CAPABILITIES SUPPORTING DIGITAL SERVITIZATION: A MULTI-ACTOR PERSPECTIVE

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Highlights

•Capabilities for digital servitization in Basic, Intermediate, and Advanced services.

• Capabilities required by manufacturers, intermediaries, and customers for digital servitization.

•Capabilities for digital servitization are analyzed through a systematic literature review.

• The study shows that digital servitization requires a multi-actor perspective on capabilities.

• We provide detailed descriptions of what each of the actors needs for different service levels.

Abstract

Digital transformation in business solutions is offering opportunities for servitization to become more digitalized. In this context, digital servitization requires the actors involved to perform new roles and develop new capabilities. Although servitization actor capabilities in the digital transformation context have been addressed in prior studies, the literature lacks a detailed understanding of how they operate according to different service types and different actor roles. Through a systematic literature review, our study aims to expound the capabilities required for digital servitization, for Base, Intermediate, and Advanced services, and analyze who of the main actors of the service triad (manufacturer, intermediaries, and customer) should own such capabilities. This analysis resulted in a final sample of 47 main articles addressing capabilities. We show how the structure of the service triad shifts the digital service provision based on the capabilities required by each actor. For instance, Base Services demand less capabilities, thus, intermediary actors play a less important role since they just execute services usually on behalf of a manufacturer in a more discrete capacity. For Intermediate Services, the intermediary actor becomes more important, with capabilities needed to deliver the digital solution. In Advanced Services, customers' relationships with manufacturers become stronger, as this actor reassumes a central role in the solution offer, and intermediaries move to a supporting role again. Our analysis offers propositions for future research on digital servitization and practical implications on the capabilities required.

Keywords: Digital transformation; Servitization; digital servitization; capabilities; service actors

1 Introduction

Servitization has gained increasing attention as an important strategy for manufacturers to achieve competitive advantage (Ayala, Gerstlberger, & Frank, 2019; Coreynen, Matthyssens, & Van Bockhaven, 2017). This strategy considers adding complementary services to the product offering or transforming the product offering into service solutions, both of which increase customer value perceptions (Baines, Lightfoot, Smart, & Fletcher, 2013a; Reim et al., 2015). The recent literature on servitization has focused on understanding how digital technologies can support these different types of service offering (Frank, Mendes, Ayala, & Ghezzi, 2019; Raddats, Kowalkowski, Benedettini, Burton, & Gebauer, 2019; Rabetino Kohtamäki, Brax, & Sihvonen, 2021). The use of digital technologies, such as the Internet of Things (IoT), cloud computing and predictive analytics (artificial intelligence), allows for the collection and intensive use of real-time data from the customers, products and services in order to offer new solutions (Schroeder Naik, Ziaee Bigdeli, & Baines, 2020; Frank, Mendes, Ayala, & Ghezzi, 2019; Lenka, Parida, & Wincent, 2017; Ritter & Pederson, 2020). Such integration of servitization and digitization typically results in the provision of digital services embedded into physical products (Holmström & Partanen, 2014; Marcon et al., 2019), which can help to enable Base (e.g., IoT-enabled spare part ordering), Intermediate (e.g., maintenance enhanced by predictive analytics) and Advanced services (e.g., condition monitoring for availability-based contracts) (Lerch & Gotsch, 2015; Paschou, Rapaccini, Adrodegari, & Saccani, 2020).

By adopting digital servitization, several changes in the manufacturer's business model can happen (Marcon, Soliman, Gerstlberger & Frank, 2021; Kohtamäki, Parida, Oghazi, Gebauer, & Baines, 2019). One such change is that the offering of digital servitization demands a complex system of interrelated capabilities that may be hard to find in a single company (Kahle, Marcon, Ghezzi, & Frank, 2021; Manresa, Prester, & Bikfalvi, 2020). The complex nature of digital solutions requires the integration of software, hardware, network and service concepts that usually are beyond the capabilities of single manufacturers (Benitez, Ferreira-Lima, Ayala & Frank, 2021; Benitez, Ayala, & Frank, 2020). Therefore, many manufacturers rely on complementary capabilities from the service triad (manufacturer, intermediary and customer actors) (Ayala, Gaiardelli, Pezzotta, Le Dain, & Frank, 2021), creating a multi-actor collaboration to provide digitally servitized offers (Story et al., 2017; Tronvoll et al., 2020). The intermediary, in this perspective, is the actor that usually provides services for the customer when the manufacturer: 1) does not hold the necessary capabilities to do so; 2) is not interested in providing activities that are important to the customer but not integral to the manufacturer's offering provision; or 3) when customers seek intermediaries to help them manage or access suppliers (e.g. project management contracts) (Wynstra, Spring, & Schoenherr, 2015). For example, when an equipment manufacturer outsources field maintenance to a company (intermediary) closer to customer's location; or operates through an intermediary when entering a new market (e.g., integrators and automation companies) (Wynstra et al., 2015).

Although the relevance of complementary capabilities for digital servitization has been acknowledged in prior studies (Ulaga & Reinartz, 2011; Huikkola, Rabetino, Kohtamäki, & Gebauer, 2020), little is known about the role and required capabilities of the actors from the service triad in delivering digital services. Some studies have addressed specific capabilities or presented practical applications of such capabilities in the development of servitized digital solutions (Ardolino et al., 2017; Töytäri et al., 2018), but the literature lacks a systematic approach to describing the required capabilities. This systematic approach is needed for several reasons. First, extant literature adopts several concurrent and overlapped concepts to describe what different actors need to offer digital services. In response to this observation and to more explicitly articulate the capabilities concept for this study, we follow Story Raddats, Burton, Zolkiewski, & Baines (2017: 56) who define capabilities as: "*socially complex, combinations of interconnected resources that are deployed to achieve a desired end goal*". This definition encompasses a broader view in which resources and capabilities are intertwined, with resources being the productive assets owned by the company, while capabilities refer to the firm's capacity to use these resources towards a goal, which generates competitive advantage (Ulaga and Reinartz, 2011). By adopting this perspective on capabilities and systematizing the literature through it, a more specific list of needs can be defined to implement a digital servitization approach. Second, the consideration of a multi-actor perspective helps to differentiate the actors' role and diminish the excessive expectation on the servitization activities usually put into account on the manufacturers (Ayala, Paslauski, Ghezzi, & Frank, 2017). This can help academics better understand the complementarities of actions taken within the service triad and help practitioners to know what to consider in the servitization implementation process. Thus, the following research question emerges: *what are the necessary capabilities for digital servitization for different service types (Base, Intermediate, Advanced Services) when considering the role of the different actors in the service triad*?

To answer the research question above, we analyze case studies on digital servitization reported in the literature to identify the different servitization-related capabilities necessary to offer digital services and which actors of the service triad they are associated with within the cases presented. We adopt a systematic literature review (SLR) approach to identify the cases of digital servitization (Grubic, 2012; Paschou et at., 2020; Tranfield, Denyer, & Smart, 2003). Such an approach allows us to consider a wide range of case study types through which we can analyze a broad set of capabilities that can be necessary for different types of services, from Base to Advanced. The final sample contained 47 articles addressing specific capabilities required for digital servitization. As a main contribution, we describe all the capabilities that are necessary for each of the actors to provide three types of services. We show how the key capabilities necessary from the service triad shifts in the provision of each of the digital service types. That is, the roles of the manufacturer and the intermediary change according to the service type provided. Based on our results, we open a new theoretical avenue for the study of capabilities for digital servitization by highlighting that these capabilities depend on the type of service offering and on the service triad configuration.

2 Research Method

To advance the understanding of the required capabilities for digital servitization, we conducted a systematic literature review (SLR) with a focus on the capabilities necessary for the three main actors (i.e., manufacturer, intermediary, and customer) to deliver Base, Intermediate, and Advanced service offerings. SLRs use a well-defined search protocol that aims to reduce bias and to ensure that the conclusions drawn are replicable and comprehensive (Tranfield et al., 2003). This method is especially important in research fields that share conceptual closeness to others, where publications are spread around several areas and different journals, and that are referred to by synonymic terms. This is the case for the digital servitization research field, which has parallel topics, such as Product-Service Systems and Digitalization. Additionally, research papers are published in several journals, using synonyms such as smart products (Porter & Heppelmann, 2015), digital product-service systems (Lerch & Gotsch, 2015), remote and/or digitally supported services, and integrated solutions (Grubic, 2014).

In conducting the SLR, we followed the recommendations of Tranfield et al. (2003), dividing it into three stages: review planning (Stage 1), performing the review (Stage 2), and reporting and dissemination (Stage 3). In Stage 1, based on the gaps identified in the literature regarding the capabilities necessary to deliver digital services, we developed the protocol used for the searches in the databases and defined the keyword combinations (**Table 1**). In this stage, we also defined Scopus and Web of Science as databases for the application of the algorithm since they are two of the databases with the highest indexing rates.

Table 1- Keyword combinations and quantity of articles retrieved

Remote	AND	("product-service system" OR "integrated solution" OR service)	AND	Capabilit*
Smart	AND	("product-service system" OR "integrated solution" OR service)	AND	Capabilit*
Digit*	AND	("product-service system" OR "integrated solution" OR service)	AND	Capabilit*
		"Smart product"	AND	Capabilit*

We opted to include the term "service" as opposed to "servitization or servitiz*" since it represents the most generic term used in the servitization literature and its different streams. For instance, Cusumano et al. (2015) adopted the term "service innovation in product firms" instead of servitization to discuss the same concept. Similarly, Visnjic, Wiengarten, & Neely (2016) adopted the term "service business models" to refer to servitization. Other work refers to "service transformation" (Ardolino et al., 2017). Thus, the adoption of this more generic term allows us to capture a wider pool of papers that follow such terminology. We also performed a posteriori analysis and the cross-checks confirmed that servitization articles all refer to service, or one of the other search terms in their title, abstract or keywords, which demonstrates that the protocol used was effective in identifying servitization articles.

In Stage 2, we searched both databases with the keyword combinations presented in **Table 1**. The following inclusion criteria were set in the search engines: 1) the keywords searched should be in the Title, Abstract, or Keywords of articles; 2) only research papers published in peer-reviewed journals were included; and 3) articles should be written in English and published between 2000 and 2020. We considered the last 20 years because it comprises the rise of the Internet 2.0, which allowed new ways of interaction with customers, while also coincidently being the period of emergence of the servitization literature. Although we were focused on identifying papers on digital servitization, which are not typically found prior to 2005 (Paschou et al., 2020), this timeframe acknowledges that older studies could contain important information on digital capabilities related to servitization that could be part of our analysis. As this study is the first SLR to consider the emergent work on multi-actor capabilities supporting digital servitization, we considered all Scopus or Web of Science listed peer-reviewed journals. Limiting journals to those in top-tier lists (such as the Academic Journal Guide) could have restricted the articles retrieved, given that digital servitization is a multidisciplinary field, and many servitization articles are still published in mid-low IF journals (Rabetino, Harmsen, Kohtamäki, & Sihvonen, 2018). Thus, following Lightfoot et al. (2013), when they considered emerging trends within servitization literature, and in line with Tranfield et al. (2003), our study was not restricted only to top-tier journals, but also included broader scope of journals to ensure that articles relevant to our study aim were included.

We filtered for articles published in the following areas: business, engineering, and social sciences. The search conducted in the two databases resulted in 2,689 articles. We eliminated 525 duplicates, resulting in 2,164 articles. The articles' titles, abstracts, and keywords were carefully read by three researchers to check whether they fitted our research objective. That is, researchers analyzed whether articles addressed digital servitization-related topics, and if not, they were rejected from the sample.

