

# Digital Product-Service Systems: A Digital Capabilities Approach

Marcon É<sup>1</sup>, Marcon A<sup>2</sup>, Ayala N F.<sup>3</sup>, Frank A G.<sup>4</sup>

**Abstract** The servitization of industrial offers in addition to the increased digitization in current industry enabled the development of Digital Product-Service Systems (DPSS). In this type of offer, manufacturing companies that seek to deliver digitized solutions must develop managerial and digital capabilities to provide value to customers. Thus, our study analyses the necessary digital capabilities based on a systematic literature review conducted with 59 articles that report 70 DPSS cases. Based on a literature classification that divides the services offered into Base, Intermediate and Advanced, we identified that Base services demand is focused on maintenance solutions demanding Monitoring, Control and Remote Access and Services capabilities. Intermediate services demand more technology capabilities to deliver complex service contracts, such as data analytics, customer operation optimization and customization of the solution offered. Finally, Advanced services demand a broad set of technology capabilities as the provider must enable cost guarantees and even manage the operation entirely, relying more on the technology employed. Thus, our article provides guidelines for DPSS providers as we show the necessary capabilities, enabling a more accurate offer with increased value to customers.

**Keywords:** digital servitization; product-service system; industrial services; capabilities;

## 1 Introduction

Servitization has gained attention over the last decades as one of the strategies for product firms to achieve competitive advantage (Ayala, Gerstlberger, & Frank, 2019; Coreynen, Matthyssens, & Van Bockhaven, 2015). The digital transformation (or simply 'digitization') is another growing trend in product firms, which affects the product development field (Dalenogare, Benitez, Ayala, & Frank, 2018; Frank, Dalenogare, & Ayala, 2019). Product firms can equip their products with intelligent digital systems to obtain real-time data about the performance and utilization of the product or even make the product autonomous (Lerch & Gotsch, 2015; Rönnberg Sjödin et al., 2016). In this sense, digital capabilities can improve the industry's competitiveness (Porter & Heppelmann, 2014) through improvements and the provision of data to increase customer relationships (Coreynen et al., 2015). Digitization is also responsible for developing and delivering smart products (Porter & Heppelmann, 2015). Smart products are able to monitor, control,

---

<sup>1</sup>Érico Marcon (e-mail: erico.marcon@ufrgs.br)

Organizational Engineering Group (Núcleo de Engenharia Organizacional – NEO), Department of Industrial Engineering, Universidade Federal do Rio Grande do Sul, Brazil.

<sup>2</sup>Arthur Marcon (e-mail: arthur.marcon@ufrgs.br)

Department of Industrial Engineering, Universidade Federal do Rio Grande do Sul, Brazil.

<sup>3</sup>Néstor Fabián Ayala (e-mail: nestor.ayala@ufrgs.br)

Organizational Engineering Group (Núcleo de Engenharia Organizacional – NEO), Department of Industrial Engineering, Universidade Federal do Rio Grande do Sul, Brazil.

<sup>4</sup>Alejandro Germán Frank (✉e-mail: frank@producao.ufrgs.br)

Organizational Engineering Group (Núcleo de Engenharia Organizacional – NEO), Department of Industrial Engineering, Universidade Federal do Rio Grande do Sul, Brazil.

optimize and even operate autonomously in order to better address customers' needs with fewer resources and better customization (Porter & Heppelmann, 2015).

The interaction between servitization and digitization is very strong, since digital technologies act as facilitators for the servitization process (Grubic, 2018), even enabling the connection among service suppliers, product companies and customers (Frank et al., 2019) which is an important aspect for companies offering servitized offers (Ayala et al., 2017). The convergence of servitization and digitization strategies results in the provision of digital services embedded into physical products (Frank et al., 2019, Porter & Heppelmann, 2014), namely digitalized product-service systems (DPSS) (Lerch & Gotsch, 2015).

