DOCTORAL THESIS

Industrial Sustainability through Digital Servitization

A Socio-technical Systems Perspective

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Entrepreneurship and Innovation

LULEÅ UNIVERSITY OF TECHNOLOGY

Industrial Sustainability through Digital Servitization:
A Socio-Technical Systems Perspective

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Abstract

Industrial providers engaged in digital servitization increasingly face the challenge of leveraging advanced digital technologies while supporting customers in improving their environmental and social sustainability performance. Meeting these objectives requires industrial providers not only to digitalize their own offerings but also to enable sustainability improvements within customer operations. Against this backdrop, many industrial providers are shifting from traditional product-centric models towards digitally enabled solutions that combine operational performance with sustainability outcomes. However, realizing this potential remains difficult. Digital solutions must be integrated with existing equipment, infrastructures, and data environments, while their use may require corresponding changes in organizational routines, skills, responsibilities, and decision-making practices. These interconnected technical and social challenges extend to providers, customers, and ecosystem partners and become more complex as digital solutions are extended across heterogeneous industrial environments. Consequently, supporting industrial sustainability through digital servitization constitutes a socio-technical alignment problem.

Accordingly, this thesis investigates *how industrial providers engaged in digital servitization align socio-technical systems – internally, with customers, and across ecosystem partners – to support industrial sustainability*. It adopts a socio-technical systems perspective and views digital servitization as a socio-technical alignment process in which technologies evolve in alignment with organizational routines, decision-making practices, and inter-organizational relationships. The thesis is based on four interrelated qualitative studies that draw on semi-structured interviews, publicly available podcast interviews, and complementary materials.

Paper 1 examines the interacting economic, technological, market, and sustainability-related conditions that drive industrial providers' engagement in digital servitization. Paper 2 examines how industrial providers support customers in aligning digital solutions with customer infrastructures, organizational routines, and operational practices to support industrial sustainability. Paper 3 analyzes how differences in power dynamics and sustainability focus among industrial actors shape ecosystem configurations and the conditions under which sustainability-oriented change unfolds. Paper 4 investigates how industrial providers coordinate intra-organizational, customer, and ecosystem practices to scale digital solutions beyond localized implementations.

Through an integrative synthesis of the four studies, the thesis develops a three-phase framework comprising *exploring solution viability*, *operationalizing solutions*, and *scaling solution implementation*. The framework explains how the socio-technical alignment problem evolves from reducing uncertainty around emerging digital solutions, through embedding workable socio-technical arrangements in customer operations, to making these arrangements sufficiently repeatable and adaptable across heterogeneous contexts. Across this process, socio-technical alignment extends within industrial providers and across customer and ecosystem boundaries. The associated outcomes progress from *demonstrated sustainability potential*, through *realized sustainability value*, to *scaled sustainability value*.

The thesis contributes to digital servitization research by conceptualizing digital servitization for industrial sustainability as an unfolding socio-technical alignment process across organizational boundaries. It further conceptualizes industrial providers as socio-technical change agents that

support the technical and organizational changes required to realize sustainability value beyond specific contexts. Finally, it shows that scaling digital servitization requires broader socio-technical configurations surrounding digital solution use to make them sufficiently repeatable and adaptable across heterogeneous contexts. These insights advance understanding of how industrial providers can translate the sustainability potential of digital servitization into realized sustainability value and extend this value across broader industrial contexts.

Keywords: digitalization, digital servitization, industrial sustainability, socio-technical systems, scaling, ecosystem collaboration, B2B manufacturing, business ecosystems

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Appended Papers

Paper 1 Kilinc, T. (202X). Revisiting Drivers of Digital Strategies: Exploring B2B Firms' Adoption of Digital Servitization. Under review in *Industrial Management & Data Systems*.

Paper 2 Kilinc, T., Sjödin, D., & Parida, V. (2025). Navigating Digital Servitization for the Twin Transition: How Manufacturers Can Support Customers with Digitalization and Sustainability. *Business Strategy and the Environment*, *34*(5), 5370–5385. https://doi.org/10.1002/bse.4255

Paper 3 Kilinc, T., & Reim, W. (2026). Control or Co-creation: Exploring Ecosystem Configurations Based on Power Dynamics and Sustainability Focus. *International Journal of Production Research*, 1–22. https://doi.org/10.1080/00207543.2026.2741381.

Paper 4 Kilinc, T., Panda, D., & Parida, V. (202X). Making Digital Solutions Scale: Practices for Improving Industrial Sustainability. Minor revision in *Business Strategy and the Environment.*

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Part I

1. Introduction

Research rarely begins with an answer. More often, it begins with the quiet realization that existing explanations no longer fully account for an evolving reality. This thesis emerged from a similar realization: the growing need to understand how industrial providers can support industrial sustainability through digital servitization. This chapter first situates digital servitization and industrial sustainability within their broader industrial context, then develops the overarching research problem that motivates the thesis. Building on this problem, the chapter identifies three key research gaps and introduces the overarching purpose that guides the thesis.

1.1 Background and relevance

Industrial providers, understood in this thesis as industrial manufacturers that supply equipment and increasingly complement their offerings with digital services and solutions for business customers, are moving beyond their traditional role as product suppliers. Through digital servitization, these providers complement product offerings with digitally enabled services and solutions such as remote monitoring, predictive maintenance, and energy optimization (Sjödin et al., 2020; Porter & Heppelmann, 2014). This development changes not only what industrial providers offer but also how they engage with customers. At the same time, providers face growing expectations to contribute to sustainability improvements, including emissions reductions, improved energy and material efficiency, and enhanced safety (Mangla et al., 2024). These expectations matter especially for industrial providers because the operation and use of industrial equipment at customer sites have implications for resource consumption, emissions, and operational safety (Beducci et al., 2025). Digital servitization gives providers opportunities to influence these outcomes beyond the point of sale (Tronvoll et al., 2020). For example, data from connected equipment can enable providers to help customers optimize equipment and resource use, thereby improving operational efficiency while reducing energy consumption and emissions (Sjödin et al., 2023). Accordingly, industrial providers are increasingly expected not only to improve their own performance but also to actively support sustainability improvements within customer operations through digital solutions (Kolagar et al., 2024). Therefore, digital servitization represents an important mechanism through which industrial providers can improve customer operations while simultaneously supporting industrial sustainability.

However, supporting industrial sustainability through digital servitization is far from straightforward. Industrial providers encounter interconnected technical and social challenges when attempting to translate digital solutions into sustainability-related improvements. Technically, digital solutions must be integrated with existing equipment, infrastructures, and data environments while generating reliable and actionable information for operational use (Sjödin et al., 2020; Schroeder et al., 2020). Organizationally, their use requires changes in routines, capabilities, responsibilities, and data-driven decision-making practices within provider and customer organizations (Sklyar et al., 2019; Kilinc et al., 2025; Sjödin et al., 2021). These changes must also support environmental and social performance objectives while maintaining viable economic performance (Chirumalla et al., 2023; Kolagar et al., 2024). Consequently, even technologically advanced digital solutions may fail to realize their sustainability potential when technological development is not accompanied by corresponding adaptation of the organizational and operational conditions surrounding their use.

The interdependence of these technical and social challenges suggests that digital servitization for industrial sustainability is fundamentally a socio-technical problem (Münch et al., 2022). Socio-technical systems comprise interdependent technical and social subsystems that must function coherently for intended outcomes to materialize (Pasmore et al., 1982). In digital servitization, this means the sustainability potential of digital technologies depends on how technological arrangements develop alongside the organizational practices through which digital solutions are implemented and used (Münch et al., 2022; Sjödin et al., 2020; Sklyar et al., 2019). Understanding how this socio-technical alignment unfolds constitutes the central problem addressed in this thesis. The following section positions this problem within existing research and develops three thesis-level research gaps.

1.2 Research problem and positioning

Despite the growing relevance of digital servitization for industrial sustainability, existing research provides valuable but partial explanations of how technological and organizational changes come together to realize sustainability-related value through digital servitization. Studies on digital servitization explain the technological capabilities that enable data-driven optimization and performance improvements (Shen et al., 2023; Sjödin et al., 2021), while research on service innovation examines how providers redesign offerings, capabilities, and value propositions around

these technologies (Chirumalla et al., 2023; Chen et al., 2024). In parallel, sustainability-oriented studies examine how firms integrate environmental and social objectives into their strategic agendas (Kolagar et al., 2024; Schiavone et al., 2022). However, these perspectives often remain fragmented, focusing on particular technologies, organizational changes, or inter-organizational relationships rather than explaining how technical and social changes become aligned as digital servitization develops (Rabetino et al., 2018; Münch et al., 2022). This creates an overarching need to understand digital servitization for industrial sustainability as a socio-technical alignment problem that develops within and across organizational boundaries.

A first research gap concerns the limited understanding of digital servitization for industrial sustainability as a socio-technical alignment process. Prior research demonstrates how AI and digital technologies can enable monitoring, optimization, automation, and data-driven decision-making and thereby contribute to operational and sustainability-related improvements (Sjödin et al., 2023; Shen et al., 2023). Digital servitization research further explains how firms develop digital capabilities, redesign service offerings, and reconfigure business models around these technologies (Coreynen et al., 2020; Kohtamäki et al., 2022). However, technological capabilities and digitally enabled offerings alone do not explain how their sustainability potential is realized in industrial practice. Digital solutions must become aligned with organizational routines, skills, decision-making processes, governance arrangements, and established ways of working (Sklyar et al., 2019; Tronvoll et al., 2020; Münch et al., 2022). Moreover, these technical and social requirements are unlikely to remain constant as digital solutions develop and become integrated into operational settings. This alignment challenge also extends beyond the industrial provider (Kolagar et al., 2022). Digital servitization increasingly connects provider technologies and organizational arrangements with customer infrastructures and operational practices, while also relying on complementary capabilities distributed across ecosystem actors (Kohtamäki et al., 2019; Sjödin et al., 2020). Consequently, realizing industrial sustainability through digital servitization requires coordinated technical and social change within organizations and across organizational boundaries. *We therefore lack an integrated explanation of how socio-technical alignment develops across organizational boundaries as industrial providers pursue digital servitization for industrial sustainability.*

A second research gap concerns the role of industrial providers in shaping the socio-technical conditions required for digitally enabled sustainability improvements across organizational boundaries. Although digital servitization research increasingly recognizes that value creation extends beyond the provider firm (Sklyar et al., 2019; Tronvoll et al., 2020), much of the literature has focused on how providers develop their services, offerings, and capabilities (Rabetino et al., 2018). Yet realizing the sustainability-related value of digital solutions ultimately depends on their use within customer operations, where solutions must be integrated with existing infrastructures, routines, skills, data practices, and decision-making processes (Kilinc et al., 2025). This may require providers to move beyond technology delivery by supporting customers in adapting these arrangements (Kamalaldin et al., 2020). At the same time, such change is not exclusively provider-driven or confined to bilateral provider-customer relationships. Customers retain agency over how digital solutions are adopted, adapted, and incorporated into their operations, while implementation may depend on dealers, technology providers, software firms, integrators, and other ecosystem actors possessing complementary capabilities (Kohtamäki et al., 2019; Kolagar et al., 2022). These actors may also differ in their interests, power positions, and sustainability priorities (Avelino & Wittmayer, 2016; Gray et al., 2022). Although ecosystem research provides important insights into collaboration (Paiola et al., 2021), orchestration (Kolagar et al., 2024), and governance (Benedict & Sebastian, 2024), it provides limited explanation of how industrial providers support the technical and social changes required across these heterogeneous customer and ecosystem relationships. *We have limited understanding of how industrial providers act across customer and ecosystem boundaries to shape the socio-technical conditions through which the sustainability potential of digital solutions can be realized in practice.*

A third research gap concerns how digital servitization for industrial sustainability is scaled beyond localized implementations. Digital solutions often demonstrate promising operational and sustainability-related benefits in pilots and individual customer settings, yet these benefits frequently remain confined to specific contexts (Garcia-Martin et al., 2025; Kocoglu & Mithani, 2025). Scaling is particularly demanding in industrial contexts because customer infrastructures, operational practices, organizational arrangements, and ecosystem configurations vary across implementation settings (Palmié et al., 2023). Consequently, extending a digital solution requires more than reproducing its technical functionality; the associated organizational routines, customer practices, coordination mechanisms, and ecosystem relationships must also be adapted and

stabilized across heterogeneous contexts. Existing research increasingly recognizes scaling as a multidimensional process and identifies challenges related to technological complexity (Momeni et al., 2024), heterogeneous infrastructures (Garcia-Martin et al., 2025), organizational alignment (Kohtamäki et al., 2021), and ecosystem reconfiguration (Tatarinov et al., 2023). However, existing research provides limited explanation of the concrete practices through which industrial providers coordinate these technical, organizational, customer, and ecosystem dimensions as digital solutions are extended across contexts. *We lack a sufficiently fine-grained explanation of how industrial providers coordinate intra-organizational, customer, and ecosystem practices to scale digital servitization for industrial sustainability beyond localized implementations*.

These gaps point to a broader theoretical problem: realizing industrial sustainability through digital servitization requires socio-technical alignment that extends across organizational boundaries and develops as digital servitization moves from early initiatives towards broader scaling. Existing research provides important insights into individual elements of this problem but lacks an integrated explanation of how industrial providers align technical and social arrangements, support their coordination across organizational boundaries, and extend them across heterogeneous industrial contexts. Addressing this problem requires examining digital servitization as an unfolding socio-technical alignment process that integrates technological, organizational, and ecosystem perspectives rather than considering these dimensions in isolation.

