Mechanisms for developing operational capabilities in digital servitization

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Abstract

Purpose – Digital servitization concerns how manufacturers utilize digital technologies to enhance their provision of services. Although digital servitization requires that manufacturers possess new capabilities, in contrast to strategic (or dynamic) capabilities, little is known about how they develop the required operational capabilities. The paper investigates the mechanisms for developing operational capabilities in digital servitization.

Design/methodology/approach – This paper presents an exploratory study based on 15 large manufacturers operating in Europe engaged in digital servitization.

Findings – Three operational capability development mechanisms are set out that manufacturers use to facilitate digital servitization: learning (developing capabilities in-house), building (bringing the requisite capabilities into the manufacturer), and acquiring (utilizing the capabilities of other actors). These mechanisms emphasize exploitation and exploration efforts within manufacturers and in collaborations with upstream and downstream partners. The findings demonstrate the need to combine these mechanisms for digital servitization according to combinations that match each manufacturer's traditional servitization phase: (1) initial phase - building and acquiring, (2) middle phase - learning, building and acquiring, and (3) advanced phase - learning and building.

Originality/value – This study reveals three operational capability development mechanisms, highlighting the parallel use of these mechanisms for digital servitization. It provides a holistic understanding of operational capability development mechanisms used by manufacturers by combining three theoretical perspectives (organizational learning, absorptive capacity, and network perspectives). The paper demonstrates that digital servitization requires the significant application of building and acquiring mechanisms to develop the requisite operational capabilities.

Keywords Acquiring, Building, Capability development mechanisms, Digital servitization learning, Operational capabilities, Traditional servitization

Paper type Research paper

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1. Introduction

Digital technologies, such as the Internet of Things (IoT), Cloud computing, and predictive analytics, have been recognized as enablers of manufacturers' journeys to becoming solution providers (Lenka *et al.*, 2017). This transition is often termed digital servitization (Paschou *et al.*, 2020), which is defined as "the utilization of digital technologies for transformational processes whereby a company shifts from a product-centric to a service-centric business model and logic" (Sklyar, 2021, p. 2). Through using these digital technologies, manufacturers can combine products, services, and information (derived from data) to create and capture value (Agarwal *et al.*, 2022; Chen *et al.*, 2021; Kohtamäki *et al.*, 2019). While traditional servitization has always involved digital technologies to some extent (Rabetino *et al.*, 2018), the introduction of these new digital technologies radically changes the offerings, business models, and basis of competition within an industry (Kohtamäki *et al.*, 2019; Martín-Peña *et al.*, 2018; Paschou *et al.*, 2020). Moreover, as part of digital servitization, manufacturers can utilize the opportunities from these new digital technologies, such as capturing and analyzing Big Data (Kohtamäki *et al.*, 2022). This means that information is an important basis of competition alongside those utilized in traditional servitization, namely products and services (Cenamor *et al.*, 2017). Thus, we view digital servitization as a novel context to research phenomena such as capabilities, which are significantly different from those required for traditional servitization (Ardolino *et al.*, 2018; Kohtamäki *et al.*, 2019).

The extant literature reports on the need to develop strategic (or dynamic) capabilities, such as business model development, value selling, and value delivery to advance digital servitization (e.g. Coreynen *et al.*, 2017; Hasselblatt *et al.*, 2018). Strategic capabilities have configurational and dynamic character and are developed over time to fit environmental demands (Coreynen *et al.*, 2017). Through applying sensing, seizing, and reconfiguring mechanisms (Teece, 2007) in the context of digital servitization, prior work suggests different ways to develop the dynamic capabilities to facilitate the transition (Chirumalla *et al.*, 2023). In the same vein, advancing digital servitization also hinges on developing operational capabilities, which are the focus of this paper. Operational capabilities are defined as manufacturer-specific sets of skills and processes that are regularly used in solving problems (Wu *et al.*, 2010), which in this case implies facilitating digital servitization. Such capabilities are even more critical in digital servitization context which demands manufacturers direct their resources, know-how, skill sets, and operational practices required for digital service operations.

This paper explores the mechanisms by which manufacturers develop capabilities for digital servitization. In this study, we argue that mechanisms for developing operational capabilities are crucial components of advancing digital servitization and they are broader than the mechanisms used for traditional servitization. In digital servitization, value creation requires that manufacturers adapt their processes to focus on services (traditional servitization), but also take advantage of new digital technologies and open up their boundaries to exploit other firms' digital capabilities (digital servitization) (Sklyar *et al.*, 2019). This, therefore, necessitates collaboration and cooperation between several actors, such as providers of digital technologies (Bustinza *et al.*, 2019; Münch *et al.*, 2022). Literature about capability development for traditional servitization focuses on learning by doing (Valtakoski, 2017). However, it is unclear to what extent this mechanism applies to digital servitization, considering the radical changes required in manufacturers' capabilities, with many of the required capabilities not possessed in-house (Marcon *et al.*, 2022). Thus, it is necessary to consider the complementarity of internal and external capabilities in facilitating digital servitization (Marcon *et al.*, 2022; Münch *et al.*, 2022).

This paper addresses three main gaps in the extant literature. First, previous research has concentrated on strategic (dynamic) capabilities (Chirumalla *et al.*, 2023), and few papers have considered the mechanisms of operational capability development for digital servitization. Understanding these mechanisms is crucial to revealing how manufacturers can successfully

deploy digital technologies in their service processes and has been called for in prior work (Gebauer *et al.*, 2021; Paschou *et al.*, 2020; Tronvoll *et al.*, 2020). Second, while some research has investigated mechanisms for capability development in both traditional and digital servitization, this work is often piecemeal and does not provide a comprehensive assessment. Many studies touch upon one specific theoretical perspective only or focus on traditional servitization (not digital servitization, specifically). We, thus, contend that existing research is fragmented and there is a need for an integrated view of operational capability development mechanisms for a complex context such as digital servitization, addressing different mechanisms in the same study. Third, as digital servitization usually takes place within manufacturers that have undertaken traditional servitization (Coreynen *et al.*, 2020), there is a need for a contextualized understanding of the use of operational capability development mechanisms within manufacturers at different stages of traditional servitization.

To address these gaps, our study aims to understand the mechanisms for developing operational capabilities for digital servitization. In particular, we address the following research questions (RQs):

RQ1. How (through which mechanisms) do manufacturers develop operational capabilities for digital servitization?

RQ2. How do different manufacturers combine operational capability development mechanisms to successfully implement digital servitization?

To answer these questions, we combine theoretical perspectives about organizational learning, absorptive capacity, and networks. This multi-theoretical perspective allows us to investigate both exploitation and exploration mechanisms that manufacturers can apply either internally or in collaboration with other actors. Thus, this study answers calls in prior work about how manufacturers facilitate their digital servitization journeys (Kohtamäki *et al.*, 2021), and in particular, mechanisms for developing operational capabilities (Raddats *et al.*, 2022).

This study makes three main contributions; first, it reveals three operational capability development mechanisms, namely learning, building, and acquiring, highlighting the parallel use of these mechanisms for digital servitization. Second, it provides a holistic understanding of these capability mechanisms by fusing three theoretical perspectives (*organizational learning* – learning, *absorptive capacity* – building, and *network* – acquiring). This approach provides a comprehensive assessment of operational capability development mechanisms in complex contexts (e.g. digital servitization). Third, the study specifies combinations of operational capability development mechanisms based on manufacturers' traditional servitization phase (initial, middle, and advanced), thereby linking traditional servitization to digital servitization. Greater use of building and acquiring mechanisms are required as manufacturers transition from traditional to digital servitization.