Based on the previously presented criteria, 1,856 articles were excluded because they did not address the research topic. That is, the articles used digital or servitization terms but studied unrelated topics, such as information security systems, digitization of shopping malls, online government information, smart city business models, etc. After this step, the remaining 308 articles were fully read, and the content-based inclusion criteria were applied. These criteria aimed to select articles that presented capabilities for and cases of digital servitization resulting in a sample of 33 accepted articles. These criteria consisted of scrutinizing the entire paper, and specially the method section, to analyze if articles reported cases of servitized solutions offered through (or improved by) digital services. Therefore, our study builds upon empirical evidence (stemming from case studies) rather than purely theoretical propositions.

Next, we analyzed the capabilities reported in the cases studied by the accepted papers. Three different researchers applied the content-based criteria. Inconsistencies and doubts were discussed among the researchers. This assured the validity of the sample of accepted papers. Additionally, we added 14 articles using a snowballing technique. These articles were not retrieved in the first scanning but were identified from the reference sections of the 33 accepted articles (Raddats et al., 2019). To determine whether a paper should be accepted through the snowball technique, we read the list of references from the accepted papers and checked against our initial list of articles and then analyzed the titles, abstracts and keywords to check whether they met our basic inclusion criteria. Then, these articles were read and filtered based on the same criteria applied to select the first 33 articles. These articles may not have been retrieved during our database search because the terms and wording used in the studies did not mention the terms defined in the SLR protocol. Also, their absence from the initial searches could also be explained by their publication journals being indexed in other databases than Scopus and Web of Science.

Finally, the sample of 47 articles was reviewed in depth in Stage 3. These articles were published in 37 different journals, with Industrial Marketing Management (5 papers) and International Journal of Production Research (4 papers) being the most recurrent journals. The results are reported in section 4 of this article. Figure 1 graphically represents the flow diagram of the steps followed in the SLR.

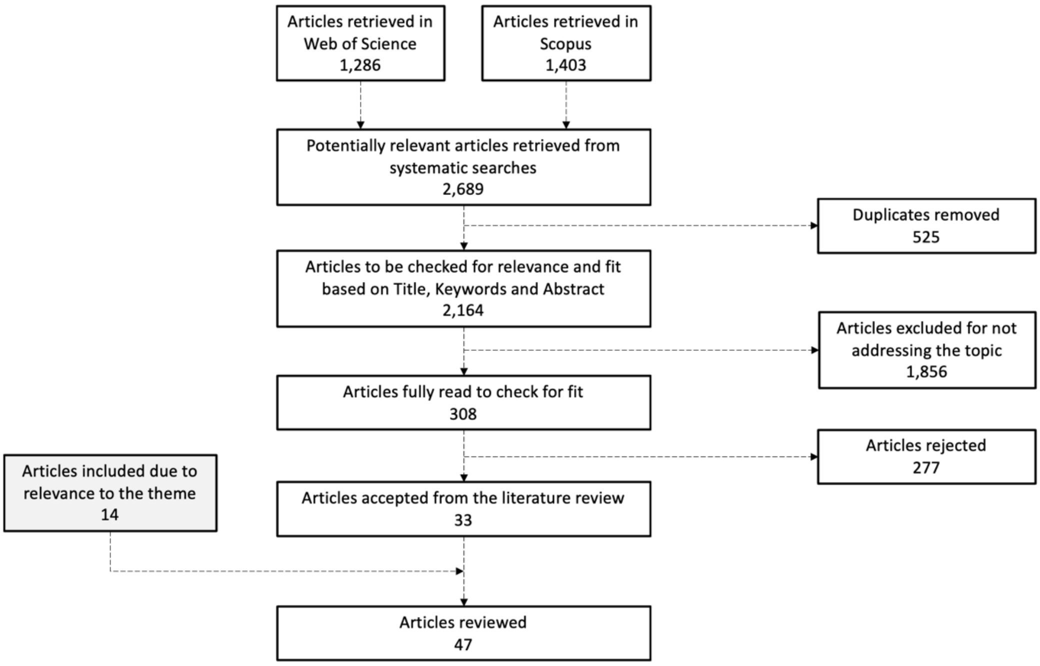

Figure 1 - Flow diagram of the steps for the systematic literature review

Once the 47 articles were defined, the cases studied reported in them were analyzed and systematized to identify the digital servitization related capabilities. In undertaking this analysis, we followed the framework proposed by Story et al. (2017), which allowed us to consider the different actors' perspectives. In total, 116 cases were identified in the 47 selected articles. These cases are summarized in **Appendix A**. The analysis of the characteristics of the cases shows that the largest proportion of manufacturers are from the machinery and equipment sector (approximately 43%), or from the computers, electronics, and optical products sector (almost 20%). Regarding manufacturer size, most cases (approximately 53%) were from large companies (many of which were multinationals). Many papers did not provide a detailed description of the studied company's size. **Table 2** presents a description of the cases' characteristics.

Table 2 – Description of Case Characteristics from the literature review

Industrial sector	**Number of identified cases**	**Size of company**	**Number of identified cases**
Machinery and equipment	50	Large	62
Computers, electronics, and optical products	23	Not specified	46
Not Specified	16	Small	8
Other transport equipment	7	**Total**	**116**
Repair and installation	5		
Motor vehicles, trailers, and semi-trailers	4		
Mining	4		
Metal products (not machinery and equipment)	2		
Others (electrical equipment, food products, footwear and parts, basic metals, printing and recorded media)	5		
Total	**116**		

Following Paschou et al. (2020) and Baines et al. (2013), we categorized the cases of services supported by digital technologies into Base, Intermediate and Advanced according to the services being offered with the products. *Base services* are focused on supporting product provision and include installation and warranty. *Intermediate services* are focused on maintaining the product's condition and include scheduled maintenance and technical support. *Advanced services* deliver an outcome-based service aligned to the performance of a product and include risk and reward sharing contracts between a supplier and customer (Baines & Lightfoot, 2014). To find the capabilities we searched specifically for the term. Then, in order to validate them, after an initial analysis of the first ten articles, the researchers involved in this step discussed the capabilities found, as a means to balance the knowledge and understanding of the concept and the examples found. To interpret capabilities in articles that did not explicitly mention the term capability, we analyzed the text to find descriptions of the use of resources deployed to achieve an end goal, following the definitions of Ulaga and Reinartz (2011) and Ardolino et al. (2019). These descriptions were typically found in the Results or Discussion sections of the papers. Then, similar capabilities were merged, whereas singular capabilities were discussed and validated in meetings.

According to Story et al. (2017) each case and article was analyzed to identify the actors involved in the service provision, i.e., manufacturer, intermediary and customer (note the distinction in our terminology between *Intermediate Services* and *intermediary actors*). Finally, the capabilities mentioned in each case were stratified following the framework presented in Figure 2. This step allowed exploration of the different capabilities for digital servitization required: (i) for each service type; and (ii) for each of the three actors involved in the relationship. According to Story et al., (2017), the capabilities of the actors involved in the delivery of Advanced Services should be analyzed by six key overarching business activities: *Innovation*; *Interaction Processes*; *Actor insight*; *Business culture evolution*; *Working with other actors;* and *Infrastructure development and management.* In the next section, the results of the analysis are presented for each of the service types.

3 Results

3.1 Actors' capabilities for Digital Servitization

The literature proposes general capabilities for the delivery of services supported by digital technologies. However, our results show that these capabilities are still very centered around the manufacturer. For instance, Ardolino et al. (2017) identified eleven capabilities underpinned by IoT, predictive analytics and cloud computing technologies. Additionally, Coreynen et al. (2017) envisaged specific operational and dynamic capabilities according to the manufacturer's digital servitization pathways. These capabilities are related to design-to-service, linking front- and back-office processes, execution of risk assessment and mitigation, value visualization and value-based sales, capture of customer needs, and the processing and interpretation of service-related data. These capabilities are similar to the findings of Ulaga and Reinartz (2011), which also show that merely collecting strategic customer data, even though necessary, is not sufficient, as manufacturers must translate these data into capabilities and new revenue opportunities, which involves preparing the workforce for its promotion and use.

Despite the manufacturer focus, some studies have addressed an extended view of the solution provision, such as the study from Huikkola et al. (2020), which analyzed the capabilities required to manage the ecosystem. Their results showed that manufacturers in the service ecosystem moved downstream to gain bargaining power but also to control compatibility and technical aspects necessary for the solution. Thus, manufacturers must develop coordination capabilities to manage relationships with customers and intermediaries, a robust service identity, and efficiency in transactions and relationships (Huikkola et al., 2020). Kamalaldin, Linde, Sjödin, & Parida (2020) analyzed provider-customer relationships during digital servitization, showing that both actors must consider how capabilities are complementary to the solution, as they must co-evolve to obtain success. Similarly, Töytäri et al. (2018) identify that changes at just a firm level are not sufficient, since the lack of access to influence the right stakeholders inside the customers (due to solution newness), and the inability to buy value-based services, due to industrial procurement models that favor short-term wins, result in a prevailing product-focused culture and a mismatch of capabilities and resources in manufacturer-customer relationships. Thus, managers must also look to improve business mindset and capability development at a network-level in order to achieve a successful match for integration activities (Töytäri et al., 2018).

Capabilities are typically discussed in terms of either those needed by the manufacturer itself (e.g., Ardolino et al., 2017; Coreynen et al., 2017) or those needed by the manufacturer to orchestrate its network (e.g., Luz Martín-Peña, Díaz-Garrido, & Sánchez-López, 2018; Vendrell-Herrero et al., 2017), whereas literature is relatively silent on the capabilities required by other actors in the digital servitization value systems, There are a few exceptions, such as Kamalaldin et al. (2020), who discusses provider-customer relationships in digital servitization and analyzes how capabilities should be combined among the actors, Herterich et al. (2016), who analyze several types of business models, or Grubic (2018), Lerch and Gotsch (2015), and Cenamor et al. (2017), who all mention capabilities that intermediaries and customers should develop to enhance the adoption of digital services in platforms. One of these examples is how a car manufacturer partnered with another company to develop a joint venture service company for a digitally enabled car rental initiative (Ardolino et al., 2017). Their work highlights that this type of relationship requires a manufacturer to ensure that servitized offers are also aligned with the goals and activities of the intermediary (Ulaga and Reinartz, 2011), which may be challenging for companies. However, these studies mainly discuss capabilities from the manufacturers' point of view.

We address this literature gap by looking for general capabilities needed for digital servitization for each actor (i.e., manufacturer, intermediary, and customer) in the service triad against each of the three types of services (Base, Intermediate and Advanced). Thus, we explored the 116 cases of services supported by digital technologies, extracting from each of them the necessary capabilities.