1.3 Research purpose

Building on the research gaps identified above, this thesis seeks to develop an integrated understanding of how socio-technical alignment unfolds as industrial providers pursue digital servitization in support of industrial sustainability. The gaps highlight three complementary aspects of this broader problem: how socio-technical alignment develops across organizational boundaries, how industrial providers support the technical and social changes required across customer and ecosystem contexts, and how digital solutions and associated socio-technical arrangements can be extended across heterogeneous industrial settings.

Accordingly, the purpose of this thesis is to investigate *how industrial providers engaged in digital servitization align socio-technical systems – internally, with customers, and across ecosystem partners – to support industrial sustainability.*

The four appended studies investigate complementary dimensions of this overarching purpose through their respective research purposes and research questions. Paper 1 contributes by explaining the interacting economic, technological, market, and sustainability-related conditions that motivate industrial providers to engage in digital servitization, providing insight into the conditions under which socio-technical alignment is initiated. Paper 2 examines how industrial providers support the implementation of digital solutions in customer contexts, providing insight into how technical and social arrangements are aligned in customer contexts. Paper 3 examines how differences in power dynamics and sustainability focus shape industrial ecosystem configurations, providing a cross-cutting perspective on the ecosystem conditions under which socio-technical alignment unfolds. Paper 4 examines how industrial providers coordinate intra-organizational, customer, and ecosystem practices to scale digital solutions, explaining how socio-technical arrangements are extended and stabilized across heterogeneous contexts.

Table 1 provides an overview of how the appended papers contribute to the respective gaps and illustrates their complementary roles within the thesis.

Thesis-level Research Gap	Contributions of the Papers to the Gaps			
	Paper 1	Paper 2	Paper 3	Paper 4
Gap 1: *Limited understanding of digital servitization for sustainability as a socio-technical alignment process.*				
Gap 2: *Limited understanding of the provider's active role in realizing industrial sustainability across organizational boundaries.*				
Gap 3: *Limited understanding of how digital servitization for industrial sustainability is scaled beyond localized implementations.*				
Note: *Shading indicates the relative depth of each paper's contribution to the thesis-level research gaps: dark shading = strong contribution; light shading = supportive contribution; no shading = no direct contribution.*				

Table 1: *Contributions of the Appended Papers to the Thesis-level Research Gaps*

1.4 Structure of the thesis

This thesis is organized into two main parts. The first part provides an integrated overview that outlines, synthesizes, and builds on the findings of four appended papers. The second part consists of the individual research papers, each providing unique yet related insights into how industrial providers engaged in digital servitization facilitate industrial sustainability.

2. Theoretical Background

This chapter develops the theoretical foundation for understanding digital servitization for industrial sustainability as a socio-technical alignment problem. It begins by positioning industrial sustainability within contemporary industrial contexts and examining digitalization as an important enabler of economic, environmental, and social sustainability outcomes (Section 2.1). It then introduces digital servitization as a mechanism through which industrial providers mobilize digital solutions to support industrial sustainability, while highlighting why technological solutions alone are insufficient to realize such outcomes (Section 2.2). Building on this problem, Section 2.3 introduces socio-technical systems theory as the overarching analytical lens and develops two dimensions central to the thesis: where socio-technical alignment is required across organizational boundaries and how such alignment develops as digital servitization progresses. These dimensions establish the theoretical basis for examining digital servitization as an unfolding socio-technical alignment process in support of industrial sustainability.

2.1 The role of digitalization in industrial sustainability

Industrial contexts face intensifying expectations to reduce emissions, increase energy and material efficiency, and strengthen social responsibility across global value chains (Mangla et al., 2024). In this thesis, industrial sustainability encompasses the economic, environmental, and social outcomes associated with industrial operations and practices (see also Lacoste, 2016; Kolagar et al., 2024). In manufacturing settings, economic outcomes may include increased productivity, reduced operational inefficiencies, and improved profitability (Kohtamäki et al., 2020). Environmental outcomes may include reduced energy consumption, waste generation, and emissions through more precise management of resource-intensive processes (Bianchini et al., 2023). Social outcomes may include improved worker safety, reduced exposure to hazardous tasks, and enhanced working conditions through greater operational visibility and risk prevention (Nenonen et al., 2020).

Digitalization, which refers to the adoption and use of digital technologies across organizational activities (Verhoef et al., 2021), is widely regarded as an important enabler of industrial sustainability. Rapid advances in digital technologies, such as artificial intelligence (AI), the Internet of Things (IoT), advanced data analytics, and cyber-physical systems, offer new opportunities to optimize operations, enhance safety, and redesign industrial processes (Sjödin et al., 2023; Porter & Heppelmann, 2014). In industrial settings, digital technologies can support activities such as real-time monitoring (Chen & Wang, 2024), predictive maintenance, energy-

intensity optimization, and digital traceability across value chains (Opresnik & Taisch, 2015; Jensen et al., 2023). Increasingly, firms are expected to leverage such technologies not only to improve productivity and innovation but also to support environmental and social improvements (Bindeeba et al., 2025).

However, digitalization does not automatically lead to industrial sustainability outcomes. While digital technologies may enable monitoring, optimization, and automation, their effects depend on how they are embedded within organizational and operational practices (Sklyar et al., 2019). Research across digital transformation and sustainability transition studies emphasizes that technological investments alone are insufficient to realize expected improvements without corresponding changes in routines, organizational structures, decision-making processes, and inter-organizational collaboration (Tronvoll et al., 2020; Verhoef et al., 2021; Geels, 2005; Savaget et al., 2019). These challenges are particularly salient in B2B manufacturing, where long asset lifecycles, capital-intensive equipment, and tightly coupled supply chains create both opportunities and structural lock-ins (Vendrell-Herrero et al., 2022; Kohtamäki et al., 2019). Accordingly, understanding how digitalization contributes to industrial sustainability requires attention not only to the technologies themselves but also to how they are mobilized operationally and organizationally. Digital servitization represents one prominent mechanism through which industrial providers undertake this integration and is explained next.

2.2 Digital servitization as an enabler of industrial sustainability

Digital servitization extends the longstanding trend of servitization, in which manufacturers move from selling products to offering services, by foregrounding the role of digital technologies in enabling new service offerings (Baines et al., 2017). It is defined as "the transformation in processes, capabilities, and offerings within industrial firms and their associated ecosystems to progressively create, deliver, and capture increased service value arising from a broad range of enabling digital technologies such as the IoT, big data, AI, and cloud computing" (Sjödin et al., 2020, p. 478). Complementing this perspective, Kohtamäki et al. (2019) emphasize the development of smart product–service–software systems that enable monitoring, control, optimization, and increasingly autonomous operation. Accordingly, digital servitization involves integrating physical products with connected digital technologies that generate and capture operational data, using analytics and software to transform these data into actionable insights, and

mobilizing service and organizational capabilities to translate those insights into digitally enabled solutions for customers (Shen et al., 2023; Kolagar et al., 2024). Unlike digitalization broadly, digital servitization specifically concerns how such technologies are integrated into service-oriented value creation and delivery. In this thesis, digital servitization is therefore understood as the mechanism through which industrial providers mobilize digital solutions to support industrial sustainability.

Digital servitization is increasingly recognized for its potential to support industrial sustainability. By improving asset utilization, extending product lifecycles, reducing unplanned downtime, and optimizing operational processes, digital solutions can contribute to reduced resource consumption, lower emissions, and improved safety outcomes (Paiola et al., 2021; Schiavone et al., 2022; Shen et al., 2023). For example, AI-enabled optimization of machine operations can reduce energy use, while predictive maintenance can minimize the need for spare parts, resource-intensive overhauls, and unnecessary interventions (Javaid et al., 2022). Providers can also design solutions that help customers track their environmental performance, benchmark against sustainability targets, or simulate alternative operating scenarios (Kilinc et al., 2025). In this way, digital servitization enables industrial providers to extend their contribution to industrial sustainability into customer operations. These practices also enable new value logics and revenue models that link provider income to sustainability-relevant performance metrics. For example, outcome-based and performance-based contracts compensate providers for delivering equipment uptime, energy savings, or emissions reductions rather than merely selling hardware or hours of labor (Schroeder et al., 2020). In this sense, digital servitization offers a potential route for aligning profitability with sustainability. Providers are incentivized to continuously improve performance and resource efficiency at customer sites, and customers pay for proven value (Komatsu, 2024). Recent research also suggests that sustainability increasingly functions not only as an outcome of digital servitization but as a factor shaping how firms design and pursue digital servitization strategies (Kolagar et al., 2024).

Despite this potential, realizing the sustainability-related value of digital servitization in practice remains challenging. Research often highlights difficulties related to integrating heterogeneous technologies, redesigning organizational roles, and coordinating activities across multiple actors (Coreynen et al., 2017; Kohtamäki et al., 2019; Reim et al., 2019). In industrial settings, digital

solutions must integrate into existing operational environments and organizational practices, and implementing them requires coordination among customers, technology partners, and service intermediaries (Kohtamäki et al., 2019; Sklyar et al., 2019). Consequently, developing and providing technologically advanced digital solutions is insufficient to realize their potential contribution to industrial sustainability (Bertassini et al., 2021). Their value depends on how technological arrangements are embedded within organizational routines, operational practices, decision-making processes, and relationships across organizational boundaries. This interdependence between technological and social change positions digital servitization for industrial sustainability as a socio-technical alignment problem and provides the rationale for adopting socio-technical systems theory as the overarching analytical lens in the following section.

2.3 A socio-technical alignment perspective on digital servitization

Socio-technical systems (STS) theory explains organizational outcomes as emerging from the interaction and joint optimization of technical and social subsystems rather than from technological or social factors in isolation. Originating in the work of the Tavistock Institute in the 1950s, particularly through studies of British coal mining and labor organization (Trist & Bamforth, 1951), STS theory conceptualizes organizations as configurations of interdependent technical and social subsystems whose effectiveness depends on their joint optimization (Pasmore et al., 1982). The technical subsystem includes tools, technologies, infrastructures, and formal processes required to perform work, while the social subsystem encompasses organizational routines, roles, skills, relationships, and governance arrangements that shape how work is carried out (Bostrom & Heinen, 1977; Pasmore et al., 1982). In contemporary digital servitization contexts, these technical elements take the form of connected equipment, digital infrastructures, data architectures, analytics platforms, and related digital capabilities, while social elements include the routines, roles, skills, decision-making practices, and organizational relationships through which these technologies are developed, implemented, and used (Münch et al., 2022; Kurtz et al., 2023; Kilinc et al., 2025). STS theory emphasizes that technical and social subsystems are interdependent and must function coherently for organizational outcomes to materialize (Trist, 1981). This interdependence underpins the principle of joint optimization, whereby technical and social subsystems are considered together rather than optimized independently. Accordingly,

misalignment between these subsystems helps explain why technologically promising initiatives often fail to deliver expected improvements (Trist, 1981; Bijker, 1997).

In this thesis, socio-technical alignment refers to the ongoing process through which technical and social subsystems are adapted and coordinated in relation to one another as digital servitization develops. Joint optimization provides the underlying STS principle guiding this process: technical and social subsystems should be considered and developed together rather than optimized independently (Trist, 1981; Pasmore et al., 1982). This conceptualization allows the thesis to focus analytically on how socio-technical alignment develops over time, including how corresponding changes in organizational routines, roles, decision-making, and relationships accompany changes in digitally enabled solutions.

Digital solutions (e.g., predictive maintenance systems, simulations, real-time data analysis, and connected equipment) are not standalone technologies; rather, their development and use are embedded within broader socio-technical systems involving how work is performed, decisions are made, and responsibilities are distributed across organizations (Münch et al., 2022). Realizing the potential value of these solutions, including sustainability-related outcomes, depends on how they are embedded in operational practices, coordinated across actors, and supported by appropriate organizational arrangements (Sklyar et al., 2019; Kolagar et al., 2022). However, existing digital servitization research provides limited integrated understanding of how such technical and social arrangements can be aligned across organizational boundaries. Importantly, these interdependencies increasingly extend beyond the industrial provider, as digital solutions are integrated into customer operations and rely on technologies, principles of use, and relationships distributed across broader ecosystems. Socio-technical alignment must therefore be considered both within and across organizational boundaries. The following subsections elaborate on how this alignment extends across organizational boundaries and develops as digital servitization unfolds.

2.3.1 Socio-technical change across providers, customers, and ecosystems

This subsection considers socio-technical alignment across three interconnected contexts relevant to digital servitization: the industrial provider, the customer, and the broader ecosystem. In each context, digital servitization involves distinct but interdependent changes across technical and social subsystems.

Digital servitization requires socio-technical change within industrial provider organizations because the introduction of digital technologies alters not only technological infrastructures but also the organizational capabilities and arrangements through which digitally enabled solutions are developed and delivered. Moving from product-centric towards digital service offerings therefore requires manufacturers to reconfigure capabilities, organizational structures, roles, and work practices while developing closer coordination among product, service, and digital activities (Kohtamäki et al., 2019; Chirumalla et al., 2023; Münch et al., 2022). For example, introducing a digital service platform may require new data and software infrastructures while simultaneously creating new responsibilities for managing the platform, coordinating across functions, and delivering and supporting the associated services. Provider-side technological development is therefore intertwined with changes in the organizational arrangements through which digital solutions are created, delivered, and supported.

