *et al.*, 2020)
Technological emphasis	Could proceed partly without technologies. While sometimes technology-enabled, not necessarily require cutting-edge digital solutions (Baines and Lightfoot, 2014)	Emphasizing the use of digital technologies like IoT, AI, and data analytics to improve service delivery and create new service offerings (Ardolino *et al.*, 2018)
Organizational aspect	Developing service-oriented skills and capabilities that involve training employees, and changing the structure to accommodate service units and teams (Kimita *et al.*, 2022)	A high level of digital literacy within the organization including the integration of IT specialists, data analysts, and professionals (Shen *et al.*, 2023)
Business model	Creating value through services, enabling revenue streams through long-term service contracts, subscriptions, or pay-per-use models (Rabetino *et al.*, 2017)	Expanding the servitization model by enabling data-driven decision-making, predictive maintenance, and automation of processes, involving partnerships with technology providers and software-as-a-service (SaaS) offerings, enabling revenue streams through digital service subscriptions and IoT device sales (Rapaccini *et al.*, 2023)
Infrastructure	Focusing on service delivery, including service centers, service network, maintenance facilities, customer support hotlines, and trained service personnel (Bikfalvi *et al.*, 2013)	Requires a robust IT infrastructure, including IoT devices for data collection, cloud computing platforms for data storage and processing, analytics tools for data analysis, and cybersecurity measures to protect digital assets (Flores-García *et al.*, 2023)

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Table 1.
Key differences between servitization and DS

To advance their DS journey, manufacturers need to implement various actions to deal with internal and external factors (Rapaccini *et al.*, 2023). Scholars have revealed alternative ways to target different competitive strategies—trajectories (Ardolino *et al.*, 2018; Coreynen *et al.*, 2017; Hsuan *et al.*, 2021). A key area of agreement among researchers is the diverse digital capabilities required in different trajectories (Ardolino *et al.*, 2018). These capabilities, spanning industrial, commercial and value servitization trajectories, emphasize the need for specific capabilities that align with a company's unique goals (Coreynen *et al.*, 2017). DS trajectories emphasize the transition from a product-centric approach to a more comprehensive model that includes connected products, IoT-driven services and software solutions (Hsuan *et al.*, 2021). The existing literature has also started to shift the focus from technological aspects to a holistic perspective on DS that encompasses ecosystems, offerings, processes and technologies (Kohtamäki *et al.*, 2021).

Overall, the previous literature agrees that DS can follow different trajectories intended to reach alternative configurations of the business model (Bustinza *et al.*, 2017). However, research rarely explicates manufacturers' actions to tackle the challenges originating from the complexities of the DS journey. In particular, there is a need to understand better how these actions vary over time. In conceptualizing the DS journey, this paper draws inspiration

from the work of Baines *et al.* (2020), which assumes that servitization is a dynamic and ongoing process that evolves through exploration, engagement, expansion and exploitation stages and has no predetermined end goals.

In our view, DS can be described according to a three-stage journey of manufacturer's actions: *emerge, consolidate and evolve*. We use this conceptual framework to depict the corresponding transformation, irrespective of the DS trajectories. While this framework shares similarities with the one from Baines *et al.* (2020), there are also some differences that are rooted in the challenges posed by digital technologies and in the corresponding distinctions between servitization and DS that are presented in Table 1.

The initial stage (i.e. emerge), aligns with the exploration stage in Baines *et al.* (2020)'s model. With our focus on organizational actions, we emphasize this stage as the foundation for initial learning and exploration of DS concepts and challenges, reflecting the crucial early task of understanding the digital landscape within the manufacturing environment. The second stage (i.e. consolidate) was chosen over "engagement" to underscore the organizational actions required to consolidate the manufacturer's strategies for the DS journey. This stage emphasizes the need for defining concrete plans, mobilizing resources and structuring the organization's approach to DS. The last stage (i.e. evolve) marks a departure from the traditional servitization model, which primarily emphasizes service offerings and market penetration. Evolve represents a critical stage where the organization not only scales up its digital services but also transforms its capabilities, finding synergies across departments, optimizing efforts and effectively utilizing resources.

2.2 Managing complexity in DS

Complexity in the DS journey originates from the increasing number and interplay of different elements of technology, organization, business models and ecosystems (Kohtamäki *et al.*, 2019b). Therefore, the adoption of complexity management theory helps unveil the efficacy of managerial approaches along the DS journey, recognizing organizations as complex systems that adapt to their rapidly changing environments through self-organizing and coevolution (Ashmos *et al.*, 2000; Benbya and McKelvey, 2006). To navigate DS complexities, this paper uses the framework from Maylor and Turner (2017). Table 2 categorizes some of the complexities identified in the previous research, considering structural complexity (involving people, disciplines, locations and interdependencies), sociopolitical complexity (cultural and cognitive aspects, resistance and conflicting priorities) and emergent complexity (organizational unpreparedness, technological and commercial readiness).