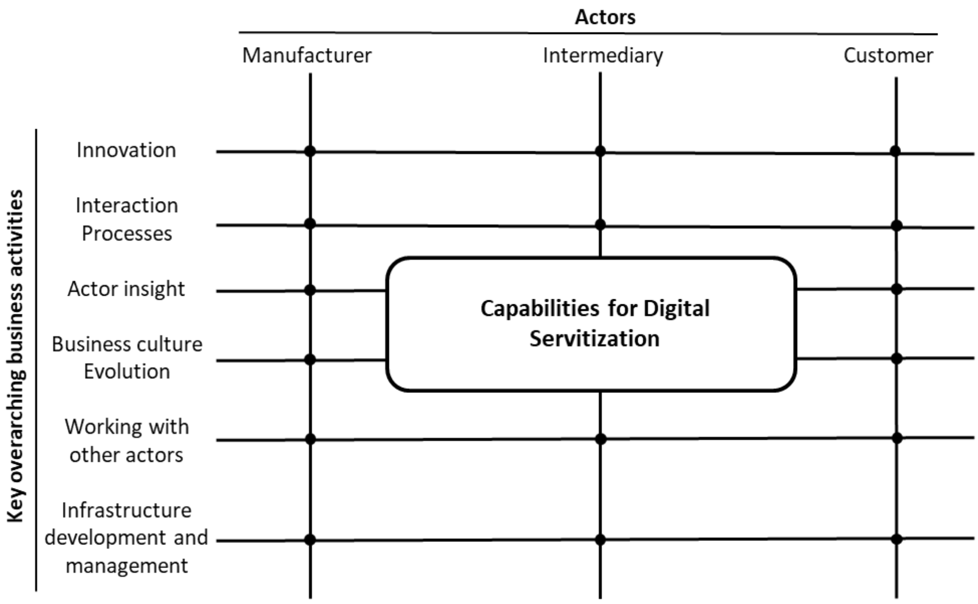

Figure 2: Theoretical framework. Adapted from Story et al. (2017)

3.1.1 Capabilities for digital servitization in Base Services

Base services demand fewer capabilities than any other type, as they are mainly focused on product delivery capabilities (Baines et al., 2013). The digital technologies embedded in the product are typically focused on monitoring conditions of the product in order to: provide the necessary spare parts at the right moment (Ness, Swift, Ranasinghe, Xing, & Soebarto, 2015; Rymaszewska et al., 2017); to avoid warranty issues (Porter & Heppelmann, 2014); and to collect data for improving the product development process (Candell, Karim, & Söderholm, 2009; Coreynen et al., 2015). Actors' capabilities for this service type are presented in **Table 3**.

For the manufacturer, the capabilities demanded to support a service supported by digital technologies are associated with adding connectivity to the products aligned with the Base services that will be offered through them (Lerch & Gotsch, 2015) and to use customers' gathered data to improve and innovate its product portfolio (Kindström, Kowalkowski, & Sandberg, 2013). Manufacturers create value to customers by helping them to manage their operations based on operational data (Rymaszewska et al., 2017) and leverage this data to provide necessary spare parts throughout the product lifecycle. This is done by connecting equipment to the customers' intranet to allow the manufacturer better control of the asset (Rymaszewska et al., 2017). In this context, knowledge management appears as a key capability, as data is used for product and spare part provision, but also to increase the knowledge on customers' preferences. For this service type, offering digital solutions to optimize product delivery allows customers' operation to run more efficiently and reduces demand distortions (Sánchez-Montesinos, Opazo Basáez, Arias Aranda, & Bustinza, 2018).

In the cases analyzed, there is evidence to suggest that only ae few services are provided by the manufacturer, so there is an expectation that the customer must develop its own capabilities to be able to make decisions based on information provided by the smart solutions involved (Lindström, Hermanson, Blomstedt, & Kyösti, 2018; Sánchez-Montesinos et al., 2018).

Our analysis of the cases highlights that customers have to be open to sharing data and processes with the manufacturer to enable improvements in both products and Base Service offerings (Holmström, Liotta, & Chaudhuri, 2018). In some cases, customers may need to develop the appropriate knowledge to be able to collaborate with other actors to achieve these service improvements (Sánchez-Montesinos et al., 2018). In addition, capabilities related to the infrastructure development are critical to allow the delivery of these services. A lack of alignment between the customer's infrastructure and the requisites for a remote Base Service can impede its delivery. For example, information flow is disrupted by the lack of a consistent high-speed internet connection across the customer's operational sites or internal information systems that do not allow communication and integration with external ones (Chang, Li, Hung, & Yen, 2013).

Somewhat surprisingly, while Intermediary service companies may be present in the provision of Base services, they are not explicitly mentioned in any of the cases evaluated. Manufacturing companies that adopt a servitization strategy usually show a lack of knowledge regarding the service offering associated to their manufactured products. However, given the simpler character of Base Services offered, as well as the manufacturers' know-how on the supply of spare parts and installation of new products, intermediaries are not shown to be required for this offer, based on the Base Service cases analyzed (see Appendix A). In such a case, intermediary actors play a less important role since they just execute services usually on behalf of a manufacturer in a more discrete capacity. One example is the provision of spare parts, which Lerch and Gotsch (2015) report as being done by the manufacturer. However, this type of service could be done by external service providers for more distant customers, for example. Nonetheless, even though external service providers can offer Base services, such as installation, directly to customers without much input from the manufacturer, this is potentially not foregrounded in cases exploring a service triad relationship, since it is a direct relationship between a customer and the company performing the installation, independent of the focal manufacturer. Consequently, this relationship is not currently a part of the digital servitization story, as our results did not provide examples of this relationship of discuss the necessary capabilities. However, it does not mean that the manufacturer develops all of the capabilities alone for Base services: they may need to develop partnerships with suppliers of software and hardware to develop the necessary product's connectivity and data solutions (Ayala et al., 2017; Lerch & Gotsch, 2015). Similarly, the customer may require support of external service providers to explore more of the potential of the smart products owned (Rymaszewska et al., 2017).

Table 3 – Actors' capabilities for digital servitization in Base Services

Key Business activities	Capabilities		
	Manufacturer	**Intermediary**	**Customer**
Innovation	Develop new parts and digital components (Lerch & Gotsch, 2015) Develop innovative processes to support new service provision (Holmström et al., 2018) Providing value to customers based on the information collected (Kowalkowski, 2013);	**NA***	Openness to provide information to support manufacturer's innovation process (Holmström et al., 2018);
Interaction Processes	Customer-supporting services (Coreynen, 2017) Analysis and integration of customer data (data relationships, patterns, and trends) (Lerch & Gotsch, 2015);	**NA***	Instant decisions based on information provided by the smart solutions (Lindstrom et al., 2018; Sánchez-Montesinos et al., 2018);
Actor Insight	Understand product value according to customer use (Chiou et al. 2009; Chang et al. 2013);	**NA***	Manage the risk of providing real time data to the manufacturer for service provision (Holmström et al., 2018);
Business Culture Evolution	Development of basic digital service skills (Lerch & Gotsch, 2015);	**NA***	Culture of data usage to improve processes and management (Kowalkowski et al., 2013; Lindstrom et al., 2018);
Working with other actors	Partner with external providers to develop digital solutions (software, data analysis, network integration) (Rymaszewska et al., 2017);	**NA***	Collaboration with suppliers to validate and improve services (Sánchez-Montesinos et al., 2018);
Infra-structure development and management	Integrate solutions with customers' current technologies (Chang et al. 2013) Remote diagnoses skills and real-time data analysis of equipment condition (Lindstrom et al., 2018);	**NA***	Align own infrastructure with external providers' new technologies (Lindstrom et al., 2018) Leverage smart diagnosis for service provision (Lindstrom et al., 2018);

***Note:** Literature does not deeply describe intermediaries' roles in Base services, however given the lower complexity characteristics of this service type, independent service suppliers could develop some of these capabilities independently from manufacturers and offer this type of service without even naming it as servitization.

3.1.2 Capabilities for digital servitization in Intermediate Services

A more profound impact is made on the capabilities demanded by actors when pursuing Intermediate Services through digital technologies. Digital technologies are used to support services to assure the state and condition of equipment (Baines et al., 2013a; Paschou et al., 2020). For instance, a remote service can be provided as customized on-demand connectivity to assist in remotely diagnosing a failure, scheduled data collection and data analysis, and continuous monitoring for critical alarms and status of products (Grubic & Peppard, 2016). The capabilities developed at this service type allow firms to optimize the use and operations of products, increasing its performance and making possible predictive diagnosis for pre-emptive service delivery (Porter and Heppelmann, 2014). Actors' capabilities identified in the cases analyzed for this service type (see Appendix A) are presented in **Table 4**.

Rymaszewska et al. (2017) present the case of a multinational manufacturer of power generators that first added IoT technologies to its generators in order to then develop the capabilities to analyze the data to provide condition-based maintenance instead of the traditional preventive maintenance. In the Intermediate type, the challenge for the manufacturers regarding innovation is to develop capabilities to supplement on-site services with digital services in hybrid offerings (Coreynen et al., 2015; Lerch & Gotsch, 2015). The solutions can be supported by the integration of software and products through sensors and actuators (Diakostefanis et al., 2017). The offer of Intermediate Service should also consider the characteristics of the product, as they can limit the services that could be delivered through it (Grubic & Jennions, 2018). For instance, products that are purely electrical/electronic deteriorate in a discrete, non-linear manner, rather than providing continuous evidence of decline in performance. For this reason, predictive maintenance services are not viable services, but the remote diagnosing of the failure through data analytics could represent a better solution (Grubic & Jennions, 2018).

The delivery of Intermediate Services supported by digital technologies impacts and disrupts manufacturers' business models, thus, they must be ready to respond to these changes. Access to data analytics capabilities allows the manufacturer to establish condition monitoring, and training contracts, which impacts on different elements of its business model (revenue sources, personnel skills, maintenance scheduling) (Lerch & Gotsch, 2015; Paluch, 2014). However, a data-driven business model demands joining these capabilities with contextual technical factors in order to offer remote services, which requires more than just data analytics skills. In other words, explicit knowledge acquired from customer's real-time data, must be combined with technical tacit knowledge (Grubic & Jennions, 2018b; Pagoropoulos, Maier, & McAloone, 2017). Technical capabilities are harder to develop than data analysis, thus manufacturers should consider this before offering Intermediate services (Grubic, 2018; Grubic & Jennions, 2018).

The manufacturer also has the challenge of introducing the new – usually unknown – digital technologies and potential benefits to the customer (Grubic & Jennions, 2018). To do this, the manufacturer should align its digital services to the customer's strategy and translate the solution to user-friendly application (Coreynen et al., 2015). In this context, an *intermediary* can appear as a strong actor to facilitate the delivery of services supported by digital technologies. On the one hand, the intermediary supports the manufacturer with round-the-clock local services delivery (Coreynen et al., 2015; Ong, West, Lee, & Harrison, 2007). Being geographically nearer the customer, the intermediary acts as a bridge between the manufacturer and the customer, constantly observing the customer's pains and monitoring new opportunities of services (Coreynen et al., 2015), thus honing contextual technical expertise. During the implementation of the products, the intermediary's technical skills are key to getting the solution up and running., i.e., integrating the manufacturer's smart products and digital technologies with those already existing on the customer's site (Eloranta & Turunen, 2016; Paluch, 2014). On the other hand, the flexibility of the intermediary is valuable for the customer. Since the intermediary is not constrained by the manufacturer's portfolio, it can adapt and/or update some existing products by adding other digital technologies. Thus, the intermediary can also develop network capabilities to build complex solutions combining competitor's services and products (Coreynen et al., 2015) based on the understanding of customer's needs (Herterich et al., 2016).

In Intermediate Services the manufacturer's lack of knowledge about the customer's processes can prevent the manufacturer from acting directly. However, the intermediary also needs to develop the capability of using real-time data provided by the manufacturer to support customer's processes (Rymaszewska et al., 2017) instead of only relying on their own technical skills. For services supported by digital technologies to be successful, actions must be based on data, and this is where the business culture evolution capabilities are more vital (Herterich et al., 2016). As narrated by Jonsson et al. (2009) in their case of maintenance services supported by digital technologies, the technicians from the intermediary used to act based solely on their own technical expertise, but now they must support their actions based on the information gathered by IoT installed on the machines and provided by the manufacturer's back-office data analyst. Large scale resistance was seen in this case, since technicians did not trust the data analyst's information (Jonsson et al., 2009).

