Unfolding the resource configuration and interaction in digital servitization: an exploratory two-stage research design

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Abstract

Purpose – This article aims to unfold digital servitization by exploring the key resources and resource orchestration (i.e. resource configuration and interaction).

Design/methodology/approach – This article conducted an explorative two-stage research strategy of Chinese servitized manufacturers using a preliminary case study and fuzzy-set Qualitative Comparative Analysis (fsQCA) design. The data collection was conducted between 2016 and 2021.

Findings – This article identifies five key resources – radical, complex technological resources, complementary, specific market resources and digital resources – and their configurations – leveraging market opportunities, leveraging innovation integration and leveraging resource advantages – to facilitate servitization in the digital age. The findings underscore the interaction between technological and market resources as well as the role of digital resources in promoting the servitization journey.

Originality/value – This article contributes to the understanding of servitization in the digital context by examining the key resources and their interactions involved. It builds upon the configurational logic of servitization, expanding the existing framework in the digital context and highlighting the significance of technological and market resource orchestration and interaction in servitization research. Moreover, the paper contributes through its exploratory two-stage approach, going beyond a conceptual understanding of servitization by focusing on both the factors that enable servitization (WHAT) and the configurations that lead to servitization (HOW). Additionally, the article investigates the attributes of resources as lower-level components, addressing the need to explore the micro-level practice of resource realignment. By providing clarity on the configurations of servitization, the paper offers practical guidelines for practitioners on how to effectively utilize resources and benefit from digital servitization.

Keywords Digital servitization, Digital resource, Resource orchestration, Mix-method research, Configurational logic

Paper type Research paper

1. Introduction

In the past decade, manufacturers have increasingly embraced servitization to gain competitive advantages, offering new value propositions through service expansion and extension (Baines *et al.*, 2017; Kamp and Parry, 2017). For example, Geely has demonstrated this trend through the acquisition of LEVC (London Electric Vehicle Company) and transformed itself from a car manufacturer into a transportation service provider, thus standing out from its competitors. Meanwhile, digitalization has accelerated this process by assisting manufacturers in market information collection, technological improvements, digital functions, etc. (Tronvoll *et al.*, 2020). As an example, Hikvision, the world's largest

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provider of security products and solutions, has built an AI Cloud open platform with a video-centric functional IoT architecture to meet specific customer security needs, allowing them to achieve revenue growth of over 28% year-on-year in 2022. Academics and practitioners have labeled the convergence of servitization and digitalization, "digital servitization" (Coreynen *et al.*, 2017; Kohtamäki *et al.*, 2019a, b).

From a practical perspective, companies consistently encounter persistent challenges in their efforts to achieve digital servitization (Chen *et al.*, 2021; Vendrell-Herrero *et al.*, 2024; Warner and Wäger, 2019). On one hand, servitization and digitalization unfold in distinct ways: servitization follows a continuous, evolutionary trajectory, while digitalization is known for its disruptive and discontinuous changes (Baines *et al.*, 2017; Bustinza *et al.*, 2017). The convergence of these two trends may increase uncertainty and lead to a mismatch in evolutionary rhythms, making coordination more challenging (Ardolino *et al.*, 2022; Kohtamäki *et al.*, 2019a, b; Naik *et al.*, 2020). On the other hand, digital servitization may lead companies to fall into the "servitization paradox" or "digitalization paradox" (Eloranta *et al.*, 2021; Gebauer *et al.*, 2021; Tronvoll *et al.*, 2020). Specifically, the service business was unprofitable, leading some manufacturers, such as Siemens, to cancel their service units (Gebauer *et al.*, 2006; Sawhney *et al.*, 2004). In other words, the transition of manufacturers into digital servitization can be likened to an unknown journey, characterized by significant challenges and complexities (Eloranta *et al.*, 2021).

The complexity associated with digital servitization indicates that it may depend on a variety of factors, with a configurational approach being a suitable method to capture the causal complexity (Forkmann *et al.*, 2017; Kohtamäki *et al.*, 2019a, b; Lexutt, 2020; Salonen *et al.*, 2021; Sjödin *et al.*, 2019; Yan *et al.*, 2021). However, on the one hand, the existing literature on digital servitization primarily focuses on case studies, emphasizing holistic and conceptual explorations (Eloranta *et al.*, 2021; Rabetino *et al.*, 2021), with limited exploration of causal explanations (Baines *et al.*, 2017; Salonen *et al.*, 2021). Indeed, market forces and technological development interact in servitization (Matthyssens and Vandenbempt, 2008). While the importance of market resources, especially relational factors, is well-documented (Kamalaldin *et al.*, 2020; Raddats *et al.*, 2017; Sjödin *et al.*, 2019), there is a research gap in understanding the impact of technological resources like R&D and production assets on service offerings and transitions in manufacturing companies (Hwang and Hsu, 2019; Matthyssens and Vandenbempt, 2008; Opazo-Basáez *et al.*, 2022). Meanwhile, for manufacturers, the resource attributes determine their capabilities and business model scenarios in servitization (Niu *et al.*, 2021), while existing studies have not delved deeply into the detailed characteristics of key resources (Coreynen *et al.*, 2017; Huikkola *et al.*, 2020), indicating a need for further exploration of the "what" factors.

On the other hand, in the context of digital servitization, digital resources exhibit distinct attributes such as shareability, reusability, self-reproducibility and reproducibility (Amit and Han, 2017; Henfridsson *et al.*, 2018; Levitin and Redman, 1998; Mamonov and Triantoro, 2018; Zeng and Glaister, 2018). These digital resources enhance interaction between the front and back ends, as well as facilitate the integration of technological and market resources, thereby fostering the potential for resource orchestration and interactions (Amit and Han, 2017; Henfridsson *et al.*, 2018; Huikkola *et al.*, 2016; Matthyssens and Vandenbempt, 2008; Opazo-Basáez *et al.*, 2022). However, current research maintains a tendency to consider technology and the market as distinct entities in servitization, highlighting the importance of further exploration into the role of digital resources by addressing "how" questions.

This study complements earlier reviews by focusing on mapping the key resources and their interactions from a two-stage configurational perspective, excelling at "looking inside the black box" (Eloranta *et al.*, 2021; Rönnberg Sjödin *et al.*, 2016; Sirmon *et al.*, 2007). The explorative two-stage research strategy, including a preliminary case study and a fuzzy-set Qualitative Comparative Analysis (fsQCA) to answer the following research questions respectively:

RQ1. What are the key resources required for manufacturers to implement servitization in the digital age?

RQ2. What are the configurations with different resources orchestrated for implementing servitization, and how could digital resources play a role in servitization?

Regarding these research questions, our research makes contributions in three key areas. First, we utilize the configurational logic to elaborate on different approaches to digital servitization, extending the traditional framework of Matthyssens and Vandenbempt (2008) to the digital context. This emphasizes the significance of technological and market resource orchestration and interactions in servitization research. Second, our investigation delves into the micro-practices of resource realignment within the servitization literature by analyzing the attributes of resources as lower-level components, in alignment with the call made by Huikkola *et al.* (2020). Moreover, we present an exploratory two-stage research approach for digital servitization, providing a comprehensive understanding of the enabling factors (WHAT) and the configurations (HOW) that drive servitization in the digital era. This contributes to the deconstruction of this complex phenomenon and its causal complexity (Forkmann *et al.*, 2017; Kohtamäki *et al.*, 2019a, b; Lexutt, 2020; Salonen *et al.*, 2021; Sjödin *et al.*, 2019; Yan *et al.*, 2021). This paper also sheds light on how innovative resources interact with other resources to drive servitization, bridging the gap in research between servitization and innovation literature (Hwang and Hsu, 2019; Matthyssens and Vandenbempt, 2008; Opazo-Basáez *et al.*, 2022).

2. Theoretical background

2.1 Servitization in the digital context

According to Vandermerwe and Rada (1988), servitization begins with the provision of products and then gradually unfolds by incorporating additional layers of complementary services. In the digital age, by obtaining valuable information through digital technology, manufacturers can promote their service offerings for better customer value (Favoretto *et al.*, 2022; Tronvoll *et al.*, 2020). Academics and practitioners have lately developed the term "digital servitization" to characterize the convergence of servitization and digitalization (Coreynen *et al.*, 2017; Kohtamäki *et al.*, 2019a, b; Liu *et al.*, 2024). Digital servitization refers to the transformation of traditional products and add-on services into smart solutions or product-service systems (Kohtamäki *et al.*, 2020). These systems are characterized by their connectivity, monitoring, control, optimization and autonomy capabilities (Kohtamäki *et al.*, 2020; Lenka *et al.*, 2017; Porter and Heppelmann, 2014).

The logic of value creation undergoes fundamental changes in digital servitization. Digital servitization entails creating a new servitized business model by implementing digital resources for new value creation (Paschou *et al.*, 2020; Vendrell-Herrero *et al.*, 2024). A significant challenge in this domain is the accelerated pace of change and increased complexity and unpredictability brought about by digital resources in service infusion (Chen *et al.*, 2022; Vargo *et al.*, 2024; Warner and Wäger, 2019). This contrasts with the nature of digitalization, characterized by disruptive and discontinuous changes, while servitization typically exhibits a more continuous, evolutionary path (Baines *et al.*, 2017; Bustinza *et al.*, 2017). This transition may involve the development of fresh value propositions and the acquisition of novel organizational resources and capabilities. Consequently, these new elements may diverge from the existing models and structures (Paiola and Gebauer, 2020; Warner and Wäger, 2019).