Socio-technical change also extends into customer contexts, where the value of digital solutions depends on their integration with customers' existing technical infrastructures and operational practices. Digital servitization transforms provider-customer relationships because providers and customers increasingly combine complementary digital capabilities, integrate digital systems and assets, establish knowledge-sharing routines, co-innovate, and develop new forms of partnership governance (Kamalaldin et al., 2020; Sjödin et al., 2023). Providers may need to support customers in developing the capabilities and ways of working required to use digital solutions effectively, while customers themselves must actively adapt how digital technologies and data are incorporated into their operations (Coreynen et al., 2017; Tronvoll et al., 2020; Sjödin et al., 2020; Sklyar et al., 2019). This also means corresponding changes in customer routines, roles, skills, data use, and decision-making practices. For example, introducing a data-driven monitoring solution may require integration with the customer's existing technical systems while simultaneously requiring employees to develop new routines for interpreting the data and incorporating it into operational decision-making. Kamalaldin et al. (2020) relatedly show that customers may need dedicated personnel and digital competence to manage newly introduced digital systems, while provider and customer organizations progressively develop new ways of working around shared digital platforms. Their findings illustrate this interdependence directly: integrating a digital platform with customer systems requires human responsibility, competence development (e.g., related to digital literacy), and new collaborative practices for the technology to be used effectively. Accordingly,

realizing digital servitization depends on interconnected technological and organizational changes on both sides of the provider-customer relationship and on active engagement by both providers and customers in supporting these changes.

These interdependencies increasingly extend across broader ecosystems. Digital servitization often relies on complementary technologies, resources, and expertise distributed among customers, technology and software providers, distributors, service partners, integrators, and other actors (Sklyar et al., 2019). For example, Kohtamäki et al. (2019) argue that smart solutions must interact with solutions provided, used, delivered, maintained, and operated by multiple organizations, making integration and collaboration across firm boundaries increasingly important. Similarly, Kolagar et al. (2022) explain that manufacturers depend on ecosystem partnerships to access complementary digital capabilities, resources, and innovations, while increasing numbers of heterogeneous and interdependent partners make coordination progressively more demanding. This interdependence also has both technical and social dimensions: for example, integrating complementary digital solutions from multiple ecosystem partners may require interoperable technical interfaces alongside corresponding agreements regarding roles, responsibilities, data sharing, and coordination across participating organizations. Such ecosystems should not be assumed to be homogeneous or uniformly collaborative. Actors often differ in their capabilities, interests, responsibilities, power positions, and sustainability priorities, which adds further complexity to coordination across organizational boundaries.

These interdependencies show that changes in one context may create corresponding alignment requirements in others, meaning that socio-technical alignment is not a one-time adjustment. As digital servitization develops, changes in technologies, practices, capabilities, and relationships tend to create new alignment requirements over time. Therefore, socio-technical alignment should also be understood as an unfolding process, as introduced next.

2.3.2 Socio-technical alignment as an unfolding process

Building on the preceding understanding, digital servitization is not a single implementation event but an unfolding transformation in which technologies, organizational arrangements, and relationships develop over time. Prior research increasingly conceptualizes digital servitization and related digital service innovation in processual terms. For example, Narvaiza et al. (2024)

describe digital service innovation as progressing through initiation, adoption, and routinization, with actor roles, functions, and interactions changing throughout the process. Similarly, recent research emphasizes that the attributes and capabilities required for digital servitization interact and evolve as firms move between different configurations during their transformation journeys (Kulkarni et al., 2025). These processual perspectives suggest that the technical and social conditions required for digital servitization are not established once but are repeatedly adapted as solutions develop and their contexts of use change. Accordingly, the requirements for socio-technical alignment are likely to change as digital servitization develops from early exploration and experimentation towards operational implementation and broader scaling.

Early digital servitization initiatives are often characterized by exploration, experimentation, and uncertainty regarding both technological possibilities and customer needs (Garcia-Martin et al., 2025). Rapid technological development makes predetermined development approaches difficult, increasing the importance of iterative, adaptive innovation and ongoing customer involvement (Narvaiza et al., 2024; Sjödin et al., 2020). For example, Narvaiza et al. (2024) contrast linear development approaches with iterative approaches in which execution informs subsequent design and customer involvement becomes more continuous. Such experimentation concerns not only what digital technologies can technically enable but also which customer problems and use cases they can meaningfully address and what organizational arrangements may be needed around their use (Kolagar et al., 2024). Consequently, both the technical solution and its surrounding organizational arrangements remain subject to learning and adaptation during early development. From a socio-technical perspective, this suggests that early alignment may involve simultaneous learning about technological possibilities and the organizational and customer arrangements needed around them. However, existing research provides limited explanation of how these technical and social requirements become connected as digital servitization develops.

As digital solutions move from exploration towards implementation, the socio-technical alignment challenge shifts from determining what may work to making the solution work within an actual organizational and operational context. Digital solutions must be integrated with existing technical infrastructures and operational systems, while the organizational arrangements surrounding their use must adapt accordingly (Münch et al., 2022; Kamalaldin et al., 2020; Kilinc et al., 2025; Coreynen et al., 2017). This touches upon changes in routines, roles, responsibilities, skills, and

ways of working as providers and customers coordinate how digital solutions are incorporated into ongoing operations. A solution that is technically functional may still fail to create value if it does not fit existing operational practices or if the roles, capabilities, and routines required for its use are not established. Accordingly, implementation can be expected to introduce alignment requirements associated with embedding digital solutions within organizational and operational settings. Yet how these technical and social requirements are coordinated across provider and customer boundaries remains insufficiently explained.

A further alignment challenge arises when digital solutions move beyond individual implementations towards broader scaling. Although digital solutions may demonstrate value through pilots, many initiatives struggle to progress beyond proof-of-concept or localized customer settings, leaving their broader potential unrealized (Kohtamäki et al., 2021; Garcia-Martin et al., 2025). Garcia-Martin et al. (2025) identify an "eternal proof of concept" problem, illustrating the difficulty of moving from successful experimentation towards broader implementation. Scaling is therefore not simply synonymous with selling more solutions or reproducing a demonstrated implementation. Solutions that function in one setting may encounter different technical infrastructures, operating conditions, levels of digital maturity, and organizational arrangements when extended to other customer contexts (Garcia-Martin et al., 2025; Kocoglu & Mithani, 2025). As implementation broadens, scaling can also increase dependence on external resources, partnerships, and coordination across organizational boundaries (Tatarinov et al., 2023; Kolagar et al., 2022). More broadly, scaling research emphasizes that extending solutions requires organizational adaptation and coordination rather than straightforward replication (Jansen et al., 2023; Bohan et al., 2024). From a socio-technical perspective, extending a digital solution across contexts may therefore require adaptation of both the technical solution and the organizational arrangements surrounding its use (Kocoglu & Mithani, 2025). This suggests that broader scaling creates additional socio-technical alignment requirements as technical solutions encounter heterogeneous environments and the organizational and inter-organizational arrangements surrounding their use must accommodate these differences. However, existing research provides limited explanation of how such alignment is coordinated as digital solutions are extended across contexts.

Building on these perspectives, this thesis conceptualizes socio-technical alignment in digital servitization as both boundary-spanning and processual. As established in Section 2.3.1, technical and social changes extend across provider, customer, and ecosystem contexts. At the same time, the literature reviewed above indicates that the requirements for socio-technical alignment change as digital servitization develops over time, from early experimentation and operational implementation to the challenge of extending solutions more broadly. Therefore, socio-technical alignment is not a static organizational condition but an evolving process in which changes in technologies and their contexts of use create corresponding requirements for organizational adaptation and inter-organizational coordination. However, existing research provides fragmented insights into these boundary-spanning and processual dimensions, leaving limited integrated understanding of how they relate and how socio-technical alignment develops across organizational boundaries as industrial providers seek to support industrial sustainability through digital servitization.

3. Research Methods

This chapter presents the research design and methodological approach adopted in this thesis and explains how they support the investigation of digital servitization for industrial sustainability. It begins by introducing the research context and empirical setting, followed by the thesis logic and researcher role, before outlining the overall research approach and rationale for the methodological choices. The chapter then presents the data sources, data collection procedures, and analytical strategies underpinning the four appended papers. Finally, it discusses research quality and reflects on the trustworthiness of the findings.

3.1 Research context and setting

The empirical setting of this thesis was shaped through participation in interdisciplinary research initiatives examining digital servitization, digital transformation, and sustainability transitions in Swedish and international industrial contexts. The primary source of empirical access was the Digital Innovation of Business Models (DigIn) Project, funded by Vinnova and hosted by Luleå University of Technology. DigIn brings together more than 40 industrial actors, including manufacturers, suppliers, digital solution providers, and public organizations, across sectors such as mining, forestry, pulp and paper, steel, technology, and energy. For this thesis, DigIn provided access to a broad network of industrial actors engaged in developing and implementing digital solutions, enabling the study of digital servitization across diverse industrial contexts.

In addition to DigIn, this thesis draws on empirical access provided by two complementary research initiatives. The first is SUN – Natural Resources for Sustainability Transitions, a strategic initiative focused on advancing sustainability goals through the responsible use of natural resources such as ore, forest, and water. The initiative emphasizes interdisciplinary collaboration and system-level transformation across sectors such as mining, energy, forestry, and manufacturing, involving globally active firms, nationally significant industrial actors in Sweden, public stakeholders, and researchers. For this thesis, SUN broadened the empirical setting by providing access to industrial actors engaged in sustainability-oriented transformation initiatives across natural resource sectors. This complemented DigIn by allowing the investigation of digital servitization within broader sustainability transition efforts.

The second complementary initiative is Green Transition North (GTN), a large-scale regional effort to accelerate the green industrial transition through research, innovation, and circular

business development. The project involves globally active industrial firms alongside a broad network of small and medium-sized enterprises (SMEs), with a focus on ecosystem collaboration and technology-enabled sustainability transformation. GTN complemented the empirical setting by providing access to regional industrial ecosystems where large firms, SMEs, and supporting organizations collaborated on digitalization, circularity, and industrial sustainability. Within this thesis, SMEs are relevant primarily as ecosystem actors and potential partners surrounding the focal industrial providers rather than as a distinct empirical focus.

Although these initiatives differed in scope and objectives, collectively they provided complementary access to industrial sectors, organizational contexts, and sustainability efforts relevant to the thesis. Their combination provided access to globally active industrial providers, a range of customers, technology partners, and other ecosystem actors across multiple sectors, enabling repeated interactions with organizations engaged in digital servitization and industrial sustainability. This empirical setting provided opportunities to investigate digital servitization across different organizational, customer, and ecosystem contexts and at varying levels of maturity. The initiatives therefore functioned primarily as platforms for empirical access rather than prescribing the thesis-specific research gaps, case boundaries, or analytical choices, as discussed in the following section.

3.2 Thesis logic and researcher role

The thesis brings together four studies that address complementary dimensions of the research problem: Paper 1 examines the interacting economic, technological, market, and sustainability-related drivers shaping engagement in digital servitization; Paper 2 examines how industrial providers support digital solution implementation and associated socio-technical change in customer contexts; Paper 3 examines how power dynamics and sustainability focus shape industrial ecosystem configurations; and Paper 4 examines how industrial providers scale digital solutions through coordinated intra-organizational, customer, and ecosystem practices. The four papers offer complementary perspectives on the overarching phenomenon, which are integrated at the thesis level through the STS lens, allowing the thesis to develop an integrated understanding of how industrial providers support industrial sustainability through digital servitization. Papers 1, 2, and 4 provide insights primarily into the drivers, customer-side implementation, and scaling of

digital servitization, respectively, while Paper 3 offers a cross-cutting perspective on the ecosystem conditions under which these processes unfold.

The research design was developed to integrate the complementary studies around the broader problem of digital servitization for industrial sustainability. This thesis was conducted within collaborative research initiatives that provided access to firms and ongoing transformation efforts. Within these initiatives, the author developed the thesis's analytical focus, research problem, and overall methodological approach. The research initiatives served as empirical access platforms rather than predefined research protocols. While industrial partners and project activities shaped the available field sites and interaction arenas (e.g., workshops, meetings, and internal briefings), the author defined the thesis's phenomenon framing and developed the thesis-level analytical perspective through which the complementary studies were connected and synthesized.

Therefore, beyond the analyses reported in the individual papers, the thesis involved a stage of integrative synthesis. Drawing on the findings of the four papers, the synthesis iteratively compared how each study explained different aspects of digital servitization, allowing complementary insights to be integrated into a framework of socio-technical alignment. While the distinction between technical and social subsystems was theoretically informed by STS theory, the phased structure emerged through comparison and synthesis of the complementary explanations developed across the four papers. Rather than simply aggregating the paper-level findings, the synthesis abstracted higher-order patterns in how socio-technical alignment develops within and across provider, customer, and ecosystem contexts. This process resulted in the phased framework presented in Chapter 5.