This paper continues with a literature review that provides the theoretical background for the study (section 2). This is followed by the methodology (section 3), which presents an exploratory study based on 15 large manufacturers operating in Europe that are actively involved in digital servitization. The findings and research propositions (RPs) are set out in section 4, while the discussion (section 5) presents the paper's theoretical contributions, managerial implications, and limitations/future research areas.

2. Theoretical background

2.1 Operational capabilities for digital servitization

With advanced digital technologies, such as the IoT and big data, more services and solutions depend on data analytics to enhance manufacturers' and customers' operations (Coreynen *et al.*, 2017). Thus, digitalization has become an enabler of servitization strategies (Kohtamäki *et al.*, 2019). Digital servitization has often been explored using a strategic (or dynamic)

capability lens to illustrate the significant reconfiguration of firms' capabilities (Chirumalla *et al.*, 2023), radically changing business models (Kohtamäki *et al.*, 2020), and positions in the value chain (Kohtamäki, 2019). In the same vein, manufacturers also need to change the service operations and processes to facilitate this transition; that is, operational capabilities are required. Digital servitization requires specific operational capabilities that have not been necessarily crucial in traditional servitization. Digital servitization business models consist of three main components: products, services, and information (Cenamor *et al.*, 2017). For digital servitization, the information component becomes central and is, in some cases, replacing product and service components (Cenamor *et al.*, 2017). Manufacturers, therefore, must be able to overcome the challenges of collecting and utilizing data that underlies this information, since it is an important approach to achieving competitive advantage (Eggert *et al.*, 2022).

Recent research highlights the importance of operational capabilities that manufacturers need when dealing with data (digital capabilities) (Ardolino *et al.*, 2018; Lenka *et al.*, 2017). Prior studies identify several such capabilities at the forefront of driving the development of digital servitization. *Intelligence capabilities* refer to intelligent functionalities through embedding smart components and monitoring and collecting data (Ardolino *et al.*, 2018; Lenka *et al.*, 2017). *Connect capabilities* are the ability to transmit data to the Cloud through wireless networks and to connect intelligent products at a network level (Lenka *et al.*, 2017). *Analytics capabilities* include processing information through rules and algorithms to turn it into predictive insights, thereby helping to visualize value through simulated scenarios (Ardolino *et al.*, 2018; Cenamor *et al.*, 2017; Lenka *et al.*, 2017; Paiola and Gebauer, 2020; Sjödin *et al.*, 2020). *Digital platform capabilities* refer to the development of operating systems that enable interoperability between providers' and customers' platform services, which in some cases, enables the configuration of autonomous services (Cenamor *et al.*, 2019; Jovanovic *et al.*, 2021; Kohtamäki *et al.*, 2019; Tian *et al.*, 2021). To advance digital servitization, manufacturers also need to be able to use digital capabilities as a way to determine appropriate interventions and actions based on predictive insights (Baines and Lightfoot, 2014), develop new digital services (Opazo-Basáez *et al.*, 2022), and thus create and capture value (Agarwal *et al.*, 2022; Ciasullo *et al.*, 2021; Machchhar *et al.*, 2022).

2.2 Capability development mechanisms for (digital) servitization

Despite growing interest in exploring digital and traditional servitization, there is limited research that discusses operational capability development mechanisms. Existing research about capability development mechanisms for traditional and digital servitization focuses on strategic approaches. In particular, there has recently been a sharp uptake of papers about the strategic capability mechanisms for digital servitization (Chirumalla *et al.*, 2023). However, there has been less focus on operational capability development mechanisms, both for traditional and digital servitization. In terms of operational capability development mechanisms for digital servitization, engaging with customers to develop new knowledge (Gremyr *et al.*, 2022) and utilizing new digital technologies (Ferreira and Lind, 2022) are highlighted (see Figure 1).

It is to be expected that at the start of the exploration of a new research topic (digital servitization), most academic attention is given to strategic capability development mechanisms setting out how manufacturers (including those that are servitized) transition their businesses to take account of the opportunities afforded by new digital technologies. We contend that is also important to consider operational mechanisms to develop the resources and skills to deliver the new digitally-focused strategy. Moreover, these mechanisms do not operate in isolation and different combinations are likely to be needed given the array of operational capabilities that manufacturers require to successfully implement digital servitization. Although some prior work has started to investigate these mechanisms in

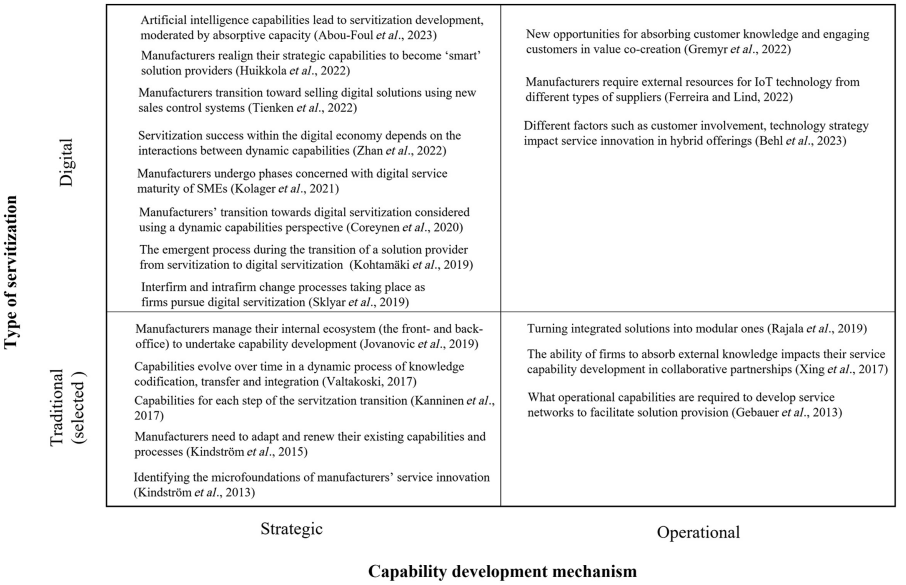

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Figure 1. Capability development mechanisms used for (digital) servitization

different sectors (Behl *et al.*, 2023), the relationship between them and manufacturers' traditional servitization efforts has not so far been explored although it would be expected that linkages would exist.

2.3 Theoretical perspectives on capability development mechanisms

Digital servitization is a new research stream that requires investigation to understand how manufacturing firms develop the required capabilities. Manufacturers use different mechanisms; that is, organized, productive activity systems (Pajunen, 2008), to develop such capabilities. The underpinning logic for this investigation is that digital servitization changes the entire business model of manufacturing firms (Chen *et al.*, 2021). For example, this occurs through changes in processes, capabilities, and offerings (Favoretto *et al.*, 2022; Paschou *et al.*, 2020). Recent studies challenge the traditional research distinctions between external exploration and internal exploitation and unravel the relationship between them to utilize data-driven opportunities from digital servitization (Coreynen *et al.*, 2020). Furthermore, digital servitization requires extensive collaboration across the manufacturer's organizational boundaries (Sklyar *et al.*, 2019), from cooperation with existing partners, such as customers and intermediaries to potential new partners, such as software companies, technology, and platform providers.

Given that digital servitization represents a complex journey for manufacturers (Favoretto *et al.*, 2022), we go beyond the usual approach of applying one theoretical perspective and instead combine multiple perspectives to provide a more holistic understanding of capability development. First, since manufacturers may already have service infrastructure and processes, it is important to see how they transform their existing operations and change their routines and processes (an organizational learning perspective). Second, digital technology and data are new components of manufacturers' business models (Cenamor *et al.*, 2017). Therefore, having an absorptive capacity perspective is useful to

understand how they exploit new knowledge and resources enabled by digitalization. Finally, digital servitization requires opening up the firm's boundaries and extending cooperation with other actors in the network (Sklyar *et al.*, 2019). Thus, we share a particular interest in how manufacturers complement their capabilities by utilizing the capabilities of other actors in the network (network perspective). In the following sub-sections, we draw from organizational learning, absorptive capacity, and network approaches to gain insight into potential ways manufacturers develop their capabilities, and how they differ.