Digital resources have the functions of enabling and enhancing (Sjödin *et al.*, 2020), while unfolding digital servitization offers critical insights into this complex phenomenon, as highlighted in recent calls for further research (Rabetino *et al.*, 2021; Tronvoll *et al.*, 2020; Vendrell-Herrero *et al.*, 2024). Recent academic efforts have provided macro-level, holistic studies on the genesis of digital servitization, constructing conceptual frameworks primarily centered on digital resources. This includes categorizing applications within digital platforms

(Kapoor *et al.*, 2021) and classifying types of servitization derived from these platforms (Liu *et al.*, 2024; Tian *et al.*, 2022), primarily focusing on the outcomes engendered by digital resources. Moreover, some scholars have explored the transformation mechanisms of servitization, underscoring comparisons of outcomes pre- and post-transformation (Tronvoll *et al.*, 2020), as well as examining the various stages (Baines *et al.*, 2020) and pathways involved (Coreynen *et al.*, 2017; Lerch *et al.*, 2024). However, these comprehensive studies have left certain aspects underexplored. For example, Baines *et al.* (2020) note that the specific sub-mechanisms of digital servitization may vary depending on the stage of implementation reached by manufacturers. Coreynen *et al.* (2017) propose three pathways, each necessitating unique key resources comprising multiple critical elements.

A pivotal question remains: how can manufacturers leverage existing resources to generate value through digital resources? Unfolding the intricacies of digital servitization requires close investigation of the resource interaction mechanisms, an area that merits further scholarly attention (Baines *et al.*, 2020; Huikkola *et al.*, 2020).

2.2 The resources-based view in servitization

2.2.1 Resource-based views for digital servitization. Considering the complicated nature of digital servitization for manufacturers (Favoretto *et al.*, 2022), investigating the underlying principles is vital. Academic discourse often emphasizes strategic capability development mechanisms, delineating how manufacturers can adeptly transition to harness opportunities presented by burgeoning digital resources (Momeni *et al.*, 2023). Traditionally, capabilities have been perceived as tacit knowledge. However, the advent of digitalization compounds the complexity of knowledge accumulation (Amit and Han, 2017; Sjödin *et al.*, 2019), revealing research gaps that warrant further exploration. Alternatively, by studying the lower-level components, like specific resources, firms can gain valuable insight into the “black box” and effectively facilitate the process of digital servitization, leading to a smoother transition (Coreynen *et al.*, 2020; Kohtamäki *et al.*, 2019a, b; Sirmon *et al.*, 2007).

The rationale behind this investigation is based on the understanding that digital servitization fundamentally transforms the business model of manufacturing firms (Chen *et al.*, 2021). Servitization prompts an update and reconstruction of the organizational resource base (Huikkola *et al.*, 2016; Khan *et al.*, 2024), a process that digital resources can not only accelerate but potentially transform (Coreynen *et al.*, 2017). Although scholars acknowledge the significance of digital resources (Amit and Han, 2017; Favoretto *et al.*, 2022; Opresnik and Taisch, 2015), the orchestration and interaction of digital resources and heterogeneous resources can further unfold the underlying implications of digital servitization. Accordingly, our research focuses on how manufacturers can effectively complement and leverage their resources for digital servitization. In the ensuing sub-sections, we will delve into key resources, further elaborating on the framework established by Matthyssens and Vandenbempt (2008). This study aims to unfold the various ways manufacturers employ their digital servitization and to identify distinguishing elements among these approaches.

2.2.2 The role of technological and market resources. Matthyssens and Vandenbempt (2008) proposed a model that highlights the interplay between market forces and technological development. This model delineates two critical steps in the interaction between technological application integration and business process integration. First, the integration of technological applications focuses on enhancing technical solutions, such as system selling. Technological expertise and production experience lay the groundwork for developing these solutions, underscoring the significance of technological resources (Eloranta and Turunen, 2015). Yet, it’s important to note that technological resources can vary among servitized firms (Raddats and Kowalkowski, 2014). Manufacturers of complex products are better positioned to offer services due to the high knowledge barriers created by technological intricacy. These barriers often lead customers to outsource their service needs to mitigate operating costs (Raddats *et al.*, 2016). Various industries exhibit distinct technology life cycles, indicating that the pace of new technology development may vary among them. This technological uncertainty provides more opportunities for customers to engage in the research and development stage (Antikainen *et al.*, 2010).

Moreover, drawing on the insights of Matthyssens and Vandenbempt (2008), business process integration focuses on process management based on the customer value chain, to help customers minimize their operating costs. Integration with customers enhances opportunities to gain valuable customer knowledge (Gebauer *et al.*, 2011). The extent and frequency of firm–customer interactions are indicative of the nature of the relationship between partners. Manufacturers foster complementary relationships among clients and suppliers to enhance external alignment, optimizing mutual benefits (Ferreira *et al.*, 2013; Niu and Jiang, 2024; Spring and Araujo, 2013). Meanwhile, as manufacturers develop more integrated processes with customers, they consequently build more specialized resources, reinforcing the interdependency and value of these partnerships (Dyer *et al.*, 2018; Dyer and Singh, 1998).

2.2.3 Further explanation of digital resources. Digital servitization refers to the process of converting conventional products and additional services into intelligent solutions or product-service systems (Kohtamäki *et al.*, 2020). These systems are distinguished by their connectivity, monitoring, control, optimization and autonomy capabilities (Kohtamäki *et al.*, 2020; Lenka *et al.*, 2017; Porter and Heppelmann, 2014). In addition to technological and relational resources, digital resources are introduced to emphasize the configuration between various constructs and contexts at the micro-level. Digital resources, like the Internet of Things and digital platforms, lay a robust foundation for digital services through proactive monitoring, maintenance and value creation (Kohtamäki *et al.*, 2019a, b). These digital resources significantly boost production efficiency, resource allocation and decision-making precision, thereby setting the stage for high-quality, customized solutions (Gebauer *et al.*, 2021; Tronvoll *et al.*, 2020). In the context of digital resources, a considerable volume of valuable data are accrued during the servitization process (Favoretto *et al.*, 2022; Opresnik and Taisch, 2015). These data are instrumental in enhancing products and services, facilitating a seamless integration of the two (Cenamor *et al.*, 2017; Vargo *et al.*, 2024; Vendrell-Herrero *et al.*, 2024). Soto-Acosta and Meroño-Cerdan (2008) highlight that while digital resources are crucial strategic assets for manufacturers, their most effective use is in creating barriers to imitation, thereby offering a competitive edge.

The attributes of digital resources and their value-creation mechanisms have changed, compared to traditional resources (Amit and Han, 2017). We further distinguish digital resources and technological resources based on their characteristics (Table 1):

2.2.4 The key resources and their interaction. Contemporary research in the realm of digital servitization has largely focused on holistic and conceptual approaches. Chirumalla *et al.* (2023) and Struyf *et al.* (2021) have developed comprehensive conceptual frameworks that span various levels, including network, organizational and individual dimensions. These frameworks have highlighted pivotal elements, such as dynamic capabilities, which are

Table 1. The differences between technological and digital resources

	Technological resource	Digital resource
Definitions	Production equipment and hardware, research and development equipment and projects, products and other related resources	Digital means embedded in original products or technologies that enable the servitization process or can constitute (part of) services
Characteristics	Exclusivity, scarcity, reduced return on repeated use, and non-renewability	Shareable, reusable, self-reproducible and reproducible
Source	Existing resources	External acquisition

Source(s): Adapted from Mamonov and Triantoro(2018) and Zahra *et al.* (2003)

essential for understanding the concept of digital servitization. However, these studies have not explicitly addressed the effective exploitation of these crucial factors. Building upon this, Matthyssens and Vandenbempt's core integration process involves the interaction mechanisms of technological push and market pull, highlighting the criticality of both technological and market resources. Yet, the specific functions and impacts of these resources in the context of digital servitization warrant further investigation. Thus, utilizing the framework proposed by Matthyssens and Vandenbempt (2008), we aim to explore the interaction of specific key resources in digital servitization.

2.2.5 The importance of identifying key resources. The experience and knowledge accumulated by manufacturers through R&D and production are important in the technological integration process, highlighting the role of technological resources; while business process integration focuses on developing solutions related to customer processes, including resource integration and process management on customer value chain (Matthyssens and Vandenbempt, 2008). This necessitates that manufacturers deeply understand their customers and sustain robust cooperation with both customers and suppliers. A manufacturer's market position and its strong relationships with partners are foundational to successfully implementing servitization (Windahl and Lakemond, 2006). Thus, market resources based on relationship development constitute another important factor in the formation of servitization. In the digital era, the mechanisms of value creation have been transformed by digital resources (Amit and Han, 2017), suggesting that traditional heterogeneous resources might not suffice for a competitive edge in digital servitization. For example, the distinction between "resources for producing high-quality products" and "resources for co-creating value with customers" has become increasingly important. Therefore, it is crucial to identify the key resources that consider both technology and market factors.