Complexity management involves two main approaches: reduction and absorption (Ashmos *et al.*, 2000; Boisot and Child, 1999). Complexity reduction simplifies by focusing on key goals, formalizing structures and minimizing decision-making interactions

Type of complexity	Examples from previous studies
Structural complexity	Establishing new business ecosystems (Bikfalvi *et al.*, 2013)
Sociopolitical complexity	Aligning goals with new partners, such as software providers and digital platforms (Kohtamäki *et al.*, 2019b, 2021; Münch *et al.*, 2022; Dalenogare *et al.*, 2023; Peillon and Dubruc, 2019)
	Customers' hesitancy to share data (Peillon and Dubruc, 2019)
Emergent complexity	Diverse capabilities and resources for developing digital services (Ardolino *et al.*, 2018; Kanovska and Tomaskova, 2018; Paiola and Gebaur, 2020)
	Customers' unpreparedness for DS (Vaittinen and Martinsuo, 2019)

Source(s): Created by authors

Table 2. Complexities in DS identified in the previous studies

(Ashmos *et al.*, 2000). For instance, understanding customers' digital service needs helps prioritize technology integration (Kohtamäki *et al.*, 2019b; Paiola *et al.*, 2022). Conversely, complexity absorption encourages flexibility by creating diverse connections to transfer information and create meaning throughout the organization (Benbya and McKelvey, 2006; Boisot and Child, 1999). This approach involves various goals, a decentralized structure and increased interactions for decision-making (Ashmos *et al.*, 2000). In manufacturing, complexity absorption can mean developing extensive data-related capabilities for DS (Ardolino *et al.*, 2018; Momeni *et al.*, 2023).

Previous research about DS has mainly focused on methods for complexity reduction (top-down) rather than complexity absorption and synergies between the different approaches (Eloranta *et al.*, 2021). Only a few studies have adopted the complexity management lens to explore the actions taken by manufacturers to handle specific complexity drivers. In addition, as Table 3 shows, the majority of these studies do not specifically focus on DS.

Furthermore, an understanding of DS journey dynamics cannot be gained by isolating it from the unique context of manufacturers (Kohtamäki *et al.*, 2019a; Shen *et al.*, 2023) but rather by considering the fit among strategy, organization and context (Kohtamäki *et al.*, 2019a). Therefore, to examine manufacturers' overall approach to managing innovation and change is vital to develop theories about managing complexity in DS. Two approaches to managing innovation can be identified: a managerial approach and an entrepreneurial approach (Boisot and MacMillan, 2004).

The managerial approach is focused on reducing complexity to ensure fast and efficient exploitation and survival (Burger-Helmchen, 2013) and is typically associated with a centralized and top-down management style emphasizing control and efficiency. In contrast, the entrepreneurial approach is focused on exploration and evolution, thus absorbing complexity to find new ways to create value (Yang and Leposky, 2022) and is associated with a decentralized and bottom-up management style emphasizing innovation and creativity (Boisot and MacMillan, 2004).

Table 3.
Previous studies on complexity management in (digital) servitization

Papers	Research methodology	Research approach	Unit of analysis	Actions taken by manufacturers
Dahmani *et al.* (2016)	Modeling and evaluation in an industrial SME	Cross-sectional	Decision-making process	Complexity reduction through a decision-making reference model
Eloranta and Turunen (2016)	Qualitative case study	Cross-sectional	Platform approach	A platform approach as a means of orchestrating a network and thus leveraging complexity, instead of trying to reduce complexity
Eloranta *et al.* (2021*)	Conceptual study	N/A	Service offering	Complexity reduction mechanisms in terms of standardization and modularization of processes and offering Complexity absorption mechanisms in terms of extending networks and increasing diversity and agility of service processes
Yan *et al.* (2022)	Qualitative case study	Cross-sectional	Platform approach	Service modularity, platform development
Zou *et al.* (2018*)	Conceptual study	N/A	Service offering	N/A

Note(s): *Papers about DS
Source(s): Created by authors

2.3 Research framework

This section connects the complexity management presented in Section 2.2 to the theoretical assumptions of this paper (i.e. DS as a three-stage journey) and introduces the framework that we use to address the research question (see Figure 1).

First, DS is a complex transition that changes different aspects of the organization, business models and manufacturers' boundaries (Kohtamäki *et al.*, 2019b; Vendrell-Herrero *et al.*, 2017). This paper argues that manufacturers undergoing DS are complex systems in which interactions between different parts cannot be understood simply by dividing them into isolated units. In fact, understanding different elements of a complex system separately cannot result in understanding the whole system (Perona and Miragliotta, 2004).

Second, in line with previous literature (Ashmos *et al.*, 2000), this paper assumes that manufacturers use different approaches to reduce or absorb complexities in their DS journey (Eloranta *et al.*, 2021). It also argues that the same organization may combine different complexity management approaches in a prolonged strategic transformation, such as the DS journey. Thus, this paper emphasizes continuous changes and adjustments occurring over time when tackling DS and abandons the dominant view of the literature that considers manufacturers to be almost static and deterministic objects. In line with the research question of manufacturers' ways to manage complexity during the DS journey, the framework that has guided the collection and analysis of empirical data is presented in Figure 1.

3. Research method

3.1 Research design

This study involves a case study of two manufacturers' DS journeys. A qualitative case study allowed the researchers to investigate and provide in-depth insights into different DS journeys (Yin, 2009). The DS journey was explored through a longitudinal study in Companies A and B to capture the evolution of DS practices over time and explore contextual factors that shape the manufacturers' DS experiences. The primary goal was to explore the DS journey within the predefined stages focused on understanding the specific DS milestones, challenges faced and strategic shifts within the predetermined stages, rather than depict the entire process as an emergent phenomenon.