This variation of the product-service systems (PSS) concept is characterized by the provision of services through digital means, which were manually performed in the past, such as data analysis, predictive maintenance, and repair and feedback data (Grubic, 2018; Lerch & Gotsch, 2015; Porter & Heppelmann, 2014; Rymaszewska, Helo, & Gunasekaran, 2017). Digital technologies are understood as any platform, software or hardware, that allows a connection to the product/service independently of its location (Lerch & Gotsch, 2015; Porter & Heppelmann, 2014). In this sense, due to digitization's potential, many are the possibilities yet to be discovered for its improvement in product-centric servitized offers, from simple data monitoring to the prediction of failures and performance that enable complex business models such as the sale of availability assurance contracts (Lerch & Gotsch, 2015). These factors show that digital technologies are a key factor for the provision of high value-added services (Rönnerberg Sjödin et al., 2016), and also to provide potential gains in operational efficiency (Coreynen et al., 2015), improving companies' competitiveness (Porter & Heppelmann, 2014).

However, even though several industrial cases of DPSS are reported in the literature, the digital capabilities necessary are not directly addressed or they are still mixed with the more general servitization as well as with the smart product capabilities. In this sense, an unstructured provision of DPSS that does not take into consideration the adequate capabilities for provision can lead to suboptimal offers that do not deliver customer value. Additionally, developing the capabilities that do not fit the DPSS level provided can become expensive to companies and still be rejected by customers.

Considering that, this study aims to identify the digital capabilities necessary to offer different levels of DPSS. In this sense, from a theoretical perspective, there is a need of framing the necessary digital capabilities that enable the offer of DPSS to further understand the conditions necessary for their offer and the changes and innovations needed inside the companies that seek to provide DPSS. While from the practical perspective, this can help companies to better plan their digital servitization journey.

## 2 Theoretical Background

From the initial definitions proposed by Vandermerwe and Rada (1988) to today's well established background on the servitization field, several studies have investigated the servitization phenomena, i.e. manufacturing firms that add services to their products with the objective of providing greater customer value. In this sense, companies can follow a direct path from pure product to pure services such as the case of IBM (Beuren et al., 2013) or toward PSS, which is a combination of products and services that delivers value during its use (Baines et al., 2007). Following this view, Baines et al., (2013) propose a classification for the services provided by manufacturers divided into base, intermediate and advanced, as depicted in Table 1.

**Table 1-** Service Classification

	Focus	Service	Risk	Revenue payment
Base (i.e. spare parts provision)	Product provision	Services are centered on the product	Low: easily provided	Payment on contract completion
Intermediate	Condition provision	Focused on exploiting production	Medium: increased exposition to	On a periodic basis, as

(i.e. scheduled maintenance, usage monitoring)		competences to assure product condition	consequences of failure	interventions are needed
Advanced (i.e. risk sharing contract, rental agreement)	Outcome provision	Extended services to activities that usually belong to the customer	High: product performance problems result in financial penalties	On a linear basis, paying as it is used

Source: Adapted from Baines et al. (2013)

We focus on manufacturing firms that aim to increase their service offer, without, however, fully detaching the product of their PSS offering (Frank et al., 2019). This is due to the DPSS necessity of integrating product features with service aspects and digital architectures to deliver value (Lerch and Gotsch, 2015). Thus, we employ Baines et al. (2013) classification to categorize the services levels adapting such view to DPSS. In this sense, we divide our analysis based on the three levels to identify differences among them, since the necessary capabilities are expected to change and grow as the service offered increases in complexity. That is, DPSS capabilities from the base level are expected to generally differ from the capabilities of the advanced level (Ardolino et al., 2017).

Current literature has addressed the digital capabilities necessary for DPSS in a more general way, such as in the studies of Ardolino et al. (2017) and Porter and Heppelmann (2015). They found that in DPSS offers value is delivered through digital technologies such as the Internet of Things (IoT), Cloud Computing, Big Data and Data Analytics which enable user and product identification, geo-localization, usage/condition monitoring and even advanced capabilities such as autonomy and prediction (Ardolino et al., 2017; Porter & Heppelmann, 2015). Examples can be seen both on the customer side with products such as smart vehicles (Ardolino et al., 2017); and on the industrial side with more intelligent machines, such as enameling lines with remote services, maintenance, and repair; or machine tools with technical support, upgrade and retrofit based on the data provided by the machine's operation (Lerch & Gotsch, 2015).