3.3 Research approach

This thesis employs a qualitative, exploratory research approach, reflected across the appended papers. This choice is grounded in the recognition that the intersection of digital servitization and sustainability is both contemporary and still developing theoretically and empirically (Minaya et al., 2024; Beducci et al., 2025). Existing literature provides important conceptual foundations but comparatively limited empirical explanation of how digital servitization unfolds across provider, customer, and ecosystem contexts in support of industrial sustainability. Given the topic's emergent nature and the multifaceted organizational, technological, and institutional dynamics

involved, a qualitative approach is well suited to uncover rich, context-sensitive insights that may be less accessible through more structured, hypothesis-driven research designs (Edmondson & McManus, 2007; Yin, 2018).

The thesis's exploratory nature also reflects the complexity of the phenomenon under investigation. Digital servitization unfolds across organizational, customer, and ecosystem contexts, involving interconnected technological, organizational, and inter-organizational processes (Linde et al., 2021). At the thesis level, the overall methodological logic was abductive and informed by systematic combining, allowing iterative movement between empirical observations, emerging interpretations, and existing theory (Dubois & Gadde, 2002; 2014).

The four appended papers address complementary dimensions of the research problem. The studies examine the conditions shaping industrial providers' engagement in digital servitization (Paper 1), how digital solutions are implemented in customer contexts (Paper 2), the ecosystem conditions shaping these processes (Paper 3), and how digital servitization scales across organizational and inter-organizational contexts (Paper 4). Addressing these interrelated dimensions required different empirical settings, units of analysis, and analytical strategies while maintaining a coherent approach throughout the thesis.

Each paper adopts a qualitative research design, with its empirical strategy tailored to the specific research question pursued:

Papers 2, 3, and 4 employ case study designs, with Papers 2 and 4 adopting multiple-case designs centered on industrial providers and Paper 3 examining three industrial ecosystem cases. Case study research was particularly valuable for examining such complex digital servitization and sustainability developments within their organizational and inter-organizational contexts (Yin, 2018; Eisenhardt & Graebner, 2007). Across these studies, cases were selected for their theoretical relevance and capacity to provide information-rich insight into digitalization, digital servitization, and sustainability-related transformation. These studies draw on semi-structured interviews and complementary material, including internal presentations, workshops, site visits, and reports, to examine the organizational and inter-organizational processes relevant to their respective research questions. Research collaborations facilitated access to key informants, internal documentation,

site visits, and workshop opportunities, enabling the collection of contextually rich data from multiple sources.

Paper 1 diverges from the case-based studies by adopting a qualitative, exploratory, archival, and documentary research design based on publicly available podcast interviews and complementary documentary sources. Focused on the strategic drivers of digital servitization in B2B manufacturing, the study analyzes publicly available accounts from senior executives, industry experts, and practitioners across multiple industrial and geographical contexts. The broad cross-sectoral and geographical coverage complements the more contextually embedded case studies in Papers 2, 3, and 4.

Table 2 presents an overview of the research design, number of interviews, and data sources for each paper.

Paper	**Research Purpose**	**Research Approach**	**Empirical Material**	**Data Collection**
Paper 1: Revisiting Drivers of Digital Strategies: Exploring B2B Firms' Adoption of Digital Servitization	To understand how B2B manufacturing firms perceive and experience the drivers behind their adoption of digital servitization, considering the rise of frontier technologies	Qualitative, exploratory, archival, and documentary	Publicly available podcast interviews featuring representatives from 24 B2B manufacturing firms operating across 15 industries	37 publicly available podcast interviews and 10 industry reports
Paper 2: Navigating Digital Servitization for The Twin Transition: How Manufacturers Can Support Customers with Digitalization and Sustainability	To understand how digital solution providers manage the process of STS transformation for the twin transition of industrial customers	Qualitative, exploratory multiple-case study	Three B2B incumbent firms, operating in manufacturing, mining, quarrying, construction, and transportation industries	36 semi-structured interviews, workshops, documents (e.g., presentations, project, executive reports, publicly available material), and follow-up interviews
Paper 3: Control or Co-Creation: Exploring Ecosystem Configurations	To examine how variations in power dynamics and sustainability focus among actors in industrial ecosystems give rise to	Qualitative, exploratory case study	Three industrial ecosystems (involving 20 ecosystem actors) in metal smelting and	35 in-depth, semi-structured interviews, public reports, internal presentations, on-site notes and

Based on Power Dynamics and Sustainability Focus	distinct ecosystem configurations		recycling, industrial automation and electrification, and mining and minerals	pictures, project congresses and briefings, and follow-up interviews
Paper 4: Making Digital Solutions Scale: Practices for Improving Industrial Sustainability	To investigate how OEMs scale digital solutions to improve sustainability by enacting practices within and beyond the firm level	Qualitative, exploratory multiple-case study	Three OEMs operating in manufacturing, mining, quarrying, construction, and transportation industries	37 semi-structured interviews, workshops, documents (e.g., presentations, project, executive reports, publicly available material), and follow-up interviews
Note: *The interview counts reported in this table are paper-specific and should not be interpreted as a thesis-wide total. Paper 1 uses publicly available podcast interviews and documentary material rather than researcher-conducted primary interviews. Papers 2 and 4 draw on the same three provider cases, but Paper 4 uses a revised, scaling-focused interview corpus in which some interviews from Paper 2 were excluded and additional scaling-focused interviews were added. Paper 3 is based on a separate ecosystem dataset.*				

Table 2: *Overview of the Papers' Research Methods*

3.4 Case selection

In this thesis, a case is an empirically bounded digital servitization setting. In Papers 2 and 4, the case is a digital servitization initiative led by an industrial provider, including the associated interactions with customers and ecosystem partners through which digital solutions are developed, implemented, and scaled. In Paper 3, the case is an industrial B2B ecosystem, bounded around a focal actor and the surrounding actors directly involved in sustainability-oriented coordination and digital servitization.

Consequently, the case boundaries differ across the studies. Papers 2 and 4 are bounded around focal providers and the actors, relationships, and activities directly associated with their digital solutions, whereas Paper 3 is bounded at the ecosystem level around the focal actor and organizations participating in the relevant sustainability-oriented activities. These boundaries maintain analytical focus while allowing the studies to capture socio-technical processes extending across organizational boundaries. These analytical boundaries align with the thesis's purpose. Papers 2 and 4 examine the same three provider-led digital servitization cases but use different paper-specific empirical corpora, with Paper 4 excluding material not relevant to scaling and

incorporating additional scaling-focused interviews and secondary material. Paper 3 draws on three separate ecosystem cases and an independent empirical dataset.

The selection process followed a purposeful sampling logic, with cases selected for their relevance to the studied phenomenon, their capacity to provide information-rich empirical material, and their involvement in ongoing digitalization and sustainability initiatives (Patton, 2015). Specifically, Papers 2 and 4 selected industrial providers actively engaged in digital servitization initiatives linked to sustainability ambitions, while Paper 3 selected industrial ecosystem settings in which digitalization and sustainability-oriented activities involved multiple interdependent actors. Across the case-based studies, selection emphasized settings characterized by (1) substantive use of digital solutions beyond basic connectivity, (2) explicit links to sustainability objectives, such as energy efficiency, emissions reduction, or safety improvement, and (3) involvement of multiple organizational actors. The selected cases also provided variation in organizational size (large incumbents and relatively smaller industrial providers), sectoral context (e.g., mining, construction, manufacturing), and the maturity of digital servitization initiatives (from early-stage pilots to more established solutions), enabling the identification of recurring patterns and contextual differences in how digital servitization unfolds.

3.5 Data collection

The four studies draw on two complementary forms of qualitative empirical material. Papers 2, 3, and 4 rely primarily on researcher-conducted semi-structured interviews supplemented by secondary data, whereas Paper 1 draws on publicly available podcast interviews and complementary documentary material (see Table 3).

For Papers 2, 3, and 4, interviews were conducted with informants from focal provider organizations, as well as with customers and ecosystem partners involved in the digital servitization initiatives under study. The focal provider served as an entry point into broader ecosystem dynamics where needed. Snowball sampling complemented initial informant selection by identifying additional participants with relevant knowledge of the studied initiatives. Informants represented different organizational roles, hierarchical levels, and actor types, providing multiple perspectives on the studied phenomenon (Eisenhardt & Graebner, 2007). Interview guides included open-ended questions and were iteratively refined during each study to

reflect emerging insights and sharpen the relevance of subsequent interviews (Eisenhardt, 1989; Miles et al., 2014).

Most interviews were conducted online via video conferencing platforms, while six were conducted face-to-face, depending on participant availability, preference, and logistical considerations. Interviews typically lasted 45 to 90 minutes. With participant consent, interviews were primarily audio-recorded and transcribed verbatim. When recording was not permitted, detailed notes were taken during and immediately after the interview.

Paper 1 used a different approach, relying on publicly available podcast interviews with senior executives, industry experts, and practitioners. These were selected based on their direct relevance to the themes of digital servitization in B2B contexts. A total of 37 podcast episodes were transcribed and analyzed. These podcast interviews were complemented by company websites, LinkedIn pages of guests and their organizations, white papers, press releases, and industry reports to provide organizational context and support data triangulation.

Papers	Main Empirical Material	Complementary Material
Paper 1	37 publicly available podcast episodes	Company websites, LinkedIn pages of guests and their organizations, white papers, press releases, and industry reports.
Paper 2	36 semi-structured interviews	Company presentations, workshops (2), and project/executive reports, publicly available material (e.g., customer stories, sustainability reports).
Paper 3	35 semi-structured interviews	Public reports, internal presentations, field trips (3), on-site notes and pictures, project congresses and briefings.
Paper 4	37 semi-structured interviews	Internal development presentations, executive briefings prepared for top management, workshops (2), pilot project documentation from customer trials, and a webinar video recording (presented to customers, consultants, some ecosystem partners), notes from informal meetings with informants, annual and sustainability reports, KPI frameworks, sales enablement materials, press releases.

Table 3: *Overview of the Papers' Data Sources*

Across the four studies, combining different empirical materials and actor perspectives supported contextualization and comparison of interpretations across sources while accommodating the distinct research questions pursued in each paper.

3.6 Data analysis

Data analysis followed an abductive logic grounded in systematic combining, characterized by an iterative movement among empirical observations, emerging concepts, and existing literature to progressively refine theoretical understanding (Dubois & Gadde, 2002; 2014). Within this logic, thematic coding was used to identify recurring patterns and relationships across interviews and complementary data sources. To enhance analytical transparency, a Gioia-inspired coding architecture (distinguishing first-order concepts, second-order themes, and aggregate dimensions) was used across the papers as an organizing and reporting device rather than as a rigid analytical template (Gioia et al., 2013).

The analysis began with a close, iterative reading of transcripts, notes, and supporting materials, during which first-order concepts were generated by coding text segments using terms that remained close to the language of the empirical material. This stage emphasized staying close to the data and preserving the meanings and terminology expressed by informants. Qualitative coding software (MAXQDA) supported the process by facilitating the organization, retrieval, and refinement of codes.

Subsequently, similar or related codes were grouped through constant comparison and discussion, yielding second-order themes that represented emerging theoretical patterns. These themes captured the underlying dynamics observed in the cases and helped bridge empirical insights with existing or emerging theoretical concepts. Finally, the analysis identified aggregate dimensions, the most abstract level of interpretation, connecting the empirical observations to broader theoretical contributions. The resulting data structures documented the progression from empirical observations to increasingly abstract conceptual interpretations, thereby enhancing analytical transparency (Gioia et al., 2013).

In Papers 2, 3, and 4, the analysis involved iterative movement among coding, within-case interpretation, cross-case comparison, and targeted engagement with prior literature, with cross-case comparison supporting the identification of common patterns and contextual variation (Dubois & Gadde, 2002; 2014). Paper 1 compared patterns across the archival podcast and documentary materials to identify recurring and interacting drivers of digital servitization. Case-

study guidance on triangulation and comparative logic (e.g., Eisenhardt, 1989; Yin, 2018) informed the use of multiple data sources.

Analytical credibility was supported by systematically comparing empirical material, engaging with complementary sources, and, in the co-authored studies, holding regular discussions of emerging interpretations among the research team. Gioia-inspired data structures facilitated transparency by making explicit the progression from empirical observations to conceptual insights while allowing flexibility in how themes were developed and refined.

In addition to the paper-level analyses, a thesis-level integrative synthesis was conducted to develop the framework presented in Chapter 5. The synthesis compared the explanations across the four papers and examined how their complementary findings could be integrated within an overarching socio-technical alignment process. STS theory informed the distinction between technical and social subsystems, while the phased structure emerged through iterative comparison of the paper-level findings. This synthesis yielded three analytically distinct but empirically overlapping phases, as presented in Chapter 5.

3.7 Research quality

This thesis evaluates quality through the lens of trustworthiness, a widely used concept in qualitative and interpretive research for assessing the rigor, transparency, and plausibility of research processes and findings (Lincoln & Guba, 1985). Rather than pursuing statistical generalization, the thesis aims to develop credible, analytically transferable, dependable, and empirically grounded explanations of digital servitization for industrial sustainability. Accordingly, the thesis discusses research quality in terms of four criteria: *credibility, transferability, dependability*, and *confirmability*.

