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Navigating Digital Servitization for the Twin Transition: How Manufacturers Can Support Customers With Digitalization and Sustainability

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ABSTRACT

As industrial sustainability concerns mount, manufacturers engaged in digital servitization grapple with the twin transition of configuring and implementing digital solutions to meet their customers' sustainability objectives. To address this challenge, a socio-technical systems theory-based framework is proposed. Drawing on case studies with three manufacturers undertaking digital servitization and on the sustainability, digital servitization, and socio-technical systems theory research, our framework highlights key processes in navigating the twin transition. It emphasizes the importance of contextual factors in defining a customer twin-transition roadmap, outlines key steps in reconfiguring technical and social subsystems, and stresses the joint optimization processes based on feedback and metrics. This systematic approach guides manufacturers in supporting their customers through the twin transition, emphasizing socio-technical systems and iterative processes for sustained success. Our findings contribute to the growing digital servitization and sustainability research by conceptualizing underlying processes in the twin transition and offering manufacturers practical insights.

1 | Introduction

> We want to take the customers on a journey starting with getting insights of the current state ... It's difficult to discuss sustainability value if you do not have a measure... Then we analyze by collecting all data and building a theoretical model of the site.
>
> – Head of sales (Constructcorp)

In industry, sustainability is not just an option; it is an imperative for a thriving tomorrow. Accordingly, leading industrial business-to-business (B2B) manufacturers are increasingly assuming greater responsibility for improving the sustainability (e.g., emissions, safety) of their customers' operations (Averina et al. 2022; Sjödin et al. 2023; Kolagar et al. 2024). Simultaneously, manufacturers are engaging in digital servitization,[1] complementing traditional product sales (i.e., industrial vehicles) by developing digital solutions (e.g., AI-enabled fleet management) to create, deliver, and capture increased service value (Kohtamäki et al. 2019). We argue that leveraging digital servitization represents a promising path to resolve industrial sustainability concerns by targeting the twin transition—implementing digital solutions to accelerate sustainability efforts. For example, Komatsu, a global mining equipment provider engaged in digital servitization, has developed a portfolio of digital solutions addressing its mining customers' key sustainability concerns, such as reducing fuel consumption and increasing worker safety (Komatsu 2020). Thus, for manufacturers, the twin transition potential of leveraging digital solutions to enhance sustainability in their industrial customer operations is clear (Kolagar et al. 2024; Neligan et al. 2022), yet large-scale implementation and effects remain elusive (Wang et al. 2023; Sjödin et al. 2023).

Indeed, manufacturers' efforts to enhance industrial sustainability through digital servitization (i.e., twin transition) encounter a number of challenges. First, varied customer operations necessitate customizing digital solutions for specific operations; a one-size-fits-all approach is inadequate given the diverse nature of the processes and sustainability requirements. For example, customers in the mining industry face varying sustainability problems, such as worker safety, CO_2 emissions, and energy consumption, depending on the configuration of the industrial site (Rathobei et al. 2024). Thus, providers of digital solutions need to analyze and prioritize the most relevant solutions for specific customer problems. Second, realizing sustainable change extends beyond merely implementing digital technology and requires a fundamental system-level transformation in the way industrial customers operate (e.g., processes, worker behaviors). Accordingly, providers of digital solutions need to support their customers increasingly in leveraging digital solutions so that they can modify their operations to unlock sustainability benefits (Sjödin et al. 2023; Chowdhury et al. 2025). For example, implementing optimization solutions (e.g., route/load optimization) may require providers to support operator training, monitor processes, and follow up on procedures to optimize fleet usage and reduce emissions in line with sustainability objectives. Third, for solution providers, this change presents a conflict between their traditional modus operandi (i.e., selling products and spare parts) and a more customer-focused service business requiring new routines, incentives, and collaboration modes across the organization (Kamalaldin et al. 2020). For example, sales and service staff may need to engage more fully in evaluating customer success to realize sustainability objectives (Alcayaga and Hansen 2024; Sjödin et al. 2023). These challenges show the complexity of effectively deploying digital solutions to enhance sustainability in the industrial sector.

To overcome these challenges in digital servitization, there is a need for novel perspectives and process-level insights into the twin transitions (Kohtamäki et al. 2019; Sklyar et al. 2019). Accordingly, this study employs socio-technical systems (STS) theory (Trist 1981) to generate richer insights into provider-driven twin transitions of industrial customers. Essentially, STS theory provides a "method of viewing organizations which emphasizes the interrelatedness of the functioning of the social and technical subsystems of the organization and the relation of the organization as a whole to the [business] environment in which it operates" (Pasmore et al. 1982, 1182). Accordingly, STS offers a holistic perspective on change by recognizing the interdependencies among technologies (e.g., digital solutions), individuals (e.g., users/operators), and organizations (e.g., customers' organizational processes/routines) in pursuing successful implementation (Kurtz et al. 2023). However, a more robust inquiry is needed into how STS thinking can be integrated into evolving digital servitization practices to steer the twin transition (Ardito 2023; Rehman et al. 2023; Rabetino et al. 2018). Accordingly, several gaps in this domain require further study.

First, there is a need for further understanding of *how firms manage the twin transition of customers' socio-technical systems in digital servitization*. Indeed, guidance is limited on how firms can manage processes, practices, and evolving service offerings in collaboration with customers in digital servitization (Kohtamäki et al. 2022; Tronvoll et al. 2020; Sjödin et al. 2020; Lenka et al. 2016). Specifically, few studies have examined how providers can support customer sustainability initiatives through digital servitization (Paiola et al. 2021; Schiavone et al. 2022). STS theory is well-suited to examining the processes involved in providing digital services to customers because these processes must account for both socio-technical dimensions (Appelbaum 1997). In this way, we respond to the call to introduce pertinent theories into the servitization research stream (Rabetino et al. 2018; Kowalkowski, Gebauer, and Oliva 2017). For example, changes in one part of the system (i.e., introducing new digital solutions) require changes in other parts (e.g., developing operators' skills, operational processes). Accordingly, an STS theory lens provides opportunities to build a more holistic understanding of digital solutions implementation for the twin transitions (Kurtz et al. 2023).

Second, there is a need for further *delineating the evolution of digital solutions and corresponding joint optimization of socio-technical systems over time*. Indeed, as companies invest in the twin transition, digital solutions are evolving rapidly, often outpacing the ability of STS to adapt, and there is a need for further understanding of these dynamics (Sjödin et al. 2020). For example, twin transition efforts often face systemic challenges such as organizational inertia, skill gaps, or inadequate governance, which hinder the joint optimization of STS. Accordingly, we contend that the relationship between digital solutions and STS is inherently complex and dynamic, requiring continuous optimization and alignment between both organizational and technical elements. For example, as one part of a process is optimized, new bottlenecks or inefficiencies in other process parts may become apparent (e.g., Sjödin et al. 2020). Similarly, without appropriate management and follow-up, twin transition initiatives may reverse back to the status quo (e.g., a gradual decline in the use of digital solutions). However, there is limited research on how this joint optimization occurs over time, especially in response to ongoing twin transitions (e.g., new sustainability requirements). In particular, there is a gap in understanding processes for tailoring and optimizing digital solutions for specific socio-technical contexts (e.g., a specific customer site) (e.g., Kamalaldin et al. 2020). Understanding this co-evolution can help ensure that innovative digital solutions deliver long-term value, not just short-term solutions.