2.3.1 Capability development through organizational learning perspective. Extant literature has covered the processes of organizational changes involved in traditional servitization for manufacturers (Brax and Visintin, 2017). The knowledge-based view, and in particular, organizational learning, that focuses on creating and using knowledge within the organization, can offer valuable insights into how an organization "learns" about the capabilities it needs (Valtakoski, 2017). Organizational learning is a process of creating, disseminating, interpreting, using, and storing information within organizations (Mohr and Sengupta, 2002; Zhu *et al.*, 2018). Valtakoski (2017) shows the relevance of applying the knowledge-based view and organizational learning in analyzing servitization challenges by reconceptualizing the manufacturer's offering as a bundle of knowledge components and different processes of learning. In particular, intuiting (recognizing the possibilities), interpreting (explaining the idea), integrating (developing a shared understanding), and institutionalizing (developing routines, rules, and procedures) are important adaptive processes to achieve strategic renewal (Crossan *et al.*, 1999).

Organizational learning processes transform experience to knowledge (Argote, 2013), and can create several changes in the firm's perception, actions, and routines (Easterby-Smith *et al.*, 2000). This resonates with manufacturers pursuing servitization and thus improving different processes, such as service sales and service delivery. For example, Kindström *et al.* (2015) identify new roles and competencies for the sales function when adding services to product-based portfolios. Moreover, digital transformations, in general, and digital servitization, in particular, are continuous processes of organizational learning that align manufacturers to the changing environment (Liu *et al.*, 2021). Thus, digital servitization requires that manufacturers change their routines and processes to utilize data-driven opportunities (Coreynen *et al.*, 2017), and adapt their resources, skills, and structures, accordingly (Favoretto *et al.*, 2022; Münch *et al.*, 2022). Organizational learning theories tend to concentrate on intra-organizational mechanisms, and cooperation with other stakeholders requires additional theoretical standpoints.

2.3.2 Capability development through absorptive capacity perspective. An important part of manufacturers' capability development during servitization is the ability to absorb and exploit new knowledge, termed absorptive capacity (Posselt and Roth, 2017). The absorptive capacity view refers to "the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990, p. 128). Absorptive capacity has often been used to examine how firms deal with changes in external technology (Jansen *et al.*, 2005; Xing *et al.*, 2017) or to investigate the learning aspects of firms in their collaborative partnerships; for example, in mergers and acquisitions (Xing *et al.*, 2017).

Although studies on absorptive capacity and knowledge integration in a servitization context are useful, research about manufacturers' mechanisms to absorb new knowledge in developing digital servitization is scant. So far, scholars have mirrored the findings of traditional servitization literature and emphasized the customers' role in developing digital solutions (Huikkola *et al.*, 2021; Kamalaldin *et al.*, 2020; Rapaccini and Adrodegari, 2022), and co-creation processes to develop new services (Ciasullo *et al.*, 2021; Paiola *et al.*, 2021; Sjödin *et al.*, 2020). Given our focus in this paper is not on customer offerings but rather manufacturer's capability-development mechanisms for digital servitization, further

investigation of the utility of absorptive capability is necessary. Digital servitization exposes manufacturers to huge amounts of data that can be generated through an installed equipment base, thereby requiring new capabilities to collect, analyze, and interpret this data. We, thus, argue that exploring the absorptive capacity associated with the digital servitization of manufacturers can offer an illuminating, although not complete, perspective for further conceptualizing this phenomenon.

2.3.3 Network perspective. A manufacturer not only develops capabilities internally but must also develop them externally, which necessitates collaboration with other actors (Raddats *et al.*, 2017). This approach goes beyond absorbing knowledge from external actors and requires inter-firm collaboration within a network (Håkansson and Snehota, 1995). Thus, capabilities for digital servitization are not limited to those possessed by manufacturers or at the customer interface but are also developed through manufacturers cooperating with upstream partners that may possess capabilities for technological innovations or digital infrastructures (Sklyar *et al.*, 2019). Since digital servitization requires novel capabilities, manufacturers need to interact with new actors, such as infrastructure providers (Gebauer *et al.*, 2021; Kamalaldin *et al.*, 2020), data analytics providers (Naik *et al.*, 2020; Sjödin *et al.*, 2021), technology suppliers (Paiola *et al.*, 2021), system integrators (Paiola and Gebauer, 2020), and third-party software providers (Ardolino *et al.*, 2018). Crucially, these actors may be different from those that manufacturers already interact with for traditional servitization (Sklyar *et al.*, 2019). Although these new actors do not necessarily have their own products, they can enable the creation of digital platforms that connect different components into integrative offerings (Coreynen *et al.*, 2020).

Although the benefits for manufacturers of collaborating with these digital servitization actors are clear (Kamalaldin *et al.*, 2020; Sklyar *et al.*, 2019), little is known about the inter-organizational mechanisms for capability development (Kapoor *et al.*, 2021). While organizational learning and absorptive capacity are typically seen as the function of experience and prior knowledge or their development is through recruitment or resource acquisition (Valtakoski, 2017), advancing digital servitization also requires new types of knowledge that manufacturers have not traditionally required. A network view of digital servitization highlights the importance of complementary capabilities within a network (Kamalaldin *et al.*, 2020; Kohtamäki *et al.*, 2019). Ferreira and Lind (2022) report one of the few digital servitization studies that have applied a network perspective to investigate different types of technology suppliers and their manufacturer interfaces, including connected, digital and digital-physical. Although the findings in this paper provide important insights into the relational aspects of manufacturer/technology supplier collaborations, little information is provided about the mechanisms in these networks that facilitate capability development for digital servitization.

3. Research methodology

3.1 Research design

We used an exploratory approach to investigate the mechanisms for developing capabilities for digital servitization, as this phenomenon remains poorly understood and existing research is fragmented (Miles and Huberman, 1994). We, therefore, used a qualitative interview-based method to develop our understanding of the phenomenon and derive RPs and theoretical contributions (Meredith, 1998). Qualitative research is useful when existing literature is extended to include new elements (Meredith, 1998); in this case, combining organizational learning, absorptive capacity, and network perspectives to frame the empirical findings about capability development mechanisms.

We collected data from 15 global manufacturers within their European operations, selected based on three main criteria: (1) the companies are global manufacturers that (2) offer

complex industrial systems and services, and (3) are involved in digital servitization. We followed a purposeful sampling approach to ensure that the selected manufacturers met these criteria (Saunders, 2012). For example, we sought companies from several sectors to help assess the prevalence of digital servitization capability development mechanisms to ensure that the resultant theory is generalizable to various contexts (Eisenhardt, 1989). Although operating in different sectors, all companies have a manufacturing background. Moreover, all the companies provide complex industrial solutions to their business customers, so we avoided those that predominantly sell to consumers. To provide further heterogeneity in the sample, the companies vary in terms of their traditional servitization phase (e.g. services offered, service infrastructure). Through an analysis of company documents (e.g. financial reports) and interview data, we categorized each manufacturer's servitization phase into one of three groups: an initial phase (few service offerings and an underdeveloped service infrastructure), a middle phase (a moderately well-developed service portfolio and service infrastructure), and an advanced phase (a highly developed service portfolio and infrastructure).