Credibility concerns whether the findings provide a plausible, well-supported account of the phenomenon under study. In this thesis, credibility was supported through triangulation across data sources and informant perspectives, as well as iterative engagement with empirical material. The studies drew on multiple sources, including in-depth interviews, follow-up interviews, workshops, internal documents, presentations, publicly available podcast material, and other documentary sources, allowing interpretations to be examined across different types of evidence. Interviews

with informants occupying diverse roles and positions (ranging from strategic decision-makers to operational and technical specialists) provided multiple perspectives on digital servitization and sustainability practices. Credibility was further supported through an iterative analytical process in which emerging interpretations were continuously examined against new data, alternative explanations, and evidence that did not readily fit developing patterns.

Transferability refers to the extent to which the findings can inform understanding beyond the specific empirical settings studied. Rather than pursuing broad statistical generalization, this thesis seeks analytical transferability through rich contextual descriptions of digital servitization initiatives, organizational settings, sustainability ambitions, and inter-organizational relationships. Cases were selected for theoretical relevance and to capture variation in industry context, ecosystem position, the maturity of digital servitization, and sustainability focus. This combination of contextual detail and empirical variation provides a basis for readers to assess the findings' relevance to other industrial settings with similar conditions.

Dependability concerns the consistency and transparency of the research process. In this thesis, dependability was supported by systematically documenting methodological decisions and analytical procedures. The research process was documented through interview guides, coding schemes, analytical memos in MAXQDA, and decisions about case inclusion and analytical focus. Because the research followed an abductive logic, analytical focus and conceptual interpretations evolved during the research process; documenting these developments helped maintain traceability between methodological choices, empirical material, and emerging interpretations.

Across the studies, emerging findings were also continuously discussed and refined through presentations at international conferences (Table 4), practitioner workshops, and exchanges with co-authors, providing additional opportunities for critical reflection and external feedback.

Year	Conference	Related Paper
2025	Kilinc, T. & Reim, W. Control or Co-Creation: Exploring Ecosystem Dynamics in the Sustainability Transition. *ERD Academy – TalTech 2025*. Tallinn, Estonia.	Paper 3
2024	Kilinc, T. Revisiting Motivations Driving Digital Strategies: Exploring B2B Manufacturing Firms' Adoption of Digital Servitization. *NORSI Conference 2024*. Bergen, Norway. (Accepted; feedback exchanged with the assigned presentation group via email.)	Paper 1

2024	Kilinc, T., Sjödin, D., & Parida, V. The Scaling Challenge: Transforming Digital Service Concept Pilots into Sustainable Offerings. *R&D Management Conference 2024*. Stockholm, Sweden.	Paper 4
2024	Kilinc, T., Sjödin, D., & Parida, V. Beyond Proof of Concept: Scaling Digital Services for Long-Term Sustainability. *27th NFF Conference – Nordic Academy of Management 2024*. Reykjavik, Iceland.	Paper 4
2024	Kilinc, T., Reim, W., & Parida, V. Transition Towards Circularity in Industrial Contexts: A Multi-Actor Business Models Perspective. *11th International Conference on Business Servitization 2024*. Lisbon, Portugal.	Paper 3
2023	Kilinc, T., Sjödin, D., & Parida, V. Digital Servitization for Sustainable Value Creation: A Sustainability-based Commercializing Driven by Digital Technologies, *10th International Conference on Business Servitization 2023*. Barcelona, Spain.	Paper 2
2023	Kilinc, T., Sjödin, D., & Parida, V. Supporting Customers' Sustainability through Digital Servitization: Value Co-Creation Process Leveraging AI and Circularity Principles, *Spring Servitization Conference 2023* (Poster). Helsinki, Finland.	Paper 2

Table 4: *Conference Presentations Contributing to the Development of the Appended Papers*

Confirmability concerns the extent to which findings are grounded in the empirical material rather than shaped by researcher bias or preconceptions. Several measures were taken to support confirmability. First, paper-level analyses used systematic coding procedures tailored to their respective research questions, and coding structures and analytical records documented the progression from empirical observations to higher-order interpretations. Second, representative quotations and concrete examples were retained to make the relationship between the empirical material and claims visible. Interpretations were also discussed within the co-author teams to challenge individual readings and refine emerging explanations. Third, reflexive engagement with theory (through abductive movement between the empirical material and relevant literature) encouraged continuous questioning of emerging explanations and underlying researcher assumptions. In addition, the author's embedded position within collaborative research initiatives provided close empirical access while requiring continuous reflexive awareness of potential interpretive bias. Regular discussions with co-authors and iterative comparison of the empirical material with theory helped maintain analytical distance throughout the research process. Cross-case comparison in the case-based studies and triangulation across complementary sources further supported the empirical grounding of the findings.

4. Summaries of Appended Papers

This chapter summarizes the four appended papers that constitute the basis for this thesis. For each paper, the chapter outlines the research gap it addresses, its specific purpose, the research method applied, its key findings, and its contribution to the thesis. The insights from the four papers provide complementary explanations of digital servitization for industrial sustainability and form the basis for the cross-paper synthesis that informs the integrative framework presented in the following chapter.

4.1 Paper one: Kilinc, T. (202X). Revisiting Drivers of Digital Strategies: Exploring B2B Firms' Adoption of Digital Servitization. *(Under review)*

Background: Digital transformation is reshaping how B2B manufacturing firms create and capture value. Building on the longstanding shift from product-centric business models to servitization, advances in frontier technologies (e.g., artificial intelligence, the Internet of Things, and big data analytics) are enabling increasingly data-driven, outcome-oriented service offerings. This development has accelerated digital servitization, in which digital technologies are increasingly embedded in service offerings and value-creation processes.

While prior research has identified key motivations for servitization (typically categorized as strategic, financial, and market-driven), the rapid diffusion of frontier technologies and growing sustainability pressures in *digital* servitization raise questions about how these established drivers are evolving and interacting in contemporary digital servitization contexts. Firms now operate in environments marked by heightened competition, evolving customer expectations, and increasing regulatory demands, particularly regarding environmental performance. At the same time, digital technologies create new opportunities for innovation, efficiency, and value co-creation across ecosystems.

Despite growing interest in digital servitization, there remains limited understanding of how these traditional drivers are evolving and interacting under current conditions. Existing studies often examine drivers in isolation or within narrower contexts, without fully capturing their interconnected and dynamic nature. As a result, there is a need to revisit how the drivers of digital servitization interact amid rapid technological development and increasing sustainability pressures.

Purpose: To understand how B2B manufacturing firms perceive and experience the drivers behind their adoption of digital servitization, considering the rise of frontier technologies.

Method: Qualitative, exploratory, archival, and documentary study based on 37 publicly available podcast interviews and complementary documentary materials.

Findings: The study identifies three interrelated drivers shaping firms' adoption of digital servitization: (1) *sustainable economic growth*, (2) *frontier technologies*, and (3) *social and environmental sustainability*. Rather than operating independently, these drivers reinforce and reshape one another. Sustainable economic growth reflects firms' pursuit of long-term competitiveness through new revenue models and customer value. Frontier technologies create opportunities for innovation, service development, and operational optimization while responding to evolving customer and market expectations. Social and environmental sustainability reflect not only regulatory pressures and stakeholder expectations but also strategic considerations that shape how firms approach digital servitization. These findings show that the adoption of digital servitization is shaped by the interplay of economic, technological, market, and sustainability-related considerations rather than by isolated motivations.

Contribution to the thesis: This paper contributes to the thesis by explaining how interacting economic, technological, market, and sustainability-related drivers shape digital servitization initiatives in contemporary industrial contexts. Rather than treating these drivers as isolated factors, the study shows how they interact to shape firms' strategic decisions about digital servitization. In particular, the paper highlights sustainability not only as an outcome of digital servitization but also as a structuring driver that influences firms' digital transformation strategies. By explaining why industrial providers engage in digital servitization under contemporary technological and sustainability conditions, the paper provides insight into the strategic conditions surrounding the emergence of the socio-technical alignment processes examined in the thesis. The paper focuses on these strategic entry conditions rather than how socio-technical alignment is enacted in customer operations, which is examined more directly in Paper 2.

4.2 Paper two: Kilinc, T., Sjödin, D., & Parida, V. (2025). Navigating Digital Servitization for the Twin Transition: How Manufacturers Can Support Customers with Digitalization and Sustainability. *Business Strategy and the Environment*, *34*(5), 5370–5385.

Background: As industrial providers increasingly pursue digital servitization to support industrial sustainability, they face growing pressure to help customers achieve both digitalization and sustainability objectives simultaneously, a challenge commonly referred to as the twin transition. Although digital servitization is increasingly recognized as an enabler of sustainability, there remains limited understanding of how providers support customers in implementing digital solutions and reconfiguring their STS to realize sustainability outcomes in practice. Moreover, while STS theory offers a useful perspective on the interdependence between technical and social change, it has received limited attention in digital servitization research. These gaps leave insufficient explanation of how providers support the technical and social changes required for customers' twin transitions.

Purpose: To understand how digital solution providers manage the transformation of socio-technical systems for the twin transition of industrial customers.

Method: Qualitative, exploratory multiple-case study drawing on three industrial manufacturers, 36 semi-structured interviews, and complementary secondary materials.

Findings: Drawing on three case studies of leading manufacturers across the mining, quarrying, construction, and transportation industries, the study develops a framework that explains how industrial providers support customers through the twin transition. Based on 36 in-depth interviews and extensive secondary data, the analysis identifies a four-phase process for navigating the twin transition: (1) defining a twin transition roadmap; (2A) orchestrating digital site transformation; (2B) enabling data-driven organizational transformation; and (4) value optimization. These phases explain how providers support technical and social subsystems through customer engagement, iterative adaptation, and joint optimization to enable sustainability outcomes.

The resulting framework conceptualizes the twin transition of customers as an iterative socio-technical alignment process. The paper highlights that achieving sustainability benefits requires not only technological integration but also customer engagement, behavior change, and the ongoing refinement of these practices. Consequently, the framework offers practical guidance for manufacturers seeking to become strategic partners in their customers' twin transitions.

Contribution to the thesis: This paper explains how industrial providers and their customers implement digital servitization in customer contexts in support of industrial sustainability. It demonstrates that sustainability outcomes depend not only on implementing digital solutions but also on aligning technical and social subsystems through provider-supported, customer-enacted changes. By introducing STS theory as an analytical lens, the paper provides an STS-based explanation of customer-side socio-technical alignment and shows how industrial providers can actively support the technical and organizational changes required within customer operations. The paper focuses on customer-side implementation rather than on the broader ecosystem conditions surrounding alignment or the practices used to scale implementations beyond lead-customer settings. The former is examined in Paper 3, while the latter is examined in Paper 4.

4.3 Paper three: Kilinc, T. & Reim, W. (2026). Control or Co-Creation: Exploring Ecosystem Configurations Based on Power Dynamics and Sustainability Focus. *(Accepted in International Journal of Production Research)* https://doi.org/10.1080/00207543.2026.2741381

Background: Sustainability transitions in industry rarely occur within a single firm; they unfold across industrial ecosystems involving manufacturers, suppliers, technology partners, public actors, and intermediaries. While collaboration among these actors is widely regarded as essential to systemic sustainability change, power asymmetries, conflicting agendas, and uneven sustainability priorities often complicate it and shape whether transitions proceed or stall. Prior research acknowledges the importance of multi-actor coordination but gives comparatively less attention to how power distribution and sustainability focus jointly shape ecosystem configurations and sustainability transitions. Consequently, understanding remains limited regarding how variations in power dynamics and sustainability focus produce different ecosystem configurations.

Purpose: To understand how variations in power dynamics and sustainability focus among actors in industrial ecosystems give rise to distinct ecosystem configurations.

Method: Qualitative, exploratory case study of three industrial B2B ecosystems, drawing on 35 interviews and complementary documentary materials.

Findings: The study develops a framework based on two interacting dimensions: power dynamics and sustainability focus. Their interaction yields four ecosystem configurations: (1) enforced efficiency, (2) balanced optimization, (3) dominated innovation, and (4) collaborative innovation.

Each configuration reflects a distinct pattern of governance, coordination, actor participation, and sustainability ambition, leading to different sustainability transition pathways:

1. Enforced Efficiency: Central actors tightly control sustainability efforts, resulting in compliance-driven, incremental improvements and limited participation by peripheral actors.

2. Balanced Optimization: Power is more evenly distributed, enabling reciprocal coordination and continuous, incremental optimization of sustainability outcomes.

3. Dominated Innovation: High sustainability ambition is pursued through hierarchical, top-down governance, in which dominant actors set agendas, accelerating progress but limiting inclusivity.

4. Collaborative Innovation: Shared leadership, a strong relational fabric, and co-creation practices support systemic and transformative sustainability efforts.

The findings further suggest discussions that these configurations need not be static, as shifts in actor influence, sustainability priorities, or institutional pressures may alter ecosystem dynamics over time. Power and sustainability focus interact, influencing whether transitions are incremental, compliance-driven, or transformative. Importantly, no configuration is inherently superior: each entails distinct trade-offs among inclusivity, pace, and depth of sustainability change.

Contribution to the thesis: This paper explains how power dynamics and sustainability focus shape the ecosystem conditions in which digital servitization for industrial sustainability unfolds. It shows that industrial providers operate within ecosystems with varying power distributions and sustainability priorities, which influence coordination mechanisms, actor roles, and transition pathways. At the thesis level, the typology provides a basis for understanding how different ecosystem conditions may enable or constrain the coordination required for digital servitization initiatives. From the thesis's perspective, this implies that socio-technical alignment is not enacted under uniform ecosystem conditions; the forms of coordination available to industrial providers vary with power distribution and the sustainability priorities of participating actors. These insights contribute to the thesis by explaining why socio-technical alignment depends not only on providers and customers but also on the broader ecosystem context in which digital servitization unfolds. Although Paper 3 explains these ecosystem conditions, it does not examine how digital solutions are scaled. Paper 4 explores this perspective.