The present study aims to contribute to these underdeveloped aspects of digital servitization research by increasing understanding of *how digital solution providers manage the process of socio-technical system transformation for the twin transition of industrial customers*. We build on case studies of three leading manufacturers engaged in digital servitization. We specifically focus on their efforts to support their industrial customers (e.g., underground mining operations, quarries) with the twin transition by incorporating manufacturers' digital solutions to drive sustainability.

Our findings present a comprehensive account of how industrial manufacturers engaged in digital servitization navigate the twin transitions to support their industrial customers in realizing sustainability objectives. The findings can be summarized in four overarching phases: (1) *twin transition roadmap,* (2A) *orchestrating digital site transformation* (technical subsystem), (2B) *enabling data-driven organizational transformation* (social subsystem), and (4) *value optimization for twin transition*. Accordingly, our results pinpoint the iterative processes leading to a roadmap framework to progressively transform operations for the twin transition.

We contribute to the research on digital servitization, twin transitions, and sustainability in several ways. First, we illustrate the potential of digital servitization in contributing to the twin transition of industry. Specifically, we detail how a targeted focus on both sustainability goals and digitalization can enable manufacturers to configure and implement digital service offerings supporting customer productivity and sustainability. Second, we provide a detailed framework of how manufacturers engaged in digital servitization can implement a socio-technical perspective to configure service offerings and re-configure customers' operations for the twin transition. In particular, we detail the interlinkages between digital solutions and related technical and social subsystem re-configuration to ensure implementation success. Finally, we contribute by shedding light on the importance of customer involvement in the digital servitization journey, particularly in the context of the twin transition.

2 | Theoretical Background

2.1 | Understanding Digital Servitization for the Twin Transition

Digital servitization is defined as "the transformation in processes, capabilities, and offerings within industrial firms and their associate ecosystems to progressively create, deliver, and capture increased service value arising from a broad range of enabling digital technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cloud computing" (Sjödin et al. 2020, 478). Research into digital servitization has evolved within servitization research at such a fast pace to the extent that it is now hard to keep servitization processes separate from digital technologies (Sklyar et al. 2019; Sjödin et al. 2020; Minaya et al. 2024). This shift first showed itself when firms, in an increasingly competitive industry, started to integrate digital technologies into their products to add greater value to their offerings with add-on services (Demirkan et al. 2015; Martín-Peña et al. 2018; Visnjic et al. 2018). Thus, new opportunities with new revenue streams arose (Kohtamäki et al. 2019), giving a greater strategic emphasis to digital servitization.

Digital technologies are at the core of digital servitization as transformation enablers. Smart connected products consisting of sensors, physical parts, networks, and software constitute the infrastructure of digital servitization, offering remote control, monitoring, and optimization capabilities (Porter and Heppelmann 2014). For example, providers increasingly develop AI and data analytics solutions using connected equipment tools and software that provide predictive maintenance and optimization services (Opresnik and Taisch 2015; Sjödin et al. 2023). Despite the growing interest, digital servitization in the B2B context is still at an immature stage and requires more focused research endeavors (Gebauer et al. 2021). In particular, the sustainability potential of digital servitization and how providers can offer digital solutions to enable twin transitions for their customers (Chen et al. 2023) remains open to extensive inquiry.

Indeed, research on the sustainability potential of digital servitization was recently suggested, and the inadequacy of current research was highlighted (Paiola et al. 2021; Kohtamäki et al. 2019; Gebauer et al. 2021; Schiavone et al. 2022). It is argued that, because it is a key driver in the transformation of manufacturers' business models (Paiola et al. 2021), digital servitization can play an important role in developing and innovating sustainable or circular business models as well (Sjödin et al. 2023; Bressanelli et al. 2024). Indeed, digital solutions, such as predictive maintenance (Karuppiah et al. 2021), waste and resource reduction using optimization algorithms (Tavakoli and Barkdoll 2020), real-time data processing for streamlined efficiency and process integration (Javaid et al. 2022), and autonomous safe transportation solutions (Thomson et al. 2023; Sjödin et al. 2023), hold considerable potential for yielding sustainable results.[2] However, while digital servitization is recognized as a key driver in transforming businesses (Paiola et al. 2021), the twin transition introduces complexities and uncertainties into the implementation phase, namely, the integration of diverse digital technologies into existing operational frameworks (Chirumalla et al. 2023), the alignment of solutions with existing environmental standards and needs (Zhang et al. 2023), and insufficient customer engagement (Kamalaldin et al. 2020).

Customer engagement in digital servitization processes is crucial (Paiola and Gebauer 2020; Kamalaldin et al. 2020). Whereas digital technologies enable companies to enhance their customer operations and deliver innovative services through feedback as an example (Rust and Huang 2014; Demirkan et al. 2015), it is active collaboration with customers that drives value creation and ensures that offerings are aligned with customer needs (Lenka et al. 2016). In addition, it is known that services require a higher level of customer involvement than product-based businesses (Tronvoll et al. 2020). Service initiatives are unlikely to succeed if customer involvement is missing throughout the processes. Consequently, many firms will find it challenging to achieve the revenue streams, customer satisfaction, and profitability desired (Kowalkowski, Gebauer, Kamp, and Parry 2017). Furthermore, customer involvement is critical to fully leverage the potential of digital technologies in delivering not only economic value but also value that achieves environmentally sustainable processes (Opazo-Basáez et al. 2018). Additionally, Ceschin and Gaziulusoy (2016) state that achieving sustainability requires process-based systemic thinking to plan for a sustainability vision. Therefore, twin transition processes and how sustainability can be included at an earlier stage with digital processes through customer involvement seem to be the missing links.

2.2 | A Socio-Technical System Theory Approach to Twin Transitions

This study leverages STS theory (Trist 1981; Appelbaum 1997) to advance the understanding of how digital solution providers can support the twin transition of industrial customers. Indeed, STS theory has been used in the literature to understand transitions, transformations, and sustainability (Geels 2005; McKelvey and Holmén 2006; Verbong and Geels 2010; Geels 2010; Savaget et al. 2019). The STS approach emphasizes the interrelatedness of *social* and *technical* subsystems in the functioning of the organization and the holistic relation of the organization to its business environment (Trist and Bamforth 1951; Pasmore et al. 1982). The *social subsystem* refers to the individuals who make up the organization and their relationships, values, processes, and associations. The *technical subsystem* pertains to the tools, techniques, and technologies necessary for employees to accomplish their organizational tasks, such as the equipment and software solutions used by employees to support the operational needs of the organization (Bostrom and Heinen 1977; Emery 1993; Ruiz-Quintanilla et al. 1996). The alignment of these subsystems is labeled *joint optimization*, which pertains to prioritizing the entire system's well-being over the singular optimization of individual subsystems (Trist et al. 2016). In essence, STS posits that organizations consist of people utilizing technology to produce products or services, where both the effectiveness and suitability of the technology and the actions of its operators are mutually influencing the performance of the system (Pasmore et al. 1982). In the context of digital servitization, the alignment of customers' social and technical elements not only defines the parameters of joint optimization but also encompasses the significant challenge of facilitating proficient engagement between providers and customers to advance the twin transition (Viljakainen and Toivonen 2014; Kamalaldin et al. 2020). Accordingly, we argue that STS theory provides a holistic approach to examining emerging processes with interconnected social and technical dimensions (Sony and Naik 2020; Kurtz et al. 2023) in the twin transitions. Thus, we seek to understand the complex interplay between human-technological and customer-provider dynamics within the evolving processes of digital servitization (Münch et al. 2022; Herzog et al. 2022; Kurtz et al. 2023; Paiola et al. 2021). Specifically, in the context of digital servitization and its potential to support customers' twin transitions, STS theory provides a relevant theoretical lens for at least three reasons.