2.2.6 The importance of resource interaction. Servitization encompasses both the integration and configuration of resources, highlighting the importance of understanding how resources interact, as well as identifying key resources themselves (Huikkola *et al.*, 2016; Matthyssens and Vandenbempt, 2008). Matthyssens and Vandenbempt (2008) observe that the initial key integration processes are typically determined by advantageous resources. However, they also suggest that additional processes may emerge during transformation, indicating the possibility of multiple concurrent processes that contribute to digital servitization. Digital servitization is becoming increasingly varied and interdependent, facilitating interconnections across back-end, front-end and both-end operations (Coreynen *et al.*, 2017). The introduction of digital resources can potentially alter existing mechanisms of resource integration and even generate new ones (Amit and Han, 2017). Therefore, exploring the critical resources and their configurations is worth noting for both academics and practitioners.

2.3 A configuration logic based on resource orchestration theory

2.3.1 A configurational logic. Digital servitization, as a multifaceted phenomenon, likely hinges on a constellation of interrelated factors. Adopting a configurational approach is an effective method to unfold this causal complexity (Forkmann *et al.*, 2017; Kohtamäki *et al.*, 2019a, b; Lexutt, 2020; Li *et al.*, 2022b; Salonen *et al.*, 2021; Sjödin *et al.*, 2019; Yan *et al.*, 2021). Manufacturers transformed to servitization by resource integration and configuration (Huikkola *et al.*, 2016; Matthyssens and Vandenbempt, 2008). From a theoretical standpoint, current studies that adopt a resource-based view primarily offer exploratory and descriptive insights, indicating a need for a deeper understanding of how resources are configured. This gap points to the necessity for more comprehensive research in the area of resource configuration within the context of digital servitization (Rönnberg Sjödin *et al.*, 2016).

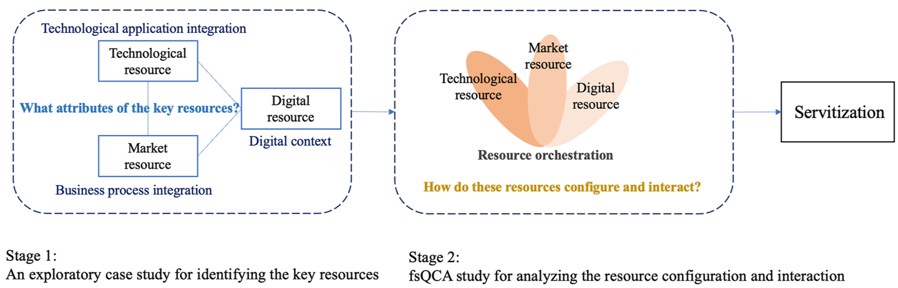
The resource orchestration theory explains value creation by firms through resource construction, resource bundling, and resource leveraging (Cao *et al.*, 2022; Sirmon *et al.*, 2011), providing a theoretical lens for understanding resource combinations. This research incorporated resource orchestration as a theoretical perspective and analytical framework. On the one hand, manufacturers transitioned to servitization through resource integration and configuration (Huikkola *et al.*, 2016; Matthyssens and Vandenbempt, 2008). The focus was on the synergistic effects of resources rather than the isolated impact of individual resources. On the other hand, digital resources possess attributes such as shareability, replicability, self-regeneration and reproducibility) that can enhance resource recombination (Henfridsson *et al.*, 2018; Levitin and Redman, 1998; Mamonov and Triantoro, 2018; Zeng and Glaister, 2018). However, a critique of the resource-based theory is its inadequate explanation of how resources can be combined and configured, especially in terms of elucidating these combinative effects (Gruber *et al.*, 2010). Therefore, resource orchestration theory, grounded in the resource-based view, is chosen to surpass this theoretical perspective and pinpoint pertinent configurations that enhance servitization. Moreover, the analysis framework of this study utilizes the "search – configuration" two-stage framework, referring to the two main processes of resource orchestration: search and configuration (Helfat, 2007; Sirmon *et al.*, 2011). Specifically, search processes include identifying the core assets for developing a business model, while the configuration process includes coordinating those resources to create value and innovate. In the subsequent sections, a detailed discussion will be elaborated.

3. Research design: two-stage research strategy

Digital servitization literature has mainly focused on conceptual exploration, as evidenced by existing studies (Rabetino *et al.*, 2021; Tronvoll *et al.*, 2020). However, two significant gaps persist. First, there's an insufficient focus on the resource configurations, particularly the coordination among resources (Baines *et al.*, 2020; Huikkola *et al.*, 2020). Second, further investigation is needed to explore the functions and nature of digital resources (Coreynen *et al.*, 2017).

To address these gaps, this study aims to scrutinize the essential resources and their orchestration methods in servitization. We will utilize a configurational logic approach using fsQCA, in conjunction with explorative case analysis, to identify key resources and their orchestration based on the framework proposed by Matthyssens and Vandenbempt (2008). To obtain comprehensive results, qualitative and quantitative data were collected. The description of the qualitative data collection and case analysis process is first outlined, along with the key insights obtained. Then, the quantitative fsQCA phase is explained in detail. The theoretical model based on Matthyssens and Vandenbempt (2008) is presented in Figure 1.

Stage 1: What are the key resources in servitization?



Source(s): Adapted from Matthyssens and Vandenbempt (2008) and created by authors

Figure 1. Framework of an exploratory two-stage research design for servitization

3.1 Sample selection and qualitative data collection

The initial phase included an exploratory qualitative study to understand various resources and their interactions, providing guidance for decision-making in the subsequent fsQCA phase (Schneider and Wagemann, 2012). To ensure the robustness of our findings, the exploratory stage was meticulously designed to encompass considerations of construct validity, internal and external validity, and reliability (Eisenhardt, 1989; Gibbert *et al.*, 2008; Meredith, 1998).

3.1.1 Sample selection. Following the theoretical sampling approach of Eisenhardt (1989), cases were selected based on criteria such as competitive advantages achievable through servitization strategies and representative service offerings manufacturing industries were prioritized for their market-oriented business model innovation, expertise in production and R&D and continuous customer relationships (Kalwani and Narayandas, 1995), making them ideal for studying the interaction of technology and market resources in servitization. Additionally, digital resources like digital platforms were considered in line with the research context.

3.1.2 Qualitative data collection. To meet the sampling criteria, data were collected from four case companies suitable for multi-case analysis (Eisenhardt *et al.*, 2020a). These companies all demonstrated service revenue growth during the observation period: Firm A saw a 253% increase in service-based revenue in 2021, service revenue surpassed machinery revenue for Firm B in 2016, Firm C has been the largest industrial service provider in China since 2010, and the solution revenue of Firm D outperforms competitors. These companies are considered typical cases for theory building, showcasing competitive advantages through servitization.

Qualitative data collection, starting in March 2016 and ending in September 2022, involved secondary data and in-depth semi-structured interviews. Triangulation techniques were applied, utilizing various data collection methods like primary and secondary data, participatory observation and informal communication channels (Eisenhardt *et al.*, 2020a). Internal and external information from the four cases, including annual reports and media coverage, was analyzed to summarize the servitization development process and extract relevant information on critical resources and their impact. Initial interviews with senior executives focused on understanding the companies' development processes, especially regarding technology and market advantages in servitization. Firm D's information primarily came from online business presentations due to distance and pandemic restrictions.

We conducted interviews with directors in the Technical, Marketing, Service and Digital departments, with each interview involving at least three employees. A total of 25 semi-structured interviews were recorded electronically, lasting on average two hours each (See Table 2).

Our exploratory case study is grounded in the existing literature while further uncovering the characteristics of key resources. It serves as a valuable complement to and refinement of the existing theoretical framework (Eisenhardt, 1989). Table 3 lists the construct descriptions.

3.2 Preliminary case findings

This paper employs inductive coding techniques, including open, axial and selective coding, to identify key resources (Corbin and Strauss, 1988; Strauss, 1987). Characteristics of specific resource attributes were logged during data collection. Initially, two authors independently coded documents, referring to the research framework constructed in the paper. The initial notions that only showed up less than three times were moved, and the main ideas were extracted (See Figure 2). Second, data comparison and coding continued until a solid understanding of sub-groups was reached among four authors and could no longer extract additional information from the data (Glaser and Strauss, 2017; Suddaby, 2006). The data analysis strategy followed Gioia *et al.* (2010), and Yin (2012) for construct validity and reliability.