Regarding the customer, their openness to co-develop solutions with the intermediary and manufacturer and to collaborate with service delivery is crucial for the success of Intermediate Services (Ardolino et al., 2017). As observed by Grubic and Jennions (2018) at Marine Co., customers are not always prepared or interested in providing additional data around a problem or failure and this can impede the delivery of a remote service, since environment data is essential in helping a service engineer resolve a failure. Thus, the customer needs to develop the capability to redesign its internal processes and resources to better benefit from digital and remote services (Diakostefanis et al., 2017). It also requires internal stakeholders being trained and persuaded to use the solutions, and the development of internal capabilities to retain knowledge about the processes (Coreynen et al., 2015; Pagoropoulos et al., 2017). These internal capabilities will afford the customer some level of independence from the providers, reducing the risk of adhering to the service. Additionally, to manage the risk, other areas than procurement must develop capabilities to understand the service delivered in order to develop better contracts, according to the operations supported (Pagoropoulos et al., 2017).

Table 4– Actors' capabilities for digital servitization in Intermediate Services

Key Business activities	Capabilities		
	Manufacturer	**Intermediary**	**Customer**
Innovation	**Balance product and service innovation** Develop software solutions integrated with products through sensors and actuators (Diakostefanis 2017) Improve product development through real-time data (Jonsson, 2009) **Development of new digitally-enabled services** Hybrid offering deployment capability, supplementing on-site services with digital services (Lerch & Gotsch, 2015; Coreynen et al., 2015; Kamalaldin et al., 2020) Leverage IoT skills for service solutions (Hasselblatt, Huikkola, Kohtamäki, & Nickell, 2018; Huikkola et al., 2020) Development of off-core competence skills to create a digital solution (Rymaszewska et al., 2017) Constant monitoring for new opportunities of data-driven services (Rymaszewska et al., 2017) Close relationship between R&D and service teams for data-based innovation (Hasselblatt et al., 2018)	**Product and Service modifications** Adapt products to a servitizable solution through digital technologies (Ardolino et al., 2017) **Development of new digitally-enabled services** Use real-time data to support customer processes (Rymaszewska et al., 2017)	**Co-creating Innovations** Openness to codevelop solutions (Ardolino et al., 2017)
Interaction Processes	**Customer-focused through-life service methodologies** Improve service delivery as technologies advance (Lim et al., 2015) Data-based diagnostic decisions (Grubic & Jennions, 2017; Lim et al., 2015) Provide customers guarantees for the equipment (Grubic & Jennions, 2017; Huikkola et al., 2020) Development of user-friendly software and applications for interactions and installation (Coreynen et al. 2015; Lim et al., 2015; Paluch, 2014) Data privacy (Paluch, 2014) Relationship development with closer contact and trainings (Paluch, 2014) Balance between digital and personal interactions (Paluch, 2014)	**Customer-focused through-life service methodologies** Workforce organization to offer the service constantly (Ong et al., 2007) Fast response and continuous contact with customer to ensure full process efficiency (Paluch, 2014)	**Processes supporting digital services** Redesign internal processes to adapt to remote operation and monitoring (Diakostefanis, 2017) Data interpretation skills (Coreynen et al., 2015) Involvement of stakeholders in remote services selection and use (Paluch, 2014)

Table 4– Actors' capabilities for digital servitization in Intermediate Services (continuation)

Key Business activities	Capabilities		
	Manufacturer	**Intermediary**	**Customer**
Interaction Processes	**Implementation of digitally-enabled services** Validate concept to allow customers to evaluate the solution (Ong et al., 2007; Grubic & Jennions, 2017) Connection of digital architecture to other actors to enable integrated connection and collaboration (Lerch & Gotsch, 2015; Durugbo, 2013) Embed service personnel into customer's processes (Eloranta & Turunen, 2016);	**Implementation of digitally enabled services** Customer training to leverage the technologies possibilities (Grubic, 2016);	
Actor Insight	**Customer Intimacy** Closer relationship with customer to provide data-based services (Grubic & Jennions, 2017; Lim et al., 2015; Durugbo, 2013) Effective contract management (Herterich et al., 2016) Customer tie-in (Durugbo, 2013) Transparency with regular exchange of information to customers (Paluch, 2014);	**Customer Intimacy** Understand customer's individual needs and objectives (Herterich et al., 2016; Eloranta & Turunen, 2016) Interactions with customers to decrease risk perception (Paluch, 2014);	**Managing risks associated with developing intimacy with external actors** Involve internal stakeholders on service contracts (Pagoropoulos et al., 2017) Openness to provide real-time process data (Grubic, 2018) Openness to use service-generated information to improve outcomes (Jonsson, 2009, Grubic, 2018) Manage the risk of losing hands-on knowledge (Jonsson, 2009);
Business Culture Evolution	**Distinct yet synergistic product and service cultures** Development of a service culture (Grubic and Peppard, 2016) Support for service provision (back-office) (Herterich et al., 2016); **Innovation to Data-driven Business Model** Openness to develop new business models based on digital technologies (Lerch & Gotsch, 2015) Development of data analysis skills, customer's business and process optimization services (Grubic & Peppard, 2016; Ong et al., 2007; Grubic & Jennions, 2017; Lim et al., 2015) Development of new forms of creating competitive advantages (Rymaszewska et al., 2017) Development of consultative selling capabilities (Huikkola et al., 2020);	**Collaborative data-driven service** Use of manufacturer's back-office support for service provision (Herterich et al., 2016);	**Outsourced-service evaluation** Internal stakeholders' adoption of the solution (Coreynen et al., 2015) Manage the risk of several providers involved in the solution delivery (Pagoropoulos et al., 2017) Development of supplier-customer reliability relationship (Eloranta & Turunen, 2016);

Table 4– Actors' capabilities for digital servitization in Intermediate Services (continuation)

Key Business activities	Capabilities		
	Manufacturer	Intermediary	Customer
Working with other actors	**Coordination and integration of third-party products/services** Integration with intermediaries to co-develop solutions (Ardolino et al., 2017) Manage actors' ecosystem to promote knowledge sharing (Ardolino et al., 2017) Open and flexible architecture platform to provide services (Herterich et al., 2016; Durugbo, 2013; Eloranta & Turunen, 2016) Overcome possible conflicts of interest when working with other actors (Huikkola et al., 2020);	**Coordination and integration of third-party products/services** Complex solution development through the combination of services from different actors (Coreynen et al., 2015; Eloranta & Turunen, 2016) Integration of IoT solutions with cloud services (Du, 2018; Diakostefanis, 2017) Attract new providers and customers to increase the solution's visibility (relational capital) (Eloranta & Turunen, 2016) Create shared vision among actors (Eloranta & Turunen, 2016);	**Maintaining procurement expertise** Internal development of digital skills to retain knowledge (Pagoropoulos et al., 2017) Openness to share knowledge about the process with the other actors (Grubic & Jennions, 2017; Eloranta & Turunen, 2016; Kamalaldin et al., 2020) Collaboration with suppliers to validate and improve solutions (Grubic, 2018; Kamalaldin et al., 2020);
Infrastructure development and management	**Service delivery** Online support to local service delivery (Coreynen et al., 2015) Simulation skills for field process optimization services (Vardar et al. 2007) Knowledge management infrastructure, both tacit and explicit (Pagoropoulos et al., 2017; Grubic, 2018; Grubic & Jennions, 2017) Fast response to problems (Paluch, 2014) Definition of common standards and protocols (Paluch, 2014); **Remote service delivery** Developing appropriate cybersecurity infrastructure to protect service delivered (Jurcevic, 2008; Pagoropoulos et al., 2017) Safeguarding intellectual property rights (Huikkola et al., 2020) Development of skills to provide remote maintenance and diagnosis (Ong et al., 2007; Hasselblatt et al., 2018)	**Localized service delivery** Support manufacturer's resources for local solution delivery (Coreynen et al., 2015) Flexible architecture and open interfaces to facilitate connections between different actors (Eloranta & Turunen, 2016) Use collected data to proactively act on problems (Lenka et al. 2017);	**Appropriate retention of service infrastructure** Collaborative (joint) processes with partners for data and solution integration (Kamalaldin et al., 2020);

	Real-time monitoring infrastructure (Lerch & Gotsch, 2015; Lim et al., 2015) Managing the distance of remote services that rely on formal and explicit knowledge (loosing contextual information and tacit knowledge) (Jonsson, 2009);		

3.1.3 Capabilities for digital servitization in Advanced Services

For this service type, digital technologies allow firms to offer outcome-focused services, bringing to the manufacturer portfolio activities that were usually performed by the customer (Baines et al., 2013a; Paschou et al., 2020). **Table 5** presents the capabilities demanded for each actor identified by analyzing cases from the literature (see Appendix A). Regarding the manufacturer, they must concentrate their capabilities to align product and service in the delivery of a broad solution focused on use and availability instead of sales or maintenance (Baines et al., 2013a; Lerch & Gotsch, 2015). For instance, this need is illustrated in the case reported by Grubic and Jennions (2018) of Aerospace Co, a jet engine manufacturer that faced barriers when the design area posed resistance to the addition of new sensors required by service delivery, as they were seen as unnecessary weight and cost.

Developing capabilities related to software and automation is also crucial to allow the customized services demanded in Advanced offers (Smith, 2013). All manufacturer's activities related to the processes must be driven by advanced data analysis, such as predictive analytics, to reduce the risk and cost of assuming operations' performance (Grubic & Jennions, 2017; Smith, 2013). For instance, Ardolino et al. (2017) present the case of Canon pay-per-page. In the past, maintenance data was manually gathered by technicians that visited customers periodically. Now, the data is automatically collected through IoT and is integrated to the manufacturer's ERP that schedules visits aligned with other customers to reduce logistics costs. Another example is from Kone Elevators Company that developed data analytics skills for predictive maintenance services that minimize downtime and speed up equipment restoration (Ardolino et al., 2017). These data skills must be supported by knowledge management capabilities. For instance, Aerospace Co. collected data from more than 3,500 engines around the world to be able to develop their diagnostic and prognostic capabilities (Grubic & Jennions, 2017).

However, not only are data analytics capabilities demanded, but also technical capabilities must be integrated inside the manufacturer (Grubic & Jennions, 2017). The mix of technical and analytics capabilities is crucial for the delivery of outcome-oriented services, much more so than for other types. Because of this, most of the Advanced Service cases reported by the literature present manufacturers that have incorporated the activities usually developed by the intermediary, by developing technical capabilities internally (e.g., Ardolino et al., 2017; Cenamor et al., 2017). This incorporation requires completely reshaping the manufacturer's business strategy (Smith, 2013), avoiding intermediaries, and having a close and direct relationship with the customer for the development and deployment of the solutions (Coreynen et al., 2015). For instance, Thyssenkrupp is using smart glasses to enhance the capabilities of on-site elevators' technicians by giving them direct and online real-time support from experienced technicians that are remotely located (Dalenogare, Baseggio, Ayala, Dain, & Frank, 2019). This direct relationship with the manufacturer, supported by digital technologies (Ardolino et al., 2017), builds trusting relationships with the customers, which are necessary to deliver outcome-based contracts (Ives, Palese & Rodriguez, 2016).