First, STS theory encourages a holistic understanding of dynamic systems in the context of new technology implementation (Sony and Naik 2020; Trist et al. 2016; Pasmore et al. 1982). Thus, in the case of digital servitization-enabled twin transitions, this concerns not only the adoption of new technologies (i.e., digital solutions) but also changes in organizational practices, customer interactions, and a significant transformation in how businesses operate and deliver value (Suppatvech et al. 2019; Tronvoll et al. 2020; Paiola et al. 2021). This viewpoint prevents a narrow focus on technology alone and promotes an examination of how technology and organizational aspects in twin transitions interact to influence sustainability outcomes (Bähr and Fliaster 2023; Bertassini et al. 2021).

Second, STS theory highlights the concept of joint optimization as a vital mechanism for enhancing the performance of interconnected components (Trist et al. 2016). Concretely, joint optimization focuses attention on achieving the best match between the requirements of the social and technical systems (Trist 1981) and asserts the process perspective of an iterative and continuously evolving process, not a static one (Pasmore et al. 1982). Notably, leveraging digital solutions to attain customers' sustainability goals is inherently intertwined with end-users' (e.g., operators) adoption of these solutions (Tuli et al. 2007; Matthyssens and Vandenbempt 2010; Baines et al. 2009; Fliess and Lexutt 2019; Kamalaldin et al. 2020), a perspective that positions customers as co-creators of value (Sjödin et al. 2020; Bednar and Welch 2019; Viljakainen and Toivonen 2014; Lenka et al. 2016). In particular, the STS perspective underscores a systems-thinking approach, treating digital solutions as integral components of larger systems characterized by complex and continuous interactions among customers, providers, technology, and their business environment over time (Pasmore et al. 1982). These are interrelated, and each requires the other to transform an input into an output, creating the functionality of a system (Trist 1981). Accordingly, joint optimization in STS is essential to balance the interactions between people, processes, and technology, ensuring that neither the technical nor the social aspects dominate. We argue that this alignment is of particular relevance in the context of digital servitization and twin transitions as a means to enhance system performance, user satisfaction, and adaptability in complex environments.

Third, STS theory emphasizes the importance of considering the specific context in which a technological change occurs, rather than imposing standardized technological solutions (Trist 1981; Cummings 1978), which is a common problem in digital servitization. For example, optimizing the performance of one subsystem may not provide benefits if it is dependent on other systems. When applied to digital servitization, this means recognizing that different customers (or even different customer sites) may have varying levels of operational conditions, technological literacy, preferences, and sustainability concerns (Shen et al. 2023). Tailoring digital solutions and the underlying implementation processes to align with these contextual factors enhances the likelihood of productive customer-provider engagement and sustainable outcomes.

To sum up, concerns over the complex environmental and social impacts of industrial activities have prompted an increased demand for novel solutions to address the sustainability challenge. The twin transition perspective highlights the role of implementing digital solutions as a promising path to increase sustainability. Accordingly, manufacturers engaged in digital servitization hold an important role in navigating the twin transition of their customers by configuring and implementing digital solutions that respond to customers' idiosyncratic sustainability challenges. Yet, how providers can support STS reconfiguration for the twin transition of industrial customers remains unclear. We argue that applying STS theory to this challenging context provides a way of furthering our understanding of the underlying processes of configuring and jointly optimizing technical and social subsystems of customers for the twin transition. Accordingly, the confluence of STS theory and digital servitization constitutes a promising avenue for further inquiry, highlighting the role of aligning contextual conditions, human agency, and technological solutions in value-creating systems.

We argue that studying these underlying relationships holds promise for revealing important insights into the processual and strategic complexities inherent in digital servitization and twin transitions.

3 | Methods

3.1 | Research Approach and Case Selection

The present study adopts an exploratory multiple-case study (Yin 2009) of B2B providers to understand how digital solution providers manage the process of STS transformation for the twin transition of industrial customers. Case studies are preferred for their ability to enrich understanding through multiple data collection methods (Eisenhardt 1989; Eisenhardt and Graebner 2007; Yin 2009). When attempting to gain new insights into phenomena that are theoretically novel, the utilization of case studies can prove to be valuable (Edmondson and McManus 2007). Given the early stage of research on digital servitization (Tronvoll et al. 2020), the complex and undetailed phenomenon of how providers can leverage technology-based solutions with their customers to successfully implement twin transitions is a good example of potential new insights that can advance our theoretical understanding.

The cases are Swedish incumbent firms with a global presence, catering to B2B clients in diverse industries, such as manufacturing, mining, quarrying, construction, and transportation. To better understand the issue, the B2B context is a pertinent setting for a transparent and non-generalized investigation because the providers in a B2B setting are more likely to work closely with customers due to smaller customer volume and more homogeneous expectations in nature compared to the business-to-consumer context, for instance (Hollyoake 2009). Therefore, the purposive sampling method is useful, considering the research aim and the relevance to the research question (Etikan et al. 2016).

Cases were selected using the purposive sampling method following four criteria. First, we selected firms actively engaged in digital servitization—that is, transforming processes, capabilities, and offerings for digital solutions. This indicates that firms' decision-makers have crafted routines and methods to provide digital solutions and have existing customer relationships. For instance, Constructcorp has a team that works with customers to configure digital solutions for their specific needs. Second, we selected firms that aim to provide digital solutions with a heightened emphasis on sustainability (e.g., CO_2 reduction, safety). For example, Truckcorp has a target to reduce CO_2 release by supporting customer processes through its new connectivity solutions. Thirdly, the cases were required to have experience in implementing digital solutions across multiple customer sites. By this means, it was possible to gain insights into the earlier development experiences of firms, such as pilot projects and failed collaborations with customers. For example, Truckcorp described the archetypes in its service development processes and revealed the lessons learned from mistakes during earlier collaborations with customers. Fourthly, it is noteworthy that we had successfully cultivated favorable relationships with both the firms and the customers in the case selection. This allowed us to gain access to several interview opportunities, other related contacts, and various secondary data.

3.2 | Data Collection

The primary data set consists of 36 in-depth interviews with key informants actively engaged in sustainable value creation through digital servitization. A semi-structured interview guide was developed through team discussions to ensure relevancy, with further refinement based on initial interviews to enhance insights. The interview themes encompassed digital servitization development, sustainability targets, value creation processes through collaborations, and general business interactions. For example, the questions in the guide included: How do digital solutions sales and implementation processes unfold? How do providers and customers identify and align sustainability targets? How are the interactions between providers and customers structured in different phases? Which activities are perceived as essential in the (co)creation of digital solutions? To address such overarching questions, we prompted interviewees to draw not only on their knowledge of the relationships that are investigated but also on their more extensive experiences from different processes, thereby facilitating empirical comparisons. Doing this and posing on-the-spot follow-up questions regarding their earlier experiences allowed us to obtain further details. Interviews were conducted with participants through online video conferencing and were recorded for subsequent transcription and detailed analysis. The interview durations ranged from approximately 30–95 min.