4.4 Paper four: Kilinc, T., Panda, D., & Parida, V. (202X). Making Digital Solutions Scale: Practices for Improving Industrial Sustainability. *(Manuscript under revision following peer review)*

Background: Original equipment manufacturers (OEMs) increasingly rely on digital solutions, such as connected equipment, monitoring platforms, analytics, and automation, to improve industrial sustainability by enhancing operational optimization, resource efficiency, and safety. However, despite this potential, many digital initiatives struggle to scale beyond localized pilots, limiting their broader sustainability impact. Although prior research recognizes scaling as a critical challenge, there is limited explanation of the concrete practices through which digital solutions are extended, reproduced, and coordinated across organizational and ecosystem contexts.

Purpose: To examine how OEMs scale digital solutions to improve sustainability by enacting practices within and beyond the firm level.

Method: Qualitative, exploratory multiple-case study of three OEMs, based on 37 interviews and complementary secondary materials.

Findings: The study conceptualizes scaling as a practice-based process enacted across three domains: intra-organizational, ecosystem, and customer scaling practices. Drawing on the scaling modes identified by Jansen et al. (2023), the analysis explains how these practices operate through expansion, replication, and synchronization. Expansion extends digital solutions across customers and operational contexts; replication reproduces successful solution configurations and practices across implementations; and synchronization aligns data, resources, and decision-making across organizational and ecosystem boundaries. These scaling practices are associated with three complementary forms of industrial sustainability value identified across the cases: operational optimization, resource efficiency, and lifecycle extension.

Contribution to the thesis: This paper explains how industrial providers scale digital servitization beyond localized pilot implementations to achieve scaled sustainability value. It conceptualizes scaling as a coordinated, practice-based process enacted through intra-organizational, customer, and ecosystem practices that operate through expansion, replication, and synchronization. By demonstrating how these practices support the transfer, replication, and continued operation of digital solutions across heterogeneous contexts, the paper provides important insight into the

processes through which digital servitization can be scaled beyond localized implementations. It further shows how scaling enables digital servitization to generate sustainability-related value through operational optimization, resource efficiency, and lifecycle extension. These findings provide an important basis for the scaling-related insights developed in Chapter 5, where they are integrated with complementary findings from across the four papers.

5. A Framework of Socio-Technical Alignment for Industrial Sustainability

This chapter synthesizes complementary insights from the four appended papers into an overarching framework of socio-technical alignment for industrial sustainability. The resulting framework explains how industrial providers align technical and social arrangements within and across organizational boundaries through digital servitization to support industrial sustainability. The chapter first outlines the framework's overall logic, then presents its three interrelated phases and explains how they collectively capture the unfolding socio-technical alignment process and its sustainability outcomes.

As outlined in Chapter 1, this thesis investigates *how industrial providers engaged in digital servitization align socio-technical systems – internally, with customers, and across ecosystem partners – to support industrial sustainability.* The three research gaps underlying this purpose point to an overarching need to understand how socio-technical alignment develops across organizational boundaries, how industrial providers support such alignment in customer and ecosystem contexts, and how digitally enabled solutions and associated practices are extended beyond localized implementations.

The four appended papers collectively provide complementary insights into digital servitization for industrial sustainability. Building on these studies' findings and underlying empirical material, this chapter develops an overarching framework that explains digital servitization as a socio-technical alignment process through which industrial providers progressively support the alignment of technical and social arrangements to realize and extend sustainability-related value across broader industrial contexts. The three phases of the framework emerged through an integrative synthesis involving iterative comparison of findings and empirical patterns across the studies; hence, the structure was not specified in advance. It emerged through the thesis-level synthesis as a processual abstraction of recurring empirical patterns. The phases thus capture an analytically derived progression in socio-technical alignment grounded in recurring empirical patterns, rather than a fixed sequence through which all digital servitization initiatives necessarily proceed.

The framework (Figure 1) comprises three analytically distinct yet interrelated phases: *Exploring Solution Viability, Operationalizing Solutions,* and *Scaling Solution Implementation*. Across the phases, the nature of the socio-technical alignment challenge changes as digital solutions move from exploratory initiatives towards more established and broadly applicable arrangements.

Within each phase, socio-technical system alignment involves changes in two interdependent subsystems: the technical and social subsystems. Building on the definitions introduced in Section 2.3, each phase distinguishes technical changes associated with digital solutions and infrastructures from social changes involving roles, routines, decision-making, governance, and relationships. These changes occur through activities within the industrial provider, with customers, and across broader ecosystem relationships, showing how socio-technical alignment extends across organizational boundaries. Each phase is associated with an indicative outcome reflecting the extension of socio-technical alignment and sustainability-related value through digital servitization: from *demonstrated sustainability potential*, through *realized sustainability value*, to *scaled sustainability value*. These outcomes are not fixed thresholds or endpoints. Rather, they indicate differences in the scope of sustainability-related outcomes associated with the developing alignment process. To complement Figure 1, Table 5 summarizes the framework according to the central alignment problem addressed in each phase.

Framework Phase	**Phase 1: *Exploring Solution Viability***	**Phase 2: *Operationalizing Solutions***	**Phase 3: *Scaling Solution Implementation***
Alignment Problem	***Uncertainty***	***Operational embedding***	***Repeatability across heterogeneity***
Provider-centric activities	* Explore digital solution opportunities ***(T)*** * Evaluate organizational adaptations ***(S)***	* Develop integrated digital solutions ***(T)*** * Define roles and delivery processes ***(S)***	* Develop modular/scalable infrastructure ***(T)*** * Create a solution-centric organization ***(S)***
Customer-centric activities	* Define initial solution concepts ***(T)*** * Demonstrate proof of value ***(S)***	* Implement data-enabled solutions ***(T)*** * Support data-driven decision-making ***(S)***	* Implement data-driven optimization ***(T)*** * Institutionalize digital-solution use ***(S)***
Ecosystem-centric activities	* Assess technology gaps and partnership opportunities ***(T)*** * Initiate technology-partner relationships ***(S)***	* Integrate partner solutions ***(T)*** * Negotiate roles, responsibilities, and value expectations ***(S)***	* Align interoperability standards ***(T)*** * Define ecosystem roles for scaling ***(S)***
Outcome	***Demonstrated sustainability potential***	***Realized sustainability value***	***Scaled sustainability value***
Legend: ***T*** = technical subsystem change | ***S*** = social subsystem change			

Table 5: *Overview of the Socio-Technical Alignment Framework*

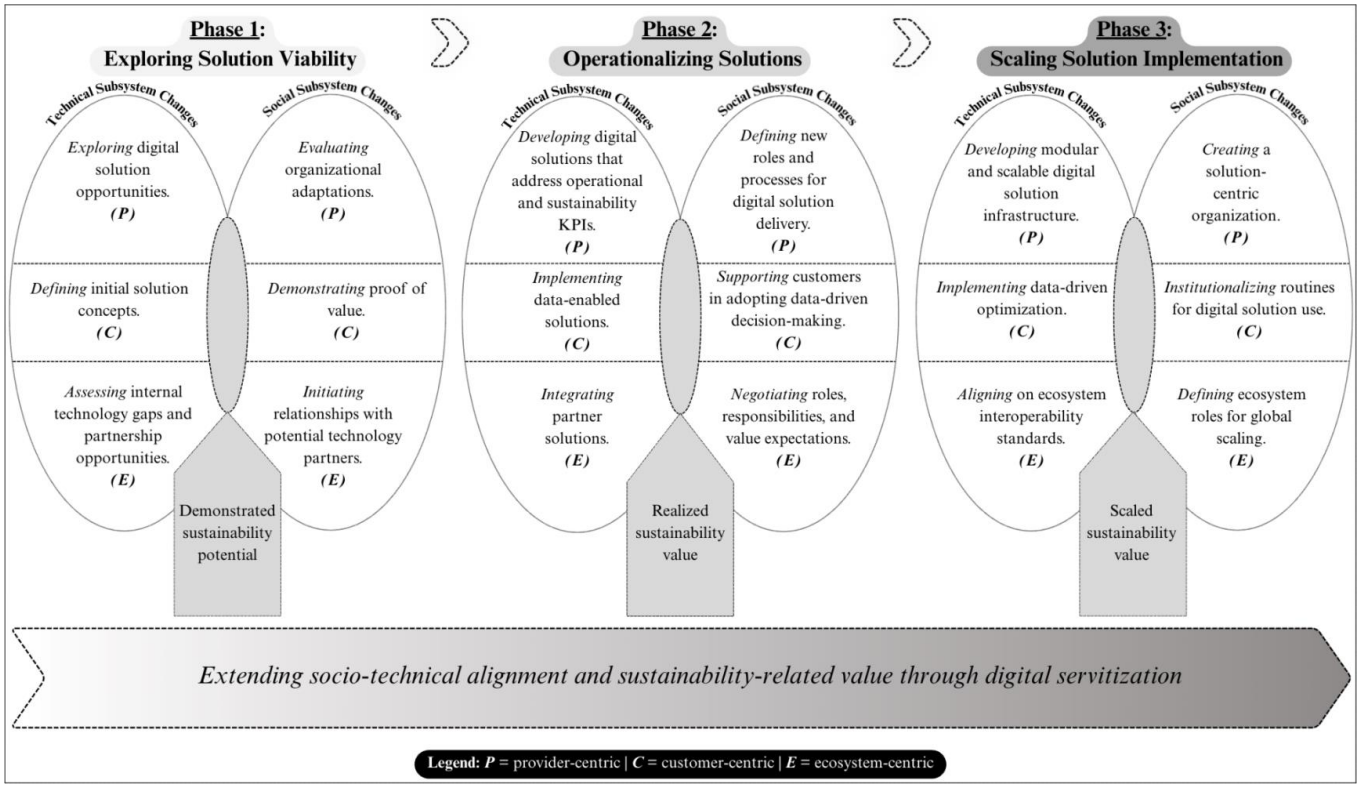

Figure 1: A Framework of Socio-Technical Alignment for Industrial Sustainability

5.1 Phase 1 – exploring solution viability

Phase 1 represents the formative stage in which industrial providers begin exploring the viability of digital solutions to support industrial sustainability. Industrial providers' engagement in digital servitization is shaped by interacting economic, technological, market, and sustainability-related drivers, through which technological opportunities and social and environmental sustainability concerns become intertwined with ambitions for sustainable economic growth (Paper 1). This phase is characterized by exploration, assessment, and early validation rather than full-scale implementation (Papers 2 and 4). Across technical and social subsystems, providers focus on identifying opportunities, testing the feasibility of digital solutions, and establishing credibility for continued digital servitization efforts. The underlying alignment problem at this stage is uncertainty: providers must determine not only whether emerging digital solutions can address meaningful operational and sustainability-related problems, but also what organizational adaptations and external capabilities would be required to turn technological possibilities into viable solutions. Phase 1 centers on learning about these technical, organizational, and relational requirements before committing to broader implementation.

In Phase 1, the industrial provider initiates ***technical subsystem change*** by *exploring digital solution opportunities*. *At the provider level*, this involves experimenting with data-enabled functionalities, testing connectivity solutions, and applying basic analytics to assess where operational and sustainability-related value might be created (Papers 2 and 4). These activities remain provisional, serving primarily to assess technical feasibility rather than to deliver fully developed solutions. For example, a construction equipment manufacturer explored technologies such as vibration sensors, drones, and load-weight measurement systems to generate new forms of operational data and identify opportunities for developing more data-driven solutions. *At the customer level*, technical exploration becomes grounded in selected pilot settings, where providers work with customers *to define initial solution concepts*, clarify use cases, and identify where digital tools could enhance efficiency, environmental performance, or safety within existing operations. This allows technological assumptions to be tested against actual operating conditions rather than developed independently of their intended use. *At the ecosystem level*, providers *assess internal technology gaps and partnership opportunities*. This includes evaluating whether additional requirements, such as software expertise, data infrastructure, or integration services, are required

beyond the provider's internal resources. The technical subsystem in this phase is thus characterized by opportunity exploration, contextual validation with pilot customers, and assessment of technology gaps and partnership opportunities. For example, a truck manufacturer explored the potential of connectivity solutions, such as route optimization, together with selected pilot customers. By combining its emerging digital capabilities with customer operating data and complementary technological expertise (e.g., startups), the manufacturer explored how transport routes could be optimized to improve safety and efficiency while reducing energy intensity and emissions. These pilots provided early insight into both the potential value of the solution and the technical and organizational requirements for its further development. In another pilot context, the manufacturer explored how similar connectivity solutions could support automated logistics workflows and real-time operational adaptation, providing early indications of potential improvements in cost efficiency, energy consumption, greenhouse gas emissions, and loss of goods.