The companies in the study utilize different technologies to drive digital servitization, such as Cloud computing, augmented reality, machine automation, etc. They develop various digital services, such as web portals for monitoring and ordering consumables and spare parts; preventive maintenance; solutions to improve service performance, safety, and energy efficiency; and different types of mobile applications. We avoided limiting our study to particular digital technologies and services, as studying them in combination is often the most enlightening (Gebauer *et al.*, 2021; Raddats *et al.*, 2022), and this seems particularly prescient for capability development mechanisms.

3.2 Data collection

Interviews were mainly used to collect data, together with company documentation such as websites, brochures, and news articles. The focus was on identifying "expert" interviewees; that is, individuals who stand out for their knowledge, designation, education, practice, or experience on a particularly complex topic (Littig, 2009). Thus, interviewees were actively involved with developing capabilities around digital servitization and, thus, had significant expertise in this topic (Bogner and Menz, 2009). Moreover, interviewees had experience working or collaborating with relevant internal business units (e.g. R&D, IT, global teams, product management), and external organizations, and had direct insights regarding their firms' digital servitization strategies. The number of employees who met these criteria was quite limited in each company, and thus only one or two interviewees were selected per company, which is in line with previous studies using expert interviews (e.g. Naik *et al.*, 2020).

Altogether, 19 interviews were conducted using a semi-structured guide (see Appendix 1), which were divided between two researchers, and were audio-recorded and transcribed. The interviews lasted between 45 and 80 min each. The main interview themes were motivations for digital servitization; the phase of traditional servitization; required capabilities for digital servitization, capability development activities, roles and responsibilities; and external companies involved in developing digital servitization. The anonymized companies and interviewees involved in the study are summarized in Table 1.

3.3 Data analysis

The first step was an in-depth analysis of the interview transcripts. This occurred by coding phrases the interviewees mentioned and triangulating these with data from company documentation (Bryman, 2008). We identified the mechanisms required for developing operational capabilities in digital servitization in each manufacturer by investigating their resources, skills, and processes (Wu *et al.*, 2010). To further categorize these descriptions, the

Company (HQ)	Revenue, employees	Main product offerings	Interviewee(s)	Traditional servitization phase
AutomationCo (Europe)	~€3.1 M ~450	Factory automation solutions	Head of service product management Head of service business development	Initial
ConstructionCo (US)	~€36 B ~97,300	Heavy construction machinery	Vice president	Middle
CraneCo (Europe)	~€3 B ~3,000	Heavy lifting equipment	Head of digital experience and business design Digital Portal Manager	Initial
DocumentCo (US)	~€7 B ~24,700	Office IT solutions	Technical service director	Advanced
GlassCo (Europe)	~€170 M ~700	Material processing equipment	Vice president of services	Initial
HeatCo (Europe)	~€300 M ~1,100	Energy transfer equipment	Director, digital services	Middle
ITCo (Japan)	~€27 B ~126,400	Corporate IT solutions	Head of service delivery	Middle
LiftCo (Europe)	~€10 B ~60,000	Lifting equipment	Head of service management	Initial
MechengCo (Europe)	~€3 B ~16,500	Plant automation solutions	Service manager	Advanced
MiningCo (Europe)	~€306 M ~1,400	Mining and tunnelling equipment	Head of services business Director of new service solutions	Initial
OfficeCo (Japan)	~€6.5 B ~41,000	Office printing equipment	Head of services	Advanced
PaintCo (Japan)	~€113 M ~2,000	Surface treatment equipment	Chief executive	Advanced
PaperCo (Europe)	~€3 B ~13,000	Industrial equipment	Vice president of industrial Internet Vice president of service development	Middle
PortCo (Europe)	~€3 B ~11,000	Cargo and load handling equipment	Director of data-driven services	Initial
PrintCo (Europe)	~€2.4 B ~11,300	Industrial printing equipment	Logistics specialist	Middle

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Table 1. Participants and manufacturers who took part in the study

data was analyzed using a three-order coding method (Corley and Gioia, 2004), where these descriptions were compared to identify similarities and differences. This resulted in 14 "mechanism characteristics", derived from direct quotations (1st order codes), nine "micro mechanisms" (2nd order codes), and three "aggregate dimensions", representing capability development mechanisms for digital servitization; that is, Learning, Building, and Acquiring (3rd order codes).

Third-order codes are based on two main factors: (1) exploitation versus exploration of internal or external capabilities, and (2) external cooperation with upstream or downstream actors in the value chain. A *learning* mechanism represents the exploitative and internal development of capabilities to facilitate digital servitization. A *building* mechanism denotes the exploration of capabilities jointly with downstream internal and upstream external actors

to facilitate digital servitization. An *acquiring* mechanism represents the exploration of new capabilities through obtaining and utilizing upstream actors' capabilities to facilitate digital servitization. This categorization and analysis are presented in Figure 2. Representative quotations from the data are presented in Appendix 2 and are aligned to the first-order codes.

Next, to develop an understanding of the combinations of mechanisms that different manufacturers used, we analyzed which manufacturers use which micro mechanisms (Appendix 3). The results were then analyzed using pattern-matching logic (Paiola *et al.*, 2013). We assessed the prevalent mechanisms that the manufacturers used and identified three main combinations: (1) Building and Acquiring, (2) Learning, Building, and Acquiring, and (3) Learning and Building. We then identified a pattern, matching the traditional servitization phase of the manufacturer with the combination of digital servitization capability development mechanisms.

4. Findings

Sections 4.1–4.3 explain each capability development mechanism and offer insights into the micro mechanisms the manufacturers have utilized to undertake digital servitization (marked in italics), answering RQ1. Section 4.4 sets out different combinations of capability development mechanisms, answering RQ2.

4.1 Learning mechanisms

A learning mechanism addresses how manufacturers develop capabilities for digital servitization in-house. Our analysis finds that existing learning capability development mechanisms, such as that proposed by Crossan *et al.* (1999), are applicable for both traditional and digital servitization, with manufacturers undertaking strategic renewal using services

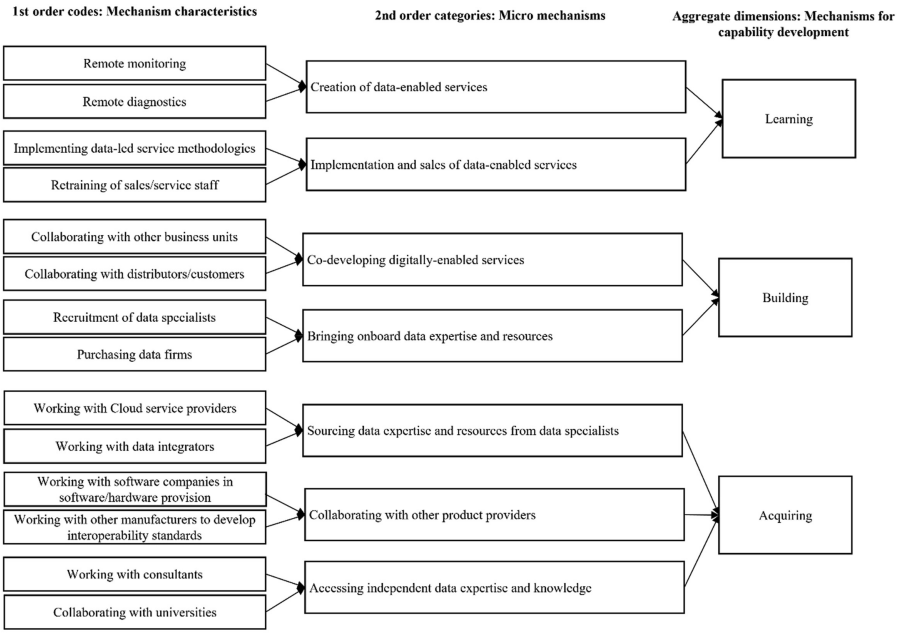


Figure 2.
Data structure

Source(s): Created by authors

for the former and digital technologies for the latter. We present two learning mechanisms that manufacturers use to change and improve their internal processes and existing offerings in light of developments brought about by the introduction of digital technologies: *creation of data-enabled services*, *implementation and sales of data-enabled services*.