### 3 Method

Based on the literature gaps in DPSS categorization and the capabilities to delivering different levels of DPSS, we conducted a systematic literature review. Systematic literature reviews use a well-defined search algorithm that aims to reduce bias and to ensure that the conclusions drawn are replicable and comprehensive (Tranfield et al., 2003). In this study, we selected a systematic literature review based on recommendations of Reim, Parida, & Örtqvist (2015) and other authors who claim that 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 is referred to by synonymic terms. This is the case of the DPSS research field, which resides next to such topics as PSS and digitization literature.

We followed the recommendations of Tranfield, Denyer, & Smart (2003) to conduct a systematic literature review, dividing it into three stages: review planning, conduction, and reporting and dissemination. In Stage 1, based on the gaps identified in the literature, we developed the protocol used for the searches in the databases and defined the keyword combination. This definition is based on the synonyms used by authors on the field. In this stage, we also defined the databases for the application of the algorithm. Scopus and Web of Science are among the two databases with the highest indexing rates and, therefore, they were selected for the application of the protocol. The keywords used are presented in Table 2.

**Table 2** - Search Protocol

		Keyword combination	
(a) Remote	+ AND +	(“product-service system” OR	+ AND + Capabilit*
(b) Smart		“integrated solution” OR service)	
(c) Digit*			
(d) “Smart product”			+ AND + Capabilit*

In Stage 2, we searched both databases with the keyword combinations presented in Table 2. The following inclusion criteria were set in the search engines: the keywords searched should be in the Title, Abstract, or Keywords of articles; only research papers published in peer-reviewed journals were included, and articles should be written in English. Additionally, to ensure that articles addressed the topic at hand, we filtered for articles published in the following areas: business, engineering, and social sciences, which retrieved 1837 articles out of which 509 were duplicates. This resulted in 1328 articles that were scanned on their titles, abstracts, and keywords to check for fit. Based on the criteria established, 1204 articles were excluded because they did not address the topic. After this filter was applied, the remaining 124 articles were fully read, and the content-based inclusion criteria (presenting digital capabilities and examples of DPSS) were applied. Thus, 46 articles were accepted and, 78 were rejected. We also added 13 articles through the snowball technique, remaining with a total of 59 articles fully read and analyzed. Afterwards, we read the articles selected, analyzed the cases reported by them and used these cases to map the digital capabilities necessary for each level of service. The next section presents the results obtained along with a discussion on these results.

## 4 Results

Based on the articles read and analyzed, our results show that when adopting a DPSS strategy to offer servitization, companies need to develop digital capabilities (Ardolino et al., 2017, Marcon et al., 2019). Digital capabilities’ concept derives from the capability definition. A capability is the firm’s capacity to deploy resources for the desired end result (Helfat et al., 2009), and digital capabilities are the capabilities deployed through digital technologies (Ardolino et al., 2017). Digital technologies on servitization allow new uses either on front-end and also on back-end activities (Coreynen et al., 2015). In this field, Ardolino et al. (2017) provide further understanding on how such digital capabilities such as Cloud Computing, Internet-of-Things (IoT), Predictive Analytics play an active role in PSS value co-creation. IoT, for instance, acts on the initial level of the hierarchy by providing the data, and next cloud computing enables data storage, data aggregation and processing, which allows for the use of information and its transformation into knowledge (Ardolino et al., 2017). In such cases, companies can use digital technologies to also reach greater accessibility, through predictive analytics, for example.

Literature mentions many capabilities. Therefore, recognizing which digital capabilities enable DPSS levels is important for a further understanding of how DPSS could create more customer value and how companies can provide more accurate DPSS according to their strategy. With this objective, in Fig., we present an analysis of the capabilities enabled by digitization in PSS according to the results from our systematic literature review. We found a total of 70 cases presenting one or more digital capabilities, where 33 were of base DPSS, 24 intermediate DPSS, and 13 were advanced DPSS. The most mentioned capabilities were monitoring (62), remote services (44), Data analysis (38), and Remote Access (38). In Figure 1, bars represent the number of cases that mentioned the specific capability within the DPSS level.