These manufacturers were selected because they (a) offer complex systems and services, (b) pursue DS and (c) differ in terms of industry. Companies A and B served as excellent

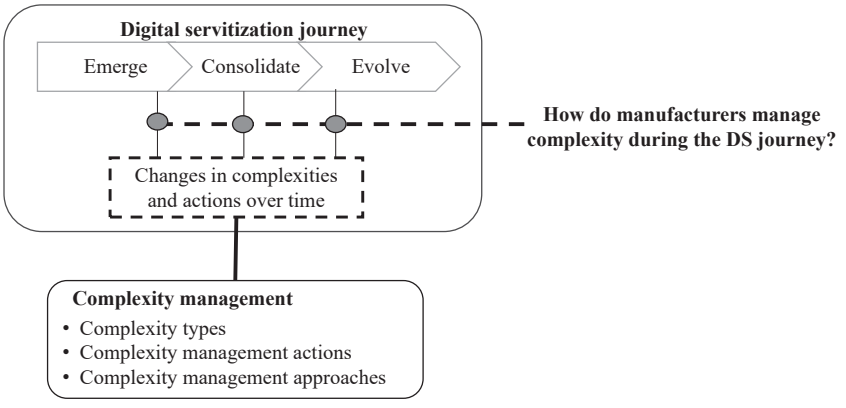

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Figure 1.
Research framework

samples for this research due to their significant involvement in previous collaborative research projects spanning 2014–2021. This long-term engagement facilitated an in-depth understanding of their organizational dynamics, strategic goals and transformational processes. The observed servitization strategy adopted by Companies A and B highlights their shared vision of enhancing their capabilities through the integration of digital technologies and the provision of services. Both companies embarked on this journey, driven by a desire to leverage the potential of IoT and develop their servitization capabilities.

3.2 Data collection

Data were collected through semi-structured interviews and secondary sources, such as websites and public reports. The focus was on identifying interviewees possessing strategic and operational insights into the manufacturer's DS journey, requiring a deep understanding of the topic. Hence, the pool of eligible managers or directors was limited. We asked for a key contact to identify the most knowledgeable managers in each data collection round. In total, 25 interviews were conducted in three rounds between 2014 and 2021. The first round occurred in 2014, when both manufacturers were at the "emerge" stage, emphasizing the development of remote monitoring systems and their applications for service businesses. The second round in 2017, when the companies were roughly at the "consolidate" stage, centered on how the companies developed their businesses around IoT technologies. The third round in 2021 gathered data on more advanced initiatives during the "evolve" stage, complementing earlier data on the manufacturers' DS journey. Interviews ranged from 45 to 90 min, averaging 70 min. All interviews were recorded and fully transcribed. Archival data, including public reports and press news, were also collected to augment the information and validate the expert interviewees' insights. Table 4 shows the details of the data collection process.

	First round—Emerge	Second round—Consolidate	Third round—Evolve
Main theme	Starting the development of remote monitoring systems and their applications for service business	Developing service business around IoT technologies and consolidating DS efforts	Developing more advanced initiatives, capabilities, and service offering
Timing	2014	2017	2021
Company A	$n = 3$ *Roles:* Director of field services, R&D manager, product manager of intelligent products *Interview theme:* Application of remote monitoring systems in service business	$n = 6$ *Roles:* Sales director, sales manager, director of service business, director of life cycle services, solution managers *Interview theme:* Data-enabled business models	$n = 3$ *Roles:* Vice president of industrial Internet,vice president of service development, director of life cycle service *Interview theme:* Advances in the DS journey
Company B	$n = 4$ *Roles:* General manager, vice president of global project management, R&D manager, vice president of life cycle services *Interview theme:* Application of remote monitoring systems in service business	$n = 6$ *Roles:* sales managers, service managers, key account managers *Interview theme:* Data-enabled business models	$n = 3$ *Roles:* Head of service product management, head of service business development, head of field service, training, and agreements *Interview theme:* Advances in the DS journey

Table 4.
Interview data

Source(s): Created by authors

3.3 Data analysis

To analyze the data, the companies were characterized based on DS contexts (chapter 4.1). The data analysis showed that manufacturers faced various complexities during their DS journey resulting from the need for significant infrastructure, different technologies and different resources and capabilities. These complexities are grouped deductively into structural, sociopolitical and emergent complexities (Maylor and Turner, 2017) (see Table 5) and mapped to the three DS journey stages. Furthermore, considering DS as a complex transition requiring various changes and innovations in manufacturers' organizations, capabilities and offerings (Ardolino *et al.*, 2018; Cenamor *et al.*, 2017; Kohtamäki *et al.*, 2019b), we investigate the architecture and structure of the two companies in managing innovation (Burger-Helmchen, 2013) and mapped them into managerial and entrepreneurial organizations (Boisot and MacMillan, 2004).

Second, open coding was used (Corbin and Strauss, 2008) to capture interviewees' perspectives on DS, focusing on identifying actions associated with DS. Third, a three-order coding procedure (Gioia *et al.*, 2013) was followed, resulting in 32 actions derived from direct quotes (first-order codes), nine groups of actions (second-order codes) and three aggregate dimensions, which included *shaping the digital service systems*, *shaping the organization* and *shaping the network* as presented in Figure 2 (and Chapter 4.3). Fourth, three stages defined in the literature review were used (emerge, consolidate and evolve) to organize actions chronologically. The three stages were general enough to fit both companies and illustrated the differences in the decisions, actions and involved actors of the DS journey. An abductive approach was adopted by applying complexity management (Ashmos *et al.*, 2000; Boisot and