With intermediaries less involved in the service delivery, manufacturers must develop several capabilities related to working with other actors. Co-developing solutions with partners that own specific knowledge on digital technologies is fundamental (Ardolino et al., 2017; Ives et al., 2016; Smith, 2013). For instance, Kone Elevators has a partnership with IBM to leverage IBM's Watson technology to explore machine learning capabilities for predictive maintenance (Ardolino et al., 2017).

Thus, the development of platform management capabilities arises as a key factor to allow the customization of services demanded by the Advanced through the modularity of offerings and the cooperative distribution of activities (Cenamor et al., 2017). As illustrated by the case of a manufacturer of press tools for the automotive industry which created a platform that globally allows monitoring services, on-site repairs, remote trouble shooting and use-based service agreements by adding an IoT monitoring device to their tools and developing an information system (Cenamor et al., 2017).

As observed in the Advanced cases analyzed, the manufacturer, supported by the digital technologies and based on the capabilities developed, no longer relies on the intermediary to make a bridge between him and the customer. However, the intermediary can continue working on services attached to the manufacturer's products. As stated by Cenamor et al. (2017), some manufacturers develop digital platforms and open them to selected distributors and third-party service providers, to allow them to develop and offer locally relevant functionalities in an independent form. Since individual markets may have unique service requirements, the regional intermediary is in an advantageous position to understand them and develop new services, based on standard digital platforms, that can better meet customers' requirements (Cenamor et al., 2017). Thus, intermediaries should develop several capabilities to be able to work in this new business model configuration, as stated in **Table 5**.

Finally, the customers' capabilities and knowledge about the processes are still essential to cocreate the solutions with the manufacturer (Ives et al., 2016), and with more intensity now that the services are customized according to the customers' needs (Cenamor et al., 2017). Even when the services are outcome-oriented, they demand on-site collaboration from the customer to use the applications and to provide contextual information to optimize the remote service delivery (Grubic & Jennions, 2017). This relationship with the manufacturer naturally has an impact on the capabilities needed by the customers' employees and its internal processes, but it also impacts the firm's culture (Grubic & Jennions, 2017). The customer needs to change how services are traditionally hired, including technical employees in decision making, in addition to the purchasing area, to avoid future service delivery problems (Grubic & Jennions, 2017; Smith, 2013). Additionally, reliable data transmitted in real-time is essential for the delivery of this services because customers' openness to share data is crucial (Ives et al., 2016). However, digital services would not be possible without investing in the infrastructure needed to support real-time data extracting from IoT (Ives et al., 2016).

Table 5 – Actors' capabilities for digital servitization in Advanced Services

Key Business activities	Capabilities		
	Manufacturer	**Intermediary**	**Customer**
Innovation	**Balance product and service innovation** Align product and service development activities (Grubic & Jennions, 2017) Hybrid offering deployment skills (Lerch & Gotsch, 2015; Ives & Rodriguez, 2016) Capability of leveraging performance and use data to feedback R&D activities to improve products (Lerch & Gotsch, 2015; Grubic & Jennions, 2017; Bressanelli et al., 2018) Leveraging platforms to increase market solutions through modularity and add-ons (Cenamor, 2017; Tongur & Engwall, 2014);	**Product and Service modifications** Develop new services based on standard digital platforms (Cenamor, 2017);	**Co-creating Innovations** Data and knowledge sharing to allow improving and innovating solutions (Ives, 2016; Grubic & Jennions, 2017) Codevelop service modules based on standards platforms (Cenamor, 2017);
	Development of new digitally-enabled services Develop new software and automate production processes to be able to provide customized services and performance-based contracts (Smith, 2013) Development (or improvement) of data-driven services to explore the data obtained from product operation through IoT and sensors (Smith, 2013, Ives, 2016; Bressanelli et al., 2018) Development of off-core competence skills to create a digital solutions (Cenamor, 2017);	**Development of new digitally enabled services** Leverage real-time information to support customer processes (Cenamor, 2017);	
Interaction Processes	**Customer-focused through-life service methodologies** Partner with customer during the solution development and deployment (Herterich et al., 2016; Bressanelli et al., 2018; Huikkola et al., 2020) Develop new solutions to adapt to the evolution of customer's needs (Ardolino et al., 2017; Cenamor et al., 2017; Kamalaldin et al., 2020) Adaptation of digital services to customer's current strategy (Cenamor, 2017; Kamalaldin et al., 2020) Knowledge management through products' life cycle (Grubic & Jennions, 2017);	**Customer-focused through-life service methodologies** Customization and value–added services based on customers' demand (Cenamor, 2017);	**Processes supporting service outsourcing** Openness for data exchange with manufacturer for performance-based contracts (Smith, 2013) Adaptation of internal processes to use manufacturer's digital platforms (Cenamor et al., 2017) Provide the manufacturer with the environmental data needed to run the solution (Grubic & Jennions, 2017);

Table 5 – Actors' capabilities for digital servitization in Advanced Services (continuation)

Key Business activities	Capabilities		
	Manufacturer	**Intermediary**	**Customer**
Actor Insight	**Customer Intimacy** Build strong relationships with customers to achieve shared trust (Ives, 2016; Baines et al. 2013) Development of digital forms (apps, software) to have a direct relationship with the customer (Cenamor, 2017) Relationship building mechanisms (e.g., storytelling) to overcome customer resistance (Boldosova, 2020);	**Customer Intimacy** Ability to deliver transparent applications of collected data (Cenamor, 2017);	**Managing risks associated with developing intimacy with external actors** Acceptance and trust on the cybersecurity for data sharing on the cloud (Ives, 2016) Permit data to be extracted to allow the service offering based on it (Ives, 2016) Adopt and manage use-based contracts (Cenamor, 2017);
Business Culture Evolution	**Distinct yet synergistic product and service cultures** Change toward an outcome-oriented business model (Smith, 2013; Huikkola et al., 2020) Reshape business strategy (Smith, 2013; Huikkola et al., 2020) Broaden service portfolio to master process maintenance and repair based on collected data (Smith, 2013; Ardolino et al., 2017) Management of operations performance contracts (Lerch & Gotsch, 2015; Ives, 2016);	**Data-driven service** Deliver services based on manufacturer's digital platforms (Cenamor, 2017) Cyber and legal security (Charro & Schaefer, 2018);	**Outsourced-service evaluation** Openness to outsource services to focus on core activities (Smith, 2013) Openness to share and support data collection (Grubic & Jennions, 2017);
Working with other actors	**Coordination and integration of third-party products/services** Coordination to diminish intermediaries' dependency (such as field technicians) (Ardolino et al., 2017) Codevelop solutions with third-parties (e.g., AI providers) to improve operations and develop skills (Ardolino et al., 2017; Smith, 2013; Ives, 2016; Bressanelli et al., 2018) Work in partnership with other firms to be able to offer customized services or to provide field support (Bressanelli et al., 2018; Cenamor, 2017) Interoperability with other devices (Ives, 2016) Maintain data security when collaborating (Cenamor, 2017);	**Coordination and integration of third-party products/services** Develop complex advanced solutions by the integration of third-party products or services (addons, extensions) (Cenamor, 2017);	**Procurement expertise** Stablish more transparent contracts, with accurate use and performance data (Lerch & Gotsch, 2015) Complement decision-making from the purchasing area with insights from the technical areas (Lerch & Gotsch, 2015) Codevelop customized solutions with providers (Kamalaldin et al., 2020);

Table 5 – Actors' capabilities for digital servitization in Advanced Services (continuation)

Key Business activities	Capabilities		
	Manufacturer	**Intermediary**	**Customer**
Infrastructure development and management	**Localized service delivery** Integration and coordination of the complete service solution (Smith, 2013) Adaptation of digital services to customer's current infrastructure (Cenamor, 2017; Kamalaldin et al., 2020); **Remote service delivery** Use of data to better assess costs (Lerch & Gotsch, 2015) Offer the service remotely based on data processing (Cenamor, 2017; Bressanelli et al., 2018) Offer upgrading services remotely (Ives, 2016) Use of digital technologies to allow cooperation between teams in different remote locations (Cenamor, 2017) Use of advanced big data analytics to support remote diagnosis and troubleshooting (Boldosova, 2020) Safeguard intellectual property rights (Huikkola et al., 2020);	**Localized service delivery** Develop and offer functionalities through platforms (Cenamor, 2017);	**Appropriate retention of service infrastructure** Align own infrastructure to receive service remotely (Ives, 2016; Grubic & Jennions, 2017; Kamalaldin et al., 2020);

3.2 Capabilities comparison for the service types

By analyzing the capabilities needed by the three actors across the service types, it is possible to observe different necessary capabilities, changes in behaviors and relationship balances. To shed light on this, in Figure 3 we align our findings using the service triad perspective that describes the different forms of interaction between the manufacturer, the intermediary, and the customer (Wynstra et al., 2015). We use this perspective to show the expected force of the ties in the observed relationships in a servitization context and how they change according to the type of service.

Previously, Tronvoll et al. (2020) have argued that digital servitization is extensively reliant on collaboration between actors for value co-creation. This is because multi-actor collaboration allows joint value creation activities in the firm's network, providing specialized competences and building more customized data-driven solutions. Also, we build on the results from Tian et al. (2021) who described how manufacturers adopt platform leveraged thinking. Their results show that manufacturers can transition from non-digital servitization to digital servitization, by changing the organization's back-end configurations, or their front-end configurations, and sometimes simultaneously changing both. These pathways and choices evidence the demand for IoT-based platforms to coordinate inter-actor relations and capabilities in the solution's value system.

Literature has shown that capabilities related to digital servitization can vary widely. For example, important contributions from Töytäri et al. (2018), and Ulaga and Reinartz (2011) have shown that data processing and interpretation, risk assessment (and mitigation), and service mindset development are essential capabilities to deliver and demonstrate value to customers. Also, the capability of bundling products and services into effective solutions through the integration of technology, requires the building of software capabilities, field service delivery capabilities, the ability to orchestrate the supplier network, and the capability of effectively transition from product to solution selling (Huikkola et al., 2020). Additionally, balancing the internal mindset of the manufacturer with the capabilities necessary for delivering effective services and solutions, especially if companies lack institutional support, was seen as a barrier to digital servitization (Töytäri et al.,2018). Huikkola et al. (2020)'s results showed that companies that have difficulties internalizing processes, or developing a service-mindset, have sought to acquire service-related companies to overcome this barrier. However, their results also highlight that developing digital servitization capabilities and an improved downstream position helps to shape the organizational identity toward servitization and facilitate servitization investments.

Our study adds to these important insights for the digital servitization process by also delving into the specific capabilities required for digital servitization for different service types, focusing on the roles of the main three actors involved, manufacturers, intermediaries, and customers. At a Base service (Figure 3a), the literature suggests that the manufacturer provides digital services but maintains a product-oriented business model, starting to understand how to use the data gathered from the customer to offer services. Thus, customer-facing intermediaries do not seem to be yet necessary, since for this service the solution delivery is simply focused on product sales, warranty and spare parts provision, which are traditionally offered even by the most product-centered manufacturers (Baines et al., 2013a; Paschou et al., 2020). However, by opting to offer Base Services through digital technologies only to increase the service efficiency, the manufacturer is not exploring the full potential of smart products, since the data gathered from the product is not used to deliver value to the customer through additional innovative services (Frank, Mendes, Ayala, & Ghezzi, 2019).