Snowball sampling was employed to recruit additional informants based on the relevance identified in initial interviews (Biernacki and Waldorf 1981). Several customer interviews were also conducted to validate emergent findings and ensure rigorous results and a broader view. As shown in Table 1, informants held various roles, assuring diverse perspectives and insights.

To enhance construct validity, the main data were triangulated through additional data collection methods, including company presentations, workshops, follow-up interviews, and project/executive reports, as well as publicly available material, such as customer stories (Eisenhardt 1989). This approach corroborated the informants' input and provided supplementary information, strengthening the overall validity of the findings.

3.3 | Data Analysis

A thematic analysis approach was employed for data analysis (Braun and Clarke 2006), allowing for the identification of connections in analytical themes in a reliable manner. To handle the complexity and nuances of qualitative analysis (Yin 2009; Braun and Clarke 2006), an abductive interpretivist approach was utilized (Van Maanen 1979). This approach involved building first-order analyses based on factual accounts from individuals involved in the events, facilitating the identification of patterns through multiple iterations and comparisons. A three-step approach was adopted, following the data structure of the phenomenon (Gioia et al. 2013).

TABLE 1 | Overview of companies.

Company	Example of digital solutions	Interviews and informants
Constructcorp: A construction equipment manufacturer (e.g., wheel loaders, haulers). 16,400 employees.	Fleet management, site simulation and optimization, predictive maintenance, real-time assistance services, autonomous vehicle solutions, performance services, etc.	Total: 16. Respondents: performance services (2), solution sales (2), head of sales (1), customer project owner (1), strategy and business development (1), service concept and design (1), solution manager (1), research strategy manager (1), chief project manager (1), project managers (2), director of business strategy (1), performance manager (1), application engineer (1). Customer interviews: cement supplier: quarry supervisor (1), trucking company: general manager (1).
Truckcorp: A manufacturer of commercial vehicles & transport solutions. 57,000 employees.	Fleet management, connectivity services, inventory management, remote diagnostics and maintenance, autonomous vehicle solutions, etc.	Total 11. Respondents: venture building (4), project manager (1), technical support (1), director of digital division (1), advanced analytics (2), digital officer (1), innovation strategy manager (1). Customer interviews: material handling and equipment supplier: strategy manager (1), mining company: product management director (1).
Minetechcorp: A mining and infrastructure equipment manufacturer. 17,000 employees.	Fleet management, autonomous vehicle solutions, mine planning and optimization, training and simulation, energy management, etc.	Total: 9. General manager (1), global director of digital division (1), vice president (1), chief technology officer (1), customer solutions director (1), president of digital solutions (1), line manager (1), advisor (1), sales director (1). Customer interviews: mining company: program manager mine automation (2), research coordinator (1).

In the first step, the interview transcriptions were thoroughly analyzed by reading them several times to familiarize ourselves with the data. Relevant lines and quotations related to the research goal of exploring how providers can ensure success in digital servitization by supporting customer twin transition were highlighted. Similar lines, quotations, and terms were then coded, establishing first-order concepts.

The second step involved developing second-order themes by evaluating each first-order concept independently, aiming to uncover patterns and associations. Through iterative discussions among the authors, first-order concepts were grouped to form theoretically distinct and comprehensive second-order themes.

The final step refined the second-order themes and identified common overall goals for each theme, leading to the aggregation of dimensions. This process resulted in the development of an overall data structure (Figure 1).

4 | Results

Our findings present a comprehensive account of how industrial manufacturers engaged in digital servitization navigate the twin transition to support their industrial customers in realizing sustainability objectives. In particular, we detail how digital solution providers manage the process of STS transformation in customer operations. The context of our findings is heavy industrial sites, such as underground mining operations, quarries, and construction sites, which hold significant opportunities for twin transitions by incorporating manufacturers' digital solutions to drive sustainability. Following STS theory, we delineate the processes of identifying important opportunities and transforming the technical and social subsystems in customers' operations. Specifically, our findings delineate four overarching phases for addressing STS change in customer operations: (1) ***twin transition roadmap,*** (2A) ***orchestrating digital site transformation (technical subsystem),*** (2B) ***orchestrating data-driven organizational transformation (social subsystem)***, and (4) ***value optimization for twin transition***. The following sections elaborate on the detailed findings and present the resulting framework.

4.1 | Twin Transition Roadmap

The opportunity for improving the sustainability of industrial operations is vast. Understanding where to begin and how to proceed is both complex and uncertain. Accordingly, informants indicated the necessity of supporting customers in defining a ***twin transition roadmap***. Essentially, this means efforts to map needs and determine an implementation plan for how digital solutions could help customers address their most pressing sustainability challenges. Our findings show that defining a customer twin transition roadmap is driven by three fundamental activity sets: *assessing customer sustainability potential, data-driven solution assessment,* and *creating solution implementation blueprint*.

Assessing customer sustainability potential was deemed a critical starting point for understanding customer needs and