In Phase 1, industrial providers initiate ***social subsystem change*** by *evaluating organizational adaptations* needed to support digitally enabled, sustainability-oriented solutions. *Within the provider organization*, this means assessing how established roles, incentives, and coordination arrangements may need to change as the firm moves beyond product-centric ways of working (Papers 1, 2, and 4). For example, several providers described how initial piloting activities provided important opportunities to learn what new roles, responsibilities, and coordination activities would be needed to support the continued development and delivery of digital solutions. At this stage, the focus is on sensemaking and problem framing rather than formal reorganization. *In pilot customer contexts*, providers seek to *demonstrate proof of value* to multiple stakeholder groups, including operators, managers, and sustainability functions. These efforts aim to build credibility and shared understanding of the relevance of digital solutions for operational and sustainability improvements. At this stage, engagement with customers remains exploratory, focusing on building trust, developing a shared understanding of the solution's potential, and creating support for continued experimentation. *At the ecosystem level*, providers *initiate relationships with potential technology partners* to reduce uncertainty and broaden access to complementary expertise. These early partnerships remain exploratory and loosely structured, supporting learning rather than formal coordination. For example, a construction equipment provider considered introducing incentives for digital solution sales among dealers, illustrating

how existing reward structures were being reconsidered as the firm explored a move beyond product-centric sales. Such considerations also highlighted the potential need for corresponding changes in coordination and responsibility across traditionally separated functions, including product, service, sustainability, and digital teams.

The outcome of Phase 1 is *demonstrated sustainability potential*. At this point, exploratory development and pilot activities provide initial evidence that digital solutions can contribute to operational and sustainability-related improvements, while also revealing the technical, organizational, and relational requirements for their continued development. In the truck manufacturer example, the emerging connectivity solution became meaningful through its combination with customer operating conditions and complementary technological expertise, illustrating how sustainability potential depended on bringing technical possibilities into alignment with the social and organizational context in which they would be developed and used. Thus, demonstrated sustainability potential reflects not only evidence that a digital technology can create value but an emerging understanding of the socio-technical requirements that need to be addressed to realize that value through further implementation.

5.2 Phase 2 – operationalizing solutions

Phase 2 represents the stage in which industrial providers move from exploratory validation towards structured alignment with lead customers to operationalize digital solutions. This phase mainly captures how industrial providers and customers align technologies, operational practices, and organizational arrangements to support industrial sustainability (Paper 2). Having demonstrated initial potential in pilot settings, providers face the challenge of integrating digital solutions into lead customer operations more systematically. This phase is characterized by solution *development, implementation, and negotiated alignment*, building on the exploratory work undertaken in Phase 1. Across both technical and social subsystems, the emphasis shifts from feasibility assessment to operational embedding and relational structuring. Therefore, the underlying alignment problem is operational embedding: digital solutions must function within existing customer environments while the roles, routines, and relationships surrounding their use are adjusted so that digital information can inform operational and sustainability-related decisions.

In Phase 2, the industrial provider advances ***technical subsystem change*** by *developing digital solutions* explicitly oriented towards operational and sustainability performance parameters. *At the provider level*, this involves *developing integrated digital solutions* that translate operational data into actionable indicators related to utilization, energy intensity, emissions, or safety (Paper 2). For example, a construction equipment manufacturer described how load-weight sensors in wheel loaders and trucks enabled operators to monitor whether vehicles were appropriately loaded. By providing more precise operational data, the solution could improve equipment utilization and reduce unnecessary traffic, breakdowns, fuel consumption, and associated CO_2 emissions. *At the customer level*, providers and lead customers *implement data-enabled solutions* within customer operations. This involves connecting digital solution architectures to existing site infrastructures and ensuring that data flows, monitoring systems, and analytics outputs are usable within everyday operational contexts. Technical work, therefore, shifts from demonstrating that data can be captured to ensuring that digital solutions are reliable, interpretable, and actionable in practice. *At the ecosystem level*, providers *integrate partner solutions* into their digital offerings. This includes incorporating complementary software, data infrastructure, or system integration requirements that extend the provider's technological base. Through this integration, technical and interoperability requirements across actors are addressed more systematically, which can reduce implementation friction and support more stable solution delivery. For example, a mining equipment provider collaborated with mining customers to integrate automated mining and monitoring solutions directly into both open-pit and underground mining. By integrating real-time tracking dashboards and decision-support software into daily workflows, site managers were able to link productivity targets to energy use and safety indicators, allowing digital solutions to function as operational tools that connect productivity decisions with energy-use and safety considerations.

In Phase 2, the industrial provider advances ***social subsystem change*** by developing organizational and relational structures needed to sustain the use of digital solutions with lead customers. *Within the provider organization*, providers *define roles and processes for digital solution delivery* by clarifying accountability for data interpretation, strengthening cross-functional coordination between digital, service, and consultancy units, and establishing structured interaction routines (e.g., coaching, training, continuous feedback loops) for supporting customers (Paper 2). *At the customer level*, providers work with lead customers to *support customers in adopting data-driven decision-making*. Through onboarding, training, coaching, and recurring interactions, providers

support operators and managers in interpreting digital indicators and incorporating them into routines for performance monitoring, sustainability tracking, and corrective action. This may require corresponding adjustments in end-user roles, reporting practices, and everyday customer operations. *At the ecosystem level*, providers *negotiate roles, responsibilities, and value expectations* with partners to support coordinated delivery of digital solutions. Collaboration with dealers, technology partners, and service actors becomes more structured, clarifying expectations for implementation support, data interpretation, and follow-up actions. These relational arrangements help maintain the operational workability of digital solutions across organizational boundaries. For example, a construction equipment provider collaborated with several lead customers to embed fuel- and route-efficiency and idle-time indicators into site review meetings. The provider facilitated structured workshops and meetings with site managers and operators to interpret performance data and define corrective measures. Dealer representatives were engaged to discuss and clarify dealer responsibilities for follow-ups and feedback loops with customers. The form these arrangements take is also conditioned by the ecosystem in which implementation occurs: differences in power and sustainability priorities influence the roles actors can assume and the forms of coordination that can be established (Paper 3).

Importantly, the provider does not drive this alignment unilaterally. Its effectiveness depends on customers actively adopting, adapting, and sustaining digital solutions within their own organizational contexts. Providers may facilitate this process, but customers shape how digital solutions are incorporated into operational routines, decision-making practices, and sustainability priorities. Consequently, in Phase 2, digital solutions are evaluated not only on technical functionality but also on their ability to support agreed roles, routines, and sustainability-relevant decision processes within customer operations. Through this reciprocal adjustment between technical capabilities and social arrangements, digital solutions become more systematically embedded within lead-customer operations. The outcome of this phase is *realized sustainability value*. The construction-equipment example illustrates how this outcome emerged through socio-technical alignment: technically, the digital solution made fuel-efficiency, route-efficiency, and idle-time indicators available for monitoring and analysis; socially, site managers and operators worked with the provider to interpret these data and agree on corrective actions, while dealer responsibilities for customer follow-up and feedback were clarified. Sustainability-related value was realized through the reciprocal alignment of digital capabilities with customer routines,

decision-making, and supporting ecosystem roles rather than through technical implementation alone. This operational alignment provides the basis for broader solution implementation in Phase 3.

5.3 Phase 3 – scaling solution implementation

Phase 3 represents the stage in which industrial providers extend digital solutions beyond lead-customer settings towards broader solution implementation across organizational and ecosystem contexts. This phase explains how providers scale digital solutions through coordinated practices that extend socio-technical alignment across customers, organizational units, and ecosystem actors (Papers 3 and 4). Having achieved structured alignment in selected contexts, providers confront the challenge of making workable socio-technical arrangements repeatable without assuming that the conditions established with lead customers can simply be reproduced elsewhere. This phase is characterized by standardization, broader implementation, and increasing repeatability across contexts. Scaling is enacted through the interrelated modes of expansion, replication, and synchronization, which extend solutions into new contexts, make proven configurations more repeatable, and coordinate the actors and activities required for broader delivery (Paper 4). Across both technical and social subsystems, the emphasis shifts from operational embedding to extending workable socio-technical configurations across heterogeneous contexts. Therefore, the underlying alignment problem is repeatability across heterogeneity: providers must standardize enough of the technical and organizational configuration to support efficient reproduction while retaining sufficient adaptability to accommodate differences across customer and ecosystem contexts.

In Phase 3, the industrial provider advances ***technical subsystem change*** by *developing modular and scalable digital solution infrastructure*. *At the provider level*, accumulated data and implementation experience are used to standardize reusable elements of solution architectures, data models, and performance parameters (e.g., emissions, energy intensity, safety metrics), reducing the need to extensively re-engineer solutions for each implementation (Paper 4). For example, all providers described significant efforts to create interoperable solutions capable of integrating into various technological environments. *At the customer level,* providers increasingly rely on the *implementation of data-driven optimization* informed by accumulated operational data. Continuous data collection across customer sites supports refining solution performance and analytics models, enabling more systematic optimization of operational and sustainability-relevant

performance. *At the ecosystem level*, providers *align on ecosystem interoperability standards* across partners to enable large-scale implementation. Common technical interfaces, data standards, and integration procedures reduce the need to renegotiate technological compatibility with dealers, software or platform providers, and technology partners in each new setting. For example, one provider increasingly standardized its digital architecture around reusable solution components and common interfaces while using operational data accumulated across implementations to refine solution performance. This reduced dependence on customer-specific technical development while preserving the ability to optimize solutions using data from different operating environments (Paper 4).

In Phase 3, the industrial provider advances ***social subsystem change*** by *creating a solution-centric organization* capable of sustaining large-scale delivery of digital solutions. *Within the provider organization*, structures, responsibilities, and performance indicators are increasingly formalized around solution delivery, reducing dependence on temporary project arrangements (Paper 4). *At the customer level*, providers support *institutionalizing routines for digital solution use*. Digital solution use becomes embedded in recurring operational reviews, long-term service agreements, and continuous performance monitoring processes. These recurring arrangements make digital solutions less dependent on individual champions or temporary implementation projects and more integrated into customers' ongoing operational and sustainability management. *At the ecosystem level*, providers *define ecosystem roles for global scaling.* Responsibilities among dealers, technology partners, and integration actors become more clearly established so that implementation and support can be reproduced across regions and markets (Paper 4). However, these arrangements cannot be assumed to take a uniform form: differences in power and sustainability priorities shape the roles available to providers and partners and the forms of coordination through which scaling can occur (Paper 3). For example, providers increasingly relied on established dealer and partner structures to reproduce solution delivery and customer support across markets, requiring clearer responsibilities and more consistent coordination routines rather than renegotiating these arrangements for each implementation (Paper 4).

The outcome of Phase 3 is *scaled sustainability value*. At this stage, the operational and sustainability-related value realized in selected customer settings becomes reproducible across a broader range of implementations. This does not imply identical configurations across customers

— reusable technical architectures are combined with institutionalized organizational routines and more defined ecosystem arrangements that allow solutions to be adapted without rebuilding the surrounding socio-technical configuration for every implementation. Thus, a provider could reuse standardized digital solution components across customer settings while accumulated operational data supported continued optimization; at the same time, established delivery routines and clearer dealer and partner responsibilities enabled implementation and follow-up to be reproduced across markets (Paper 4). For example, a mining equipment provider had invested substantially in developing modular and interoperable digital solutions that could be configured to different customer requirements. This technical modularity was complemented by a more solution-centric organization, in which front-end sales personnel could work with customers to identify their operational needs and configure the appropriate combination of solution modules. These technical and organizational arrangements enabled the provider to offer more standardized and repeatable solutions while retaining the flexibility needed to address heterogeneous customer contexts.

Collectively, the framework explains socio-technical alignment as an unfolding process through which industrial providers align and extend technical and social arrangements for sustainability-related value through digital servitization. Across the three phases, the alignment problem develops from reducing uncertainty around emerging digital opportunities, to operationalizing digital solutions within customer operations, and ultimately to making workable socio-technical configurations repeatable across heterogeneous contexts. Correspondingly, the outcomes develop from *demonstrated sustainability potential*, through *realized sustainability value*, to *scaled sustainability value*. This progression shows that realizing and extending sustainability value requires more than the development of digital technologies alone; it depends on aligning evolving technical solutions with corresponding changes in provider organizations, customers, and ecosystem contexts. In this way, the framework explains how socio-technical alignment extends across organizational boundaries as digital servitization develops from initial exploration towards broader industrial implementation.

6. Discussion

This chapter discusses the theoretical contributions of the thesis and presents its managerial implications. It concludes by critically reflecting on the thesis's limitations and identifying directions for future research.

6.1 Theoretical contribution

This thesis develops three interrelated theoretical contributions at the intersection of digital servitization, industrial sustainability, and socio-technical systems research. Although prior research has examined digital service innovation, customer engagement, ecosystem collaboration, and sustainability transitions, these streams have largely developed in parallel. This thesis draws on these perspectives by conceptualizing digital servitization as a socio-technical alignment process through which industrial providers coordinate technologies, organizational practices, and inter-organizational relationships to support industrial sustainability. The thesis, through four appended papers and the integrative framework developed in Chapter 5, generates three overarching theoretical contributions.

First, this thesis contributes to digital servitization research by conceptualizing digital servitization for industrial sustainability as an unfolding socio-technical alignment process across organizational boundaries. Prior digital servitization research has provided important explanations centered on business model innovation, digital capability development, and ecosystem orchestration (Kohtamäki et al., 2019; Sjödin et al., 2020; Gebauer et al., 2021), while sustainability-oriented research has marked digitalization as an enabler of sustainability outcomes (Schiavone et al., 2022). However, these perspectives provide a more limited explanation of how technological and organizational changes become aligned across providers, customers, and ecosystem actors as digital servitization moves from strategic intent towards implementation and scaling.