Type of complexity	Complexities in the DS journey	Examples
Structural complexity	- Organizational structure - Skillsets and workforce - IT infrastructure - Customer engagement	- New departments or teams focused on service design, remote support, and data analytics - New employees with expertise in data analysis, software development, service designetc. - New software systems, data analytics tools, and communication technologies to support their service offerings - New ways of customer engagement, e.g. subscription-based models or remote monitoring
Sociopolitical complexity	- Supply chain - Customers - Regulatory and legal challenges	- The need for interoperability among different systems and aligning interests and incentives - Customers' new needs and preferences, conflicts in setting priorities, and the need to manage various touchpoints - Data privacy, intellectual property, and contractual issues
Emergent complexity	- Digital technology - Data - Business model	- Issues related to connectivity, interoperability, data security, and scalability - The complexity of managing and integrating large volumes of data from various sources and leveraging analytics to drive service improvements and value creation - The need for rethinking existing business models and designing new business models and new pricing structures

Source(s): Created by authors

Table 5.
Complexities in the DS journey

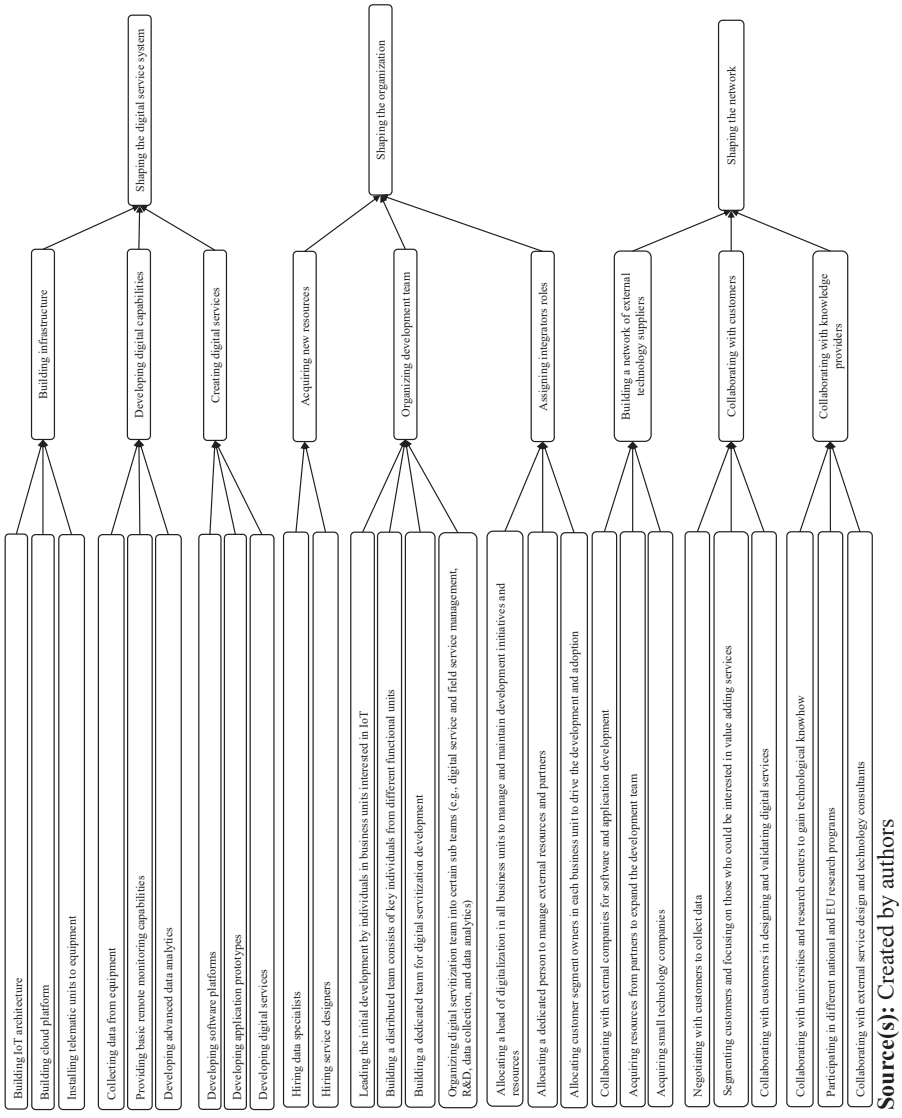

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Figure 2.
Data structure

Child, 1999) to differentiate the approaches used by manufacturers in different stages of DS. For complexity reduction, data related to codification and abstraction actions was identified, e.g. considering a few selected main strategic goals, formalizing and centralizing structure and minimizing the interactions needed for decision-making. For complexity absorption, actions that create various connections throughout the organization were identified, e.g. having multiple goals, a variety of strategic initiatives, a more informal or decentralized structure and increasing the number of participants and interactions for decision-making.

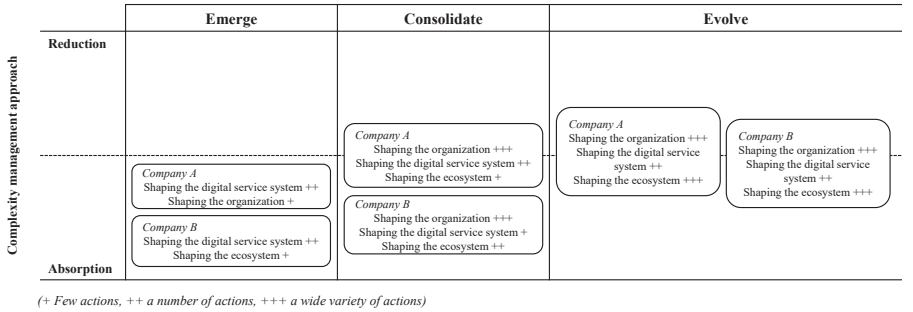
As illustrated in Figure 3, we use different symbols to indicate the intensity of actions taken by the companies. In particular, + represents a small number (one or two) of actions. The symbol ++ indicates several (usually three to five) actions. Last, the symbol +++ signifies a wide variety of actions, of both small and large relevance. Finally, through a cross-case comparison, four propositions are developed. Case-specific narratives and cross-tabulation are also used when introducing the main findings.