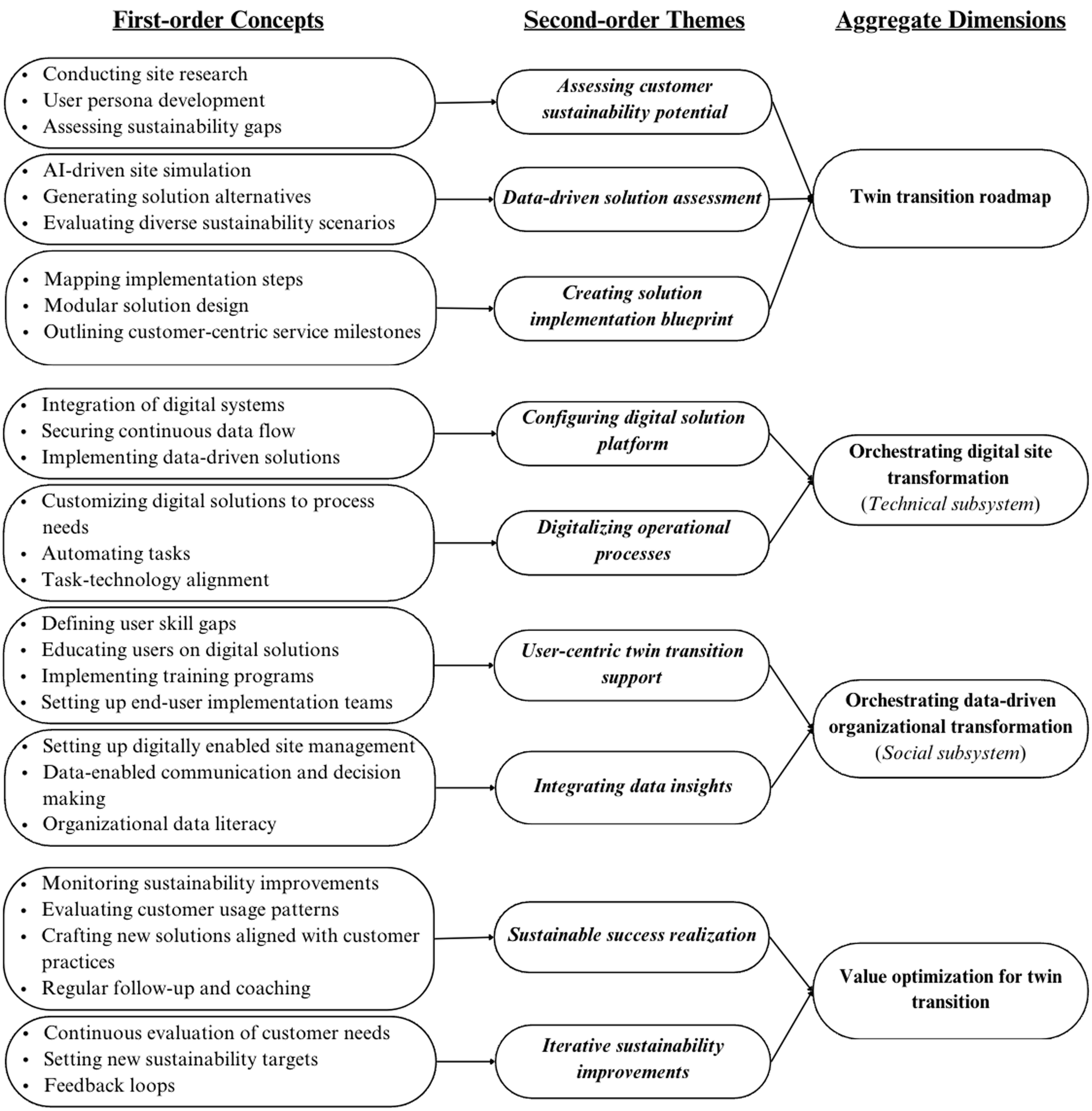

FIGURE 1 | Data structure.

requirements. This represents a commitment to understanding the customer's business to provide more goal-directed value through engaging in different activities to understand the customer site, operational processes, and sustainability gaps. For example, Constructcorp described a comprehensive approach to site mapping by conducting site research, focusing on collaboratively determining the most appropriate applications for each customer's unique context and setup. As informants highlighted, different sites and customers possess varying sustainability requirements and technological readiness. Some customers' sustainability initiatives can benefit considerably from simpler digital solutions, such as monitoring fuel consumption, tracking speeding (e.g., safety risk), and optimizing routes. On the other end of the spectrum are customers who aim to monitor and optimize every facet of their operations to achieve net zero emission, which requires the connection of more advanced technologies comprising sensors, physical parts, networks, and software. By acknowledging these variations, it is evident that an essential aspect of assessing customer sustainability potential is conducting site research and developing a user persona specific to the needs and ambitions of each customer. For example, Truckcorp mentioned an approach for assessing each client's existing context and operations by leveraging fleet-level data and customers' internal systems. Likewise, a project manager from Constructcorp described the importance of joint preparation and leveraging customer insights from internal systems to engage in assessing the potential sustainability values that are possible to obtain:

> We want customers to prepare before the meetings. We also want to have prepared from our side, which we can take from our systems about the customers before the meetings. So, we started looking at that, but not focusing specifically on the [technology] … That's a partnership together with the customer, which is much more important in this way of working.

Our informants described how *data-driven solution assessment* is critical in simulating and analyzing the appropriate solution alternatives to help customers identify decision-making mechanisms both for sustainability and day-to-day operations. For example, a customer project owner from Constructcorp illustrated that its AI-driven site simulator program assists decision-making through various simulations, providing information on idling time, cost per ton, CO_2 emissions, and fuel consumption. A line manager at Minetechcorp similarly emphasized the significance of evaluating different metrics to ensure appropriate cost–benefit outcomes depending on the customer sustainability objectives:

> For example, if you want a machine to start driving from, say, 5 kilometers per hour to 11 kilometers per hour, we say, "Alright, we will develop this system for you, this is how much it's going to cost. However, these are the KPIs that we agree to."

Another aspect of the data-driven approach to the transition involves evaluating diverse sustainability scenarios. Manufacturers recognize that addressing customer needs goes beyond the mere provision of solutions. It entails empowering customers with valuable data-driven insights:

> You get more information, and you get a much better awareness of things: what's happening and maybe what's not happening. By doing that, you can then take measures to keep the mine more sustainable. I mean, less waste, less energy consumed, and so on. So, it's like giving information. The information is usually for people to receive and then to take action … By knowing that they can drive more carefully and consume less, but more importantly get out of the way of dangerous vehicles, which are both safety and sustainability… A decision support to people, for them to make decisions to become more sustainable.
>
> – Global director of digital division (Minetechcorp)

Finally, informants described the importance of *creating solution implementation blueprint*. This entails outlining an implementation plan and solution configuration based on a portfolio of different service modules customized according to customers' specific needs. A key to such solution blueprint is to include a concrete implementation plan with steps to transform both technical and social subsystems at the customer site—for example, outlining a timeline of solution installation, operator training, and process changes. Creating customized solution blueprints for the specific customer site allows the provider to cater to a range of requirements and sustainability ambitions. Therefore, the approach allows for scalable and flexible configurations to ensure that the provider's offerings can adapt to varying customer requirements. As expressed by a business development leader at Constructcorp:

> We start playing a much bigger role in the setup. That's also where this 50% of services comes in because we are no longer just a machine supplier, we are more of a solution supplier … We sit down with the customer, we agree and get his input because he knows a lot more about his operation than we do, but we have all the data elements to it. We agree on what we are going to improve. It could mean training operators, adding a digital surface, customer contract, the CO_2 consumption, and drilling down into what's happening in the CO_2 sides, and then of course, we sustain that improvement over time, so that means some guys on consultancy going back to the customer.

4.2 | Orchestrating Digital Site Transformation (Technical Subsystem)

Informants emphasized the significance of ***orchestrating digital site transformation*** to effectively help customers utilize data in the context of servicing diverse tools, machines, and brands collectively in operations. Our findings demonstrate that orchestrating digital site transformation is driven by two key activity sets: (1) *configuring digital solution platform* and (2) *digitalizing operational processes*.

Configuring digital solution platform is a key element in instigating the twin transition at the customer site. It entails building up a data infrastructure by connecting different systems and machines to enable continuous data flow on which AI and digital solutions can function. Minetechcorp mentioned that it is crucial to consider the integration of different brands of machines (i.e., competitors) because the machines in the system rely on each other, and their performance collectively affects the overall productivity and continuity of customer operations. By collecting and securing continuous data flow holistically from various sources, manufacturers can configure digital solutions to gain insights into site-, machine-, and operator-level performance. For example, Minetechcorp described systematic efforts to configure a mining intelligence platform for its customers, capturing positioning, shift, and production data. This data-driven approach allows customers to make informed decisions regarding productivity, energy consumption optimization, waste reduction, and safety improvements. A performance manager from Constructcorp explained the company's systematic approach:

> The software we're using is connected to different databases. We're collecting data regarding the

> machine and attachments that they can add to the system. Then, the system will live by adding additional data that we are collecting at the customer site. We can make a simulation and come up with ideas about how to improve productivity, how to reduce cost, how to reduce bill consumption, and all those details … As you know, when we simulate the site, you cannot just look at one machine. They're dependent on each other.