Table 2. Overview of case manufacturers

	Firm A	Firm B	Firm C	Firm D
Industry	Motor industry	Air separation equipment	Instrument manufacturing and industrial automation	Wind turbine manufacturing
Service offerings	Travel services, mobile APP, customer data analysis services etc.	Air services, solutions, Engineering Procurement Construction (EPC), etc.	Data services, digital transformation services, industrial APP, etc.	Operational services, technical solutions, platform-based management, investment solutions, etc.
Ages	30+	60+	30+	20+
Location	Hangzhou, China	Hangzhou, China	Hangzhou, China	Beijing, China
Employees	10,000+	5,000+	3,000+	9,000+
Key informants	Manager of Information Technology Department, Sales Department, and Strategic Research Center	General Manager, Manager of Service Department, Technical Department, Information Technology Department, Marketing Department, Human Resources Department, and Strategic Research Center	Manager of Service Department, Information Technology Department, Marketing Department, and Strategic Research Center	Company executives, service department managers, digital technology department managers, strategic department supervisors, marketing department managers and general manager

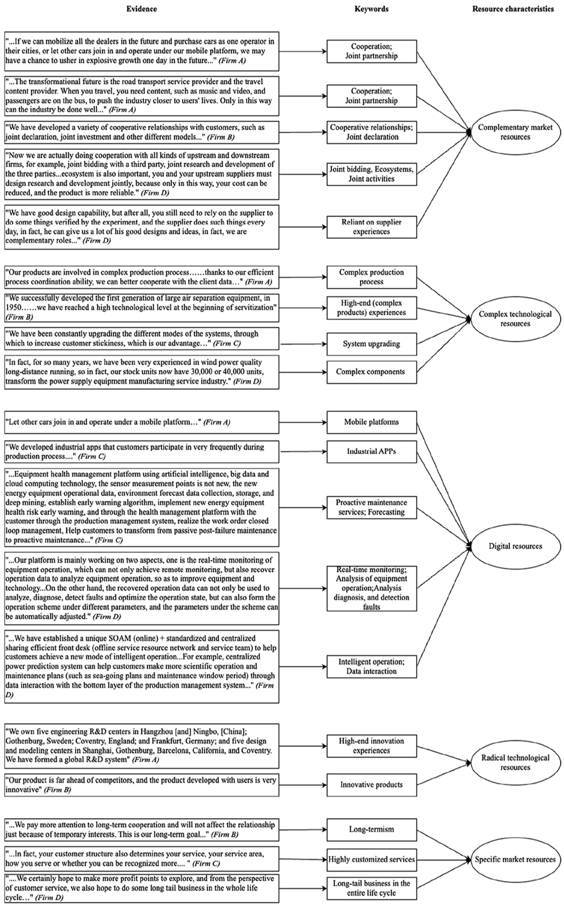
Note(s): We conducted interviews with directors in the Technical, Marketing, Service and Digital departments to understand their roles in the servitization process. Subsequent interviews with service project managers and digital technology engineers provided further insights. We compared and validated case evidence, addressing any data inconsistencies, with each interview involving at least three employees. A total of 25 semi-structured interviews were recorded electronically, lasting on average two hours each. The final coding results were shared with interviewees for data reliability, and an overview of the four sample companies is detailed in Table 2
Source(s): Annual reports and interviews of case manufacturers

Table 3. Constructs and descriptions

Construct	Dimension	Definition and measurement
Key resources in servitization	Technological resources	Production equipment, R&D patents, products etc.
	Market resources	Relationship type, length of relationships, competitors and suppliers
	Digital resources	Monitoring, control, optimization, and intelligence functions and other related digital technologies

Note(s): Technological resources refer to Zahra *et al*. (2003), Market resources refer to the relationships between suppliers and customers (Windahl and Lakemond, 2006); digital resources refers to Kohtamäki *et al*. (2019), including resources related to monitoring, control, optimization, and intelligence functions
Source(s): Adapt from Zahra *et al*. (2003), Windahl and Lakemond (2006), Kohtamäki *et al*. (2019)

Based on the above analysis strategies, a data structure comprising first-order coding, second-order coding and aggregation constructs was derived from key resource attributes for achieving servitization. Figure 2 outlines five types of resource attributes influencing



Note(s): At this stage, key outcomes involved: (1) identifying core resources and (2) gathering qualitative knowledge for fsQCA calibration. We suggest that different combinations of resources can drive servitization in the digital realm. Servitization, a complex process influenced by various factors (Forkmann et al., 2017; Lexutt, 2020) , requires integrating technical and customer processes. Technological and market resources lay the groundwork for integration mechanisms, while digital resources offer a new context

Complexity is predominant in technological resources, encompassing production processes, high-end experiences, system upgrades, and complex components. Radical technological resources feature innovation and innovative products. Specific market resources impact servitization through long-term relationships, customization, and long-tail business. Complementary market resources involve cooperation, partnerships, ecosystem building, and supplier reliance. Digital resources include digital platforms, industrial apps, maintenance services, monitoring, and data interactions

Source(s): Created by authors

Figure 2. Codings and case findings

servitization: radical technological, complex technological, complementary market, specific market and digital resources. For more details, refer to Figure 2 due to space limitations.

Stage 2: How does the resource orchestrate in servitization?

The two-stage exploratory research design aims to progress from the initial qualitative phase of the study by identifying a contextually appropriate quantitative instrument for rigorous testing (Ivankova and Plano Clark, 2018). Building on the Stage 1 findings on five key resources (radical technological, complex technological, complementary market, specific market and digital resources), measurements were conducted using established scales to assess their levels across different enterprises (refer to Table 4).

In this stage, we used the fsQCA configurational approach that combines inductive and deductive elements (Greckhamer, 2016). The deductive approach in QCA was used to analyze the identified key attributes of resources from Stage 1. Additionally, an inductive approach in QCA was applied to examine the orchestration of these resources. This methodology included firms of different sizes and industries to enhance result generalizability.

3.3 Sample selection and quantitative data collection

3.3.1 Sample selection. As Ragin (2014) mentioned, small- and medium-sized samples in fsQCA require theoretical support for each case. Study 2 selected cases from the Hidden Champion Research Center, Service Research Center and Enterprise Innovation Research Center, with long-standing collaborations with four authors to ensure case intimacy and interview availability. Specifically, cases were preliminarily chosen from the firm lists of the research institutions mentioned, focusing on manufacturing industries aligned with the research objective. Additionally, the verification process examined if the business composition included typical servitization manifestations outlined in the official document "Guidance on Further Promoting the Development of Manufacturing Servitization," such as industrial design services and customized services.

In addition to ensuring the representativeness of the cases, firms surveyed in Shandong and Zhejiang Provinces in China were specifically chosen to enhance sample diversity. In 2016, China's Ministry of Industry and Information Technology (MIIT) initiated a manufacturing servitization program. MIIT annually releases a list of servitized demonstration cities, with Zhejiang and Shandong having the highest numbers. The two provinces exhibit differences in industrial digitalization, with Zhejiang leading in digitalization according to the Cyberspace Administration of China, while Shandong ranks seventh. This selection strategy aimed to maximize sample coverage, ensuring the reliability and validity of the study while encompassing firms of various sizes, ages and industries to prevent common method biases.

3.3.2 Data collection. The surveys were conducted from March 2020 to September 2022. Questionnaires were distributed to 97 manufacturers, with 82 responding. Twelve companies were excluded due to poor quality, which included questionnaires completed in under 3 min, incomplete responses and contradictions in answers. Seventy valid questionnaires were obtained, with thirty of them from listed companies. Respondents were predominantly male managers (85.7%) with an average age of 45.2 years. Educational backgrounds varied, with 18 respondents holding bachelor's degrees or higher and 15 having technical university degrees. Furthermore, 87.5% of the questionnaires were completed by the company CEO. Table 5 outlines the data collection methods and techniques for fsQCA.

3.4 Measurement and calibration

3.4.1 Measurement. Five key resources – radical technological resources, complex technological resources, complementary market resources, specific market resources and digital resources – were identified in the case analysis. The measurement of five attributes was based on existing literature, with survey items rated on a seven-point Likert scale (1 = fully disagree, 7 = fully agree) (Table 6). All variables exhibited reliable Cronbach's alpha values ($\alpha > 0.7$). Data distribution characteristics and correlations are suggested in Appendixes 1-3.

3.4.2 Validity and reliability for small-sample QCA. QCA offers advantages for small- and medium-sized analyses (Ragin and Fiss, 2008), with a focus on ensuring data reliability and validity (Du and Kim, 2021). Factor analysis typically requires a large-sample size (Hair *et al.*,

Table 4. Linked results for the two-stage research design

Exploratory case findings	Key constructs and definitions	Survey instrument (adapted from established survey items)
"We have good design capability, but after all, you still need to rely on the supplier to do some things verified by the experiment, and the supplier does such things every day. In fact. he can give us a lot of his good designs and ideas. In fact. We are complementary roles.. . . . . ." *Findings*: Some cases (Firm A, B, and D) highlighted the importance placed on complementary resources, such as collaborative partnerships, ecosystems, and joint research and development among partners	Referring to *complementary market resources* (Iyer *et al*., 2019) *Definition:* Market complementary resource refers to the pooling of resources by partners as a collective, wherein the resources are complementary in nature (Iyer *et al*., 2019)	• To what extent do they rely on each other's resources to achieve their goals and fulfill their responsibilities? • To what extent have the resources provided by your company and key partners been significant in achieving growth? • To what extent are they bringing into the supply chain very valuable to each other? • What is the degree of differentiation with key supply chain partners' resources/ capabilities?
"We pay more attention to long-term cooperation and will not affect the relationship just because of temporary interests. This is our long-term goal . . . " *Findings:* Some cases (Firm B, C and D) value the importance of specific resources for long-term cooperation, long-tail business models and the entire life-cycle in the market	Referring to *specific market resources* (Iyer *et al*., 2019) *Definition:* Market specific resources idiosyncratic to a partnership and are inimitable in nature (Iyer *et al*., 2019)	• To what extent have resources been invested to understand the way they do things? • To what extent have they spent a lot of time getting to know their end customers? • To what extent have they spent time thoroughly understanding the products? • To what extent has the money been invested in people who are committed to our business
"Our products are involved in complex production process . . .. thanks to our efficient process coordination ability. We can better cooperate with the client data." *Findings:* In some cases (Firm A, B, C and D), Firm A suggest certain production processes involve more intricate integration and collaboration among components	Referring to *complex technological resources* (Caniato and Größler, 2015) *Definition:* Defined as the combination of materials and components, the number of levels present in the bill of materials, or the variety of technologies integrated within a product (Caniato and Größler, 2015)	• What is the degree of modularity, and complexity of the main products? Complexity of the production factors, and complexity of the production steps?
"*Our product is far ahead of competitors, and the product developed with users is very innovative . . . "* *Findings:* Some cases (Firm A and B) have advantages in technological innovation resources, as they exhibit rapid product updates and replacements	Referring to *radical technological resources* (Chandy and Tellis, 2000) *Definition:* integrating a significantly distinct core technology and offers considerably greater customer benefits when compared to previous industry products (Chandy and Tellis, 2000).	• To what extent have they made technological innovation in most of their products? • To what extent is different from competitors? • To what extent are their technology new to the industry? • To what extent can their technology significantly improve the features of existing products?
"For example, centralized power prediction system can help	Referring to *digital resources* (Eller *et al*., 2020).	• To what extent do they rate your company's level of digitization