4. Findings

4.1 Case context

4.1.1 Company A. Company A, a market leader in process and automation technologies and services for pulp, paper and energy industries, has over €3 billion in net sales and 13,000 employees. The service business has become an important part of its portfolio, offering various services, including spare parts, process parts, field services, upgrades, service agreements, automation services and training. Recognizing the servitization potential early on, they aimed to complement the product-centric approach with remote monitoring services, IoT-based solutions and process and production optimization for their customers. This chapter illustrates how complexities evolved throughout Company A's DS journey.

Emerge: Company A faced structural complexities due to changes in organizational structure, workforce and information technology (IT) infrastructure. For instance, the integration of telematics units required the hiring of or reallocating skilled professionals with expertise in IoT and remote monitoring. The adoption of these technologies led to diverse internal and external interdependence, as different departments had to collaborate closely to implement and maintain these systems. Managing diverse stakeholder interests and aligning customer needs with digital transformation goals posed significant sociopolitical complexities. For example, employees needed to adapt to new roles and responsibilities and customers demanded enhanced services and responsiveness. Navigating these complexities required continuous efforts in communication and negotiation. Emergent complexities were raised due to the lack of prior experience in digital technologies and slowed



(+ Few actions, ++ a number of actions, +++ a wide variety of actions)

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Figure 3. Differences in complexity management approaches over the DS journey

progress, necessitating continuous understanding and adaptation to new technologies and customer expectations. The unfamiliarity with the requirements of these technologies led to delays and setbacks in implementation. For instance, employees faced a learning curve when utilizing IoT-based solutions for remote monitoring and the adjustment period affected the overall pace of adoption.

Consolidate: During this stage, Company A continued to face structural complexities. The need for diverse capabilities such as software development and data analysis persisted, leading to ongoing internal collaboration challenges. Teams had to work closely together to bridge the skills gap and ensure the integration of digital solutions into existing processes. Ongoing efforts were made to improve IT infrastructure. Sociopolitical complexities intensified, requiring constant adaptation to meet the evolving needs of stakeholders. In particular, building strong relationships with technology providers became crucial. While emergent complexities were reduced, challenges in scaling digital technologies persisted. The learning process accelerated, enabling the company to adapt more quickly to emerging challenges. This involved refining internal processes and enhancing collaboration mechanisms with customers and technology providers.

Evolve: Structural complexities became more manageable as internal collaborations streamlined and strategic investments in IT infrastructure enhanced efficiency. Sociopolitical complexities evolved, with increased relationships with technology providers. Challenges related to data privacy were reduced through data governance policies. The company faced fewer emergent complexities, but the focus shifted to implementing and scaling digital technologies, as well as developing pricing models and sales strategies.

Overall, company A has a more managerial approach with a traditional hierarchical structure and clearly defined roles and responsibilities. This is suggested by the allocation of dedicated persons to manage external resources and partners and the assignment of customer segment owners in each business unit to drive development and adoption. The company appears to have a top-down management style, as evidenced by the strategic initiatives introduced by top management, e.g. the decision-making for investing in IoT technologies and building centralized teams were all top-down decisions.

4.1.2 Company B. Company B, a leading supplier of manufacturing management and factory automation solutions, has €100 million in net sales and 450 employees. Their service offering includes spare parts, service agreements, upgrades, remote support, software maintenance, maintenance, modernizations and extensions and training. By embracing servitization, they aimed to enhance manufacturing processes, optimize production efficiency and provide value-added services to their customers. The company originally invested in developing IoT-based solutions to enable real-time monitoring and predictive maintenance. This chapter explains the complexities throughout Company B's DS journey.

Emerge: Company B faced significant structural challenges similar to Company A during this stage. Internal collaboration was a main challenge that required a re-evaluation of existing workflows and the creation of cross-functional teams. The establishment of new IT infrastructure was another complexity that demanded significant investments and technological upgrades. Sociopolitical complexities, like managing diverse stakeholder interests and data privacy, added further complexity. Particularly, understanding customer needs and expectations in the context of emerging digital solutions was a challenge for Company B. Emergent complexities were particularly significant for Company B during this stage. Unclear goals and strategies caused confusion among employees, hindering progress. However, it is noteworthy that the two companies have different levels of technological capabilities. Company B is already a strong automation hardware and software provider and has resources to develop various applications which reduced the emergent technological complexities.

Consolidate: Structural challenges persisted, with evolving internal collaborations and IT investments. While customer engagement mechanisms were refined, challenges in managing the diversity of tasks and specialized fields remained. The fluid structure and bottom-up style of the company, allowing individuals to involve themselves in different projects, contributed to the ongoing complexity of task management. Sociopolitical complexities became more important. Although stakeholder understanding improved, aligning them with DS goals remained a challenge. Data privacy concerns were managed, but adapting to technology providers' and customers' needs was ongoing. Emergent complexities persisted. The lack of clear goals and strategies persisted, impacting the company's ability to measure progress effectively.

Evolve: Structural challenges diminished as internal collaborations and strategic IT investments improved. Sociopolitical complexities evolved, considering the increased number of technology providers and customer segments involved, especially in defining a cohesive strategy that covers the diverse stakeholders' interests and relationships. Emergent complexities were resolved as Company B's direction became clearer, leading to reducing employee uncertainty and enabling the effective implementation of digital technologies.