Another important step is *digitalizing operational processes,* which involves leveraging digital solutions to make concrete changes in site operations in line with the target sustainability outcomes. For example, Constructcorp described how data from its digital solutions could be leveraged to identify ideal locations for critical production equipment or change driving routes to optimize sustainability. Moreover, digital solutions hold the potential to automate certain tasks (e.g., material tracking) to free workers to address more value-adding tasks. In addition, task-technology alignment is a critical facet that resonates throughout the digital site transformation. This relates to aligning the specific tasks of the customers (e.g., site managers following the dashboard) with the technologies they are employing in the digitalized operating areas because the digital transformation not only involves deploying advanced technologies but also ensures that the technologies are integrated into existing task structures. This alignment assures that digital tools are effectively leveraged to enhance performance. For example, the director of digital division at Minetechcorp described it as harnessing data from various machine brands and connected sensors. The director added that this forms the foundation for mixed fleet management, which demands the strategic utilization of tools and potentially AI to effectively automate, interpret, and make decisions based on diverse data sources. Similarly, the head of sales at Constructcorp recounted:

> You have the right machines, you have the right application, your whole route is looking good, but your operators are not doing what they should.

4.3 | Orchestrating Data-Driven Organizational Transformation (Social Subsystem)

In parallel with the technical aspects of steering the twin transition, an equally critical factor in this change is the reconfiguration of the social subsystem in the customer organization to utilize the technology. In fact, this is an essential part of realizing meaningful change for the twin transitions. For example, a customer of Minetechcorp described how implementing digital technology was only 10% of the total effort to create value from digital solutions and that the remaining 90% was all about involving and training the workforce and changing the organizational culture to work differently. Correspondingly, informants referred to the need to help customers in enabling data-driven organization. This essentially means helping the customer to harness the potential of human capital coherently, redefine roles and responsibilities, and cultivate a data-driven ethos throughout the organization. Based on this, the findings show that two factors come to prominence: *user-centric twin transition support* and *integrating data insights*.

First, *user-centric twin transition support* emerged as a primary element in transforming the way people work, enabling a data-driven organization that can realize twin transition objectives. As our informants indicated, engaging end-users (e.g., machine operators and technicians) is crucial for the successful implementation of digital solutions in traditional industries because it ensures alignment with actual operational needs, facilitates smoother adoption, and maximizes the potential for a positive impact on productivity, efficiency, and sustainability. A key issue for manufacturers is defining user/operator skill gaps both in terms of the use of digital applications (e.g., digital illiteracy) and in terms of doing actual work (e.g., inefficient driving style). Our informants stated that once the skill gaps were identified, they could design specific education programs on digital tools in addition to focused training programs (e.g., fuel-efficient driving). For example, Constructcorp described how training programs for operators could increase safety (e.g., less speeding), fuel efficiency (i.e., CO_2), and even productivity by 20%. Another fundamental aspect in terms of realizing the value of digital solutions is setting up dedicated implementation teams in the end-user organization responsible for coordinating and following up on the implementation progress. The head of sales from Constructcorp described the central role of user-centric support to ensure lasting change for sustainability initiatives:

> We've seen that it's very important … that you need to have a [implementation] team board that is owned by the operators. The [site manager], of course, owns it as well, but the [operators] need to be involved. Seeing the KPIs, seeing the improvement and the continuous improvement because, otherwise, it will lead us to be that we are delivering one time, and then it gets better for three months, and then it goes back to [the original state].

Second, *integrating data insights* was described as a key driver for changing the organizational culture of customers. This includes a concerted focus on establishing digitally enabled site management with customers through promoting collaboration, data-enabled communication, commitment to these new practices, and improving organizational data literacy. A vital part of this process is putting data insights into the hands of operators to ensure more informed decision-making. For example, all companies described putting tablets in moving vehicles where critical data insights are displayed (e.g., collision warnings, driving efficacy, optimal routing). Minetechcorp even extended this by connecting smartphone applications to the mining intelligence system. The benefits of setting up these systems are increased situational awareness and personally monitoring productivity, safety, and situational metrics to drive behavioral change at the operator level.

> They're training some of the safety people going out there and asking [customers], "How's your operation and what are your problems in your daily operation?"

> Really outside-in. "Does it fit your business?" Then, they can look into, "Okay, it should be this, it might be a machine with whatever."
>
> – Solution sales (Constructcorp)

4.4 | Value Optimization for Twin Transition

As our informants related, realizing sustainability improvements in customer sites extends beyond ensuring initial changes in technical and social subsystems to focus on continuous improvements and joint optimization of these systems over time. Accordingly, there is a need for continuous ***value optimization for twin transition***. In essence, this relates to refining both the digital solutions and how they are used. Our findings demonstrate that value optimization is driven by two fundamental activity sets: *sustainable success realization* and *iterative sustainability improvements*. These approaches set the stage for manufacturers to manage change both on the technical and social sides while remaining relevant to evolving customer needs and sustainability imperatives.

Sustainable success realization entails the provider adopting a consultative role in ensuring the productive usage of digital solutions. For example, informants at all manufacturers highlighted the importance of defining metrics and enacting processes for monitoring the newly instituted design to achieve operational synergy and optimize the overall system performance. Metrics could include response times, customer satisfaction, safety, and impact on waste reduction. Informants stressed that it is critical to maintain a focus on continuous improvement throughout the customer organization. By involving multiple stakeholders, the provider aims to create comprehensive and effective coaching programs that positively impact efficiency and sustainability. This points to the need for a tailored approach to repeated follow-ups that considers the specific needs and challenges faced in different contexts. Through coaching that addresses the unique requirements of operations as well as customers, the aim is to optimize performance and contribute to overall sustainability improvements. The head of solution sales at Constructcorp explained:

> I think that together with the support, the coaching angle of approach, we can improve by measuring and opening their eyes and seeing, "This is what you actually perform, and this is the difference we have between your different operators or different flow in operation." We can identify what the next needs to be.

Second, *iterative sustainability improvements* emphasize the adaptive response to evolving customer needs. Continuous engagement through customer feedback is instrumental, allowing the digital solutions to be iteratively refined. For example, informants at Constructcorp emphasized that it is crucial to establish a continuous dialog and build a relationship with the operational personnel to understand their emerging needs and collaboratively identify opportunities and new targets for improvement. Excluding individuals who are directly involved in the operations can lead to a lack of evaluation and hinder the successful implementation of necessary changes. In addition, the ability to simulate future scenarios in customer operations is key. For example, these forward-looking simulations enable setting new targets and maintaining feedback loops. Continuous adaptation to ever-shifting needs demands such approaches. This signals that a forward-thinking approach for continuous improvement is needed, utilizing data for monitoring and decision-making purposes. For example, at Constructcorp, a continuous structured approach to engaging customers in enhancing the sustainability value process is emphasized. Moreover, a line manager at Minetechcorp highlighted continuous evaluation by starting from new KPI achievements:

> Once the KPI is achieved and once we know that we achieved it consistently … then we start talking about, "Alright. Moving forward. How do we want to do this?" There's also the ongoing support which we are starting to look at from a licensing-type model, which encompasses not only the software but also the support perspective.