The thesis advances this research by showing that the requirements for socio-technical alignment change as digital servitization develops across organizational boundaries. The framework identifies three interrelated phases that capture how the alignment problem develops from exploratory activities towards operational embedding and scaling across heterogeneous contexts. Across these phases, technical infrastructures, including data architectures, digital platforms, and

interoperability, must be aligned with social arrangements such as organizational routines, roles, governance structures, decision-making practices, and inter-organizational relationships. While prior research recognizes that digital servitization entails substantial organizational transformation and increasingly extends beyond the boundaries of the focal provider (Kohtamäki et al., 2019; Sklyar et al., 2019; Gebauer et al., 2021; Kolagar et al., 2022), this thesis explains how socio-technical alignment develops across provider, customer, and ecosystem contexts. The framework further shows that the nature of the alignment problem changes as digital servitization develops, from reducing uncertainty around emerging digital opportunities, to embedding solutions within customer operations, and ultimately to making workable socio-technical configurations repeatable across heterogeneous contexts. The contribution is therefore to extend understanding of digital servitization beyond the development of digital technologies and organizational capabilities towards explaining how technical and social arrangements are coordinated across organizational boundaries. In doing so, the thesis provides a processual socio-technical explanation of how digital servitization develops in support of industrial sustainability.

Second, the thesis contributes to industrial sustainability research by highlighting the active role of industrial providers in realizing sustainability improvements beyond their own organizational boundaries. Existing research increasingly recognizes digital technologies, digital servitization, and ecosystem collaboration as important enablers of industrial sustainability, for example through improved resource efficiency, operational optimization, and new sustainability-oriented value creation opportunities (Paiola et al., 2021; Schiavone et al., 2022; Shen et al., 2023; Kolagar et al., 2024). Research on digital servitization further emphasizes that realizing the value of digital solutions increasingly requires interaction and coordination among providers, customers, and broader ecosystem actors (Sklyar et al., 2019; Kohtamäki et al., 2019; Sjödin et al., 2020; Kolagar et al., 2022). However, these streams provide a more limited explanation of the active role that industrial providers can play in supporting the changes in customer operations through which the sustainability potential of digital technologies can be realized. Correspondingly, this thesis contributes to industrial sustainability research by conceptualizing industrial providers as active socio-technical change agents across organizational boundaries. Their role extends beyond delivering digital solutions to supporting changes in customers' operational routines, data-driven decision-making practices, roles, and ways of working, as well as helping establish coordination arrangements with ecosystem actors. In this way, providers actively support the development of

both the technical and social conditions through which sustainability improvements can be realized in industrial operations. Importantly, this does not imply that providers unilaterally determine such changes. Customers actively adapt and embed digital solutions within their own operational contexts, making sustainability-oriented socio-technical change a reciprocal process between provider support and customer adaptation. The provider's ability to act as a socio-technical change agent is also conditioned by the ecosystem in which these changes unfold. In particular, differences in power dynamics and sustainability focus shape the roles providers can assume and the forms of coordination through which they can support sustainability-oriented change. The contribution therefore shifts attention from industrial providers primarily as suppliers of sustainability-enabling technologies towards their role as active socio-technical change agents that support the technical, organizational, and inter-organizational changes through which industrial sustainability is realized.

Third, the thesis contributes to research on scaling of digital servitization for industrial sustainability by explaining how industrial providers extend digitally enabled sustainability solutions from localized implementations to broader industrial contexts. Prior research has demonstrated the potential of digital servitization to support industrial sustainability through, for example, operational optimization, resource efficiency, improved asset utilization, and sustainability-oriented value creation (Paiola et al., 2021; Schiavone et al., 2022; Shen et al., 2023; Kolagar et al., 2024). However, realizing broader sustainability impact depends on whether such solutions can move beyond individual pilots and customer-specific implementations. Research on scaling increasingly recognizes that this requires more than technological replication and involves coordinated organizational and ecosystem action across heterogeneous contexts (Jansen et al., 2023; Tatarinov et al., 2023; Palmié et al., 2023; Garcia-Martin et al., 2025). Yet, there remains limited understanding of the concrete practices through which industrial providers scale digital servitization for sustainability across different customer and organizational contexts.

This thesis contributes to this literature by showing that scaling digital servitization for industrial sustainability is enacted through aligned intra-organizational, customer, and ecosystem practices. These practices support three complementary scaling processes—expansion, replication, and synchronization—through which providers extend solutions to new contexts, reproduce workable arrangements, and coordinate the organizational and ecosystem activities required for their continued operation (Jansen et al., 2023; Tatarinov et al., 2023; Coviello et al., 2024). Importantly,

these scaling processes reveal that what must become scalable is not only the digital solution but the broader socio-technical alignment through which it is implemented and used. Technical architectures need to become sufficiently reusable and repeatable across implementations, while organizational routines, customer practices, and ecosystem arrangements must develop in ways that allow the solution to function across different contexts. This requires providers to manage the tension between repeatability and contextual adaptation, as socio-technical alignment must become sufficiently standardized to support replication while remaining adaptable to heterogeneous customer infrastructures, operational practices, and ecosystem arrangements. The theoretical contribution is therefore to explain scaling digital servitization as requiring socio-technical alignment that can be repeatedly deployed and adapted across heterogeneous industrial contexts, rather than the replication of a technological solution dominantly. The coordinated intra-organizational, customer, and ecosystem practices identified in this thesis explain how providers work towards this repeatability and adaptability.

These contributions advance understanding of digital servitization for industrial sustainability in three interrelated ways. First, they conceptualize digital servitization as an unfolding socio-technical alignment process that develops across organizational boundaries. Second, they highlight the active role of industrial providers as socio-technical change agents that support the technical and organizational changes required to realize sustainability value within customer and ecosystem contexts. Third, they explain that scaling digital servitization requires socio-technical configurations to become sufficiently repeatable and adaptable across heterogeneous contexts. The resulting explanation connects how socio-technical alignment develops, how industrial providers actively support it across organizational boundaries, and how aligned arrangements can be extended across heterogeneous contexts to realize industrial sustainability more broadly.

6.2 Managerial implications

The socio-technical alignment framework developed in this thesis provides several managerial implications for industrial providers seeking to use digital servitization to support industrial sustainability. Consistent with the framework's three phases, these implications relate to exploring solution viability, operationalizing solutions, and scaling solution implementation.

First, managers should evaluate digitalization and sustainability objectives together rather than treating them as separate strategic agendas. Early-stage initiatives should begin by assessing how technological, market, and sustainability-related priorities jointly create opportunities for digital servitization that deliver viable customer value. Early pilot projects should therefore focus on testing use cases jointly with customers while simultaneously preparing the organization internally. This includes clarifying responsibilities for digital solution delivery, encouraging collaboration between digital, solution-service, and sustainability teams, and building organizational commitment and shared strategic direction among internal stakeholders and lead customers. At this stage, managers should prioritize experimentation while avoiding premature standardization. Establishing common solution principles can support future transferability, but standardizing solutions before sufficient learning occurs may constrain adaptation to varying customer needs and limit what can be learned from pilot tests. Since customers may pursue their own operational and sustainability priorities, successful implementation depends on identifying shared value rather than assuming provider-led implementation alone will achieve alignment.

Second, managers should actively support customer and ecosystem-partner alignment during digital solution implementation. The sustainability-related value of digital solutions depends on their integration into customers' operational routines and decision-making processes. Managers should therefore invest in structured onboarding, training, coaching, and continuous interaction with customers to help translate digital data into actionable insights for operational and sustainability-related decision-making. At the same time, providers should formalize collaboration with ecosystem partners, such as dealers, technology providers, and software firms, by clarifying roles, responsibilities, and expectations for solution delivery and follow-up activities. Importantly, the appropriate form of ecosystem coordination depends on the provider's position within the ecosystem. Where power is concentrated, providers with limited influence may need to work through dominant actors and established governance structures rather than assuming an orchestration role. In more distributed configurations, managers can place greater emphasis on shared decision-making, reciprocal coordination, and co-creation. Managers should therefore diagnose the prevailing distribution of power and sustainability priorities before deciding how to organize ecosystem collaboration. Managers must also balance customer-specific adaptation with future repeatability. Extensive customization may strengthen fit and adoption within an individual

customer setting, but it can make successful solutions more difficult to reproduce across subsequent implementations.

Third, managers should design digital solutions and their surrounding delivery arrangements with scalability in mind starting from the early development stages. Scaling digital servitization requires managers to coordinate expansion, replication, and synchronization simultaneously rather than focusing predominantly on reproducing successful pilot projects. For example, providers must develop modular and interoperable digital infrastructures that can operate across different customer contexts while maintaining consistent performance standards. The scaling tension also concerns the balance between standardization and contextual adaptability. Excessive customization can undermine repeatability and increase the resources required for each implementation, whereas excessive standardization can reduce fit with heterogeneous customer infrastructures and operational requirements. Managers should standardize reusable architectures, interfaces, and delivery routines while preserving flexibility where customer contexts materially differ. At the organizational level, managers should institutionalize solution-delivery routines, define clear partner roles across the ecosystem, and embed sustainability indicators into digital platforms and performance-monitoring systems. These actions can reduce dependence on project-based delivery and make digital solutions more repeatable across customers and markets. This is also where economic viability becomes important: scaling requires not simply wider implementation but delivery models that can be sustained without repeatedly rebuilding the solution and associated organizational arrangements for each customer.

Across all three phases, the findings emphasize that *exploring solution viability* requires learning without premature standardization; *operationalizing solutions* requires embedding digital solutions in customer operations through coordinated technical and organizational adaptation; and *scaling solution implementation* requires making workable socio-technical arrangements sufficiently repeatable while retaining adaptability across heterogeneous contexts. Managers should therefore treat socio-technical alignment as an ongoing process in which technical architectures, organizational routines, customer practices, and ecosystem relationships are adjusted as digital servitization develops.

6.3 Limitations and suggestions for future research

While this thesis contributes to understanding of digital servitization as a socio-technical alignment process supporting industrial sustainability, its limitations also provide opportunities for further research.

First, although the thesis conceptualizes socio-technical alignment as a process that unfolds across different phases, the framework was developed through an integrative synthesis of the four studies rather than through a longitudinal research design that systematically followed individual digital servitization initiatives across the entire process. Some of the studies examined the same digital servitization initiatives over time and thereby captured developments at different points in their evolution; however, they were designed around distinct research purposes rather than as a continuous longitudinal investigation of socio-technical alignment. The framework therefore represents an analytically derived process structure and does not imply that every initiative necessarily follows the same fixed sequence. Future longitudinal research could follow specific digital servitization initiatives over extended periods to examine how movement across phases occurs, whether organizations move back and forth between phases, and whether alternative pathways emerge. Such studies could also investigate how technical and social changes reinforce or constrain one another over time as technologies, organizational arrangements, customer practices, and ecosystem relationships evolve. This would provide a deeper understanding of the temporal dynamics of socio-technical alignment and help refine the proposed framework.

Second, although the thesis incorporates customer and ecosystem perspectives, its thesis-level analytical focus remains centered primarily on the industrial provider. Customers and ecosystem actors are represented in the empirical material, and Paper 3 explicitly adopts an ecosystem-level perspective; however, the integrative framework places greater emphasis on how industrial providers support and shape socio-technical alignment than on how other actors independently interpret, negotiate, resist, or redirect the alignment process. Future research could therefore examine socio-technical alignment more explicitly from the perspectives of customers, partners, or other ecosystem actors. Customer-centered studies could investigate how customers adapt digital solutions and reorganize their own practices, while partner- and ecosystem-centered studies could examine how actors with different capabilities, interests, and power positions influence how socio-technical alignment unfolds. Multi-actor or network-based research could thereby provide a

more relational and distributed understanding of how socio-technical alignment develops across organizational boundaries.

Third, the thesis is grounded in qualitative research within industrial B2B contexts. The empirical settings were purposefully selected to provide theoretically relevant and varied insights across several industrial sectors. However, the case-based studies are concentrated primarily in Swedish industrial settings, even though the broader empirical material, particularly in Paper 1, includes firms from multiple geographical contexts. The findings therefore aim for analytical transferability rather than statistical generalizability, and digital servitization for industrial sustainability may unfold differently across industrial, institutional, and regulatory contexts. Future comparative research could examine the framework across countries, industries, and institutional environments to identify how regulatory requirements, industry standards, policy regimes, and other contextual conditions shape socio-technical alignment. Such research could help establish the boundary conditions of the framework and clarify where and under what conditions its proposed processes apply.

Finally, the qualitative design provides rich and context-sensitive insights into how socio-technical alignment develops but does not establish the extent to which the patterns identified in the framework are observable across broader populations and industrial contexts. Future quantitative or mixed-method research could therefore complement these process-oriented findings by examining selected dimensions of the framework across larger samples. For example, survey-based studies could investigate associations among the alignment of technical and social arrangements, cross-organizational coordination, the ability to extend digital solutions across contexts, and sustainability-related outcomes. Such research would complement the process explanation developed in this thesis by assessing the broader applicability and empirical robustness of selected elements of the framework.

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