Company B has generally an entrepreneurial approach with a fluid structure and bottom-up style, where people can involve themselves in different projects. This is suggested by the development of various applications and services through the distributed team. Company B seems to be more technologically innovation-oriented and short-term-oriented in its development, with a focus on software provision, as evidenced by following a minimum viable product strategy.

4.2 Complexity management actions

Findings revealed three main categories of manufacturers' actions to manage complexities during DS journeys: shaping (1) the digital service systems, (2) the organization and (3) the network. Table 6 summarizes the actions and empirical evidence in Companies A and B.

4.2.1 Shaping the digital service system. Digital service systems pose complexities in infrastructure, technologies involved and links between products, services and software. The cases revealed three main actions to shape digital service systems: building infrastructure, developing digital capabilities and creating digital services. Both cases started with individuals' initiatives in business units embedding sensors in equipment to establish remote connections to support the execution of the service agreements. This increased emergent complexity due to lack of previous experience and technological maturity. While Company A evaluated cloud platforms and later started collaborating with a world-class platform provider, Company B initially focused on building IoT architecture to be used for developing connectivity and data collection capabilities.

Both companies focused on data analytics and software development. Company A's DS was organized into different development streams, including remote service, customer portals, advanced applications, optimization and industrial Internet. In contrast, Company B followed a minimum viable product strategy and developed some application prototypes as the simplest and least expensive solutions. This approach resulted in the fast development of digital services. The sales manager explained one example during the consolidate stage: "*. . . as a result, there is an application for the customer to get the system status and also for us to monitor the status and be able to do proactive activities and alert the customer when we notice something . . .*"

4.2.2 Shaping the organization. The cases revealed how DS requires acquiring new resources, organizing the development team and assigning integrator roles. Company A took systematic organizational actions, transitioning from a decentralized to a solid-line team led by a vice president reporting directly to top management who managed and integrated DS

Actions	Company A	Company B
Shaping the digital service system • Building infrastructure • Developing digital capabilities • Creating digital services	Installing telematics units for equipment Building a cloud platform Collecting data from equipment Providing basic remote monitoring capabilities Developing advanced data analytics Developing software platforms Developing digital services	Building IoT architecture Installing telematics units for equipment Collecting data from equipment Providing basic remote monitoring capabilities Developing application prototypes Developing digital services
Shaping the organization • Acquiring new resources • Organizing development team • Assigning integrator roles	Hiring data specialists Building a dedicated team for DS development Organizing the DS team into certain sub-teams Allocating a head of digitalization in all business units to manage and maintain development initiatives and resources Allocating a dedicated person to manage external resources and partners Allocating customer segment owners in each business unit to drive development and adoption	Hiring service designers Leading development by individuals in business units interested in IoT Building a distributed team consisting of key individuals from different functional units Allocating the head of DS
Shaping the network • Building a network of external technology suppliers • Collaborating with customers • Collaborating with knowledge providers	Collaborating with external companies for software and application development Acquiring resources from partners to expand the development team Acquiring small technology companies Negotiating with customers to collect data Collaborating with universities and research centers to gain technological know-how	Collaborating with external companies for software and application development Negotiating with customers to collect data Segmenting customers and focusing on those who could be interested in value-adding services Collaborating with customers in designing and validating digital services Collaborating with universities and research centers to gain technological know-how Participating in different research programs Collaborating with external service design and technology consultants

Table 6.
Complexity management actions in studied cases

Source(s): Created by authors

efforts. The vice president of the industrial Internet explained: *"Then [after deciding on the cloud platform provider], we set ourselves targets and then planned how we are organizing ourselves around this topic. We decided to move from fully decentralized teams into a solid-line team to speed up the development and implementation of the solutions on top of the platform."* Simultaneously, Company A hired data specialists to develop data analytics and organized certain sub-teams (e.g. digital service and field service management, R&D, data collection and data analytics). To manage complexities, they assigned different integrator roles, such as a head of digitalization in all business units, a dedicated person to manage external resources and partners and customer segment owners in each business unit to drive development and adoption.

Company B utilized all resources perceived to be important in terms of creating more innovative ideas in the organization. Certain individuals in different business units tried to develop data collection and analysis tools in their own business units increasing the sociopolitical and structural complexity resulting from a lack of shared understanding and strategic goals. For a considerable period, people from different business units were assigned to a distributed team to advance DS in addition to their functional roles.

4.2.3 Shaping the network. According to the cases, DS depends on shaping a network in a way that often surpasses traditional collaborations. Both cases highlighted building a network of external technology suppliers, collaborating with customers and knowledge providers. Company A expanded its development team by acquiring resources from external companies, some providing capabilities and others contributing resources. The vice president of the industrial Internet explained the latter way: *"With regards to collaboration with the partners when we select some partners to provide us certain competencies or resources, those resources are coming into our office, sitting together with our team so in that sense collaboration is quite smooth."* Additionally, customer collaboration was further developed in designing and validating digital services.