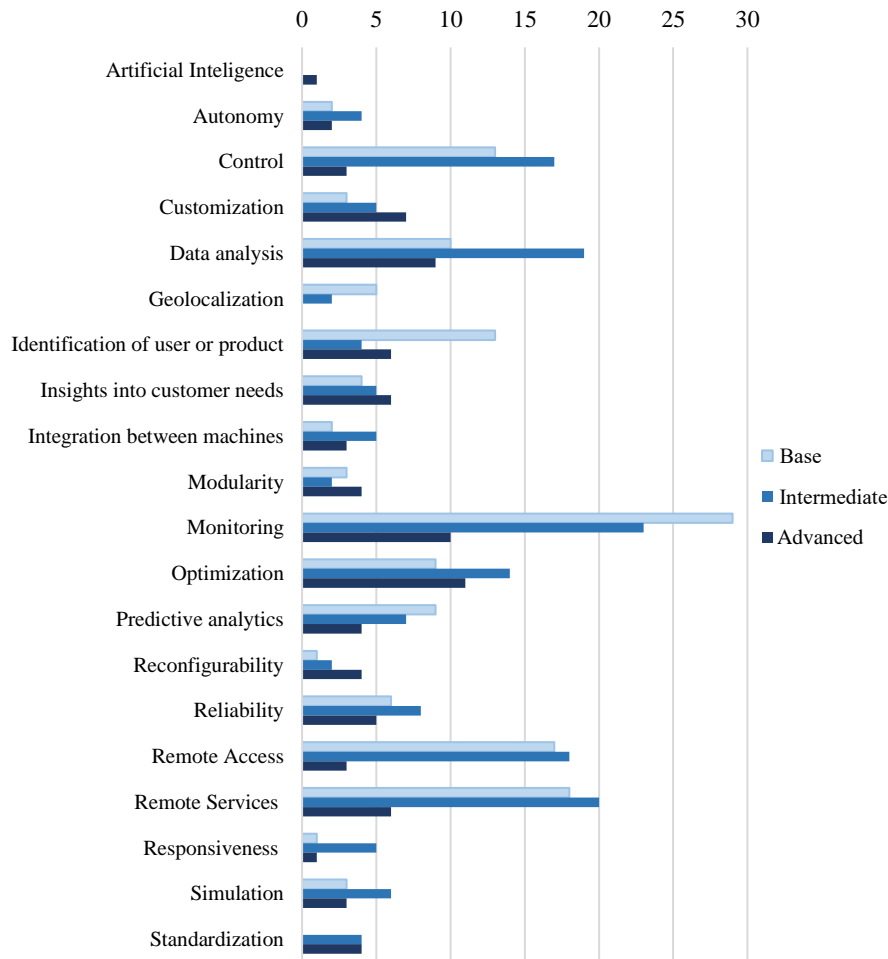


Fig. 1 - Digital capabilities by DPSS level

Figure 1 depicts the most mentioned capabilities necessary for each DPSS level providing a further understanding of the bundle of capabilities necessary to offer a solution. To offer a Base DPSS, first, providers should develop the capability to remotely access the data generated by the products in the customer's site. Also, the identification of products is necessary to offer traceability services. Following, the provider must have the capability of analyzing the collected data to offer remote monitoring, and control services. In addition, companies providing Base DPSS can remotely diagnose failures and better estimate the failure cause, such as the example provided by Lenka et al. (2017) where the load indication information on a ball bearings crane provides information on the operation, improving maintenance time and spare part orders. Thus, based on these results we define proposition 1.

**Proposition 1:** Base DPSS are mostly focused on maintenance solutions and are enabled by Monitoring, Control, and Remote Access and Services, as they increase service provider's capabilities through the provision of information and access over distance.

Alternatively, to be able to offer an Intermediate level of DPSS, providers should detain or integrate more digital capabilities due to service complexity increase. That is, they must build on the digital capabilities from the base level and integrate training and consulting capabilities to increase the reliability of customer's processes and help them to extract the most value from the DPSS offer. The employment of data analytics to reach better efficiency and performance optimization allows providers to sign hardware availability contracts with customers (Rymaszewska et al., 2017). This intermediary level is characterized by an analytic approach, leveraging the data gathered and its processing to better use the current product or

allow new (more efficient or more suited) uses in an automated way (Herterich et al., 2016; Lenka et al., 2017). Therefore, our second proposition is stated as follows.