Digital technologies play a role in manufacturers' internal process improvement. The companies in our sample often use remote monitoring (Porter and Heppelmann, 2014) to underpin the *creation of data-enabled services*, including logistics, forecasting spare part requirements, and product design (ConstructionCo, PaintCo). While a service offering (e.g. maintenance) may not change in terms of the customer offering, the way it is delivered may change with more remote monitoring and diagnostics (MechengCo, OfficeCo). Building on this technology, predictive maintenance can help the manufacturer's service team to optimally target on-site maintenance in order to improve efficiencies (DocumentCo).

Manufacturers also reported various internal changes for *implementation and sales of data-enabled services*, echoing Valtakoski's (2017) call to reconceptualize manufacturers' offerings as a bundle of knowledge components. For example, PrintCo underwent a major corporate change in its go-to-market strategy when it introduced a subscription-based business model driven by remote monitoring and data analytics. This was not an easy change for PrintCo, as it is a traditional manufacturer that is used to selling capital equipment. However, it is a change that mirrors those that many similar manufacturers made when transitioning from a product to a service focus, but in this case, the application of digital technologies led to the change. The introduction of digital technologies has led to retraining sales/service staff. For example, for pre-sales activities, augmented reality (AR) and virtual reality (VR) enable a manufacturer to demonstrate what a customer installation could look like before it is built, and customers can contribute to its design (PaintCo). If the manufacturer has changed its main customer offerings from product to service, then the salesforce has to move to sell capital equipment to digital-enabled services (PaperCo, PrintCo), although this may not be easy for some salespeople. Changes in service processes are also likely as manufacturers may need fewer field service engineers since more faults can be fixed remotely, and this requires that they (ideally) need to be moved to other roles within the company (OfficeCo).

Some of the manufacturers actively utilize their experience and renew their processes and offering while developing digital servitization (Argote, 2013). This observation aligns with Coreynen *et al.* (2017) view of considering exploitation activities as part of manufacturers' capability development for digital servitization. Our research lends further support to this by showing how manufacturers recognize the possibilities created by digitalization and define ways to integrate data within their current offerings and change their processes and routines, accordingly.

RP1. Manufacturers use exploitative and internal learning mechanisms through the creation, implementation, and sales of data-enabled services to facilitate digital servitization.

4.2 Building mechanisms

A building mechanism concerns how manufacturers develop the required capabilities for digital servitization by bringing them on board from other internal business units, distributors, and customers to extend their capability base. The mechanism aligns with the absorptive capacity view where firms assimilate external knowledge (Cohen and Levinthal, 1990). Our analysis shows that the need to "build' capabilities is greater for digital than traditional servitization since many of the required capabilities, such Big Data analysis, are not routinely available to manufacturers. Thus, this study confirms the need to absorb external knowledge from other actors (Xing *et al.*, 2017). We identify two specific mechanisms that manufacturers applied to build capabilities for digital servitization: *co-developing digitally-enabled services* and *bringing onboard data expertise and resources*.

A clear opportunity garnered from introducing digital technologies is developing new digital services (Raddats *et al.*, 2022; Sjödin *et al.*, 2020). While some manufacturers already had the experience of utilizing customers' information in developing advanced services (Gremyr *et al.*, 2022), sharing operational data from the installed products increased the importance of *co-developing digitally-enabled services* with internal business units, customers, and distributors (DocumentCo). Some interviewees highlighted the need for collaboration between the digitalization center of expertize and other business units within the manufacturer. For example, the interviewee from PortCo explained how the development of a digital solution involved (1) engineers in the digitalization center combining different data sets and analytics, (2) the service design team responsible for creating the service concept, and (3) a functional business unit that owned the customer relationship and could facilitate the concept validation.

Our data revealed several examples of where manufacturers build their capabilities by working with customers and distributors. Some manufacturers seek customer input to validate and test new service concepts (AutomationCo, CraneCo, GlassCo). PrintCo developed a Web portal that enables customers to view consumable stock levels and, using QR codes, order new stock via its ERP system. The offering's development required extensive concept testing with customers to configure a viable solution. Working with both its own and customers' engineers, HeatCo developed a predictive maintenance service offering using historical performance data, engineers' tacit knowledge about equipment failures, and regulatory information for each region (e.g. how long a part should be in service). ConstructionCo works with its distributors to jointly develop holistic maintenance service offerings. This requires the manufacturer to utilize baseline equipment performance data and requires its distributors to provide a more fine-grained analysis of what the data is "saying". Thus, ConstructionCo's capability base has been enhanced so that it can offer its customers a service that it could not on its own.

Digital servitization presents manufacturers with opportunities to build new capabilities that are aligned with services that they may not have been able to offer customers in the past (supporting Sjödin *et al.*, 2020). For example, manufacturers can help customers with business case modeling and demonstrate how value can be captured from new digitally-enabled services since it is difficult for customers to quantify the benefits of digital implementations (HeatCo, MechengCo). Likewise, although a customer may know that it has inefficiencies in vehicle utilization, it may not know their scale and how much they cost (ConstructionCo). If undertaking business case modeling for customers, most value may come from capturing operational data from the customer's entire (multi-vendor) estate (ConstructionCo). However, this raises an issue regarding who "owns" data captured from sensors (Eggert *et al.*, 2022; Wünderlich *et al.*, 2015), and customers may have concerns about data confidentiality and storage, and manufacturers having too much power from having this vast data set (HeatCo).

A requirement for many manufacturers is data skills development, and the company may newly require these skills with the advent of digital servitization. Thus, manufacturers *bring onboard data expertise and resources* by recruiting data specialists and purchasing data firms. The interviewee from ConstructionCo noted the difficulties in hiring these data specialists, with the recruitment of these people being arguably easier for ConstructionCo than it is for its customers, but harder than for companies like Google and Amazon. The interviewee from PrintCo noted that his company had even set up a new data business unit that was responsible for recruiting data specialists, although this may be part of the manufacturer's wider R&D organization (DocumentCo, HeatCo). Several manufacturers in our study are investing in data-focused businesses to strengthen their digital capabilities (DocumentCo, GlassCo, and OfficeCo). Building capabilities through targeted investments is important for digital servitization, more so than it is for traditional servitization. This indicates the gap between a manufacturer's existing capabilities and those that are required

in this field. Finally, some manufacturers have built new capability-development initiatives that recognize the significant challenges that digital servitization presents. For example, PortCo created a specific fund (DigiFund) that reserved corporate money to speed up the development of digital servitization initiatives, including recruiting data specialists.

Previous research shows the importance of building capabilities through working with customers (Sjödin *et al.*, 2020). Our findings show that manufacturers are expanding their data centers of expertise to absorb and integrate two new sources of knowledge: data from sensors, which is then manipulated to create useable information, and that from recruited data specialists and acquired data companies. Thus, it is not sufficient to just rely on learning-based capability development mechanisms (Kamalaldin *et al.*, 2020), and manufacturers need to build at least some level of data analytics in-house (Jansen *et al.*, 2005).

RP2. Manufacturers implement explorative and data-centric building mechanisms with other actors through co-developing digital services and bringing onboard data expertise and resources.