Company B took an innovative approach, initiating shaping the network early by collaborating in public-funded research programs to start the development and prototyping. Emphasizing closer customer collaborations in DS, it adopted new methods for segmenting customers, targeting segments interested in advanced services. Tailored business cases were developed for specific market segments, fostering closer customer collaboration and aiding in designing and validating digital services. Simultaneously, they collaborated with external consultants to better understand the digital service design methods and the organizational requirements to proceed with creating digital services. The head of service business development explained: *"We have a service design partner to help us get through with the service design of the digital services . . . They build a new concept for the digital services based on the interviews and of course together with us. They help us build a business model and validate the concept."*

4.3 Complexity management approaches in the DS journey

Complexity management approaches can be divided into complexity absorption and reduction (Ashmos *et al.*, 2000). Empirical evidence shows that manufacturers differ in their complexity management approaches that change over the DS journey. Taking a cross-case perspective revealed that while all three main categories of actions appeared in Companies A and B, they differed in how the actions worked in practice (Figure 3). Moreover, the emphasis on their actions at each stage varied between cases.

The evidence suggests that the actions along DS journey differ in not only types and intensities of complexities but also contingencies related to the organizational context, influenced by distinct company objectives and resource constraints. For example, Company B, being an automation and software provider, had a stronger focus on developing technological capabilities and collaborating with external partners from the early stages to leverage their expertise. Differences in organizational architecture, such as Company A's top-down approach and centralized teams versus Company B's decentralized, collaborative culture, led to diverse complexity management actions. Furthermore, the dynamic nature of the DS journey, with its evolving technological landscape and market demands, also contributes to differences in complexity management actions. As the companies progressed through different stages, they encountered new complexities that required different approaches. The specific challenges faced by each company, i.e. the types of complexities and customer demands, could influence their decision-making regarding complexity absorption and reduction. Figure 2 describes complexity management approaches over DS journey stages, especially concerning the differences between the stages and the two companies.

4.3.1 Complexity absorption. Emerge: Both companies started the DS journey mainly by absorbing emergent complexities at this stage by exploring different technologies, developing connectivity and data collection capabilities and collecting more data from the installed base of equipment. Some individuals in different teams of Company A developed DS locally in their own team, presenting a complexity absorption approach. Company B started shaping the network and collaborating with technology providers and consulting companies during the emerge stage, showing a stronger complexity absorption approach.

Consolidate: Both companies took several actions to absorb the complexity created by huge amounts of collected data by developing analytic capabilities and creating several ideas for developing new digital services. In particular, as an automation hardware and software provider, Company B did not face critical issues in terms of technological capabilities and developed various applications and services through its distributed team. A key account manager explained, *"We have this kind of a task group that was supposed to collect these bit crazy ideas and test them in a sprint model where you just test quickly. You see if it works or not, and then you do the next thing."* The interviewees clarified that some of these applications and services have still been in use, while others have forgotten when proceeding to the next stage.

Evolve: Findings reveal an interesting struggle during the evolve stage between the complexity absorption approach to shape the network and the complexity reduction approach to shape the organization. Company A had considerably expanded its collaboration with different types of actors, increasing its structural and sociopolitical complexity. The vice president of service development explained, *"We have contracts with multiple partners, mostly smaller companies, but some larger companies as well. For example, we have partnered with platform capabilities and set them to lead the project to set up the platform."* Similar to Company A, Company B also absorbed structural and sociopolitical complexities by expanding its networks through collaborating with different customers in service design and with technology and knowledge providers in developing digital capabilities.

4.3.2 Complexity reduction. Emerge: The case companies' approach was solely complexity absorption, and the interviewees did not report any evidence regarding the complexity reduction approach.

Consolidate: Company A tried to reduce complexity during consolidate. One of the key influential actions was the decision-making of top management to unify DS efforts across the company. The director of life cycle services explained the reason: *"... the tools are quite local, and we spent quite much cost for setting up the data collection and setting up the analysis tools per site per customer."* To reduce organizational complexity and direct the efforts toward certain goals and strategies at the company level, Company A's key actions were building a team of key individuals from information systems and technology departments, building centralized teams and assigning committed persons to manage DS development.

Evolve: Company A defined several integrator roles to manage business units, external partners and customer interfaces. For example, they allocated a dedicated person to manage external resources and partners and assigned customer segment owners in each business unit to drive development and adoption. The vice president of industrial Internet explained, *"Since we are working with a selected number of key customer segments, we have nominated kind of a customer segment owner for each customer segment who is in that business area. They are in a matrix reporting role to me, so they are in solid line in their home businesses."* After a period of experimentation, the top management of Company B also decided to reduce complexities and centralize DS development. As a result of the complexity reduction approach, they hired a dedicated individual to manage DS development and create a DS roadmap. Further, they built a dedicated team for developing digital services and hired data specialists and service designers.

5. Discussion and propositions on complexity management approaches

Overall, the choice of a complexity management approach in DS depends on the manufacturers' architecture and structure. Both complexity management approaches have strengths and weaknesses, and successful DS strategies likely involve a mix of both. As shown in Figure 2, the companies' approaches to complexity management differed, and both used a combination of complexity reduction and absorption.

Emerge: Findings show that during the emerge stage manufacturers mainly focused on absorbing emergent complexities by shaping digital service systems, e.g. exploring different technologies, developing connectivity and data collection capabilities, collecting more data from the installed base of equipment and developing different remote monitoring systems. This confirms evidence for increased complexities in manufacturers in the early stages of DS in terms of new technologies, digital capabilities and a variety of digital-technology-enabled innovations (Ardolino *et al.*, 2018; Grubic, 2014; Kanovska and Tomaskova, 2018; Paiola and Gebaur, 2020), as summarized in the following theoretical proposition:

Proposition 1. Manufacturers primarily adopt a complexity absorption approach during the emerge stage of the DS journey, setting the stage for their DS journey.