**Proposition 2:** Intermediate DPSS demand more technology capabilities to deliver service contracts based on availability, such as data analytics, customer operation optimization and customization of the solution offered.

Differently from the base and intermediate levels, where few capabilities were clearly emphasized, in the Advanced DPSS level, there is no clear difference of proportion between the capabilities. Thus, companies that offer Advanced DPSS usually present most of the digital capabilities mapped to offer a complete value proposition to its customers. This occurs because Advanced DPSS requires a greater focus on outcome provision and greater risks are involved. Moreover, DPSS providers become responsible for extended services that are usually customers' responsibility. These capabilities include most of the necessary capabilities to base and intermediate levels, but also digital capabilities to reach the customization of the PSS offer. With advanced digital capabilities, the provider identifies and recognizes customers' demands to then offer customization through the modularity and reconfigurability of the PSS. Additionally, maintenance and repair capabilities remain important but now associated with the utilization of data for simulation and predictive analytics toward a more comprehensive solution.

**Proposition 3:** Advanced DPSS demand a broad set of technology capabilities to be delivered as the solution is result-oriented, thus the provider must enable lifecycle cost guarantees and higher availability rates, relying more on the technology employed.

Notably, the capability to offer maintenance and repair services is highly presented in the three levels of DPSS, which demonstrates that most applications of digital technologies are still highly restricted to this kind of service, which has been also stated by Grubic (2018). However other applications are brought by studies, which demonstrates that there are several uses yet to be discovered in the DPSS field. Thus, proposition four depicts the current DPSS scenario which still presents room for improvement, even though companies still need to consider operational and outcome barriers that surround DPSS offer (Marcon et al., 2019).

**Proposition 4:** Maintenance is the most focused area for DPSS; however, data monitoring and process improvements are becoming more explored as DPSS providers develop the necessary capabilities to deliver advanced solutions.

## 5 Conclusion

Based on the results presented, our research provides an overview of the necessary capabilities demanded for the provision of each DPSS level. Our findings also enable an understanding of how each offer is configured, and how the DPSS offer relates to technological aspects since the capabilities demanded tend to grow in quantity and complexity as the DPSS level increases. Our results show that the more advanced the DPSS level, the more complex the offer tends to become. In addition, this study provides insights on the extent of such a relationship and how practitioners and researchers can leverage such information to improve their knowledge in the servitization field. In this sense, companies can follow two entering ways toward a DPSS offer. They can either use digital technologies to support their existing PSS offer, or product companies can leverage servitization opportunities while adding digital technologies to their products, which tends to lead to more aggressive innovation outcomes.

Our results also provide managerial contributions since we show that the company that is servitizing by digital means should develop all (or at least most) of these capabilities to be able to offer a complete value package to its customer at each DPSS level, otherwise, the customer may not be able to extract all value from the DPSS and thus, they may not adopt it. Therefore, a deeper understanding of DPSS level differences and their required capabilities can prevent product companies from venturing in servitization strategies without holding the necessary capabilities for the entire delivery of the DPSS package. Thus, companies seeking to offer digitally-servitized offers through DPSS can decide the appropriate digital capabilities to incorporate to its products based on the chosen servitization strategy being able to do smarter investments.