(*continued*)

Exploratory case findings	Key constructs and definitions	Survey instrument (adapted from established survey items)
customers make more scientific operation and maintenance plans (such as sea-going plans and maintenance window period) through data interaction with the bottom layer of the production management system . . . ” *Findings:* Some enterprises emphasize the utilization of digital resources such as proactive monitoring, predictive analytics, artificial intelligence and data interchange during servitization	*Definition:* Encompasses the range of digital assets utilized throughout the entire life-cycle of a company’s product or service offerings (Eller *et al.*, 2020; Verhoef and Bijmolt, 2019).	(e.g. use of digital platform, digital production, digital investment, etc.) compared to their competitors? • To what extent do they rate the use of your company’s digital tools (e.g. platforms)? • To what extent has their company digitized its workflow, production, sales, service, etc?

Source(s): Taking reference to Creswell and Clark (2017) for interpreting two-stage linked results from the interview

2009), which may not be suitable for the 70 samples with 30 questionnaire items in this study. Instead, the authors conducted various survey interviews to supplement reliability checks, including telephone communications (20/70), onsite interviews (23/70), interviews through forums and conferences (11/70) and online meetings (16/70). A comparison of survey items with at least two enterprise executives further validated the data. Details of the survey data are presented in Table 7.

3.4.3 Calibration. Five conditions were identified from an exploratory case study in Stage 1. Following the recommendations of Greckhamer (2016), Misangyi *et al*. (2017) and Pappas and Woodside (2021), thresholds (0.1, 0.5, 0.9) were selected based on data distribution characteristics, with mediation as the cross-over point, in dealing with the absence of theoretical guidance. Cross-over data analysis and practical examples supported data accuracy, with neutral points at 4 and 5. Robustness checks in Table 10 confirmed the calibration results (Greckhamer *et al.*, 2018; Pappas and Woodside, 2021).

3.5 fsQCA analysis and findings

3.5.1 Analysis of necessary conditions. We first tested these conditions and their negation for servitization (Table 8). The results show none of the causal conditions met the 0.9 consistency threshold, while consistencies ranged from 0.44 to 0.83. Therefore, all conditions were retained for further sufficient analysis (Schneider and Wagemann, 2012).

3.5.2 Analysis of sufficient conditions. We performed a standard analysis to avoid logical contradictions, setting 0.9 and 1 as the consistency and frequency thresholds, respectively. PRI (proportional reduction in inconsistency) scores of ≥0.65 (Greckhamer, 2016). The resulting number of cases included in the analysis was 57, comprising more than 80% of cases, of which at least 80% proportion is recommended by Greckhamer *et al.* (2008) and Ragin and Fiss (2008). Due to a small-sample study, the case frequency threshold is 1.

From this analysis, we identified three potential causal configurations of servitization. Table 9 displays the paths of these configurations leading to the outcome, with consistency scores ranging from 0.89 to 0.92. The overall solution coverage in Table 9 is around 0.66, indicating a significant coverage of the study sample. Each configuration also shows raw coverage values between 0.18 and 0.58, suggesting that all configurations can explain the outcome when their unique coverage exceeds 0 (Ragin, 2014).

Table 5. Data collection procedures for fsQCA*

Data classification	Data source	Duration	Data information	Data collection	Sample
Interview data	Survey	From March 2020 to 2022 (30 months)	70 valid questionnaires	Combination of Online and Offline	The main participants were middle and senior management personnel of the companies, including CEOs, Vice Presidents, Heads of Service, Strategy, Technology and other related departments
	Interview		Interview time not less than one hour to confirm the accuracy of questionnaire information	20 companies were investigated through field research conducted by the author, and 13 companies were interviewed during government or consulting projects undertaken by the team or institution In 7 companies, the author conducted interviews during breaks at corporate forums, conferences, and similar events organized by the team or institution For the remaining cases, due to the pandemic, interviews were conducted via online platforms such as Tencent Video, ZOOM, etc.	Senior and mid-level managers with a good understanding of the overall corporate strategy and business development
Second-hand data	Annual Report Company News and Company Official Account Posts	Searching for typical cases and achievements of companies in the areas of manufacturing servitization, digitization, product features and customer relationship types			

Note(s): *To mitigate common method biases, program control was implemented through the inclusion of reverse items to filter out inadequate responses. In addition, multi-angle questioning was utilized to challenge respondents' habitual thinking and enhance the accuracy of the data. For instance, managers were prompted to define "radical technological resources" during interviews to prevent ambiguity or assumptions in the questions
Source(s): Created by authors

Table 6. Measurement of conditions

Condition	Mark	Description
Complementary market resources (Iyer *et al.*, 2019) (CA = 0.887)	Com1	Both our companies and our partners need each other's resources to achieve their goals and responsibilities
	Com2	The resources provided by our company and key partners have been significant in achieving growth
	Com3	The resources that we and our partners bring into the supply chain are very valuable to each other
	Com4	There is a high degree of similarity/overlap with key supply chain partners' resources/capabilities (reverse)
Specific market resource (Iyer *et al.*, 2019) (CA = 0.876)	Spec1	A lot of resources have been invested to understand the way we do things
	Spec2	To be effective, spend a lot of time getting to know our end customers
	Spec3	Spend a lot of time thoroughly understanding our products
	Spec4	A lot of money has been invested in people who are committed to our business
Complex technological resource (Caniato and Größler, 2015) (CA = 0.74)	PC1	Please rate the modularity degree of the main products of your company (1 point represents modularity; 7 points for integration)
	PC2	Please give a score on the complexity of the main products of your company (1 point means only producing single manufacturing parts; 7 points means providing complete machine products)
	PC3	Please score the complexity of the production factors of the main products of your company (1 point means fewer parts and single raw materials; 7 points means many parts and various raw materials)
	PC4	Please rate the complexity of the production steps of the main products of your company (1 point means few operation steps; 7 points means many steps)
Radical technological resource (Chandy and Tellis, 2000) (CA = 0.9)	TR1	Our products always use the latest technology
	TR2	We have made major technological innovations in most of our products
	TR3	Our technology is different from our competitors
	TR4	Our technology is very new to the industry
	TR5	Our technology can significantly improve the features of existing products
Digital resource (Eller *et al.*, 2020)	DC1	Please rate your company's level of digitization (e.g. use of digital platform, digital production, digital investment, etc.) compared to your competitors
	DC2	Please rate the use of your company's digital tools (e.g. platforms)
	DC3	Has your company digitized its workflow, production, sales, service, etc.?
Service offering (Kohtamäki *et al.*, 2013)		How active you are in providing a particular service to a customer (1 being not active at all, 7 being very active)
	ASO1	Installation services
	ASO2	Maintenance services
	ASO3	Product Upgrade Service
	ASO4	Maintenance service
	ASO5	Research and development services
	ASO6	Basic Research Services
	ASO7	Prototyping and development services
	ASO8	Feasibility analysis service
	ASO9	Problem analysis service
	ASO10	Product Display Service
	ASO11	Customer seminar
	ASO12	Customer technical training services
	ASO13	Written information materials service
	ASO14	Provide consultation and support to customers by telephone

Source(s): According to the existing scales (listed)

Table 7. Overview of sample data

	Mean	SD	Cronbach's alpha	CR	AVE	Full member	Cross-over	Non-member
Complex technological resource	4.61	1.61	0.95	0.83	0.56	6.8	4.8	2
Radical technological resource	4.74	1.64	0.90	0.85	0.53	6.75	5	2.5
Complementary market resources	4.7	1.6	0.92	0.75	0.43	6.525	4.75	2.25
Specific market resource	5.12	1.10	0.81	0.78	0.47	6.5	5.33	3.65
Digital resource	4.44	1.54	0.94	0.91	0.78	6.2625	4.625	2.11
Service offering	5.27	1.27	0.88	0.94	0.54	7	5.4	3.6

Note(s): Qualitative analysis in QCA drew on prior studies and leveraged the benefits of a small sample size (Forkmann *et al.*, 2017; Guerola-Navarro *et al.*, 2021; Rodrigo and Palacios, 2021), allowing for in-depth familiarity with sample firms and clear selection criteria
A fuzzy-set score is generated using Ragin's (2014) calibration technique to represent the degree of set membership. Average marks of each item were used due to the multi-item nature of causative circumstances. The fuzzy-set scale, converted from a seven-point Likert scale, assigns levels of membership from 0 to 1, indicating varying degrees of membership (Ragin and Fiss, 2008)
Source(s): Created by authors