Consolidate: The findings provide insights into how manufacturers manage complexities during the DS journey based on their unique organizational setting. Therefore, this paper expands the findings on the importance of considering the fit among strategy, organization and context (Kohtamäki *et al.*, 2019a; Shen *et al.*, 2023) and shows that manufacturers with a managerial approach focus more on creating a solid foundation of efficient and effective processes and systems. This involves reducing complexity wherever possible and creating well-defined roles and responsibilities across the organization. In contrast, manufacturers with an entrepreneurial approach focus more on experimentation and exploration, seeking out new digital services and incorporating more complexity into the system, emphasizing agility and adaptability and a willingness to take risks and make mistakes in the pursuit of innovation (Boisot and MacMillan, 2004). Therefore, the following proposition can be stated:

Proposition 2. Complexity management approaches differ in the consolidate stage of the DS journey, based on the organizational context. Manufacturers with a managerial approach focus on complexity reduction through shaping the organization, while manufacturers with an entrepreneurial approach emphasize complexity absorption through shaping the digital service systems and network.

Evolve: The findings elaborate on the drivers of complexities during the evolve stage and identify a variety of simultaneous complexity management actions during this stage. The insights from the case companies reveal their struggle with balancing complexity absorption and reduction. This complements previous studies characterizing DS in terms of absorbing complexities through the involvement of external software suppliers and other service providers (Dalenogare *et al.*, 2023; Kohtamäki *et al.*, 2019b, 2021), development of novel capabilities (Münch *et al.*, 2022) and changes in the business models (Paiola *et al.*, 2022). Manufacturers expanded their collaboration with various actors and allocated several integrator roles to manage external resources and customer interfaces. Therefore, our findings suggest that both managerial and entrepreneurial manufacturing approaches require a certain level of capability for absorbing and reducing complexities. DS is not an easy transformation, and manufacturers must be able to navigate the challenges that arise as they integrate new systems and processes into their organizations. Simultaneously, they need to focus more on streamlining and standardization. In sum, we derive the last theoretical proposition:

Proposition 3. Manufacturers in the evolve stage of the DS journey balance complexity reduction and absorption to drive business growth and exploit new opportunities.

6. Conclusion

6.1 Theoretical contributions

This study investigated how manufacturers manage complexities during their DS journeys. First, it reveals fine-grained insights into the differences between servitization and DS journeys and complements the scant literature on complexities management in DS (Eloranta and Turunen, 2016; Eloranta *et al.*, 2021). Specifically, the paper offers a comprehensive framework that encompasses complexity types, complexities management actions and complexities management approaches of manufacturing firms. The findings on different categories of actions—shaping the digital service system, the organization and the network—expand the current understanding of DS as a trial-and-error journey (Paiola *et al.*, 2022), identifying the key actions for handling this complex transformation. This study also develops three theoretical propositions that explain how manufacturers navigate DS complexities and contingently adopt different approaches along the stages of the DS journey.

Second, this study complements the dominant cross-sectional approaches to DS by revealing the evolving nature of the DS journey. It also unravels manufacturers' actions during the transition process longitudinally as the focal phenomenon, thereby responding to the requests from Kohtamäki *et al.* (2021) and Hsuan *et al.* (2021). The findings highlight the importance of balancing complexity reduction and absorption during the DS journey. By identifying different complexity management actions and approaches, this study shows that DS is a dynamic journey with varying requirements during emerge, consolidate and evolve stages. Therefore, this study has important theoretical implications for the DS literature, challenging the deterministic objects in DS trajectories and highlighting the need for a dynamic approach that considers changes in complexities and actions over time.

6.2 Managerial implication

Understanding DS from a complexity management perspective helps manufacturers navigate challenges and facilitate the transition. First, manufacturers must recognize the inherent complexity in DS and adopt an appropriate complexity management approach aligned with their structure. Second, DS is a continuous journey requiring ongoing adaptation, evaluation of initiatives and openness to new opportunities. Third, the foundational emerge stage sets the way for future development, allowing manufacturers to prioritize complexity absorption over reduction to focus on innovation or maintain flexibility with different technological alternatives. Subsequent stages involve complex reduction strategies, e.g. simplifying processes and streamlining decision-making, but trade-offs between complexity reduction and priorities such as innovation and flexibility must be considered.

6.3 Limitations and future studies

The validity of this study has some limitations. The sample was limited to two manufacturers, limiting generalizability. The companies were chosen based on some business-to-business manufacturing similarities, making findings applicable primarily to such contexts. This study focused only on manufacturers' perspectives and did not consider customers' or other actors' views, suggesting further research to understand their roles in the DS journey. Relying on interviews may introduce biases, but efforts were made to choose knowledgeable informants to strengthen the credibility of the research. Public data was used to validate the main stages, strategic decisions and actions during the DS journey.

Future research should validate or debate the propositions developed in this study using a broader sample of companies, through additional case studies or quantitative methods. The study focused on large market leaders. Further research can focus on small- and medium-sized enterprises for unique complexity management actions and approaches. Further research is encouraged on complexity management approaches' impacts on DS performance

outcomes, trade-offs and synergies between complexity reduction and absorption and understanding managerial and entrepreneurial orientations. Understanding the reasons behind the variations and the implications they have for manufacturers can guide practitioners and decision-makers in making informed choices regarding managing the DS journey. Our findings suggest that companies with different organizational settings may apply varying approaches to manage complexity during their DS journeys. Further research can investigate these underlying conditions to provide insights into why companies with similar starting points may take different paths in managing complexity, enabling practitioners and researchers to better comprehend and navigate the complexities of DS.

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