5 | Discussion

This study applies STS theory to understand the underlying processes of digital servitization for the twin transition of industrial customers. The findings illustrate four overarching phases: (1) *twin transition roadmap,* (2A) *orchestrating digital site transformation* (technical subsystem), (2B) *orchestrating data-driven organizational transformation* (social subsystem), and (4) *value optimization for twin transition*. We summarize our findings in an STS framework for digital servitization in support of the twin transition (Figure 2), emphasizing the iterative processes inherent in the reconfiguration of the customers' socio-technical system for increased sustainability. The framework holds several key insights:

First, our findings demonstrate the importance of approaching customers in a different way to initiate the twin transition. Unlike the traditional technology push approach, leading providers engage customers by listening, analyzing, and simulating customer operations to identify potential sustainability improvements. By utilizing data and analytics tools, providers can collaborate with customers in assessing the potential solutions (e.g., an AI-enabled route optimization solution) to their problems, as well as trade-offs and costs. This allows for the creation of a jointly agreed upon ***twin transition roadmap***. This includes not only technological solutions but also comprehensive implementation plans and support and training for users (e.g., operators, managers).

Second, the framework emphasizes the need to consider both social and technical dimensions in ensuring the twin transition. Beyond ***orchestrating digital site transformation*** (i.e., technology sub-tasks), such as configuring digital solution platforms and digitalizing operational processes, the social aspects hold a critical role in ensuring that digital solutions

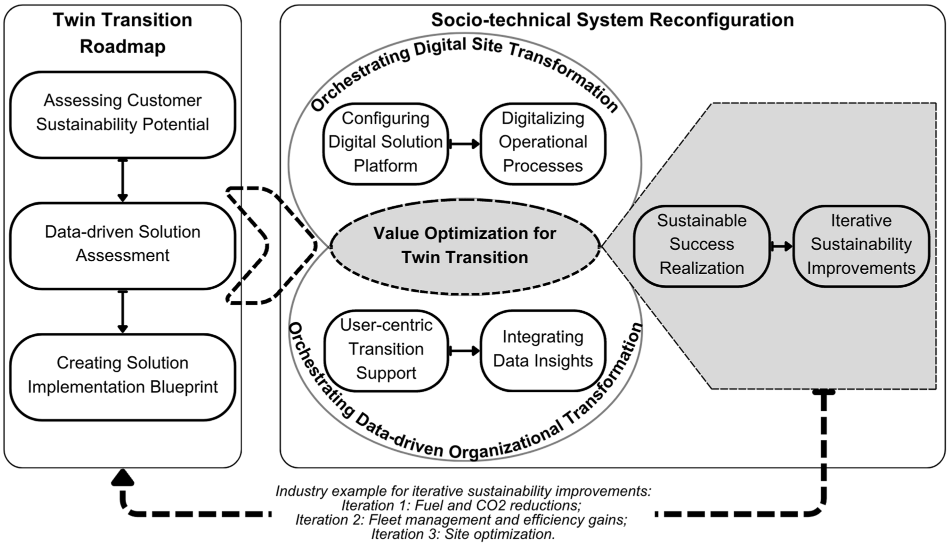

FIGURE 2 | A socio-technical systems framework for digital servitization in support of the twin transition.

are used and acted upon to drive increased sustainability. Specifically, we emphasize the providers' role in supporting their customers in ***orchestrating a data-driven organizational transformation***. This includes vital aspects such as user-centric transition support (e.g., education/training) and integrating data insights to drive behavior change for the twin transition. A key to STS change is understanding the need for joint optimization between social and technical systems. Specifically, working with these dimensions jointly and over time allows value optimization for the twin transition. Accordingly, manufacturers engaged in digital servitization need to be prepared to extend their engagement by monitoring customers' sustainability improvements, solution usage patterns, and potential problems and offer coaching and support where needed.

Finally, the key sustainability effects of this approach materialize over time through ***iterative sustainability improvements*** and additions to the twin transition roadmap. Therefore, defining a twin transition roadmap for customers is not a one-time occurrence but rather an ongoing engagement with the customers. It is difficult to chart all potential paths to sustainability in advance, and changes in customer needs, requirements, and operational conditions are common. Accordingly, providers regularly follow up with customers on what next steps and improvements to focus on. For example, Constructcorp's initial twin transition roadmap for a customer was focused on the reduction of fuel consumption (Iteration 1), which was later complemented by a fleet management solution (Iteration 2) to further increase the efficiency of site traffic. Ultimately, substantial sustainability improvements to the site were generated by focusing on site optimization (Iteration 3). These iterative improvements contributed to making the site more efficient, reducing traffic, CO_2 emissions, and idle time, as well as improving operator safety.

The practical relevance of this framework lies in its applicability for managers in firms engaged in digital servitization for supporting their customers with the twin transitions. This roadmap can help systematically address the socio-technical challenges and ensure that both technological and social aspects are integrated into commercial efforts to drive the twin transition, particularly in the context of digital servitization. However, companies that provide digitalization support for sustainability without servitization may also benefit from these insights, especially concerning understanding the need for organizational alignment and integrating social and technical systems. Accordingly, the results of this study can have important implications for both theory and practice in the context of digital servitization and the twin transition.

5.1 | Theoretical Implications

This study has several theoretical implications for the research on digital servitization, sustainability, and twin transitions.

First, we *illustrate the potential of digital servitization to contribute to the twin transition*. While recent research on digital servitization has started to discuss the sustainability potential of digital services (Ardito 2023; Paiola et al. 2021; Schiavone et al. 2022), this stream of research is still nascent and in need of more concrete examples and insights into the underlying processes. By building on the twin transition (Rehman et al. 2023), our research illustrates how a targeted focus on both sustainability goals and digitalization can enable manufacturers to configure and implement digital solutions supporting customer productivity and sustainability. For example, with our framework, we emphasize that newly introduced technological advancements should not outpace the adaptation of social configurations, that the transition should be approached holistically, and that individuals in the organization should be properly acclimatized. In contrast to prior research discussing digital servitization transformation as more digital-heavy (e.g., Coreynen et al. 2017; Frank et al. 2019), we find that technology development is one side of the picture that, in itself, has little value for a successful and sustainable transformation without the joint optimization of subsystems.

Second, we *use an STS framework to explain how manufacturers engaged in digital servitization can successfully configure* *digital solutions and reconfigure their customers' processes for the twin transition*. STS theory provides a well-established framework for organizational and technological change (Appelbaum 1997) that is suitable for understanding microfoundations in the context of digital servitization. Our use of STS theory is a response to the call to introduce pertinent theories into digital servitization research to drive richer insights into the phenomena (Rabetino et al. 2018; Kowalkowski, Gebauer, and Oliva 2017). Leveraging the STS perspective has allowed us to reach beyond prior research to focus on customer collaboration in the design and implementation of digital solutions (e.g., Sjödin et al. 2020; Iriarte et al. 2023; Favoretto et al. 2022; Dmitrijeva et al. 2020) and more accurately portray the configuring and implementation processes inherent in digital service commercialization. We show how working together with customers in defining goals and setting a sustainability roadmap are key. We further detail the interlinkages between technical and social subsystem re-configuration to ensure implementation success. Finally, we highlight the need for iterative refinements in joint optimization throughout the digital servitization journey, emphasizing ongoing adaptation and fine-tuning of digital solutions and customer operations. Iterative processes ensure that sustainability objectives are not only met but also evolve in response to changing dynamics and emerging opportunities. This provides a more nuanced framework to understand joint optimization for appropriate steps in the commercialization of digital solutions. In addition, although this framework is designed with servitization in mind, the core principles of STS thinking—such as joint optimization and the interplay between technology and organizational processes—could also inform broader digitalization efforts aimed at achieving sustainability.