Thus, two negative scenarios for the manufacturer can ultimately appear. In one scenario, with no added value, the customer could just see the smart product as a more expensive option, and sales could even be diminished because the customer prefers a less expensive, traditional product. In a second scenario, other third-party firms not related to the manufacturer could explore the smart capabilities of the product to offer services to the customer, such as start-ups or technology firms. Consequently, the manufacturer loses the opportunity to add value and make profit from the smartness already embedded in its products. This leads us to our first two propositions, the first one (P1a) summarizing our findings on Base Service and the second one (P1b) considering what should be necessary to explore digital servitization in Base services:

P1a: For Base Services, capabilities for delivering digital servitization are concentrated in the manufacturer, who needs to develop and explore their own capabilities to provide greater value to the customer.

P1b: For effective digital servitization in Base Services, manufacturers and customers both need to develop greater capabilities of intimacy, data sharing, and openness than they would for non-digital servitization relating to Base Services.

For Intermediate Services (Figure 3b), manufacturer appear to explore the potential of smart products by co-operating more with intermediary service providers. Our analysis of these cases suggest that manufacturers collect data from their products and provide the information to intermediaries that deliver these services to the customer. In such cases, there is a development of strong ties between the manufacturer and intermediary. Also, the manufacturer appears to be more reliant on the intermediary to learn the many value-creating possibilities of its Intermediate services and for improving service delivery (Ayala et al., 2017). On the other hand, due to its flexibility, the intermediary can deliver complete complex solutions for the customer, based on the technology of the smart product, but also combining it with the technologies already owned by the customer, creating greater added value, and developing strong customer ties, as represented in Figure 3b.

As a result of this dynamic, the manufacturer is prone to the ‘bridge decay’ phenomenon (Li & Choi, 2009), where the intermediary gains more importance than the manufacturer in the eyes of the customer, and the manufacturer ends up occupying a vulnerable position in which its product could be relatively easily substituted. However, this depends upon the extent to which the manufacturer is involved and visible in the data analysis process. Digital servitization offers manufacturers an opportunity to remain more involved in Intermediate Service delivery touchpoints than they might for non-digital servitization involving intermediaries. If manufacturers can control the data analytics pertaining to their products, then they can maintain a greater control in the value system. This is assuming that they can manage any associated tensions that emerge with other actors. This is evidenced by Huikkola et al. (2020), where manufacturers were shown struggling to deliver service sales to end customers when intermediaries (such as engineering companies) were involved in the relationship. In these cases, manufacturers sought different ways to decrease the intermediaries’ relevance regarding the key capabilities in the value system with acquisitions and strategic alliances. This approach allowed for the building of deep and direct relationships with (end) customers, but also involves more risks and changes in the business model, such as using intermediaries as subcontractors, instead of relational partners.

Thus, two further propositions emerge:

P2a: Digital servitization related to Intermediate Services offers actors the opportunity to develop more balanced, shared capabilities related to data sharing and deployment of technical expertise between the manufacturer, the service intermediary, and the customer than might be expected under non-digital servitization.

P2b: The development of capabilities for digital servitization for Intermediate Services based on value co-creation between intermediaries and customers creates the greatest risk to the manufacturer's position in the value system*. Therefore, although intermediaries play an important role in the service triad for Intermediate Services, manufactures need to stay involved and visible in the data integration process with the customer.*

Finally, our findings from the literature point out that, for Advanced Service offerings, the manufacturer gains more importance in the triad by developing more capabilities (Figure 3c). Advanced service cases highlight a phenomenon described by the digital servitization literature, where adding smart capabilities to products produces a shift in the value provided by manufacturers, from the design and manufacturing stages to outcome stages related to product usage, performance and availability (Bressanelli, Adrodegari, Perona, & Saccani, 2018; Lenka et al., 2017; Porter & Heppelmann, 2014). This is in line with the finding from Huikkola et al. (2020) who showed that as the focus shifts toward the delivery of solutions, servitizing manufacturers must move downstream, i.e. closer to customers, to establish a position of solution provider, bypassing intermediaries and expanding the firm boundaries.

Data analytics and integration with supply chain actors are enablers of such change, which facilitate the provision of even non-core competence services and helps to improve competitive positioning in the market (Benitez, Ayala, & Frank, 2020; Kahle et al., 2020). In the context of Advanced services, IoT technologies are important enablers as they support increased value propositions by providing a data-based specific product maintenance schedule, products' risk of failure, operational misuse identification, optimal time for maintenance, and downtime prediction (Schroeder et al., 2020). However, these technologies belong to a broader context that should also be considered, such as social and information subsystems interacting toward the value delivery. Hence, the interaction between technologies and their social and organizational context allows manufacturers to leverage the product-service offerings, develop consulting functions, reduce customers' dissonance, and create knowledge (Schroeder et al., 2020).

In this sense, Ulaga and Reinartz (2011) discuss that solution providers need deep insights into how they can develop solutions based on product usage and customer process data to deliver productivity and/or cost benefits to customers. However, data and integration can cause a shift in the key capabilities between actors. The intermediary still has the advantage of being flexible to deliver solutions that can be based on products and services from different firms or platforms and may possess more localized infrastructure. However, the intermediary's capabilities are now at a secondary level of importance, as the manufacturer has developed significant knowledge about the implementation/use of its products, which allows it to reduce operational costs by directly providing remote services or localized services based on predictive analytics and digital technologies (Ayala et al., 2017).

Our results point out that the manufacturer should master the operation of its products, eventually demanding from the intermediary only a localized lower skilled workforce rather than one with technical capabilities. Also, the transformation of smart products on digital platforms allows manufacturers to deliver customized solutions globally at a lower cost through modularization (Cenamor et al., 2017). Because of this, for Advanced Services, a manufacturer no longer needs to rely on intermediaries, making the tie between the manufacturer and the customer stronger, compared to the ties with the intermediary actor (Figure 1c). This is in line with the results from Ulaga and Reinartz (2011), which showed that manufacturers proactively seek to protect access to products and their data in design phases, so that neither competitors nor intermediaries (pure service actors) can properly provide service on their equipment. For the manufacturer, this makes the 'bridge decay' phenomenon (Li & Choi, 2009) less likely to occur.

These changes in the relationship can occur due to the capabilities demanded, and changes in relationships among intermediaries and manufacturers (Huikkola et al., 2020). One of the strategies manufacturers can resort to in order to develop the necessary capabilities is by acquiring service-related companies to internalize processes and the service-mindset in the company (Huikkola et al., 2020). Therefore, digital servitization through Advanced services requires more mature capabilities from manufacturers. Therefore, we propose the following two complementary propositions related to Advanced Services:

P3a: In Advanced Services the key capabilities for digital servitization are more concentrated in the manufacturer, who plays a central role in the value delivery, while intermediaries act as complementors of the offered solution to the customer.

P3b: To provide digital Advanced Services, manufacturers need to improve their products and services for digital servitization to be the central actor of the triad for the value delivery and need to develop and manage capabilities for integrating intermediaries in the provision of complementary service skills.

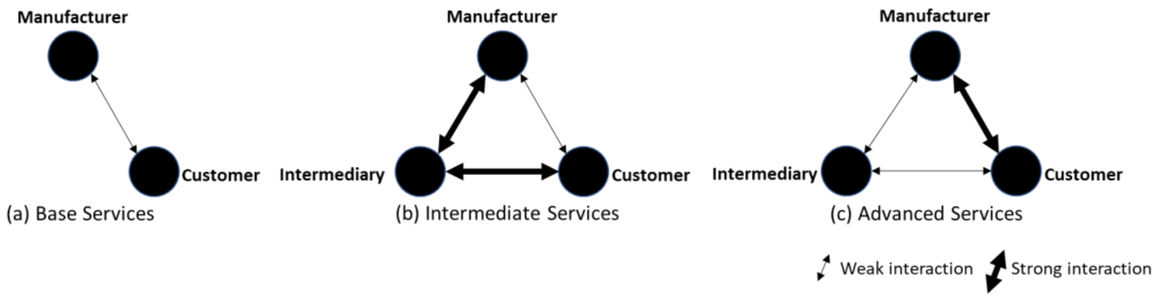

Figure 1: Interaction in a service triad according to services supported by digital technologies

4 Discussions

Our study contributes to the capabilities research by illustrating the capabilities of three key actors in these complex value systems. We focused on understanding how the actor' capabilities differ by service types in digital servitization literature since capabilities lack a more precise definition (Ritter and Pedersen, 2020). In this sense, Ulaga and Reinartz (2011) also proposed specific capabilities of data processing and interpretation for service offers, risk assessments and mitigation, design-to-service, development of hybrid offering sales, and deployment of hybrid offerings. We show that such capabilities, present in the three actors, can be explored in many other ways, demonstrating a much more complex value system. Therefore, this study contributes by expanding such prior capabilities in different service types and actors' role in the provision of digital servitization.

Moreover, the digital servitization literature has discussed the relationship between capabilities among the actors for the delivery of solutions and has shown that the capabilities related to service-mindset, reconfiguration of resources, solution selling, and the integration between technology and the service provided can improve the manufacturer's position against market competition, resulting in stronger solution-related capabilities (Huikkola et al., 2020). However, as shown in our results, the process requires not only new capabilities but the development of a stronger service identity, ecosystem position, and relationships with other actors. To handle the complexity of these offers, manufacturers and intermediaries can seek a business model modularity strategy in which new offers are added as new modules. This facilitates strategic flexibility and innovation, as well as enhancing a firm's ability to orchestrate an increasing number of partners involved in the offer (Hsuan et al., 2021; Huikkola et al., 2020). Nevertheless, the strategy definition, operationalization, and shift to more innovative offers (versus more standardized offers) are needed. This involves deciding if digital servitization will occur in the front-end, in the back-end; radically or incrementally, or even if these changes will occur simultaneously (Tian et al., 2021).

The general capabilities presented in the literature, in addition to those explored in this article, can help to create mindset changes in product-centered companies, who are still experiencing internal barriers to the development of digital offers (Ulaga and Reinartz, 2011). Töytäri et al. (2018) question the legitimacy of the offers and set out product identity, equipment readiness to serve as a platform (due to heterogeneity), low data quality, and product-centered management practices as some of the challenges to offering digitally enabled services. We argue that these challenges pose barriers to the evolution of a digital servitization strategy inside companies. However, exploring the capabilities described for each service type and by each actor, provides the means to further improve the internal structures of manufacturers, intermediaries, and customers. The actors can understand the types of capabilities necessary and prepare their organization for the necessary mindset and positioning changes (Töytäri et al., 2018).

Regarding our specific findings for the different service types, we show that actors' capabilities for digital servitization in *Base Services* mostly relate to the activities of manufacturers and their customers. However, in some instances, third-party actors can play a role in either outsourced software and/or hardware provision for the manufacturer or in helping end customers to make efficient/effective use of digital product offers where manufacturers do not provide such services (Ardolino et al., 2017; Rymaszewska et al., 2017). For effective value creation from Base Services, customers need to develop capabilities relating to openness to sharing information and data and they must develop a collaborative culture in which they manage the risks of data sharing and align their own infrastructures with those of the manufacturer (Holmström et al., 2018; Lerch & Gotsch; 2015; Lindstrom et al., 2018). Manufacturers need to develop capabilities around information gathering and analysis including basic digital services skills and utilizing remote diagnostics for spare part provision based on customer data. The nature of digital technologies requires that these capabilities be built on greater intimacy and openness between manufacturer and customer (Chang et al., 2013; Lindstrom et al., 2018), which was not expected for the delivery of non-digital servitization Base Services.