Table 8. Analysis of necessary conditions

Key resources	Conditions	Service offerings Consistency	Coverage
Market resources	Specific resource	0.75	0.75
	~Specific resource	0.53	0.50
	Complementary resource	0.81	0.73
	~ Complementary resource	0.44	0.46
Technological resources	Complex resource	0.83	0.79
	~ Complex resource	0.48	0.47
	Radical resource	0.76	0.74
	~Radical resource	0.47	0.46
Digital resources	Digital resource	0.76	0.72
	~Digital resource	0.47	0.47

Note(s): According to Ragin (2014) and Fiss (2011), a condition is considered "necessary" when it is constantly present or absent corresponding to the outcome. If the consistency score reaches 0.90 or above, the condition can be regarded as necessary. The results show None of the causal conditions met the 0.9 consistency threshold, while consistencies ranged from 0.44 to 0.83. Therefore, all conditions were retained for further sufficient analysis (Schneider and Wagemann, 2012)
Source(s): Created by authors

3.5.3 Robustness of findings. Considering the particularity of small-sample QCA, this study adopted the most common method of changing calibration crossing points in the literature (Fiss, 2011) and adjusted the crossing points to calibrate (0.95,0.5,0.05) in combination with the research questions, according to Campbell *et al*. (2016). Despite a few changes in consistency and coverage, they exert no effect on the interpretation of the results and cause no substantial changes in the results after adjusting the crossing points (see Table 10). Therefore, the results can be considered reliable.

Table 9. Analysis of sufficient conditions

Condition		Configuration 1	Configuration 2	Configuration 3
Technological resource	Complexity	○	•	●
	Radicalness	●	●	
Market resource	Complementary	○	●	
	Specification	●	○	●
Digital resource		○		●
Consistency		0.950541	0.920836	0.89242
Raw coverage		0.179039	0.358952	0.572344
Unique coverage		0.0084424	0.0655022	0.275982
Overall solution consistency: 0.877179				
Overall solution coverage: 0.659098				

Note(s): Solid circles suggest the existence of conditions, whereas hollow circles show the lack of conditions. The solid big circle and hollow big circle represent core conditions, where the solid small circle and hollow small circle represent non-core conditions

We identified 3 potential causal configurations of servitization. Table 9 displays the paths of these configurations leading to the outcome, with consistency scores ranging from 0.89 to 0.92. The “coverage” concept reflects how well solutions explain all cases when the outcome is present. The overall solution coverage in Table 9 is around 0.66, indicating a significant coverage of the study sample. Each configuration also shows raw coverage values between 0.18 and 0.58, suggesting that all configurations can explain the outcome when their unique coverage exceeds 0 (Ragin, 2014)

Source(s): Created by authors

4. Results

4.1 Configurational analysis: resource orchestration

Based on the observations presented in Table 9, we conducted an analysis of our cases using QCA. For each configuration, we describe exemplar cases in accordance with best practices for small- to medium-sized QCA studies (Greckhamer *et al.*, 2013). While considering the contextual complexities as much as possible, we will further describe the specific manifestations of service offerings, case characteristics and resource orchestration in each configuration respectively, combined with interview data.

4.1.1 Configuration 1: leveraging market opportunity. Configuration 1 represents the combination of high-specificity market resources and sufficient novelty technological resources while lacking the complex technological resources as well as complementary market resources as core conditions to achieve a high degree of servitization, while digital resources belong to the missing condition, indicating that digital technology has no direct influence on this combination.

In this path, manufacturers leverage the resources by highly customized solutions and joint R&D services, highlighting the importance of customers in servitization. Specifically, highly specialized market resources suggest that a large amount of time and costs have been invested in forming specific assets with customers. The relation-specific investment could help lock in customers from competitors (DYER, 1996) while existing innovative resources of manufacturing firms provide a certain resource base in the R&D services, particularly when investigating personalized solutions for customers.

This configuration represents specialized and innovative small- to medium-sized enterprises (SMEs) that primarily provide customer-centric services, such as offering experimental platforms for the development of new technologies, new materials, etc., and customized services. As one of the general managers in the sample firm said that:

Table 10. Robustness of sufficient condition analysis

		Configuration		
Condition		1	2	3
Technological resource	Complexity	○	•	●
	Radicalness	●	●	
Market resource	Complementary	○	●	
	Specification	●	○	●
Digital resource		○		●
Consistency		0.936636	0.913435	0.899365
Raw coverage		0.236406	0.383542	0.576812
Unique coverage		0.0130852	0.0619366	0.250654
Overall solution consistency: 0.879251				
Overall solution coverage: 0.66909				

Note(s): Solid circles suggest the existence of conditions, whereas hollow circles show the lack of conditions. The solid big circle and hollow big circle represent core conditions, whereas the solid small circle and hollow small circle represent non-core conditions

Regarding the robustness of QCA, Schneider and Wagemann (2012) summarized three methods to evaluate the robustness of QCA conclusions: changing calibration, changing consistency levels, and dropping or adding cases. Adjusting the threshold and adding or deleting the sample size is more suitable for large-sample QCA (Thomann and Maggetti, 2020; Witt et al., 2022). Considering the particularity of small-sample QCA, this study adopted the most common method of changing calibration crossing points in the literature (Fiss, 2011), and adjusted the crossing points to calibrate (0.95,0.5,0.05) in combination with the research questions, according to Campbell et al. (2016). Despite a few changes in consistency and coverage, they exert no effect on the interpretation of the results and cause no substantial changes in the results after adjusting the crossing points (See Table 10). Therefore, the results of the current study have met the requirements of QCA robustness, and the results can be considered reliable

Source(s): Created by authors

> The customer utilizes our fundamental R&D platform, together with our manufacturing and technological expertise while we utilize the client's market knowledge to do some collaborative R&D, jointly applying for several patents.

Besides, the relation-specific investment includes transaction-specific capital investment (Dyer and Singh, 1998). More customized products and solutions could facilitate the differentiation strategies and may enhance the fit between product or solution innovation and market opportunities, allowing manufacturers to seize the first-mover advantage. Thus, it has the potential to enhance customer-specific needs and processes (Genzlinger *et al.*, 2020). For example, the company can expand its service offerings by adding additional modules to the equipment and improve and innovate its products and services. The marketing manager from a machine tool manufacturer mentioned that:

> During the long-term cooperation with customers, we have significantly improved the operational efficiency of our equipment, increasing it by over three times compared to previous business models . . . We have also incorporated modules such as equipment alert systems that are specifically designed to meet the unique needs of our customers . . . in order to accommodate our clients' flexible product usage requirements, we have introduced a special version of our handling equipment that is more compact and portable . . . . . .

Product refinement plays a crucial role in achieving performance-based outcomes, such as servitization. Incremental innovation, as observed by Dosi (1982) and Nelson and Winter (1977), often leads to significant improvements in functionality for customers. These incremental innovations can be observed in Configuration 1.

4.1.2 Configuration 2: leveraging innovation integration. Configuration 2 represents high-complementary market resources, and this combination of high-novelty technology resources is conducive to realizing high-level servitization. The use of complex technological resources may exert an implied effect in this scenario.

In this path, manufacturers leverage the resources through R&D alliances, including cooperation with upstream and downstream partners for the whole process solutions, increasing the varieties of service offerings. Highly complementary market resources bring various partners into the supply chain, placing more emphasis on both upstream and downstream cooperation. The development of new technology is often accompanied by a high degree of uncertainty, such as constant revision and iteration, increasing the demand from customers for related services support. While laying a certain foundation for R&D alliances, the complementary resources established with partners can strengthen the ability of manufacturers to cope with innovation uncertainty (Dyer and Singh, 1998), by designing services and solutions.

Moreover, larger firms occupying central network positions are included in this configuration, Cases A and C in Study 1 appear in this configuration. Many of these companies state that R&D alliances with upstream partners help in increasing the varieties and scopes of services in breadth. While the complex technologies appear to increase varieties of service offerings as well. For example, as a large machinery manufacturer, the R&D department director mentions that:

> R&D alliance is important for us . . . . . .Our technological base could be enhanced to design more R&D services, such as “the whole process support solutions”, compared with the competitors.

4.1.3 Configuration 3: leveraging resource advantages. Configuration 3 denotes the combination of high-complexity technological resources, high-specificity market resources and high digital resources to realize servitization.

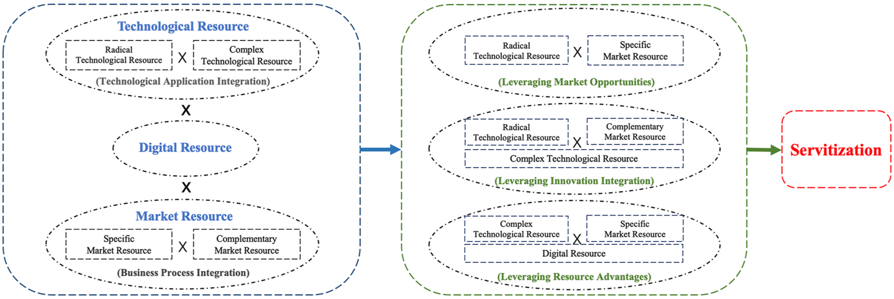
In this path, manufacturers leverage the resources by creating resource barriers, including long life-cycle complex products and long-lasting customer relationships. Therefore, complex product and equipment manufacturers are included in this configuration. Cases B and D in Study 1 appear in this configuration. Specifically, the complexity of technology causes such complex products to frequently encounter certain industry and knowledge barriers; thus, the nature of the products often necessarily involves a certain service content (Raddats *et al.*, 2016). For this type of product, high-specificity market resources denote a high degree of customization, indicating the specific investment made by customers. The past cooperation has built long-lasting relationships with customers based on the long life-cycle product.