4.3 Acquiring mechanisms

An acquiring mechanism requires a manufacturer to utilize the capabilities of other actors, particularly in the upstream value chain; for example, developed through working with technology providers, other manufacturers, consultants, and universities. Our findings draw on literature about network theory (Håkansson and Snehota, 1995), and reveal that to advance digital servitization, manufacturers rely more on external capabilities than they do for traditional servitization (Ferreira and Lind, 2022). Our findings suggest three acquiring mechanisms: *sourcing data expertise and resources from proprietary data specialists, collaborating with other product providers,* and *accessing independent data expertise and knowledge*.

Our findings confirm that, for digital servitization, manufacturers depend on accessing the capabilities of other companies within their networks (Kohtamäki *et al.*, 2019). Thus, the manufacturers cannot always build these capabilities in-house and instead they are *sourcing data expertise and resources from proprietary data specialists*. Most of the organizations in the study (e.g. PaperCo, PrintCo) use Cloud offerings from providers such as Amazon and Microsoft since these companies have established data center infrastructure and running them is not a core competence for most manufacturers, even for IT providers such as ITCo. Some manufacturers procure the requisite capabilities from software companies; for example, for predictive maintenance and application platform development (AutomationCo, ConstructionCo, MiningCo). In contrast with previous research emphasizing the benefits of relying on actors in the network (e.g. Kohtamäki *et al.*, 2020), our analysis also reveals the challenges. Often, manufacturers had concerns about intellectual property rights when creating new digital solutions with external companies (PortCo, MiningCo). The interviewees also shared their concerns about the risks of committing to only a few suppliers. Some interviewees explained that, since most of these companies are start-ups, there is a risk of losing the relationship with them due to their acquisition by another company or due to corporate failure (CraneCo, GlassCo).

Manufacturers' customers with multi-vendor product estates may ask one vendor to monitor the entire estate (ConstructionCo, PaperCo). Thus, the interoperability between different providers and customers' platforms is a novel requirement that enables autonomous solutions (Jovanovic *et al.*, 2021). To be able to monitor other manufacturers' products, system interoperability is required between remote monitoring technologies. To achieve this holistically, manufacturers in some industries *collaborate with other product providers* to develop common application programming interfaces (APIs) (ConstructionCo, MechengCo, ITCo). Other manufacturers (e.g. GlassCo, MiningCo) intend to purchase Software as a Service (SaaS) solutions from external companies, as developing APIs is not a core capability.

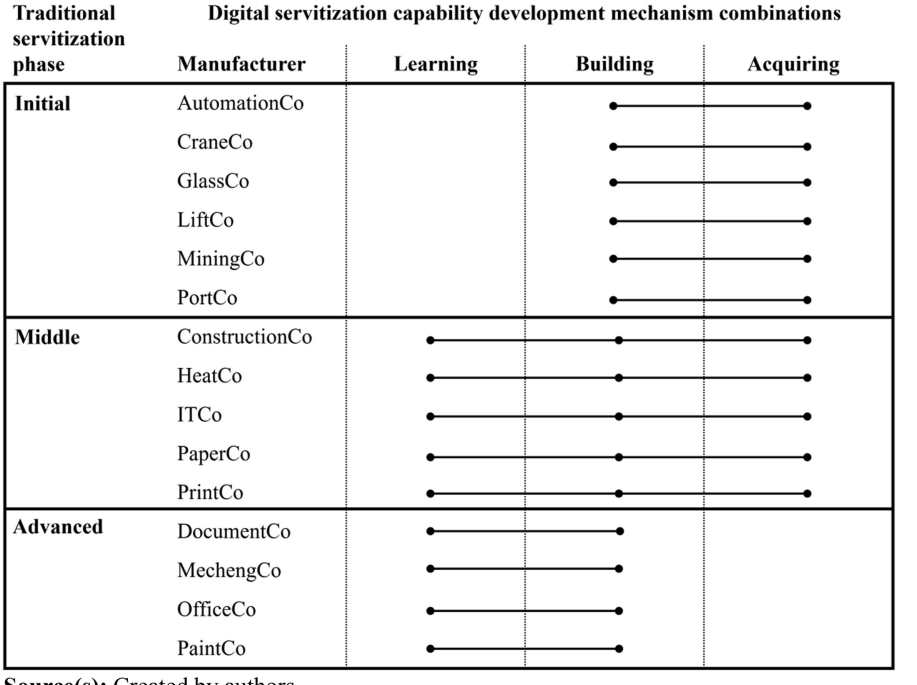
While having common APIs has clear benefits for customers, the benefits are less clear-cut for manufacturers, and there may be a reluctance to develop full open standards in an industry as there are benefits to having proprietary equipment and services (ConstructionCo, PortCo).

Our findings highlighted *accessing independent data expertise and knowledge* as a frequently used mechanism by the manufacturers to develop technological know-how. For example, OfficeCo is working with a university on a 3D printing application for parts that need to be replaced quickly. The fast and continuous changes in digitalization force manufacturers to explore what technology can be applied in their businesses (GlassCo, ConstructionCo). Manufacturers collaborate with universities and can access their knowledge-based capabilities as well as use them as intermediaries to exchange knowledge with other manufacturers (LiftCo). In this example, LiftCo participates in publicly-funded research projects where other manufacturers and research centers collaborate to develop use cases for interoperability standards. Universities, in particular, can provide research about specific applications that may not yet be commercialized (MiningCo, PortCo). Moreover, manufacturers work with consultants to obtain knowledge about different digital technologies; for example, AutomationCo about Cloud solutions and service design.

RP3. To facilitate digital servitization, manufacturers implement explorative and collaborative acquiring mechanisms through sourcing expertise and resources from proprietary data specialists, collaborating with other product providers, and accessing independent data expertise and knowledge.

4.4 Capability development mechanism combinations

To facilitate digital servitization, our study shows that manufacturers use combinations of capability development mechanisms (Figure 3). Manufacturers are positioned on this table



Source(s): Created by authors

Figure 3.
Capability development mechanism combinations by phase of servitization

according to which capability development mechanisms they employ (see Appendix 3). In particular, three combinations emerge when matching each manufacturer's traditional servitization phase with its capability development mechanisms, namely: (1) Building and Acquiring (initial phase), (2) Learning, Building and Acquiring (middle phase), and (3) Learning and Building (advanced phase).

Manufacturers at the initial phase of traditional servitization implement a set of building and acquiring mechanisms to develop the necessary capabilities for digital servitization. These manufacturers have recently started their digital servitization journey, and their development activities have been distributed in different functional units, such as product management, service design, and R&D (e.g. CraneCo, LiftCo). However, the interviewees argue that, considering the increased availability of data expertise, they are rapidly filling this gap by acquiring the capabilities of external data specialists (e.g. GlassCo) and building their capabilities by recruiting data specialists and purchasing data firms (e.g. Mining Co, PortCo).

Manufacturers in the middle phase of traditional servitization have some internal resources in place for digital servitization, and use all three mechanisms to develop it. They have developed more basic data-enabled services through a learning mechanism that utilizes data (e.g. PaperCo). However, with the advent of digital technologies, such as Cloud computing and APIs, they shift their attention towards new actors in their networks (Ferreira and Lind, 2022; Sklyar *et al.*, 2019), and have increasingly sourced data expertise to develop more advanced digital solutions. At the same time, they use building mechanisms to absorb new knowledge (Big Data and data specialists) to develop capabilities, such as data analytics and new service development (e.g. HeatCo).

Manufacturers at the advanced phase of traditional servitization have extensive resources for digital servitization, and mainly use a combination of learning and building mechanisms to enhance the capabilities they already possess. Manufacturers such as DocumentCo have less need to acquire capabilities from external suppliers as they are mostly learned in-house or can be built using other actors' capabilities. This finding lends support to organizational learning and absorptive capacity perspectives that have often studied capability development as the function of experience and prior knowledge (Gremyr *et al.*, 2022; Valtakoski, 2017).