We identified that actors' capabilities for digital servitization in *Intermediate Services* are distinct from the capabilities normally required by actors creating non-digital Intermediate Services because the presence of digital resources offers the manufacturer an opportunity to gain more intimacy in the relationship with the intermediary, via the customer-specific data generated by IoT technologies that are built into manufacturers' products. In a non-digital context, manufacturers' lack of knowledge about customer processes and needs, and their geographic distance from the customer means that they must often rely on intermediaries' technical expertise and localized resources to co-create value with customers (Lerch & Gotsch; 2015). However, their ability to gather and analyze customer use and activity data strengthens their position with the intermediary and encourages a networked co-creation process between all three actors. This requires manufacturers to manage tensions between its staff and the intermediaries, who may feel that their territory is being invaded (Burton et al., 2016). Thus, similar to the case with Base Services, digital servitization involves greater intimacy in terms of data sharing between the actors, and if this can be achieved then there is scope for a more balanced relationship position and value creation for and between all actors (Eloranta & Turunen, 2016; Paluch, 2014).

Lastly, our results show that the offering of Advanced Services is dependent upon the development of several capabilities. It is contended that digital servitization capabilities are now a necessary tool for manufacturers to co-create Advanced Services with other actors. Advanced services are, by their very nature, 'digitally' advanced. In contrast, a manufacturer could servitize and offer Intermediate or Base Services without necessarily engaging in digital servitization, as capabilities for digital servitization could be developed by intermediaries, customers, or other third-party actors. However, for Advanced Services, if manufacturers are to retain a key role in the value system and remain competitive it is likely that they need to internally develop capabilities for digital servitization and/or do so in close collaboration with other actors. However, literature shows that to achieve the increased gross margins from outcome-based services, such as Advanced Services, manufacturers must be prepared to make higher R&D investments and focus on the develop modular services (Korkeamäki, Kohtamäki & Parida, 2021). In addition, they need to develop closer relationships with customers, built on trust, commitment and long-term partnerships. These partnerships maintain or increase legitimacy, which is a key value-adding factor in the offer of Advances Services, such as those based on outcomes (Korkeamäki and Kohtamäki, 2020).

A key antecedent for this is much greater data sharing between actors; particularly the manufacturer's capability to build IoT data sharing computing into their physical systems and customers' willingness to openly share data in order to co-create greater value and to manage the risk implications to their business. However, the use of the collected data allows companies to achieve many benefits, such as differentiation, reduced service delivery costs, and the possibility of providing consulting services to customers (Ulaga and Reinartz, 2011). But, as the solutions grow in complexity, risk management and assessment become key factors, especially for Advanced Services, as these can involve performance agreements that manufacturers may not be prepared to deliver, or performance variables that cannot be controlled (Ulaga and Reinartz, 2011). Thus, more capabilities are demanded, and more preparation is necessary for companies to become involved in the digital solution.

5 Conclusions

Our study describes the capabilities necessary to implement digital servitization in the service triad. Although prior studies have mentioned several capabilities that are necessary in the digital servitization context, we provided a systematization of these capabilities. We adopted Story et al.'s (2017) framework and applied it to the context of digital servitization. This allowed us to classify the necessary capabilities for Base, Intermediate and Advanced Services and according to the different actors involved in the service triad, namely the manufacturer, the intermediary and the customer. We analyzed 47 papers that describe empirical case studies in which the necessary capabilities were identified. As a result, this paper provides a taxonomy of service types and actors' roles regarding capabilities for digital servitization. The study is novel because it systematizes prior findings that were spread and disconnected, providing a new view for digital servitization. In this new view, we clarify that capabilities are much more complex than usually addressed when the manufacturer is the focus. We show that digital servitization requires a multi-actor perspective and that the required capabilities of each of these actors vary according to the type of service being offered.

5.1 Theoretical Contributions

One of the major contributions of this study for theory is that we organize the capabilities, showing clearly that they have differences according to the type of service offered. In this sense, our study advances a step further on the results presented by Frank et al. (2019). These authors showed that the type of service provision and the level of digitalization of the service solution create different degrees of complexity for the implementation of the servitized business model. They argued that such levels of complexity may vary because of the complexity of dealing with different dimensions of the business model. Our results suggest that such complexity will also vary because different capabilities may be necessary for each of the servitization offers provided. Thus, Base Services demand fewer capabilities than Advanced Services and are more concentrated in the manufacturer. On the other hand, Advanced Services require a larger set of more complex capabilities, which demand higher interactions with external actors and technology partners.

Moreover, our framework shows that the implementation of digital servitization requires capabilities not only from the manufacturer, but also from the other service triad actors. This contributes to the recent findings of Chen et al. (2021) who addressed the changes to business models that underpin digital servitization. While the literature has mainly focused on the manufacturer's side, we show that other capabilities are necessary in the complementary actors. This is important when one should consider the implementation of digital servitization since companies can expend a great deal of effort to provide unsuccessful digital solutions because either the intermediaries and/or customers are not mature enough for the provision of digital solutions. The digital transformation literature has highlighted the necessity of actor interactions and the importance of contributions from different complementary actors to provide complex solutions (Benitez et al., 2021, 2020; Kahle et al., 2020), but such studies focusing on the ecosystem tend to foreground manufacturers and intermediaries. We move a step further by showing that customers also need to possess capabilities for such implementations. Consequently, in line with prior studies, we show that digital servitization challenges a company's service operations logic, requiring a different mindset, and a renewal of their capabilities in order to be able to manage different actors and digital service offers (Töytäri et al., 2018; Tronvoll et al., 2020).

5.2 Managerial Implications

Our findings contribute to practice in several ways. First, we show that the implementation of digital servitization is a complex process requiring a large range of capabilities, that do not reside in one actor. Managers in manufacturing firms should keep in mind that they will need to focus not only on the internal capabilities of their manufacturing firm. An important step in the digital servitization implementation process is assessing the external conditions of the intermediaries and customers to successfully implement the digital solution. Second, when the customer does not have the necessary capabilities, managers in manufacturing firms should ensure that they prepare the conditions necessary for digital servitization implementation by encouraging potential partners to develop the necessary complementary capabilities. Similarly, manufacturing practitioners should assess whether their intermediaries have the necessary conditions to act in the digital servitization process. The list of capabilities for intermediaries developed here may help manufacturers to better select partners that are more capable of operating in the digital services sphere. Third, intermediaries should consider how they utilize their existing capabilities and/or develop new capabilities to build digital services that complement the manufacturer's offerings. Fourth, customers should consider how they develop their contracting capabilities to support the advantages they can gain from sharing data. In providing these insights, our study offers a form of checklist to verify the minimum conditions that each of the actors needs to implement digital solutions.

5.3 Limitations and future research

We systematized the capabilities for digital servitization for the service triad. However, by focusing on the triad, we did not consider wider stakeholders or new perspectives in this field, such as the growing field of service ecosystems for digital servitization (e.g., Benitez, Ayala, & Frank, 2020; Kahle et al., 2020). This new and growing literature has acknowledged that some service solutions can be very complex in the digital domain, requiring the orchestration of a large number of different actors, with different capabilities. In this case, our study presents the fundamental actors (manufacturer, intermediary and customer) that could be deployed within a network of companies. Future studies can expand our findings on the capabilities for the service triad, towards an ecosystem perspective.

Our research method also has limitations that create opportunities for future research. As a matter of scope, we only considered studies that use keywords related to digitalization and servitization. Our study did not cover studies that were published prior to the digital servitization age, but which could be included in the modern concept of digital servitization. Moreover, while we conducted a manual content analysis, other advanced analytic techniques such as the use of machine learning-based SLR, which allows the researcher to analyze more information from the literature, especially regarding research communities. These interfaces could be helpful to gather more details from this new literature (e.g., Meindl, Ayala, Mendonça, & Frank, 2021). Additionally, other methods for conducting content analysis could also be used, for example Dynamic Topic Modeling which enables complex forms of content analysis combining quantitative and qualitative analyzes to identify clusters within textual documents and their evolution over time (Rabetino et al., 2021).

Another limitation from the method employed in this research is that we could not analyze the resources owned by companies and how they are transformed into capabilities, since literature usually lacks this depth in describing cases for digital servitization. Further case studies, and in particular, longitudinal case studies (e.g., Ulaga and Reinartz, 2011) could bring important insights into this field.

Future studies could also analyze how the innovation ecosystem's actors can provide resources for the development and provision of digital services that the manufacturer lacks, similar to the approach adopted by Marcon and Ribeiro (2021).

Future studies could also improve the understanding on the pathway for digital servitization evolution from Base to Advanced. Is it a linear progression, or a hybrid approach, or does disruptive innovation lead to a more disjointed pathway? Moreover, although our paper considered a large sample of literature-retrieved cases, the sample is mostly composed of large enterprises. Future research could delve into the interactions between start-ups and small and medium-sized manufacturers and compare them against the relationships established with intermediaries and customers by large manufacturers and how capabilities change depending on the size and role of the actors involved. Future studies could theorize how intermediaries are related with the digitalization paradox by exploring whether they can help maximize the revenue and reduce the investments made by manufacturers, in line with studies of Gebauer et al. (2020) and Kohtamäki et al. (2020).

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Appendix A – Cases of services supported by digital technologies

Article	Case	Information about the case	Service type
Ardolino et al. (2017)	Piaggio	Motorcycle sharing service enabled by digital technologies	Intermediate
	Kone	Leading manufacturer of elevators and 'people flow' systems for small and large buildings for full risk contractual services	Advanced
	Canon	Document management solutions with pay-per-use contracts, with connection to company's ERP and automatic invoicing	Advanced
	Alpha	Industrial products and repair services for the Oil and Gas industry through a cloud and IoT platform for condition monitoring toward a PaaS offer via tailored solutions.	Intermediate
Baines and Lightfoot (2013)	Case 1	Train manufacturer that provides maintenance, renovation, spare parts and technical support. Revenue based on reliability and availability.	Advanced
	Case 2	Truck and bus manufacturer that provides fleet management, inspection, maintenance services, along with visibility of driver and vehicle performance. Revenue based on performance.	Advanced
	Case 3	Manufacturer of excavation equipment that offers customer support. Service of monitoring condition, use and location. Revenue: charge by operating hour, and hours out of service	Advanced
	Case 4	Manufacturer of office equipment. Manage print service, fleet management, document management, print infrastructure optimization. Revenue: Pay per copy, reduced ownership cost	Advanced
Baines et al. (2013)	Four cases	Not deeply described	Advanced
Boldosova (2020)	Steel Co.	Real-time remote monitoring service based on online machine usage data collected through sensors, controls, software, and cameras installed in its machinery	Advanced
Brad, Murar, and Brad (2018)	Manufacturing resources for factory of the future	Service of robot arm integrated with digital resources that allows remote fast reconfigurability of manufacturing facilities	Advanced
Bressanelli et al. (2018)	Alpha	Household appliances retailer (i.e., washing machines, dishwashers, and tumble dryers) via a servitized model (pay-per-month or use)	Advanced
Caggiano (2018)	CNC machine with cloud monitoring	Cloud solutions that provide remote smart diagnosis services to monitor the manufacturing process based on sensorial data	Intermediate
Candell et al. (2009)	E-maintenance for the aircraft industry	Digital solutions for the remote monitoring, collection, recording and distribution of aircraft system health and maintenance data	Base
Cenamor et al. (2017)	Alpha	Construction equipment that provides customer support and availability agreement including use optimization	Advanced
	Beta	Network equipment and software for network design and optimization services	Advanced
	Delta	Press tools for automotive industry for optimization services	Advanced
	Gamma	Services and manufacturing tools for operation optimization	Advanced
Chang, et al. (2013)	Wireless Monitoring Module	Detection of abnormalities of industrial appliances and turn off in dangerous situations connected via wireless mobile application	Base
Charro and Schaefer (2018)	3D Hubs	3D printing service that connects customers and 3D printer owners	Advanced
	Fictiv's	Company that works with both 3D printing and CNC equipment by providing access to prototyping tools.	Advanced
	Opendesk	Open-source manufacturing and a platform for designers to monetize their designs focused on furniture	Advanced
	Maketime	Company focused on the manufacturer's point of view by selling CNC machine time	Advanced
	MFG.COM	Global contract manufacturing marketplace, connecting designers and engineers to manufacturers. Offers services in virtually all areas of manufacturing	Advanced
Chiou, Mookiah, and Kwon (2009)	Remote quality web-based machine vision	Solution of remote quality diagnosis to monitor part quality status using machine vision integrated with a robotics system.	Base