Digital resources are used as the core condition, specifically performing functions such as prediction and monitoring, as well as using the intelligent platform. As mentioned by a digital department representative in an interview:

> We have implemented an integrated platform system solution and established a new R&D mechanism called “what you see is what you get” process guidance production, which strengthens the collaboration between product design, process, and manufacturing. This enhancement has significantly improved our service offerings

Coreynen *et al.* (2017)divided digital technologies into different front- and back-end functions, including facilitating interactions with customers at the front-end, while at the back-end, digital technologies help manufacturing enterprises realize customized production and improve the efficiency of the production process. This configuration extends the finding of Coreynen *et al.* (2017) by highlighting that product complexity and the depth of relationship could interplay by digitalization. As core conditions, combined resources can strengthen the depth of services provided by firms through customized solutions and long-term cooperation, eventually promoting servitization.

The detailed explanations of the three configurations are listed in Figure 3 and Table 11.



Source(s): Created by authors

Figure 3. Resource configuration and interaction in servitization

Table 11. Summary of configurations of servitization

Resource leveraging configuration	Description	Configuration of servitization
Leveraging market opportunities	Leveraging resources by customer-centric, including highly customized solutions and joint R&D services	Building long-term relationships with customers × enhancing R&D competencies
Leveraging innovation integration	Leveraging resources by R&D alliances, including cooperation with upstream and downstream partners for the whole process solutions, increasing the varieties and complexities of service offering	Building diverse cooperation relationships with partners × enhancing R&D alliance competencies
Leveraging resource advantages	leverage resources by creating resource barriers, including long life-cycle complex products, and long-lasting customer relationships. Digital applications stand out	Building complex product knowledge ×applying long-term contract × digital applications

Source(s): Created by authors

4.2 Supplementary analysis: resource interaction in servitization

The fsQCA approach is a set-theoretic method that examines how key antecedents combine systematically into configurations and uncovers their complex causality or causal conditions (Ragin and Fiss, 2008). Introducing a qualitative explanation before and after the main body of QCA helps to address the limitations of the sole focus on the presence or absence of conditions in QCA (Mitchell *et al.*, 2022; Ong and Johnson, 2023; Ragin and Fiss, 2008). To gain a more comprehensive understanding of how resource configurations and interactions in digital servitization, we employed triangulation by combining the findings from QCA with qualitative data. At the same time, to further summarize patterns from configurations (Ong and Johnson, 2023; Ragin, 2008), we conducted a cross-case comparison of commonalities among three configurations.

4.2.1 The role of digital resources. First, to strengthen the validity of our research (McMahon and Patton, 2016; Stake, 1995), we adopted a triangulation approach by integrating the results from QCA with qualitative data from further interviews. The results reveal that digital resources are present in Configuration 3, demonstrating the highest level of coverage compared to the other two configurations. To gain a deeper understanding of digital resources, we specifically examined the occurrences of Case B and Case D within Configuration 3 [1].

Case D: Case D primarily offers services for wind power development and operation, as well as wind power solutions. It establishes a bundling relationship between its complex technological resources and specialized market resources by leveraging digital resources to explore new opportunities. Our interview data of the managers explain that: "*The independently developed technologies such as the Customizable Intelligent Direct Drive Fan, Wind Power Planning and Design Platform, SOAM Smart Maintenance Service System, and EFarm Radar Wind Measurement System have been successfully implemented on a large scale for commercial applications*." Digital resources also provide greater opportunities for establishing long-term cooperation, as mentioned by the marketing manager: "Based on the platform, we fully explore the potential value of customer data and create new types of service offerings, such as credit guarantees, data trading, and financing leasing, to lock the customers."

Case B: The core business of Case B is categorized into equipment sales, engineering services, and industrial gas services. The equipment and engineering sectors encompass the design, production and sales of air separation equipment. The industrial gas services business involves investment in and construction of air separation projects based on customer requirements, as well as overseeing operational management to ensure the delivery of gas services.

The digital resources employed by Case B not only improve the efficiency of equipment operations and market decision-making but also support the development of long-term relationships. For instance, as the manager from the digital department said: "The gas logistics department will collect nationwide price information and market dynamics data through a logistics digital platform. This will allow the department to promptly access information, such as prices, and assist us in making more efficient service decisions," while the marketing manager mentioned that: "We will jointly take the lead with our clients and participate in the bidding for major long-term projects." Eventually, the equipment, customization capabilities and relationship with the customers have been improved.

4.2.2 The interaction of technological and market resources. The three approaches identified all involve the integration of market and technological resources, highlighting the significance of aligning both types of resources based on their characteristics. Indeed, Raddats *et al.* (2016) argue that the complexity of a product is a key driver for servitization, while they further suggest that for products with low complexity, it is essential to enhance their differentiation advantages. Moreover, according to Raddats *et al.* (2016), relationship resources are deemed to play a critical role in servitization. This is further supported by our findings of radical resources as core conditions for gaining a competitive advantage (Dahlin and Behrens, 2005) in Configurations 1 and 2, as well as the identification of complex technological resources as a core condition in Configuration 3. Furthermore, we have found that aligning complementary (or specialized) market resources with radical technological resources can promote servitization. In the case of complex products, establishing specialized customer relationships, for example, co-investment and joint bidding for large-scale projects, can greatly facilitate the servitization journey. In addition, previous research on servitization has placed greater emphasis on the importance of external relationships (Eloranta and Turunen, 2015; Kamalaldin *et al.*, 2020; Sjödin *et al.*, 2019). However, we have found that the configuration of technology and market factors is equally important. Our findings indicate that both technological and customer resources are significant factors in the integration process. Moreover, the attributes of these resources determine the representation of the configuration. These findings also enhanced the back and front-end configuration studies in servitization (Raja *et al.*, 2017). Especially in the digital era, the opportunities for resource interaction have increased, and the alignment between technology and the market is beneficial when designing service offerings (Coreynen *et al.*, 2017; Raddats *et al.*, 2016; Raja *et al.*, 2017).

5. Discussion and conclusions

Servitization and digitalization are operated in different logics (Baines *et al.*, 2017; Bustinza *et al.*, 2017). To shed light on the "black box" of digital servization, this paper aims to explore servitization within the realm of digitalization through a configurational perspective. In summary, based on the exploratory two-stage research strategy, this research unfolds the key resources including *radical, technological resources, complementary, specific market resources, as well as digital resources*, while we further uncover three leveraging configurations including *leveraging market opportunities, leveraging innovation integration and leveraging resource advantages* in providing insights for both academics and practitioners.

5.1 Theoretical contribution

Our study makes three main contributions. First, we provide configurational logic for unfolding digital servitization, highlighting resource orchestration and interaction. Depending on the advantages of the configurational approach to explain the complex nature of servitization (Forkmann *et al.*, 2017; Kohtamäki *et al.*, 2019a, b; Lexutt, 2020; Salonen *et al.*, 2021; Sjödin *et al.*, 2019; Yan *et al.*, 2021), our research explores three resource configurational ways to emphasize the importance of resource orchestration and interaction. On the one hand, our research expands upon the work of Mathyssens and Vandenbempt (2008) in the digital context and takes a configurational logic approach instead of a single, independent perspective. By introducing new digital resources, we provide multiple configuration options for digital servitization, deviating from the traditional belief that pathways in servitization are mutually exclusive (Coreynen *et al.*, 2017; Matthyssens and Vandenbempt, 2008). On the other hand, our study highlights the technology and market interaction from a configurational logic. Previous studies have predominantly focused on a single perspective, such as the market and customers, as key external drivers of servitization (Eloranta and Turunen, 2015; Kamalaldin *et al.*, 2020; Sjödin *et al.*, 2019). In the digital context, where front-end and back-end interactions are continuously evolving and strengthening, our findings respond to the call by Coreynen *et al.* (2017) to investigate specific resource configuration for value digital servitization. Furthermore, our findings reveal the matching of innovative resources with complementary and specific relational resources. We enhance the connection between servitization and innovation literature by unfolding the alignment of innovative resources with other resources that drive servitization, addressing the research gap concerning the integration of servitization and innovation literature (Hwang and Hsu, 2019; Matthyssens and Vandenbempt, 2008; Opazo-Basáez *et al.*, 2022).

Second, our findings contribute to the literature on servitization by employing an exploratory two-stage research approach that combines preliminary case analysis with the QCA methodology, which enhances the depth and specificity of our analysis. Mixed approach in servitization literature is relatively limited, while understanding complex phenomena like digital servitization necessitates diverse research methods (Kowalkowski *et al.*, 2017; Li *et al.*, 2022a; Rabetino *et al.*, 2018; Salonen *et al.*, 2021). Hybrid data and analytical methods thus allow us to focus on both the factors that enable servitization *(WHAT)* and the configurations that lead to servitization *(HOW)* in the digital era. On the one hand, our study diverges from existing literature, which tends to excessively rely on descriptive and exploratory case studies to construct conceptual models (Eloranta *et al.*, 2021; Rabetino *et al.*, 2021). Instead, we not only developed theoretical frameworks but also tested and validated these theories by QCA, which enabled us to gain a deeper understanding of unfolding servitization and its causal complexity, going beyond conceptual understanding. On the other hand, we complemented our analysis with interview data to delve into the specific circumstances of each trajectory in the QCA analysis, thereby addressing the limitations of solely focusing on condition presence or absence in QCA (Mitchell *et al.*, 2022; Ong and Johnson, 2023; Ragin and Fiss, 2008). As a result, we were able to achieve a more focused and conclusive outcome, which significantly contributed to our understanding of the complex servitization journey.