RP4. Manufacturers employ different operational capability development mechanism combinations for digital servitization depending on their traditional servitization phase.

5. Discussion and conclusions

5.1 Theoretical contributions

This study makes three notable contributions. First, as a response to the first research question, our findings reveal three operational capability development mechanisms for digital servitization: learning, building, and acquiring. Our study complements the strategic (dynamic) view on capability development (Chirumalla *et al.*, 2023), which shows how firms respond to the environment (i.e. sensing, seizing, and reconfiguring) to take advantage of new opportunities (Teece, 2007). By comparison, this study characterizes the mechanisms for operational capability development, which has barely been addressed by the extant literature in this context. Furthermore, our findings show the parallel use of these three capability development mechanisms. While the literature on traditional servitization often discusses capability development as a "make or buy" decision (Paiola *et al.*, 2013), our findings reveal that manufacturers have a more sophisticated array of mechanisms. While "make" corresponds to "learn" and "buy" corresponds to "build", an "acquire" mechanism acknowledges that manufacturers will never possess all the capabilities they need for digital servitization in-house, such as those to access various digital technologies, data knowledge, and expertise.

Second, drawing on organizational learning, absorptive capacity, and network perspectives, this paper provides a holistic explanation of capability development mechanisms for digital servitization, a complex phenomenon where different capabilities and processes are intertwined (Favoretto *et al.*, 2022). Thus, we argue that related empirical investigations fall outside the scope of a single theory and require combined theoretical perspectives (Von Krogh *et al.*, 2012), despite most prior research in this field employing single theoretical perspectives (e.g. Gremyr *et al.* (2022) – absorptive capacity). What we see as important in the discussion of capability development for digital servitization is that utilizing one theory may limit how we come to understand manufacturers' experiences. Relying on one theory may offer some explanation of capability development but also limits the discussion to certain internal or external aspects (e.g. Ferreira and Lind, 2022 – acquisition of digital technologies from external suppliers). Combining multiple theoretical perspectives facilities a greater understanding of the complementarity of these mechanisms and how they combine to advance digital servitization.

Third, while responding to the second research question, this paper is the first to specify the need for combinations of operational capability development mechanisms, depending on the phase of traditional servitization. Prior work has paid limited attention to the heterogeneity in different manufacturers about this issue; for example, Behl *et al.* (2023) surveyed companies from a range of sectors but draw conclusions from the whole sample. By contrast, our findings deepen our understanding of the interdependency between traditional servitization and digital servitization (Kohtamäki *et al.*, 2021). While Kohtamäki *et al.* (2021) set out the need for new capabilities to move from traditional to digital servitization, our study proposes the mechanisms by which operational capabilities are developed in different firms. Our findings unfold capability development by going beyond the exploitation versus exploration paradox (Coreynen *et al.*, 2020), and show how manufacturers with different traditional servitization phases apply specific mechanism combinations. Manufacturers who are at the advanced phase of traditional servitization can learn from their experience, transfer it into new knowledge and build new capabilities by integrating their existing resources and abilities with external knowledge. However, manufacturers at the initial and middle phases of traditional servitization depend more on acquired capabilities from different technology and knowledge providers (Ferreira and Lind, 2022). Thus, many manufacturers require a more extensive reconfiguration of their capability development mechanisms, particularly concerning partner collaboration. While traditional servitization literature mainly emphasizes mixed/hybrid capability development with, for example, customers and external service providers (Paiola *et al.*, 2013), digital servitization changes the value chain of these manufacturers so that new upstream partners have a stronger position in a manufacturer's network (Sklyar *et al.*, 2019).

5.2 Managerial implications

Digital technologies, such as the IoT, Cloud computing, and predictive analytics, allow manufacturers to advance servitization through improved products and services, revenue generation, and reduced operational costs. However, manufacturers may struggle with developing operational capabilities to exploit the opportunities that digitalization enables. Our study offers guidance on how manufacturers accomplish this undertaking by setting out several capability mechanisms. For manufacturers that are already advanced with servitization, it should be possible to adapt existing development and sales processes to create new data-enabled services, often with customers' input. Where critical data expertise is lacking in the organization, it can often be brought on board by recruiting data specialists, and even acquiring data-focused companies. For manufacturers that are moderately advanced with servitization, a range of mechanisms to develop the requisite capabilities is

recommended, including in-house development, acquiring key data skills and working with upstream partners, such as technology providers and software companies. For manufacturers at the initial phase of servitization, there should be a stronger focus on bringing onboard new data-focused skills and setting up new partnerships with data-focused technology and knowledge providers.

Managers should be aware of the risks associated with these capability development mechanisms. For example, there may be concerns regarding insufficient in-house knowledge for developing digital capabilities, difficulties in attracting personnel with the required data skills, problems with integrating new data-focused businesses into an existing organizational structure, intellectual property rights concerning customers' data, and potentially "losing" external capabilities through bankruptcy or by the acquisition of external partners by other firms. Despite these risks, by understanding their current phase of traditional servitization, our study should help managers select appropriate capability development mechanisms.

5.3 Limitations and further research

This is an exploratory study with a limited number of manufacturers, which limits the generalizability of the findings. However, we were careful to select a range of large manufacturers from different sectors to improve the transferability of the findings. Moreover, we selected experts who had key roles in digital servitization to develop a deep understanding of the capability development mechanisms. Other organizational functions, including product management, product and service development, and service delivery can also affect or be affected by digital servitization activities. Thus, further research could study internal collaboration between these functions and the challenges in their relationships. Future research might also address the perspectives of small- and medium-sized enterprises and seek to uncover the reasons for choosing certain capability development mechanisms, the links between them, and changes over time.

This study involved collecting data from manufacturers, but it would also have benefited from collecting data from other actors. Manufacturers' capabilities are tightly connected with those of their upstream, and to a lesser extent, downstream partners, intertwined in a process of collaboration for capability development during digital servitization. Thus, multi-actor studies are encouraged to explore these dynamic relationships between different network actors. Future research could also investigate the risks and challenges of collaborating with these partners and the potential tensions related to those collaborations and how they are overcome.

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Appendix 1
Semi-structured interview guide

(1) General questions about the interviewee

(2) Service business development of the company

- What are the key services of your company at the moment?
- How has the current service business been developed?
- What kinds of changes in the industry and/or customers have you noticed during these years?

(3) Digitalization

- What might that expression of "digital servitization" or "digital services" mean for you and your company?
- What technologies are particularly used for services? Why? For which services?
- What kinds of benefits have you experienced when adopting "specific" digital technology systems for delivering services?
- What kinds of challenges has your company faced in developing, organizing, and delivering "specific" digital services?

(4) Developing capabilities for digital servitization within the company

- When and how did the company start developing its current digital technology systems?
- What have been the main drivers and actions at that time?
- What are the main roles and responsibilities in developing, organizing and delivering digital services in your company?
- What types of resources are needed for developing digital services?
- How "particular" capabilities have been developed in your company?

(5) Developing capabilities for digital servitization within the business network

- How much knowledge do you have about what competitors or other companies (e.g. suppliers, technology providers) are doing in this area?
- What are the roles of customers in developing digital services?
- Who are the main collaborators outside your own company to help the company in offering digital services? For what purpose?
- What benefits is the company trying to gain through collaborating with a "particular" partner?
- What are the main capabilities that need to be developed or acquired in collaboration with a "particular" partner?
- How has the company practically proceeded regarding collaboration with a "particular" partner to enable offering digital services? Any examples?

(6) Future plans

- Reflecting on the first question on the initial drivers and actions, what are the current drivers to develop digital technology systems?
- What are the current actions and plans for the near-term future?
- How do you anticipate the future of digital servitization – how far will it proceed within the next 5 years?