Coreynen et al. (2017)	Alfa	Supplier of metalwork of laser and plate treatment, welding, and assembly with a digital system for back-end digitization and workflow improvement.	Base
	Beta	Engineering, assembly, and sale of custom-made electric switchboards in the B2B market with digitized customer interface for the delivery of service solution worldwide.	Intermediate
	Gamma	Company that develops, produces, and supplies precision-engineered components and parts with 3D printing technology for customized solutions, especially for the dental industry	Intermediate
	Delta	Company that develops and produces functional shoe insoles through 3D printing and scanner.	Intermediate
Diakostefanis et al. (2017)	Aero gas turbine	Gas turbine remote operation combined with other remote Internet applications to provide powerful gas turbine performance simulation and real time performance monitoring.	Intermediate
Du, Liu, Ma, Wu, and Wu (2018)	IIOT-Based Intelligent System	Solution for the remote real-time monitoring of motorcycle endurance test process	Intermediate
Durugbo (2013)	CorpA	Provision of product-related services, consultancy services, pay-per-service units and outsourcing services	Intermediate
	CorpB		Intermediate
	FirA		Intermediate
	FirB		Intermediate
Eloranta and Turunen (2016)	Case Marine Co	Remote diagnostics platform to integrate technological modules	Intermediate
	RoofCo	Component producer and service provider of building infrastructure solutions using a platform to gather diverse actors	Intermediate
	LogisticsCo	Customer care, manufacturing, after sales, maintenance, and optimization of the logistics fleet. The company created a platform for maintenance workers discuss on-site solutions	Intermediate
	MaterialCo	Produces materials and components for the construction industry with a platform aiming to gather diverse actors of the supply chain	Intermediate
Grubic (2018)	Aerospace	Jet engine sensing, and proactive maintenance and support that supports the offer of availability and performance-based contracts.	Advanced
	Equipment co.	Equipment manufacturer that monitors and analyzes data for customer companies.	Intermediate
	Marine	Remote services provided as customized on-demand connectivity to assist in diagnosing a failure, data collection and analysis, and continuous monitoring of products onboard the vessel	Intermediate
	Transportation	Train monitoring and performance guarantees for fleet management via proactive maintenance and services	Advanced
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Hasselblatt et al. (2018)	Power Gmbh	Condition-based maintenance of engines and power plants	Intermediate
	Thrust Co	Condition monitoring service	Intermediate
	Process automation	Remote monitoring service	Intermediate

	Manufacturing process	Provides a worldwide service network with five levels of service agreements for cranes	Intermediate
	Machine Oy	Condition-based maintenance for machine tools and production lines. Offers services through own units and outsourced operators	Intermediate
Herterich et al. (2016)	Thyssenkrupp Vista	Maintenance, repair, and overhaul through condition monitoring	Intermediate
	Mindsphere	Open digital platform for digital industrial service offerings	Intermediate
	Thyssenkrupp MAX	Platform for proactive actions and MRO activities	Intermediate
	Thyssenkrupp Local Service Improvement	Improvement solution of field service through data analysis and remote connection	Intermediate
	Siemens Mobility	Railway rolling stock availability service	Advanced
Holmström et al. (2018)	Siemens plant for gas turbines	Combination of product modeling and manufacturing technology to convert digital models into physical objects without tooling.	Base
	DDM for jet redesign and refurbishment	Additive manufacturing solution for spare parts supply	Base
Huikkola et al. (2020)	Case A	Propulsion systems and power plants	Advanced
	Case B	Minerals and metals processing technology	Intermediate
	Case C	Industrial cranes and lifting systems	Intermediate
	Case D	Lifting equipment	Unspecified
Ives et al. (2016)	GE Brilliant	IoT solution to increase efficiency and optimize industrial operations through services of preventive maintenance	Advanced
	Tetra Pak	Case machines equipped with sensors that stream data for instant analysis, facilitating preventive maintenance when needed	Intermediate
Jonsson et al. (2009)	Monitoring Control Centre	Condition-based maintenance monitoring for the mining industry. Operations analysis, implementation of infrastructure, and collection and analysis of measurement data.	Intermediate
	PowerDrive	Manufacturer of motors that offers a remote diagnostics service to enhance maintenance for motors.	Intermediate
Jurčević, Boršić, Malarić, and Hegeduš (2008)	Calibration service	Remote execution of the calibration procedure, automatic acquisition, and real-time processing of calibration results.	Intermediate
Kamalaldin et al., (2020)	Alpha and Beta	Power and automation technology; Mining. Solution of information connection and integration of Beta's fleet from Alpha's machines to optimize operations.	Advanced
	Alpha and Gamma	Power and automation technology; Energy and utilities. Solution of information connection and integration of Gamma's network to visualize performance and identify improvements.	Intermediate
	Delta and Epsilon	Machinery manufacturing; Forestry. Digital service platform and predictive maintenance service to lower lifecycle costs.	Intermediate
	Zeta and Eta	Telecom equipment; Telecom. Digital solutions to continuously improve network operations.	Unspecified
Kowalkowski et al. (2013)	Endress + Hauser	Measuring instruments and automation solutions for the industrial process engineering industry with asset management system, where customers can use this information for their own processes.	Base
	Toyota Material Handling Europe	Supplier of trucks and services platform for services and ICT solutions with data analysis and consulting where customer can manage their fleet remotely.	Intermediate
Lenka, Parida, and Wincent (2017)	Heavy Machinery	Company of machinery with cloud platform for product monitoring in real-time and preemptive maintenance	Intermediate
	Telecommunications Infrastructure	Network design and optimization solution for the minimization of downtime and problem resolution toward higher availability	Intermediate
Lerch and Gotsch (2015)	Case 1: Theatrical stage manufacturer	Theatrical stage maintenance and repair, testing, spare parts, 24-hour service hotline via digital monitoring	Base
	Case 2: Enameling line manufacturer	Remote services, maintenance, engineering services, project planning and implementation, training, service hotline to optimize the functioning and operation of the product	Intermediate
	Case 3: Machine Tool Manufacturer	Technical support, spare parts, maintenance, training, inspections, upgrade and retrofit of machines, to enable Advanced Services	Advanced
Lim et al. (2015)	Case 1 -VOHM service concepts	System that gathers, analyzes, and identifies vehicle operations and health data. The insights from the data are used to develop customized services to drivers based on their characteristics	Intermediate

	Case 2 - Driving safety	Services to enhance driving safety for commercial vehicle drivers based on data analysis of drivers' behaviors	Intermediate
Lindström et al., (2018)	Sensor-bridge-cloud system	Solution that integrates data from sensors embedded into wet concrete and data analysis to know when the concrete is set and to optimize adjustments of parameters.	Base
	Real Estate Sensor	Service that measures moisture level in buildings' exterior walls to detect excessive moisture levels and avoid wall renovation.	Base
	Recycling Management	Recycling service to municipalities and companies for managing recycling containers. Sensors in the containers allow the waste management company to know which containers require emptying	Base
Liu, Zha, Miao, and Lee (2005)	Intelligent maintenance system	Smart software system that predicts product failure such as performance degradation measurement, fault recovery, self-maintenance, and remote diagnostics in advance.	Intermediate
Marinova, de Ruyter, Huang, Meuter, and Challagalla (2017)	Financial Services Information Sharing and Analysis Centre	Solution for cyber and physical threat analysis to the global financial industry using machine learning.	Base
Ness et al. (2015)	Stress sensors	Stress sensors to components to quantify the stress properties of steel over its working life.	Base
Ong et al. (2007)	Component-based maintenance in the automotive industry	Architecture for remote maintenance services through a network of hardware and software components in the automotive industry	Intermediate
Pagoropoulos et al. (2017)	Performance management for tanker vessels	Digital capabilities in the maritime industry to monitor KPIs and feedback into the company's processes for processes improvements and training	Intermediate
Paluch (2014)	Medical equipment industry	Remote maintenance services for medical high-tech equipment via IT-infrastructure allowing real-time remote monitoring	Intermediate
Rymaszewska et al. (2017)	Company A: Machinery	Multinational provider of machinery for sheet metal processing with services of maintenance, spare parts, training, support and advisory on the customers' operation	Intermediate
	Company B: Power plants	Provider of power generators and gas-operated power plants with solutions of power system design and installation, and maintenance via monitoring of the customers' operation.	Intermediate
	Company C: Electrical engineering	Technology for power generation and distribution with real-time view for the user to monitor operation to increase the product life cycle. It also provides maintenance based on data monitored	Base
Sánchez-Montesinos et al. (2018)	Coviran cooperative	Large food cooperative that adopted digital capabilities to communicate with partners, collect information, predict demand, and enhance product supply chain	Base
Sjödin, Parida, Kohtamäki, and Wincent (2020)	Construction equip. and Customer Mining	Connection and integration of equipment for digital fleet management and site optimization	Advanced
	Power and automation and Energy and utilities	Connection and integration of information to visualize system performance and improvements	Intermediate
	Mining equip. and Mining	Automation solution and mine optimization platform	Intermediate
	Telecom equip. and Telecom	Digital solutions to continuously improve network operations	Unspecified
Smith (2013)	Rolls Royce Power-by-the-hour	Jet engine manufacturer that charges for the use of the engine based on the data monitored, while providing constant maintenance and monitoring to assure availability of the product.	Advanced
Tongur and Engwall (2014)	Slide in Electric Road System	Electric road system technology of electrified roads that continuously and dynamically transfer power to vehicles	Advanced
Töytäri et al. 2018	Beta	Measurement engineering industry that offers smart services of commissioning, remote training, and remote system upgrades;	Intermediate
	Gamma	Machine industry that offers smart services of remote condition diagnostics, predictive services, performance, contracting, data-based benchmarking, data-based consulting services	Advanced

	Delta	Agricultural engineering industry that offers remote training, remote data transfer, data warehousing, remote system upgrades, remote condition diagnostics, predictive services, performance contracting, data-based consulting services	Advanced
	Epsilon	Building infrastructure industry that offers service platform, remote data transfer, visualization of data, data evaluation, automated data evaluation, remote condition diagnostics, predictive services	Intermediate
	Zeta	Industrial products and services for analyzing production equipment, training, consulting, outsourcing, performance-based contracting, benchmarking	Advanced
	Theta	Platform for preventive and predictive maintenance and services of production support processes	Intermediate
Vardar, Gel, and Fowler (2007)	Service provider for wafer fabrication facilities	Onsite and offsite field service provision for the wafer fabrication industry, in a maintenance network system optimized by an algorithm that considers location, type and actors' capacity	Intermediate
Wen and Zhou (2016)	Inventec	Cloud-based service platforms that provide cloud services of manufacturing, design, and logistics	Intermediate