Third, we investigate the resource attributes as lower-level components to gain a deeper understanding of digital servitization, answering the call from Huikkola *et al.* (2020) that addresses the micro practice of resource realignment in servitization literature, comparing to previous research on capability (Coreynen *et al.*, 2017; Jovanovic *et al.*, 2019; Momeni *et al.*, 2023). On the one hand, we extend the investigation of Matthyssens and Vandenbempt (2008) by identifying the key resources in the core integrating processes, specifically introducing the importance of the resource attributes in explaining complex servitization mechanisms. On the other hand, our findings enrich the understanding of traditional technological factors (Hwang and Hsu, 2019; Matthyssens and Vandenbempt, 2008) in achieving servitization success. While the existing literature primarily focuses on the significance of digital technologies (Kapoor *et al.*, 2021; Tronvoll *et al.*, 2020), our findings underscore the importance of considering technological attributes related to products and production. In particular, we highlight the value of radical technological resources and complex technological resources as advantageous resources in servitization, which empirically aligns with the conclusions reached by Raddats *et al.* (2016).

5.2 Managerial implications

Our research has crucial managerial implications as well. First, when manufacturers choose servitization for transformations, analyzing its own advantages and disadvantages resources can help clearly define the focused configurations of servitization, rather than simply imitate the so-called successful cases. We provide different resource applications with different paths to servitization for managers, which managers can deploy, combining resources depending on the resource characteristics. Specifically, manufacturers with innovation resources could build intense relationships with customers to provide customized solutions, while integrating diverse relationships in the value chain could help manufacturers increase the service scopes and varieties. This indicates that the innovation strategy (orientation) of manufacturers stands out as well in the servitization process. In other words, servitization transformation is not only changing or adjusting service offering scopes, but the technological factors also need to be considered in sustaining competitive advantages.

Digital resources considerably differ from traditional resources in reproducibility and possibilities for sharing. Based on understanding the nature of digital attributes and the value creation mechanisms, we find that digital technologies performed well on more complex products rather than innovative products. This implies that digital technology is not a panacea, but it needs to combine its resource characteristics to give full play to its value.

5.3 Limitations and future research

This study has limitations that offer insights for future research. It focused on the impact of technological, market and digital resources on servitization from a configurational logic perspective but did not consider the sequential pathway of implementation priorities and the impact of time. Longitudinal studies in the future could explore these aspects. The reliability and validity of the research conclusions were considered in sample selection, but external validity was limited compared to large-sample studies. Future research is recommended to focus on the impact of different configurations on performance using other quantitative methodologies. Additionally, the study focused only on five key resources, potentially neglecting other conditions. Future research could explore additional contextual factors like industry characteristics and product lifecycles. There is also the potential to include more contextual factors beyond the digital context studied and to delve deeper into the categorization and discussion of service offerings.

During our investigation, there were shifts in innovation and technological capabilities, yet our study focused on resource characteristics. Future research could explore processes underlying these changes to deepen understanding of servitization and innovation and examine the impact of servitization on companies' technological capabilities. Digital servitization enables firms to enhance value creation through features like streaming and remote monitoring (Vendrell-Herrero *et al.*, 2022),. There is a need for further exploration of the relationship between servitization and digital innovation.

Furthermore, there is potential for a more detailed categorization of digital resources. Digital resources in Case B and Case D configurations indicated different natures and future research should include longitudinal and evolutionary studies to delve deeper into this phenomenon to enhance our comprehension of digital servitization.

Finally, servitization began to be implemented much earlier in developed countries, our findings provide the research context in the emerging economies. Comparing digital servitization practices in different countries could provide a comprehensive theoretical insight.

Note

1. Configuration 1 and Configuration 2, which are not directly relevant to the digital context, were excluded from further discussion in this study.

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Further reading

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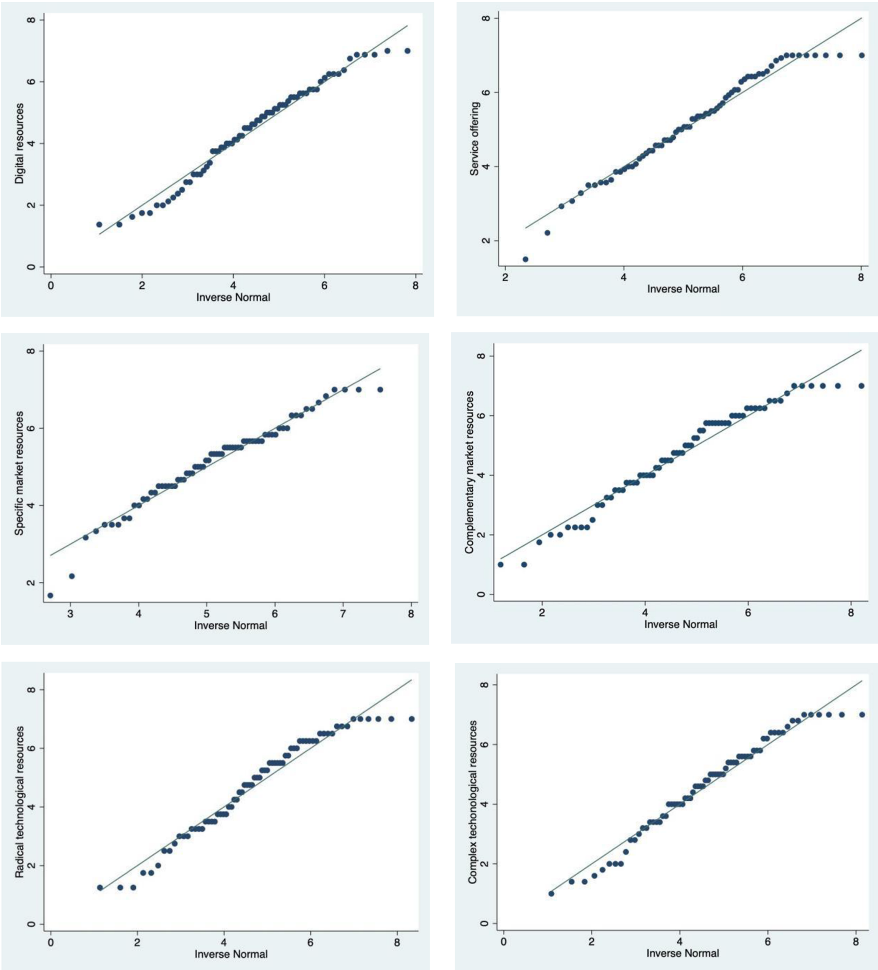
Appendix 1

Table A1. Shapiro–Wilk W test for normal data*

Variable	Observations	W	V	z	Prob > z
Specific market resources	70	0.96347	2.248	1.762	0.03905
Complementary market resources	70	0.96978	1.860	1.349	0.08861
Radical technological resources	70	0.96845	1.942	1.443	0.07446
Complex technological resources	70	0.98040	1.206	0.408	0.34181
Digital resources	70	0.97316	1.652	1.092	0.13740
Service offering	70	0.96549	2.124	1.638	0.05069

Note(s): *The Shapiro–Wilk test, widely applied to assess normality for various sample sizes (Shapiro and Wilk, 1965), suggests rejection of normality for the "Specific Market Resources" variable due to a *p*-value below 0.05 (Field, 2013). Given the small-sample sensitivities noted by Lumley *et al*. (2002) and Razali and Wah (2011), this may reflect an amplified response to minor distributional deviations. Complementarily, we supplemented our analysis with a Quantile-Quantile Plot (Q-Q plot), which provides a visual means of assessing the degree of deviation from a normal distribution (Wilk and Gnanadesikan, 1968), shown as follows in Appendix 2
Source: Created by authors

Appendix 2



Note(s): *We supplemented our analysis with a Quantile-Quantile Plot (Q-Q plot), which provides a visual means of assessing the degree of deviation from normal distribution (Wilk and Gnanadesikan, 1968). If the data points on the Q-Q plot closely follow the reference line, it suggests that despite statistical deviations, the distribution of the data remains approximately normal. Such deviations may have limited impact on the actual analysis

Source(s): Presented according to the data results

Figure A1. Q-Q Plot result*

Appendix 3

Table A2. Correlations

	Specific market resource	Complementary market resources	Radical technological resource	Complex technological resource	Digital resource	Service offering
Specific market resource	1					
Complementary market resources	0.717***	1				
Radical technological resource	0.586***	0.586***	1			
Complex technological resource	0.535***	0.685***	0.759***	1		
Digital resource	0.379**	0.347**	0.432***	0.426***	1	
Service offering	0.585***	0.574***	0.581***	0.677***	0.436***	1

Note(s): *** $p < 0.001$. ** $p < 0.01$.* $p < 0.05$
Source(s): Created by authors

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