Appendix 2

Remote monitoring	It's more interesting for me to capture this data for my internal operational processes because I want to have better product design, I want to have better forecasting, and I want to know where the machines are working in the world so I can distribute my parts close to where they're needed (ConstructionCo)
	The machines can go out with a template of how that machine should operate and what "good" and "bad" looks like. And we remotely monitor against that. So, we can give early advice as to the failure of components, failure of parts, a system not working as it should, so anomalies (PaintCo)
Remote diagnostics	We have got quite a mobile force, but we don't need to be as mobile. We can do remote diagnostics and possibly fault rectification remotely rather than keep having to go to site (MechengCo)
	Now, using mobile phone technology with the video, we actually talk to customers, draw on our screens and actually show them, so we're getting the data from inside the machine and we're able then to talk to customers and actually visualize what the customer has seen as well as visualizing it from our side (OfficeCo)
Implementing data-led service methodologies	So, we started to do some work with the device data on planning which parts were likely to fail and where and when in order to help the supply chain guys change the stocking echelons, so where they stock those parts to get more predictability of failure. So, the supply chain division now knows that they can send a very targeted specific, particular parts kit to that machine for my engineer to do that particular work (DocumentCo)
	What we've really done is to develop a "process bot", which is an expert that sits on their site and looks after the process for them. It's there 24/7 and is absolutely consistent and is really a very good process engineer (PaintCo)
Retraining of sales/service staff	I don't want to get rid of people, I want to utilise people in other areas and other ways to support our customers; we've spent a lot of time training them, we've spent a lot of time developing them, we've got great customer skills (OfficeCo)
	During training programs with our own salespeople, we need to think about what the sales arguments are, what our sales concept is, what we can guarantee, what we cannot guarantee, what is a big risk, and what is a small risk that we can accept. (PaperCo)
Collaborating with other business units	DocumentCo has got this big place in X, which they've had for years, developing innovation in patents related to print technologies. So, the first "port of call' is always to go to the guys at X to say, "What have you got? We've got this customer requirement, what can you design?" So, they typically do that part of it in-house (DocumentCo)
	We have a joint project going on. From the business side there's going to be automation versions and from data-driven team robotic versions and it is complemented with software developers (PortCo)

Table A1.
Representative quotes from interviewees

(*continued*)

Collaborating with distributors/customers	When we bring some additional features or these apps for instance, we want to test this with a certain real-life environment before going to the big launches globally for this offering. So, some customers are actively involved in testing the early development versions of dashboards or reports. For example, they [customers] tell us "Hey can you tweak this one' and "If this was available it would be much better". It is an essential part of development (GlassCo)
	The thing we find very useful is giving the customer an opportunity to interact with something we're designing for them in the virtual world, very early on. It means that any changes that they make can be made much more quickly and more easily (PaintCo)
Recruitment of data specialists	Finding these people is difficult. So, the bigger, more focused you are the better your chances that the talent pool comes to you. And ConstructionCo will find it easier to hire 20 data scientists than our customers. But even ConstructionCo finds it difficult to recruit them compared with Google (ConstructionCo)
	I recruited in MiningCo last year to work as a Cloud Solution Architect and I have been involved with the IoT project that strongly ties with the service business (MiningCo)
Purchasing data firms	In the last year or two probably, we started strategic acquisitions, so niche AI or software companies that are adjuncts to the document process. So, DocumentCo has an "appetite" for acquisition. That's much more the focus now. Niche acquisitions to fill gaps. And then integrate that into the broad portfolio of services (DocumentCo)
	In the really big machines, we bought a company called X, it's a German company. We describe it as a computer with an eye or a computer with a lens. So, that's starting to go into manufacturing processes to identify where something is not looking right, it doesn't look right using AI technology to be able to pick out of the process (OfficeCo)
Working with Cloud service providers	We had a Cloud partner because all the printing machines sent data 24/7, so as soon as they're switched on they sent data and we received all the data from these machines. We know which type of paper a customer is printing on, how much ink are they using, and all this data needs to be stored somewhere. This would not work without an external Cloud service provider (PrintCo)
	So, what happened over the last few years with the advent of the Cloud, you can now purchase computer power without actually having to have a computer yourself. You can go to Amazon, or you can go to Azure. You can effectively "spin up" an environment very quickly and then you are away. So, the market has changed dramatically in that space over the last few years. And it is continuing to accelerate with application consolidation, and provider consolidation (ItCo)

(*continued*)

Table A1.

Working with data integrators	We work with telematics providers, and they have boxes that can be put on any piece of equipment. Your construction equipment, your service trucks, you name it. And you have all of this information available very easily. The platform is mobile-enabled and works on any type of asset (ConstructionCo)
	We use third-party providers for collecting the data from the machine and providing it to us via cloud service. That is the way of ingesting the data from the machines as well as providing the user interfaces, visualization and data storages at the moment (MiningCo)
Working with software companies in software/hardware provision	There is the Management Information System (MIS) side and then there is the internet of Things (IoT)/analytics side. So we are partnered with two or three software companies to offer customers this platform (MechengCo)
	We have a network of companies that helps us in software development. They have been qualified based on past experiments. If we have a new need, we call them. It is a practical relationship, and it works quite well (PortCo)
Working with other manufacturers to develop interoperability standards	The platform that ConstructionCo has needs to be able to accept data or Application Programming Interfaces (APIs) from other manufacturers or other third-party telematics systems that you can just plug in. An API allows a platform to either ingest or export data to other platforms (ConstructionCo)
	There are a number of things that are going to radically alter the services market. One of them is active sensing of devices, and active monitoring - doing it across platforms. There has been some coming together in terms of standards and open Application Programme Interfaces (APIs), which enable you to start to monitor across platforms, so you can now start to monitor multiple platforms through open APIs, so breaking down those (proprietary) barriers (ITCo)
Working with consultants	We use consultants to follow the technology, digitalisation, and continuously think about how we could apply that one. Because there are a lot of things that we do not know that is possible. We want to know what is going on there and what is theoretically possible (GlassCo)
	There is one consulting company that we are working with now to build a kind of new concept for the data processing part, and we need their help for the IoT processing and managing IoT data (MiningCo)
Partnering with universities	There is a group of data scientists that work very closely with the University of X; so there may be something like 20 people there that do analytics for us (ConstructionCo)
	There are different types of research funding, national funding, EU funding, different kinds of programs. We try actively to participate in those to get resources but also to hear and see the latest developments. Because if you are in such kind of programs, there are other big players there as well and it is very important for a company like us to be part of that. (PortCo)

Table A1. **Source(s):** Created by authors

Appendix 3

Table A2. Capability development mechanisms in manufacturers

	Learning		Building		Acquiring		
Manufacturer	Creation of data-enabled services	Implementation and sales of data-enabled services	Co-developing digital services	Bringing onboard data expertise and resources	Sourcing data expertise and resources from proprietary data specialists	Collaborating with other "product" providers	Accessing "independent" data expertise and knowledge
AutomationCo	x		x	x	x		x
ConstructionCo	x	x	x	x	x	x	x
CraneCo	x		x	x	x		x
DocumentCo	x	x	x	x			x
GlassCo			x	x	x	x	x
HeatCo	x		x	x		x	
ITCo	x		x		x	x	
LiftCo			x	x	x	x	x
MechengCo	x	x	x	x		x	
MiningCo			x	x	x	x	x
OfficeCo	x	x	x	x			x
PaintCo	x	x	x				
PaperCo	x	x	x	x	x	x	x
PortCo	x		x	x	x	x	x
PrintCo		x	x	x	x		

Source(s): Created by authors