Third, we *contribute by shedding light on the importance of customer involvement in the digital servitization journey, particularly in the context of the twin transition*. Our research stresses that engaging customers in defining sustainability goals and collaboratively designing solutions is not only beneficial but also imperative to achieve the twin transition effectively. This emphasis on customer co-creation aligns with the broader trend in the service literature (e.g., Lusch et al. 2007; Edvardsson et al. 2012; Gustafsson et al. 2012; Lenka et al. 2016; Sjödin et al. 2020; Kindström et al. 2013; Artto et al. 2015) and underscores its significance in the context of digital servitization. Furthermore, our study introduces the concept of the twin transition roadmap, which provides a structured approach for manufacturers to align their digital solutions with customer needs and sustainability objectives. By emphasizing the role of customer-centric processes and offering a practical roadmap, we propel existing research on digital servitization into a more customer-centric and sustainable direction.

5.2 | Managerial Implications

This study offers several implications for managers engaged in the commercialization of digital solutions, providing straightforward guidance for navigating their customers' twin transitions.

The first implication relates to *understanding customer twin transition needs and jointly designing a roadmap*. The framework can serve as a guide for manufacturers to comprehensively understand their customers' sustainability requirements while aligning them with their digital objectives. This involves close collaborative engagement with customers in the early stages of digital solution implementation to jointly design a roadmap. The active involvement of customers in defining sustainability goals and harmonizing digital solutions with these objectives ensures that the solutions significantly address the twin transition of digital servitization and sustainability. This collaborative approach not only strengthens relationships with customers but also positions the manufacturer as a trusted partner in sustainability initiatives.

Second, *synchronized re-configuration of technical and social subsystems together with customer input during the transition was seen as crucial*. The successful orchestration of digital servitization transformations hinges on the adoption of a holistic approach (Paschou et al. 2020; Struyf et al. 2021) that synchronously reconfigures both technical and social subsystems. This means investing in advanced digital technologies as well as addressing the transformation's organizational and human dimensions. Manufacturers are required to be vigilant in ensuring that their workforce possesses the requisite competencies to adeptly leverage these new technologies. For example, this connects to undertaking the task of clearly delineating roles and responsibilities to enable customer success and nurture customer-centric teams. The harmonization of equally significant technical and social components in the organizational fabric assumes a position of critical importance. It is this alignment that holds the potential to optimize the outcomes of digital servitization. It facilitates the achievement of both new technology adoption and sustainability targets. Thus, manufacturers should navigate the twin transition by adopting a well-rounded approach, ensuring that technological advancements are complemented by corresponding human and organizational adaptations.

The third implication emphasizes *continuous follow-up, refinements, and joint optimization*. The process of digital servitization is iterative and ongoing (Struyf et al. 2021). Therefore, manufacturers should attach importance to continuous follow-up and refinements throughout the process. This involves establishing a feedback loop with customers that can serve as a conduit for gathering insights and identifying new opportunities for improvement from new practices throughout the transition. To remain responsive, manufacturers should implement flexible practices characterized by modularity and interoperability. Such practices allow for swift adaptation to changing customer needs and emerging sustainability objectives. Joint optimization with customers should be a recurring practice, ensuring that digital solutions evolve in tandem with customer operations.

While this study focused on digital solutions for enhancing customer sustainability (i.e., twin transitions), the learnings from this study are also replicable to firms offering advanced forms of digital servitization (e.g., smart services, autonomous solutions, connected vehicles). Our research underlines the necessity for social and technical dimensions to work together to achieve guaranteed performance, regardless of whether sustainability is a core goal.

5.3 | Limitations and Further Research

Our findings need to be tempered with an appreciation of the study's limitations and the possibilities for future research that arise from these shortcomings. First, this study is mainly explorative and qualitative, thus including three cases of manufacturers engaged in digital servitization. The generalizability of the findings is limited to the context of large industrial firms operating mainly in European markets. We encourage digital servitization researchers to collect data from a larger number of varying industrial cases and explore whether our findings hold in different contexts. Moreover, the current study excludes in-depth data from customer organizations, which is vital in understanding the extent to which digital servitization influences customers' internal processes and sustainability outcomes. Future studies would benefit from espousing these empirical perspectives.

Furthermore, while our study has focused on the dyadic relationship between manufacturers and customers, we recognize that the digital servitization process often involves a broader ecosystem of stakeholders (Sklyar et al. 2019). Actors such as software developers, connectivity providers, component manufacturers, and other third-party providers can play significant roles in shaping outcomes. Future research can explore these multi-actor dynamics and triadic relationships, as understanding the interactions between multiple stakeholders is imperative to fully grasp the complexities of digital servitization. Investigating multi-actor joint optimization activities could provide valuable insights into new lines of understanding that have not yet been fully explored. This deepens our understanding of how different stakeholders co-create value, optimize processes, and influence the success of digital servitization initiatives, particularly concerning sustainability outcomes.

We also acknowledge that other theoretical perspectives can also be relevant when it comes to digital servitization driving twin transitions. For example, the capability-based perspective and the relational view could provide additional insights that complement the STS perspective.

Another avenue for future research would entail conducting quantitative studies to test and validate the relationship between digital servitization and sustainability, which has been proposed in numerous studies (e.g., González Chávez et al. 2024; Kolagar et al. 2024; Paiola et al. 2021) but has not been fully investigated. In addition, it would be highly relevant to explore which moderators and mediators include these proposed relationships. For example, based on the STS perspective, following organizational culture, employee engagement, technological maturity, and customer support would be relevant influencing variables. Finally, given the current theoretical and empirical attention to the circular economy and circular business models for industrial firms (Cuevas-Pichardo et al. 2024; Schöggl et al. 2024; Sjödin et al. 2023), we encourage future studies to adopt this perspective. These research opportunities can further enhance understanding of digital servitization processes in such business models, identify best practices, address existing limitations, and contribute to developing more effective strategies for organizations undergoing digital transformations in service-oriented contexts.

Endnotes

[1] Digital servitization is "the transformation in processes, capabilities, and offerings within industrial firms and their associate ecosystems to progressively create, deliver, and capture increased service value arising from a broad range of enabling digital technologies such as the Internet of Things (IoT), big data, artificial intelligence (AI), and cloud computing" (Sjödin et al. 2020, p. 478).

[2] While digital solutions can advance sustainability, it is also necessary to acknowledge that digital technologies (e.g., cloud servers) carry a significant carbon footprint, and their implementation may paradoxically have adverse environmental impacts. Indeed, recent research has highlighted the need to quantify and manage the environmental costs associated with digital technologies (Ingemarsdotter et al. 2021), although this is beyond the scope of this study.

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