## 6 References

- Ardolino, M., Rapaccini, M., Sacconi, N. et al (2017) The role of digital technologies for the service transformation of industrial companies. *Int. J. Prod. Res.* 7543, 0.
- Ayala, N.F., Gerstlberger, W., Frank, A.G. (2019) Managing servitization in product companies: the moderating role of service suppliers. *Int. J. Oper. Prod. Manag.* 39, 43–74.
- Ayala, N.F., Paslauski, C.A., Ghezzi, A. et al (2017) Knowledge sharing dynamics in service suppliers' involvement for servitization of manufacturing companies. *Int. J. Prod. Econ.* 193, 538–553.
- Baines, T., Lightfoot, H., Smart, P. et al. (2013) Servitization of manufacture. *J. Manuf. Technol. Manag.* 24, 637–646.
- Baines, T.S.S., Lightfoot, H.W., Evans, S. et al. (2007) State-of-the-art in product-service systems. *Proc. Inst. Mech. Eng. Part B J. Eng. Manuf.* 221, 1543–1552.
- Beuren, F.H., Gomes Ferreira, M.G. et al. (2013) Product-service systems: A literature review on integrated products and services. *J. Clean. Prod.* 47, 222–231.
- Coreynen, W., Matthyssens, P., Van Bockhaven, W. (2015) Boosting servitization through digitization: Pathways and dynamic resource configurations for manufacturers. *Ind. Mark. Manag.* 60, 42–53.
- Dalenogare, L.S., Benitez, G.B., Ayala, N.F. et al. (2018) The expected contribution of Industry 4.0 technologies for industrial performance. *Int. J. Prod. Econ.* 204, 383–394.
- Frank, A.G., Dalenogare, L.S., Ayala, N.F. (2019) Industry 4.0 technologies: Implementation patterns in manufacturing companies. *Int. J. Prod. Econ.* 210, 15–26.
- Frank, A.G., Mendes, G.H.S., Ayala, N.F. et al. (2019) Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. *Technol. Forecast. Soc. Change* 141, 341–351.
- Gago, D., Rubalcaba, L. (2007) Innovation and ICT in service firms: Towards a multidimensional approach for impact assessment. *J. Evol. Econ.* 17, 25–44.
- Grubic, T. (2018) Remote monitoring technology and servitization: Exploring the relationship. *Comput. Ind.* 100, 148–158. <https://doi.org/10.1016/j.compind.2018.05.002>.
- Helfat, C.E., Finkelstein, S., Mitchell, W. et al. (2009) *Dynamic capabilities: Understanding strategic change in organizations.* John Wiley & Sons.
- Herterich, M.M., Uebernickel, F., Brenner, W. (2016) Stepwise Evolution of Capabilities for Harnessing Digital Data Streams in Data-Driven Industrial Services. *MIS Q. Exec.* 15, 297–318.
- Holmström, J., Partanen, J. (2014) Digital manufacturing-driven transformations of service supply chains for complex products. *Supply Chain Manag. An Int. J.* 19, 5.
- Lenka, S., Parida, V., Wincent, J. (2017) Digitalization Capabilities as Enablers of Value Co-Creation in Servitizing Firms. *Psychol. Mark.* 34, 92–100.
- Lerch, C., Gotsch, M. (2015) Digitalized Product-Service Systems in Manufacturing Firms: A Case Study Analysis Digitalized Product-Service Systems in Manufacturing Firms 6308.
- Marcon, É., Marcon, A., Le Dain, M.-A. et al. (2019) Barriers for the digitalization of servitization. *Procedia CIRP* 83, 254–259.
- Porter, M., Heppelmann, J. (2015) How smart, connected products are transforming industry. *Harv. Bus. Rev.*
- Porter, Michael E, Heppelmann, J.E. (2014) How smart, connected products are transforming companies. *Harv. Bus. Rev.* 1.
- Reim, W., Parida, V., Örtqvist, D. (2015) Product-Service Systems (PSS) business models and tactics - A systematic literature review. *J. Clean. Prod.* 97, 61–75.
- Rönnerberg Sjödin, D., Parida, V., Kohtamäki, M., et al. (2016) Capability configurations for advanced service offerings in manufacturing firms: Using fuzzy set qualitative comparative analysis. *J. Bus. Res.* 69, 5330–5335.
- Rymaszewska, A., Helo, P., Gunasekaran, A. (2017) IoT powered servitization of manufacturing – an exploratory case study. *Int. J. Prod. Econ.* 192, 92–105.
- Tranfield, D., Denyer, D., Smart, P. (2003) Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *Br. J. Manag.* 14, 207–222.
- Vandermerwe, S., Rada, J. (1988) Servitization of business: Adding value by adding services. *Eur. Manag. J.* 314–324.